

ASSESSING THE SOCIAL AND ECONOMIC IMPACT OF CHANGED WATER USE BEHAVIOUR IN FOOD PRODUCTION: EVIDENCE FROM SELECTED CASE STUDIES IN SOUTH AFRICA

Report to the

WATER RESEARCH COMMISSION

by

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Executive Summary

Effective water management and the adoption of water-saving technologies are important for ensuring sustainable water management (SDGs 6), combatting climate variability and its impact (SDGs13), ending hunger and poverty (SDGs 2) and ending hunger and intensifying sustainable food production with the alignment of NDP of South African needs (African Union CAADP Strategy and Action Plan: 2026-2035).

Effective water management in irrigated agriculture is critical, considering the significant stress on water resources, the rising demand for food, rapid increases in climate variability, industrialisation, urbanisation, population growth, and growing reliance on groundwater. In view of this, declining water availability presents significant social, economic, environmental challenges and complicates water management and the long-term sustainability of irrigated farming. Managing water effectively in food production has become increasingly important not only from an environmental perspective but also from social and economic perspectives.

Understanding the social and economic impacts of variability in the behaviour of water users when using water for food production is important, not only for improving water use but also for developing policies to enhance water resource management and designing effective interventions for behavioural change. This may be achieved by incorporating psychological dimensions of environmental programmes, enabling better predictions of responses to environmental changes, and supporting the scaling of targeted solutions in agricultural water management.

This project aimed to develop an integrated model and socio-economic indicators to assess the economic and social impacts of changed water use behaviour in selected irrigation schemes and selected commodities in South Africa. To achieve the objectives of the project, the research team utilised a survey covering 909 smallholder and commercial farmer participants, a literature review, a Social Accounting Matrix (SAM) developed by the research team with the assistance of DALRRD, secondary data (obtained from the Agricultural Research Council (ARC) and others), and multiplier analysis. Empirically, the study applied a standard and extended Theory of Planned Behaviour (TPB, Structural Equation Model, AquaCrop model, and Multiplier Analysis/partial equilibrium).

This project fills a knowledge gap, including but not limited to the well-established importance of human behaviour in influencing water use and management. Many *integrated frameworks do not adequately consider psychological and behavioural factors, especially when assessing the broader implications of changes in water use behaviour. Although various frameworks in water resource management have integrated biophysical, socio-economic, institutional, economic, and ecological dimensions of food*

systems, they often overlook farmers' water use behaviours and the broader implications of these behaviours on other dimensions of the food system.

To address this gap, this project developed a novel integrated framework that combines psychological, biophysical, and socio-economic dimensions to effectively measure the social and economic implications of changed water use behaviour in food production. The integrated framework (conceptual tool) demonstrates the crucial role that farmers play in the economy and the importance of their decisions. The project highlights a novel integrated framework to assess the implications of changing water use behaviour among irrigators. The framework integrates the Theory of Planned Behaviour to understand irrigators' adoption intentions, the AquaCrop model to simulate yield and water productivity under different scenarios, and a Social Accounting Matrix through multiplier analysis (partial equilibrium model) to evaluate the broader socio-economic impacts and implications.

The following key results emanate from this project:

- *Interventions targeting attitudes, social support, and access to resources can improve adaptive behaviours.*
- *Participation in irrigation schemes and the adoption of different policies play a significant role in growing and sustaining the crop industry and other agricultural industries in reducing food insecurity.*
- *The full adoption of water-saving technology increased yields in the irrigation scheme. This improvement is attributed to better water management practices, which led to more efficient water use and ultimately increased the total output in the South African economy, as well as in provinces, including labour, household income, land, institutions, value added, and gross operating surplus.*

Adopting different water technologies requires financial resources, especially for smallholder farmers. Accordingly, the project team recommended that the South African government and various stakeholders should introduce a Grameen Bank module, which has proved effective in different parts of the world. To be successful, commitment from policymakers and the government is needed. From the farmers' side, a behavioural change needs to take place.

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List of Acronyms

AC	Awareness of Consequences
ACOSP	AquaCrop-OSPy- an open source, Python implementation of the crop-water productivity model
AR	Access to Resources
ARC	Agricultural Research Council
AT	Attitudes
AVE	Average Variance Extracted
AWC	Available Water Content
CAADP	Comprehensive Africa Agriculture Development Programme
CGE	Computable General Equilibrium
CHANS	Coupled Human and Natural Systems
CHES	Coupled Human-Environment Systems
ClimGen	Weather Generator
CO ₂	Carbon Dioxide
CropSyst	Cropping Systems Simulator
DALRRD	Department of Agriculture, Land Reform and Rural Development
DPSIR	Drivers–Pressures–State–Impact–Response
DSR	Driving force–State–Response
DSSAT	Decision Support System for Agrotechnology Transfer
DYNSYSTEM	Dynamic System
ECLAC	Economic Commission for Latin America and the Caribbean
ENW	EndNote Import File
EPIC	Environmental Policy Integrated Climate
FAO	Food and Agriculture Organization
GAMS	General Algebraic Modelling System
GHREC	General/Human Research Ethics Committee
GIR	Gross Irrigation Requirement
GIS	Geographic Information System
GS	Governance Systems
HI	Harvest Index
HLU	Hydrologic Land Use Unit

HTMT	Heterotrait-Monotrait
HWSD	Harmonized World Soil Database
INT	Intentions
I-O	Input-Output Models
ISRIC	International Soil Reference and Information Centre
IWRM	Integrated Water Resources Management
KZN	KwaZulu-Natal
LAI	Leaf Area Index
MB	Mulched-hole Border
MF	Mulch in Furrow
NAM	Norm activation Model
NAMC	National Agricultural Marketing Council
NaN	Not a Number
NC	Northern Cape
NDP	National Development Plan
NEP	New Environmental Paradigm
NIR	Net Irrigation Requirement
OECD	Organisation for Economic Co-operation and Development
PBC	Perceived behavioural control
PFC	Perceived Financial Cost
PICO	Population, Intervention, Comparison, and Outcome
PLS-SEM	Partial Least Squares Structural Equation Modelling
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analysis
PSR	Pressure–State–Response
RANAS	Risk, Attitude, Norms, Abilities, and Self-regulation
RAW	Readily Available Water
RDI	Regulated Deficit Irrigation
SADC	Southern African Development Community
SAM	Social Accounting Matrix
SCT	Socio-Cognitive Theory
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling
SES	Socio-Ecological Systems
SETS	Social-Ecological-Technological Systems

SIE	Specific Indirect Effects
SIS	Saline Infusion Sono Hysteroqram
SMU	Soil Mapping Unit
SN	Subjective Norms
SOTWIS	Harmonised continental SOTER-derived database
TACT	Target – Action- Context and time
TF	Technical Factors
TPB	Theory of Planned Behaviour
TRA	Theory of reasoned action
UN	United Nations
US	United States
VBs	Village Banks
VCN	Value-Belief-Norm
VIF	Variance Inflation Factor
WAU	Water Allocation Unit
WEF	Water-Energy-Food
WOS	Web of Science
WP	Water Productivity
WRB	World Reference Base
WRC	Water Research Commission
WSA	Water-Saving Agriculture
WUE	Water-Use Efficiency

CHAPTER 1: INTRODUCTION

Effective water management is crucial in agriculture, as the sector is one of the largest water consumers worldwide. Most pressures on the world's land, soil, and water resources derive from agriculture (FAO, 2021). The Food and Agriculture Organization (FAO, 2021) estimates that by 2025, agriculture will need to increase food, livestock fodder, and biofuel production by 50% compared with 2012 levels. According to the FAO (2017), the highest increase in agricultural production is required in Sub-Saharan Africa and South Asia, where a 232% increase will be needed by 2050 to meet the rising demand for food. However, this expected increase in food demand is particularly problematic, as many regions in Asia and Africa are already experiencing significant water stress (FAO, 2021). In addition to the various regions globally that are water-stressed, other challenges, such as rapid industrialisation, urbanisation, and population growth, will further complicate water management.

Furthermore, the FAO (2021) highlights the point that the global population is expected to grow from 7.7 billion in 2019 to 9.7 billion by 2050. Notably, Sub-Saharan Africa is projected to witness the most rapid population expansion, with projections indicating a doubling of its population by 2050. Considering these challenges, sustainable water management policies and practices are more imperative than ever.

Given the increasing strain on water resources and the rising demand for food, declining water availability presents significant social, economic, and environmental challenges for agriculture (Dolan et al., 2021; Ingrao et al., 2023). Policymakers are emphasising the need for more efficient and equitable water use in agriculture, while enhancing farmers' resilience to water scarcity (OECD, 2021; Salman et al., 2019; UN, 2003; UN, 2025). Managing water efficiently in food production has become increasingly important because of environmental pressures, the effects of climate variability, and the need to produce more food (Bates et al., 2008; Fu & Wu, 2014). Climate variability further complicates water management by altering rainfall patterns, reducing water availability, expanding the need for irrigation, and affecting both water demand and crop yields (Cotera et al., 2023; Hunink & Droogers, 2011; Turrall et al., 2011). Groundwater is a vital resource for agriculture, supporting irrigation and supplying nearly half of the world's drinking water (GW-Project.org, 2025). However, growing reliance on groundwater, combined with increasing water scarcity, raises concerns about the long-term sustainability of irrigated farming. Policymakers face the urgent challenge of ensuring water security while maintaining agricultural productivity.

Given the complexity of agricultural systems, water management and policies must take a comprehensive approach that considers social, economic, and environmental factors (Cotera et al., 2023; Mendonça et al., 2023). Water use in agriculture is closely linked to food security, economic stability, and social well-being. For example, Onyeaka et al. (2024) have demonstrated how climate variability negatively impacts food

prices and availability, exacerbating income inequality and contributing to social unrest and political instability. Similarly, Al-Muqdad et al. (2024) studied the Water-Food-Socioeconomic Nexus in Iraq. They showed how climate variability creates a ripple effect across water, food, and economic security, ultimately causing national security concerns. In another study, Song et al. (2024) analysed agricultural drought in the Republic of Korea (South Korea) and its widespread effects on production, employment, and prices across various sectors. These studies provide just a few examples of how changes in water use and availability in agricultural contexts can impact multiple sectors, emphasising the need for integrated policy and management approaches to be taken.

Climate variability has devastating effects on water availability, water demand, and investments in water systems for food production in South Africa, resulting in water scarcity. Climate variability causes changes in temperature and rainfall regimes, as well as the carbon dioxide fertilisation effect (Alavian et al., 2009; Hoffmann, 2013; Hunink & Droogers, 2011; Jorgensen et al., 2009). Additionally, available evidence suggests that human activities, such as unconstrained water use, can have a significant and sometimes devastating impact on these factors (Aufleger & Mett, 2011; FAO, 2012). Yet, most water-resource planning efforts and prior studies (Singh et al., 2013; Yi & Solis, 2015) tend to overlook human behaviour, failing to integrate such behaviours into the complex interactions that lead to water scarcity and thus misrepresenting farmers' behaviour towards water use. Similarly, information on the social and economic impacts of water use behaviours in food production is lacking, especially in South Africa. The lack of information is regrettable because it disincentivises policymakers from anticipating and integrating diverse perspectives, including human behaviour, into formulating effective water management policies. Furthermore, the recognition of water management and climate variability as multidimensional and multi-scalar issues (Downing, 2012; Meinke et al., 2009) provides impetus for integrating human behaviour into the different factors driving water scarcity in food production.

Recognising the far-reaching impacts of water use in agriculture, multiple frameworks and approaches have been developed and applied to manage water resources more comprehensively. For instance, the Water-Energy-Food Nexus (WEF) approach has been widely applied to assess the relationship between water use, food production, and energy demands (Cui et al., 2022; Hamidov & Helming, 2020; Mirzaei et al., 2024; Ramirez et al., 2021; Taguta et al., 2022; Zhang et al., 2022). In order to enhance its applicability in addressing complex water-related challenges, extensions of the standard WEF Nexus framework have incorporated additional dimensions, such as risk (Zhang et al., 2022), health (Mutanga et al., 2024), climate (Barati et al., 2023; Ioannidou et al., 2022; Radini et al., 2021), carbon (Cui et al., 2023; Ren et al., 2022; Su et al., 2024; Ye et al., 2024), and ecosystems and the environment (Basin, 2024; Correa-Cano et al., 2022; Halytsia et al., 2024; Karnib et al., 2024; Ma et al., 2024).

Beyond the WEF Nexus, other integrated water management approaches have been widely applied. Integrated Water Resources Management (IWRM) is another commonly used approach that aims to manage water, land, and related resources in a way that balances economic, social, and environmental needs (Ben-Daoud et al., 2021; Haulofu et al., 2022; Hu et al., 2014; Islam et al., 2023; Mersha et al., 2021; Zarghaami, 2006). Alongside the WEF Nexus and IWRM frameworks, other integrated approaches have been applied in the context of agricultural water management and policy. For instance, integrated frameworks have combined biophysical and ecological factors (Myburgh et al., 2024), biophysical and socioeconomic aspects (de Lange et al., 2010; Neupane et al., 2014; You et al., 2011), and social and biophysical interactions (Bastakoti et al., 2017) to assess water-related challenges. Other approaches have examined social and ecological dynamics (Daloğlu et al., 2014), and biophysical-economic linkages (Arndt et al., 2011; Baldos et al., 2020; Bullová et al., 2024; Kragt, 2013; Slootweg et al., 2001; Qureshi et al., 2008). More comprehensive frameworks, incorporating socioeconomic, biophysical, and institutional factors (Mohammedshum et al., 2023), have also been applied, along with those integrating agronomic, social, and demographic aspects (Brown et al., 2023), as well as hydrological, ecological, and economic factors (Kragt, 2013).

While the integrated frameworks provide valuable insights into water resource management, they often overlook the role of psychological and behavioural factors in shaping water use decisions. Research has shown that human behaviour is a contributing factor to inefficient water use (Callejas Moncaleano et al., 2021). Understanding the behaviour of agricultural water users is not only crucial for improving water-use efficiency (WUE) but also for developing tailored policies (Alotaibi & Kassem, 2021; Ataei et al., 2022; Bourceret et al., 2022; Mills et al., 2017; Seidl et al., 2021), enhancing water resource management (Yuan et al., 2021b) and designing effective interventions for behavioural change (Biesheuvel et al., 2021). Furthermore, incorporating psychological dimensions can enhance the effectiveness of environmental programmes (Bourceret et al., 2022), enable better predictions of responses to environmental changes (Sabzevar et al., 2021), and support the scaling of targeted solutions in agricultural water management (Dessalegn et al., 2022). Despite the well-established importance of human behaviour in influencing water use and management, many integrated frameworks do not adequately consider psychological and behavioural factors, especially when assessing the broader implications of changes in water use behaviour. Although various frameworks in water resource management have integrated biophysical, socioeconomic, institutional, economic, and ecological dimensions of food systems, they often overlook farmers' water use behaviours and the broader implications of these behaviours on other dimensions of the food system.

Changes in water use behaviour at the farm level can have ripple effects beyond individual farms, influencing local agricultural productivity, rural livelihoods, and even national water security (Brown,

2017; Kirsten & van Zyl, 1990; Pfunzo et al., 2024). Given these far-reaching impacts, integrated water management approaches and policy formulation must take water users' behaviour into account to strengthen water management frameworks. Without integrating behavioural aspects, even well-designed policies might fail to achieve their intended outcomes (Mills et al., 2017). To address this gap, this project developed an integrated framework that combines psychological, biophysical, and socio-economic dimensions to effectively measure the social and economic implications of changed water use behaviour in food production.

The integrated framework developed as part of this research project has been applied across various irrigation schemes and commodities in South Africa to explore its broader applicability in assessing water use behaviours in agriculture. South Africa is among the most water-scarce countries globally, ranked as the 30th driest, with an average annual rainfall of just 500 mm, compared with the global average of 860 mm (GreenCape, 2017). Water availability remains a critical constraint, especially in the agricultural sector, which uses more than 60% of the country's total water supply, and most of it in a consumptive manner (WRC, 2021). This heavy reliance on irrigation underscores the sector's vulnerability to water shortages and highlights the importance of promoting more efficient and sustainable water use practices. The framework developed in this project provides a structured and adaptable approach for evaluating the social and economic consequences of changing water use behaviour in agriculture. Rather than focusing on past trends, it allows for a forward-looking perspective by illustrating potential outcomes of behavioural change, helping decision makers to anticipate and respond to future policy, regulatory, and management challenges. The framework was applied in several case studies to illustrate its practical value across diverse production systems.

1.1 Problem Statement

Water scarcity is a significant challenge in agriculture, particularly in South Africa, where efficient water use is crucial for ensuring food security and economic stability. Researchers have explored various strategies to address this issue, including technological innovations (Bwambale et al., 2022; Khan et al., 2021; Salem et al., 2022; Shah et al., 2024), policy frameworks (Shah et al., 2023; Yang et al., 2022a; Zhao & Li, 2020), and economic incentives (Garrick et al., 2020; Piñeiro et al., 2020; Zhang & Oki, 2023) that promote the adoption of water-saving technologies. However, despite their potential to reduce water consumption while maintaining crop yields, adoption rates remain low in many agricultural contexts (Abdulai & Huffman, 2014; Blanke et al., 2007; Huang et al., 2020; Jha et al., 2019; Jordán & Speelman, 2020; Mi et al., 2021; Mohan et al., 2024; Perret & Stevens, 2006; Whittenbury & Davidson, 2009).

Various conceptual frameworks have been proposed to support a more integrated approach to understanding how different dimensions within agricultural systems interact and influence outcomes. These frameworks increasingly acknowledge the role of human systems. Still, they often remain at a conceptual level and lack clear methodological guidance on how to incorporate human dimensions, particularly social aspects such as the behaviour of actors, into broader system assessments. The lack of a clear, replicable framework for integrating behavioural drivers into broader system models leads to inconsistent methodologies being followed across studies and limits the ability to compare results across contexts (Feola & Binder, 2010; Nagel & Partelow, 2022; Maltby, 2024)

Although various frameworks in water resource management have integrated biophysical, socioeconomic, institutional, economic, and ecological dimensions of food systems, they often overlook the psychological aspects of decision-making. This gap limits our understanding of what drives farmers and irrigators to adopt or resist certain water use behaviours, such as the adoption of water-saving technologies (Mills et al., 2017; O'Shea et al., 2018). More importantly, not addressing this gap prevents the full assessment of how changes in water use behaviour at the farm level affect the broader agricultural and economic landscape. Changes in farmers' decision-making do not occur in isolation but instead have ripple effects across food systems, influencing market dynamics and rural livelihoods (Pfunzo et al., 2024).

1.2 Objectives

The main objective of this study is to develop an integrated framework that assesses the social, economic, and psychological implications of changing water-use behaviour among irrigators. To achieve the main objective, the following sub-objectives are defined:

- To identify the key psychological factors influencing irrigators' water-use behaviour in diverse agricultural contexts.
- To assess the influence of these identified factors on the intention to adopt water-saving technologies using the Theory of Planned Behaviour.
- To simulate different adoption scenarios of water-saving technologies and assess their impact on crop yields using a biophysical modelling approach.
- To quantify the economic and social implications of changes in water-use behaviour for the broader economy.

1.3 Innovation and Contribution of the Study

The study will contribute to policy in several ways. First, gaining an understanding of water use behaviours in food production can help to shed light on how to achieve more sustainable and equitable use of freshwater in food production through behavioural change in water management. Second, a fundamental decision confronting South Africa concerns integrating behavioural change into water conservation and management strategies in food production. Knowledge of the factors influencing water use behaviours in food production can serve as input to decision-making by helping policymakers to introduce social, economic, agronomic, and environmental considerations into water policy formulation and dissemination. Similarly, the study will guide environmentalists and policymakers in understanding how farmers respond to diverse water management and conservation strategies.

The main contribution of this study is an integrated framework that provides a clear and practical approach to including human decision-making in agricultural systems analysis. The framework links psychological factors that shape behaviour to biophysical outcomes and economic effects, allowing for a more complete understanding of how changes in behaviour influence outcomes across different parts of the system. Unlike existing conceptual models, this framework provides a structured method for tracing how individual decisions, such as the adoption of water-saving practices, impact crop production and the broader economy. The framework supports forward-looking assessment and enables a more consistent comparison to be made across different irrigation schemes and commodities. The structure and components of the framework are shown in Figure 1.1 below. Furthermore, the integrated framework (Conceptual tool) demonstrates the crucial role that farmers play in the economy and the importance of their decisions. As indicated above, the main contribution of this research is the integration of biophysical, psychosocial, and economic models to assess water-use behaviours and the impact of water-limited scenarios on food production in South Africa.

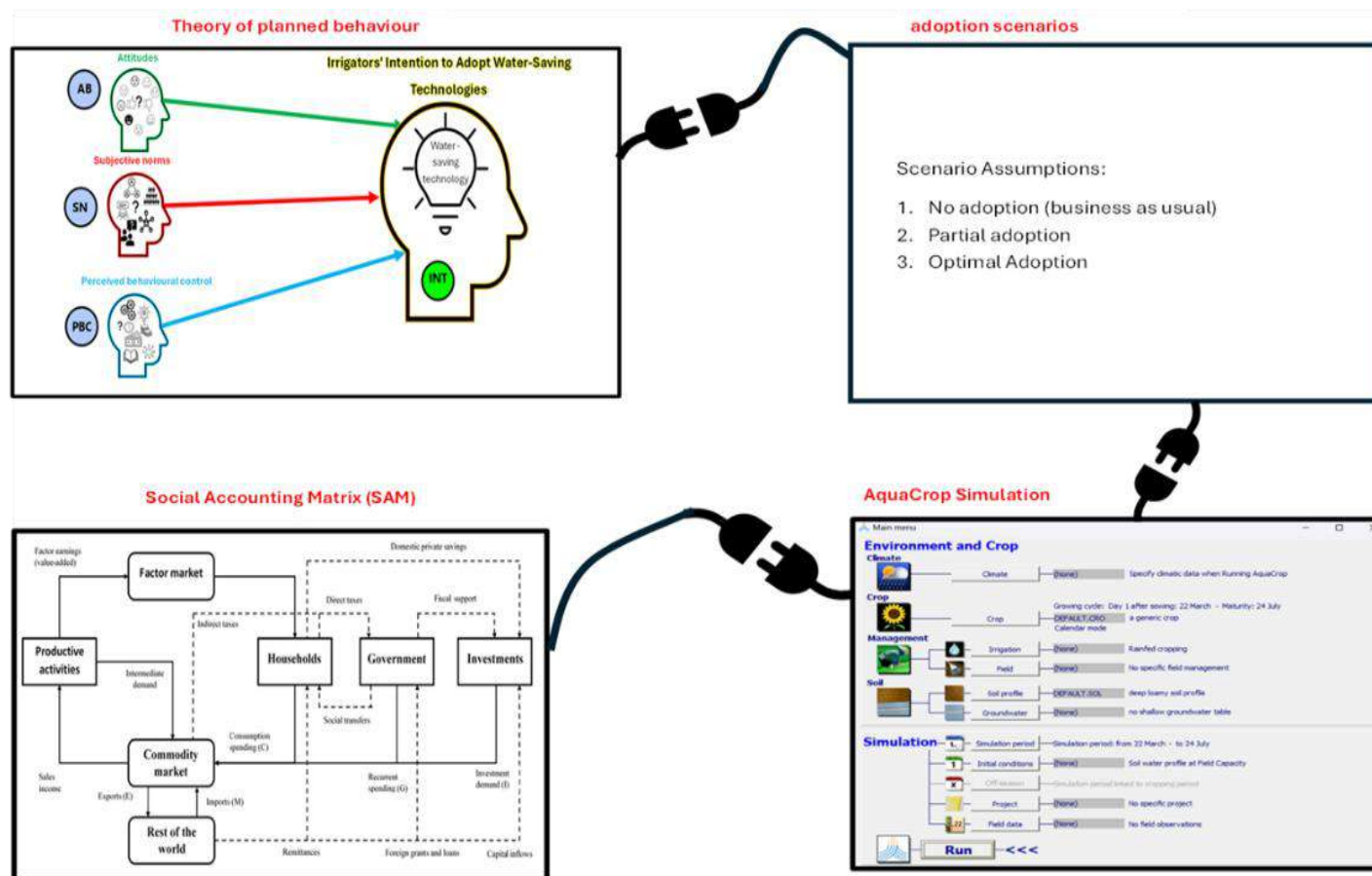


Figure 1.1: Integrated Framework for Assessing the System-Wide Impacts of Farmer Behaviour

Source: Project team compilation

The following stages are involved in achieving this integration (Figure 1.2 below). In the first stage, water use behaviour is defined, drivers of water use behaviours are identified, and questionnaires on behaviour are developed and administered under the Theory of Planned Behaviour (TPB). In the second stage of scenario development, simulations are based on TPB results, providing insights into the types of psychological conditions under which the behaviour occurred. In the third stage, the alignment of scenarios with the AquaCrop model simulation of yield is incorporated in the Social Accounting Matrix (SAM) to develop an integrated framework that assesses the social, economic, and psychological implications of changing water-use behaviour among irrigators.

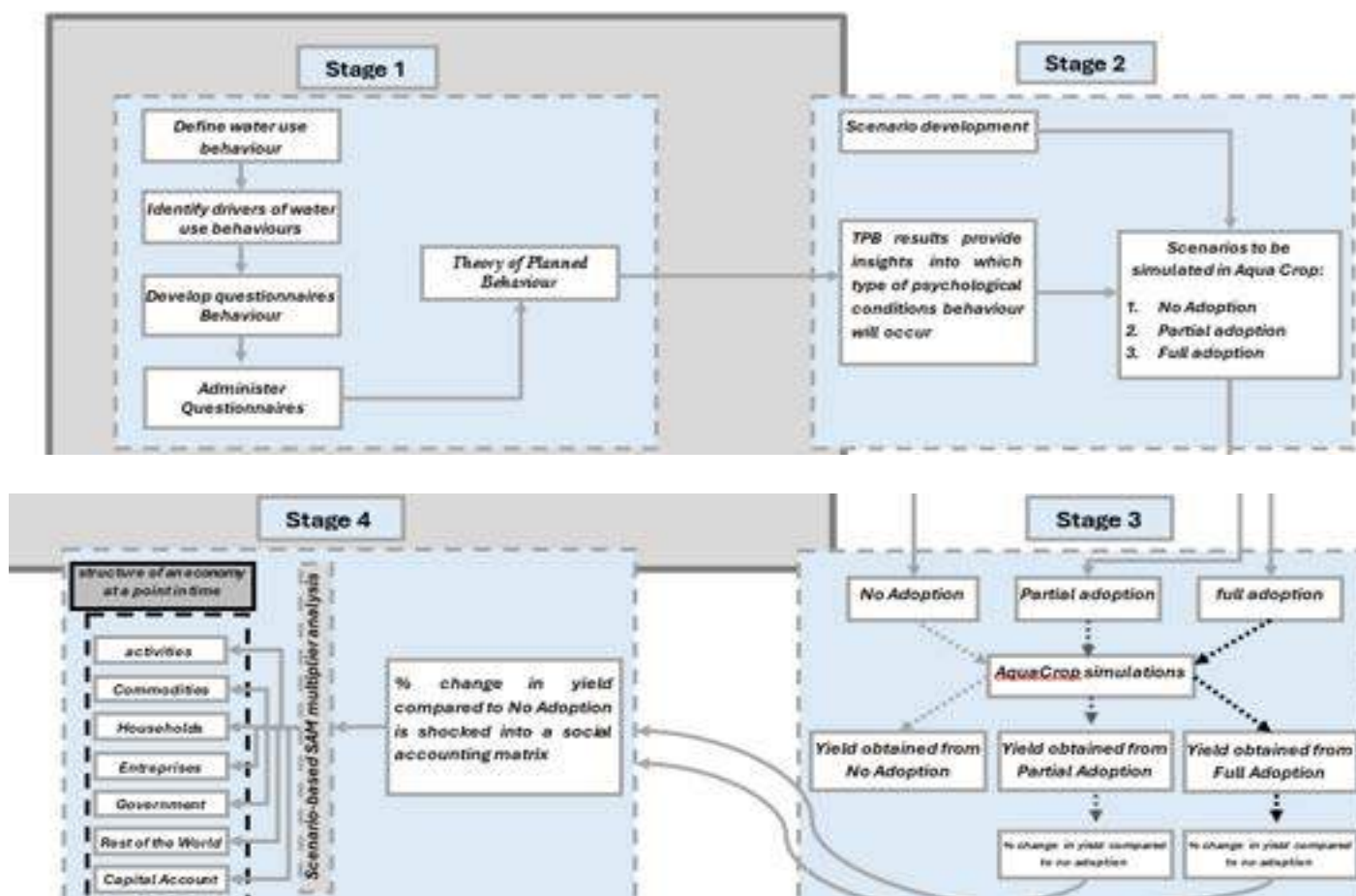


Figure 1.2: Steps for Integrated Framework

Source: Project team compilation

1.4 Layout of the Report

This report consists of ten chapters. Chapter 1 introduces the study by providing the background and motivation, a problem statement, and the objectives and contributions. Chapter 2 presents the literature review, and Chapter 3 outlines the data and methods used to develop and apply the integrated framework. Chapters 4 to 9 present case studies from different irrigation schemes and commodities. Chapter 4 focuses on small-scale maize irrigators in the Tshiombo Irrigation Scheme; Chapter 5 covers commercial sugarcane production in the Impala Irrigation Scheme; Chapter 6 examines commercial lucerne production in the Kakamas Irrigation Scheme; Chapter 7 and Chapter 8 focus on commercial wheat and soybean production, respectively, in the Hartbeespoort Irrigation Scheme; and Chapter 9 presents commercial maize production in the Orange Riet Irrigation Scheme. Chapter 10 concludes the report by summarising the findings and providing policy recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

Chapter 2 provides a structured foundation for understanding water use behaviour in agricultural systems by integrating insights across disciplinary boundaries. Chapter 2 begins by defining water use behaviour in the context of agriculture and examining how it has been conceptualised and studied across different disciplines. It also identifies the range of psychological, social, economic, and contextual factors that influence this behaviour. The review then proceeds to examine crop growth simulation models, assessing their strengths, limitations, and applicability in capturing agricultural processes. Following this, economic and social impact assessment models are discussed, with a focus on how they measure the effects of behaviour changes on broader systems. Lastly, the review examines integrated frameworks that incorporate human systems, particularly the social and psychological aspects of actors, into the wider environmental and agricultural systems. This helps to identify appropriate models and frameworks to address the interplay between human systems and other dimensions of agricultural systems, and to guide the selection and adaptation of suitable tools for each domain within the newly proposed integrated framework developed in this project.

2.2 Defining Water Use Behaviour¹

In addressing the complex interplay between human actions and sustainable water management, numerous studies have been undertaken, employing various theories and models, to analyse human environmental behaviours. Callejas Moncaleano et al. (2021) provide a comprehensive overview of these models, including the norm activation model (NAM); the new environmental paradigm (NEP); the theory of planned behaviour (TPB); the theory of values; the values, beliefs and norms theory (VBN); the theory of environmentally significant behaviour; and the risk, attitude, norms, abilities and self-regulation (RANAS). Although these conventional behavioural models have been extensively used, they have also been augmented to increase their predictive efficacy (He & Zhan, 2018; Tommasetti et al., 2018). For example, studies have augmented the NAM (Kiatkawsin et al., 2020; Landon et al., 2017; Rosenthal & Ho, 2020; Yan & Chai, 2021), TPB (Gibson et al., 2023; Hoong Chan et al., 2022; Marcos et al., 2021; Savari & Khaleghi, 2023; Si et al., 2022; Wang et al., 2023), and the VBN (Choi et al., 2015; Chunhua et al., 2023;

¹ Part of Chapter 2, which has already been published in an accredited scientific journal: Monteiro, M.A.; Bahta, Y.T.; Jordaan, H. (2024). A Systematic Review on Drivers of Water-Use Behaviour among Agricultural Water Users. *Water*, 16, 1899. DOI: 10.3390/w16131899

Li et al., 2018). The extension of these standard models indicates a growing recognition of the need to refine these models to better capture the complexities of behaviour in specific contexts.

The augmentation of conventional behavioural models is based on considering either potential specific factors or using empirical evidence to guide the augmentation process. In this regard, a literature review of the factors influencing water-use behaviour in agricultural settings could be a valuable starting point. According to the project team's best knowledge, two reviews (Callejas Moncaleano et al., 2021; Meempatta et al., 2019) have been conducted related to the water-use behaviour in agricultural contexts. Callejas Moncaleano et al. (2021) reviewed the contextual and behavioural factors influencing water-use efficiency (WUE). They proposed a conceptual framework to link these factors to address the knowledge gaps on human water-use behaviour, considering WUE. The study by Meempatta et al. (2019) reviewed the decision-making process of irrigators and the impact of their decisions on resource use, societal welfare, and environmental sustainability. Despite the valuable insights offered by the authors of the studies by Callejas Moncaleano et al. (2021) and Meempatta et al. (2019), an up-to-date review is crucial for staying on track in achieving SDG 6, particularly Targets 6.4 (increase water-use productivity across all sectors) and 6.5 (implement integrated water resources management at all levels). More importantly, this section serves as a foundation for augmenting the behavioural model applied in the psychological component of the integrated framework developed in this study.

2.2.1 Systematic review approach for defining Water Use Behaviour

This study adopts the systematic review framework developed by Koutsos et al. (2019), which provides a structured roadmap for conducting effective systematic reviews in agricultural research. Koutsos et al. (2019)'s framework builds upon the fundamental steps outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, offering a refined approach better suited to agricultural research contexts. The systematic review framework proposed by Koutsos et al. (2019) consists of six key steps, which comprise scoping, planning, identification, screening, eligibility/assessment, and presentation, as illustrated in Figure 2.1 below.

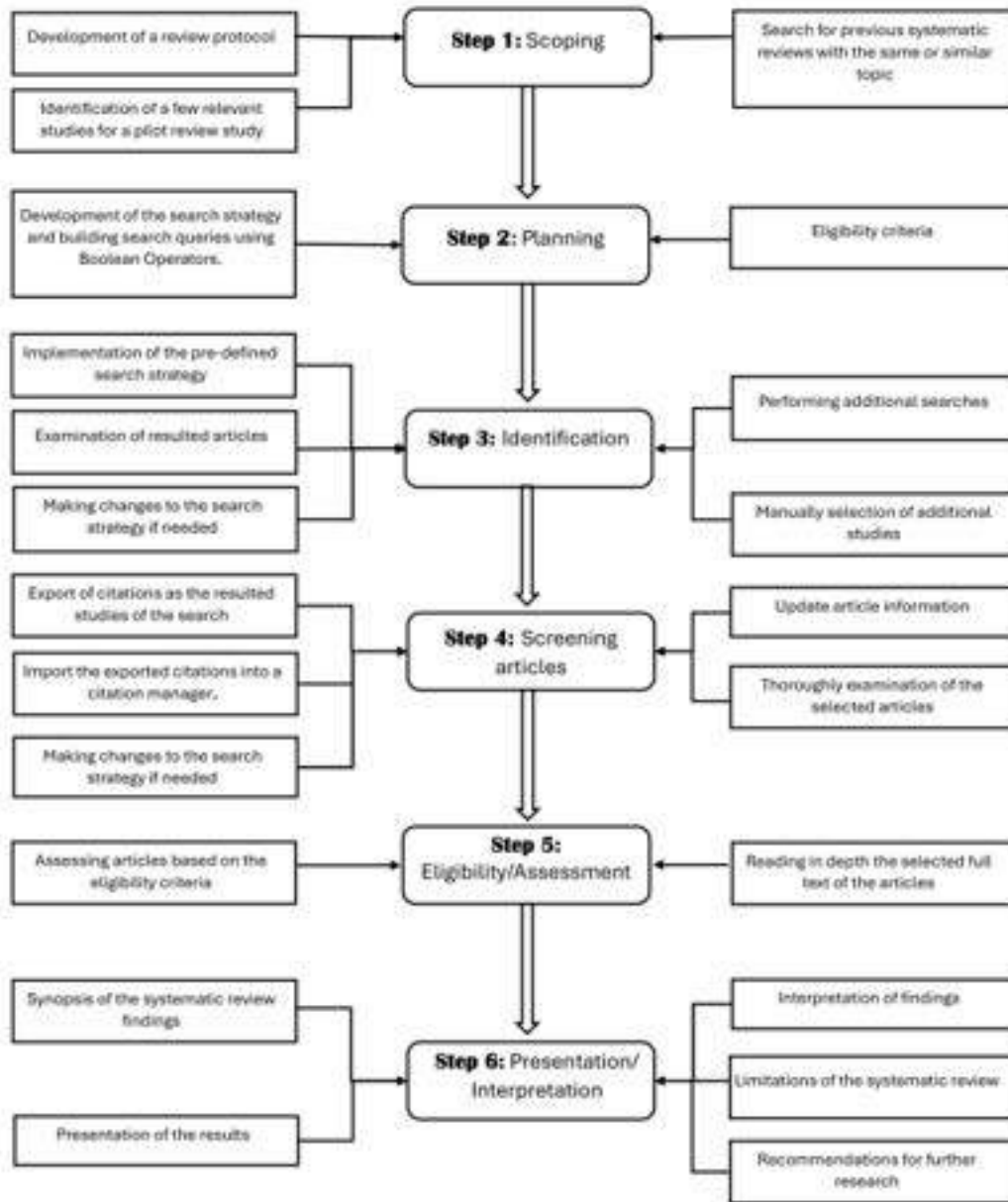


Figure 2.1: A systematic review framework for agricultural research

Source: Adopted from Koutsos et al. (2019)

2.2.1.1 Step 1: Scoping

The initial scoping phase is crucial as it establishes the foundation for the systematic review process. A well-structured review protocol requires a clearly defined research question and study design. To formulate a precise research question, the Population, Intervention, Comparison, and Outcome (PICO) framework was applied, based on the specified PICO elements illustrated below and in Table 2.1.

“What are the main factors influencing water-use behaviours among agricultural irrigators globally, considering psychological factors, decision-making processes, technological interventions, policy frameworks, and socioeconomic conditions?”

Table 2.1: Specific PICO elements for a systematic review and specific keywords tailored to each PICO element

PICO Component	Description
Population	Irrigators; farmers; producers; growers; water users; irrigation practitioners; agricultural practitioners; crop growers
Intervention	Water use behaviour; water management practices; psychological drivers; irrigation techniques; decision-making; behavioural drivers
Comparison	Regional, countries, farming systems, irrigation schemes, water management approaches, farming system variations, international perspectives
Outcome	Determinants of water use behaviour; patterns of water use behaviour; water management practices; agricultural water usage patterns; behavioural insights in irrigation

Source: Project team’s compilation

To mitigate bias in study selection and interpretation, studies were independently screened and selected for inclusion. The web-based tool Rayyan was utilised to streamline the screening process. Rayyan is a widely recognised tool for enhancing efficiency in systematic reviews by expediting study selection, fostering organisation, and improving productivity (Ouzzani et al., 2016).

The systematic integration of Rayyan in this review process is outlined in Figure 2.2 below. First, search results from relevant databases were uploaded into Rayyan. The tool automatically identified duplicate records, which were carefully managed to ensure the appropriate versions were retained. Following this, independent screening was conducted in Rayyan, with articles categorised as ‘Include,’ ‘Maybe,’ or ‘Exclude.’ To ensure consistency in selection, any discrepancies and articles marked as ‘Maybe’ were reviewed and reassessed in collaboration with the main supervisor and co-supervisor. Once the screening process was finalised, subsequent steps in the systematic review proceeded accordingly.

A pilot review was conducted to refine the search strategy and ensure familiarity with the systematic review process. This pilot review assessed search terms, databases, and inclusion/exclusion criteria to identify potential challenges before conducting the final evaluation. The search strategy was based on keywords

derived from the PICO framework and specific keywords tailored to each PICO element, as outlined in Table 2.1 above.

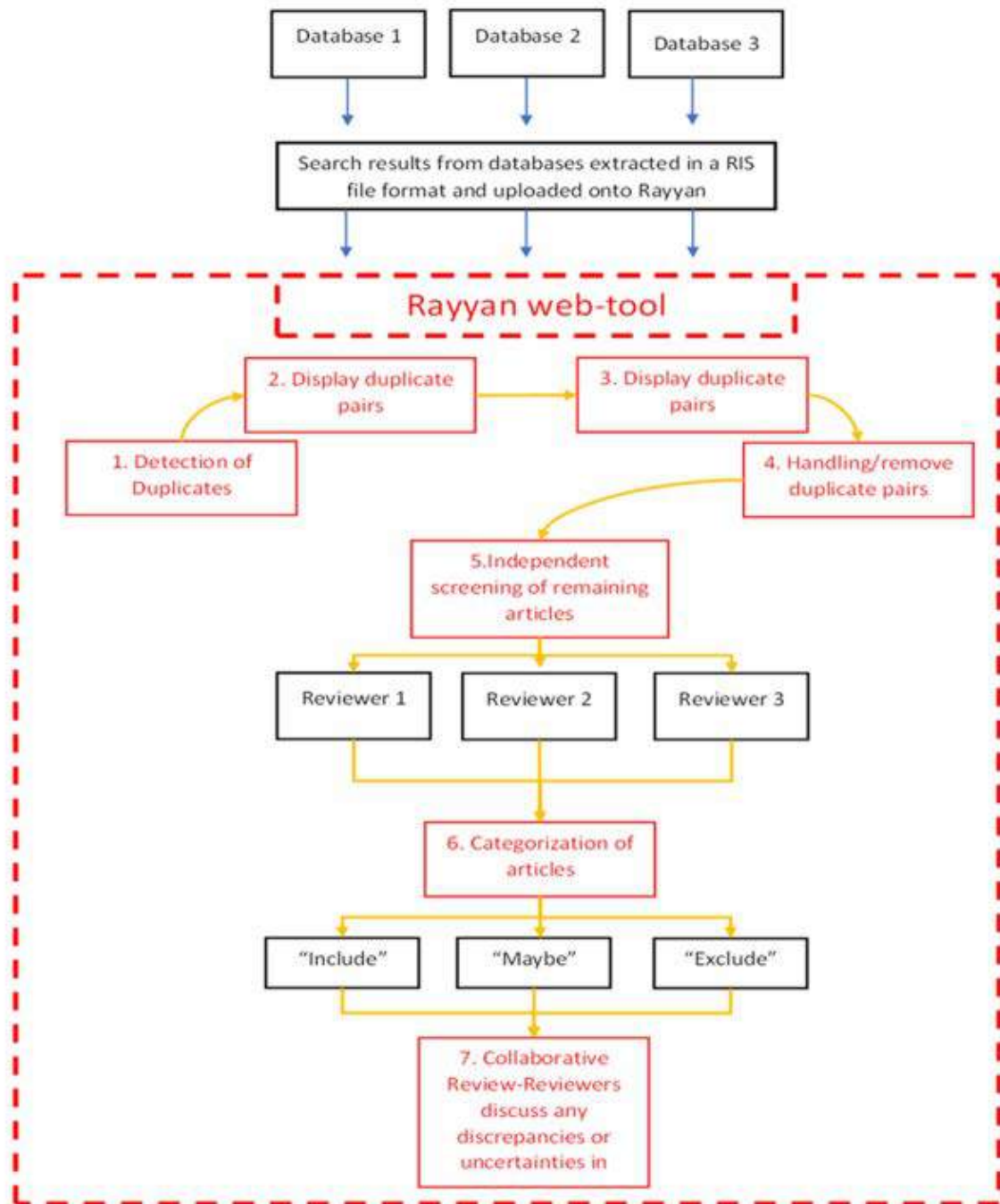


Figure 2.2: Steps Followed in Integrating Rayyan into the Systematic Review

Source: Project team compilation

2.2.1.2 Step 2: Planning

This study employed a systematic approach to the literature review, utilising Scopus, Web of Science, and EBSCOHost databases (specifically Academic Search Ultimate, Africa-Wide Information, CAB Abstracts with Full Text, E-Journals, GreenFILE, and MEDLINE). Scopus and Web of Science are well-known for their coverage of various disciplines (Pranckut, 2021). In contrast, EBSCOHost databases provide a wide range of academic resources, including full-text articles, abstracts, and specialised information relevant to the study's aims. Table 2.2 below outlines the specific Boolean operators used for each database to ensure that relevant search results are obtained.

Table 2.2: Databases and associated Boolean operators

PICO Component	Description
Web of Science	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and (“water use” or “water usage” or “water management” or “irrigation technique*” or “irrigation management*”) and (behav* or pattern* or practice* or insight* or adapt*) and title (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)
Scopus	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and (“water use” or “water usage” or “water management” or “irrigation technique*” or “irrigation management*”) W/5 (behav* or pattern* or practice* or insight* or adapt*) and ti (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)
EBSCOHost (Academic Search Ultimate, Africa-Wide Information, CAB Abstracts with Full Text, E-Journals, GreenFILE, MEDLINE	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and (“water use” or “water usage” or “water management” or “irrigation technique*” or “irrigation management*”) N5 (behav* or pattern* or practice* or insight* or adapt*)) and ti (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)

Source: Project team compilation

An additional search was conducted using the advanced search function in Google Scholar. Table 2.3 below outlines the approach followed for this advanced search, detailing the specific search fields and terms used. The results obtained from Google Scholar were exported in an ENW file following the search. These search results were then uploaded to Rayyan for further screening and analysis.

Table 2.3: Google Scholar additional search protocol

Google Scholar Advanced Search Field	Description
With all of the words	irrigators farmers' water use irrigation
With the exact phrase	behave*
With at least one of the words	producers' growers water users irrigation practitioners agricultural practitioners crop growers water management practices psychological drivers irrigation techniques behavioural drivers
Where my words occur	anywhere in the article
Return articles dated between	2020–2024

Note: The “*” symbol is a wildcard used to include all variations of a word (e.g. “behav” captures “behavior”, “behaviour”, “behaviors”, “behaviours”, etc.).

Source: Project team compilation derived from the keywords of the PICO framework

2.2.1.3 Eligibility criteria

For the selection of articles, the following inclusion criteria were set: (1) studies published within the last five years (2020 to 2024) to ensure the relevance of the research; (2) all studies published in peer-reviewed English language journals; (3) studies that investigate various interventions or practices related to water use in agriculture; (4) studies involving farmers, agricultural workers, or any individuals directly involved in agricultural activities related to water use will be considered; and (5) peer-reviewed papers, reports, and relevant publications that meet the criteria for eligibility will be included.

To ensure that the papers included in this systematic review are relevant, the following exclusion criteria were established: (1) book chapters were omitted to keep the focus on peer review articles; (2) papers that were work-in-progress or labelled as “short papers” were excluded; (3) to ensure that this systematic review does not duplicate existing secondary literature captured in other review types (such as scoping reviews, critical reviews, narrative reviews, opinion pieces, and systematic reviews), the project team specifically excluded these review types. Our systematic review focuses exclusively on primary studies, avoiding duplication of research that other systematic reviews have already covered. Studies that did not focus on water-use behaviour in agricultural contexts were also excluded. Additionally, theses and dissertations are excluded from consideration to maintain consistency with the focus on peer-reviewed articles.

2.2.1.4 Identification/Search

The predefined search queries were executed, and the results were exported. For the databases listed in Table 2.2 above, the search results were exported in RIS file format, and for Google Scholar (Table 2.3

above), the search results were exported in EWN file format. Both RIS and EWN file formats are compatible with Rayyan. The results were then uploaded and briefly scanned in Rayyan to confirm their relevance before proceeding with in-depth screening in the next step. During this initial screening, it was ensured that the search results accurately reflected the intended scope of the review. No additional changes were made to the search terms, as the formulated strategy was comprehensive and aligned with the keywords derived from the PICO framework.

The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement (Figure 2.3 below). We retrieved 867 records, of which 709 were obtained from electronic databases (WOS, Scopus, and EBSCOHost), and 158 additional records were obtained from Google Scholar. After removing 361 duplicates, 506 records remained for screening of their titles and abstracts.

2.2.1.5 Step 4: Screening articles

At this stage, each reviewer categorised the 506 records in Rayyan as either “include”, “exclude”, or “maybe” based on their titles and abstracts (see Figure 2.3). Out of the 506 records, 381 were marked as “exclude”, while 71 were classified as “include”. Additionally, 31 records were tagged as “maybe”, and 23 records had conflicting classifications among the authors. The authors engaged in discussions to reach an agreement for the 31 “maybe” records and the 23 conflicting records. Eventually, 7 out of the 31 “maybe” articles and 5 out of the 23 conflicting records were included in the final analysis. Therefore, a total of 83 records remained to be assessed for eligibility.

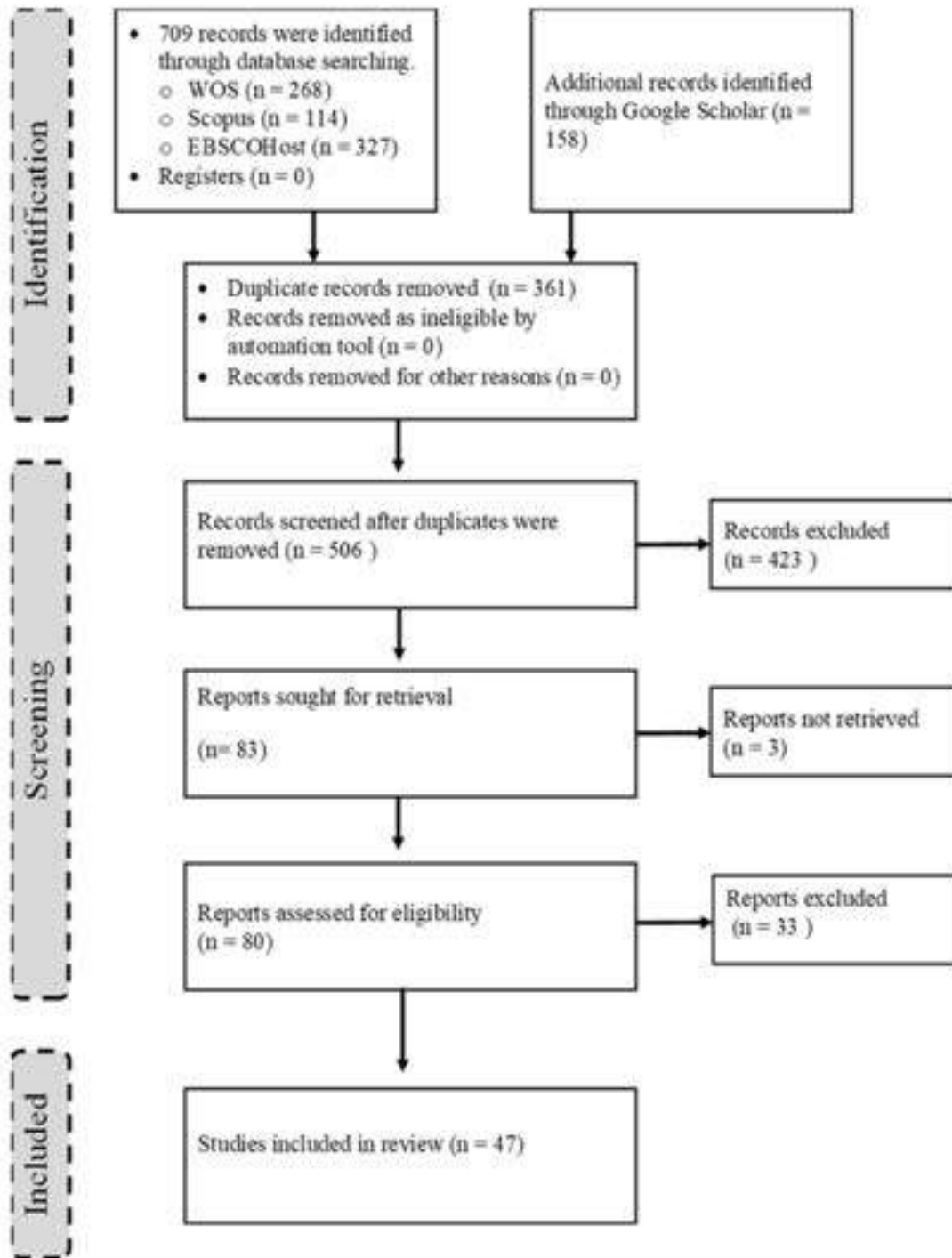


Figure 2.3: PRISMA flow chart to illustrate the article search and the inclusion process

Source: Project team compilation based on Page et al. (2021)

2.2.1.6 Step 5: Eligibility/Assessment

The 83 articles that remained after the title and abstract screening were chosen for full-text analysis. Initially, attempts were made to retrieve the full texts of all articles. However, full texts for 3 out of the 83 articles could not be obtained because access to these articles required payment that was not within our financial resources. Therefore, a total of 80 full-text records were evaluated against the predefined eligibility criteria to determine whether they aligned with the study's objectives. A total of 33 articles were deemed unsuitable and removed based on the requirements, resulting in 47 eligible articles.

Based on the methodology described by van Dinter et al. (2021), a quality assessment of the 47 articles was carried out to ensure that this systematic review maintained an acceptable standard. Table 2.4 below displays the detailed criteria used to evaluate the quality of all 47 studies. Studies with a score below 4 out of 8 were removed, while those with a higher score were retained, ensuring high-quality input for our systematic review. Nevertheless, no studies scoring below four were identified, meaning the total number of articles to be included in our systematic review remained at 47.

Table 2.4: Quality Checklist

Quality criteria	Question
Q1	Are the aims of the study clearly stated?
Q2	Are the scope, context, and experimental design clearly defined?
Q3	Are the variables in the study likely to be valid and reliable?
Q4	Is the research process documented adequately?
Q5	Are all the study questions answered?
Q6	Are the negative findings presented?
Q7	Are the main findings regarding credibility, validity, and reliability clearly stated?
Q8	Do the conclusions relate to the purpose of the study? Are they reliable?

Source: Project team compilation based on the adopted from van Dinter et al. (2021)

2.2.2 Systematic review results

2.2.2.1 Publication trends

In this review, the 47 articles² selected provides and help to assess an overview of the authors of each study, the year of publication, the country where the study was conducted, the type of water-use behaviour examined, a summary of the key findings of each research, and key topics explored in U.S.(Bailey et al. (2021); Berthold et al. (2021); Davenport et al. (2022); Fan & McCann (2020); Fischer & Sanderson (2022); Irmak et al. (2022); Reints et al. (2020); Roberts et al. (2022)) and Chinese studies on water-use behaviour (Cui et al. (2022); Mi et al. (2021); Ren & Yang (2023); Wang et al. (2021b); Wang et al. (2023); Yuan et al. (2021a); Xiuling et al. (2023)). The year range of publication for the 47 studies is illustrated in Figure 2.4 below. The publication output ranged from 2020 to 2024, with the highest number of publications observed in 2021 and 2022, each of these years totalling 15 publications. Notably, the low number of publications in 2024 might be attributed to the fact that the searches for this systematic review were conducted in March 2024, and that the number of publications in 2024 would likely increase after this systematic review was published.

² Detailed explanations are available in an article published as part of this project as “Monteiro, M.A.; Bahta, Y.T.; Jordaan, H. (2024). A Systematic Review on Drivers of Water-Use Behaviour among Agricultural Water Users. *Water*, 16, 1899. DOI: 10.3390/w16131899” The included 47 studies are “Abebe et al., 2022; Alauddin et al. 2020; Aldaya et al., 2023; Alotaibi & Kassem, 2021; Asthana, 2022; Aldaya et al., 2023; Ataei et al. 2022; Bailey et al., 2021; Berthold et al., 2021; Bogdan & Kulshreshtha, 2021; Cavazza et al. 2022; Davenport et al., 2022; Dessalegn et al. 2022; Bourceret et al., 2022; Cui et al., 2022; Danso et al., 2021; Fan & McCann, 2020; Fischer & Sanderson, 2022; Gao et al., 2024; Hoang-Thi et al. 2023; Irmak et al. 2022; Johnson et al., 2023; Leroy, 2023; Mahdavi, 2021; Mekonnen et al., 2022; Mi et al., 2021; Michalak, 2020; Muenratch & Nguyen, 2023; Ortiz et al., 2023; Rafii, 2022; Reints et al., 2020; Ren & Yang, 2023; Ricart & Rico-Amorós, 2021; Roberts et al., 2022; Sabbagh & Gutierrez, 2023; Sabzevar et al., 2021; Sajid et al., 2022; Salas-Zapata et al., 2023; Seidl et al., 2021; Usman et al., 2023; Velasco-Muñoz et al., 2022; Wheeler et al., 2021; Wang et al., 2021b; Wang et al. 2023; Woldeselassie et al. 2021; Yuan et al. 2021; Xiuling et al., 2023.”

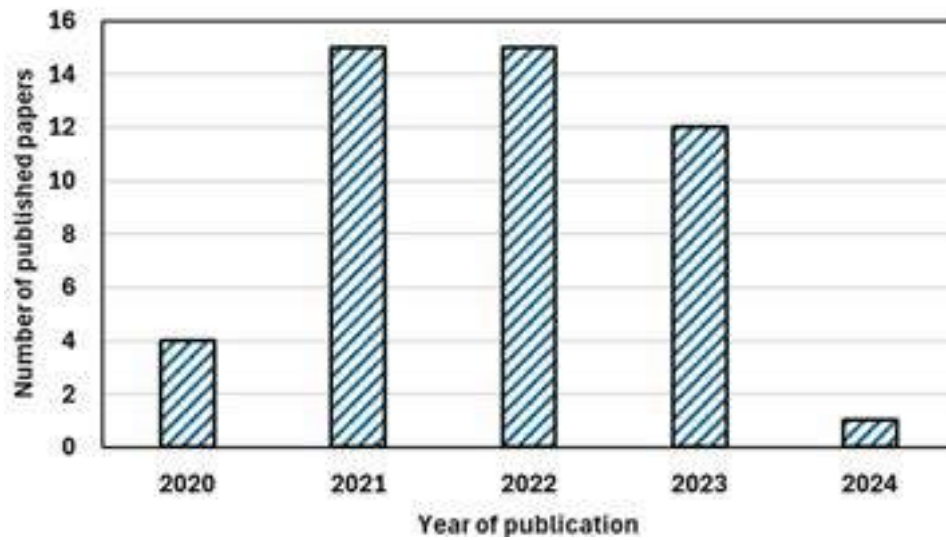


Figure 2.4: Number of papers published in each year over the five years (2020–2024)

Source: Project team compilation

2.2.2.2 Geographic Distribution of Studies

The tree map shown in Figure 2.5 below visually summarises the distribution of study counts across different countries within the final 47 articles identified. In Figure 2.5, the size of each rectangle in the tree map corresponds to the number of studies conducted in that specific country. The United States and China are the top countries in terms of research on water-use behaviour in agriculture, with the United States conducting eight studies and China conducting seven studies between 2020 and 2024.

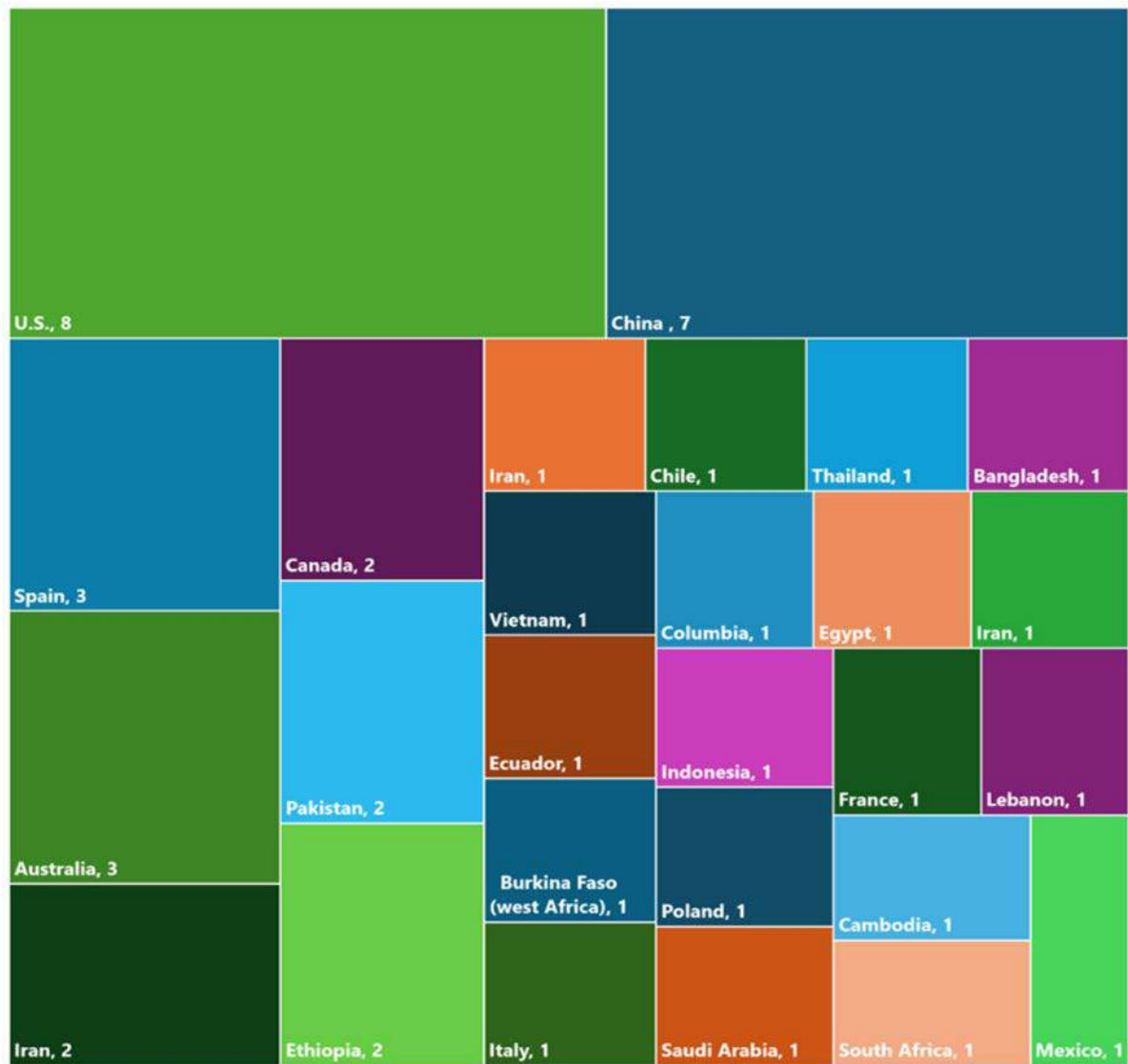


Figure 2.5: Tree map of study distribution across countries (2020–2024)

Source: Project team compilation

Furthermore, a keyword co-occurrence analysis was conducted to examine the thematic focus of water-use behaviours studies in the U.S. (8 studies) and China (7 studies). This analysis was performed using VOSviewer, which was used to generate density visualisation plots based on the frequency and intensity of keyword co-occurrences. Separate density plots were created for the eight studies conducted in the U.S. (Figure 2.6 below) and the seven studies in China (Figure 2.7 below).

The density visualisation plot (Figure 2.6 below) for the eight studies conducted in the U.S. reveals how research efforts have focused on understanding and enhancing water-use behaviour in agricultural contexts. Key themes, such as “water conservation,” “soil moisture sensors,” “irrigation management,” and “agriculture,” indicate that these topics have been prominent in the studies analysed. Additionally, there is

increasing attention being given towards “climate change/variability beliefs”, “adaptation”, and “irrigation”, underscoring a growing recognition of climate impacts and the necessity for adaptive strategies in agricultural water management. The visualisation where “water conservation” is the largest and bright red, close to nodes like “soil moisture sensors”, “agriculture”, and “irrigation”, suggests strong connections and frequent co-occurrences among these concepts in eight U.S. studies. Furthermore, the connection between “climate change/variability beliefs” and “adaptation” suggests that U.S. farmers’ perceptions and beliefs about climate change/variability are an important factor shaping their adaptive behaviours and water-use practices.

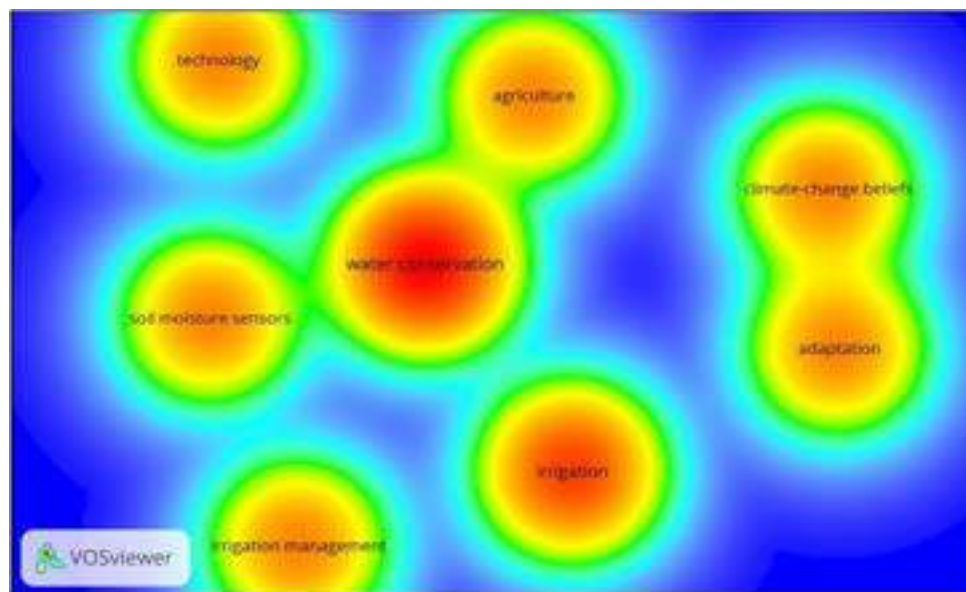


Figure 2.6: Keyword Co-Occurrence Density Visualisation of Agricultural Water-Use Behaviour Studies Conducted in the U.S.

Note: Nodes represent keywords extracted from the literature. Larger and brighter nodes indicate keywords that appear more frequently or are central to the network. Connections (edges) between nodes represent co-occurrences of keywords within the selected studies. The colour scheme in the density visualisation plot ranges from bright red to blue. Key nodes are depicted in bright red, indicating higher density or significance, while surrounding areas are shaded blue, showing lower density or importance.

Source: Project team compilation using VOSviewer software

The keyword co-occurrence analysis of the seven studies on water-use behaviour in China, shown in Figure 2.7 below, reveals six significant keywords. The analysis highlights "management" as the largest and brightest node, closely linked to "scarcity", indicating a strong research focus on managing water resources in response to scarcity issues in China. These findings reflect substantial efforts to implement strategies tackling water scarcity. The proximity of nodes for “determinants” and “land” suggests a strong relationship between factors influencing water use and land-related issues. Furthermore, the term “smallholder farmers”

is closely associated with “land”, emphasising the importance of land use practices by smallholder farmers in research. This clustering shows recent research emphasis on understanding the various determinants and land management practices, particularly involving smallholder farmers, in studies conducted in China.

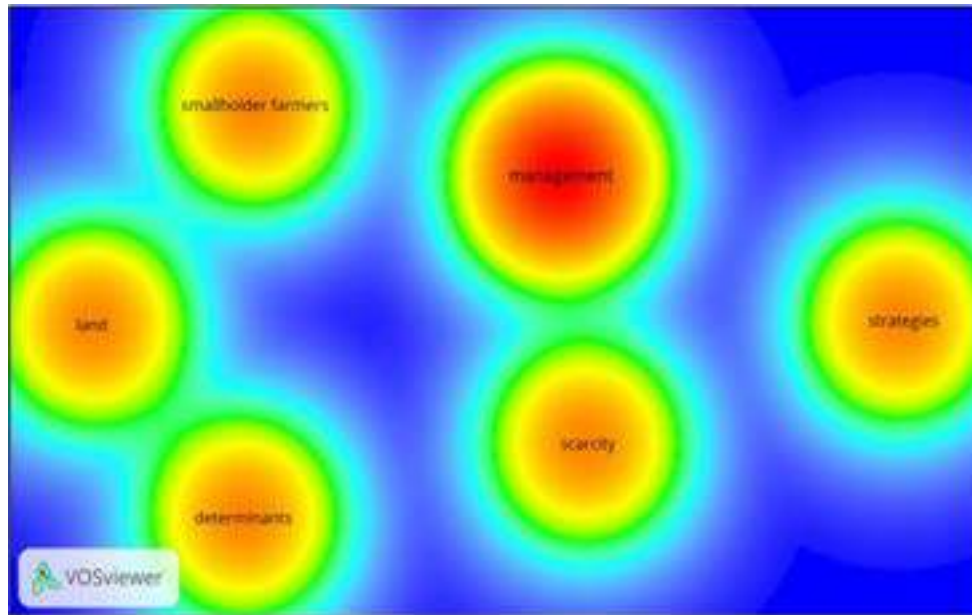


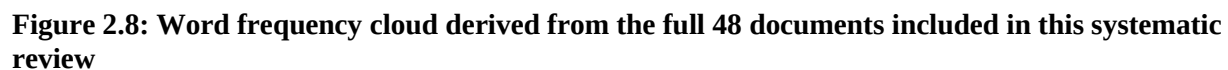
Figure 2.7: Keyword Co-Occurrence Density Visualisation of Agricultural Water-Use Behaviour Studies Conducted in China

Note: Nodes represent keywords extracted from the literature. Larger and brighter nodes indicate keywords that appear more frequently or are central to the network. Connections (edges) between nodes represent co-occurrences of keywords within the selected studies. The colour scheme in the density visualisation plot ranges from bright red to blue. Key nodes are defined in bright red, indicating higher density or significance, while the surrounding areas are shaded in blue, showing lower density or importance.

Source: Project team compilation using VOSviewer software

The density visualisation plots provide a detailed overview of the main themes and concepts explored in research on water-use behaviour in the U.S. and China. As it mentioned above studies on water-use behaviour in Chinese agriculture cover key issues such as government policies and social security measures affecting water-management practices; the implementation and impact of water pricing policies; farmers’ decision-making processes and risk preferences; adoption of water-saving technologies; the role of social networks and economic incentives in water management strategies; and awareness of environmental consequences related to agricultural water use. These topics reflect the diverse factors influencing water-use behaviours and strategies in Chinese agriculture. Studies on water-use behaviour in U.S. agriculture explored key issues such as irrigation practices and scheduling, the adoption of water conservation technologies, multilevel modelling of water-use behaviour, and policy implications of water conservation efforts.

Next, a word frequency analysis was conducted using NVivo 14 software to identify key themes and focus areas discussed across the 47 articles included in this systematic review. Figure 2.8 below presents the word frequency cloud derived from the full-text body of the 47 articles and places greater prominence on words that occurred most frequently across the 47 articles. The words “climate”, “irrigation”, “water”, “change”, “farmers”, and “adoption” were found to be the most frequently occurring words expressed in red, indicating that these words occurred with the highest frequency.



Source: Project team compilation

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managing water resources. In addition, the inclusion of words such as “climate” and “change” suggests a growing concern regarding the impacts of climate variability on water resources and agricultural practices.

Table 2.5: Word Frequency Distribution Across the 47 Reviewed Articles

Word ranking	word	length	Count	Weighted percentage	Word ranking	word	length	Count	Weighted percentage
1	water	5	7674	2.01	16	crop	4	1001	0.26
2	irrigation	10	4270	1.12	17	risk	4	888	0.23
3	farmers	7	2783	0.73	18	data	4	873	0.23
4	climate	7	1817	0.47	19	information	11	847	0.22
5	change	6	1679	0.44	20	level	5	845	0.22
6	adoption	8	1659	0.43	21	factors	7	828	0.22
7	management	10	1589	0.42	22	research	8	823	0.22
8	agricultural	12	1558	0.41	23	saving	6	817	0.21
9	farm	4	1344	0.35	24	land	4	816	0.21
10	farmers'	8	1310	0.34	25	soil	4	790	0.21
11	adaption	10	1276	0.33	26	used	4	789	0.21
12	technology	10	1216	0.32	27	area	4	758	0.20
13	model	5	1176	0.31	28	variables	9	749	0.20
14	study	5	1138	0.30	29	agriculture	11	744	0.19
15	practices	9	1042	0.27	30	policy	6	740	0.19

Note: the weighted percentage in a word frequency query assigns a portion of the word's frequency to each group to ensure the overall total does not exceed 100%.

Source: Project team compilation using NVivo 14 software

2.2.2.4 Keyword Co-Occurrence Network

The word frequency cloud (Figure 2.8 above) and Table 2.5 (above) highlight several key themes that are covered across the literature, including water management and irrigation, farmers' perceptions, climate variability and its impacts, and agricultural practices, management, and technology adoption.

Additionally, further insights were gained by constructing a keyword co-occurrence network (Figure 2.9 below), which helped to identify key themes, clusters, and connections across the 47 included studies. The keyword co-occurrence network was generated in VOSviewer, where 383 keywords were extracted, among which 33 keywords met the threshold of three, meaning that the minimum occurrence of a keyword is three. Each node in Figure 2.9 represents a keyword, with the size of the node indicating the frequency of occurrence of that keyword. Larger nodes signify keywords that are more significant within the corpus. The distance between nodes reflects the relatedness of keywords based on their co-occurrence, where nodes closer to each other indicate that keywords appear together more frequently in the same articles. The thickness of the lines between the nodes indicates the strength of the co-occurrence relationship. Furthermore, keywords are grouped into clusters that are thematically connected. Additionally, the colour

of each node denotes the cluster to which the keyword belongs, and the words within each cluster tend to co-occur more frequently with each other than with words in other clusters.

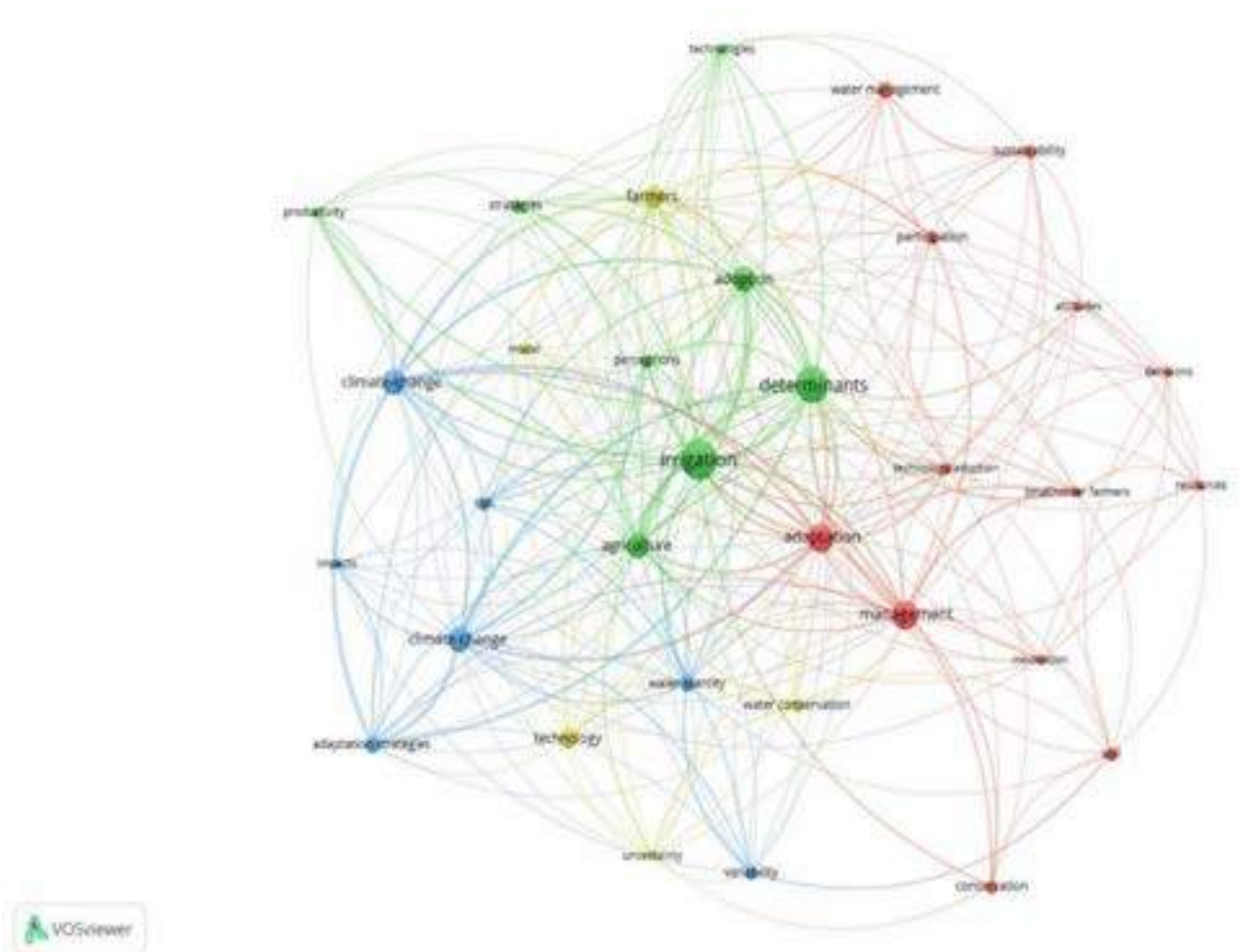


Figure 2.9: Keyword co-occurrence network

Note: In the keyword co-occurrence network, the different colours represent different clusters. Each cluster represents a group of keywords that frequently co-occur, highlighting related themes or topics within the dataset.

Source: Project team compilation

A total of four clusters occur in Figure 2.9, each with distinct colours. In the first cluster (red), keywords such as “adaptation”, “conservation”, “innovation”, “management”, “sustainability”, and “water management” are all related to sustainable agricultural practices and resource management. In the second cluster (green), keywords such as “adoption”, “agriculture”, “irrigation”, “productivity”, and “technologies” are all associated with the adoption and use of technologies in agriculture to improve productivity, particularly in water management. Conversely, phrases such as “climate change/variability”, “adaptation strategies”, “impacts”, “risk”, and “water scarcity” are included in the third cluster (blue), indicating a thematic emphasis on understanding and addressing the impacts of climate variability on water

availability and agricultural practices. Lastly, the fourth cluster (yellow) highlights keywords such as “farmers”, “model”, “technology”, “uncertainty”, and “water conservation”, suggesting a thematic focus on modelling approaches and uncertainties in agricultural water management.

Viewing the interlinkages between clusters in Figure 2.9 above reveals that “adaptation” (cluster one, red) is closely linked to “irrigation” and “agriculture” (cluster two, green), which implies that efficient irrigation practices are an important component of adaptive strategies in agriculture. In addition, “adaptation” (cluster one, red) is also linked to “climate change/variability” and “impacts” (cluster three, blue), highlighting the need for adaptive strategies to mitigate the adverse effects of climate variability and its related impacts.

2.2.2.5 Types of water use behaviour investigated

Furthermore, a detailed breakdown of the various specific water-use behaviours investigated across the 47 studies was provided. From the 47 articles, a total of six distinct categories of water-use behaviour have been identified. These behaviours were categorised as follows: (1) adaptation to climate change/variability; (2) adoption of water-saving technologies; (3) adoption of water conservation techniques/practices; (4) complying with water-saving policies; (5) water-use behaviour in light of institutional performance; and (6) seasonal irrigation water usage patterns.

A sunburst chart (Figure 2.10 below) was created to visually represent the distribution of studies across the six water-use behaviour categories. It is important to note from Figure 2.10 that some studies address multiple water-use behaviours and therefore appear in more than one category. Figure 2.10 reveals that the adoption of water conservation techniques and practices (Behaviour 3) emerges as the dominant focus among the identified water-use behaviours, with a notable 24 studies dedicated to this specific behaviour. Following closely, the adoption of water-saving technologies (Behaviour 2) emerges as another prominent behaviour investigated, with 17 studies devoted to studying the adoption of water-saving technologies. However, the remaining four water-use behaviours identified (Behaviours 1, 4, 5, and 6) received considerably less attention. Specifically, six studies focused on adaptation to climate variability (Behaviour 1), while four studies examined compliance with water-saving policies (Behaviour 4). Additionally, only one study examined water-use behaviour about institutional performance (Behaviour 5), and similarly, only one study focused on seasonal irrigation water usage patterns (Behaviour 6).

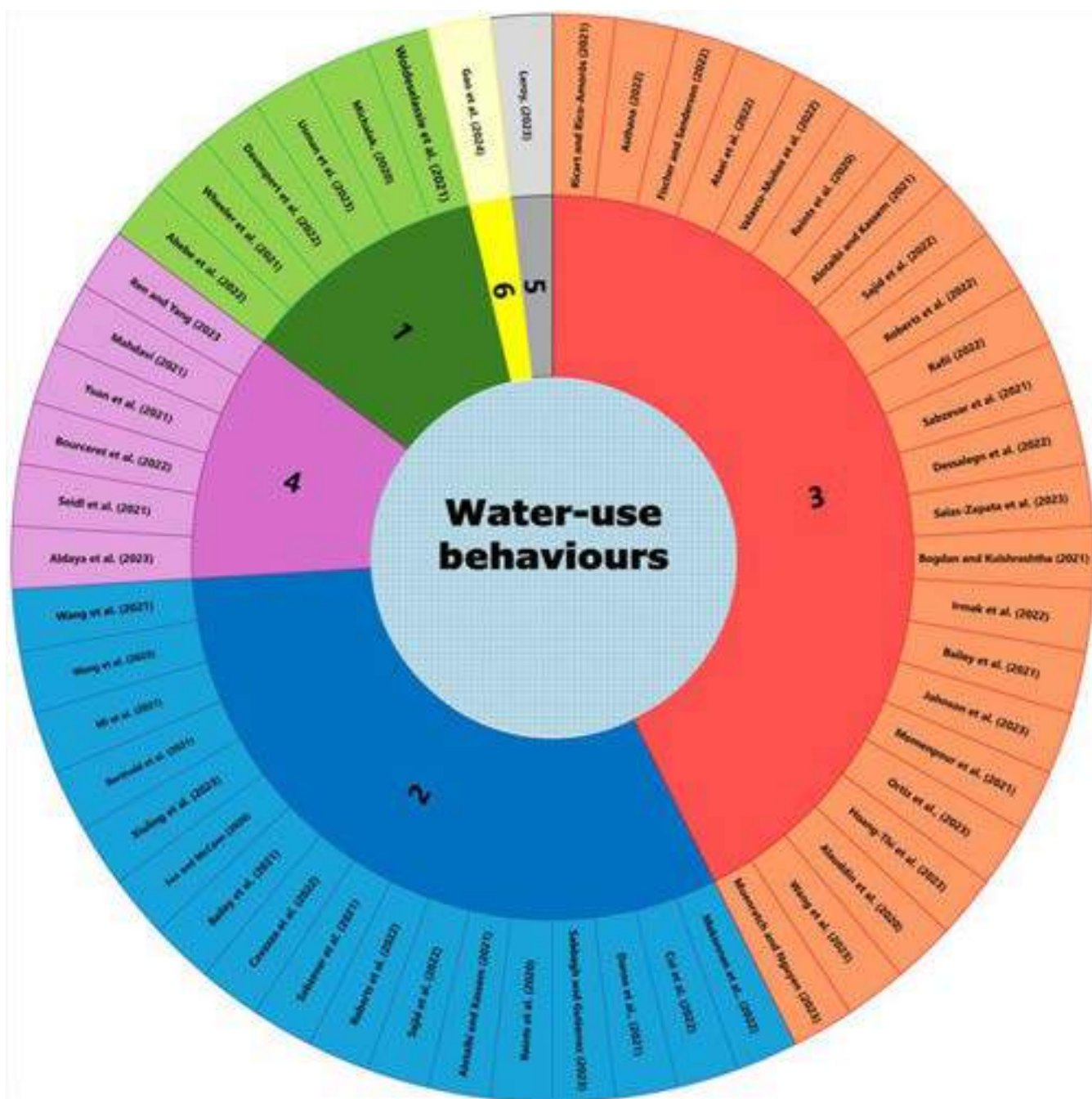


Figure 2.10: Distribution of studies across water-use behaviour categories

Note: The number in the middle layer of the sunburst chart represents a specific water-use behaviour: (1) adaptation to climate variability; (2) adoption of water-saving technologies; (3) adoption of water conservation techniques/practices; (4) complying with water-saving policies; (5) water-use behaviour in light of institutional performance; and (6) seasonal irrigation water usage patterns.

Source: Project team compilation

Next, the six water-use behaviours shown in Figure 2.10 were further analysed by exploring the driving factors behind each behaviour as identified in the relevant studies. Considering the diverse agricultural contexts reflected across the 47 studies, a deeper understanding of the variables that have been found to

influence each water-use behaviour will provide valuable insights into the broad spectrum of determinants driving water-use behaviours in diverse agricultural landscapes.

It is clear from Figure 2.11 below that the variables influencing climate variability adaptation in agricultural water-use-related contexts are multifaceted. Economic and financial factors, institutional and information access, farm characteristics and resources, sociodemographic factors, and perceptions and experience influence farmers' ability to implement adaptive measures. The economic and financial factors identified include the cost and availability of resources (Woldeselassie et al., 2021), financial resources (Michalak, 2020), debt levels (Wheeler et al., 2021), debt-to-equity ratios (Wheeler et al., 2021), and access to credit (Abebe et al., 2022; Usman et al., 2023). Institutional and information access factors involve support from government institutions (Michalak, 2020), access to information (Michalak, 2020), information on weather forecasting (Wheeler et al., 2021), information on climatic and natural hazards (Usman et al., 2023), and agricultural extension services (Abebe et al., 2022; Usman et al., 2023). Farm characteristics and resources include crop characteristics and requirements (Wheeler et al., 2021; Woldeselassie et al., 2021), irrigation timing and frequency (Woldeselassie et al., 2021), supplemental irrigation (Woldeselassie et al., 2021), crop type (Michalak, 2020), farm size (Abebe et al., 2022; Michalak, 2020; Usman et al., 2023; Wheeler et al., 2021), tenancy status (Usman et al., 2023), irrigated area (Wheeler et al., 2021), and soil quality (Usman et al., 2023). Sociodemographic factors are age, education, and household size (Usman et al., 2023). Lastly, perception and experience factors involve future drought exposure beliefs (Davenport et al., 2022), farm sensitivity appraisal (Davenport et al., 2022), drought risk perception (Davenport et al., 2022), climate variability perceptions (Abebe et al., 2022; Davenport et al., 2022), and previous adaptation experience (Abebe et al., 2022).

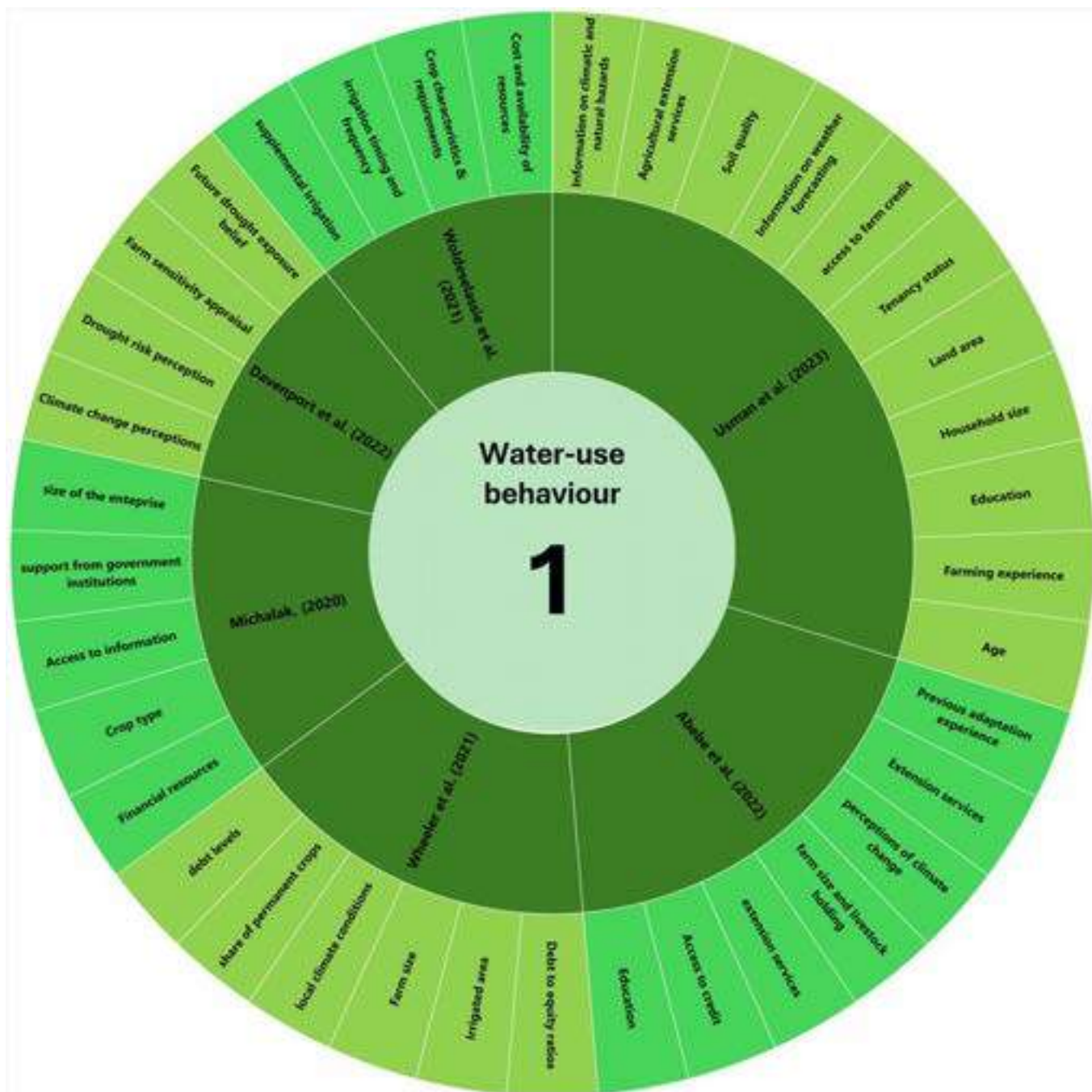


Figure 2.11: The factors influencing adaptation to climate variability in agricultural water-use contexts

Source: Project team compilation

The results shown in Figure 2.12 below indicate that the implementation of water-saving technologies (water-use Behaviour 2) is influenced by a range of factors, including demographic and socioeconomic variables, awareness and perceptions, institutional and policy influences, environmental and farm characteristics, psychological and behavioural elements, access to information, and interaction and collaboration. Demographic and socioeconomic variables include education level (Bailey et al., 2021; Berthold et al., 2021; Sajid et al., 2022; Wang et al., 2021a; Xiuling et al., 2023), off-farm work participation (Wang et al., 2021a), household income level (Bailey et al., 2021), age (Berthold et al., 2021; Reints et al., 2020; Sabbagh & Gutierrez, 2023; Xiuling et al., 2023), family size (Cui et al., 2022), and health (Cavazza et al., 2022).

Awareness and perceptions encompass environmental awareness (Wang et al., 2023), water scarcity perception (Sabzevar et al., 2021), perceived ease of use of technology (Wang et al., 2023), knowledge about water management (Sabzevar et al., 2021), awareness towards water pollution and disasters (Alotaibi & Kassem, 2021; Cui et al., 2022), and awareness of water management interventions (Sajid et al., 2022). Institutional and policy factors comprise access to extension services (Roberts et al., 2022; Wang et al., 2021a), subsidies (Danso et al., 2021; Mi et al., 2021; Sajid et al., 2022), cooperative membership (Mi et al., 2021), and supportive policies (Cavazza et al., 2022).

Environmental and farm characteristics involve crop types (Alotaibi & Kassem, 2021; Bailey et al., 2021; Fan & McCann, 2020), irrigation practices (Bailey et al., 2021), planting scale (Cui et al., 2022; Mi et al., 2021), regional climates (Reints et al., 2020), income from crops (Reints et al., 2020), farm size (Fan & McCann, 2020; Sajid et al., 2022; Xiuling et al., 2023), irrigation complexity (Reints et al., 2020), climate variability (Fan & McCann, 2020) and seasonal precipitation patterns (Bailey et al., 2021). Psychological and behavioural elements include subjective norms (Wang et al., 2023), attitudes (Sabzevar et al., 2021; Wang et al., 2023), perceived control (Wang et al., 2023), self-efficacy and risk-taking (Sabzevar et al., 2021), effort, and performance expectancy (Sabbagh & Gutierrez, 2023; Roberts et al., 2022). Informational variables include general access to information (Sabzevar et al., 2021; Fan & McCann, 2020) and access to reliable data (Berthold et al., 2021). Interaction and collaboration include neighbours' decisions (Mi et al., 2021), coordination and cooperation among relevant actors (Cavazza et al., 2022), friendships among irrigators (Mekonnen et al., 2022), spatial proximity between farms (Mekonnen et al., 2022), and shared knowledge among farmers (Mekonnen et al., 2022).

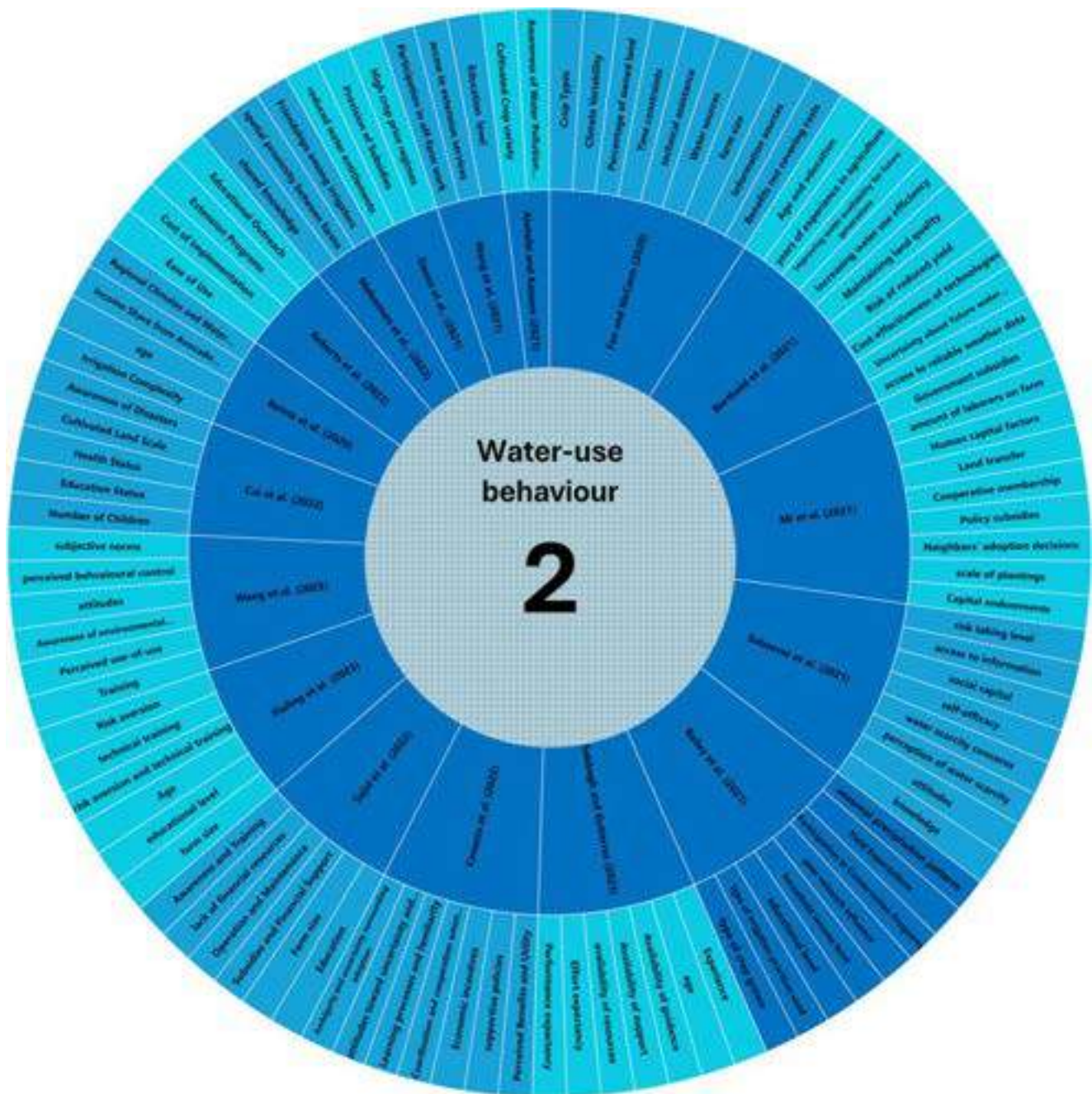


Figure 2.12: Factors influencing the adoption of water-saving technologies in agricultural water-use contexts

Source: Project team compilation

The adoption of water conservation techniques and practices (Figure 2.13 below) in agricultural contexts is influenced by a wide range of variables that can be categorised into several key areas. Demographic and socioeconomic factors play a significant role, including variables such as age and education level (Alauddin et al., 2020; Bailey et al., 2021; Bogdan & Kulshreshtha, 2021; Sajid et al., 2022; Salas-Zapata et al., 2023; Reints et al., 2020), household income (Hoang-Thi et al., 2023; Johnson et al., 2023), household assets

(Hoang-Thi et al., 2023), land ownership (Alauddin et al., 2020; Bogdan & Kulshreshtha, 2021), and gender (Dessalegn et al., 2022; Johnson et al., 2023).

Awareness and perception variables were also found to be significant, with influences including environmental knowledge (Muenratch & Nguyen, 2023; Rafii, 2022; Sabzevar et al., 2021), awareness of extraction impacts and environmental consequences (Alotaibi & Kassem, 2021; Asthana, 2022; Muenratch & Nguyen, 2023; Velasco-Muñoz et al., 2022; Wang et al., 2023), perception of climate variability and water scarcity (Hoang-Thi et al., 2023; Johnson et al., 2023; Sabzevar et al., 2021), and perceived water availability (Johnson et al., 2023).

The third category of variables focuses on technological, institutional, and policy factors, which encompass groundwater tariffs (Muenratch & Nguyen, 2023), training programmes (Sajid et al., 2022; Wang et al., 2023), institutional factors (Dessalegn et al., 2022; Johnson et al., 2023; Momenpour et al., 2021), and supportive regulations and policies (Dessalegn et al., 2022; Irmak et al., 2022). Informational variables were also significant, including access to prior weather information (Alauddin et al., 2020), general information (Bailey et al., 2021), and access to information (Sabzevar et al., 2021).

The next category identified focuses on environmental and farm characteristics, including topography and soil type (Alauddin et al., 2020; Momenpour et al., 2021; Roberts et al., 2022), irrigated land area, elevation, rainfall (Hoang-Thi et al., 2023; Irmak et al., 2022), climatic conditions (Johnson et al., 2023), farm size and location (Bogdan & Kulshreshtha, 2021; Ortiz et al., 2023; Sajid et al., 2022; Salas-Zapata et al., 2023; Ricart & Rico-Amorós, 2021), water quality, and context (Dessalegn et al., 2022; Fischer & Sanderson, 2022; Ricart & Rico-Amorós, 2021), and cultivated crop variety (Alotaibi & Kassem, 2021).

Another crucial category identified comprises psychological and behavioural factors, which entail variables such as subjective norms (Ataei et al., 2022; Muenratch & Nguyen, 2023; Wang et al., 2023), perceived behavioural control (Muenratch & Nguyen, 2023; Wang et al., 2023), attitudes (Ataei et al., 2022; Rafii, 2022; Sabzevar et al., 2021; Wang et al., 2023), self-efficacy (Rafii, 2022), personal norms and intentions (Ataei et al., 2022), and environmental values (Fischer & Sanderson, 2022).

Lastly, the adoption of water conservation techniques/practices was found to be influenced by interaction and collaboration factors, including social networks (Velasco-Muñoz et al., 2022), social norms (Ataei et al., 2022), social capital (Sabzevar et al., 2021), and other social factors (Momenpour et al., 2021). These categories collectively highlight the complex interplay of factors that drive the adoption of water-saving technologies in the agricultural sector.

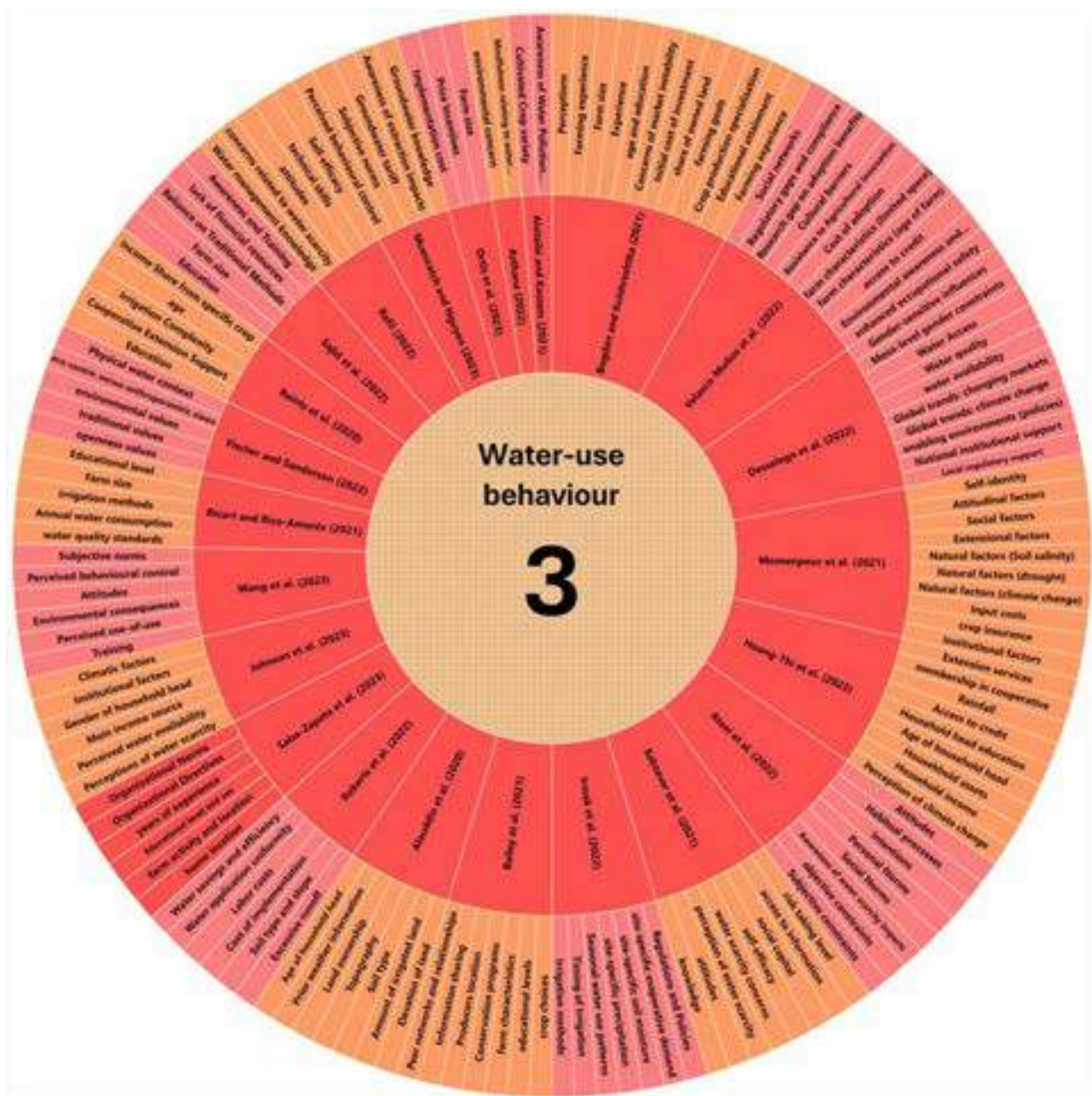


Figure 2.13: Factors influencing the adoption of water-saving conservation techniques/practices in agricultural water-use contexts

Source: Project team compilation

Figure 2.14 below summarises the factors influencing compliance with water-saving policies in agricultural water-use contexts. Farm characteristics, including farm productivity (Ren & Yang, 2023; Seidl et al., 2021), farmland value and excess water holdings (Seidl et al., 2021), farm area under irrigation (Seidl et al., 2021), soil type and agronomic factors (Aldaya et al., 2023), and mobility of resource units (Ren & Yang, 2023) have been found to play an essential role in farmers' decisions to comply with water-saving

policies. In addition, economic factors were also found to be important, such as farm financial metrics (Aldaya et al., 2023; Seidl et al., 2021; Yuan et al., 2021a), labour considerations (Aldaya et al., 2023), water pricing, and market conditions (Aldaya et al., 2023). Environmental factors are also crucial determinants, encompassing climatic variables and precipitation levels (Aldaya et al., 2023; Yuan et al., 2021a), regional variations in water resources (Ren & Yang, 2023), and territorial features (Aldaya et al., 2023). Furthermore, psychological and behavioural aspects were also identified as being important, entailing factors such as attitudes (Bourceret et al., 2022; Mahdavi, 2021), subjective norms (Bourceret et al., 2022; Mahdavi, 2021), perceived behavioural control (Bourceret et al., 2022; Mahdavi, 2021), adventurous perceptions, and tolerance for profit variation (Yuan et al., 2021a). Moreover, demographic and socioeconomic dimensions, including gender and education levels (Seidl et al., 2021), were found to be significant. Perceptions related to climate variability risks were also found to act as a substantial driver (Seidl et al., 2021).

organisation and association membership) and awareness and perception (perceptions of fairness in water distribution, perceptions of water scarcity) (Leroy, 2023). For seasonal irrigation water usage patterns (Behaviour 6), the influencing variables include farm characteristics (soil properties, crop type), technological factors (number of irrigation days in the season, early season irrigation intensity, duration of the irrigation period), and environmental factors (climate predictors) (Gao et al., 2024).

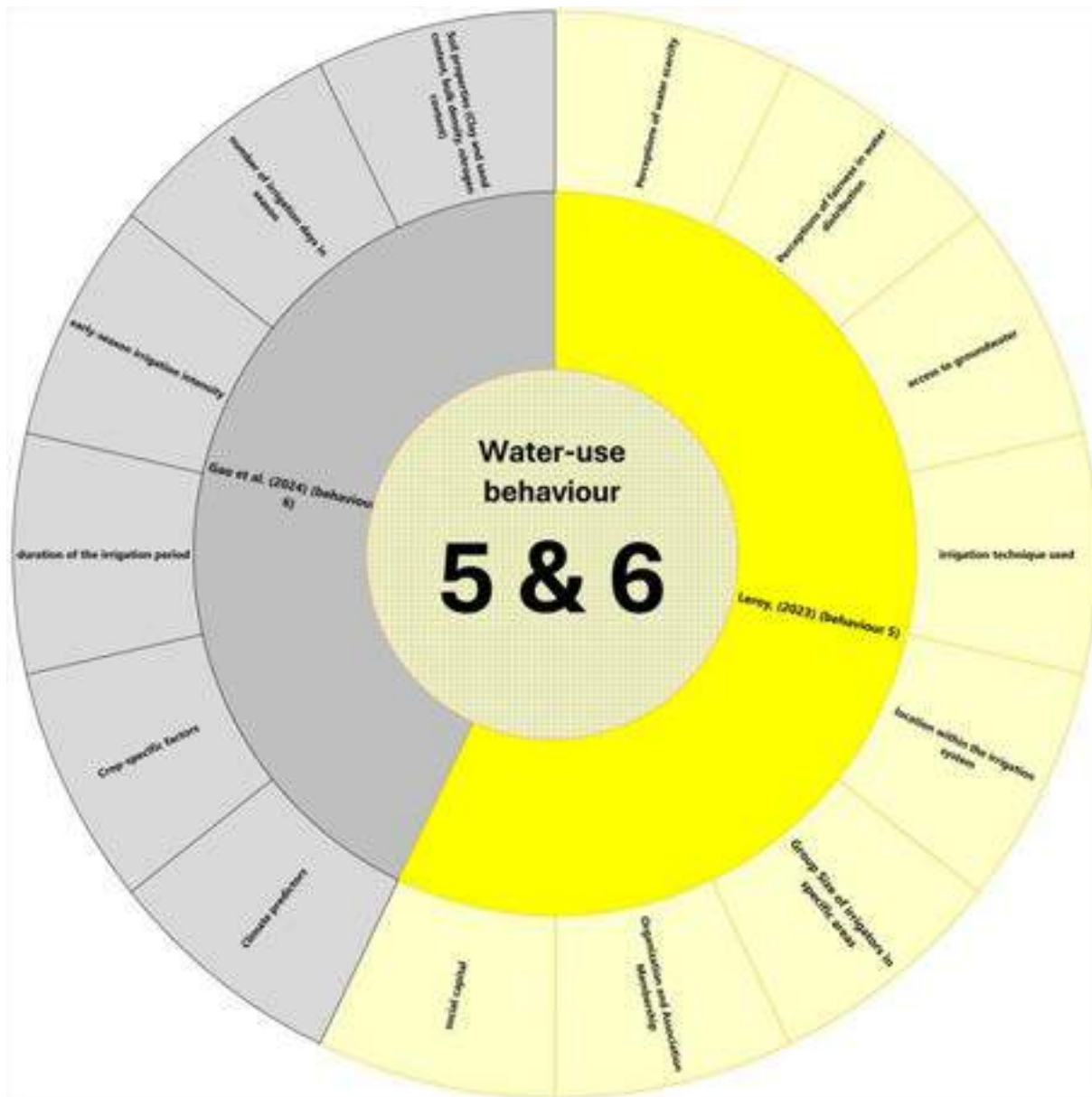


Figure 2.15: Influential factors in agricultural water-use behaviour in light of institutional performance (water-use Behaviour 5) and seasonal irrigation water usage patterns (water-use Behaviour 6)

Source: Project team compilation

2.2.3 Discussion of systematic review findings

In this systematic review, the project team explored the different water-use behaviours in agricultural settings as reported by the 47 studies included in this review. Our analysis highlighted several key themes and trends in the reviewed studies, providing valuable insights into current practices and areas that require further investigation. Firstly, the geographic distribution of the 47 studies revealed a concentration of research efforts in a few key countries between 2020 and 2024. The United States leads with eight studies and is followed closely by China with seven studies. As highlighted above, it is clear that understanding behavioural aspects is crucial for achieving water-use productivity in sustainable agriculture and broader water resource management goals. However, it is concerning that research efforts directed at understanding water-use behaviour in agricultural contexts over the study period (2020–2024) are concentrated in only a few countries.

This geographic distribution of studies is concerning, especially in light of water stress affecting various regions globally, as reported by the Food and Agriculture Organization (FAO, 2021c). The FAO (2021c) applied SDG Indicator 6.4.2 to assess global water stress levels. The SDG Indicator 6.4.2 measures water stress as the ratio of total freshwater withdrawals (across agricultural, industrial, and municipal sectors) to total renewable freshwater resources, taking into account environmental flow requirements. The FAO's (2021c) findings indicate that the highest levels of water stress occur in East Asia, Western Asia, Central Asia, Southern Asia, and Northern and Southern Africa. By not adequately studying water-use behaviour in these countries, we risk hindering progress toward sustainable water management and ultimately reducing the likelihood of achieving SDG 6 by 2030.

Moreover, our results from the word frequency and the keyword co-occurrence network analysis revealed several key themes. The keyword co-occurrence network analysis identified four main clusters, each representing a distinct theme. The first cluster's theme was recognised as “Sustainable Agricultural Practices”, emphasising the importance of long-term resource availability and minimising environmental impacts through efficient water management in agriculture. This finding is sensible, given the extensive attention that sustainable agricultural practices in general have received in the literature (Foguesatto et al., 2020; Oyetunde-Usman et al., 2021; Singh et al., 2020; Tahat et al., 2020; Trivedi et al., 2021), particularly focusing on sustainable agricultural practices (Chartzoulakis & Bertaki, 2015; Cofie & Amede, 2015; Russo et al., 2014; Velasco-Muñoz et al., 2018). Foguesatto et al. (2020) highlighted the various potential benefits of adopting sustainable regional and global agricultural practices.

However, Foguesatto et al. (2020) further mentioned that, despite these potential benefits, the adoption rate of these practices remains low in many countries. Considering the points mentioned above, our systematic

review revealed sustainable agricultural practices as a prominent theme. A more profound comprehension of water-use behaviour within sustainable agricultural systems could enhance the adoption rate of such methods.

The theme of the second cluster revolves around technology adoption for productivity, highlighting the role that technological advancements play in enhancing agricultural productivity, particularly in the context of water management. Jararweh et al. (2023) argued that, given the restricted farming space, water shortages, climate variability, and continually changing environmental circumstances, new and novel smart agricultural technologies must be developed. However, according to Levidow et al. (2014), while innovative irrigation practices could enhance water productivity, provide economic advantages, and reduce environmental burdens, farmers do not fully realise these benefits because of various challenges. Barriers include the cost of adopting new technology (Jararweh et al., 2023; Koech et al., 2021; Levidow et al., 2014), lack of adequate knowledge and data (Jararweh et al., 2023; Mi et al., 2021), and risk of reduced yield (Mi et al., 2021).

Policies and educational programmes are vital for supporting farmers in overcoming these challenges (Mariano et al., 2012). Ultimately, integrating advanced technologies into agriculture is crucial for achieving sustainable water management and is seen as an important way to reduce water scarcity (Ingrao et al., 2023). This importance is underscored by our results, which show that 17 of the 47 papers addressed the adoption of water-saving technology as a water-use behaviour, demonstrating an increasing need to understand and promote water-saving technologies in agricultural contexts.

Furthermore, the results of the keyword co-occurrence analysis showed that the theme of the third cluster revolves around climate variability, adaptation strategies, and water scarcity, particularly in relation to agricultural practices. The emergence of climate variability adaptation and water scarcity as common themes in our systematic review is sensible, given that agriculture is widely recognised as one of the most vulnerable sectors to climate variability (Anderson et al., 2020; Bedeke, 2023; Kourgialas, 2021; Nikolaou et al., 2020).

According to Mehrazar et al. (2020), given the vulnerability of the agriculture sector to climate variability, studying the potential impacts of climate variability is crucial to ensure food and water security in the future. Moreover, Hanjra and Qureshi (2010) highlighted the point that, with increasing population and income growth, there will be a corresponding increase in demand for food and water. Hanjra and Qureshi (2010) further mention that irrigation will be the first sector to lose water, as water competition from non-agricultural sectors intensifies, which will have implications for food security, hunger, poverty, and ecosystem health and services. There is a growing need to develop effective adaptation measures to

safeguard agricultural productivity against the adverse effects of climate variability and water scarcity. Strategies such as climate-resilient crop varieties (Acevedo et al., 2020; Banga & Kang, 2014; Magesa et al., 2023), improved irrigation techniques (Magesa et al., 2023; Tang et al., 2016; Zhang et al., 2019), and sustainable water-management practices (Delgado et al., 2011; Nikolaou et al., 2020) emerge as critical components in mitigating the adverse effects of climate variability on water availability and agricultural systems. However, addressing the adverse impacts of climate variability, Srivastav et al. (2021) emphasised the importance of following a holistic approach. This aligns with the findings of our systematic review, which revealed the multifaceted nature of farmers' adaptation to climate variability in water-use-related contexts. Future studies on farmers' adaptive behaviour in water-use-related contexts should consider a holistic approach to modelling their adaptive behaviours.

The fourth cluster identified in our keyword co-occurrence analysis highlighted the theme of modelling and uncertainty in water conservation. The significance of employing models to understand behaviour cannot be overstated. Through behavioural models, researchers gain a better understanding of the complex interplay of factors influencing water usage in agriculture. These models not only serve an academic purpose but are also important for informing policymakers and stakeholders to develop effective water-saving behaviour change strategies (Graymore & Wallis, 2010), efficient resource allocation (Andriyas & McKee, 2014), and effective policy design (Mirzaei & Azarm, 2022). It is, therefore, crucial to measure behaviour accurately. According to Reimer et al. (2014), it is crucial to consider contextual factors when measuring behaviour, as the variation in these factors can make it difficult to predict and measure farmers' adoption and behaviour. However, this systematic review revealed six water-use behaviours and the various variables influencing these behaviours over the past five years (2020–2024). Therefore, this systematic review can be a valid starting point for future studies when modelling behaviour. Additionally, uncertainty emerged as a significant theme in the fourth cluster, underscoring its pivotal role in water management decisions.

Dessai and Hulme (2007) emphasised that uncertainty is inherently part of decision-making in environmental management, influencing the sensitivity of management decisions to uncertainties in environmental predictions. For example, Sun et al. (2018) showed that projections of future climate variability are plagued with uncertainties, making it difficult for decision-makers to plan adaptation measures. Our keyword co-occurrence analysis results align with the points raised by Dessai and Hulme (2007) and Sun et al. (2018), as the word “uncertainty” is linked to both “climate change/variability” and “management”, suggesting that uncertainty is an issue affecting various aspects of water management, particularly in light of climate variability. Therefore, when modelling behaviour, it is crucial to account for the influence of uncertain environmental factors on farmers' water-use behaviour.

Furthermore, the findings from our systematic review revealed the multifaceted nature of the variables driving farmers' water-use behaviours in diverse agricultural contexts. This systematic review identified six water-use behaviours, each with its unique drivers and barriers. However, several overarching themes emerge, despite the differences among the six water-use behaviours identified. Firstly, it is clear that a wide range of factors influence farmers' decisions and actions regarding their water usage. Various factors are all identified as crucial components, including economic considerations, demographic variables, socioeconomic variables, farmers' awareness and perceptions, institutional and policy influences, technical factors, farm and environmental characteristics, psychological and behavioural elements, informational factors, and interaction and collaboration among relevant stakeholders. The complex interplay of these various variables in influencing agricultural water-use behaviours highlights the need for comprehensive approaches to water management policies and interventions. The importance of following a comprehensive approach to water management is evident, as underlined by past initiatives such as the Comprehensive Assessment of Water Management in Agriculture (CA) (de Fraiture et al., 2010).

Secondly, the results of the systematic review underscore the complexity of water-use behaviours in agricultural settings. It is crucial to acknowledge the limitations of existing behavioural models in capturing this complexity. Academically, the recognition of these complexities in human decision-making is evident, with various studies augmenting traditional behavioural models by integrating additional constructs (Gibson et al., 2023; Hoong Chan et al., 2022; Savari & Khaleghi, 2023; Wang et al., 2023). The systematic review findings provide a significant starting point for future studies that aim to measure water-use behaviour in agricultural contexts. Subsequent research can build upon our findings to determine essential constructs for a more comprehensive understanding.

Lastly, considering that the 47 articles included in this systematic review are from diverse regions globally, it is crucial to recognise that the unique contextual factors of each agricultural setting significantly influence water-use behaviours. Farm characteristics, such as farm size, location, and type of crop produced, as well as irrigation complexity and scale of plantings, interact directly with environmental factors, including climate, soil quality, and seasonal precipitation patterns. Recognising the contextual interplay is essential for resource efficiency (Van Halsema & Vincent, 2012), reducing water waste and pollution (Dobson & Morgan, 2021), promoting water sustainability research (Rodriguez-Sanchez & Sarabia-Sanchez, 2020), and designing tailored interventions (Nelson et al., 2021).

2.2.4 Integrating systematic review findings into Behavioural Theory for agricultural water use

The systematic review provided a comprehensive overview of various water use behaviours investigated in recent agricultural research, along with the diverse variables identified as being key drivers of these behaviours. Six distinct water use behaviours were identified; however, to maintain a clear and focused scope, this research project prioritised three for inclusion in the integrated framework: the adoption of water-saving technologies, the adoption of water-related policies, and adaptation to climate variability.

Given that commercial and small-scale irrigators operate under different contextual realities, including variations in resources, infrastructure, institutional support, and risk exposure, it is expected that the behavioural drivers influencing their decisions will differ accordingly. As such, the behavioural models used in this study were adapted to account for these context-specific factors.

The following section provides a detailed justification for the inclusion of each construct used to model the behaviour of commercial irrigators, followed by a separate overview of the constructs selected for modelling the behaviour of small-scale irrigators.

2.2.4.1 Constructs used to model the behaviour of Commercial Irrigators

2.2.4.1.1 Technical factors

Technical factors, such as education, training, and farm-level characteristics, play a critical role in shaping water use behaviour across multiple domains. Educational programmes and technical training have been shown to enhance farmers' knowledge and skills, thereby influencing their likelihood of adopting water-saving technologies, adapting to climate variability, and responding to water-related policies. For example, participation in vocational training has been associated with increased uptake of water-saving methods (Hoang-Thi et al., 2023), while both online and offline training have positively influenced the adoption of efficient irrigation technologies (Xiuling et al., 2023).

In addition, studies have highlighted how technical support, communication, and knowledge sharing contribute to broader behavioural shifts in agriculture (Choudhary et al., 2023; Fan & McCann, 2020; Laureti et al., 2021; Ortiz et al., 2023). On a more specific level, adoption decisions are also influenced by farm characteristics such as irrigation complexity, perceived ease of use, and crop types (Alotaibi & Kassem, 2021; Bailey et al., 2021; Reints et al., 2020; Wang et al., 2023). Together, these factors inform the inclusion of technical constructs in modelling the three targeted water use behaviours in this research project.

2.2.4.1.2 Trust factors

Trust plays a foundational role in shaping farmers' water use behaviour, particularly in adoption, cooperation, and response to policy interventions. Trust factors are defined as the expectation that others will act competently, transparently, and in the interest of the common good (Ezezika & Oh, 2012). Trust underpins effective communication and collaboration between farmers and key stakeholders such as policymakers, researchers, and extension officers.

Several studies have shown that different types of trust influence decision-making among farmers. Institutional trust and dispositional trust have been identified as key factors (Castillo et al., 2021; Hamm et al., 2013). General trust and trust within water communities further shape behavioural responses (Hunecke et al., 2017), while social trust can enhance collective engagement in sustainable practices (Nguyen & Drakou, 2021). Trust in relevant intermediaries, such as advisors, also plays a role (Giampietri et al., 2020), as does specific trust in individuals (Zhou et al., 2023) and trust in government (Scutt et al., 2023).

Moreover, interaction and collaboration between farmers, including coordination, friendships, and knowledge exchange, further reinforce trust and influence behavioural intentions (Cavazza et al., 2022; Mekonnen et al., 2022). These insights collectively support the inclusion of trust as an extended construct in the behavioural framework developed in this research project.

2.2.4.1.3 Information factors

Informational factors are crucial to understanding irrigators' water use behaviour, as they influence individuals' awareness, knowledge, and comprehension of water-related challenges and solutions. Access to relevant information can create opportunities for farmers to enhance their decision-making and improve their farming practices and livelihoods (Chen & Lu, 2020).

The literature shows that access to both general and technical information plays a significant role in shaping farmers' adoption behaviour. For example, the availability of reliable information has been found to support the adoption of irrigation scheduling tools (Berthold et al., 2021), pressure irrigation systems, and scientific scheduling practices (Fan & McCann, 2020). Access to information also influences the adoption of water-saving irrigation technologies (Zhang et al., 2019) and water management techniques (Alauddin et al., 2020). Similarly, information plays a key role in the uptake of improved irrigation scheduling methods (Wang et al., 2015), innovative farming technologies (Caffaro et al., 2020), and sustainable crop residue management practices (Raza et al., 2019).

Other studies highlight the importance of informational access in farmers' strategic responses to environmental changes such as declining rainfall and reduced crop productivity (Adimassu & Kessler, 2016). Moreover, variables such as general access to information (Fan & McCann, 2020; Sabzevar et al.,

2021) and the quality or reliability of that information (Berthold et al., 2021) have consistently been linked to higher likelihoods of adopting water-saving and climate-resilient practices. These findings support the inclusion of informational factors in the behavioural model developed in this study.

2.2.4.1.4 Perceived risks and benefits

Farmers operate in environments marked by increasing uncertainty and risk. Understanding how they perceive and respond to these risks and benefits is essential for developing behavioural models that reflect real-world decision-making. Risk perception influences how farmers weigh the trade-offs in adopting new practices, especially those related to water use.

The literature shows that perceived risks, such as water scarcity (Johnson et al., 2023) and the impact of climate variability on income (Hoang-Thi et al., 2023), can act as significant deterrents to behavioural change. Other studies have shown that perceptions of crop production failure (Mase et al., 2017) and risks associated with unpredictable or unreliable weather conditions (Eitzinger et al., 2018) contribute to farmers' reluctance to adopt water-saving methods. Broader climate variability risks and their influence on decision-making have also been highlighted (Khan et al., 2022; Le Dang et al., 2014).

At the same time, perceived benefits play a central role in promoting adoption. Expected improvements in water use efficiency and land quality encouraged the uptake of new practices (Berthold et al., 2021). Farmers who perceived high utility in water-saving technologies were more likely to adopt them (Cavazza et al., 2022). However, where risk aversion is present, adoption tends to be lower (Xiuling et al., 2023).

Beyond water use efficiency and productivity, several studies have identified a broader range of perceived benefits that influence decision-making. These include perceived benefits associated with farming activities (Kliebenstein et al., 1980), risk management strategies (Valeeva et al., 2011), best management practices (Reimer et al., 2012), and participation in training programmes (Okwuokenye, 2022). Perceived benefits have also been linked to the adoption of specific innovations, such as water-efficient drip irrigation (Greenland et al., 2019) and the reuse of wastewater for irrigation (Michetti et al., 2019).

Perceived risks and benefits, therefore, influence farmer behaviour in opposing ways and must be accounted for to explain variation in the adoption of water-saving practices across different settings.

2.2.4.1.5 Perceived risks from load-shedding and tariffs

In the South African context, irrigators face additional layers of risk beyond environmental uncertainty, especially risks related to electricity load-shedding and rising water and electricity tariffs. These risks disrupt irrigation schedules, damage infrastructure, and increase operational costs, which influence farmers' behaviour and decisions around water use (Cloete et al., 2023; Mouton, 2024).

Although no studies have specifically examined how farmers perceive load-shedding as a risk, its impact on agricultural productivity and water management is evident. Eskom's long-standing electricity crisis, which began in 2008, has led to widespread power outages attributable to infrastructure failures and increasing national demand (Piliso et al., 2021). These outages affect the reliability of irrigation systems and undermine the feasibility of adopting technologies that depend on a stable power supply. In parallel, rising electricity and water tariffs place financial strain on farmers, thus increasing production costs and discouraging investment in water-saving practices.

The broader literature also reflects how load-shedding and unstable energy supply affect agriculture in other countries (Ali et al., 2019; Gill & Punt, 2010; Lawson, 2022; Timilsina & Steinbuks, 2021; Umar & Kunda-Wamuwi, 2019). Additionally, farmers' perceptions of increasing electricity, water, and fuel prices have been found to increase their awareness of climate-related risks and influence their adaptive decisions (Le Dang et al., 2014).

To reflect these challenges, this study includes a separate construct titled Perceived Risks from Load-shedding and Tariffs. It captures how utility-related risks shape farmers' confidence in their ability to plan, invest, and sustain production under uncertain energy and cost conditions.

2.2.4.1.6 Institutional and legal factors

Institutions influence farmers' water use behaviour by shaping the regulatory and support environment in which decisions are made. Government's promotion of best practices and supportive policies encourages the adoption of sustainable irrigation methods (Cavazza et al., 2022; Dai et al., 2015). Extension activities and access to agricultural extension services provide vital technical guidance and training to irrigators (Alauddin et al., 2020; Momenpour et al., 2021). Environmental laws and government policies establish standards and incentives for compliance, while subsidies reduce financial barriers to investing in water-saving technologies (Danso et al., 2021; Mi et al., 2021; Momenpour et al., 2021; Sajid et al., 2022).

Membership in farming associations and cooperative organisations creates networks for knowledge sharing and collective action (Johnson et al., 2023; Zhang et al., 2019; Yuan et al., 2021b). Support services from institutions and friendships with local political organisations further reinforce farmers' awareness of regulations and available resources (Hoang-Thi et al., 2023; Wang et al., 2023). Farmers' perceptions of farm laws and their legitimacy also affect their willingness to adopt new water management practices (Kumar et al., 2021; Zhou et al., 2023).

Given the multifaceted role of institutional and legal influences, this study includes these factors as a core construct in the extended behavioural framework to model the three selected water use behaviours.

2.2.4.1.7 Access to resources

Access to resources shapes the ability of farmers to adopt new practices by reducing financial and informational barriers. Institutional and policy influences, such as access to extension services (Roberts et al., 2022; Wang et al., 2021a), subsidies (Danso et al., 2021; Mi et al., 2021; Sajid et al., 2022), and cooperative membership (Mi et al., 2021), were identified as key determinants of water use behaviour. These resources provide farmers with the technical guidance, equipment, and financial support needed to adopt water-saving technologies, comply with water-related policies, and implement adaptive measures. For these reasons, access to resources is included as a core construct in the extended behavioural framework for this study.

2.2.4.1.8 Perceived financial cost

Perceived financial costs, therefore, encompass both the tangible expenses of adopting new water use practices and the hidden transaction costs that farmers face. Evidence shows that higher income levels increase the likelihood and intensity of using scientific scheduling practices (Rosene, 2019), while participation in agri-environmental schemes can be discouraged by administrative and compliance burdens (Riccioli et al., 2023). Favourable financing conditions, such as lower interest rates and flexible collateral terms, boost farmers' confidence and uptake of green finance options (Wang et al., 2021a), whereas limited resources and high implementation and maintenance costs continue to pose significant barriers to the adoption of water-saving technologies (Roberts et al., 2022; Sajid et al., 2022). For these reasons, the category of perceived financial costs is included as a core construct in the extended behavioural framework to capture the full spectrum of economic barriers and enablers affecting water use behaviour.

2.2.4.1.9 Overview of the Extended Behavioural Model for Commercial Irrigators

To demonstrate how the extended model works in practice, Figure 2.16 below presents an example that is focused on one of the three water use behaviours considered in this project. The example focuses on the adoption of water-saving technologies. It shows how the additional constructs identified in the review are included alongside the original TPB components, such as attitude, subjective norms, and perceived behavioural control, to explain behavioural intention and actual adoption. The same set of extended constructs will be used to model the other two water use behaviours in the study.

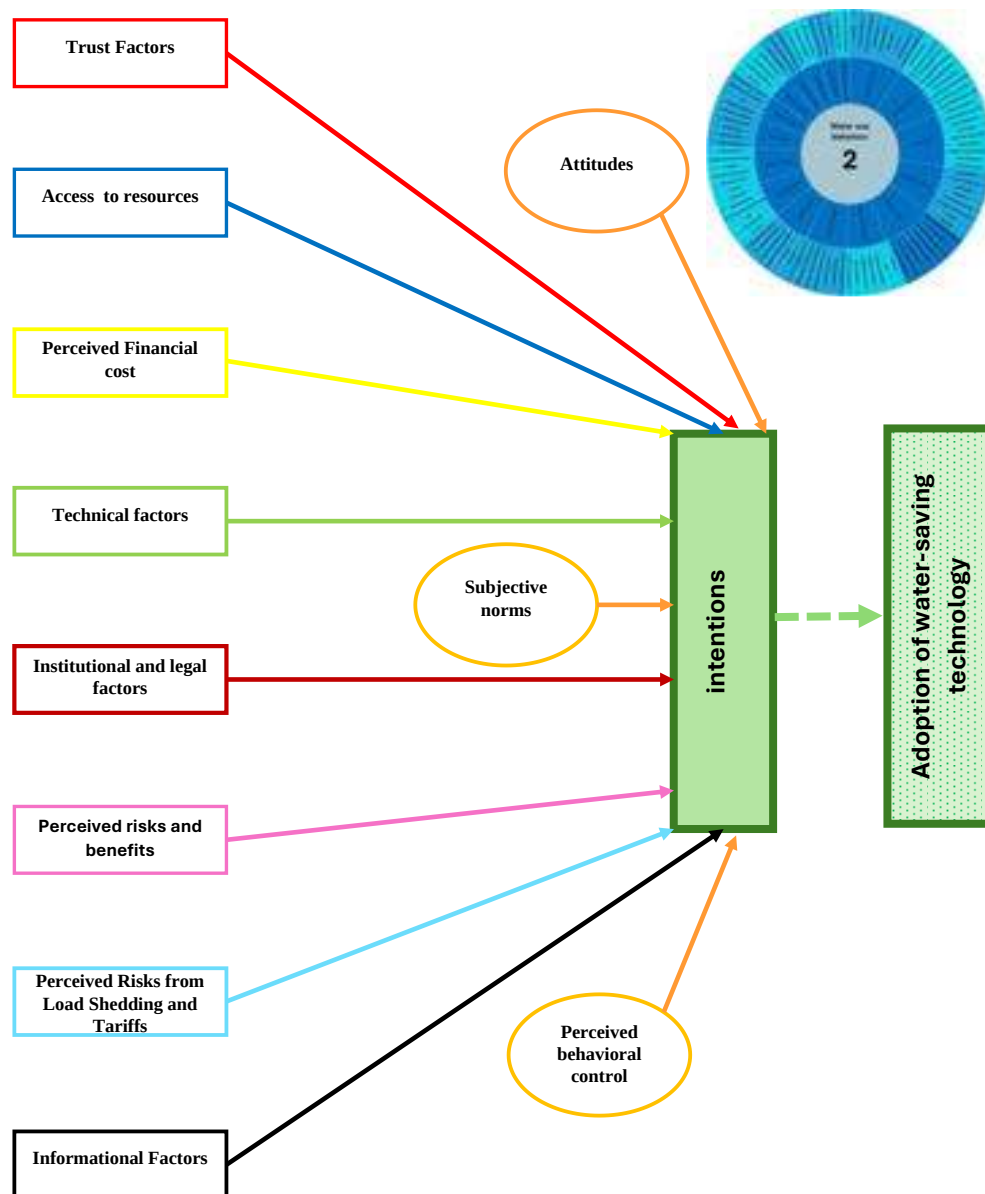


Figure 2.16: Theoretical Framework of the Augmented Theory of Planned Behaviour for Commercial Irrigators' Adoption of Water-Saving Technologies

Source: Project team compilation

2.2.4.2 Constructs used to model the behaviour of Small-Scale Irrigators

This section provides an overview of the justification for including additional constructs in the behavioural models for small-scale irrigators. Small-scale irrigators often face unique resource constraints and contextual challenges, as compared with commercial farmers. To accurately model their water use behaviours, specifically the adoption of water-saving technologies, adherence to water-related policies, and adaptation to climate variability, it is necessary to expand the standard Theory of Planned Behaviour with additional constructs. These constructs reflect the real-world complexities and factors that influence their behavioural intentions and actions, providing a complete and more realistic framework for understanding the decision-making of small-scale farmers.

2.2.4.2.1 Access to resources

Access to resources is a crucial factor that influences the capabilities and actions of small-scale farmers in the agricultural sector. Research indicates that access to key resources influences the behaviour of these farmers. For example, the availability of water is essential for irrigation and has been discussed by Greig (2009), Jambo et al. (2021), and Serote et al. (2021). Access to credit helps farmers to buy necessary inputs and is highlighted by Feyisa (2020); Mwale et al. (2021); Nkonki-Mandleni et al. (2022); Salite & Poskitt (2019), and Sanga et al. (2013). Skills and knowledge, or human capital, are also important, as noted by Mwale et al. (2021).

Access to infrastructure, like roads and irrigation systems, helps farmers to work more efficiently, as highlighted by Salite and Poskitt (2019). Access to irrigation equipment and markets has also been shown to affect small-scale farmers' choices and success (Jambo et al., 2021; Serote et al., 2021). Because these resources strongly influence the decisions of small-scale farmers, it is important to include access to resources as an additional construct in each of the behavioural models applied by this study. Incorporating this construct allows each behavioural model developed in this research project to reflect better the context-specific constraints that are likely to influence small-scale farmers' adoption of water-saving technologies, their compliance with water-related policies, and their adaptation to climate variability.

2.2.4.2.2 Access to resources for resilience

While the previous construct focused on access to resources directly related to the three water use behaviours examined in this study – namely, the adoption of water-saving technologies, adherence to water-related policies, and responses to climate variability – it is also important to consider a separate but related aspect. This is access to resources that support resilience, which plays a significant role in shaping the capacity of small-scale farmers to cope with climate and policy changes. These resources include access to markets, assets, water resources, and safety nets. Studies have shown that smallholder farmers with greater

access to such resources are better equipped to cope with climate-related shocks and stresses (He et al., 2024; Kapari et al., 2023). For instance, access to markets enables farmers to sell their products and obtain necessary inputs, which is essential for maintaining livelihoods during adverse conditions (Connolly et al., 2022; Kapari et al., 2023). Possession of assets, such as livestock and machinery, provides a buffer against climate impacts, allowing for more flexible responses to environmental changes (Acosta et al., 2021). Reliable access to water resources is crucial for irrigation and sustaining crop production, particularly during drought periods (Tesfaye et al., 2008; Umer et al., 2024). Furthermore, safety nets such as government grants, insurance, and credit facilities offer financial support that can help farmers recover from climate-induced losses (Zelege et al., 2021). The aim of the "access to resources for resilience" construct is to capture the broader livelihood and support conditions that enable small-scale irrigators to respond to and recover from environmental and policy-related stresses.

2.2.4.2.3 Institutional Factors

Institutional factors are widely recognised as important influences on the behaviour of small-scale irrigators in agricultural settings. Several studies have shown that access to agricultural extension services can enhance farmers' knowledge, skills, and decision-making, which in turn influences the adoption of improved practices (Abid et al., 2019; Feyisa, 2020; Nkonki-Mandleni et al., 2022; Salite & Poskitt, 2019; Soltani et al., 2014; Zamasiya et al., 2017). Participation in cooperatives can support behaviour change by improving access to resources, information, and collective action (Feyisa, 2020). Broader institutional conditions, such as policy implementation, the quality of government support, and relationships between the state and society, have also been shown to influence how small-scale farmers make decisions (Bjornlund et al., 2019; Burnham & Ma, 2017; Mwale et al., 2021). In addition, membership in social groups and access to government subsidies have been linked to more proactive and adaptive behaviour (Ahmad et al., 2023; Zamasiya et al., 2017). For these reasons, this study includes institutional support as an additional construct in the behavioural models developed for small-scale irrigators.

2.2.4.2.4 Perceived Social Support

Perceived social support refers to an individual's belief that they can receive practical help, emotional comfort, and understanding from their social network during times of need or difficult situations. Several studies have highlighted the importance of perceived social support in influencing the behaviour of small-scale farmers. For example, Abid et al. (2019) studied agricultural systems in Pakistan and found that cooperation among farmers and regular interactions helped them to make better decisions regarding climate variability adaptation. In Mozambique, Salite (2019) demonstrated that elders in the community had a significant influence on farmers' behaviour because of the respect and trust placed in them. Similarly, Truelove et al. (2015) examined paddy farmers in Sri Lanka. They found that a sense of connection to the

local community affected their intention to adopt socially oriented behaviours in response to drought. These findings highlight the substantial impact of perceived social support on the actions of small-scale farmers. Therefore, perceived social support is included as an additional construct when investigating the water use behaviour of small-scale irrigators in South Africa.

2.2.4.2.5 Perceived Financial Costs

Perceived financial cost is an important factor influencing the behaviour of small-scale farmers in South Africa. For example, Serote et al. (2021) found that the monthly water cost for irrigation had a significant negative impact on the adoption of climate-smart irrigation technology among small-scale farmers in Limpopo province. Farmers who could afford the monthly water fees were more likely to adopt these technologies, indicating that the perceived financial burden influences adoption decisions. Similarly, Smidt and Jokonya (2022) emphasised the importance of cost-effectiveness for small-scale farmers in adopting digital technologies within South Africa's agricultural value chains. Their findings demonstrate that perceived financial feasibility plays a key role in technology adoption decisions. Beyond South Africa, Martínez-García et al. (2013) studied small-scale dairy farmers in Mexico. They found that intentions to adopt improved grassland management were positively influenced by lower animal feeding costs. These examples suggest that the water use behaviour of small-scale irrigators is likely influenced by their perceptions of financial costs associated with irrigation and technology adoption.

2.2.4.2.6 Perceived financial costs related to energy and debt

The previous perceived financial cost construct focused on financial costs specifically related to the three water use behaviours considered in this study. However, this construct does not fully account for broader financial pressures, such as energy-related expenses and farm debt, which can also influence small-scale irrigators' decisions and capacity to change their practices. Therefore, a separate construct was included to capture the perceived financial costs associated with energy and debt.

Studies have found that energy-related expenses and indebtedness can significantly constrain the behaviour and decision-making of small-scale farmers (Bhattarai et al., 2025; Durga et al., 2024; Tesfaye et al., 2021). In many cases, the high cost of alternative energy sources, such as solar power or diesel generators, limits the ability of farmers to reduce their reliance on grid electricity. For instance, research in Pakistan by Daraz et al. (2025) demonstrated that, while solar-powered smart irrigation systems improved crop yields and reduced energy consumption, the initial investment costs remained a significant barrier for many smallholder farmers. Additionally, high levels of farm debt can limit farmers' financial flexibility, reducing their ability to invest in technologies that are more efficient or to adopt improved irrigation practices. A study analysing the importance of off-farm income for servicing farm debt found that indebtedness often

compels small-scale farmers to seek additional income sources, which can divert attention and resources away from optimal farm management, including irrigation practices (Briggeman, 2011).

Therefore, including this construct in the behavioural model helps to capture important financial constraints specific to energy use and debt, both of which are increasingly relevant in the context of rising input costs and financial vulnerability among small-scale farmers in South Africa.

2.2.4.2.7 Informational factors

Studies have shown that access to timely and accurate information is crucial in shaping the decisions of small-scale farmers across various agricultural contexts. For example, Makate et al. (2019) found that the adoption of climate-smart agriculture innovations increases when farmers receive relevant information about climate variability management strategies. Zamasiya et al. (2017) reported that access to climate information enabled smallholder farmers to make better-informed decisions on how to adapt to climate variability. Similarly, Abid et al. (2019) demonstrated that improved access to weather forecasts, market information, and agricultural practices leads to higher adoption rates of climate adaptation measures. Research by Serote et al. (2021) also showed that farmers who were knowledgeable about Climate Smart Irrigation Technologies were more likely to adopt technologies in South Africa. Sanga et al. (2013) found that knowledge of adaptation methods and weather forecasts improved small-scale farmers' responses to climate variability in Tanzania. In addition, Smidt and Jokonya (2022) indicated that access to agricultural information and expertise encouraged the use of digital technologies among small-scale farmers in South Africa's agricultural value chains. Based on these studies and the scope of this project, informational factors are included to assess their influence on the water use behaviours of small-scale irrigators.

2.2.4.2.8 Perceived risks and benefits

Research has shown that small-scale farmers' perceptions of risks and benefits significantly influence their decisions and behaviours in agricultural settings. Wu and Mweemba (2010) found that farmers who perceive higher vulnerability and seriousness of environmental degradation are more motivated to take adaptive actions. Eitzinger et al. (2018) emphasised the importance of considering the broader context of risk perception in designing effective climate variability adaptation policies. Salite (2019) demonstrated that changes in weather and climate negatively impact farmers' ability to predict droughts, thereby increasing their perceived risks and uncertainty. Wheeler et al. (2021) reported that farmers who face greater exposure to risk are more likely to view climate variability as a serious threat. Truelove et al. (2015) found that farmers who perceive higher drought risks are more inclined to adopt drought-resistant crops. These findings support the inclusion of perceived risks and benefits as a key factor in understanding and modelling the behaviour of small-scale irrigators in South Africa.

2.2.4.2.9 Perceived Risks Related to Tariffs and Load-shedding

The inclusion of the construct 'Perceived Risks Related to Tariffs and Load-shedding' is essential for understanding the water use behaviours of small-scale irrigators in South Africa, particularly in the context of escalating electricity costs and unreliable power supply. According to Cloete et al. (2023), load-shedding disrupts irrigation schedules and water management practices, which in turn affect crop growth and productivity. Additionally, the increased cost of electricity, particularly during peak periods, adds financial strain, making it challenging for small-scale farmers to maintain consistent irrigation practices (NAMC, 2010). Furthermore, WRC (2017) found that time-of-use tariffs, such as Ruraflex, can be more cost-effective for irrigation than flat-rate tariffs, like Landrate. However, they require careful scheduling and management because of higher energy demands and longer irrigation hours, highlighting the economic and operational risks that farmers perceive under variable electricity pricing structures. The inclusion of this construct is therefore justified, as both rising electricity tariffs and frequent load-shedding present significant perceived risks that influence how small-scale irrigators plan and manage their water use.

2.2.4.2.10 Overview of the Extended Behavioural Model for Small-Scale Irrigator

Figure 2.17 below provides a visual overview of the extended TPB model. Recall that three water use behaviours will be investigated for both commercial and small-scale irrigators. To illustrate how the extended model applies to small-scale irrigators, the water use behaviour of adopting water-saving technologies is used as an example. The model integrates additional constructs beyond the standard TPB. These added constructs are justified based on their relevance to the context and aim to enhance the model's ability to explain the factors influencing the decisions and intentions of small-scale irrigators.

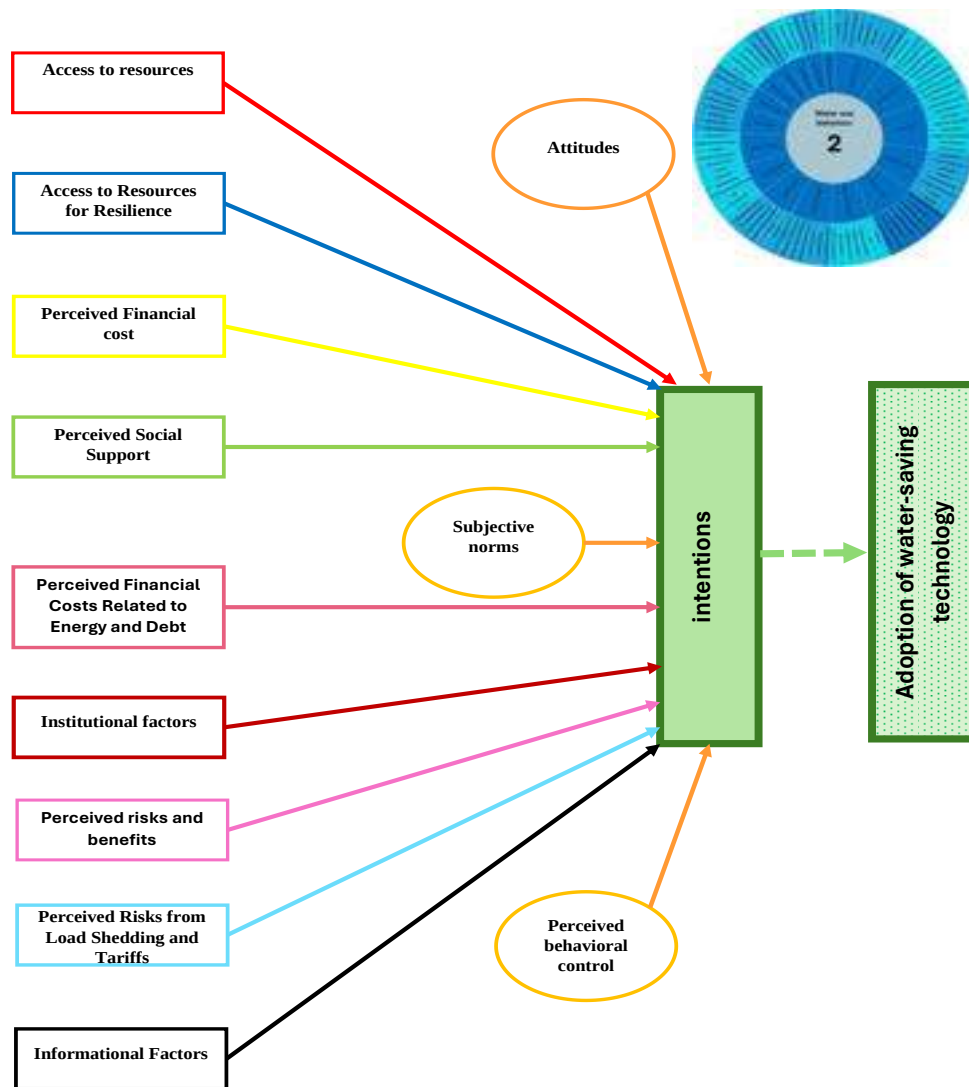


Figure 2.17: Theoretical Framework of the Augmented Theory of Planned Behaviour for Small-Scale Irrigators' Adoption of Water-Saving Technologies

Source: Project team compilation

2.3 Key Psychological Theories of Behaviour

A range of psychological theories and frameworks has been developed to investigate human behaviour and decision-making. These theories highlight the factors that drive individuals' intentions and actions in diverse contexts. The following sections review some of the most widely recognised psychological theories in behavioural research.

2.3.1 Socio-Cognitive Theory (SCT)

The Social Cognitive Theory (SCT), developed by Bandura (1986), describes how individuals learn and adjust their behaviour through observation, thought processes, and interactions with their surroundings. Bandura (1986) and Govindaraju (2021) proposed that human behaviour is influenced by the continuous, dynamic interaction between behaviour, personal factors, and environmental factors (Figure 2.18).

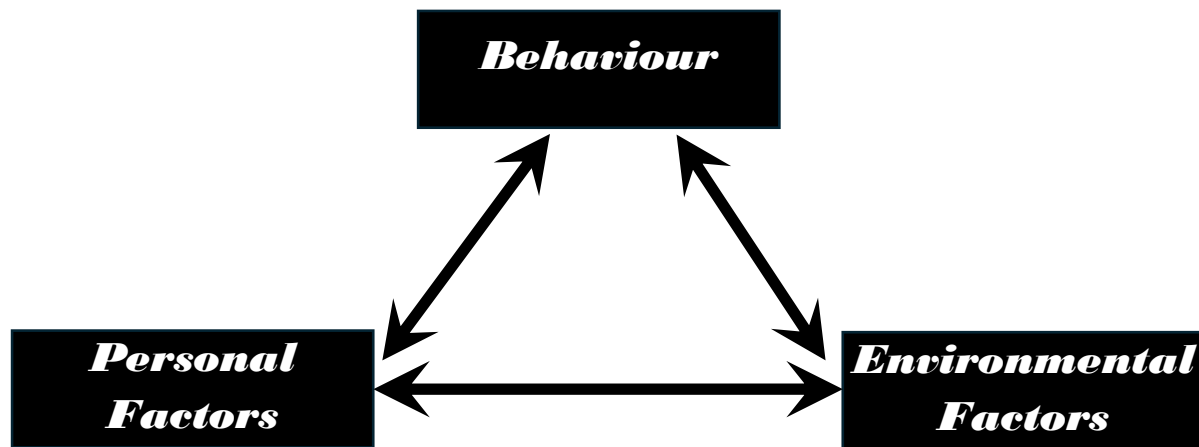


Figure 2.18: The Social Cognitive Theory

Source: Adapted from Govindaraju (2021)

Beyond this three-way interaction, SCT highlights the role of thought processes and planning in shaping human behaviour. According to Luszczynska and Schwarzer (2015), motivation and action are strongly influenced by anticipation, particularly self-efficacy and outcome expectancies. As part of the personal factors in SCT, self-efficacy refers to a person's belief in their ability to perform a specific action successfully. At the same time, outcome expectancies relate to their beliefs about the possible results of that action. SCT also considers goals, perceived barriers, and supporting factors, all of which influence behaviour and decision-making. These personal factors interact with environmental influences and behavioural patterns, reinforcing the idea that multiple influences shape human behaviour. The relationship between these factors is shown in Figure 2.19 below.

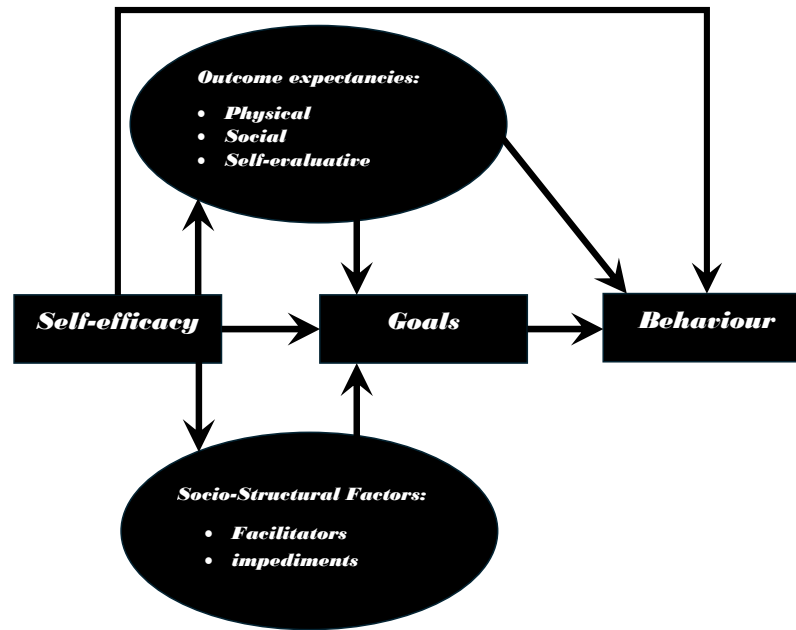


Figure 2.19: Personal Factors Influencing Behaviour in Social Cognitive Theory

Source: Adapted from Luszczynska and Schwarzer (2015)

Like various psychological frameworks, the SCT has both strengths and limitations that are important to consider. One of the key strengths of SCT is that it offers a broad perspective by emphasising the interconnectedness of personal factors, behaviours, and environmental influences, and it highlights the role of human agency, where individuals can actively shape their environment to achieve their goals (Nickerson, 2025).

Nickerson (2025) highlighted three main limitations of the SCT. The first limitation is that the SCT is criticised for being overly broad and addressing a wide range of factors, including personal, behavioural, and environmental aspects, without providing clear guidelines on how to prioritise or measure them. The second limitation is that, while the theory suggests an interaction between beliefs, environment, and behaviours, it does not specify which of these variables is most important in any given context. The third limitation is that, in some studies, researchers selectively measure only certain aspects of the theory, such as observational learning or self-efficacy, while leaving other factors, such as social norms or emotional states, less explored.

2.3.2 Norm Activation Model (NAM)

The Norm Activation Model (NAM), developed by Schwartz (1977), is a behavioural theory that explains and predicts individuals' altruistic and pro-environmental behaviours. NAM is based on the assumption that personal norms (PN) are key predictors of pro-social behaviour (Lopes et al., 2019). The model further

suggests that personal norms are activated by two factors: awareness of consequences (AC) of one's actions and the acceptance of individual responsibility (AR) for those consequences (Figure 2.20 below). Thus, the structure of the NAM model indicates that AC and AR contribute to the development of personal norms, which in turn influence pro-social intentions and behaviours.

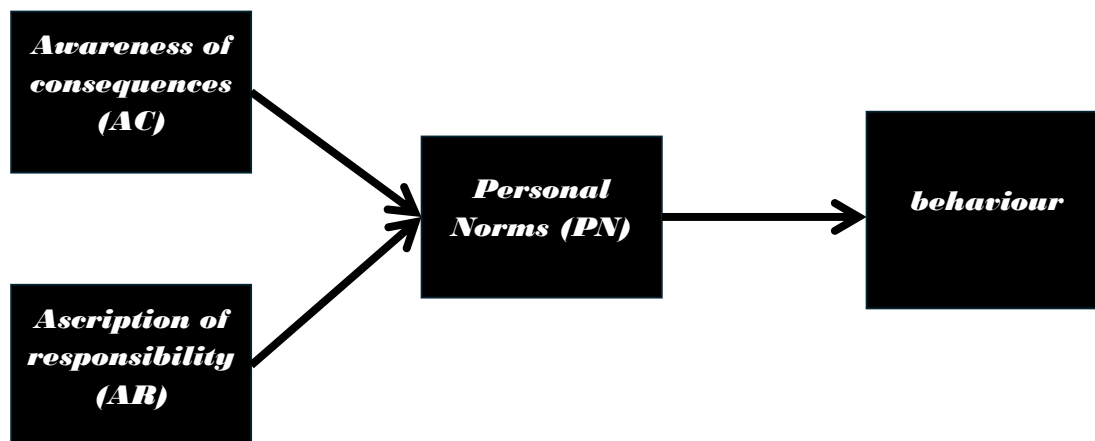


Figure 2.20: Structure of the Norm-Activation Model (NAM)

Source: Adapted from Lopes et al. (2019)

The NAM has been applied in various fields, including environmental behaviour, altruistic behaviour, and even speeding behaviour, showcasing its versatility (Stern, 2000). A significant strength of the NAM is its clear conceptual distinction between personal norms and other behavioural constructs, such as intentions and attitudes. This distinction allows for a more precise understanding to be gained of the role of moral obligation in shaping pro-social behaviour (Harland et al., 1999). Additionally, the NAM model has served as the foundation for more comprehensive models, such as the VBN theory (Stern, 2000). However, the NAM also has notable limitations. While the model emphasises personal moral norms, Biel and Thøgersen (2007) point out the importance of situational and social factors, such as cooperation norms, which the NAM does not explicitly address. This suggests a potential gap in the model's ability to account for external influences on pro-social and pro-environmental behaviours fully.

2.3.3 New Ecological Paradigm (NEP)

The New Ecological Paradigm (NEP) was developed by Dunlap and Van Liere (1978) and is a behavioural framework designed to assess an individual's ecological worldview, which reflects their beliefs about the relationship between humans and the environment. The NEP is based on the notion that there is an inevitable limit to economic growth and that humans are not above nature, but instead depend on an ecologically

balanced nature to survive (Xiao & Buhrmann, 2017). To measure this shift in worldview concerning human-environment relationships, Dunlap and Van Liere (1978) developed the NEP scale.

The original version of the scale contained 12 statements that focused on three core aspects of a pro-environmental perspective: the potential for humans to disrupt the natural balance (balance of nature); the existence of limits to growth in human societies (limits to growth); and the belief that humans do not have an inherent right to dominate nature (anti-anthropocentrism). However, Dunlap et al. (2000) revised the scale, expanding it to 15 statements, addressing technical issues in the structure, removing outdated language, and introducing two new dimensions: anti-exceptionalism (rejecting the idea that humans are exempt from environmental consequences) and eco-crisis (acknowledging the environmental crisis) (Dorward et al., 2024). The final version of the NEP scale, including all 15 measurement items grouped by their respective dimensions, is presented in Table 2.6 below.

Table 2.6: The New Ecological Paradigm (NEP) statements

	NEP Statement	Dimensions of pro-environmental worldview measured by each statement
NEP 1	We are approaching the limit of the number of people the Earth can support.	Limits to growth
NEP 2	Humans have the right to modify the natural environment to suit their needs.	Anti-anthropocentrism
NEP 3	When humans interfere with the natural environment, it often produces disastrous consequences.	Balance of nature
NEP 4	Human ingenuity will ensure that we do not make the Earth unlivable.	Anti-exceptionalism
NEP 5	Humans are severely abusing the environment.	Eco-crisis
NEP 6	The Earth has an abundance of natural resources if we learn how to harness them effectively.	Limits to growth
NEP 7	Plants and animals have as much right as humans to exist.	Anti-anthropocentrism
NEP 8	The balance of nature is strong enough to cope with the impacts of modern industrial nations.	Balance of nature
NEP 9	Despite our special abilities, humans are still subject to the laws of nature.	Anti-exceptionalism
NEP 10	The so-called “ecological crisis” facing humankind has been greatly exaggerated.	Eco-crisis
NEP 11	The Earth is like a spaceship with minimal room and resources	Limits to growth
NEP 12	Humans were meant to rule over the rest of nature.	Anti-anthropocentrism
NEP 13	The balance of nature is very delicate and easily upset.	Balance of nature
NEP 14	Humans will eventually learn enough about how nature works to be able to control it.	Anti-exceptionalism
NEP 15	If things continue on their present course, we will soon experience a major ecological catastrophe.	Eco-crisis

Source: Adapted from Dorward et al. (2024).

To further conceptualise the structure of the revised NEP scale, a theoretical framework is presented in Figure 2.21 below. This framework illustrates how pro-environmental beliefs are shaped by the five core dimensions outlined in the revised NEP. Each of these constructs is measured using three specific items as listed in Table 2.6.

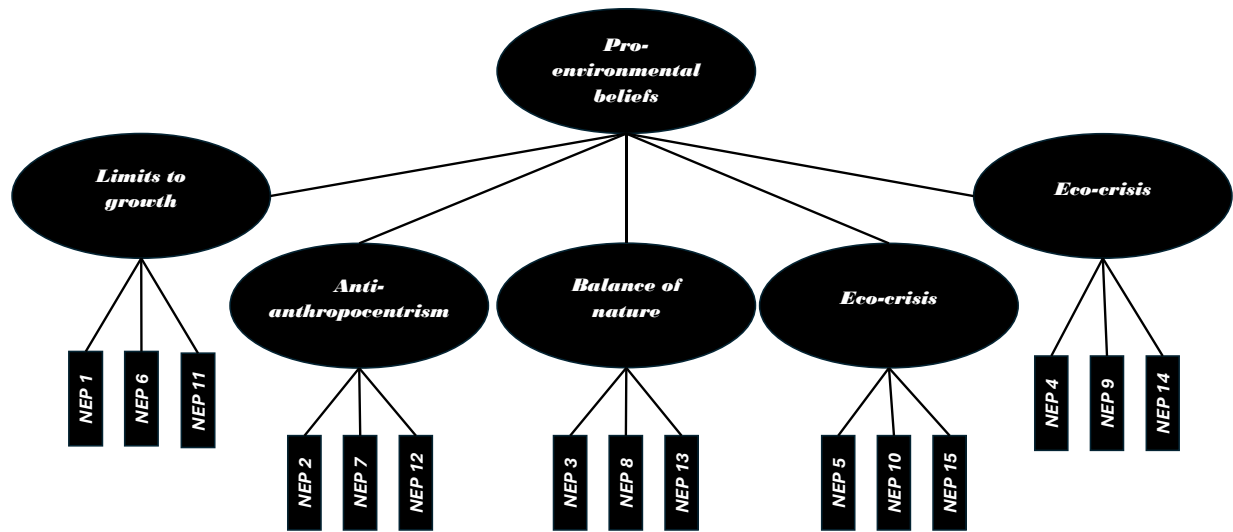


Figure 2.21: Theoretical Framework of the New Ecological Paradigm

Source: Adapted from Dorward et al. (2024).

The revised NEP scale has proven to be a valuable tool for assessing pro-environmental worldviews; however, it also has its strengths and limitations that are important to consider when applying it. The NEP is widely regarded as one of the most commonly used measures of environmental values and attitudes globally, with applications spanning disciplines such as environmental psychology, sustainability studies, environmental education, and conservation science (Anderson, 2012; Dorward et al., 2024).

Despite its widespread use, Anderson (2012) highlights several important criticisms of the revised NEP scale. First, it has been argued that the scale is incomplete, as it fails to capture key aspects of a biocentric worldview, which is emphasised in environmental ethics. Second, concerns have been raised about its validity, especially given inconsistent links between NEP scores and actual pro-environmental behaviours. Finally, Anderson notes the ongoing debate about the dimensionality of the scale, as empirical studies often identify multiple factors rather than a single, unified construct, which raises concerns about both its reliability and conceptual coherence. The NEP scale has been criticised for its outdated wording, which fails to capture the complexity of modern ecological issues and shifts in public attitudes, and for its inability to reflect recent environmental concerns such as climate variability, deforestation, and biodiversity loss (Lalonde & Jackson, 2002).

2.3.4 Value-Belief-Norm Theory (VBN)

The Value-Belief-Norm (VBN) Theory is a psychological framework used to explain pro-environmental behaviours and the motivation behind individuals' decisions to engage in environmentally friendly actions. The VBN theory was initially proposed by Stern et al. (1999) and further developed by Stern (2000). The VBN theory integrates elements from the NAM and the NEP, aiming to explain environmentally significant behaviour through a causal chain involving values, beliefs, and personal norms (Figure 2.22).

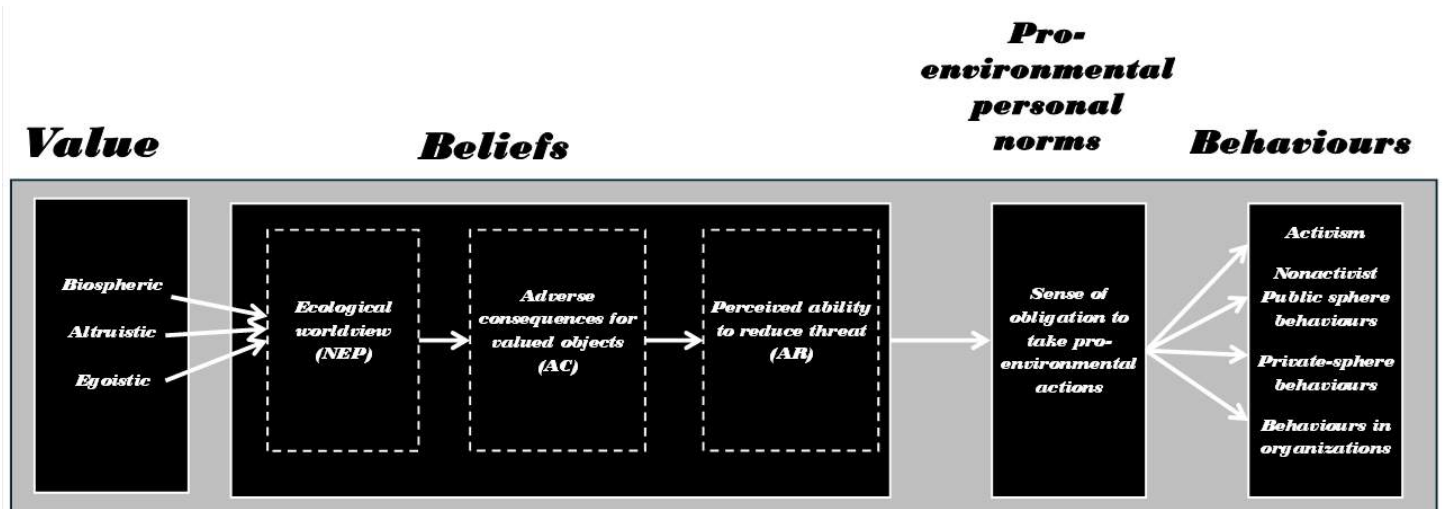


Figure 2.22: Schematic representation of variables in the Value-Belief-Norm Theory (VBN)

Note:

- Arrows represent postulated direct effects, which may also be observed on variables more than one level downstream from a causal variable.
- Empirically, measures of egoistic values have been negatively correlated with indicators of environmentalism.

Source: Adapted from Stern (2000)

According to Stern (2000), the causal chain of the Value-Belief-Norm (VBN) theory, as illustrated in Figure 2.22 above, begins with core values that include biospheric, altruistic, and egoistic orientations. These values influence the belief system, which comprises an ecological worldview, as captured by the New Ecological Paradigm, awareness of adverse consequences for valued objects, and the perceived ability to mitigate environmental threats. When individuals acknowledge these beliefs, a sense of moral obligation is activated, leading to the formation of pro-environmental personal norms. These norms reflect an internalised responsibility to take environmentally responsible action. Once these personal norms are established, they guide behaviour across various domains, including non-activist, public-sphere behaviours such as voting or policy support, private-sphere behaviours like household conservation, and

environmentally oriented behaviours within organisations. This sequential pathway illustrates how abstract values are translated into specific pro-environmental actions through a structured psychological process.

While the VBN theory offers a structured and empirically supported framework for understanding pro-environmental behaviour, it presents both notable strengths and certain limitations. VBN theory builds on foundational frameworks like NAM and NEP, enhancing its robustness and allowing extensions with additional variables to improve explanatory power (Chunhua et al., 2023). The VBN theory has been shown to effectively predict and explain a range of pro-environmental behaviours across diverse contexts (Canlas et al., 2022). However, the VBN theory has several limitations. It does not account for social norms and peer influence, which are critical in shaping individual behaviour (Al Mamun et al., 2022). Moreover, it does not explicitly model cognitive processes or reasoning mechanisms involved in decision-making, such as cost-benefit analysis or situational constraints (Fauzi et al., 2024). The theory also assumes a rigid, linear progression from values to beliefs to norms and ultimately behaviours, which may not accurately reflect the dynamic, non-linear nature of real-world behavioural influences (Walters, 2021). Furthermore, VBN theory is conceptually weak in explaining habitual or repeated behaviours, as it lacks integration of behavioural routines and environmental cues that often drive everyday actions automatically (Sigurðardóttir, 2017).

2.3.5 Expectancy-Value-Based Models of Behavioural Intentions

Theories of human behaviour often emphasise the role of individuals' expectations and the value they assign to specific outcomes in shaping their decisions. The Expectancy-Value Theory provides the foundation for understanding how people evaluate their actions, based on perceived benefits and costs. Building on this, the Theory of Reasoned Action introduces the influence of social norms and attitudes in shaping behavioural intentions. The Theory of Planned Behaviour further extends this framework by incorporating perceived behavioural control, recognising that external constraints can affect decision-making. Together, these theories offer a structured approach for understanding and predicting human behaviour in various contexts. The following sections provide an overview of each of these theories.

2.3.5.1 Expectancy-Value Theory

Fishbein's (1963) expectancy theory posits that expectancy perceptions and value evaluations shape an individual's motivation to adopt specific actions (Figure 2.23 below). The Expectancy-Value Theory posits that an individual's motivation is influenced by their beliefs about the relationship between effort, performance, and outcomes. For example, an individual will not choose to undertake a task or continue engaging in it when they expect to fail. Value belief refers to the extent to which an individual values the

desired outcome. Expectancy belief and value are integrated through multiplication, which is presented in Equation 2.1:

$$A_B = \sum_i^n B_i a_i \quad (2.1)$$

where:

A_B Attitude towards the object (product, service) B

B_i Personal belief about the probability of the object possessing the i th attribute

a_i personal evaluation of the i th attribute

n Number of attributes

Based on Equation 2.1, it can be seen that the motivation or attitude for a given behaviour will be high when both expectancy and value are high; however, if one of these two variables equals zero, then motivation will also subsequently be zero.

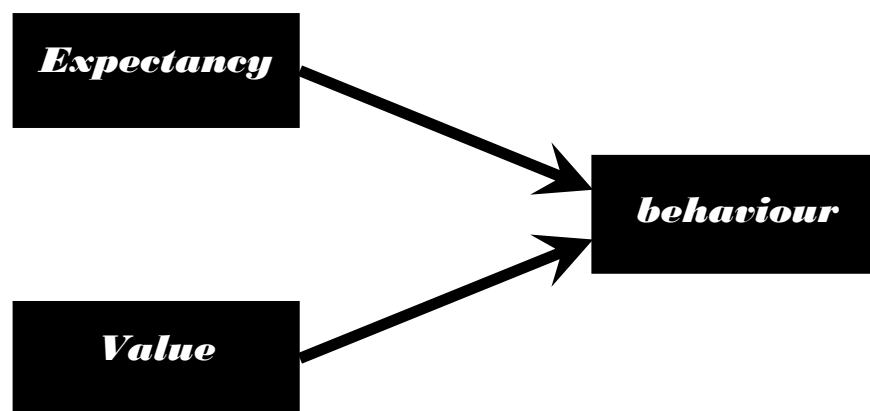


Figure 2.23: Expectancy-Value Theory

Source: Adapted from Fishbein (1963)

The Expectancy-Value Theory is not without its limitations. Firstly, the Expectancy-Value Theory stipulates that motivation is a function of expectancies and values. However, the theory does not take into account the individual's personality, abilities, knowledge, skills, or other factors that influence motivation. Furthermore, the theory assumes that expectancy and value beliefs equally weigh the participants' motivation.

Various studies have also questioned the validity by analysing attitudes to explain social behaviour. Wicker (1969) highlighted the inconsistency between attitudes and behaviour by stating that "It is considerably

more likely that attitudes will be unrelated or only slightly related to covert behaviours than the attitudes will be closely related to actions.” According to Ajzen (2012), in his article on the “Martin Fishbein Legacy”, Fishbein turned his attention to the growing concern about the weak relationship between attitudes and behaviour and was heavily influenced by the work of Dulany (1968). Dulany (1968) proposed the theory of proportional control, which stipulates that individuals form a conscious intention to select a certain response, and that behavioural intention determines the response emitted. The theory of proportional control led to the development of the Theory of Reasoned Action (TRA). The following section will provide a detailed overview of the TRA.

2.3.5.2 Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) was developed by Fishbein and Ajzen (1980) and suggested that a person's volitional behaviour³ is determined by their intention to perform a certain behaviour. In turn, an individual's behaviour intentions are influenced by subjective norms and attitudes related to the behaviour (Figure 2.24 below). Subjective norms refer to the extent to which the opinions of relevant groups (friends, family, and peers) may influence one's execution of a certain activity. Specifically, as defined by Ajzen (1991), subjective norms are perceived as comprising the social pressure to perform or not perform a specific behaviour. Specifically, the strength of each normative belief is weighted by the motivation to comply with the referent, and the products are aggregated across all accessible referents, which can be expressed as:

$$SN = \sum_i^n n_i m_i \quad (2.2)$$

where:

n the strength of each normative belief regarding the referent i

m the motivation to comply with the referent i

Moreover, an individual's attitude towards a certain behaviour refers to how they perceive the act of engaging in that behaviour in general. According to TRA, stronger intentions result in greater effort to carry out the action, which increases the possibility that it will be carried out. Mathematically, the TRA can be expressed in Equation 2.3, as proposed by Hale et al. (2002):

$$B = BI = (A_B)w_{A_B} + (SN)w_{SN} \quad (2.3)$$

³ Volitional behaviour refers to a cognitive process through which an individual decides on and commits to a certain course of action.

where:

B Behaviour of interest

BI An individual's behavioural intention

A_B An individual's attitude towards performing the behaviour

SN Subjective norm related to performing the behaviour

w_{AB} The relative weight of A_B

w_{SN} The relative weight of SN

Important to note from Equation 2.3 is that the attitudes and subjective norms are unlikely to be weighted equally in predicting behaviour. Therefore, the influence that attitudes and norms have on behaviour will have to be weighted, based on their importance, which will be context-specific to the target person.

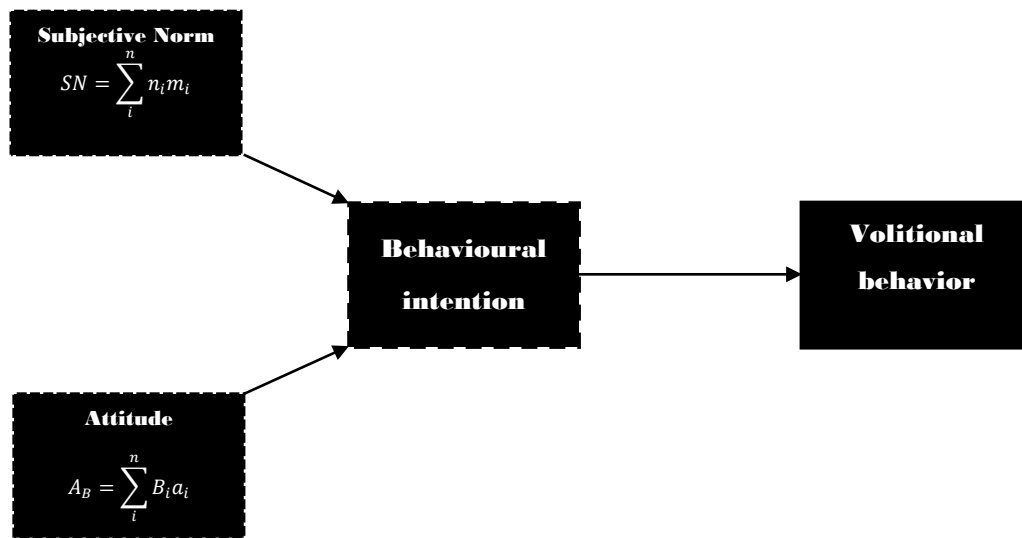


Figure 2.24: Flow diagram of the core components of the Theory of Reasoned Action

Source: Adapted from Fishbein and Ajzen (1977)

Several studies have utilised TRA as a framework for studying particular types of behaviour, such as communication behaviour (Karnowski et al., 2018; Lee et al., 2013; Roberto et al., 2011), consumer behaviour (Paço & Lavrador, 2017; Paul et al., 2016; Prakash & Pathak, 2017), and health behaviour (Dippel et al., 2017; Hagger et al., 2018; McEachan et al., 2016). However, the TRA is not without its limitations. The TRA paradigm presupposes that the behaviour under research is volitionally controlled, meaning that people have significant control over the behaviour. As a result, the efficacy of the theory in explaining behaviour relies on the degree to which the behaviour is under control. The TRA may not be

adequate in predicting behaviours when volitional control is compromised by variables such as limited ability, time, environmental and organisational restrictions, and unconscious habits.

The next section discusses the Theory of Planned Behaviour (TPB), an extension of the TRA to address the issue of factors outside individual control that may affect intentions and behaviours.

2.3.5.3 Theory of Planned Behaviour (TPB)

One of the assumptions of the TRA is that it is only confined to the behaviour over which individuals have volitional control (Ajzen, 2012). It soon became apparent, nevertheless, that this formulation placed an unreasonably strict constraint on a theory designed to anticipate and account for all kinds of socially meaningful actions. Ajzen (1985) introduced the TPB by adding a component referred to as “perceived behavioural control” to the framework of the TRA (Figure 2.25 below) to accommodate behaviours over which individuals have limited volitional control. Perceived behavioural control is a key component of the Theory of Planned Behaviour (TPB), along with attitudes and subjective norms, and it plays a crucial role in shaping behavioural intentions and, ultimately, behaviour. When individuals perceive a high level of control over performing a behaviour, they are more likely to have positive intentions and engage in the behaviour. On the other hand, if individuals perceive that they have low control over performing a behaviour, they may be less likely to intend to engage in the behaviour or carry it out. Mathematically, the perceived behavioural control component of the TPB can be expressed as:

$$PBC = \sum_i^n c_i p_i \quad (2.4)$$

where:

c the perceived occurrence of factors i

P the perceived power of the control factor i

The TPB asserts that attitudes, subjective norms, and perceived behavioural control can lead to the formation of a behavioural intention, expressed as:

$$B = BI = (A_B)w_{A_B} + (SN)w_{SN} + (PBC)w_{PBC} \quad (2.5)$$

where:

PBC Perceived behavioural control

w_{PBC} The relative weight of PBC

Equation 2.5 above illustrates the point that behaviour is a function of an individual's intention to engage in the behaviour of interest. The individual's intention, in turn, is a function of the individual's attitude towards performing the behaviour, their perception of how peers and people of importance would want them to behave, and the extent to which the individual believes in having control over the behaviour. Perceived behavioural control has a direct effect on behaviour and an indirect effect on behaviour through intentions. The direct measure of perceived effects of behavioural control on behaviour entails the degree of control an individual has over the behaviour, i.e. how difficult or easy it is to carry out a specific behaviour. Conversely, the indirect measure focuses on a factor's occurrence and perceived power that affects how difficult or easy it is to carry out a specific behaviour.

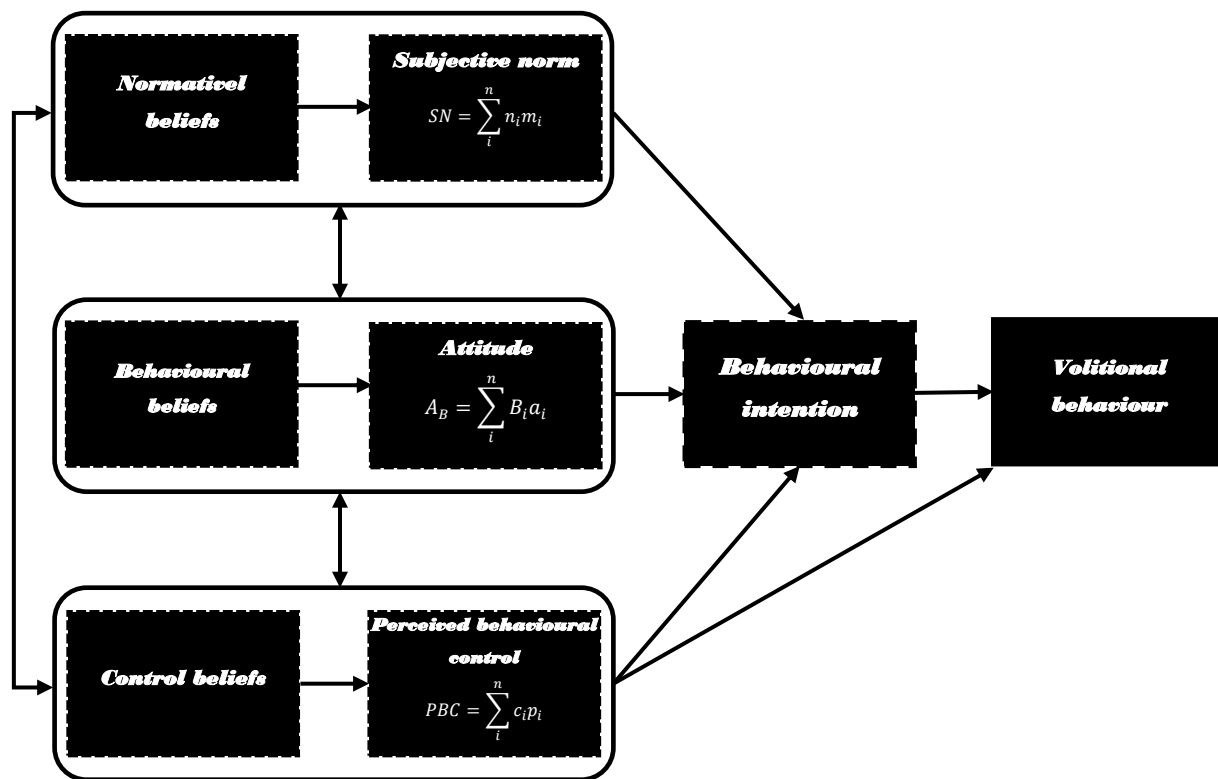


Figure 2.25: The core components of the Theory of Planned Behaviour

Source: Adapted from Pourmand et al. (2020)

The existing body of literature demonstrates that the Theory of Planned Behaviour (TPB) has been frequently utilised to investigate human behaviour across diverse fields. Nevertheless, despite its frequent usage, the TPB suffers from several limitations. Firstly, the TPB mainly focuses on conscious processes, and it assumes that an individual's intentions drive behaviour. However, the TPB fails to account for unconscious or automatic processes in shaping behaviour, such as habits, automatic associations, and

emotional reactions (Ajzen, 2011; Sheeran et al., 2013). If the unconscious mind is not considered, the complexity of human behaviour may not be fully understood.

Furthermore, the TPB typically relies on self-reports, which are vulnerable to self-presentational biases (Ajzen, 2011; Armitage & Conner, 2010; Hessing et al., 1988). For example, when individuals complete a questionnaire, they provide their subjective responses. In other words, the individual's responses are based on their perceptions and beliefs and are not observed directly by an external observer.

A further issue with the TPB is the assumption of sufficiency – a concept known as the TPB's sufficiency assumption. According to the TPB, one should be able to predict behaviour based on the standard constructs illustrated in Figure 2.23 above. However, it has been proposed that these standard constructs may not be sufficient to fully understand an individual's intentions and behaviour (Ajzen, 2011; Conner & Armitage, 1998). To improve the usefulness of the theory's predictive capacity, other academics in different research disciplines have contributed their own constructs to the theory (Al-debei et al., 2013; Baker & White, 2010; Donald et al., 2014; Maleksaeidi & Keshavarz, 2019; Mittelman & Rojas-Méndez, 2018; Rhodes & Courneya, 2003; Savari & Gharechae, 2020; Tama et al., 2021; Wang et al., 2023). Ajzen (2011), however, proposed that supplementary predictors should be introduced with caution and only after careful consideration and empirical investigation to maintain parsimony. Despite the criticisms and limitations of the TPB, it remains a preferred framework for understanding human behaviour in diverse fields because of its extensive application, empirical validation, and practical utility.

2.4 Biophysical Models

2.4.1 AquaCrop model

According to Steduto et al. (2012), the AquaCrop model was developed as an evolution of the approach introduced by FAO Irrigation and Drainage Paper No. 33 (Doorenbos & Kassam, 1979). This paper linked the reduction in evapotranspiration to a proportional reduction in yield, as expressed by the following Equation 2.6:

$$\frac{Y_X - Y_a}{Y_X} = K_y \left(\frac{ET_x - ET_a}{ET_x} \right) \quad (2.6)$$

where:

Y_X Maximum yield

Y_a Actual yields

K_y Proportionality factor

ET_x Maximum evapotranspiration

ET_a Actual evapotranspiration

However, the approach of Doorenbos and Kassam (1979) has drawbacks owing to the aggregation of variables, such as using final yield instead of its components and considering evapotranspiration rather than just transpiration (Steduto et al., 2012). The FAO has had to update its Paper No. 33 since 1979 as a result of numerous experimental and theoretical advancements in crop relations, in light of increased pressure to improve water productivity to address water scarcity (Cao et al., 2016).

Maintaining the original approach proposed in the FAO's paper No.33 (direct link between crop water use and crop yield), the AquaCrop model evolved by separating non-productive soil evaporation from productive crop transpiration and estimating biomass production directly from actual crop transpiration through a water productivity parameter (Steduto et al., 2012). By addressing the limitations of the FAO's original approach and incorporating these improvements, the AquaCrop model provides a more refined understanding of the relationship between water use and crop yield. Steduto et al. (2012) further highlighted the point that these changes to the original concept led to Equations 2.7 and 2.8 (below), which are the core of the AquaCrop growth engine.

$$B = WP \cdot \sum Tr \quad (2.7)$$

where:

B Biomass produced cumulatively (kg per m²),

Tr Crop transpiration (mm or m³ per unit surface),

WP Water productivity parameter (either kg biomass/m² or mm or kg of biomass per m³ of water transpired),

$$Y = B \cdot HI \quad (2.8)$$

Where:

Y Yield derived from the harvested organ,

HI Harvest Index (ratio of yield to biomass).

It is essential to note that Equations 2.7 and 2.8 represent a simplified illustration of the AquaCrop model, and that additional factors and variables are involved in the complete mathematical formulation. FAO (2022) has developed a reference manual to aid in the application of AquaCrop. This reference manual

provides a schematic summary of the AquaCrop model, which has been reproduced in Figure 2.26 below. The four steps outlined in Figure 2.24 serve as a structural guide for delineating the core components of the AquaCrop model.

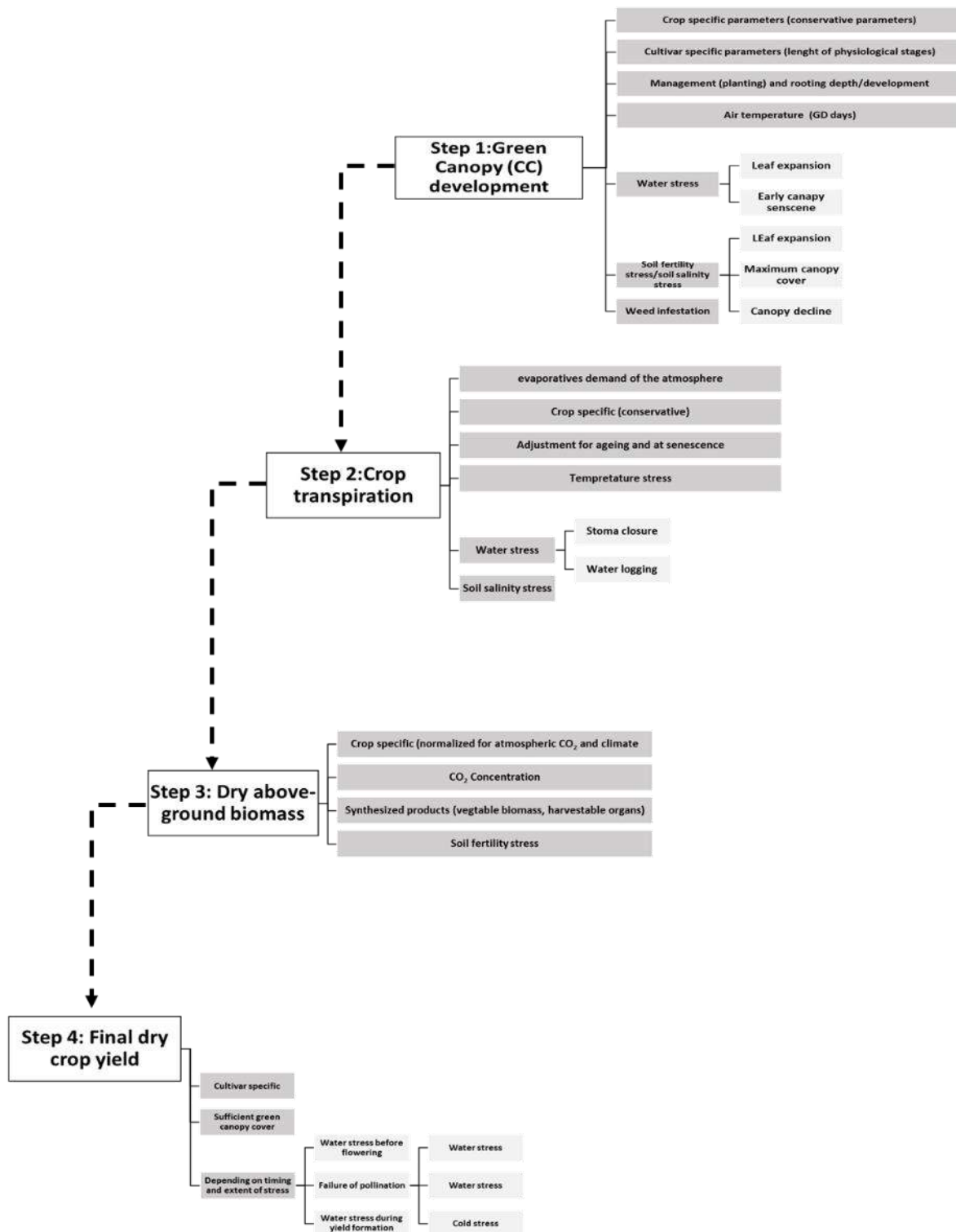


Figure 2.26: Core Simulation Steps of the AquaCrop Model

Source: Adapted from FAO (2022)

As shown in Table 2.7 below, AquaCrop not only offers several strengths, including simplicity and data efficiency, but also presents limitations related to crop-specific calibration and socio-economic factors, and does not assess data at the household, district, provincial, or regional levels.

Table 2.7: Overview of AquaCrop’s models: Strengths and Limitations

Strengths	1. The AquaCrop model is well-suited to conditions where water is a key limiting factor in crop production, such as in South Africa (Kephe et al., 2021).
	2. The AquaCrop model is designed to strike a balance between accuracy, simplicity, and robustness, making it suitable for a variety of users and applications, including water use and crop yield analysis (Maher et al., 2019).
	3. AquaCrop’s model outputs can be directly linked to easily accessible data from visual field observations and remote sensing, facilitating model calibration and validation (Foster et al., 2017).
	4. AquaCrop model accounts for a broader range of water stress impacts on transpiration, including stomatal closure, reduced leaf expansion, and premature canopy senescence, compared with most other water-driven crop models (Foster et al., 2017).
	5. AquaCrop model accounts for the dynamic effects of environmental stressors, such as water, temperature, and elevated CO ₂ , on crop growth, and considers the impacts of soil fertility and salinity through local calibration (Foster et al., 2017).
	6. AquaCrop’s model flexibility enables implementation in MATLAB, R, and Python, with AquaCrop-OSPy facilitating integration with optimisation libraries (Kelly et al., 2023).
	7. A distinctive feature of the AquaCrop model is its use of canopy cover to express foliage development, which simplifies simulation by directly accounting for planting density. This approach facilitates the estimation of canopy cover visually or using satellite data, as opposed to the more complex leaf area index (Vote et al., 2015).
	8. AquaCrop’s model ability to normalise water productivity (WP) for evaporative demand using ET ₀ and CO ₂ , along with its insensitivity to soil nutrient variability, enables accurate assessment of water-limited productivity across various agro-ecological zones, crops, and climate scenarios (Vote et al., 2015).
	9. The AquaCrop model requires fewer input parameters and data compared to other crop models, and these inputs are generally easy to measure or readily available. This configuration makes the AquaCrop model more accessible and user-friendly for a broader range of users (Vote et al., 2015).
	10. The AquaCrop model is an improved version of CropWat, offering a more accurate simulation of the crop environment owing to its more advanced and detailed crop routines, which enable it to represent better the conditions in which crops grow (Vote et al., 2015).

	11. Despite its simplicity, the AquaCrop model performs well compared with more complex models by incorporating fundamental physiological and agronomic processes, allowing it to accurately predict attainable yields and model crop responses to water supply, considering factors such as soil type, sowing dates, and irrigation strategies (Vote et al., 2015).
	12. The AquaCrop model calculates water productivity (WP) using reference evapotranspiration instead of the traditional vapour pressure deficit, enabling it to account for the advective transfer of energy, which vapour pressure deficit does not capture (Vote et al., 2015).
Weaknesses	1. The AquaCrop model has been documented to underestimate canopy cover in certain crops (Kephe et al., 2021).
	2. The AquaCrop model is designed to predict crop yields at the single field scale (point simulations). The field is assumed to be uniform without spatial differences in crop development, transpiration, soil characteristics, or management (FAO, 2025).
	3. The AquaCrop model considers only vertical incoming (rainfall, irrigation, and capillary rise) and outgoing (evaporation, transpiration, and deep percolation) water fluxes (FAO, 2025).
	4. AquaCrop model shows reduced accuracy in predicting crop evapotranspiration (ET _c) and water use efficiency (WUE) under extreme weather conditions, such as intense rainfall and high temperatures (Greaves & Wang, 2016).
	5. The AquaCrop model has been found to struggle with accurately simulating biomass and soil-water dynamics, particularly in years with low precipitation, high evaporative demand, and wet conditions (Sandhu & Irmak, 2019).

Source: Compiled by the project team

2.4.2 Decision Support System for Agrotechnology Transfer (DSSAT)

The Decision Support System for Agrotechnology Transfer (DSSAT) is a software programme designed to simulate crop growth, development, and yield. DSSAT integrates crop simulation models for over 45 crops with database management tools for soil, weather, crop management, and experimental data. DSSAT enables users to evaluate various crop management options by simulating soil-plant-atmosphere interactions and their impact on crop performance (DSSAT, 2025). DSSAT is widely used for applications ranging from farm-level management to regional assessments of climate variability impacts, making it a valuable tool for researchers, policymakers, and practitioners. Figure 2.27 below illustrates the DSSAT framework, showing the integration of database, application, and support software components with crop models.

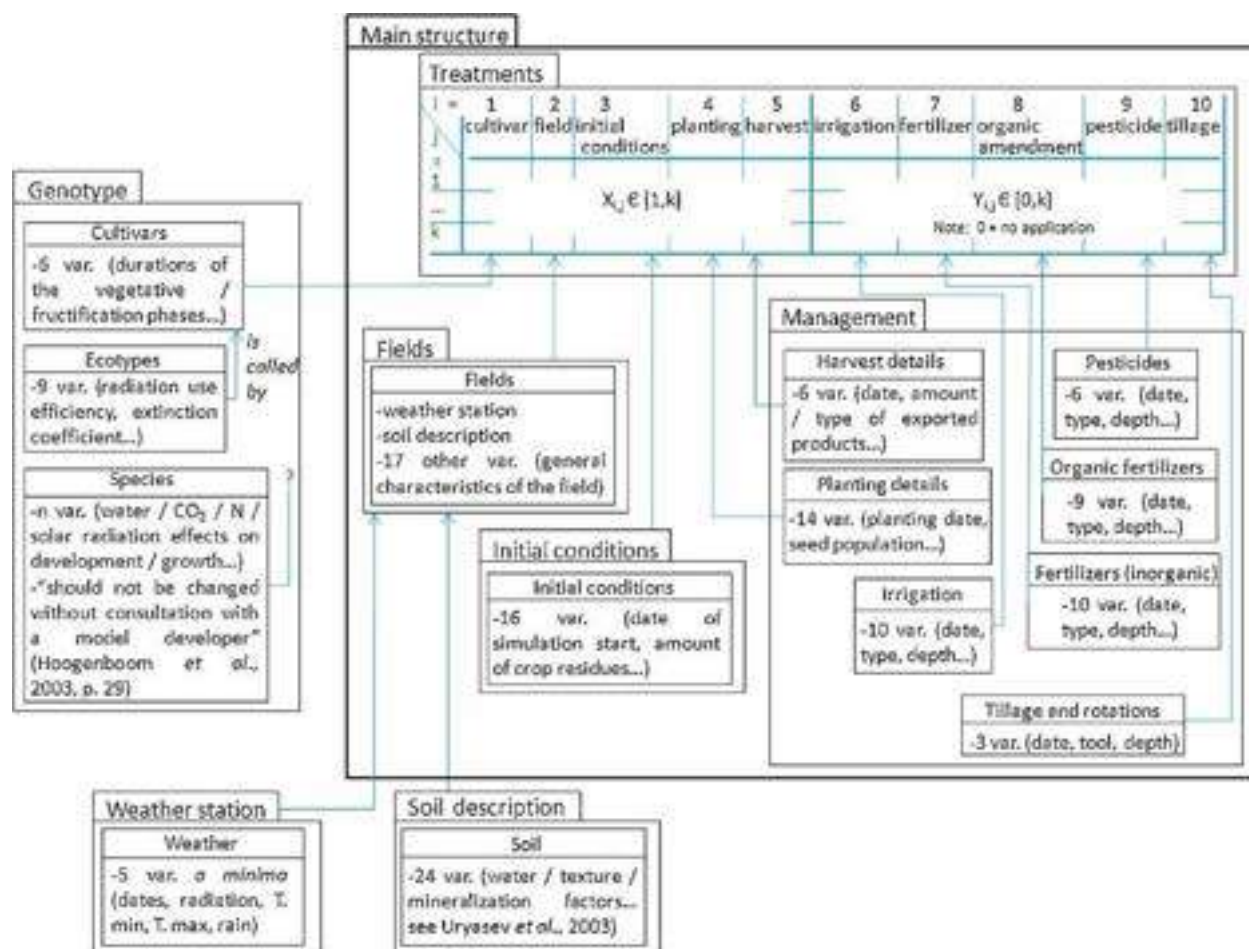


Figure 2.27: Overview of DSSAT's Database, Application, and Support Software Components

Source: Adapted from Corbeels et al. (2016)

Corbeels et al. (2016) provide a basic overview of the DSSAT model, which operates by using specific input files that define weather, crop, and soil characteristics. These files are integrated into the model's main structure, which is organised as a matrix of simulation treatments. This structure implements the selected crop and soil models, allowing DSSAT to simulate daily changes in plant and soil variables in response to weather conditions and management practices. The model is designed to simulate these processes for a specific land unit, such as a field. An overview of DSSAT's main advantages and limitations is provided in Table 2.8 below.

Table 2.8: Overview of DSSAT's Strengths and Limitations

Strengths	1. DSSAT supports diverse applications, ranging from on-farm precision management to regional climate impact assessments, and reduces the time and cost of field experimentation for evaluating new cultivars and management systems.
	2. DSSAT enables individual components to be plugged in or unplugged, with little impact on the main programme or other modules, i.e., for comparison of different models or model components (Jones et al., 2003).
	3. DSSAT enables modules written in different programming languages to be linked together (Jones et al., 2003).
	4. DSSAT allows for easy integration into different types of application packages owing to the well-defined and documented interface to the modules (Jones et al., 2003).
	5. DSSAT enables the integration of other components, such as livestock and intercropping, through well-defined module interfaces (Jones et al., 2003).
	6. DSSAT includes a Seasonal Analysis tool that evaluates and compares crop management options biophysically and economically, aiding in the selection of efficient practices (Ngwira et al., 2014).
Weaknesses	1. DSSAT is unable to accurately predict responses to extreme weather events, such as severe droughts and flooding (Sekar, 2023).
	2. DSSAT does not account for macro- and micro-nutrients apart from nitrogen and phosphorus (Sekar, 2023).
	3. DSSAT does not account for most pests, diseases, and weeds, covering only a few crop pests (Kephe et al., 2021; Sekar, 2023).
	4. DSSAT's extensive data requirements limit its use to well-equipped experimentation stations, restricting its potential application in land use planning in developing countries (FAO, 2025a).
	5. DSSAT's soil water balance model is limited to well-drained soils and struggles to simulate conditions in poorly drained soils, where oxygen stress impacts crop growth (Abayechaw, 2021).
	6. The large number of input parameters in DSSAT, combined with uncertainty in these inputs, reduces the accuracy and reliability of predictions across diverse plant growth conditions (Corbeels et al., 2016; Mesasi & Masasi, 2024).

Source: Compiled by the project team

2.4.3 Environmental Policy Integrated Climate (EPIC) Crop Growth Model

The Environmental Policy Integrated Climate (EPIC) model is a process-based tool that simulates the interactions between soil, water, and agricultural management practices. It operates at the scale of a field or watershed, typically referred to as a Hydrologic Land Use Unit (HLU), where homogeneity is assumed

in climate, soil, land use, and topography (Gerik et al., 2015). Although the model does not include explicit spatial components, it operates over time. EPIC simulates crop growth by accounting for factors like nutrient and water availability, temperature, and sunlight. It also considers various management practices such as tillage and crop rotations. The model provides detailed simulations of the impact of these practices on plant growth, with time scales ranging from daily to annual outputs. The operations of the EPIC model, including the interactions between its components, are illustrated in Figure 2.28 (Gerik et al., 2015).

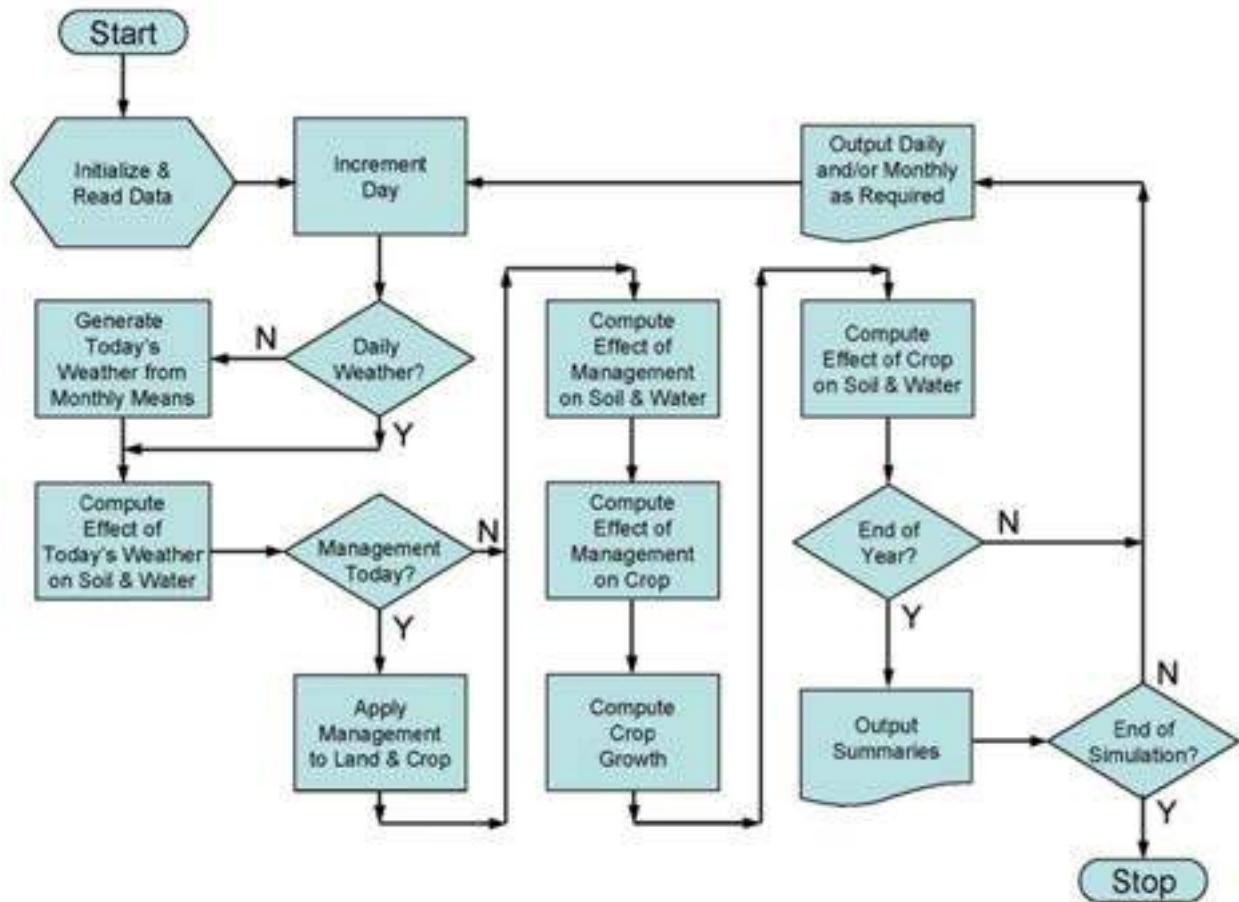


Figure 2.28: Overview of the Operations and Flow of the EPIC Model

Source: Adapted from Gerik et al. (2015)

Table 2.9 summarises the key strengths and limitations of the EPIC model.

Table 2.9: Overview of EPIC's Strengths and Limitations

Strengths	1. EPIC is regarded as flexible and applicable across diverse agricultural systems, given its ability to simulate approximately 80 crops with unique parameter values (Brilli et al., 2017).
	2. EPIC can predict changes in soil, water, nutrient, and pesticide dynamics, as well as crop yields, in response to different management practices (Brilli et al., 2017).
	3. EPIC can perform long-term simulations for hundreds or even thousands of years, making it valuable for understanding the impacts of climate variability and soil erosion on agricultural productivity (Brilli et al., 2017; Wang et al., 2022).
	4. Various management practices, such as drainage, fertilisation, grazing, terracing, and tillage, can be simulated (Wolfe et al., 2021).
Weaknesses	1. EPIC is less accurate in predicting annual variations in crop yields owing to factors such as soil variability, terrain attributes, overestimation of available nitrogen in organic systems, extreme weather events like hailstorms, and a lack of validation for contemporary crop varieties (Lychuk et al., 2017).
	2. EPIC has limitations when applied at larger spatial scales, including restricted species diversity, time-intensive parameterisation, and poor simulation of interactions between abiotic factors across spatial units (McMaster et al., 2006).

Source: Compiled by the project team

2.4.4 CROPWAT

CROPWAT is a decision-support system developed by the FAO for use by agronomists, agro-meteorologists, and irrigation engineers (FAO, 2025b). It is an empirical, process-based crop model used to calculate crop water and irrigation requirements based on crop and climate data. The model also estimates crop performance under rain-fed and irrigated conditions through daily soil water balance calculations. At the field scale, it aids in evaluating irrigation practices, while at larger scales, it supports the development of water supply schedules for different cropping patterns within irrigation schemes (Vote et al., 2015).

CROPWAT is a decision-support system developed by the FAO's Land and Water Development Division for agronomists, agro-meteorologists, and irrigation engineers. The software is designed to calculate reference evapotranspiration, simulate irrigation water requirements, and estimate crop water use under various climatic and management conditions. It utilises inputs such as meteorological data (e.g. temperature, humidity, wind speed, and precipitation), crop data (e.g., growth stages, crop coefficients, and yield response factors), and soil data (e.g. available water content and rooting depth). The model facilitates

the evaluation of irrigation efficiency and rain-fed production, assesses the impacts of drought, and develops water supply schedules for diverse cropping patterns (FAO, 2025b; Vote et al., 2015; Yetik & Şen, 2023). Figure 2.29 provides an overview of the operations and flow of the CROPWAT model.

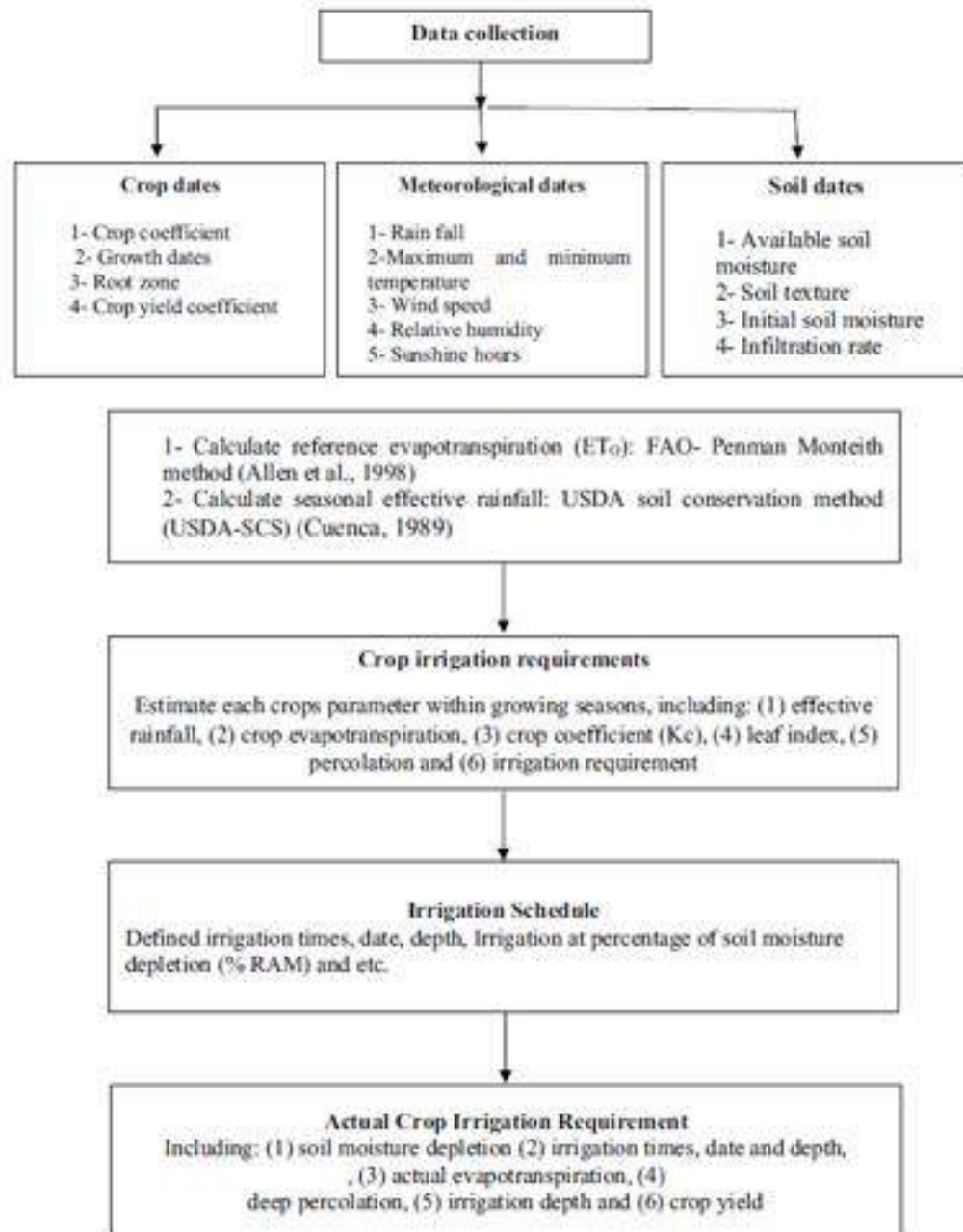


Figure 2.29: Overview of CROPWAT Model Operations and Flow

Source: Adapted from Bazrafshan et al. (2022)

Table 2.10 summarises the strengths and weaknesses of the CROPWAT model.

Table 2.10: Overview of CROPWAT's Strengths and Limitations

Strengths	1. Requires minimal input data compared with other models, making it practical and easy to use across various agroecological zones and climates (Vote et al., 2015).
	2. Compatible with the CLIMWAT 2.0 database, which provides climate data from 3,200 meteorological stations in 144 countries (Vote et al., 2015; FAO, 2025c).
	3. Widely applicable for predicting crop water and irrigation requirements at multiple spatial scales, from field to national levels (Vote et al., 2015).
	4. Provides rapid approximations of yield reductions under water-limited conditions, making it useful for irrigation planning and water management (Vote et al., 2015).
	5. Capable of estimating actual evapotranspiration and yield response to water using average monthly rainfall and reference evapotranspiration data (Vote et al., 2015).
	6. Can be integrated with other software and datasets, such as GIS tools and satellite-derived crop evapotranspiration estimations, to improve accuracy and visualise results (Vote et al., 2015).
Weaknesses	1. The simplified use of yield response factors assumes a single, empirically derived value over a defined period, which limits accuracy in estimating crop performance under varying microclimates, soils, and nutrient conditions (Vote et al., 2015).
	2. CROPWAT cannot carry soil moisture over calendar years, as simulations are restricted to discrete, individual years, despite using daily rainfall and ET _o data (Hess, 2010).
	3. The USDA SCS method for estimating adequate rainfall in CROPWAT was developed for semi-arid environments with well-drained soils and may underestimate adequate rainfall in tropical or humid climates (Vote et al., 2015; Mohan et al., 1996).
	4. CROPWAT cannot simulate the effects of rising atmospheric carbon dioxide (CO ₂) concentrations on crop water use, limiting its applicability in scenarios involving climate variability (Vote et al., 2015; Pinto et al., 2008).

Source: Compiled by the Project team

2.4.5 Cropping Systems Simulator (CropSyst)

CropSyst is a versatile crop growth simulation model designed to analyse the productivity and environmental impacts of cropping systems across different temporal and spatial scales (Stöckle et al., 2003). It is a user-friendly, conceptually robust yet straightforward multi-year, multi-crop model that operates with a daily time step (FAO, 2025d). The model simulates critical processes, including soil water and nitrogen budgets, crop canopy and root growth, biomass production, yield, residue decomposition, and

erosion. Management practices, including cultivar selection, crop rotation, irrigation, fertilisation, tillage, and residue management, can also be simulated within the model (FAO, 2025d).

CropSyst operates on a daily time step, where crop development is driven by thermal time and influenced by water stress, photoperiod, and vernalisation requirements. It evaluates crop growth based on four main limiting factors: water, nitrogen, light, and temperature, providing an integrated perspective on resource constraints. The model incorporates precipitation, irrigation, runoff, water redistribution, transpiration, and evaporation in its water budget calculations, while the nitrogen budget includes transformations, symbiotic fixation, crop demand, and uptake (FAO, 2025d). Additionally, the CropSyst suite consists of several components, including the CropSyst parameter editor, the core CropSyst simulator, a weather generator (ClimGen), a GIS simulation co-operator (ArcCS), and tools for watershed analysis, alongside other utility programs (Stöckle et al., 2003). An overview of the flow and operation of CropSyst is depicted in Figure 2.30.

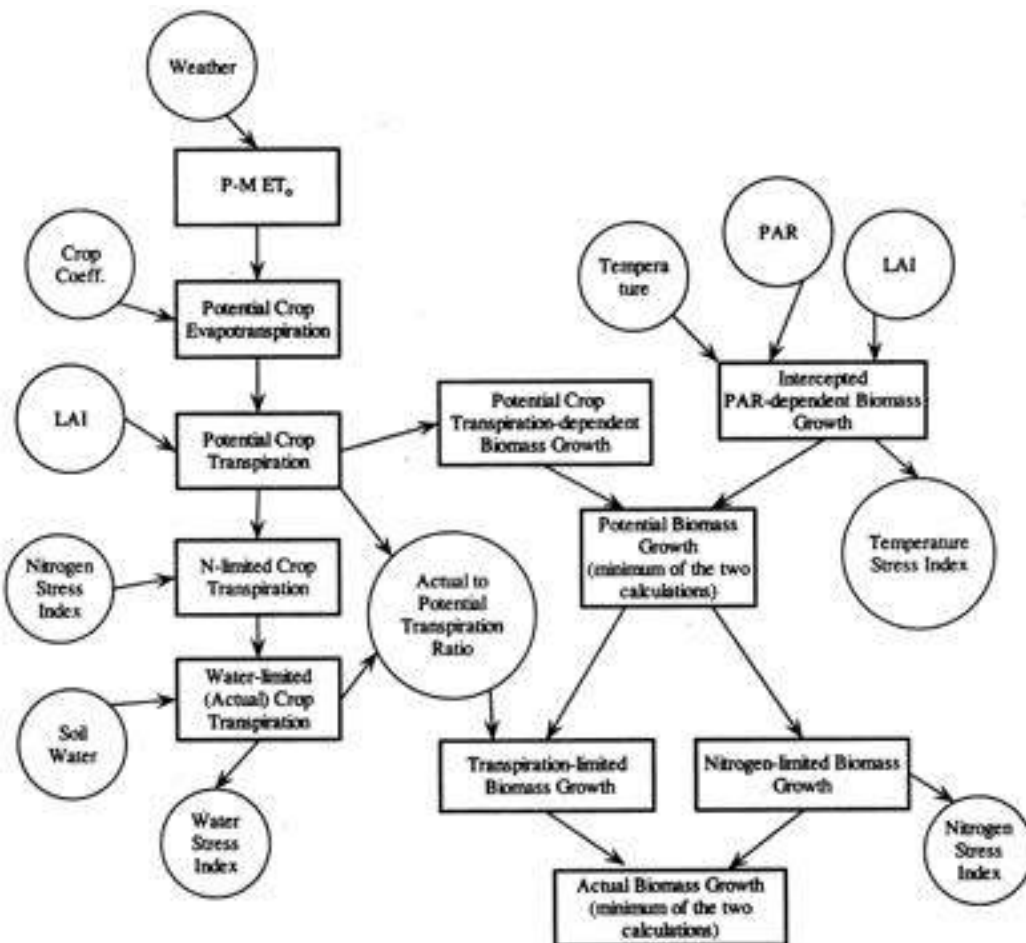


Figure 2.30: Overview of CropSyst Model Operations and Flow

Source: Adapted from Stöckle et al. (2003)

An overview of the strengths and limitations of CropSyst is provided in Table 2.11.

Table 2.11: Overview of CropSyst's Strengths and Limitations

Strengths	1. CropSyst is designed to be conceptually simple, making it accessible for users with varying levels of expertise in crop modelling (FAO, 2025d).
	2. The generic crop growth framework of CropSyst has proven suitable for simulating not only annual and perennial herbaceous crops, but also horticultural and fruit tree crops (Stöckle et al., 2014).
	3. CropSyst is continually upgraded to address emerging needs, including the assessment of climate variability impacts on agriculture and the evaluation of mitigation and adaptation strategies at larger spatial scales and higher system complexities (Confalonieri et al., 2008; Stöckle et al., 2014).
	4. CropSyst is adaptable for integration into hydrologic models, regional simulation platforms, and decision-support tools, leveraging advances in hardware and software for innovative applications (Stöckle et al., 2014).
	5. CropSyst's ability to simulate complex crop rotations under varying management and environmental conditions makes it a valuable tool for evaluating cropping systems and assessing sustainable agricultural practices (Umair et al., 2017).
Weaknesses	1. CropSyst may not produce reliable results in scenarios where its parameters do not fully capture the conditions, such as in areas with complex soils like cracking vertisols or when pests and diseases are present, as these are not included in the model (Stöckle et al., 2003).
	2. CropSyst's descriptions of crop growth and related biophysical processes are considered simplistic. This can lead to inaccuracies in simulating complex interactions within cropping systems (Stöckle et al., 2003).

Source: Compiled by the project team

2.5 Economic and Social Impact Assessment Models

Complex networks of interconnected industries, institutions, and individuals characterise modern economies. Understanding how policy interventions or behavioural changes within one part of this complex system can have cascading effects on other areas is essential for effective decision-making. Economic modelling provides crucial tools for analysing these system-wide impacts, allowing policymakers and researchers to anticipate the direct, indirect, and induced effects across various sectors and institutions. This literature review presents a comparative analysis of commonly used economic modelling approaches, methods, and tools, specifically Input-Output (I-O) models and Social Accounting Matrix (SAM) models.

2.5.1 Input-Output Models (I-O)

Input-Output (I-O) models are quantitative economic tools designed to represent the intricate interdependencies that exist between the various sectors of an economy (van Leeuwen et al., 2005). These models illustrate the relationships between industries by detailing how the output from one industrial sector serves as a crucial input for another. At its core, an I-O model represents the interdependencies between industries by showing how the production of each sector is distributed across the economy as intermediate inputs or final demand, typically using a system of linear equations (D'Hernoncourt et al., 2021; Van Wyk et al., 2015). A basic single-region input-output model is built using data from a specific area over a set time period. It tracks the exchange of goods and services between sectors, covering both intermediate production and final consumption. The model includes a matrix that reflects how much each sector relies on inputs from other sectors to produce its total output, highlighting the interdependence across the economy (Yu, 2018).

I-O models have been widely applied across various fields to analyse economic structures, environmental impacts, and policy outcomes. For instance, an I-O model was employed to assess the economic role and effects of the mining industry in South Korea, providing insights into inter-industry linkages and value-added contributions. Similarly, an I-O framework was used to analyse water use in Spain, enabling a detailed assessment of how different economic sectors contribute to, and are affected by, water demand, particularly under resource-scarce conditions. Similarly, an I-O model was applied in Morocco to examine the relationships between economic activity and water resource use, providing insights that support sustainable water policy and planning. Furthermore, the Economic Commission for Latin America and the Caribbean (ECLAC) has utilised I-O tables to analyse value chains, import dependencies, and employment impacts in Latin American countries, aiding in the formulation of informed economic policies.

These examples represent just a few of the many ways in which I-O models have been employed to inform decision-making across sectors and regions.

Considering its wide application across sectors and policy domains, it is important to acknowledge both the strengths and limitations of the I-O modelling approach. One of the key advantages of input-output models is their internal consistency, allowing for the systematic recording of all effects arising from any change in final demand (van Leeuwen et al., 2005). Additionally, the well-known concept of the I-O multiplier provides a powerful tool to analyse the economic consequences of shocks. Specifically, Type 1 multipliers account for direct and indirect effects. Type 2 multipliers extend this by incorporating induced effects, offering a more comprehensive understanding of the impacts across various economic variables such as output, employment, and income (Yu, 2018).

I-O models, while helpful in assessing economic interdependencies, have several theoretical and practical limitations. I-O models rest on restrictive assumptions, including identical technologies within sectors, no supply constraints, constant returns to scale, and fixed prices (Miao et al., 2024; van Leeuwen et al., 2005). These assumptions yield rigid, linear results that ignore substitution, scale effects, and long-term economic shifts. The approach is also data-intensive and prone to inaccuracies from survey-based inputs. It assumes full resource availability, which is unrealistic in constrained settings like water-scarce regions (Cámara & Llop, 2021). Moreover, it fails to capture income distribution, wage differences, or employment characteristics, limiting its use for equity analysis (Van Wyk et al., 2015).

2.5.2 Social Accounting Matrix (SAM)

A Social Accounting Matrix (SAM) serves as a comprehensive and consistent framework for depicting the economic transactions within an economy over a specified period (Mainar-Causapé et al., 2018). Functioning as a square matrix, each account in the economy, such as industries, households, government entities, and the rest of the world, is represented by both a row and a corresponding column (Babu et al., 2017; Bwanakare, 2017). Each cell within the matrix reveals the payment flow from the account in its column to the account in its row. Consequently, an account's row details its receipts or income, while its column outlines its expenditures or outlays. A fundamental principle of a SAM is its inherent accounting consistency, which mandates that the total revenue (the sum of the row) for each account must equate to its total expenditure (the sum of the column) (Babu et al., 2017).

A SAM extends the foundation of Input-Output (I-O) tables by not only capturing the inter-industry linkages associated with production, but also by incorporating the feedback mechanisms between income and expenditure, which include various economic institutions (Mainar-Causapé et al., 2018). Furthermore, it encompasses income distribution, wage differences, employment characteristics, and other institutions that are not accounted for in the I-O model.

The typical accounts within a SAM encompass production activities, commodities, and factors of production, such as labour, capital, and land, as well as institutions like households, enterprises, the government, and the rest of the world. Additionally, accounts for taxes and savings-investment are integral components. A SAM provides a valuable snapshot of the economy's structure, offering a robust framework for organising both structural and institutional data. Within this framework, a distinction is often made between endogenous accounts, which typically include production, factor, and household accounts, and exogenous accounts, such as those for government, capital investment, and the rest of the world, which incorporate the import and export of commodities.

In agricultural and water-related research, Social Accounting Matrices have been adapted to explicitly capture irrigation dynamics and water use, thus enabling the analysis of how water-related interventions impact the broader economy. For example, Amayed and Boujelbene (2023) developed a water-focused SAM for Tunisia that disaggregates water accounts into raw water and treated wastewater, distinguishing between agricultural sectors based on their water sources. This detailed structure enables the simulation of the socioeconomic impacts of water policy reforms, including the potential role of recycled wastewater as an alternative resource. Similarly, Pfunzo et al. (2024) used South Africa's 2017 national SAM, modified to separate irrigation and rainfed agricultural activities, to evaluate the economic impact of irrigation development in Limpopo Province. Their results showed that, while rainfed agriculture had stronger output multipliers, irrigation agriculture generated higher income, land returns, and value added, demonstrating its broader economic importance. These studies illustrate how SAMs can be tailored to assess the structural role of water in agriculture and its implications for economic development.

While SAM models have proven helpful in capturing the economic implications of agricultural water use, it is equally important to recognise their strengths and weaknesses as decision support tools. A key strength of SAMs is their ability to disaggregate households into meaningful socioeconomic categories, enabling the analysis of policy impacts on income distribution (Thorbecke & Babcock, 2000). Furthermore, SAM disaggregates based on the study's objective. For example, if you want to assess the impact of yield on irrigation agriculture, the SAM should incorporate irrigation agriculture, depending on the simulation. A detailed explanation of SAM will be discussed in Chapter 3.

SAM also captures the circular flow of income and inter-sectoral linkages, enabling the analysis of direct, indirect, and induced effects through multiplier analysis and partial equilibrium, which will be discussed in detail in Chapter 3. The process of constructing a SAM consolidates data from multiple sources, enhancing overall data quality by revealing inconsistencies and gaps (Round, 1997). Finally, SAMs provide a robust analytical foundation for various modelling approaches, serving both as the basis for fixed-price multiplier models and as the benchmark database required for calibrating Computable General Equilibrium (CGE) models (Round, 1997).

Despite the transparency, SAM models have notable limitations. Round (1997) highlights several limitations of SAM models. First, the assumption of excess capacity and underutilised resources across sectors can lead to overestimations of economic impacts when capacity constraints are present. Second, the fixed-price nature of SAM models prevents substitution between goods and factors, which may also result in inflated outcomes. Third, the lack of price adjustments to supply-demand imbalances means that real-world market responses, such as price changes, are not captured, further exaggerating the total effects. Lastly, the distinction between endogenous and exogenous accounts restricts the model's ability to account

for feedback effects, such as changes in government expenditure following external shocks. Given that SAM and multiplier analysis are still best used as preliminary estimates, with caution applied in contexts where these assumptions do not hold.

2.6 Integrated Frameworks in Agricultural Systems

Agricultural systems are increasingly understood as complex socio-ecological entities where interactions between various dimensions of these systems determine overall functionality and sustainability (Hendrickson et al., 2008). Given the central role that human behaviour plays in agricultural decision-making, understanding the psychological dimensions of these systems is essential for improving outcomes, whether in terms of resource use, policy implementation, or sustainability efforts. This section reviews existing studies, frameworks, and models that integrate psychological dimensions, such as farmer behaviours, attitudes, intentions, and decision-making, within the broader context of agricultural systems.

2.6.1 Overview of well-established frameworks and models

2.6.1.1 Socio-Ecological Systems (SES) Framework

The Socio-Ecological Systems (SES) Framework is an interdisciplinary approach used to understand the complex interactions between societal and ecological systems. The SES framework emphasises the complex, interdependent relationships between social (human) systems (comprising individuals, communities, governance structures, and institutions) and ecological systems (natural resources, ecosystems, and biodiversity) (Nagel & Partelow, 2022). The SES framework proposes that these systems are not isolated, but rather that they co-evolve and influence each other over time, shaping sustainability and resilience outcomes.

The SES framework is considered to be one of the most highly cited and empirically applied conceptual frameworks for diagnosing social ecological systems (Nagel & Partelow, 2022). However, the SES framework does not provide a standardised methodology or a prescribed set of procedures for its empirical application.

Instead, the SES framework offers a set of guiding principles and a flexible structure to help researchers identify and analyse the key components and interactions within a socio-ecological system. These principles include defining first-tier variables (Figure 2.31 below), such as Resource Units (RU), Resource Systems (RS), Governance Systems (GS), Actors (A), and their interactions (I), along with the resulting Outcomes (O) and feedback loops (Basurto et al., 2013). Each first-tier variable can be broken down into several second-tier variables, which can themselves be further detailed into third-tier variables and beyond. Once the relevant first- and second-tier variables are identified, researchers typically analyse the relationships,

patterns, and feedback among these variables to diagnose system dynamics. This multi-tiered, decomposable structure allows researchers to tailor their analysis to both general and highly specific contexts.

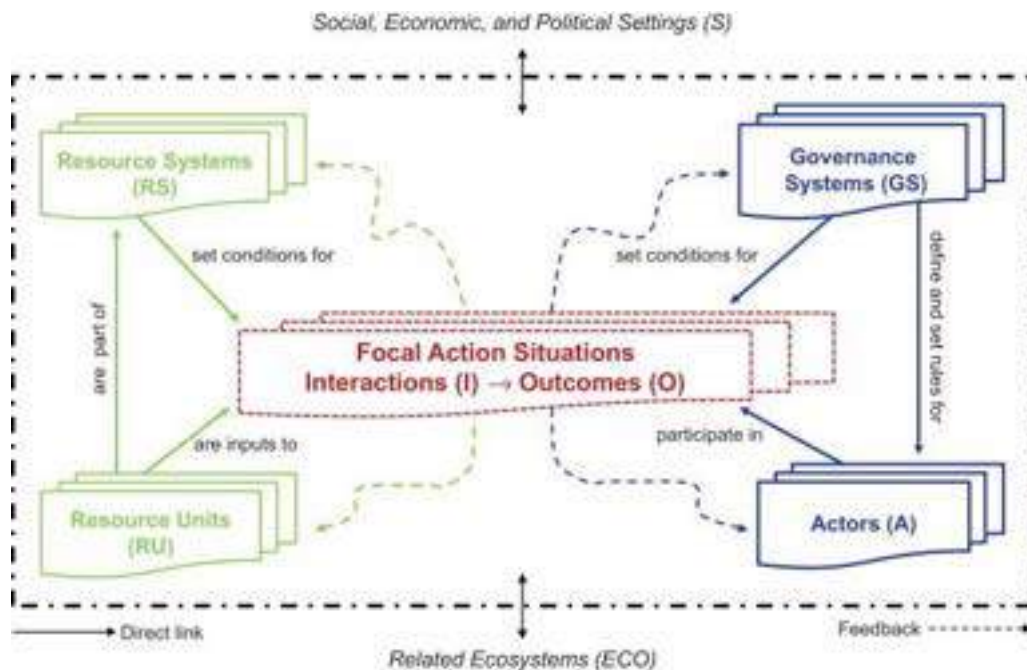


Figure 2.31: Conceptual organisation of the social-ecological systems framework first-tier variables

Source: Adopted from McGinnis & Ostrom (2014)

The SES framework has various strengths and limitations. One key strength is that the SES framework incorporates ecological, economic, institutional, and social factors together, providing a holistic view of how certain practices can simultaneously affect soil, biodiversity, markets, and policies (Nagel & Partelow, 2022). Furthermore, the SES framework enables researchers to customise variables for local contexts while using a standardised vocabulary, balancing detailed analysis with cross-case comparability. The SES framework also enables adaptive, participatory analysis by integrating local knowledge with general sustainability metrics, empowering communities to define sustainability and identify shared challenges (Figueroa et al., 2024). While the flexibility of the SES framework allows for innovative and context-specific applications, it also leads to methodological variability, ambiguity in variable definitions, and inconsistent measurement approaches (Nagel & Partelow, 2022). A further limitation is that applying the SES framework often requires extensive, high-quality data and expert judgment, making the process resource-intensive (Figueroa et al., 2024). The SES framework also lacks a systematic way to incorporate ecological rules and knowledge from natural sciences, which are essential for deductive reasoning about system dynamics (Esptein et al., 2016).

2.6.1.2 Social-Ecological-Technological Systems (SETS) Framework

The Social-Ecological-Technological Systems (SETS) framework represents an important evolution of the Social-Ecological Systems (SES) perspective by explicitly integrating the technological dimension as a core component of complex human-environment systems (Manyani et al., 2024). Figure 2.32 below illustrates the foundational structure of the SETS framework, highlighting the dynamic and bidirectional interactions between the social, ecological, and technological dimensions.



Figure 2.32: The conceptual framework of the Social-Ecological-Technological System (SETS)

Source: Adopted from McPhearson et al. (2022)

While the SES framework, previously discussed, has been instrumental in advancing understanding of the dynamic interactions between human societies and natural ecosystems, it often treats technology as an external or enabling factor, rather than as a structuring force (Ahlborg et al., 2019; Crooks & Heppenstall, 2012; Smith & Stirling, 2008). The SETS framework addresses this limitation by recognising that infrastructure, engineered systems, and digital technologies actively mediate both ecological processes and human decision-making, creating new feedback loops, dependencies, and vulnerabilities (Bixler et al., 2019). Building on the simplified illustration presented in Figure 2.32 above, Figure 2.33 below provides a more detailed visualisation of the SETS framework, specifying the core components within each of its three dimensions. The technological or infrastructure technical dimension includes systems such as water infrastructure, stormwater and sanitation services, energy grids, information and communication technologies, building materials, and transportation networks. The socio-economic demographic dimension includes land use and mobility, demographics, public health, social equity, civic engagement, education, the economy, and public safety. These elements reflect the societal structures and behaviours that both shape and respond to ecological and technological change. The ecological dimension encompasses biophysical components, including vegetation structure and function, hydrological and biogeochemical

processes, faunal biodiversity, soil and geological features, and land- and water-based food production systems.

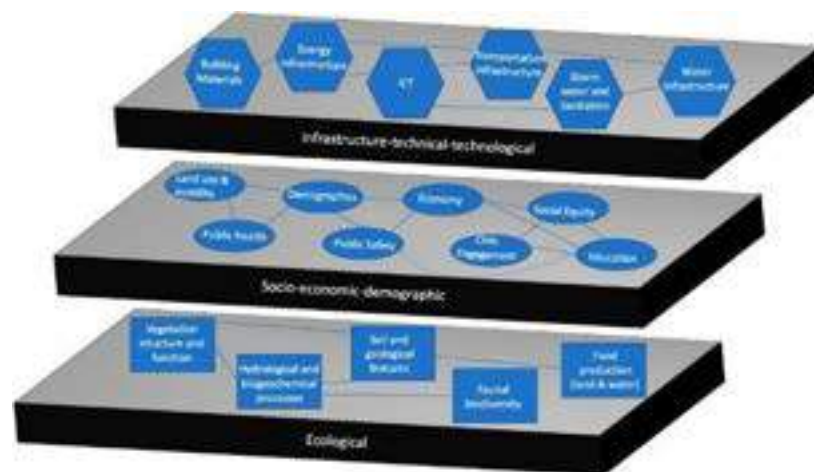


Figure 2.33: Overview of the SETS framework showing dynamic interactions between technological infrastructure, socio-economic systems, and ecological processes

Source: Adopted from Bixler et al. (2019)

The SETS framework offers several key strengths that make it a valuable tool for analysing complex sustainability challenges. One of its primary advantages is its ability to capture the dynamic interactions and feedback loops between human societies, ecosystems, and technological infrastructures, allowing for a more integrated understanding to be gained of system interdependencies (McPhearson et al., 2022). This integrative capacity is instrumental in addressing urban sustainability issues, where nature-based solutions require the coordination of natural, technological, and socio-economic systems to achieve outcomes that are both equitable and resilient (McPhearson et al., 2022). The framework also aligns closely with resilience thinking, as it incorporates principles such as adaptability, transformability, flexibility, redundancy, and equity, which are essential for understanding and strengthening resilience in coupled systems (Sharifi, 2023). Furthermore, by explicitly including technology as a core dimension, the SETS framework expands the range of possible interventions and governance strategies available to planners and decision-makers working toward sustainability and resilience goals (Chester et al., 2023).

Despite its strengths, the SETS framework also faces several important limitations. The integration of three distinct yet interdependent systems – namely, the social, ecological, and technological domains – introduces a high level of analytical complexity. This complexity makes it difficult to consistently map, model, and measure the interactions and feedback that occur within and across these systems in different contexts (Sharifi, 2023). Another significant challenge is the difficulty of achieving complete disciplinary representation across the three dimensions. In many cases, SETS applications fail to adequately incorporate

all relevant perspectives, which can result in biased or incomplete interpretations of complex system dynamics, particularly in the context of ecosystem service assessments.

2.6.1.3 Coupled Human-Environment Systems (CHES)

The Coupled Human-Environment Systems (CHES) Framework, also frequently referred to as Coupled Human and Natural Systems (CHANS), is designed to characterise the dynamic two-way interactions that occur between human systems and natural systems (Farahbakhsh et al., 2022). The CHES framework is intended to include a bidirectional feedback loop that continuously integrates interactions between human activities and environmental changes in a cyclical process (Figure 2.34 below). The CHES framework acknowledges that these systems are composed of multiple interconnected components and sub-components, which interact in complex ways (Yu et al., 2019). Over time, these interactions can either intensify or diminish, as both human societies and environmental conditions evolve. Central to the CHES framework is the emphasis on well-being, encompassing both human development and the health of ecological systems, thereby aligning closely with sustainability objectives.

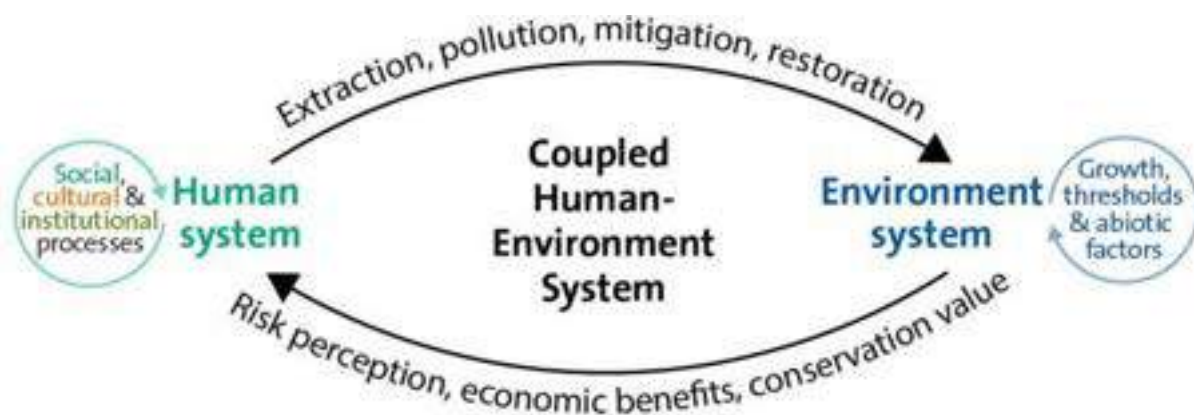


Figure 2.34: Conceptual Representation of Coupled Human and Natural Systems (CHES) framework

Source: Adopted from Farahbakhsh et al. (2022)

The CHES framework offers several notable strengths that make it a valuable tool for analysing human-environment interactions. The CHES framework is often considered to be more realistic than static human parameter representations in classical environmental system models. It has been utilised in various ways in environmental systems research (Thampi et al., 2024). Another key strength of the CHES framework is its ability to explicitly model bidirectional feedback, or reciprocal effects, revealing how changes in the environment influence human decision-making and, in turn, how human actions impact ecological systems (Farahbakhsh et al., 2022; Perera et al., 2024). According to Perera et al. (2024), the CHES framework accounts for nonlinear dynamics, such as thresholds and regime shifts, by modelling reciprocal interactions and system adaptability, enabling researchers to analyse how human and ecological components co-adjust

to avoid critical tipping points. Despite these strengths, the CHES framework also has certain limitations that warrant consideration. A key limitation of CHES models is their inherent complexity, as they integrate multiple interacting natural and human processes (Farahbakhsh et al., 2022; Perera et al., 2024). Perera et al. (2024) further noted that the CHES framework is limited by its high data demand, often leading to the exclusion of key factors, such as political and cultural influences, owing to the incomplete integration of human and natural systems.

2.6.1.4 Drivers–Pressures–State–Impact–Response (DPSIR) Framework

The Drivers–Pressures–State–Impact–Response (DPSIR) framework is a structured model used to organise environmental and policy analysis. It describes a step-by-step process where broader social and economic factors, known as drivers, lead to specific human activities that put pressure on the environment. These pressures alter the ecosystem's state, thereby influencing human well-being and the services it sustains. In response to these impacts, society takes action through policies or changes in behaviour (FAO, 2025e).

The DPSIR framework builds on earlier models such as the Pressure–State–Response (PSR) and Driving Force–State–Response (DSR) frameworks developed in the 1970s and 1990s, respectively (Burkhard & Müller, 2008). Initially, the PSR model conceptualised that human activities exert pressures on the environment, which affect the quality and quantity of natural resources (state), and society responds to these changes through policies and behavioural changes (response), highlighting the cause-and-effect relationships between human actions and environmental conditions (Figure 2.35 below) (Jatav & Naik, 2023; Waheed et al., 2009). This was later extended by the Organisation for Economic Co-operation and Development (OECD) and adapted into the DSR model by the United Nations Commission for Sustainable Development, which emphasised human-induced changes and their effects on natural systems (Malekmohammadi & Jahanishakib, 2017).



Figure 2.35: Pressure-state-response (PSR) framework

Source: Adopted from Waheed et al. (2009)

However, both PSR and DSR were found to be insufficient in capturing the complexity of socio-economic and environmental interactions. The DPSIR framework addresses this gap by introducing a more comprehensive cause-and-effect structure (Figure 2.36 below). The DPSIR framework conceptualises a causal chain linking human societal needs and activities (Drivers) that exert environmental pressures (Pressures), which alter the condition of the environment (State), leading to effects on ecosystems and human well-being (Impacts), and ultimately prompting societal and political actions (Responses) to manage or mitigate these changes (Malekmohammadi & Jahanishakib, 2017).

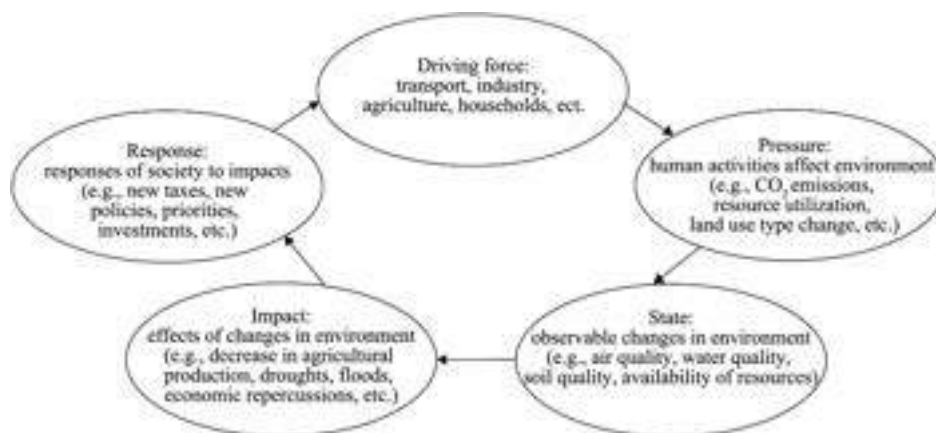


Figure 2.36: Driver-Pressure-State-Impact-Response (DPSIR) framework of sustainability

Source: Adopted from Jatav and Naik (2023)

The DPSIR framework has been effectively applied across diverse environmental contexts to analyse complex socio-ecological systems and inform policy decisions. In Indonesia, Kristiadi et al. (2022) utilised the DPSIR model to assess urban climate variability impacts, integrating remote sensing data and statistical modelling to identify key drivers, such as population growth and industrialisation, leading to environmental pressures like increased water consumption and wastewater production. In Iran, Salehi and Zebardast (2016) applied the DPSIR framework to evaluate climate variability factors affecting the city under study, examining drivers like urbanisation and energy consumption, pressures including greenhouse gas emissions, and their impacts on environmental states such as air quality.

Mukuvari (2014) employed the DPSIR approach to assess the recovery of the Benguela Large Marine Ecosystem, analysing socio-economic drivers and pressures from fishing activities, and evaluating the state of marine biodiversity. In Tanzania, Kazuva et al. (2018) employed the DPSIR framework to assess environmental risks associated with municipal solid waste, identifying basic human needs as drivers that lead to pressures from waste generation, and evaluating the state of waste management infrastructure. These examples demonstrate the versatility of the DPSIR framework in addressing environmental challenges across diverse geographical and thematic contexts, offering structured methodologies for understanding and managing human-environment interactions.

While the DPSIR framework is widely used because of its straightforward structure and clear policy orientation, and it explicitly links human activities to environmental outcomes (FAO, 2025e), it has notable limitations. Specifically, DPSIR tends to view driving forces as external pressures and does not adequately capture the complex social and cultural factors influencing environmental change (Svarstad et al., 2008). Additionally, its focus on separate linear causal chains for each environmental issue oversimplifies the complex interactions and interconnections between drivers and impacts, which limits a comprehensive understanding of environmental systems (Niemeijer & De Groot, 2008).

2.7 Summary

This chapter set out to identify and evaluate the theoretical foundations, modelling tools, and integrated frameworks relevant to understanding water use behaviour in agriculture. The review identified six distinct water use behaviours that have been examined in the literature, shaped by a diverse set of psychological, social, economic, and contextual factors across agricultural contexts. Among the behavioural theories reviewed, the Theory of Planned Behaviour (TPB) emerged as being the most suitable foundation for this study because of its clarity, empirical support, and adaptability to agricultural decision-making.

In evaluating biophysical tools, the AquaCrop model was identified as the most appropriate crop simulation model for the integrated framework, offering a balance between reliability and data efficiency. Various

economic and social impact models were considered to assess broader system-wide implications. The Social Accounting Matrix (SAM) and SAM Multiplier/Partial Equilibrium were selected for their ability to trace both direct and indirect effects of behavioural changes through the economic structure, making them well-suited for capturing the ripple effects of water use decisions at the household, district, provincial, and regional levels.

Finally, while several integrated frameworks exist that conceptually link human and environmental systems, these are often limited to broad outlines without offering operational guidance on how to integrate psychological, biophysical, and economic components methodologically. This chapter, therefore, identifies a clear gap in the literature; specifically, there is a need for a methodologically explicit, interdisciplinary framework that captures the dynamic interactions between farmer behaviour, biophysical outcomes, and socio-economic impacts. The insights from this review directly inform the design of the integrated framework developed in this study.

CHAPTER 3: DATA AND RESEARCH METHODOLOGY

3.1 Overview

The Data section (3.2) provides an overview of the data used for each component of the integrated framework. The section first describes the selection of commodities and an overview of data collection, including provinces and irrigation schemes. It then follows with the development of the instrumentation and the administration process for the questionnaires designed to measure farmer behaviour using the TPB. This is followed by a description of the biophysical datasets required for the AquaCrop simulations, including climate variables, crop characteristics, and spatial soil data. The next part outlines the data sources and procedures used to construct the Social Accounting Matrix (SAM) as a database for the multiplier analysis, which captures the economic structure and linkages relevant to water use in agriculture.

After discussing the data, Section 3.3 presents the empirical specification of the TPB component, with specific emphasis on the structural equation modelling approach used to estimate relationships between behavioural constructs. The AquaCrop model is then introduced, with a detailed explanation of how it simulates crop yields under varying irrigation and behavioural scenarios. This is followed by an explanation of the SAM and its use in evaluating the broader economic impacts of changes in water use behaviour. The section concludes with a summary of the integrated framework, highlighting how the psychological, biophysical, and economic components are linked to assess the system-wide impacts of changes in water use behaviour.

3.2 Data

3.2.1 Selection of food production (crops), irrigation areas, and data collection

The study selects five commodities from six provinces, namely maize (smallholder and commercial farmers – Tshiombo Irrigation Scheme and Orange Riet Irrigation Scheme in Limpopo and Free State provinces, respectively), wheat (commercial farmers – Hartbeespoort Irrigation Scheme in the North West province), soybean (commercial farmers – Hartbeespoort Irrigation Scheme in North West province), sugarcane (commercial farmers – Impala Irrigation Scheme in KwaZulu-Natal province) and lucerne (commercial farmers – Kakamas Irrigation Scheme in Northern Cape province of South Africa).

The selection of food crops was based on their economic importance – monetary contribution to the total value of agricultural production (gross value); the role of irrigation – area (ha) and production output (tons) under irrigation; domestic supply and demand; importance of the crops regarding trade (import and export); water consumption and the availability of water in production and value chains. It is estimated that there

are approximately 2 million small-scale farmers in South Africa, and various studies have been conducted to improve their productivity and better integrate them into South Africa's agricultural economy (Mazenda & Maiya, 2022). The project will further substantiate the agenda of improving and developing small-scale farmers in South Africa by better understanding their water use behaviour.

The monetary importance of various crops was identified, based on the Abstract of Agricultural Statistics Report published by the Department of Agriculture, Land Reform and Rural Development (DALRRD, 2021). The water footprint assessment was used to measure the water consumption of the various crops. By analysing the value chain of a commodity, one can determine how each step adds or subtracts value from the final products. The analysis of value chains can enhance policy dialogue by providing a deeper understanding of market dynamics and their impacts on smallholders, businesses, and the environment.

The common theme among research conducted on water usage along value chains is that, to improve water use productivity along a value chain, emphasis should be placed on enhancing production with minimum water. Water availability is a key factor determining the economic potential of the SADC region (Turton, 2010). Therefore, although this project will only focus on selected provinces and selected crops in South Africa, the findings obtained from this project can serve as a benchmark for investigating and analysing the water use behaviour of other SADC members.

As water scarcity in South Africa becomes increasingly alarming, the efficient and sustainable management of freshwater resources has become a critical policy issue (Mohlotsane et al., 2018). As indicated, one of the driving factors behind inefficient water usage is human behaviour, which is not fully understood in a South African agricultural context.

The project team utilises primary data collected from 909 commercial and smallholder farmers between 2023 and 2024, after obtaining ethical clearance. The Research Ethics Committee approved ethical clearance for the protocol in accordance with the General/Human Research Ethics (GHREC) guidelines and regulations, Reference number UFS-HSD2023/0373/3. Participants took part voluntarily after the ethical principles had been publicly declared. All participants were informed, and they completed and signed consent forms before actively participating in the study. The project also utilised secondary data obtained from the Agricultural Research Council (ARC) and other stakeholders. Table 3.1 below summarises the primary data collected from different provinces.

Table 3.1: Selected commodities

Provinces	Districts	Irrigation scheme	Locations	Respondents
Limpopo	Vhembe	Tshiombo	(-22.798548, 30.485129)	366
Free State	Orange Riet	Jacobsdal	(-29.135345, 24.776585)	131
Northwest	Bojanala	Hartbeespoort/Madibeng and Madibeng	(-25.684185, 27.805955) and (-25.607614, 27.748385)	124
Northern Cape	Kakamas	Kai ! Garib	(-28.777694, 20.633453), (-28.626875, 21.120777) (-28.636264, 20.320341)	170
KwaZulu-Natal	Zululand/Pongola	Impala	(-27.390220, 31.632004)	54
Northwest	Bojanala/Hartbeespoort	Hartbeespoort/Madibeng and Madibeng	(-25.684185, 27.805955), (-25.607614, 27.748385)	64
Total				909

Sources: Project team compilations

Figure 3.1 below illustrates the collection of data from different irrigation schemes.



Figure 3.1, Panel A: Data collection from the Tshiombo Irrigation Scheme



Figure 3.1, Panel B: Data collection from the Impala Irrigation Scheme



Figure 3.1, Panel C: Data collection from the Orange Riet Irrigation Scheme

Figure 3.1: Data collection procedure

Sources: Project team compilation

3.2.2 Theory of Planned Behaviour

The primary method for collecting data by applying the TPB is through the use of a structured questionnaire. Developing a well-constructed questionnaire is crucial for accurately capturing all the constructs of the extended Theory of Planned Behaviour (TPB) model applied in this study. Therefore, a systematic approach was followed to ensure that the questionnaire effectively measured these constructs. The development of the TPB questionnaire followed the structured steps outlined by Ajzen (2006) and Francis et al. (2004),

which provided a framework for designing the questionnaire. The specific steps followed in the questionnaire development process are presented in Figure 3.2.

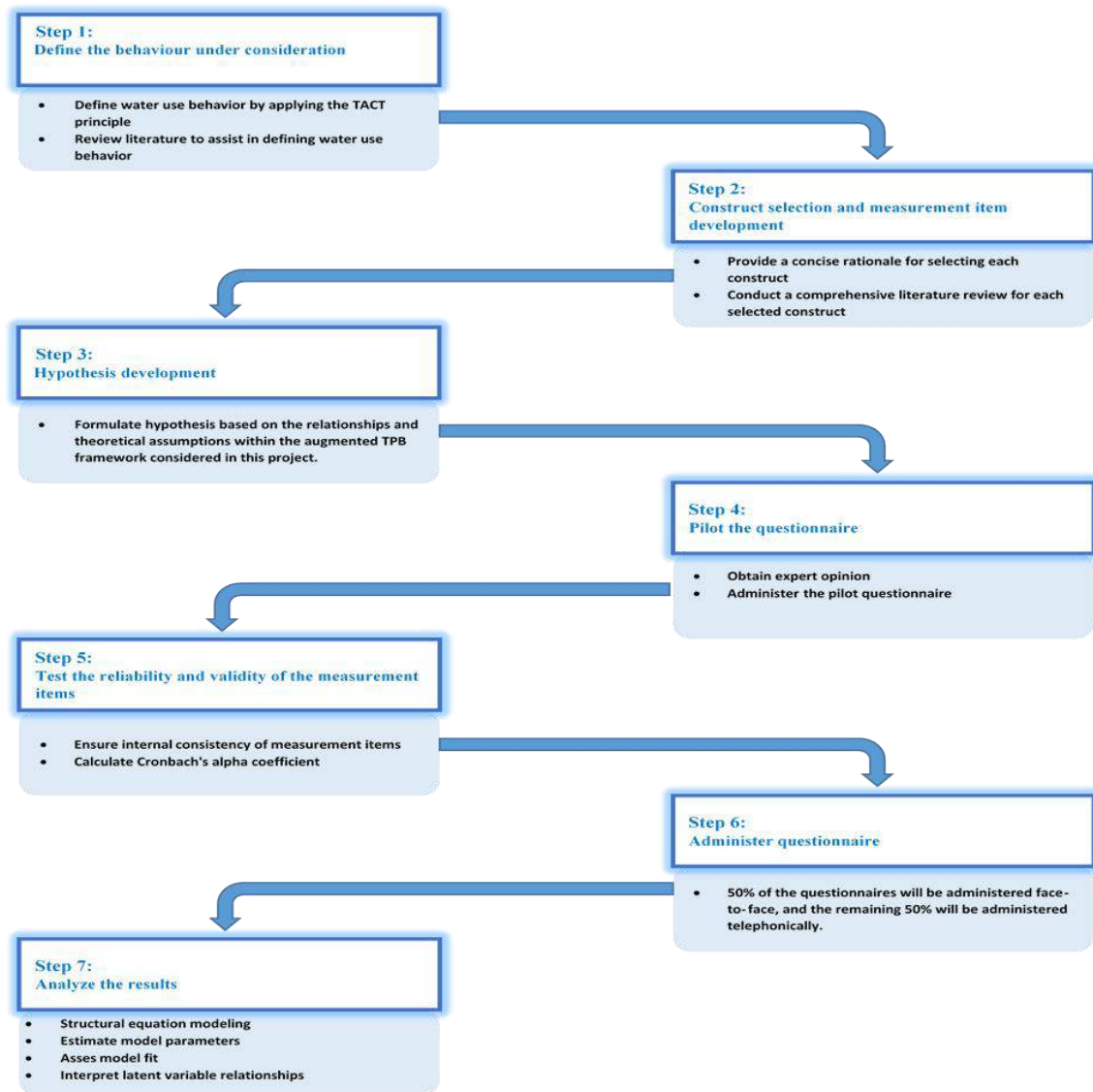


Figure 3.2: Questionnaire development process

Source: Project team compilation based on Ajzen (2006) and Francis et al. (2004)

In the following subsections, each step involved in developing the questionnaires used in this project is described in detail. These steps ensure that the questionnaires are well-structured, valid, reliable, and effective in measuring the relevant constructs. Please note that the processes for testing reliability and validity (Step 5) and for analysing the results (Step 7) are discussed in greater detail in the methods section of this chapter.

3.2.2.1 Operationalising water use behaviours using the TACT principle

Before developing the questionnaire instruments used to model irrigators' water use behaviour, it was essential to frame these behaviours within the specific context of this study. While Chapter 2 provided a conceptual definition and identified six key water use behaviours through a comprehensive systematic literature review, this section focuses on how those behaviours are operationalised for empirical measurement.

To ensure precision and internal validity in how behaviour is measured and modelled, Ajzen's (2006) 'TACT principle' is applied. TACT stands for Target, Action, Context, and Time, offering a structured method for specifying behaviours within the TPB framework. The first element, "target", refers to the specific behaviour under investigation. The second element, "action", relates to the particular steps involved in executing the behaviour. The third element, "context", pertains to the setting where the behaviour is being performed. Lastly, the fourth element, "time", emphasises the specific time during which the behaviour occurs. Specifically, within the scope of this project, the application of the TACT principle to water-use behaviour is summarised in Table 3.2.

Table 3.2: TACT Framework for Defining Water-Saving Technology Adoption Among Irrigators in the Orange-Riet Irrigation Scheme

Component	Description
Target	Water use behaviour in food production in certain irrigation schemes in South Africa
Action	• Adoption of water-saving technologies • Adoption of water-saving policies. • Adaptation to climate change/variability
Context	Among irrigators operating in five targeted irrigation schemes: Orange-Riet, Kakamas, Impala, Hartbeespoort, and Tshiombo.
Time	Crop type, weather conditions, and individual farming practices may influence the timing of irrigation activities, implying that farmers may not continuously irrigate at the same time every day. As such, the questionnaire does not define a time frame in specific terms. Ajzen (2006) stated that it is possible to increase the generality of one of the TACT elements by using aggregation. Hence, in this project, the time component will focus on farmers' general water use behaviour.

Source: Project team compilation

Ajzen (2006) further emphasised that, once the TACT elements of the behaviour have been clearly defined, it is important to ensure that the principle of compatibility is adhered to. The principle of compatibility

suggests that the different constructs in the TPB should align and be consistent with each other, ensuring internal consistency within the TPB framework. When the constructs align with behavioural intentions, it increases the likelihood that intentions will translate into actual behaviour (Francis et al., 2004).

3.2.2.2 Measurement Item Development

The systematic review in Chapter 2 guided the augmentation process by identifying additional constructs to be incorporated into the standard TPB model. These additional constructs were justified based on the insights obtained from the systematic literature review in Chapter 2.

When developing constructs, researchers must consider two broad types of measurement models in structural equation modelling, namely reflective and formative measurement models (Hair et al., 2021). The decision on whether a construct should be measured reflectively or formatively is not inherently fixed, but depends on how the construct is conceptualised. Hair et al. (2021) provide a set of guidelines to assist researchers in making this decision. To ensure that the appropriate measurement specification was selected for this study, the guidelines outlined in Table 3.3 were applied.

Table 3.3: Guidelines for Selecting Measurement Model Specification

Criterion	Decision
What is the causal priority between the indicator and the construct?	From the construct to the indicators: reflective
	From the indicators to the construct: formative
Is the construct a trait explaining the indicators, or rather a combination of the indicators?	If trait: reflective
	If combination: formative
Do the indicators represent consequences or causes of the construct?	If consequences: reflective
	If causes: formative
Is it necessarily true that, if the assessment of the trait changes, all items will change similarly (assuming they are equally coded)?	If yes: reflective
	If no: formative
Are the items mutually interchangeable?	If yes: reflective
	If no: formative

Source: Adopted from Hair et al. (2021)

Based on the guidelines presented in Table 3.3 above, the measurement model specification for each construct in this study will follow a reflective approach. This means that the causal relationship will flow from the construct to the indicators, with each construct representing a trait that explains the indicators. The indicators will act as consequences of the construct rather than its causes, and any change in the construct will result in a corresponding change across all indicators in a similar manner. Additionally, the indicators

are mutually interchangeable. This specification is crucial for ensuring the correct setup of measurement items in the SEM analysis.

The questionnaires used to collect data for modelling the water use behaviour of commercial irrigators are provided in Appendix A (Tables A.1–A.13), while those used for small-scale irrigators are included in Appendix B (Table B.1–B.14). This research project employed a single questionnaire to collect data on three key water use behaviours within its scope, including the adoption of water-saving technologies, the adoption of water-related policies, and adaptation to climate variability. To maintain consistency and keep the questionnaire as concise as possible, most constructs were measured using only two indicators. However, for certain constructs where additional detail was necessary, additional measurement items were included. The empirical specification of the SEM model will be detailed in the methods section of this chapter.

3.2.2.3 Rationale for selecting the Measurement Scale

A Likert scale was used to assess these measurement items appropriately because of its widespread recognition and ease of understanding for respondents. Specifically, each measurement item was evaluated using a five-point Likert scale. Five-point Likert scales have been extensively applied in various agriculture-related studies, enabling respondents to distinguish between response alternatives effectively (Senger et al., 2017). The proposed five-point Likert scale for this project consisted of the following response options: "Highly Disagree", "Disagree", "Neutral", "Agree", and "Highly Agree". This structure ensures equidistance between response categories, reducing potential biases in data analysis (Hair et al., 2021). Table 3.4 below provides an illustrative example of how the Likert scale was applied, using the “Attitudes” construct as a demonstration.

Table 3.4: Illustrative example of Likert Scale application for the Attitudes Construct

		Strongly disagree	Disagree	Neither	Agree	Strongly agree
	Measurement item	1	2	3	4	5
A_{B_1}	Maximising production and farm efficiency is more important than adopting water-saving technologies.					
A_{B_2}	Conserving water should not be prioritised over adopting water-saving technologies.					

Source: Project team compilation

3.2.2.4 Hypothesis Development

Since this study focuses on three distinct water use behaviours, and an extended TPB model is applied to each, a large number of hypotheses have been developed. To maintain conciseness within the main text, only the hypotheses related to the adoption of water-saving technologies by commercial irrigators are visually illustrated in the figures below. The complete list of hypotheses for all water use behaviours across both commercial and small-scale irrigators is provided in Appendices C1 and C2, Tables C.1–C.90. The formulated hypotheses test direct effects, specific indirect effects, total indirect effects, and total effects, as illustrated in Figures 3.3 to 3.6 below.

In structural equation modelling, relationships between constructs can be hypothesised and tested in terms of direct effects, specific indirect effects, total indirect effects, and total effects. Figure 3.3 below illustrates the hypothesised direct impact between the additional constructs included in the extended model and the three core Theory of Planned Behaviour constructs: attitudes, subjective norms, and perceived behavioural control. Figure 3.3 focuses on the case of commercial irrigators adopting water-saving technologies and provides a visual summary of the direct pathways proposed for empirical testing.

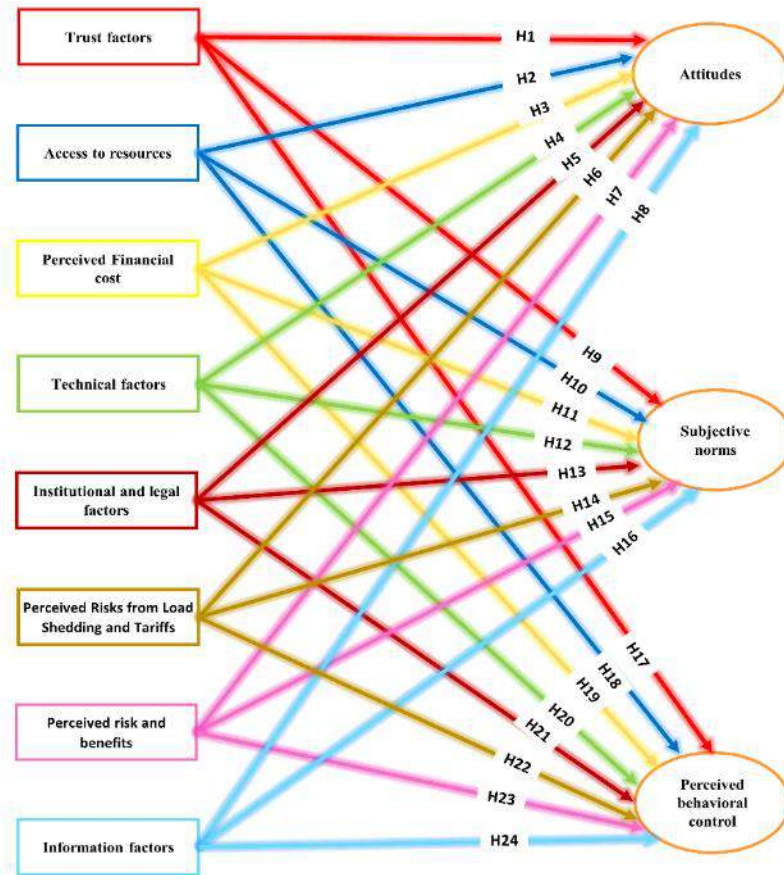


Figure 3.3: Hypotheses on direct effects of additional constructs on the standard Theory of Planned Behaviour constructs

Source: Project team compilation

Figure 3.4 below illustrates the hypothesised direct effects of the additional constructs, alongside the standard TPB constructs, on the intentions of commercial farmers to adopt water-saving technologies. Figure 3.4 highlights how each construct is expected to influence intention, providing a basis for testing the strength and significance of these relationships within the structural equation modelling framework.

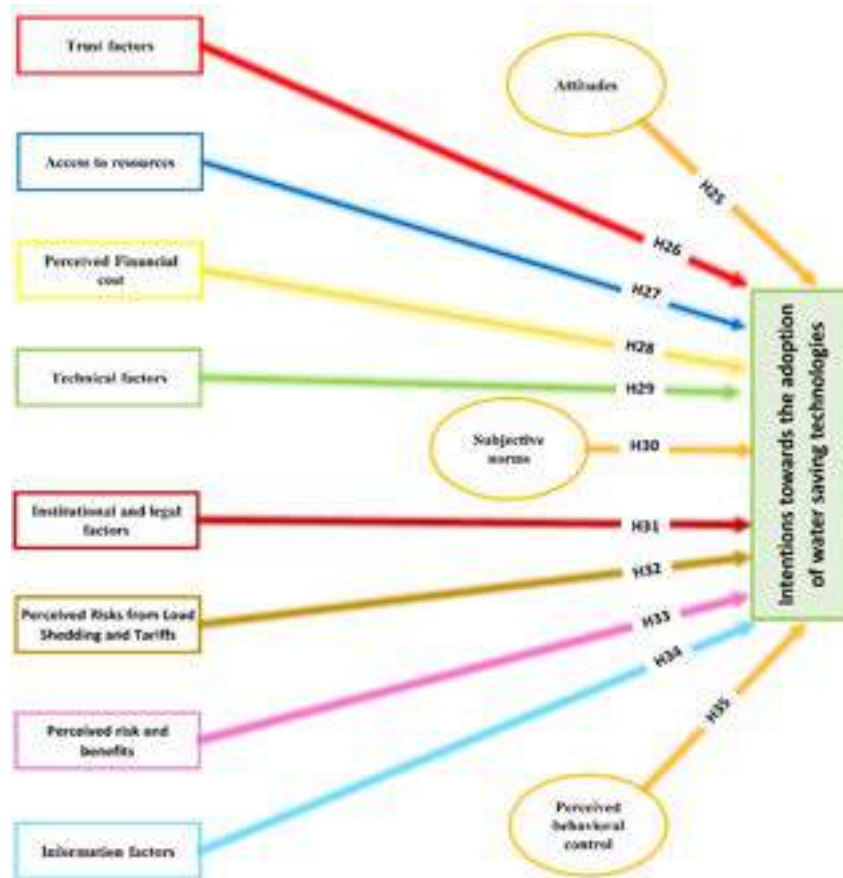


Figure 3.4: Hypotheses on direct effects of additional and standard constructs on intentions to adopt water-saving technologies

Source: Project team compilation

Figure 3.5 below presents the hypothesised specific indirect effects of the additional constructs on intentions to adopt water-saving technologies, as mediated through the standard TPB constructs. Figure 3.5 illustrates how the additional constructs influence intentions indirectly by impacting attitudes, subjective norms, and perceived behavioural control among commercial farmers.

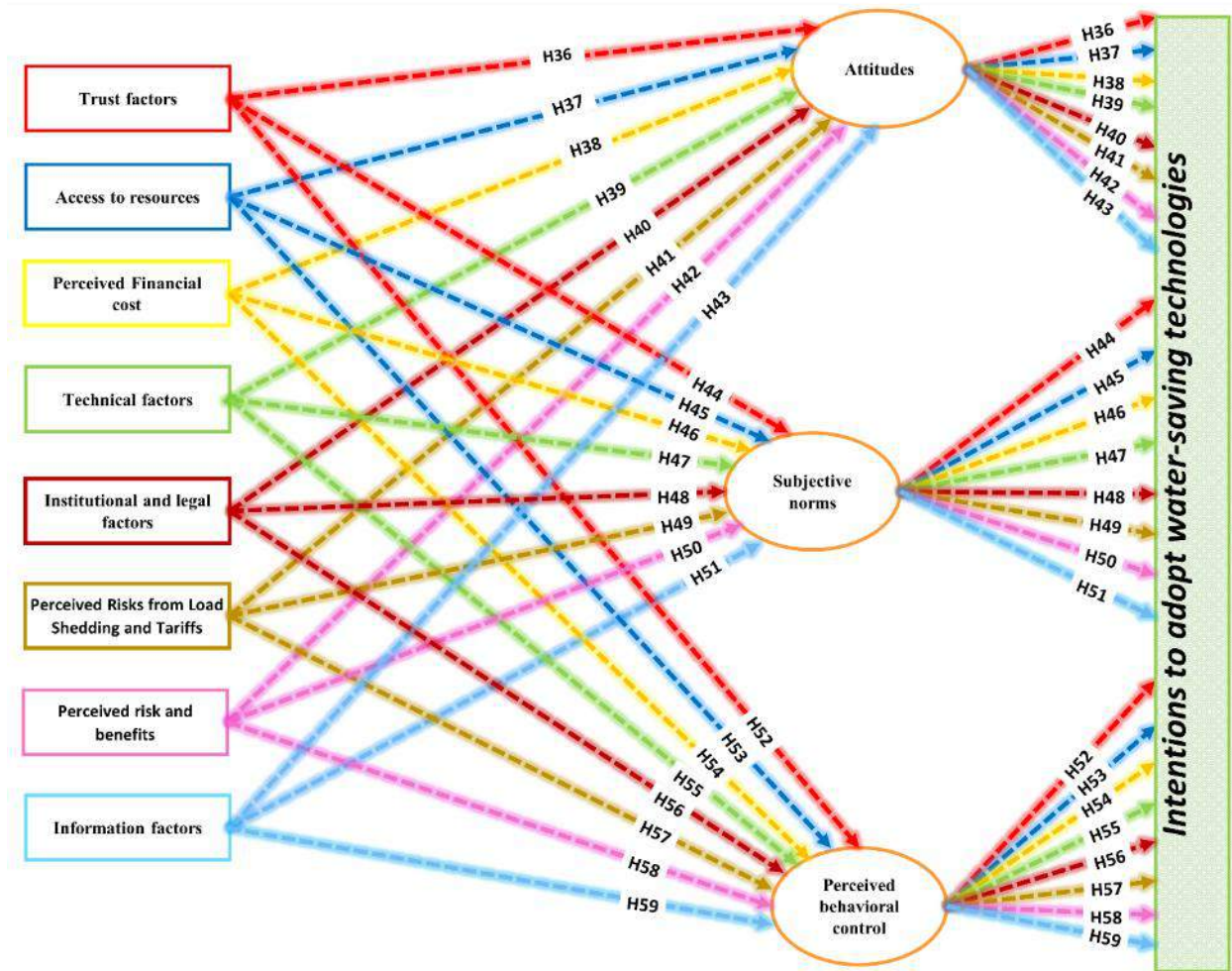


Figure 3.5: Hypotheses on Specific Indirect Effects of Additional and Standard Constructs on Intentions to Adopt Water-Saving Technologies

Source: Project team compilation

Figure 3.6 below illustrates the hypotheses concerning the total indirect effects of both the additional constructs and the standard TPB constructs on intentions to adopt water-saving technologies, capturing the combined indirect influence of these factors on farmers' intentions and highlighting the overall mediated pathways within the extended model.

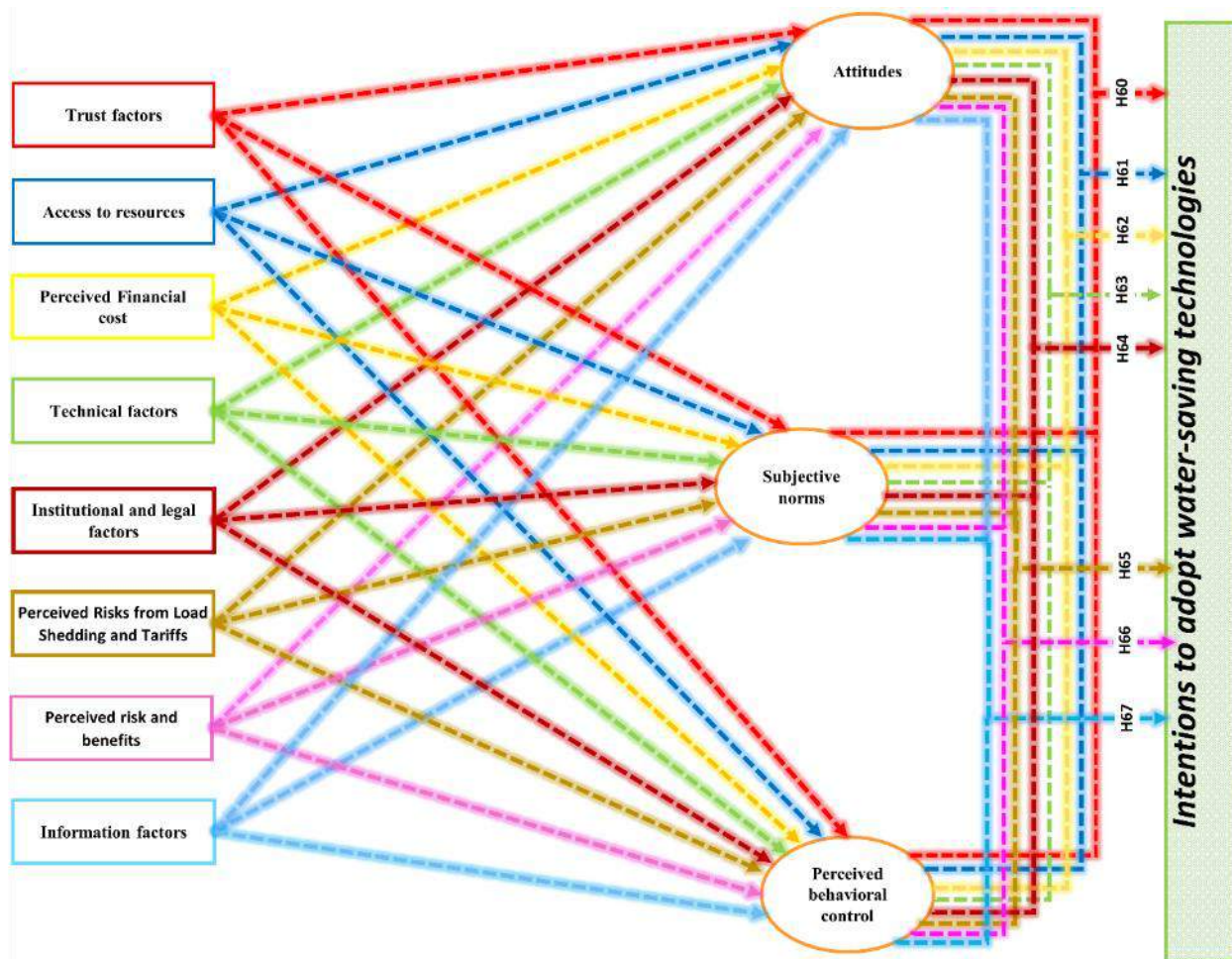


Figure 3.6: Hypotheses on Total Indirect Effects of Additional and Standard Constructs on Intentions to Adopt Water-Saving Technologies

Source: Project team compilation

The final set of hypotheses concerning the total effects, combining both direct and indirect influences, was not visually illustrated because of the complexity of representing these relationships clearly. However, the complete list of hypotheses to be tested, including those for total effects, is provided in Appendices C1 and C2, Tables C1–C89 for reference.

3.2.2.5 Pilot the questionnaire

Before administering the questionnaires across the various irrigation schemes included in the scope of this project, a pilot study was conducted with a small group of respondents. This preliminary step was crucial in refining the questionnaires by ensuring clarity, evaluating the length and response formats, and identifying any technical issues. The pilot study also helped to assess the internal consistency, validity, and reliability of the questionnaires for effectively capturing water use behaviour within the scope of this project.

To ensure that the piloting phase was conducted in a scientifically sound manner, a review of relevant literature was undertaken to examine how previous studies have approached this process. The literature review revealed that a common practice is to administer questionnaires to a small percentage of the intended sample size (Ataei et al., 2021; Bagheri et al., 2019; Bagheri & Teymouri, 2022; Damalas et al., 2022; Elahi et al., 2022; Shahangian et al., 2021; Tatar et al., 2022). Additionally, seeking expert opinions on questionnaire design is widely recommended to enhance validity and reliability (Li et al., 2021; Ranjbar et al., 2022; Shahangian et al., 2021; Tatar et al., 2022; Yang et al., 2022b; Yazdanpanah et al., 2014).

The project team initially reviewed the questionnaires, and consultations were held with some members of the reference group to ensure clarity and relevance. Following established practices, the pilot study was conducted in two phases. First, the head of the Orange-Riet Irrigation Scheme Farmers' Association reviewed the questionnaire and provided feedback, leading to necessary adjustments. Second, the questionnaire was field-tested with a small sample of 11 irrigators in the Orange-Riet Irrigation Scheme. This iterative process allowed for further refinements to be made before the main data collection commenced.

Following the guidelines of Francis et al. (2004), the respondents were also asked to comment on key aspects of the questionnaire, including:

- Are the items too ambiguous or complex to answer?
- Do the questionnaires feel too repetitive?
- Does it feel too long?
- Does it feel too superficial?
- Are there annoying features of the wording or formatting?
- Do inconsistent responses suggest that changes in response scales or endpoints may have confused respondents who completed the questionnaire quickly?

3.2.2.6 Test the reliability and validity of the measurement items

Following the piloting phase, the measurement model was assessed by using the piloted data to evaluate reliability and validity. Specifically, indicator reliability, internal consistency, convergent validity, and discriminant validity were examined to ensure the robustness of the TPB constructs. The detailed methodology for these assessments is provided in the methods section of this chapter. Questionnaires were administered in person to ensure direct engagement with respondents.

3.2.2.7 Analyse the results

A detailed overview of the methods used to analyse the results is provided in the methods section of this chapter. At the same time, the findings of each irrigation scheme are presented through case studies in the following chapters.

3.2.3 AquaCrop model

This section provides an overview of the data used to simulate an AquaCrop model. Specifically, it will cover the key data components, including climatic data, soil characteristics, crop parameters, management practices, and the irrigation schedule. These data inputs are crucial for accurately simulating crop growth and water use under various conditions, thereby ensuring the reliability and validity of the results of the AquaCrop model.

3.2.3.1 Climatic data inputs

The AquaCrop simulations conducted for this project relied on daily climate data obtained from the Agricultural Research Council (ARC). These data were sourced from weather stations situated within or near each of the irrigation schemes included in the study. The climate variables used in the model included daily minimum and maximum temperatures (°C), minimum and maximum relative humidities (%), solar radiation (MJ/m²), wind speeds (m/s), rainfall (mm), and reference evapotranspiration (mm). Incorporating these site-specific variables was essential to accurately represent the agroclimatic conditions under which crops are grown in each scheme. In the following sections, the climate data for each irrigation scheme is presented individually, beginning with a map that shows the location of the relevant weather station marked by a red dot, followed by a summary of the key climatic characteristics.

3.2.3.1.1 Orange-Riet Irrigation Scheme

Figure 3.7 below shows the position of the ABI-Modderivier WS11 weather station (latitude: -29.1485, longitude: 24.67665), from which climate data were obtained for the Orange-Riet Irrigation Scheme. The daily dataset covers the period from July 2018 to December 2023.

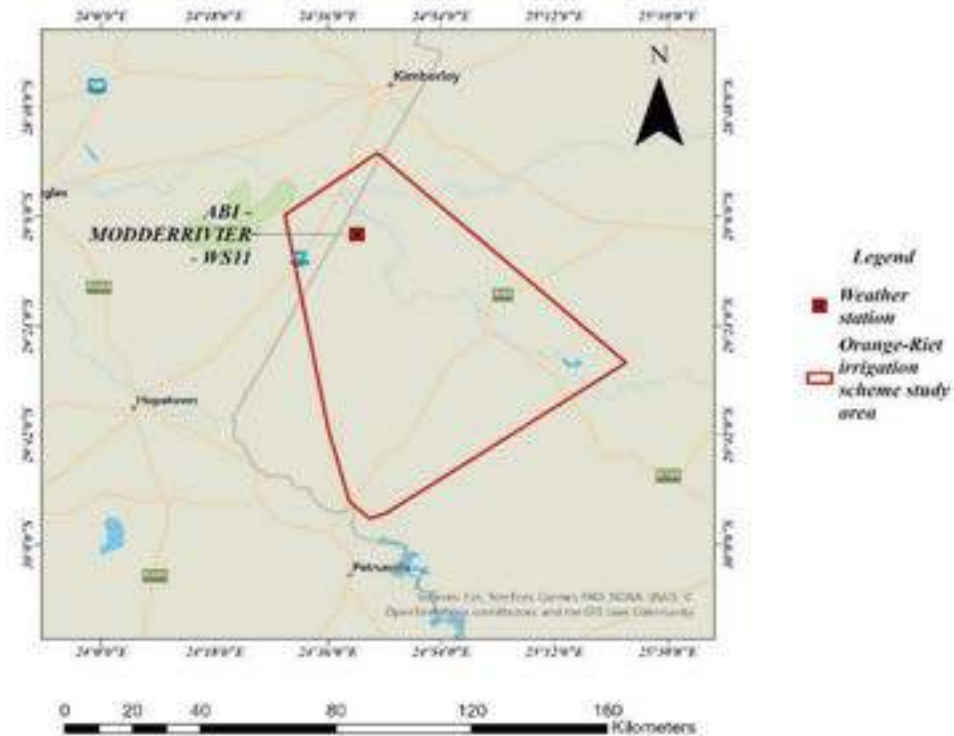


Figure 3.7: Location of the Weather Station Used for Climate Data in the Orange-Riet Irrigation Scheme

Source: Project team compilation

3.2.3.1.2 Hartbeespoort Irrigation Scheme

Figure 3.8 below displays the locations of two weather stations used for the Hartbeespoort Irrigation Scheme. Climate data were obtained from the Wildebeesthoek station (latitude -25.66849 and longitude 28.0342) and the Brits station (latitude -25.5914 and longitude 27.76871) (Figure 3.8). These were the only stations available for the study area, and the dataset is limited to periods from 2015 to 2019 for Wildebeesthoek and 2010 to 2014 for Brits.

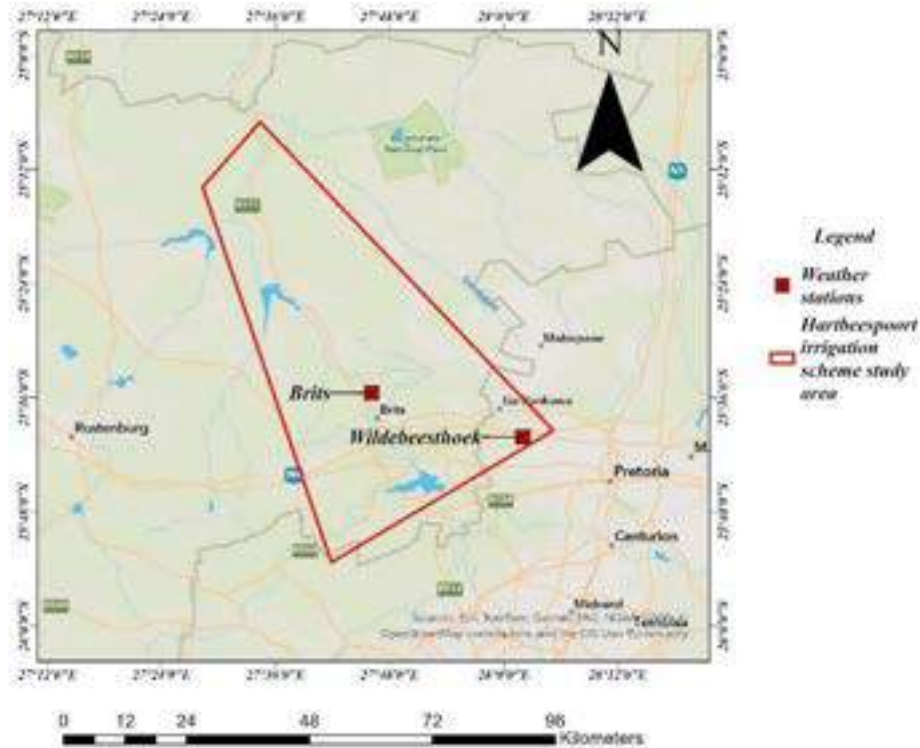


Figure 3.8: Locations of the Weather Stations Used for Climate Data in the Hartbeespoort Irrigation Scheme

Source: Project team compilation

3.2.3.1.3 Impala Irrigation Scheme

Figure 3.9 below displays the location of the weather station used for the Impala Irrigation Scheme. The station is Pongola SASRI Experimental Farm, with the latitude of -25.66849 and longitude of 28.0342 (Figure 3.9). Climate data from this station were used in the simulations. The dataset spans from 2004 to 2011.

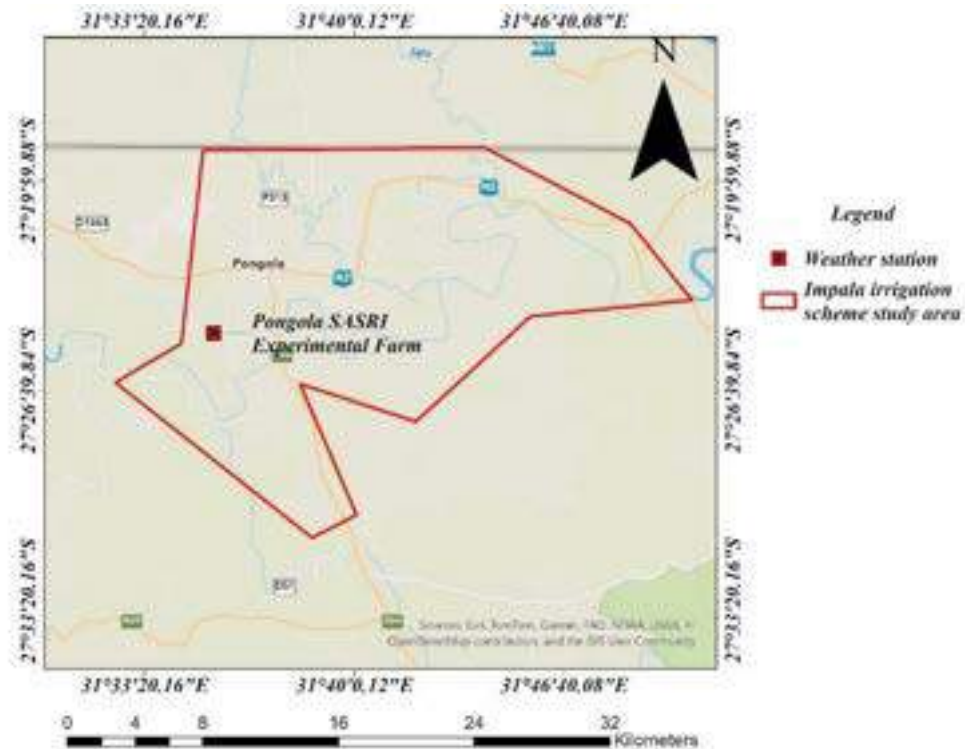


Figure 3.9: Location of the Weather Station Used for Climate Data in the Impala Irrigation Scheme

Source: Project team compilation

3.2.3.1.4 Kakamas Irrigation Scheme

Figure 3.10 below displays the locations of two weather stations used for the Kakamas Irrigation Scheme. The first is Augrabies-Witklip (latitude -28.643196 and longitude 20.353052) and the second is Kakamas Kromhout Boerdery (latitude -28.787417 and longitude 20.645379) (Figure 3.10). Climate data from these stations were used in the simulations. Data from both stations were utilized in the AquaCrop model simulations from 2000 to 2023.

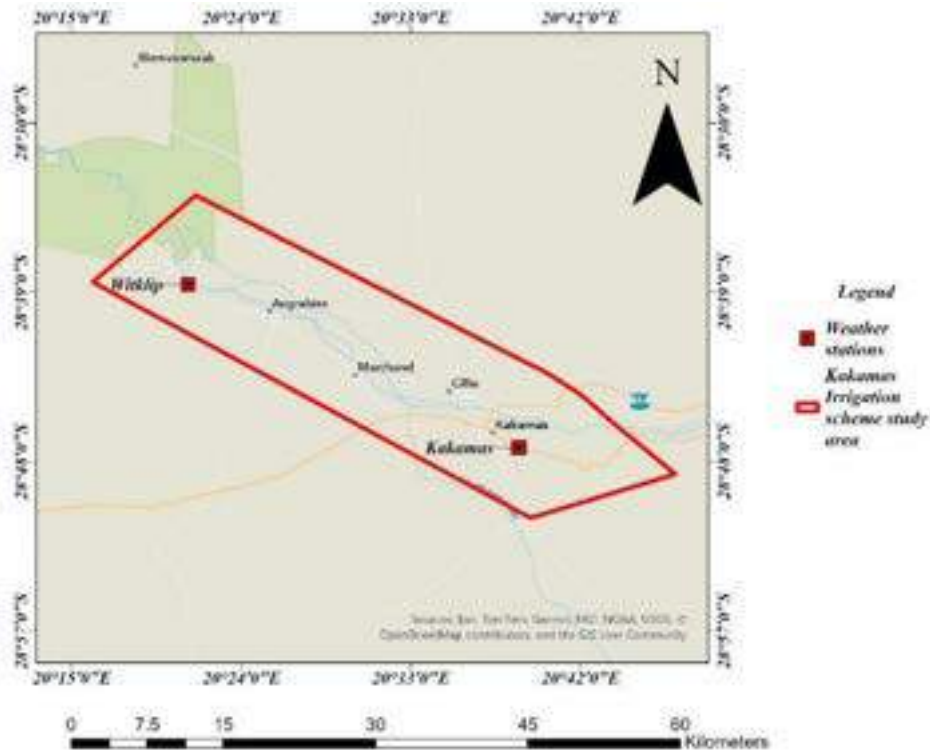


Figure 3.10: Location of the weather stations used for the Kakamas Irrigation Scheme

Source: Project team compilation

3.2.3.1.5 Tshiombo Irrigation Scheme

Figure 3.11 below displays the location of the weather station used for the Tshiombo Irrigation Scheme. The station is Thohoyandou Mutale, at latitude -22.734546 and longitude 30.521784 (Figure 3.11). Climate data from this station were used in the simulations. The dataset covered the period from 2006 to 2022.

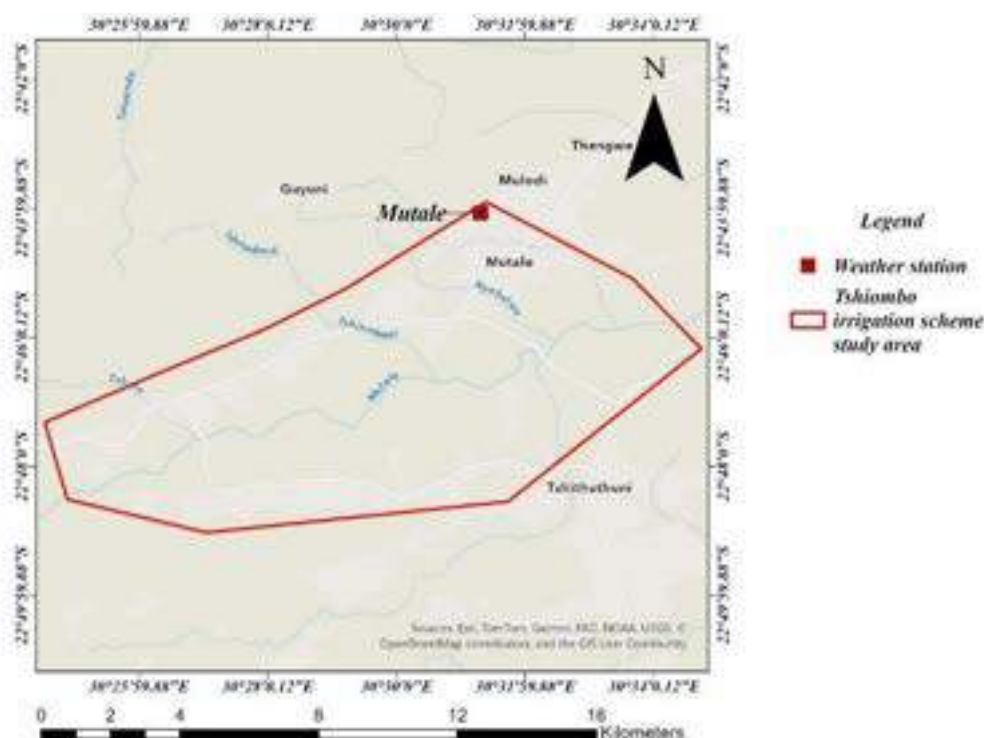


Figure 3.11: Location of the weather station used for the Tshiombo Irrigation Scheme

Source: Project team compilation

3.2.3.2 Soil data inputs

A systematic approach was employed to achieve a fair and accurate representation of soil conditions within each irrigation scheme. First, the study area for each irrigation scheme was identified and mapped using ArcGIS. Within these mapped boundaries, the main irrigation zone representing the core area under active irrigation was delineated. Within each main irrigation zone, the dominant soil types were identified and used as inputs for yield simulations in AquaCrop. Simulations were run separately for each soil type, and the results were combined using a weighted average based on the relative extent of each soil within the zone. This approach ensured that the final yield estimates reflected the actual distribution and influence of soils across the main irrigation areas.

The sections that follow provide a detailed overview of the main irrigation zones, soil characteristics, and modelling process for each irrigation scheme.

3.2.3.3 Orange Riet Irrigation Scheme

To illustrate the process followed in identifying the main irrigation zone and extracting relevant soil data, Figure 3.12 below presents a series of maps for the Orange-Riet Irrigation Scheme. The first, larger map panel shows the broader study area, delineated by clipping a land cover dataset to the scheme's boundaries. Based on this land cover information, the main irrigation zone was mapped by creating a new shapefile that

captures the actively irrigated core of the scheme. This shapefile was then used to identify the dominant soil group occurring within the main irrigation zone, as shown in Figure 3.12, Panel A. Within this dominant soil group, the dominant soil units were subsequently identified using the exact spatial boundaries, as depicted in Figure 3.12, Panel B.

Figure 3.12, Panel A, shows the dominant soil units in the irrigation-concentrated area, with Calcisols and Cambisols being the only two units present. Figure 3.12, Panel B, further breaks these down into the dominant soil types within each unit. Under Cambisols, the two soil types are Chromic Cambisols and Eutric Cambisols. Under Calcisols, the type present is Petric Calcisols. These three soil types form the basis for the AquaCrop simulations.

By conducting separate simulations for each of these dominant soil types, rather than relying on a single representative soil, the model captures a more realistic representation of maize yield variability across the main irrigation zone. This approach ensures that soil heterogeneity is accurately reflected in the simulated outcomes, thereby enhancing the accuracy of yield estimates derived for the Orange-Riet Irrigation Scheme. To make the results more relatable to a South African audience, the explanation provides supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale), available in Appendix D (Tables D.1–D.3) and Figure D.1.

Land Cover and Main Irrigation Area of the Orange-Riet Irrigation Scheme

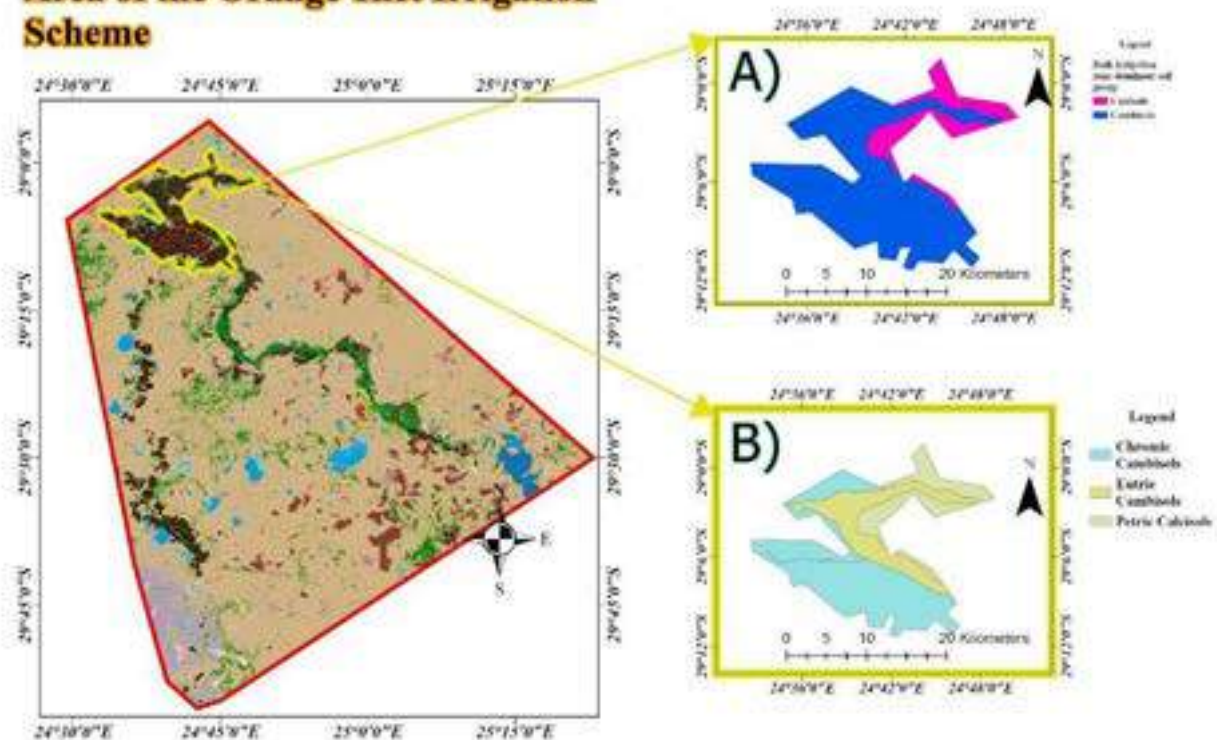


Figure 3.12: Dominant soil units and dominant soil types within the main irrigation zone of the Orange-Riet Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.13 below incorporates Panel B, situated within the main irrigation zone polygon in Figure 3.12, which highlights the three different soil types. Each of the three maps in Figure 3.13 includes the area size covered by each soil type, the percentage share of the main irrigation zone, the soil mapping unit, the dominant soil type, the percentage share of the mapping unit, and other soil types present with their respective percentage share of the mapping unit. The first dominant soil type is Chromic Cambisols, which accounts for 14,701 hectares, or 58% of the main irrigation zone. Within the soil mapping unit, Chromic Cambisols make up 65%, with other soils contributing 15% (Eutric Leptosols), 13% (Calcaric Cambisols), and 7% (Chromic Luvisols). The second dominant soil type is Petric Calcisols, covering an area of 4,642 hectares, which represents 18% of the main irrigation zone. Within the Calcisols mapping unit, Petric Calcisols comprise 85%, with the remaining 15% consisting of Rhodic Nitisols. The third dominant soil type is Eutric Cambisols, covering an area of 6,137 hectares, or 24% of the main irrigation zone. Within the Cambisols mapping unit, Eutric Cambisols account for 89%, with the remaining 11% being Calcaric Luvisols.

Soil Distribution in the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

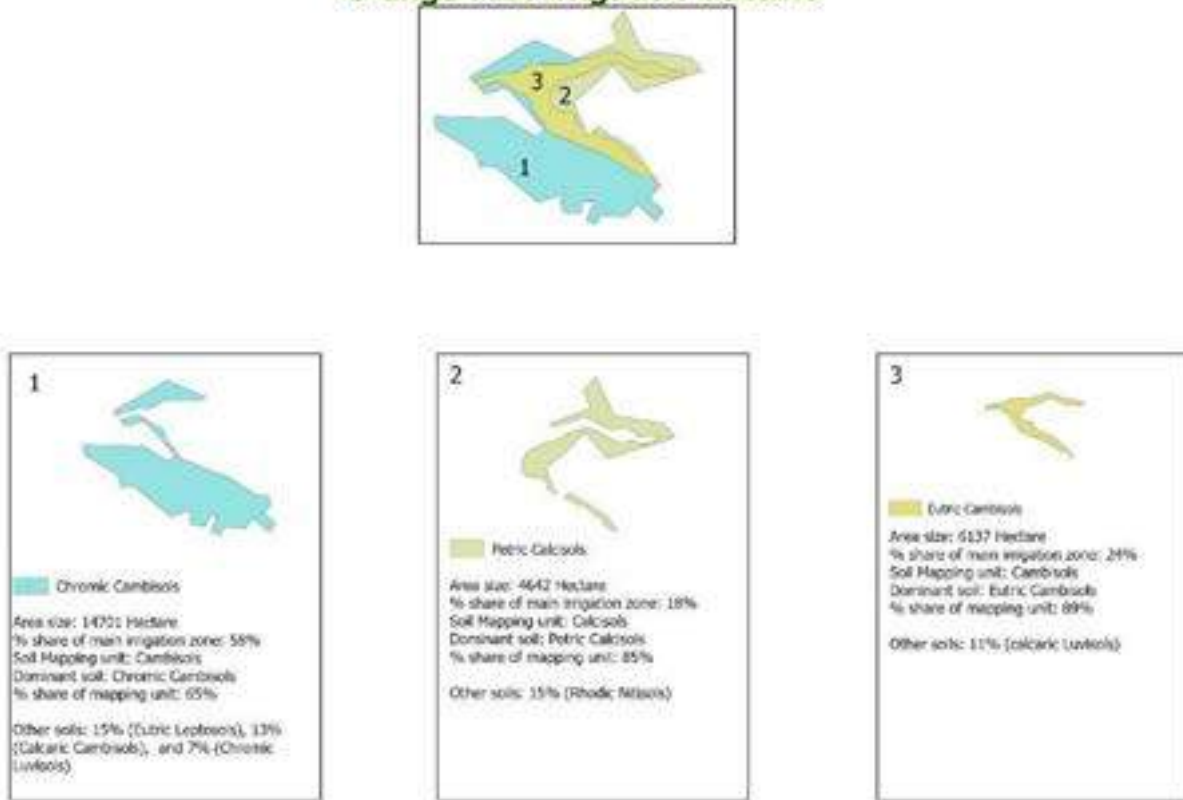


Figure 3.13: Dominant Soil Types in the Main Irrigation Zone of the Orange Riet Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

To obtain the detailed soil properties for the three dominant soil types shown in Figure 3.13, the Harmonized World Soil Database Version 2.0 (HWSD v2.0) was used, providing a clear tabular presentation of soil attributes. For spatial representation, all maps in this study were generated using SOTWIS soil data from ISRIC's website and imported into ArcGIS Pro for analysis. Notably, HWSD v2.0 for South Africa also relies on SOTWIS as its primary data source. Figure 3.14 below displays the world map from the HWSD v2.0 interface, where each colour represents a different soil type.

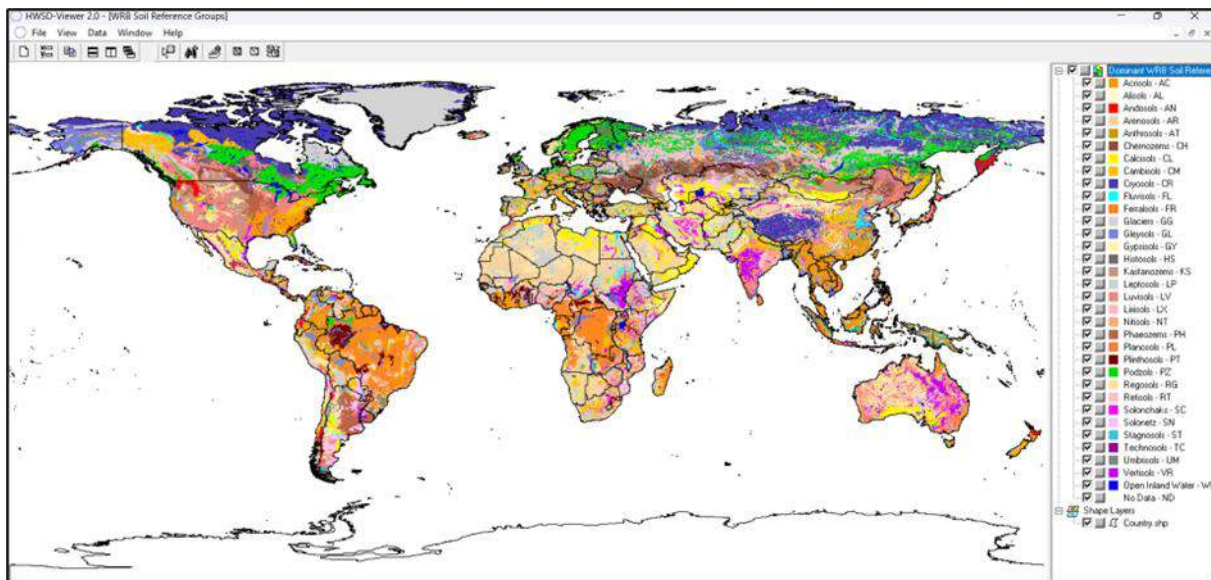


Figure 3.14: Global Soil Distribution Map from the Harmonized World Soil Database (HWSD, Version 2)

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Panel B within the polygon created in ArcGIS Pro, which outlines the main irrigation zone of the Orange Riet Irrigation Scheme and also highlights the dominant soil types (Figure 13.2 above), was imported into the HWSD v2.0 (Figure 3.15 below). By importing the dominant irrigation zone, the corresponding soil data for each location in the HWSD map could be accurately extracted. When clicking on the dominant soil attribute within the polygon shown in Figure 3.15, a detailed table is generated. This table presents the soil properties for the dominant soil types, and the tables for the three dominant soil types will be detailed in the following subsections.



Figure 3.15: Main Irrigation Zone of the Orange-Riet Irrigation Scheme, overlaid in HWSD 2.0 for Soil Data Extraction

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

3.2.3.3.1 Chromic Cambisols Soil Properties

Using the SOTWIS data extracted from the HWSD v2.0, Table 3.5 below provides an overview of the key soil properties of Chromic Cambisols within the maize irrigation zone of the study area, which is shown in Panel "1" in Figure 3.13 above. In line with Figure 3.13, the dominant soil unit is the Chromic Cambisols, which make up 65% of the mapping unit. The soil has a rootable depth of more than 100 cm and is moderately well-drained.

Table 3.5: Soil Properties of Chromic Cambisols in the main Irrigation zone of the Orange-Riet Irrigation Scheme

Coverage	SOTWIS			
Soil Mapping Unit (SMU)	28579			
Dominant Soil Unit (WRB 2022)	Akroskeletal Chromic Cambisol (CMcrkk)			
Dominant Soil Unit (FAO 1990)	Chromic Cambisols (CMx)			
	Dominant soil	Associated soils and inclusions		
Sequence in Soil Mapping Unit	1	2	3	4
Share in Soil Mapping Unit (%)	65	15	13	7
Database Internal ID	74828	142240	44539	202257
Soil Unit Symbol (WRB 2022)	CMcrkk	LPeu	CMca	LVcr
Soil Unit Name (WRB correlat.FAO90)	Chromic Cambisols	Eutric Leptosols	Calcaric Cambisols	Chromic Luvisols
Soil Unit Symbol (FAO 1990)	CMx	LPe	CMc	LVx
Soil Unit Name (FAO 1990)	Chromic Cambisols	Eutric Leptosols	Calcaric Cambisols	Chromic Luvisols
Rootable Soil Depth	Deep (> 100 cm)	Shallow (< 50 cm)	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Imperfectly drained	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	162	29	173	146

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.6 presents the detailed soil characteristics of the dominant soil type, Chromic Cambisol, provided by the HWSD for seven soil layers, as shown on the left-hand side of the table. However, this poses a challenge, as the AquaCrop model only allows a maximum of five layers when defining a new soil profile. Figure 3.16 below illustrates this limitation, showing the dropdown menu in AquaCrop, where the maximum selectable number of layers is five.

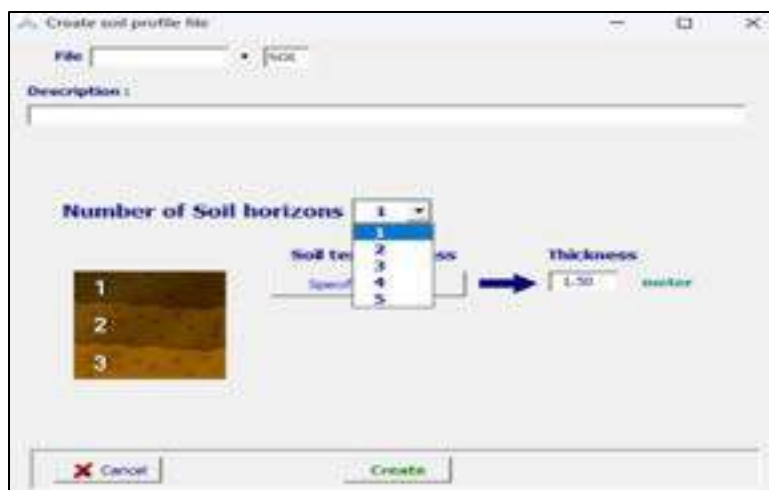


Figure 3.16: Soil Profile Layer Setup in AquaCrop Showing a Maximum of Five Layers

Source: Project team compilation

To comply with AquaCrop's limitation of five soil layers, the original seven layers from the Harmonized World Soil Database (HWSD) were merged by combining layers with similar characteristics. The merging process was based on similarities in key soil properties, ensuring that the new layers accurately represent the soil profile, while complying with AquaCrop's constraints. Layers D2 and D3 were merged because they share several similar characteristics. Both layers are classified as sandy clay loam and have nearly identical percentages of sand, silt, and clay. Their bulk density, reference bulk density, organic carbon content, pH in water, total nitrogen content, carbon/nitrogen ratio, CEC soil, CEC clay, ECEC, and TEB values are either identical or show minimal variation. Layers D4 and D5 were also merged because of their comparable properties. They have nearly the exact percentages of sand, silt, and clay, and their bulk density, reference bulk density, and organic carbon content are identical. The pH in water and the total nitrogen content of these layers are also very similar. Additionally, their CEC soil values are the same, while their CEC clay values differ only slightly. Details of both the original seven layers and the newly merged five layers are presented in Table 3.6 below.

Table 3.6: Chromic Cambisols Soil Properties: Comparing HWSD Seven Layers and Merged Five Layers for AquaCrop Simulation

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	Dept layer D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	100	150	200
Coarse fragments (% volume)	9	7	11	17	10	19	9	9	9	13.5	19	9
Sand (% weight)	61	56	59	57	58	60	49	61	57.5	57.5	60	49
Silt (% weight)	19	19	17	18	19	18	28	19	18	18.5	18	28
Clay (% weight)	20	25	24	25	23	22	23	20	24.5	24	22	23
Texture class (USDA conventions)	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loam
Bulk Density (g/cm ³)	1.4	1.3	1.4	1.4	1.5	1.5	1.5	1.4	1.35	1.45	1.5	1.5
Reference Bulk Density (g/cm ³)	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8
Organic Carbon Content (% weight)	0.7	0.5	0.4	0.4	0.3	0.3	0.2	0.7	0.45	0.35	0.3	0.2
pH in water (-log(H ⁺))	6.7	7	7.1	7.1	7.4	7.5	8.2	6.7	7.05	7.25	7.5	8.2
Total nitrogen content (g/kg)	0.8	0.5	0.4	0.4	0.4	0.5	0.3	0.8	0.45	0.4	0.5	0.3
Carbon/Nitrogen ratio (C/N)	11	11	8	8	8	7	8	11	9.5	8	7	8
CEC soil (cmolc/kg)	11	13	13	13	15	15	14	11	13	14	15	14
CEC clay (cmolc/kg)	45	45	53	57	60	59	79	45	49	58.5	59	79
ECEC (cmolc/kg)	13	16	13	13	22	18	45	13	14.5	17.5	18	45
TEB (cmolc/kg)	12	15	13	18	23	16	45	12	14	20.5	16	45
Base Saturation (% CEC soil)	82	92	92	93	93	84	100	82	92	93	84	100
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	1	2	2	2	2	2	24	1	2	2	2	24
Calcium Carbonate (% weight)	0	1	1	10	11	11	10	0	1	10.5	11	10
Gypsum content (% weight)	2	2	2	2	2	2	3	2	2	2	2	3
Electric Conductivity (dS/m)	1	1	1	1	1	1	1	1	1	1	1	1

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

When creating a soil profile in AquaCrop, specifying soil hydraulic properties is also required for each layer of the soil profile. Figure 3.17 below displays the AquaCrop interface where these properties need to be selected for each soil layer.



Figure 3.17: AquaCrop Soil Hydraulic Properties Input Interface

Source: Project team screenshot from *AquaCrop Version 7.1* (FAO, 2023)

Since the Harmonized World Soil Database (HWSD) Version 2.0 does not provide data on soil hydraulic properties, a Soil Hydraulic Property Calculator was employed to estimate these properties for each soil layer. Figure 3.18 below illustrates the interface of this calculator, which estimates hydraulic properties based on the percentages of clay and sand in the soil. Table 3.7 below presents the hydraulic properties of Chromic Cambisols soil layers, as derived by using a soil hydraulic property calculator.

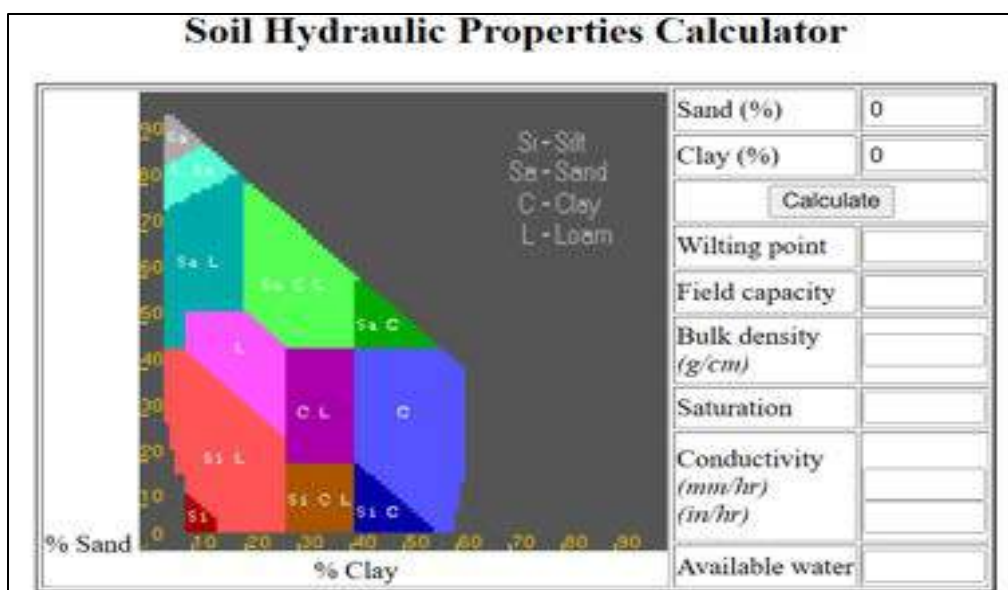


Figure 3.18: Soil Hydraulic Property Calculator Used for Deriving Hydraulic Properties of the Dominant Soil

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025), based on equations obtained from Saxton et al. (1986)

Table 3.7: Hydraulic Properties of Chromic Cambisols Soil Layers

	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	D7
Permanent wilting point (%)	12.9	14.8	14.6	13.8	14
Field capacity (%)	23.0	24.9	24.8	23.8	25.7
Saturation (%)	45.4	46.8	46.6	46	47
Conductivity (mm/hr)	7.176	4.489	4.729	5.741	5.738
Conductivity (mm/day)	172.20	107.74	113.50	137.78	137.71

Source: The Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025), based on equations obtained from Saxton et al. (1986)

The default values were used for the remaining parameter inputs related to the soil data, soil surface, and capillary rise parameters.

3.2.3.3.2 Petric Calcisols Soil Properties

Table 3.8 below presents an overview of the key soil properties of Petric Calcisols within the main irrigation zone of the Orange-Riet Irrigation Scheme, as shown in Panel "2" in Figure 3.13 above. The data, sourced from the HWS2.0, shows that Petric Calcisols dominate the mapping unit, covering 85% of the area. This

soil type has a deep rootable depth of over 100 cm and is classified as moderately well-drained. The available water content (AWC) for the rootable soil depth is 101 mm.

Table 3.8: Soil Properties of Petric Calcisols in the main Irrigation zone for the Orange-Riet Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28459	
Dominant Soil Unit (WRB 2022)	Petric Calcisol (CLpt)	
Dominant Soil Unit (FAO 1990)	Petric Calcisols (CLp)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	85	15
Database Internal ID	42073	217728
Soil Unit Symbol (WRB 2022)	CLpt	NTro
Soil Unit Name (WRB correlat.FAO90)	Petric Calcisols	Rhodic Nitisols
Soil Unit Symbol (FAO 1990)	CLp	NTr
Soil Unit Name (FAO 1990)	Petric Calcisols	Rhodic Nitisols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	101	162

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023).

Table 3.9 below presents the original seven soil layers obtained from the HWSD 2.0 for the Petric Calcisols soil type, shown on the left-hand side. To make the soil data compatible with AquaCrop, two pairs of layers were merged, reducing the original seven soil layers to five. The merged soil layers are shown on the right-hand side of Table 3.9. Layers D1 and D2 were merged because both layers are sandy loam with nearly identical sand, silt, and clay percentages. Their bulk density, reference bulk density, organic carbon content, pH, total nitrogen content, carbon/nitrogen ratio, CEC soil, CEC clay, ECEC, and TEB values show minimal variation, making them suitable for merging into a single layer. Similarly, layers D5 and D6 were merged because of their sandy loam texture and nearly identical sand, silt, and clay percentages. The bulk density, reference bulk density, organic carbon content, pH, total nitrogen content, and CEC soil values of these layers are almost identical, while their CEC clay values differ slightly. Furthermore, the exchangeable sodium percentage and calcium carbonate content of layers D5 and D6 are also comparable, justifying their combination into a single layer for the AquaCrop model.

Table 3.9: Petric Calcisols Soil Properties Comparing HWSD Seven Layers and Merged Five Layers for AquaCrop Simulation

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1 and D2	Dept layer D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	40	60	80	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	40	60	80	150	200
Coarse fragments (% volume)	18	29	31	33	33	34	25	23.5	31	33	33.5	25
Sand (% weight)	61	60	64	66	68	67	55	60.5	64	66	67.5	55
Silt (% weight)	22	21	17	20	17	18	27	21.5	17	20	17.5	27
Clay (% weight)	17	19	19	14	15	15	18	18	19	14	15	18
Texture class (USDA conventions)	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Bulk Density (g/cm ³)	1.4	1.4	1.5	1.5	1.5	1.6	1.7	1.4	1.5	1.5	1.55	1.7
Reference Bulk Density (g/cm ³)	1.7	1.7	1.7	1.6	1.6	1.6	1.7	1.7	1.7	1.6	1.6	1.7
Organic Carbon Content (% weight)	0.6	0.5	0.4	0.3	0.3	0.2	0.1	0.55	0.4	0.3	0.25	0.1
pH in water (-log(H ⁺))	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.15	8.3	8.4	8.55	8.7
Total nitrogen content (g/kg)	0.8	0.6	0.6	0.4	0.3	0.3	0.3	0.7	0.6	0.4	0.3	0.3
Carbon/Nitrogen ratio (C/N)	9	10	12	12	12	10	4	9.5	12	12	11	4
CEC soil (cmolc/kg)	12	12	11	8	8	8	9	12	11	8	8	9
CEC clay (cmolc/kg)	71	61	50	53	49	51	40	66	50	53	50	40
ECEC (cmol/kg)	31	36	36	36	36	36	37	33.5	36	36	36	37
TEB (cmolc/kg)	31	36	36	36	36	36	37	33.5	36	36	36	37
Base Saturation (% CEC soil)	100	100	100	100	100	96	98	100	100	100	98	98
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	5	8	5	5	13	17	22	6.5	5	5	15	22
Calcium Carbonate (% weight)	17	34	47	48	43	38	44	25.5	47	48	40.5	44
Gypsum content (% weight)	0	1	1	1	2	6	3	0.5	1	1	4	3
Electric Conductivity (dS/m)	0	2	3	2	2	2	2	1	3	2	2	2

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

The soil hydraulic properties were calculated using the Soil Hydraulic Property Calculator, based on the percentages of sand and clay in each soil layer, and are presented in Table 3.10 below.

Table 3.10: Hydraulic Properties of Petric Calcisols Soil Layers

	Dept layer D1 and D2	Dept layer D3	Dept layer D4	Dept layer D5 and D6	D7
Permanent wilting point (%)	12.1	12.6	10.5	10.9	12
Field capacity (%)	22.5	22.3	20.5	20.6	23.3
Saturation (%)	44.8	44.9	43.0	43.3	45.2
Conductivity (mm/hr)	9.177	7.947	15.21	13.216	9.506
Conductivity (mm/day)	220.25	190.73	365.04	317.18	228.14

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025) based on equations obtained from Saxton et al. (1986)

3.2.3.3.3 Eutric Cambisols Soil Properties

Table 3.11 below presents an overview of the key soil properties of Eutric Cambisols within the main irrigation zone of the Orange-Riet Irrigation Scheme, as shown in Panel "3" in Figure 3.13 above. Table 3.11 below indicates that Eutric Cambisols dominate the mapping unit, covering 89% of the area, with associated soils, namely Calcic Luvisols, comprising the remaining 11%. Both soil units are classified as deep (>100 cm) and moderately well-drained. The available water content (AWC) for the rootable soil depth is 155 mm for Eutric Cambisols and 124 mm for Calcic Luvisols.

Table 3.11: Soil Properties of Eutric Cambisols in the main Irrigation zone for the Orange-Riet Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28605	
Dominant Soil Unit (WRB 2022)	Eutric Cambisol (CMeu)	
Dominant Soil Unit (FAO 1990)	Eutric Cambisols (CMe)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	89	11
Database Internal ID	57751	196876
Soil Unit Symbol (WRB 2022)	CMeu	LVcc
Soil Unit Name (WRB correlat.FAO90)	Eutric Cambisols	Calcic Luvisols
Soil Unit Symbol (FAO 1990)	CMe	LVk
Soil Unit Name (FAO 1990)	Eutric Cambisols	Calcic Luvisols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	155	124

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.12 below presents the original seven soil layers obtained from the HWSO2.0 for the Eutric Cambisols soil on the left-hand side. On the right-hand side, the five layers used in AquaCrop are shown. To reduce the total number of layers to five, two pairs of layers were created by averaging them, based on similar properties. Specifically, Layers D1 and D2 were merged because of their similar texture (Loam), sand, silt, and clay percentages, as well as their comparable values for bulk density, organic carbon content, pH, nitrogen content, and CEC. Similarly, Layers D3 and D4 were merged because they exhibited nearly identical textures (Loam), as well as similar percentages of sand, silt, and clay, and similar bulk density, organic carbon content, and CEC values. These merged layers ensure that the soil profile is consistent with AquaCrop's requirements, while retaining the essential soil characteristics.

Table 3.12: Eutric Cambisols Soil Properties: Comparing HWSD Seven Layers and Merged Five Layers for AquaCrop Simulation

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layers D1 and D2	Dept layers D3 and D4	Dept layer D5	Dept layer D6	Dept layer D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	40	80	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	40	80	100	150	200
Coarse fragments (% volume)	10	13	16	20	21	16	15	11.5	18	21	16	15
Sand (% weight)	52	51	50	50	52	51	49	51.5	50	52	51	49
Silt (% weight)	28	28	28	28	27	29	31	28	28	27	29	31
Clay (% weight)	20	21	22	22	21	20	20	20.5	22	21	20	20
Texture class (USDA conventions)	Loam	Loam	Loam	Loam	Sandy clay loam	Loam	Loam	Loam	Loam	Sandy clay loam	Loam	Loam
Bulk Density (g/cm ³)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Reference Bulk Density (g/cm ³)	1.7	1.7	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.7	1.7	1.7
Organic Carbon Content (% weight)	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.55	0.35	0.2	0.2	0.1
pH in water (-log(H ⁺))	7.5	7.7	7.8	7.8	7.8	8	8.1	7.6	7.8	7.8	8	8.1
Total nitrogen content (g/kg)	0.8	0.6	0.5	0.5	0.3	0.4	0.4	0.7	0.5	0.3	0.4	0.4
Carbon/Nitrogen ratio (C/N)	10	10	9	8	8	11	11	10	8.5	8	11	11
CEC soil (cmolc/kg)	15	16	17	16	15	15	15	15.5	16.5	15	15	15
CEC clay (cmolc/kg)	78	83	84	85	85	85	88	80.5	84.5	85	85	88
ECEC (cmolc/kg)	23	28	32	37	37	38	41	25.5	34.5	37	38	41
TEB (cmolc/kg)	23	28	32	36	36	38	41	25.5	34	36	38	41
Base Saturation (% CEC soil)	99	100	99	99	100	100	100	99.5	99	100	100	100
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	5	4	5	6	8	11	12	4.5	5.5	8	11	12
Calcium Carbonate (% weight)	2	2	3	2	2	2	3	2	2.5	2	2	3
Gypsum content (% weight)	2	2	2	2	2	2	3	2	2	2	2	3
Electric Conductivity (dS/m)	2	1	1	1	1	1	1	1.5	1	1	1	1

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

After merging these pairs, the hydraulic properties for each of the five consolidated soil layers were derived using a hydraulic property calculator based on the sand and clay percentages of the layers. These calculated hydraulic properties for the Petric Calcisols soil type are detailed in Table 3.13 below.

Table 3.13: Hydraulic Properties of Eutric Cambisols Soil Layers

	Dept layer D1 and D2	Dept layer D3	Dept layer D4	Dept layerD5 and D6	D7
Permanent wilting point (%)	12.1	12.6	10.5	10.9	12
Field capacity (%)	22.5	22.3	20.5	20.6	23.3
Saturation (%)	44.8	44.9	43.0	43.3	45.2
Conductivity (mm/hr)	9.177	7.947	15.21	13.216	9.506
Conductivity (mm/day)	220.25	190.73	365.04	317.18	228.14

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations obtained from Saxton et al. (1986)

3.2.3.3.4 Application of Soil Data in AquaCrop Simulations for the Orange-Riet Irrigation Scheme

To estimate an average crop yield for the scheme, a weighted average approach will be used that accounts for the relative area coverage of each dominant soil unit. Specifically, the soil properties and simulation results for each soil unit were weighted according to their proportional share of the main irrigation zone. This ensures that the yield estimate reflects the heterogeneity of soil profiles within the scheme, providing a more accurate representation of overall productivity. Figure 3.19 below provides a visual summary of this process.

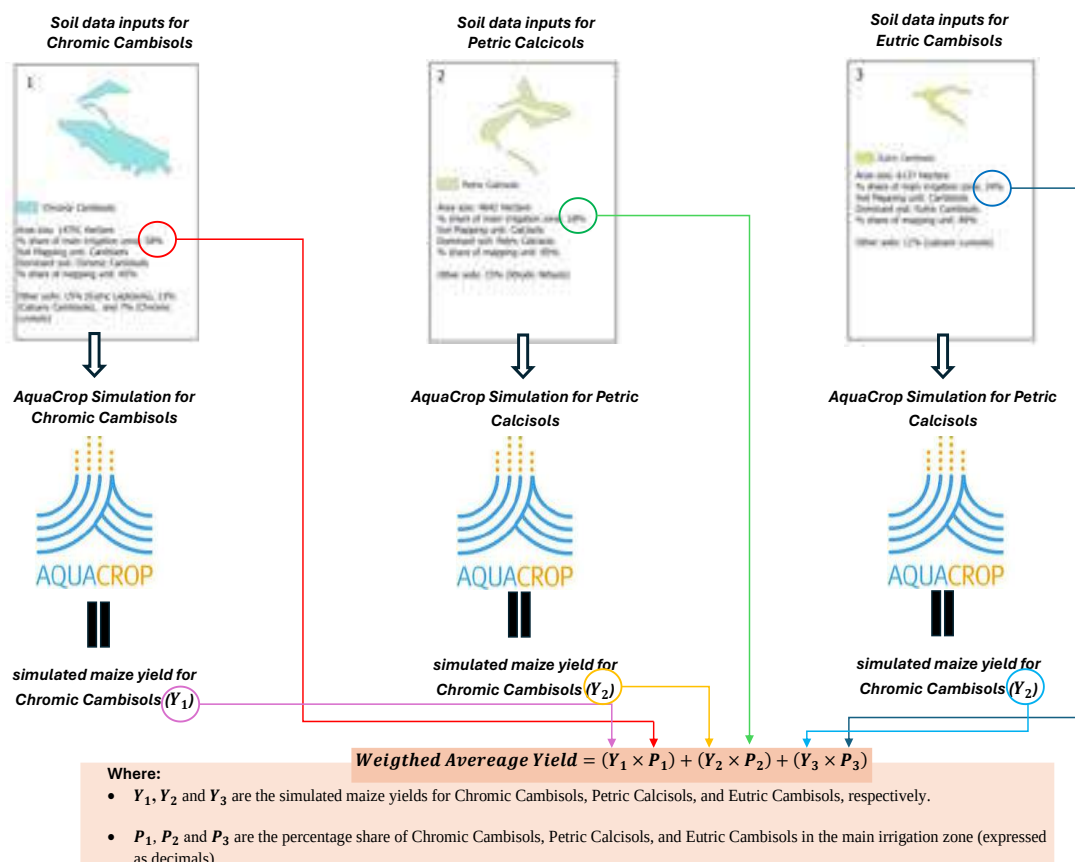


Figure 3.19: Summary of Soil Data Approach for AquaCrop Simulations in the Orange-Riet Irrigation Scheme

Source: Project team compilation

3.2.3.4 Hartbeespoort Irrigation Scheme

The same approach was used for the Orange-Riet Irrigation Scheme and applied to the Hartbeespoort Irrigation Scheme. First, the study area polygon was overlaid on a land cover dataset. Within this broader study area, the main irrigation zone was visually identified and mapped as a separate polygon shapefile (Figure 3.20 below). This delineated zone represents the area where irrigation activities are most concentrated. Using this main irrigation zone shapefile, the dominant soil groups within the zone were extracted, followed by the identification of the dominant soil units within each group. Figure 3.20, Panel A, illustrates the three dominant soil groups occurring in the Hartbeespoort Irrigation Scheme: Luvisols, Plinthosols, and Vertisols. Figure 3.20, Panel B, presents the dominant soil units within these groups. Specifically, within the Luvisols group, the dominant soil unit was identified as Ferric Luvisols; within the Plinthosols group, it was Eutric Plinthosols; and within the Vertisols group, the dominant unit was Calcic Vertisols. To make the results more relatable to a South African audience, the explanation provides

supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale) available in Appendix D (Tables D.4–D.6) and Figure D.2.

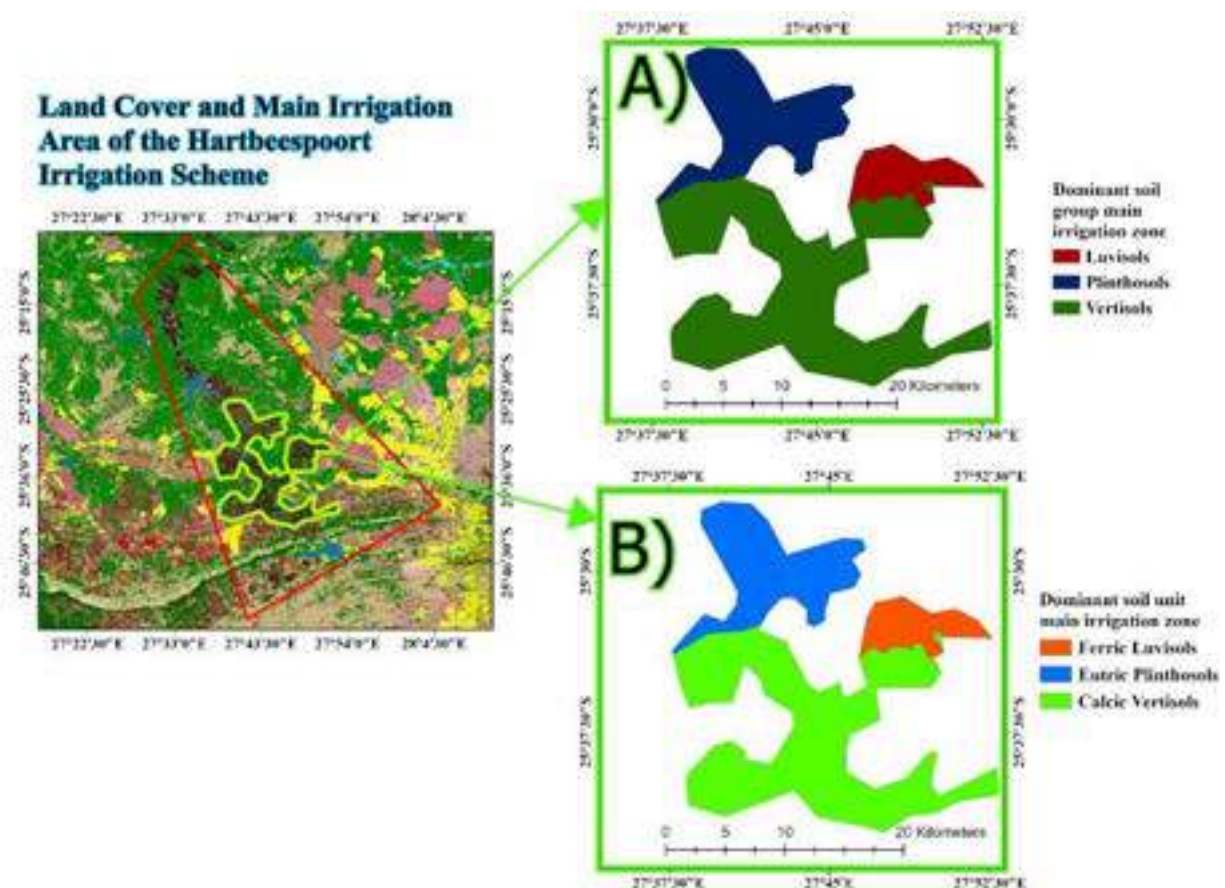


Figure 3.20: Dominant soil units and dominant soil types within the main irrigation zone of the Hartbeespoort irrigation scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.21 below provides a detailed breakdown of the dominant soil units within the main irrigation zone of the Hartbeespoort Irrigation Scheme, with each unit visually separated and numbered on the exact figure. The first soil unit, Eutric Plinthosols, is indicated as Panel “1” and covers an area of approximately 8,079.17 hectares, which constitutes around 26% of the main irrigation zone. The second unit, Calcic Vertisols, indicated as Panel “2”, is the most dominant in terms of area, covering approximately 19,390.89 hectares, or roughly 64% of the irrigation zone. The third unit, Ferric Luvisols, marked as Panel “3”, spans approximately 3,034.63 hectares, accounting for the remaining 10% of the area. This spatial disaggregation of soil units forms the basis for AquaCrop simulations, allowing for a more representative analysis of yield responses under varying soil conditions across the scheme.

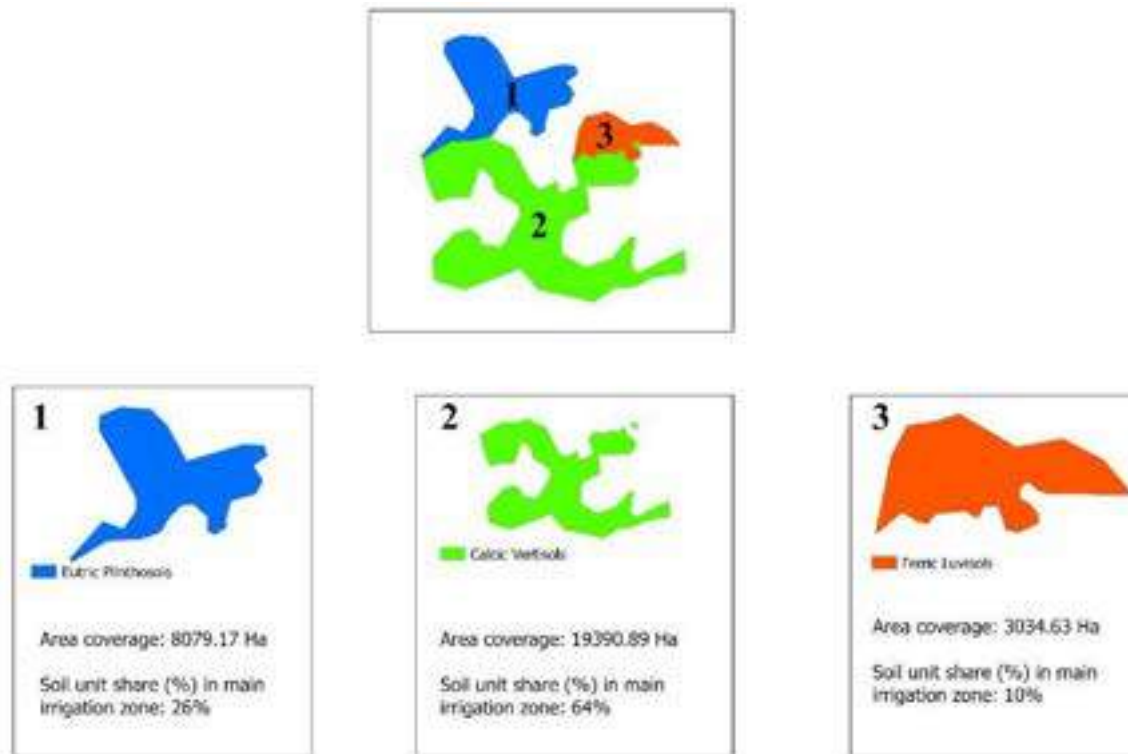


Figure 3.21: Dominant Soil Types in the Main Irrigation Zone of the Orange Riet Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

The next step involved obtaining detailed soil data for the dominant soil units identified within the main irrigation zone of the Hartbeespoort Irrigation Scheme. To achieve this, the polygon shapefile created in ArcGIS Pro to represent the main irrigation zone was imported into the HWSD 2.0. This allowed for the extraction of soil profile data specific to the identified dominant soil units. Figure 3.22 below provides an overview of the main irrigation zone polygon, overlaid within HWSD 2.0, illustrating the spatial alignment between the defined irrigation area and the soil database environment used for data extraction.

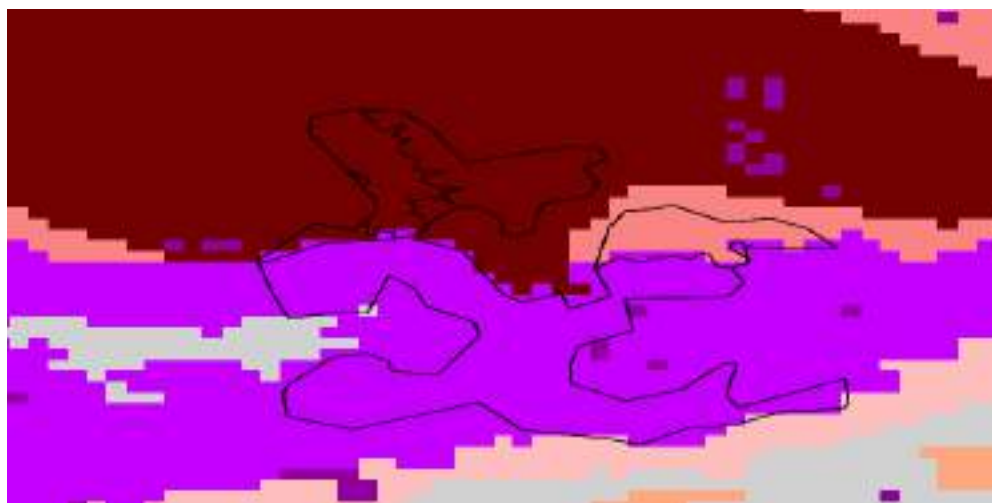


Figure 3.22: Main Irrigation Zone of the Hartbeespoort Irrigation Scheme Overlaid in HWSD 2.0 for Soil Data Extraction

Source: Project team compilation using HWSD 2.0

3.2.3.4.1 Eutric Plinthosols soil properties

Based on the soil data extracted from the HWSD2.0 database using the polygon shapefile representing the main irrigation zone of the Hartbeespoort Irrigation Scheme, Table 3.14 below provides a summary of the key soil properties associated with Eutric Plinthosols.

Table 3.14: Soil Properties of Eutric Plinthosols in the main Irrigation zone of the Hartbeespoort Irrigation Scheme

Coverage	SOTWIS				
Soil Mapping Unit (SMU)	28375				
Dominant Soil Unit (WRB 2022)	Eutric Plinthosol (PTeu)				
Dominant Soil Unit (FAO 1990)	Eutric Plinthosols (PTe)				
	Dominant soil	Associated soils and inclusions			
Sequence in Soil Mapping Unit	1	2	3	4	5
Share in Soil Mapping Unit (%)	41	37	10	7	5
Database Internal ID	240678	60165	4832	191217	235460
Soil Unit Symbol (WRB 2022)	PTeu	CMeu	ACha	LVha	PLeu
Soil Unit Name (WRB correlat.FAO90)	Eutric Plinthosols	Eutric Cambisols	Haplic Acrisols	Haplic Luvisols	Eutric Planosols
Soil Unit Symbol (FAO 1990)	PTe	CMe	ACh	LVh	PLe
Soil Unit Name (FAO 1990)	Eutric Plinthosols	Eutric Cambisols	Haplic Acrisols	Haplic Luvisols	Eutric Planosols
Rootable Soil Depth	Poorly drained	Moderately well-drained	Moderately well-drained	Moderately well-drained	Poorly drained
Reference Soil Drainage	126	150	138	159	181
AWC for Rootable Soil Depth (mm)	126	150	138	146	118

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.15 below presents the detailed soil layer information for the Eutric Plinthosols soil type, as obtained from the HWSD2.0, using the polygon shapefile that delineates the main irrigation zone of the Hartbeespoort Irrigation Scheme. On the left-hand side of the table, the original HWSD soil layers for Eutric Plinthosols are presented. However, for AquaCrop simulation, certain layers were consolidated to better align with the model's input requirements. Specifically, layers D2 and D3 were merged, as were D5 and D6, resulting in a revised set of five soil layers, shown on the right-hand side of the table. These adjusted layers will be used in the AquaCrop simulations to ensure an accurate representation of the soil profile and its influence on crop growth.

Table 3.15: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Hartbeespoort Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	80	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	80	150	200
Coarse fragments (% volume)	10	17	23	31	32	34	18	10	20	31	33	18
Sand (% weight)	63	57	50	47	44	44	43	63	53.5	47	44	43
Silt (% weight)	20	18	18	18	20	20	19	20	18	18	20	19
Clay (% weight)	17	25	32	35	36	36	38	17	28.5	35	36	38
Texture class (USDA conventions)	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay	Clay loam	Clay loam	Clay loam	Sandy loam	Sandy clay loam	Sandy clay	Clay loam	Clay loam
Bulk Density (g/cm ³)	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.5	1.55	1.6	1.65	1.7
Reference Bulk Density (g/cm ³)	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.7	1.85	1.9	1.9	1.9
Organic Carbon Content (% weight)	0.8	0.4	0.3	0.2	0.2	0.2	0.1	0.8	0.35	0.2	0.2	0.1
pH in water (-log(H ⁺))	5.9	5.8	5.7	5.8	5.8	5.9	5.7	5.9	5.75	5.8	5.85	5.7
Total nitrogen content (g/kg)	0.6	0.4	0.3	0.3	0.3	0.4	0.3	0.6	0.35	0.3	0.35	0.3
Carbon/Nitrogen ratio (C/N)	13	10	8	8	7	7	5	13	9	8	7	5
CEC soil (cmolc/kg)	6	7	8	8	9	9	10	6	7.5	8	9	10
CEC clay (cmolc/kg)	25	25	26	22	20	23	27	25	25.5	22	21.5	27
ECEC (cmolc/kg)	6	5	5	6	7	8	11	6	5	6	7.5	11
TEB (cmolc/kg)	5	4	5	6	6	7	10	5	4.5	6	6.5	10
Base Saturation (% CEC soil)	68	66	64	62	67	69	82	68	65	62	68	82
Aluminium saturation (% ECEC)	33	52	6	2	2	2	6	33	29	2	2	6
Exchangeable Sodium Percentage (%)	2	2	2	2	2	2	2	2	2	2	2	2
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Electric Conductivity (dS/m)	0	0	0	0	0	0	0	0	0	0	0	0

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Table 3.16 below presents the hydrological properties of the Eutric Plinthosols soil unit. Since the Harmonized World Soil Database (HWSD 2.0) does not provide data on the soil's hydraulic properties, which are required for AquaCrop simulations, these values were derived using a soil hydraulic properties calculator. Specifically, the Soil Water Characteristics Hydraulic Properties Calculator from DYNSSYSTEM (2025) was used, which is based on the equations developed by Saxton et al. (1986). This tool estimates key hydraulic parameters, including field capacity, wilting point, saturated hydraulic conductivity, and bulk density, thus ensuring that the AquaCrop model is supplied with realistic and site-specific input data.

Table 3.16: Hydraulic Properties of Consolidated Soil Layers for AquaCrop

	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Permanent wilting point (%)	11.7	16.5	19.5	20	21
Field capacity (%)	21.8	26.9	30.4	31.3	32.2
Saturation (%)	44.3	47.9	49.5	49.9	50.2
Conductivity (mm/hr)	10.278	3.199	2.116	2.083	1.879
Conductivity (mm/day)	246.672	76.776	50.784	49.992	45.096

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations obtained from Saxton et al. (1986)

3.2.3.4.2 Calcic Vertisols soil properties

Based on data extracted from HWSD2.0 using the polygon shapefile for the main irrigation zone of the Hartbeespoort Irrigation Scheme, Table 3.17 below provides an overview of the general soil properties for this soil unit, as well as its associated soils. However, only the dominant soil unit, Calcic Vertisols, will be used in the AquaCrop simulations to ensure consistency and reflect the soil conditions that most significantly influence crop production in the scheme.

Table 3.18 below presents the soil layers obtained from the HWSD 2.0 for Calcic Vertisols, with the original layers shown on the left-hand side of the table. However, to make the data compatible with AquaCrop, certain layers were merged to reduce the total number of soil layers to five. Layers D2 and D3 were merged because they exhibit highly similar characteristics across all major soil parameters. Both layers are classified as “Clay (light)” and have identical percentages of sand (15%), silt (32%), and clay (53%). Their bulk density is either similar or nearly identical (1.8 g/cm³ for D2, 1.9 g/cm³ for D3), and their reference bulk density values are the same (2.0 g/cm³). The organic carbon content is closely matched (0.9% in D2 and 0.7% in D3), and both layers exhibit a consistent decline in total nitrogen, at 0.9 and 0.7 g/kg,

respectively. Their pH values in water are nearly identical (7.8 and 7.9). The CEC soil (40 and 39 cmolc/kg), CEC clay (69 and 69 cmolc/kg), ECEC (56 and 59 cmolc/kg), and TEB (56 and 58 cmolc/kg) show only minor variations, further supporting their compatibility for merging.

Table 3.17: Soil Properties of Calcic Vertisols in the main Irrigation zone of the Hartbeespoort Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	30699	
Dominant Soil Unit (WRB 2022)	Calcic Vertisol (VRcc)	
Dominant Soil Unit (FAO 1990)	Calcic Vertisols (VRk)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	82	18
Database Internal ID	298825	172447
Soil Unit Symbol (WRB 2022)	VRcc	LPli
Soil Unit Name (WRB correlat.FAO90)	Calcic Vertisols	Lithic Leptosols
Soil Unit Symbol (FAO 1990)	VRk	LPq
Soil Unit Name (FAO 1990)	Calcic Vertisols	Lithic Leptosols
Rootable Soil Depth	Deep (> 100 cm)	Very shallow (< 10 cm)
Reference Soil Drainage	Poorly drained	Imperfectly drained
AWC for Rootable Soil Depth (mm)	198	12

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023).

Layers D6 and D7 were also merged because of their strongly aligned soil properties, particularly in the context of deeper subsoil conditions. Both layers are classified as “Clay (light)” and exhibit minimal variation in sand content (13% vs. 14%), silt content (36% vs. 38%), and clay content (51% vs. 48%). Their bulk density is identical (1.9 g/cm³), as is their reference bulk density (2.0 g/cm³). The organic carbon content (0.4% and 0.2%) and total nitrogen (0.5 and 0.3 g/kg) exhibit a steady decline with depth, which is typical of lower horizons. Both layers share the same pH in water (8.1), and their CEC soil (35 vs. 31 cmolc/kg), CEC clay (65 vs. 63 cmolc/kg), ECEC (66 vs. 67 cmolc/kg), and TEB (66 vs. 67 cmolc/kg) values are very closely aligned. These similarities justify treating D6 and D7 as a single homogeneous deep soil layer for modelling purposes.

Table 3.18: Original HWSD Soil Layers and Consolidated Layers for the calcic vertisols for AquaCrop Input in the Hartbeespoort Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5	Dept layer D6 + D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	80	100
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	80	100	200
Coarse fragments (% volume)	2	3	2	2	2	1	1	2	2.5	2	2	1
Sand (% weight)	17	15	15	15	14	13	14	17	15	15	14	13.5
Silt (% weight)	33	32	32	32	33	36	38	33	32	32	33	37
Clay (% weight)	50	53	53	53	53	51	48	50	53	53	53	49.5
Texture class (USDA conventions)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)
Bulk Density (g/cm ³)	1.8	1.8	1.9	1.8	1.9	1.9	1.9	1.8	1.85	1.8	1.9	1.9
Reference Bulk Density (g/cm ³)	2	2	2	2	2	2	2	2	2	2	2	2
Organic Carbon Content (% weight)	1.5	0.9	0.7	0.6	0.5	0.4	0.2	1.5	0.8	0.6	0.5	0.3
pH in water (-log(H ⁺))	7.6	7.8	7.9	8	8.1	8.1	8.1	7.6	7.85	8	8.1	8.1
Total nitrogen content (g/kg)	1.5	0.9	0.7	0.6	0.5	0.5	0.3	1.5	0.8	0.6	0.5	0.4
Carbon/Nitrogen ratio (C/N)	11	10	10	11	10	6	6	11	10	11	10	6
CEC soil (cmolc/kg)	40	40	39	39	37	35	31	40	39.5	39	37	33
CEC clay (cmolc/kg)	68	69	69	68	66	65	63	68	69	68	66	64
ECEC (cmol/kg)	55	56	59	63	65	66	67	55	57.5	63	65	66.5
TEB (cmolc/kg)	55	56	58	63	65	66	67	55	57	63	65	66.5
Base Saturation (% CEC soil)	100	100	99	100	100	100	100	100	99.5	100	100	100
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	1	3	4	5	7	8	17	1	3.5	5	7	12.5
Calcium Carbonate (% weight)	12	14	15	15	17	19	21	12	14.5	15	17	20
Gypsum content (% weight)	1	1	0	0	1	1	1	1	0.5	0	1	1
Electric Conductivity (dS/m)	1	1	1	1	2	3	3	1	1	1	2	3

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

The hydraulic properties of the five consolidated soil layers for the Hartbeespoort Irrigation Scheme were calculated by using an online hydraulic soil property calculator, which derives values based on the percentage of clay and sand. These results, presented in Table 3.19 below, complete all the necessary soil data requirements for running AquaCrop simulations for the study area.

Table 3.19: Hydraulic Properties of Consolidated Soil Layers for Calcic Vertisols

	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Permanent wilting point (%)	28.8	30.9	30.9	30.9	28.6
Field capacity (%)	43.6	45.5	45.5	45.7	43.9
Saturation (%)	53.6	54.1	54.1	54.2	53.8
Conductivity (mm/hr)	2.082	2.103	2.103	2.155	2.270
Conductivity (mm/day)	49.97	50.472	50.472	51.72	54.48

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025) based on equations obtained from Saxton et al. (1986)

3.2.3.4.3 Ferric Luvisols soil properties

Table 3.20 below presents the general soil properties of the Ferric Luvisols soil unit, as well as the general properties of the associated soil types. However, only the dominant soil unit, Ferric Luvisols, will be used for the AquaCrop simulations to ensure consistency and focus on the primary soil conditions within the main irrigation zone.

The soil data obtained from the HWSD 2.0 for the Ferric Luvisols soil unit includes seven layers, as shown on the left-hand side of Table 3.21 below. However, to ensure compatibility with AquaCrop, some of these layers were merged. The resulting five-layer profile, presented on the right-hand side of the table, will be used in the simulation process. Layers D2 and D3 were merged because of their close alignment in soil texture and chemical composition. Both layers are classified as Clay loam and have nearly identical sand (32% and 29%), silt (36% and 37%), and clay (32% and 34%) content. Their bulk density is identical (1.6 g/cm³), and the reference bulk density is the same (1.9 g/cm³). The organic carbon content (0.5% and 0.4%) and total nitrogen (0.5 and 0.4 g/kg) show a consistent decline from the surface. The pH in water is nearly identical (6.1 and 6.2), and the CEC of the soil (11 and 12 cmolc/kg), ECEC (10 cmolc/kg for both), and TEB (7 and 10 cmolc/kg) show only minor variations. These factors justify their treatment as a single intermediate layer.

Table 3.20: Soil Properties of Ferric Luvisols in the main Irrigation zone of the Hartbeespoort Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	30748	
Dominant Soil Unit (WRB 2022)	Ferric Luvisols (LVfr)	
Dominant Soil Unit (FAO 1990)	Ferric Luvisols (LVf)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	93	7
Database Internal ID	184560	298762
Soil Unit Symbol (WRB 2022)	LVfr	VRcc
Soil Unit Name (WRB correlat.FAO90)	Ferric Luvisols	Calcic Vertisols
Soil Unit Symbol (FAO 1990)	LVf	VRk
Soil Unit Name (FAO 1990)	Ferric Luvisols	Calcic Vertisols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Poorly drained
AWC for Rootable Soil Depth (mm)	168	198

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Layers D5 and D6 were also merged because of shared characteristics, especially in terms of physical structure and chemical composition. Both are classified as Clay loam and have identical sand (26%), silt (39%), and clay (35%) content. Bulk density (1.6 and 1.7 g/cm³), reference bulk density (both 1.9 g/cm³), organic carbon (both 0.3% and 0.2%), and total nitrogen (0.3 g/kg in both) are very similar. The figures for pH (6.1 and 6.3), CEC soil (14 and 15 cmolc/kg), and TEB (12 and 11 cmolc/kg) support their functional similarity. Furthermore, electrical conductivity (2 dS/m in both) and the presence of gypsum (2% and 3%) reinforce their compatibility for merging.

Table 3.21: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Hartbeespoort Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	80	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	80	150	200
Coarse fragments (% volume)	6	9	6	26	3	3	14	6	7.5	26	3	14
Sand (% weight)	39	32	29	29	26	26	24	39	30.5	29	26	24
Silt (% weight)	39	36	37	38	39	39	44	39	36.5	38	39	44
Clay (% weight)	22	32	34	33	35	35	32	22	33	33	35	32
Texture class (USDA conventions)	Loam	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Loam	Clay loam	Clay loam	Clay loam	Clay loam
Bulk Density (g/cm ³)	1.6	1.6	1.6	1.7	1.6	1.7	1.7	1.6	1.6	1.7	1.65	1.7
Reference Bulk Density (g/cm ³)	1.7	1.9	1.9	1.9	1.9	1.9	1.9	1.7	1.9	1.9	1.9	1.9
Organic Carbon Content (% weight)	1.1	0.5	0.4	0.3	0.3	0.2	0.1	1.1	0.45	0.3	0.25	0.1
pH in water (-log(H ⁺))	5.8	6.1	6.2	6	6.1	6.3	6.6	5.8	6.15	6	6.2	6.6
Total nitrogen content (g/kg)	0.8	0.5	0.4	0.4	0.3	0.3	0.3	0.8	0.45	0.4	0.3	0.3
Carbon/Nitrogen ratio (C/N)	12	10	10	10	10	9	8	12	10	10	9.5	8
CEC soil (cmolc/kg)	11	11	12	13	14	15	12	11	11.5	13	14.5	12
CEC clay (cmolc/kg)	33	32	36	41	41	44	44	33	34	41	42.5	44
ECEC (cmolc/kg)	8	10	10	10	13	11	10	8	10	10	12	10
TEB (cmolc/kg)	7	7	10	10	12	11	9	7	8.5	10	11.5	9
Base Saturation (% CEC soil)	78	75	74	75	84	80	86	78	74.5	75	82	86
Aluminium saturation (% ECEC)	12	0	0	24	0	0	0	12	0	24	0	0
Exchangeable Sodium Percentage (%)	2	2	1	3	12	2	6	2	1.5	3	7	6
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	0	0	0	0	2	3	1	0	0	0	2.5	1
Electric Conductivity (dS/m)	0	0	1	1	2	2	2	0	0.5	1	2	2

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

The hydraulic properties of the five soil layers extracted from Table 3.21 above are presented in Table 3.22 below. These properties were derived by using a soil hydraulic property calculator to provide the necessary input parameters for the AquaCrop simulations.

Table 3.22: Hydraulic Properties of Consolidated Soil Layers for AquaCrop

	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Permanent wilting point (%)	13.3	18.4	18.3	19.4	17.8
Field capacity (%)	27	32.6	32.9	34.3	33.3
Saturation (%)	47.5	50.4	50.5	51.0	50.7
Conductivity (mm/hr)	7.155	3.213	3.303	3.073	3.884
Conductivity (mm/day)	171.72	77.112	79.272	73.752	93.216

Source: Adapted from The Soil Water Characteristics Hydraulic Properties Calculator from (DYNSTEM, 2025) based on equations obtained from Saxton et al. (1986).

3.2.3.4.4 Application of Soil Data in AquaCrop Simulations for the Hartbeespoort Irrigation Scheme

For the Hartbeespoort Irrigation Scheme, AquaCrop simulations were conducted individually for each dominant soil unit identified in Figure 3.23 below. A weighted average was calculated based on the proportional area coverage of each soil unit to obtain an overall average yield for the main irrigation zone. This approach ensures that the final yield estimate accurately reflects the spatial distribution of soil types within the scheme, incorporating the variability in soil properties and their influence on crop growth.

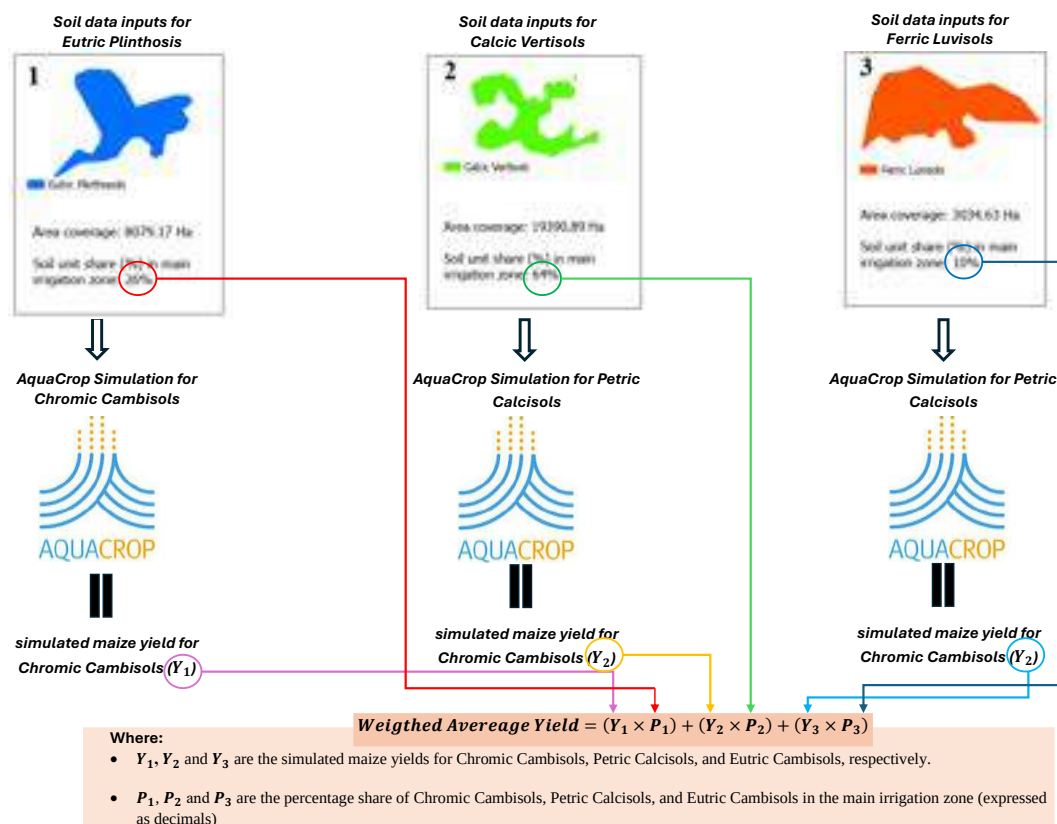


Figure 3.23: Summary of Soil Data Approach for AquaCrop Simulations in the Hartbeespoort Irrigation Scheme

Source: Project team compilation

3.2.3.5 Impala Irrigation Scheme

Figure 3.24 below displays three maps related to the spatial setup of the study. The first map presents the land cover layer, with the broader study area and the main irrigation zone mapped out. Initially, the study area polygon was overlaid on a land cover dataset to provide spatial context. Within this broader study area, the main irrigated zone was visually identified and mapped as a separate polygon shapefile to distinguish the main irrigated region. Figure 3.24, Panel A, illustrates the dominant soil groups occurring within the main irrigation zone of the Impala Irrigation Scheme. These soil groups include Cambisols, Leptosols, Planosols, and Regosols. Figure 3.24, Panel B, provides a more detailed breakdown, showing the dominant soil units within each of these soil groups. Specifically, Chromic Cambisols were identified within the Cambisols group, Dystric Leptosols within the Leptosols group, Dystric Regosols within the Regosols group, and Eutric Planosols within the Planosols group. To make the results more relatable to a South African audience, the explanation provides supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale) available in Appendix D (Tables D.7–D.9) and Figure D.3.

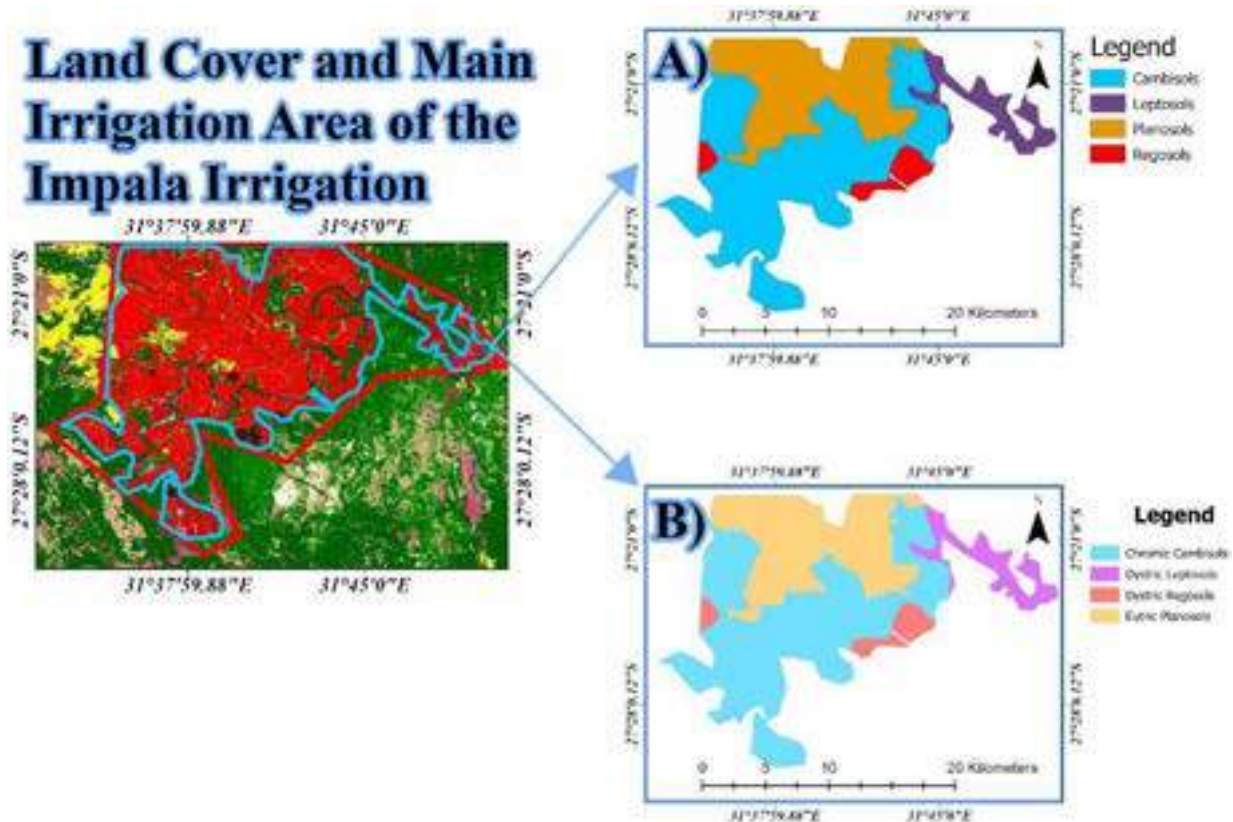


Figure 3.24: Dominant soil units and dominant soil types within the main irrigation zone of the Impala Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.25 below displays the spatial distribution of the four dominant soil units identified within the main irrigation zone of the Impala Irrigation Scheme. Using the Calculate Geometry function in ArcGIS, the area covered by each of these dominant soil units within the main irrigation zone was determined. Dystric Leptosols cover an area of 2,112 hectares, accounting for approximately 8% of the main irrigation zone. Dystric Regosols cover 1,215 hectares, representing 5% of the zone. Eutric Planosols occupy 8,233 hectares, which equates to 32% of the main irrigation area. Lastly, Chromic Cambisols cover the most considerable portion, with 14,430 hectares, making up 55% of the main irrigation zone.

Soil distribution in the Main Irrigation Zone of the Impala Irrigation Scheme

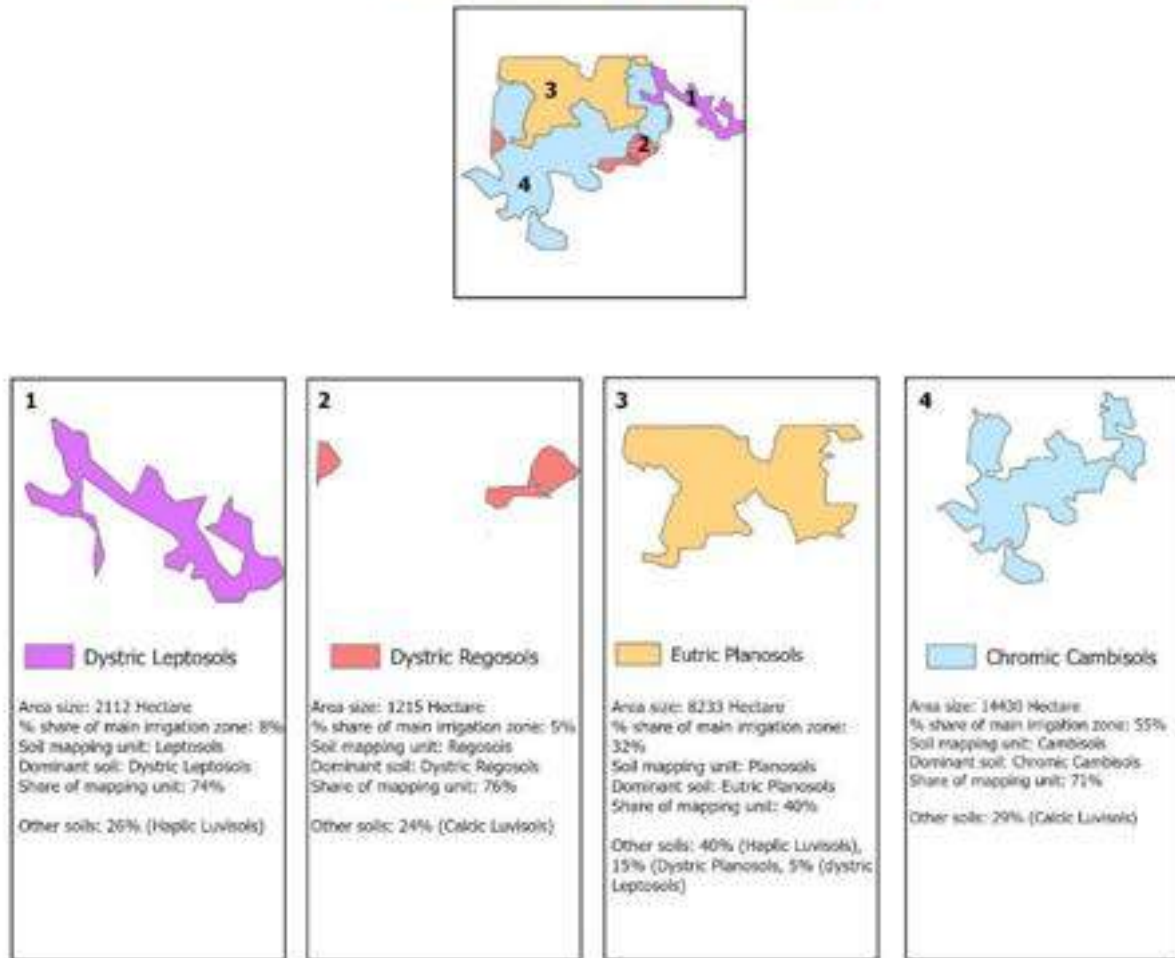


Figure 3.25: Dominant Soil Types in the Main Irrigation Zone of the Impala Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.26 below illustrates the process of identifying the dominant soil units within the main irrigation zone of the Impala Irrigation Scheme by using the HWSO2.0. The main irrigation zone polygon, created in ArcGIS Pro, was imported into HWSO2.0 to enable the extraction of soil profile data specific to this area.

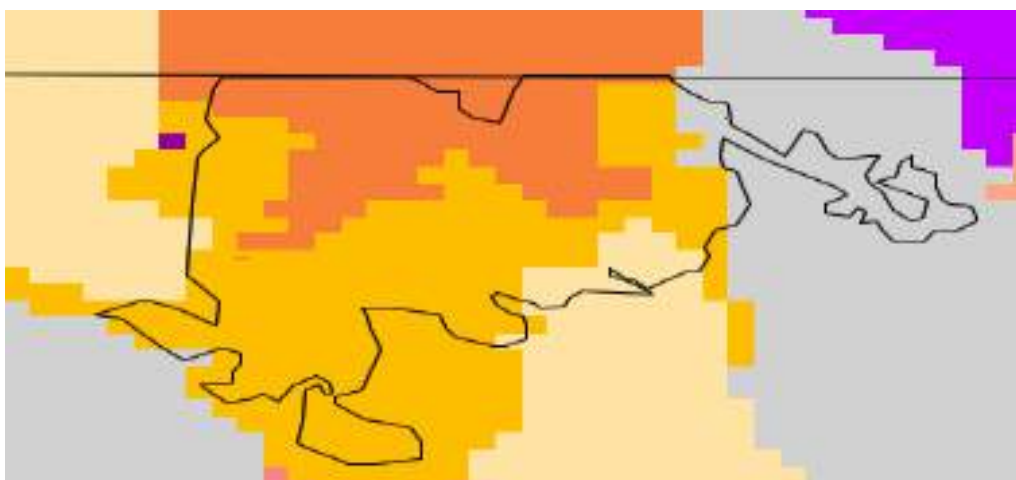


Figure 3.26: Main Irrigation Zone of the Hartbeespoort Irrigation Scheme Overlaid in HWSD 2.0 for Soil Data Extraction

Source: Project team compilation using HWSD2.0

3.2.3.5.1 Dystric Leptosols soil properties

Based on the soil data extracted from the HWSD2.0, the general soil properties of the Dystric Leptosols soil unit are presented in Table 3.23 below. Within the corresponding soil mapping unit, Dystric Leptosols account for 74% of the area, while Haplic Luvisols comprise the remaining 26%. However, for the AquaCrop simulation, only the dominant soil unit, Dystric Leptosols, will be used.

Table 3.23: Soil Properties of Dystric Leptosols in the main Irrigation zone of the Impala Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28111	
Dominant Soil Unit (WRB 2022)	Dystric Leptosol (LPdy)	
Dominant Soil Unit (FAO 1990)	Dystric Leptosols (LPd)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	74	26
Database Internal ID	138992	188909
Soil Unit Symbol (WRB 2022)	LPdy	LVha
Soil Unit Name (WRB correlat.FAO90)	Dystric Leptosols	Haplic Luvisols
Soil Unit Symbol (FAO 1990)	LPd	LVh
Soil Unit Name (FAO 1990)	Dystric Leptosols	Haplic Luvisols
Rootable Soil Depth	Shallow (< 50cm)	Deep (> 100 cm)
Reference Soil Drainage	Imperfectly drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	27	146

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

The Dystric Leptosols soil unit is represented by only two layers in the HWSD2.0 dataset, as shown in Table 3.23 above. The limited number of layers aligns with the typical profile of Leptosols, which are inherently shallow. According to ISRIC (1994), Leptosols are soils that are restricted in depth as a result of continuous hard rock, highly calcareous material (containing more than 40% calcium carbonate), or a cemented layer occurring within 30 cm of the surface, or by having less than 20% fine earth within a depth of 75 cm. These inherent limitations in soil depth justify the use of only two layers for this soil type in AquaCrop simulations, as deeper layers would not accurately reflect field conditions.

Table 3.24: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Impala Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	N/A	N/A	N/A	N/A	N/A	0	20	N/A	N/A	N/A
Depth of the bottom of the layer (cm)	20	40						20	40			
Coarse fragments (% volume)	8	32						8	32			
Sand (% weight)	64	60						64	60			
Silt (% weight)	18	16						18	16			
Clay (% weight)	18	24						18	24			
Texture class (USDA conventions)	Sandy loam	Sandy clay loam						Sandy loam	Sandy clay loam			
Bulk Density (g/cm ³)	1.5	1.5						1.5	1.5			
Reference Bulk Density (g/cm ³)	1.7	1.8						1.7	1.8			
Organic Carbon Content (% weight)	0.3	0.3						0.3	0.3			
pH in water (-log(H ⁺))	5.3	4.9						5.3	4.9			
Total nitrogen content (g/kg)	0.3	0.3						0.3	0.3			
Carbon/Nitrogen ratio (C/N)	11	12						11	12			
CEC soil (cmolc/kg)	5	5						5	5			
CEC clay (cmolc/kg)	20	16						20	16			
ECEC (cmolc/kg)	3	3						3	3			
TEB (cmolc/kg)	3	3						3	3			
Base Saturation (% CEC soil)	33	28						33	28			
Aluminium saturation (% ECEC)	14	6						14	6			
Exchangeable Sodium Percentage (%)	1	2						1	2			
Calcium Carbonate (% weight)	0	0						0	0			
Gypsum content (% weight)	0	1						0	1			
Electric Conductivity (dS/m)	1	0						1	0			

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Table 3.25 below presents the hydrological properties of the Dystric Leptosols soil unit. Since the HWSD2.0 does not provide data on the soil's hydraulic properties, which are required for AquaCrop simulations, these values were derived using a soil hydraulic properties calculator. Specifically, the Soil Water Characteristics Hydraulic Properties Calculator from DYNSSYSTEM (2025) was used, which is based on the equations developed by Saxton et al. (1986).

Table 3.25: Hydraulic Properties of Dystric Leptosols Soil Layers

	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5
Permanent wilting point (%)	12.1	14.6	N/A	N/A	N/A
Field capacity (%)	22.0	24.4			
Saturation (%)	44.6	46.5			
Conductivity (mm/hr)	9.005	4.616			
Conductivity (mm/day)	216.12	110.78			

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations from Saxton et al. (1986).

3.2.3.5.2 Dystric Regosols soil properties

Table 3.26 below presents the general soil properties of the Dystric Regosols soil unit, as determined by HWSD2.0, which accounts for a 76% share of the soil mapping unit. The associated soil is the Calcic Luvisols, which accounts for the remaining 24% of the soil mapping unit.

Table 3.26: Soil Properties of Dystric Regosols in the main Irrigation zone of the Impala Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28111	
Dominant Soil Unit (WRB 2022)	Dystric Leptosol (LPdy)	
Dominant Soil Unit (FAO 1990)	Dystric Leptosols (LPd)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	76	24
Database Internal ID	258169	199200
Soil Unit Symbol (WRB 2022)	RGdy	LVcc
Soil Unit Name (WRB correlat.FAO90)	Dystric Regosols	Calcic Luvisols
Soil Unit Symbol (FAO 1990)	RGd	LVk
Soil Unit Name (FAO 1990)	Dystric Regosols	Calcic Luvisols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	133	146

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

The soil data details obtained from the HWSD2.0 for the Dystric Regosols soil unit are presented in Table 3.27 below. The original seven soil layers from the database are shown on the left-hand side of the table, while the reduced five-layer structure that will be used in the AquaCrop model is shown on the right-hand side. To conform to the five-layer limit required by the AquaCrop model, the original seven soil layers from the HWSD 2.0 were consolidated into five distinct layers. This was achieved by merging layers with similar physical and chemical properties. Layers D1 (0–20 cm) and D2 (20–40 cm) were combined because both had the same soil texture (sandy loam) and exhibited comparable values for sand, silt, and clay content, bulk density, organic carbon, pH, total nitrogen, and cation exchange capacity. Similarly, layers D3 (40–60 cm) and D4 (60–80 cm) were merged because of their shared sandy loam texture and closely matching soil physical and chemical characteristics.

Table 3.27: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Impala Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	40	80	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	40	80	100	150	200
Coarse fragments (% volume)	9	23	16	14	16	19	24	16	15	16	19	24
Sand (% weight)	54	53	60	59	53	50	39	53.5	59.5	53	50	39
Silt (% weight)	30	29	23	23	26	28	38	29.5	23	26	28	38
Clay (% weight)	16	18	17	18	21	22	23	17	17.5	21	22	23
Texture class (USDA conventions)	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Loam	Loam	Sandy loam	Sandy loam	Sandy clay loam	Loam	Loam
Bulk Density (g/cm ³)	1.6	1.7	1.6	1.7	1.6	1.8	1.8	1.65	1.65	1.6	1.8	1.8
Reference Bulk Density (g/cm ³)	1.6	1.7	1.7	1.7	1.7	1.8	1.8	1.65	1.7	1.7	1.8	1.8
Organic Carbon Content (% weight)	1.2	0.6	0.4	0.2	0.2	0.4	0.8	0.9	0.3	0.2	0.4	0.8
pH in water (-log(H ⁺))	5.3	5.6	5.8	5.8	5.8	5.8	6.3	5.45	5.8	5.8	5.8	6.3
Total nitrogen content (g/kg)	0.9	0.5	0.4	0.4	0.3	0.4	0.6	0.7	0.4	0.3	0.4	0.6
Carbon/Nitrogen ratio (C/N)	12	10	9	8	7	6	11	11	8.5	7	6	11
CEC soil (cmolc/kg)	12	9	11	12	12	13	13	10.5	11.5	12	13	13
CEC clay (cmolc/kg)	40	39	39	38	46	44	48	39.5	38.5	46	44	48
ECEC (cmolc/kg)	10	10	12	12	12	15	15	10	12	12	15	15
TEB (cmolc/kg)	8	8	10	11	10	13	14	8	10.5	10	13	14
Base Saturation (% CEC soil)	61	67	68	92	92	77	96	64	80	92	77	96
Aluminium saturation (% ECEC)	5	34	33	38	46	40	0	19.5	35.5	46	40	0
Exchangeable Sodium Percentage (%)	2	7	7	10	9	10	5	4.5	8.5	9	10	5
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	3	3	3	3	2	3	2	3	3	2	3	2
Electric Conductivity (dS/m)	1	1	1	2	1	0	1	1	1.5	1	0	1

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Since the HWSD does not provide hydraulic properties of the soil, these properties were estimated by using a soil calculator. Table 3.28 below presents the hydraulic properties of the soil, derived based on the sand and clay content of each layer.

Table 3.28: Hydraulic Properties of Consolidated Soil Layers for AquaCrop

	Dept layer D1 +D2	Dept layer D2 + D3	Dept layer D4	Dept layer D5	Dept layer D7
Permanent wilting point (%)	11.6	11.9	13.2	13.6	13.7
Field capacity (%)	23.2	22.5	24.4	25.2	27.3
Saturation (%)	45.0	44.7	46.2	46.7	47.7
Conductivity (mm/hr)	10.840	9.822	6.827	6.305	6.475
Conductivity (mm/day)	260.14	235.73	163.85	151.32	155.4

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSTEM, 2025) based on equations from Saxton et al. (1986)

3.2.3.5.3 Eutric Planosols Soil Properties

Table 3.29 below presents the general soil information for the Eutric Planosols soil unit as obtained from the HWSD2.0. Table 3.29 shows that Eutric Planosols are the dominant soil unit, covering approximately 40% of the soil mapping unit, and also highlights the associated soils, including Haplic Luvisols (40% of the mapping unit), Dystric Planosols (15%), and Dystric Leptosols (5%). For the AquaCrop simulations, only the dominant Eutric Planosols soil unit will be used.

Table 3.29: Soil Properties of Eutric Planosols soil unit in the main Irrigation zone of the Impala Irrigation Scheme

Coverage	SOTWIS			
Soil Mapping Unit (SMU)	28109			
Dominant Soil Unit (WRB 2022)	Eutric Planosol (PLeu)			
Dominant Soil Unit (FAO 1990)	Eutric Planosols (PLe)			
	Dominant soil	Associated soils and inclusions		
Sequence in Soil Mapping Unit	1	2	3	4
Share in Soil Mapping Unit (%)	40	40	15	5
Database Internal ID	234399	188894	232890	138995
Soil Unit Symbol (WRB 2022)	PLeu	LVha	PLdy	LPdy
Soil Unit Name (WRB correlat.FAO90)	c	Haplic Luvisols	Dystric Planosols	Dystric Leptosols
Soil Unit Symbol (FAO 1990)	PLe	LVh	PLd	LPd
Soil Unit Name (FAO 1990)	Eutric Planosols	Haplic Luvisols	Dystric Planosols	Dystric Leptosols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)	Deep (> 100 cm)	Shallow (< 50 cm)
Reference Soil Drainage	Poorly drained	Moderately well-drained	Poorly drained	Imperfectly drained
AWC for Rootable Soil Depth (mm)	162	146	170	27

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

To comply with the five-layer requirement of the AquaCrop model, two pairs of soil layers were merged based on their similarity in soil texture and key physical and chemical properties (Table 3.30 below). Layers D2 (20–40 cm) and D3 (40–60 cm) were combined because they both have a sandy clay loam texture and closely aligned sand (67% and 66%), clay (22% and 26%), bulk density (1.5 g/cm³ each), pH (6.4 and 6.6), and organic carbon content (0.2% each). Layers D5 (80–100 cm) and D6 (100–150 cm) were also merged for similar reasons, sharing the sandy clay loam texture and having comparable sand content (68% and 63%), clay content (24% and 26%), bulk density (1.6 g/cm³), pH (7.2 each), and organic carbon levels (0.1% and 0.2%).

Table 3.30: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Hartbeespoort Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 and D3	Dept layer D4	Dept layer D5 and D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	80	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	80	150	200
Coarse fragments (% volume)	21	10	6	5	6	5	9	21	8	5	5.5	9
Sand (% weight)	80	67	66	64	68	63	43	80	66.5	64	65.5	43
Silt (% weight)	9	11	8	8	8	11	23	9	9.5	8	9.5	23
Clay (% weight)	11	22	26	28	24	26	34	11	24	28	25	34
Texture class (USDA conventions)	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Clay loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Clay loam
Bulk Density (g/cm ³)	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.4	1.5	1.5	1.6	1.7
Reference Bulk Density (g/cm ³)	1.5	1.8	1.8	1.8	1.8	1.8	1.9	1.5	1.8	1.8	1.8	1.9
Organic Carbon Content (% weight)	0.5	0.2	0.2	0.2	0.1	0.2	0.1	0.5	0.2	0.2	0.15	0.1
pH in water (-log(H ⁺))	6.2	6.4	6.6	6.8	7.2	7.2	7.3	6.2	6.5	6.8	7.2	7.3
Total nitrogen content (g/kg)	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4
Carbon/Nitrogen ratio (C/N)	9	7	8	8	7	7	6	9	7.5	8	7	6
CEC soil (cmolc/kg)	6	10	12	14	12	14	18	6	11	14	13	18
CEC clay (cmolc/kg)	38	49	49	52	52	48	50	38	49	52	50	50
ECEC (cmol/kg)	7	11	13	15	13	16	18	7	12	15	14.5	18
TEB (cmolc/kg)	7	11	13	15	13	13	17	7	12	15	13	17
Base Saturation (% CEC soil)	78	90	92	92	95	90	97	78	91	92	92.5	97
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	5	7	7	8	5	4	7	5	7	8	4.5	7
Calcium Carbonate (% weight)	0	0	0	1	1	2	1	0	0	1	1.5	1
Gypsum content (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Electric Conductivity (dS/m)	1	1	1	1	2	2	2	1	1	1	2	2

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Since the HWSD2.0 does not report hydraulic properties, these were derived by using a soil hydraulic property calculator. Table 3.31 below presents the hydraulic properties of the Eutric Planosols, based on the five consolidated soil layers shown on the right-hand side of Table 3.30 above. These consolidated layers result from merging the original seven layers into five to meet the input requirements for the AquaCrop model.

Table 3.31: Hydraulic Properties of Eutric Planosols Soil Layers

	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5 and D6	Dept layer D7
Permanent wilting point (%)	9.1	14.8	16.5	15.2	19
Field capacity (%)	17.5	23.6	25.3	24.1	30.7
Saturation (%)	40.7	46.0	47.0	46.3	49.6
Conductivity (mm/hr)	24.481	4.363	2.968	3.952	2.416
Conductivity (mm/day)	587.54	104.71	71.23	94.85	51.50

Note: Wilting point and other soil hydraulic properties were derived from the HWSD soil database using the Saxton et al. (1986) texture-based calculator. These values represent generalized soil-based thresholds at specified matric potentials and do not account for crop-specific water extraction.

Source: Adopted from the Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025) based on equations obtained from Saxton et al. (1986)

3.2.3.5.4 Chromic Cambisols Soil Properties

Table 3.32 below presents the general soil information for the Chromic Cambisols soil unit, as obtained from the HWSD2.0. The Chromic Cambisols are identified as the dominant soil in the soil mapping unit, comprising 71% of the total area. One associated soil is present in this mapping unit, Calcic Luvisols, which accounts for the remaining 29%. For the purposes of the AquaCrop simulations, only the dominant soil unit, Chromic Cambisols, will be used.

Table 3.32: Soil Properties of Chromic Cambisols in the main Irrigation zone of the Impala Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28110	
Dominant Soil Unit (WRB 2022)	Chromic Cambisol (CMcr)	
Dominant Soil Unit (FAO 1990)	Chromic Cambisols (CMx)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	71	29
Database Internal ID	77432	199241
Soil Unit Symbol (WRB 2022)	CMcr	LVcc
Soil Unit Name (WRB correlat.FAO90)	Chromic Cambisols	Calcic Luvisols
Soil Unit Symbol (FAO 1990)	CMx	LVk
Soil Unit Name (FAO 1990)	Chromic Cambisols	Calcic Luvisols
Rootable Soil Depth	Deep (> 100cm)	Deep (> 100cm)
Reference Soil Drainage	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	165	146

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

To reduce the number of soil layers from seven to five for use in AquaCrop simulations, two pairs of layers were merged, based on similarity in key soil properties and texture class (Table 3.33 below). This approach ensures that the consolidated layers accurately reflect the soil profile's hydrological behaviour, while simplifying the model input structure. Specifically, layers D2 (20–40 cm) and D3 (40–60 cm) were merged because of their identical USDA texture classification (light clay), nearly identical sand (30–31%) and clay content (41%), and similar bulk densities (1.3–1.4 g/cm³). Likewise, D4 (60–80 cm) and D5 (80–100 cm) were consolidated, as both layers also fall under the same texture class (light clay) and show minimal variation in key properties such as clay content (41%), sand content (33–35%), and bulk density (1.4–1.5 g/cm³).

Table 3.33: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Hartbeespoort Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	Dept layer D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	100	150	200
Coarse fragments (% volume)	5	13	11	21	32	35	25	5	12	26.5	35	25
Sand (% weight)	33	30	31	33	35	32	49	33	30.5	34	32	49
Silt (% weight)	31	29	28	26	24	26	28	31	28.5	25	26	28
Clay (% weight)	36	41	41	41	41	42	23	36	41	41	42	23
Texture class (USDA conventions)	Clay loam	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Clay (light)	Loam	Clay loam	Clay (light)	Clay (light)	Clay (light)	Loam
Bulk Density (g/cm ³)	1.4	1.3	1.4	1.4	1.5	1.5	1.6	1.4	1.35	1.45	1.5	1.6
Reference Bulk Density (g/cm ³)	1.9	2	2	2	2	2	1.8	1.9	2	2	2	1.8
Organic Carbon Content (% weight)	1.9	1.2	0.8	0.6	0.6	0.6	0.3	1.9	1	0.6	0.6	0.3
pH in water (-log(H ⁺))	6.1	6.2	6.3	6.2	6.2	6.7	6.2	6.1	6.25	6.2	6.7	6.2
Total nitrogen content (g/kg)	1.3	0.9	0.9	0.6	0.6	0.5	0.5	1.3	0.9	0.6	0.5	0.5
Carbon/Nitrogen ratio (C/N)	12	10	10	10	10	7	7	12	10	10	7	7
CEC soil (cmolc/kg)	20	19	20	15	15	17	12	20	19.5	15	17	12
CEC clay (cmolc/kg)	34	38	52	48	55	64	57	34	45	51.5	64	57
ECEC (cmolc/kg)	15	22	21	17	21	24	17	15	21.5	19	24	17
TEB (cmolc/kg)	17	20	20	17	21	24	15	17	20	19	24	15
Base Saturation (% CEC soil)	82	83	85	90	92	91	67	82	84	91	91	67
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	1	1	1	2	2	1	3	1	1	2	1	3
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	2	1	3	3	5	5	14	2	2	4	5	14
Electric Conductivity (dS/m)	1	0	0	0	0	0	1	1	0	0	0	1

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Table 3.34 below presents the soil hydraulic properties of the Chromic Cambisols profile. Since HWSD 2.0 does not provide information on hydraulic properties, these values were derived using a soil hydraulic property calculator based on the consolidated layers shown in Table 3.33 above.

Table 3.34: Hydraulic Properties of Chromic Cambisols Soil Layers

	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	Dept layer D7
Permanent wilting point (%)	20.0	22.8	22.7	23.3	14.0
Field capacity (%)	33.5	36.3	35.5	36.4	25.7
Saturation (%)	50.7	51.6	51.3	51.6	47.0
Conductivity (mm/hr)	2.531	2.042	1.905	1.896	5.738
Conductivity (mm/day)	60.744	49.008	45.720	45.504	137.712

Source: Adapted from The Soil Water Characteristics Hydraulic Properties Calculator from (DYNSTEM, 2025) based on equations from Saxton et al. (1986)

3.2.3.5.5 Application of Soil Data in AquaCrop Simulations for the Impala Irrigation Scheme

Sugarcane yields will be simulated separately for each of the four dominant soil units identified in the main irrigation zone of the Impala Irrigation Scheme, as shown in Figure 3.27 below. A weighted average yield will then be calculated across these four soil types, based on the proportional area each soil unit occupies within the main irrigation zone.

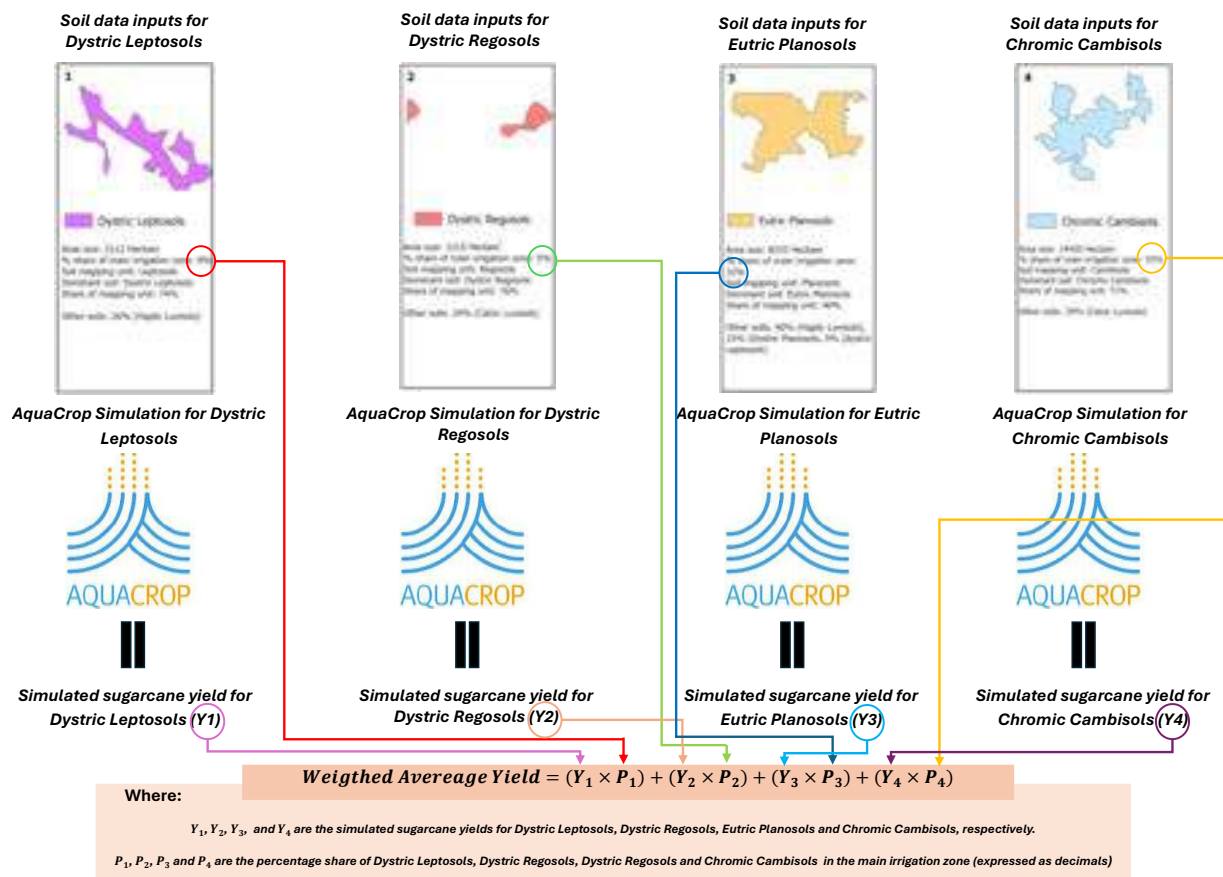


Figure 3.27: Summary of Soil Data Approach for AquaCrop Simulations in the Impala Irrigation Scheme

Source: Project team compilation

3.2.3.6 Kakamas irrigation scheme

Figure 3.28 below presents a series of maps illustrating the spatial distribution of soils within the Kakamas study area. The first map delineates the broader study area and highlights the main irrigation scheme, indicating where the bulk of irrigation activity occurs. Figure 3.28, Panel A, focuses on this core irrigation zone and overlays it with the dominant soil group layer, revealing that the main soil groups in the area are Arenosols, Cambisols, and Fluvisols. Figure 3.28, Panel B provides further detail by identifying the dominant soil units occurring within these main soil groups, specifically Chromic Cambisols, Eutric Fluvisols, and Ferralic Arenosols. To make the results more relatable to a South African audience, the explanation provides supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale) available in Appendix D (Tables D.10–D.12) and Figure D.4.

Land Cover and Main Irrigation Area of the Kakamas Irrigation Scheme

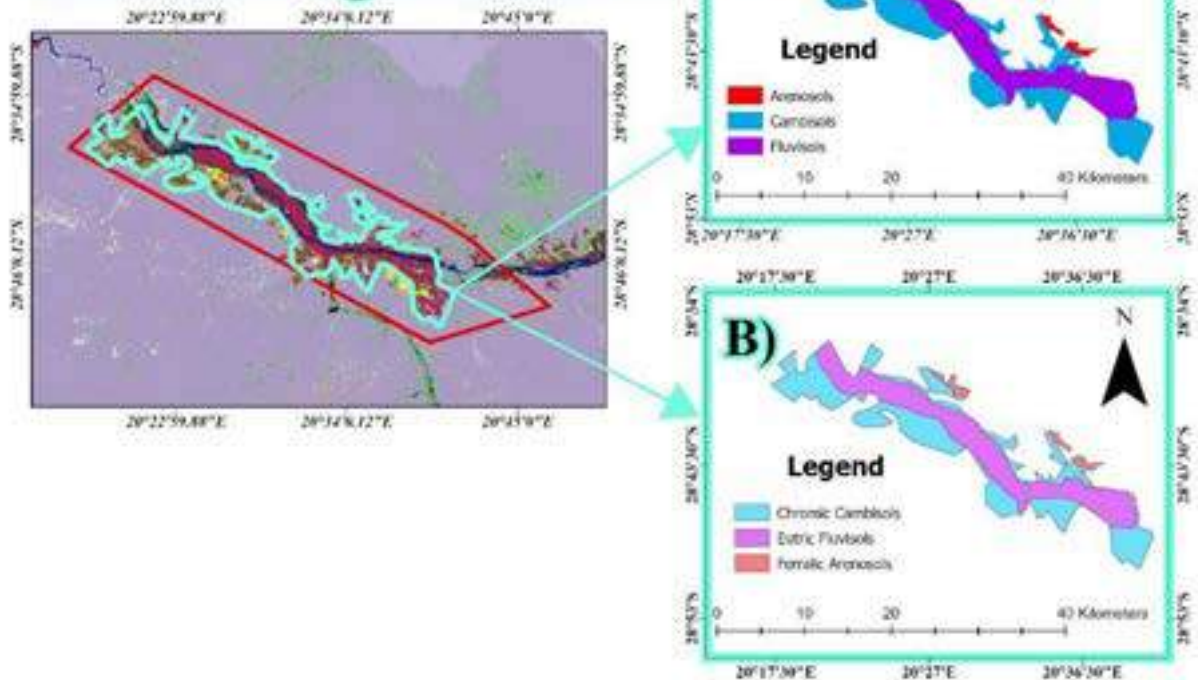


Figure 3.28: Dominant soil units and dominant soil types within the main irrigation zone of the Kakamas Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.29 below provides an overview of the soil distribution of the dominant soil units identified in Figure 3.28, Panel B above. Using the Calculate Geometry function in ArcGIS, the area covered by each dominant soil unit within the main irrigation zone of the Kakamas Irrigation Scheme was determined. The results show that Ferralic Arenosols cover approximately 695 hectares, Eutric Fluvisols cover 9,528 hectares, and Chromic Cambisols occupy the largest area, at 11,609 hectares.

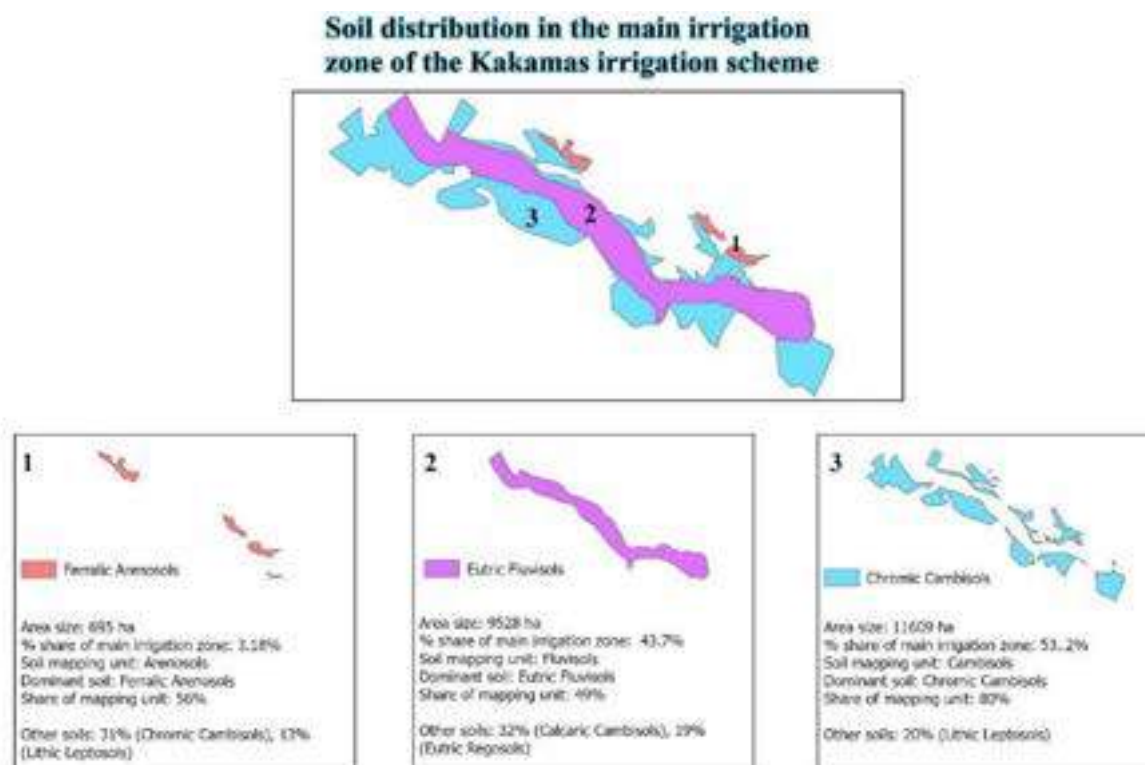


Figure 3.29: Dominant Soil Types in the Main Irrigation Zone of the Impala Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.30 below illustrates the integration of the main irrigation zone of the Kakamas Irrigation Scheme into the HWS2.0 database. The polygon shapefile representing the core irrigation area, previously created in ArcGIS, was imported into HWS2.0 to enable the extraction and alignment of standardised global soil classification data with the Kakamas Irrigation Scheme.



Figure 3.30: Main Irrigation Zone of the Hartbeespoort Irrigation Scheme Overlaid in HWSD2.0 for Soil Data Extraction

Source: Project team's compilation using HWSD2.0

3.2.3.6.1 Ferralic Arenosols soil properties

Table 3.35 below provides an overview of the Ferralic Arenosols soil unit in the main irrigation zone of the Kakamas Irrigation Scheme. The Ferralic Arenosols hold a 56% share in the soil mapping unit. The associated soils are Chromic Cambisols, which account for 31% of the mapping unit, and Lithic Leptosols, which comprise the remaining 69%.

Table 3.35: Soil Properties of Ferralic Arenosols in the main Irrigation zone of the Kakamas Irrigation Scheme

Coverage	SOTWIS		
Soil Mapping Unit (SMU)	28417		
Dominant Soil Unit (WRB 2022)	Acrisol (ARse)		
Dominant Soil Unit (FAO 1990)	Ferralic Arenosols (ARo)		
	Dominant soil	Associated soils and inclusions	
Sequence in Soil Mapping Unit	1	2	3
Share in Soil Mapping Unit (%)	56	31	13
Database Internal ID	28672	74666	160969
Soil Unit Symbol (WRB 2022)	ARse	CMcr	LPli
Soil Unit Name (WRB correlat.FAO90)	Sideritic Arenosols	Chromic Cambisols	Lithic Leptosols
Soil Unit Symbol (FAO 1990)	ARo	CMx	LPq
Soil Unit Name (FAO 1990)	Ferralic Arenosols	Chromic Cambisols	Lithic Leptosols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)	Very shallow (< 10 cm)
Reference Soil Drainage	Somewhat excessively drained	Moderately well-drained	Imperfectly drained
AWC for Rootable Soil Depth (mm)	82	162	10

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.36 below presents the soil data obtained from the HWSD2.0. The left-hand side of the table displays the original seven soil layers extracted from the HWSD2.0 dataset. However, to align with AquaCrop's input structure, which allows a maximum of five soil layers, two adjacent pairs of layers were combined to form a single layer. Specifically, Layer 2 (20 to 40 cm) was merged with Layer 3 (40 to 60 cm) and Layer 4 (60 to 80 cm) with Layer 5 (80 to 100 cm).

This decision was based on the observation that the layers in each pair were physically and chemically similar. For example, all layers were classified as loamy sand, with consistent sand content (around 89 to 90%), bulk density (1.5 to 1.6 g/cm³), field capacity (5.6% to 5.8%), and wilting point (1.4%). By consolidating these layers, the soil profile retains its representativeness while ensuring compatibility with the model's structural limitations. The simplification avoids redundancy and maintains the integrity of vertical soil water dynamics in the AquaCrop simulations.

Table 3.36: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Kakamas Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 + D3	Dept layer D4 and D5	Dept layer D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	100	150	200
Coarse fragments (% volume)	2	4	4	6	6	31	4	2	4	6	31	4
Sand (% weight)	90	89	89	89	90	90	90	90	89	89.5	90	90
Silt (% weight)	4	4	4	4	3	3	3	4	4	3.5	3	3
Clay (% weight)	6	7	7	7	7	7	7	6	7	7	7	7
Texture class (USDA conventions)	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
Bulk Density (g/cm ³)	1.6	1.6	1.6	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.6	1.6
Reference Bulk Density (g/cm ³)	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.4	1.4	1.4	1.4
Organic Carbon Content (% weight)	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.3	0.15	0.1	0.1	0.1
pH in water (-log(H ⁺))	5.9	5.8	5.7	5.6	5.6	5.7	5.6	5.9	5.75	5.6	5.7	5.6
Total nitrogen content (g/kg)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.15	0.1	0.1	0.1
Carbon/Nitrogen ratio (C/N)	12	12	12	11	11	11	9	12	12	11	11	9
CEC soil (cmolc/kg)	2	2	2	2	2	2	2	2	2	2	2	2
CEC clay (cmolc/kg)	25	25	24	25	27	28	26	25	24.5	26	28	26
ECEC (cmol/kg)	2	2	2	2	2	2	1	2	2	2	2	1
TEB (cmolc/kg)	2	2	2	2	2	2	2	2	2	2	2	2
Base Saturation (% CEC soil)	75	78	78	72	72	72	40	75	78	72	72	40
Aluminium saturation (% ECEC)	6	6	6	6	6	6	6	6	6	6	6	6
Exchangeable Sodium Percentage (%)	3	3	4	4	5	7	5	3	3.5	4.5	7	5
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	0	0	0	1	1	0	0	0	0	1	0	0
Electric Conductivity (dS/m)	0	0	0	0	0	0	0	0	0	0	0	0

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Since the HWSD 2.0 does not provide the soil hydraulic properties required by AquaCrop, a hydraulic calculator was used to derive these properties, based on the sand and clay content of each layer. Table 3.37 below presents the derived hydraulic properties.

Table 3.37: Hydraulic Properties of Consolidated Soil Layers for AquaCrop

	Dept layer D1	Dept layer D2 + D3	Dept layer D4+D5	Dept layer D6	Dept layer D7
Permanent wilting point (%)	6.3	6.9	6.9	6.9	6.9
Field capacity (%)	13.7	14.4	14.3	14.2	14.2
Saturation (%)	36.6	37.5	37.5	37.5	37.5
Conductivity (mm/hr)	65.547	53.479	53.893	54.314	54.314
Conductivity (mm/day)	1573.128	1283.496	1293.432	1303.536	1303.536

Source: Adapted from The Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations obtained from Saxton *et al.* (1986)

3.2.3.6.2 Eutric Fluvisols Soil Properties

Table 3.38 below presents the general soil data obtained from HWSD 2.0. The Eutric Fluvisols soil unit accounts for 49% of the mapping unit. The associated soils comprise Calcaric Cambisols, accounting for 32% of the mapping unit, and Eutric Regosols, which account for 19% of the mapping unit. The AquaCrop simulation will focus only on the dominant soil type in the mapping unit.

Table 3.38: Soil Properties of Eutric Fluvisols in the main Irrigation zone of the Kakamas Irrigation Scheme

Coverage	SOTWIS		
Soil Mapping Unit (SMU)	28375		
Dominant Soil Unit (WRB 2022)	Eutric Fluvisol (FLeu)		
Dominant Soil Unit (FAO 1990)	Eutric Fluvisols (FLe)		
	Dominant soil	Associated soils and inclusions	
Sequence in Soil Mapping Unit	1	2	3
Share in Soil Mapping Unit (%)	49	32	19
Database Internal ID	86603	44570	262430
Soil Unit Symbol (WRB 2022)	FLeu	CMca	RGeu
Soil Unit Name (WRB correlat.FAO90)	Eutric Fluvisols	Calcaric Cambisols	Eutric Regosols
Soil Unit Symbol (FAO 1990)	FLe	CMc	RGe
Soil Unit Name (FAO 1990)	Eutric Fluvisols	Calcaric Cambisols	Eutric Regosols
Rootable Soil Depth	Deep (> 100 cm)	Deep (> 100 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Moderately well-drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	142	173	106

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.39 below presents the soil data obtained from the HWSD 2.0. The left-hand side of the table displays the original seven soil layers extracted from the HWSD 2.0 dataset. However, to align with AquaCrop's input structure, which allows a maximum of five soil layers, two adjacent pairs of layers were merged. Specifically, Layer 1 (0 to 20 cm) was merged with Layer 2 (20 to 40 cm), and Layer 5 (80 to 100 cm) was merged with Layer 6 (100 to 150 cm). This decision was based on the observation that the layers in each pair were physically and chemically similar. For example, the paired layers had consistent texture classes (both sandy loam), comparable sand content (around 54 to 57%), bulk density (1.5 g/cm^3), organic carbon content (0.5 to 0.8%), and pH values (7.5 to 7.8).

Table 3.39: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Kakamas Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1 + D2	Dept layer D3	Dept layer D4	Dept layer D5 + D6	D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	40	60	80	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	40	60	80	150	200
Coarse fragments (% volume)	3	2	2	4	11	11	18	2.5	2	4	11	18
Sand (% weight)	55	54	53	55	56	57	60	54.5	53	55	56.5	60
Silt (% weight)	27	27	27	27	25	24	23	27	27	27	24.5	23
Clay (% weight)	18	19	20	18	19	19	17	18.5	20	18	19	17
Texture class (USDA conventions)	Sandy loam	Sandy loam	Sandy clay loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Sandy loam	Sandy loam	Sandy loam
Bulk Density (g/cm ³)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Reference Bulk Density (g/cm ³)	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Organic Carbon Content (% weight)	0.8	0.5	0.4	0.3	0.3	0.2	0.3	0.65	0.4	0.3	0.25	0.3
pH in water (-log(H ⁺))	7.5	7.7	7.7	7.8	7.7	7.8	8.2	7.6	7.7	7.8	7.75	8.2
Total nitrogen content (g/kg)	0.9	0.7	0.4	0.4	0.3	0.3	0.3	0.8	0.4	0.4	0.3	0.3
Carbon/Nitrogen ratio (C/N)	9	9	8	8	8	9	7	9	8	8	8.5	7
CEC soil (cmolc/kg)	14	13	14	13	11	14	12	13.5	14	13	12.5	12
CEC clay (cmolc/kg)	63	65	67	69	63	67	76	64	67	69	65	76
ECEC (cmolc/kg)	22	24	25	25	25	25	32	23	25	25	25	32
TEB (cmolc/kg)	22	21	24	23	24	25	32	21.5	24	23	24.5	32
Base Saturation (% CEC soil)	94	98	96	98	98	100	100	96	96	98	99	100
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	4	5	5	6	6	6	19	4.5	5	6	6	19
Calcium Carbonate (% weight)	2	2	3	2	3	2	3	2	3	2	2.5	3
Gypsum content (% weight)	1	1	1	1	1	2	1	1	1	1	1.5	1
Electric Conductivity (dS/m)	2	1	1	2	2	2	3	1.5	1	2	2	3

Source: Adapted from Harmonized World Soil Database v2.0 (HWSD)

Table 3.40 below presents the soil hydraulic properties derived by using a soil hydraulic calculator, which estimates values based on the percentage of sand and clay in each soil layer. Since the HWSD 2.0 database does not provide the soil hydraulic properties required by AquaCrop, such as field capacity, wilting point, and saturated hydraulic conductivity, these properties were externally derived. The resulting parameters for each of the five merged soil layers are shown in Table 3.40, and these were used as input for the AquaCrop simulations.

Table 3.40: Hydraulic Properties of Consolidated Soil Layers for AquaCrop

	Dept layer D1 + D2	Dept layer D3	Dept layer D4	Dept layer D5 + D6	D7
Permanent wilting point (%)	12.2	12.8	12.0	12.4	11.7
Field capacity (%)	23.5	24.1	23.3	23.3	22.2
Saturation (%)	45.4	46.0	45.2	45.4	44.5
Conductivity (mm/hr)	8.987	7.640	9.506	8.345	10.429
Conductivity (mm/day)	215.688	183.360	228.144	200.28	250.296

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations obtained from Saxton et al. (1986)

3.2.3.6.3 Chromic Cambisols soil properties

Table 3.41 below presents a general overview of the soil units found in the Kakamas Irrigation Scheme. The dominant soil type in this mapping unit comprises the Chromic Cambisols, which account for 80% of the area. The associated soil comprises the Lithic Leptosols, which occupy the remaining 20% of the mapping unit. For the AquaCrop simulations, only the dominant soil unit, Chromic Cambisols, was used as the basis for input data.

Table 3.41: Soil Properties of Chromic Cambisols in the main Irrigation zone of the Kakamas Irrigation Scheme

Coverage	SOTWIS	
Soil Mapping Unit (SMU)	28439	
Dominant Soil Unit (WRB 2022)	Akroskeletal Chromic Cambisols (CMcrkk)	
Dominant Soil Unit (FAO 1990)	Chromic Cambisols (CMx)	
	Dominant soil	Associated soils and inclusions
Sequence in Soil Mapping Unit	1	2
Share in Soil Mapping Unit (%)	65	20
Database Internal ID	74828	161231
Soil Unit Symbol (WRB 2022)	CMcrkk	LPli
Soil Unit Name (WRB correlat.FAO90)	Chromic Cambisols	Lithic Leptosols
Soil Unit Symbol (FAO 1990)	CMx	LPq
Soil Unit Name (FAO 1990)	Chromic Cambisols	Lithic Leptosols
Rootable Soil Depth	Deep (> 100 cm)	Very shallow (< 10 cm)
Reference Soil Drainage	Moderately well-drained	Imperfectly drained
AWC for Rootable Soil Depth (mm)	162	10

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

To comply with AquaCrop's five-layer limit, the original seven soil layers from HWSD2.0 were consolidated, based on similarities in key physical and chemical properties. Layer D3 was merged with D4, as both share nearly identical texture (sandy clay loam), sand/silt/clay content, bulk density, organic carbon, pH, nitrogen, and cation exchange characteristics. Similarly, Layers D5 and D6 were combined because of their closely aligned texture, bulk density, organic carbon, and pH, with minimal variation in other properties. The original and merged layers are presented in Table 3.42 below.

Table 3.42: Chromic Cambisols Soil Properties Comparing HWSD Seven Layers and Merged Five Layers for AquaCrop Simulation

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	Dept layer D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	100	150
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	100	150	200
Coarse fragments (% volume)	9	7	11	17	10	19	9	9	9	13.5	19	9
Sand (% weight)	61	56	59	57	58	60	49	61	57.5	57.5	60	49
Silt (% weight)	19	19	17	18	19	18	28	19	18	18.5	18	28
Clay (% weight)	20	25	24	25	23	22	23	20	24.5	24	22	23
Texture class (USDA conventions)	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loam
Bulk Density (g/cm ³)	1.4	1.3	1.4	1.4	1.5	1.5	1.5	1.4	1.35	1.45	1.5	1.5
Reference Bulk Density (g/cm ³)	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8
Organic Carbon Content (% weight)	0.7	0.5	0.4	0.4	0.3	0.3	0.2	0.7	0.45	0.35	0.3	0.2
pH in water (-log(H ⁺))	6.7	7	7.1	7.1	7.4	7.5	8.2	6.7	7.05	7.25	7.5	8.2
Total nitrogen content (g/kg)	0.8	0.5	0.4	0.4	0.4	0.5	0.3	0.8	0.45	0.4	0.5	0.3
Carbon/Nitrogen ratio (C/N)	11	11	8	8	8	7	8	11	9.5	8	7	8
CEC soil (cmolc/kg)	11	13	13	13	15	15	14	11	13	14	15	14
CEC clay (cmolc/kg)	45	45	53	57	60	59	79	45	49	58.5	59	79
ECEC (cmolc/kg)	13	16	13	13	22	18	45	13	14.5	17.5	18	45
TEB (cmolc/kg)	12	15	13	18	23	16	45	12	14	20.5	16	45
Base Saturation (% CEC soil)	82	92	92	93	93	84	100	82	92	93	84	100
Aluminium saturation (% ECEC)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium Percentage (%)	1	2	2	2	2	2	24	1	2	2	2	24
Calcium Carbonate (% weight)	0	1	1	10	11	11	10	0	1	10.5	11	10
Gypsum content (% weight)	2	2	2	2	2	2	3	2	2	2	2	3
Electric Conductivity (dS/m)	1	1	1	1	1	1	1	1	1	1	1	1

Source: Project team using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.43 provides an overview of the soil hydraulic properties of five consolidated soil layers presented on the right-hand side of Table 3.42.

Table 3.43: Hydraulic Properties of Chromic Cambisols Soil Layers

	Dept layer D1	Dept layer D2 and D3	Dept layer D4 and D5	Dept layer D6	D7
Permanent wilting point (%)	12.9	14.8	14.6	13.8	14
Field capacity (%)	23.0	24.9	24.8	23.8	25.7
Saturation (%)	45.4	46.8	46.6	46	47
Conductivity (mm/hr)	7.176	4.489	4.729	5.741	5.738
Conductivity (mm/day)	172.20	107.74	113.50	137.78	137.71

Source: Adapted from the Soil Water Characteristics Hydraulic Properties Calculator from (DYNSSYSTEM, 2025) based on equations obtained from Saxton et al. (1986)

3.2.3.6.4 Application of Soil Data in AquaCrop Simulations for the Impala Irrigation Scheme

Figure 3.31 below provides an overview of how AquaCrop simulations were conducted within the main irrigation scheme of the Kakamas Irrigation Area. Three distinct soil units have been identified in this zone. To estimate the overall crop yield, a weighted average yield was calculated across these soil units, with weights proportional to the area each soil type occupies within the main irrigation scheme.

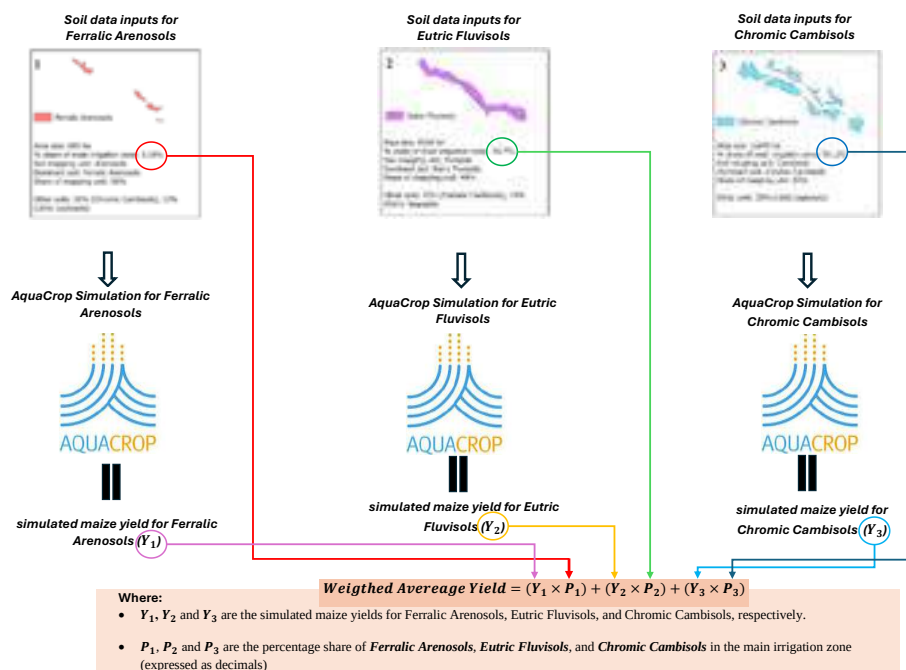


Figure 3.31: Summary of Soil Data Approach for AquaCrop Simulations in the Kakamas Irrigation Scheme

Source: Project team compilation

3.2.3.7 Tshiombo irrigation scheme

Figure 3.32 below provides a spatial overview of the Tshiombo Irrigation Scheme using three maps. The first map displays the broader land cover layers, with the study area highlighted in red. Within this boundary, the main irrigation zone was delineated in blue, based on a visual assessment of land cover patterns. Figure 3.32, Panel A, shows that the dominant soil group within this irrigation zone comprises Lixisols, with no other soil groups present in the area. Figure 3.32, Panel B, further specifies the soil unit within this group as Haplic Lixisols, which is the sole soil unit found in the main irrigation zone. To make the results more relatable to a South African audience, the explanation provides supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale) available in Appendix D (Tables D.13–D.15) and Figure D.5.

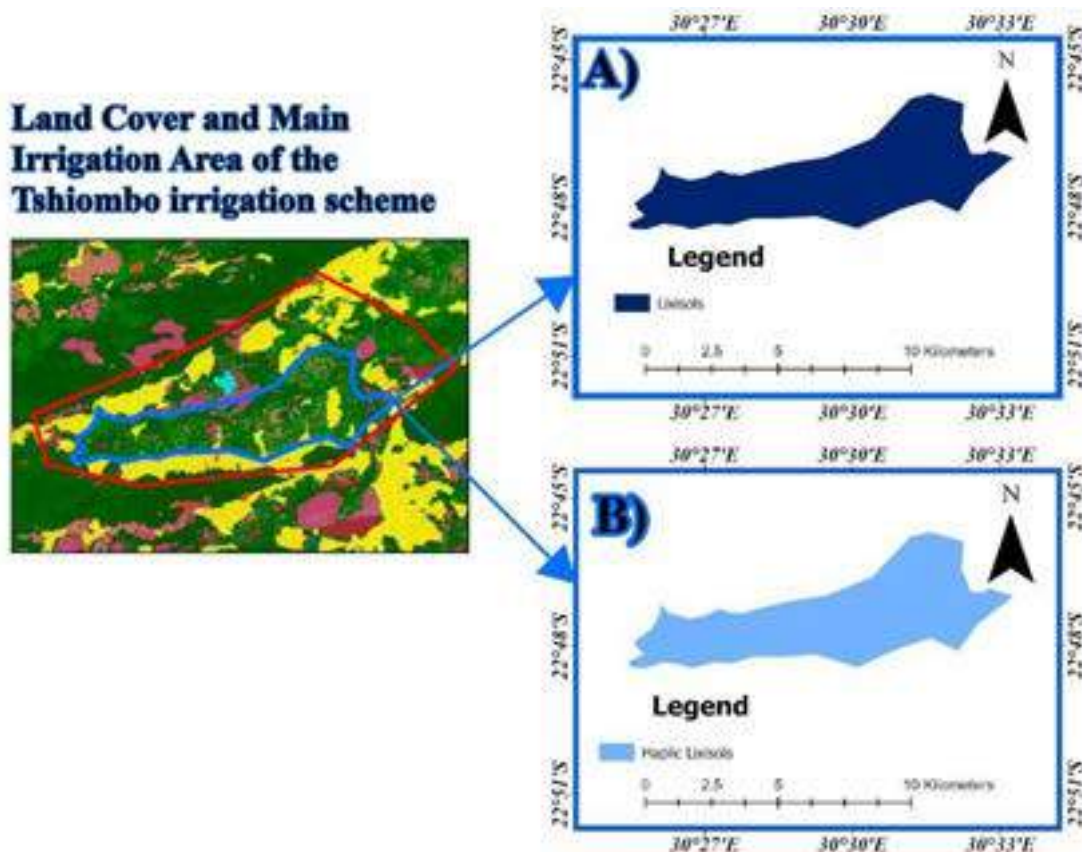


Figure 3.32: Dominant soil units and dominant soil types within the main irrigation zone of the Tshiombo Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.33 below provides an overview of the dominant soil type, Haplic Lixisols, within the main irrigation zone of the study area. The area covered by this soil type is approximately 3,064 hectares, representing 48% of the mapping unit within the irrigation zone.

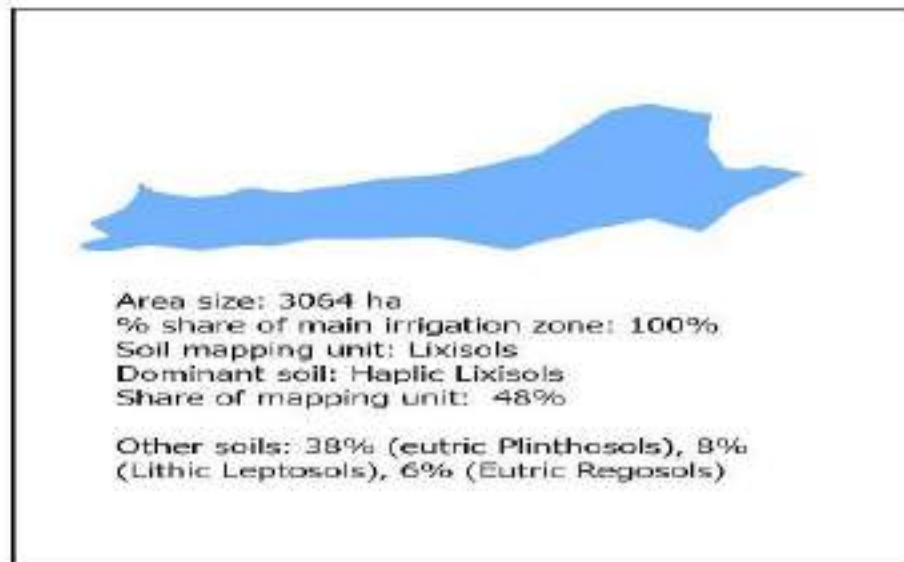


Figure 3.33: Dominant Soil Type in the Main Irrigation Zone of the Tshiombo Irrigation Scheme

Source: Project team compilation using ArcGIS Pro version 10.7.1

Figure 3.34 below shows the polygon shapefile of the main irrigation scheme imported into HWSD 2.0, from which soil data for the Haplic Lixisols were extracted.

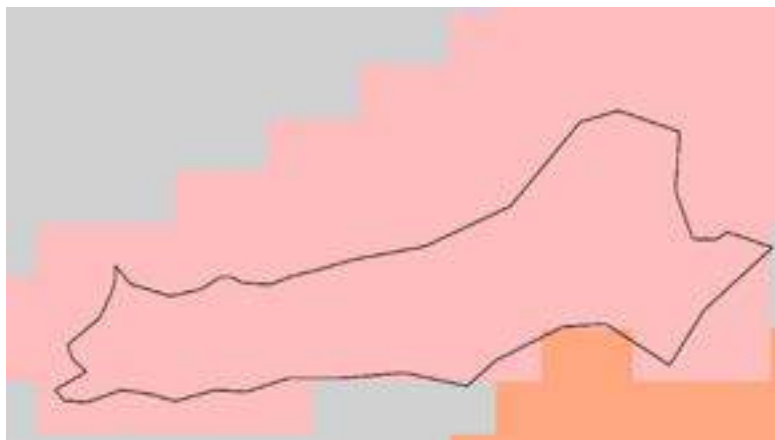


Figure 3.34: Main Irrigation Zone of the Tshiombo Irrigation Scheme Overlaid in HWSD 2.0 for Soil Data Extraction

Source: Project team compilation using HWSD2.0

3.2.3.7.1 Haplic Lixisols soil properties

Table 3.44 below provides an overview of the general soil information obtained from the HWSD 2.0. The dominant soil unit within the mapping unit shown in Figure 3.34 above is Haplic Lixisols, accounting for 48% of the area. This mapping unit also includes three associated soils: Eutric Plinthosols, with a 38% share; Lithic Leptosols, with an 8% share; and Eutric Regosols, with a 6% share.

Table 3.44: Soil Properties of Haplic Lixisols soil unit in the main Irrigation zone of the Tshiombo Irrigation Scheme

Coverage	SOTWIS			
Soil Mapping Unit (SMU)	30705			
Dominant Soil Unit (WRB 2022)	Haplic Lixisol (LXha)			
Dominant Soil Unit (FAO 1990)	Haplic Lixisols (LXh)			
	Dominant soil	Associated soils and inclusions		
Sequence in Soil Mapping Unit	1	2	3	4
Share in Soil Mapping Unit (%)	48	38	8	6
Database Internal ID	211910	240389	160248	262260
Soil Unit Symbol (WRB 2022)	LXha	PTeu	LPli	RGeu
Soil Unit Name (WRB correlat.FAO90)	Haplic Lixisols	Eutric Plinthosols	Lithic Leptosols	Eutric Regosols
Soil Unit Symbol (FAO 1990)	LXh	PTe	LPq	RGe
Soil Unit Name (FAO 1990)	Haplic Lixisols	Eutric Plinthosols	Lithic Leptosols	Eutric Regosols
Rootable Soil Depth	Deep (> 100cm)	Deep (> 100 cm)	Very shallow (< 10 cm)	Deep (> 100 cm)
Reference Soil Drainage	Moderately well-drained	Poorly drained	Imperfectly drained	Moderately well-drained
AWC for Rootable Soil Depth (mm)	132	126	10	106

Source: Project team compilation using data obtained from the Harmonized World Soil Database (HWSD version 2.0), downloaded from FAO (2023)

Table 3.45 below presents the original seven soil layers for the Haplic Lixisols, as obtained from HWSD2.0 on the left-hand side, and the five consolidated layers used for AquaCrop simulations on the right-hand side. To comply with AquaCrop's limit of a maximum of five soil layers, layers were merged based on similarities in key soil characteristics. Specifically, D2 (20–40 cm) and D3 (40–60 cm) were combined because they share nearly identical physical and chemical properties, including texture class, bulk density, organic carbon content, pH, and nutrient levels. Similarly, D6 (100–150 cm) and D7 (150–200 cm) were merged because of their comparable texture, bulk density, organic carbon, and cation exchange capacity. These consolidations ensure that the simplified soil profile remains representative of the original data, while conforming to AquaCrop's input requirements.

Table 3.45: Original HWSD Soil Layers and Consolidated Layers for AquaCrop Input in the Tshiombo Irrigation Scheme

	Original soil data obtained from HWSD (Seven Layers)							Soil Profile Input data AquaCrop (Five Layers)				
	Dept layer D1	Dept layer D2	Dept layer D3	Dept layer D4	Dept layer D5	Dept layer D6	Dept layer D7	Dept layer D1	Dept layer D2 and D3	Dept layer D4	Depth layer D5	Depth layer D6 and D7
Depth of top of layer (cm)	0	20	40	60	80	100	150	0	20	60	80	100
Depth of the bottom of the layer (cm)	20	40	60	80	100	150	200	20	60	80	100	200
Coarse fragments (% volume)	3	2	4	23	14	11	12	3	3	23	14	11.5
Sand (% weight)	76	69	67	65	64	65	67	76	68	65	64	66
Silt (% weight)	10	10	9	10	9	9	9	10	9.5	10	9	9
Clay (% weight)	14	21	24	25	27	26	24	14	22.5	25	27	25
Texture class (USDA conventions)	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam
Bulk Density (g/cm ³)	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.5	1.5	1.5	1.5	1.6
Reference Bulk Density (g/cm ³)	1.6	1.8	1.8	1.8	1.8	1.8	1.8	1.6	1.8	1.8	1.8	1.8
Organic Carbon Content (% weight)	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.4	0.25	0.2	0.2	0.15
pH in water (-log(H ⁺))	6.1	5.9	6	5.9	6.1	6.1	5.9	6.1	5.95	5.9	6.1	6
Total nitrogen content (g/kg)	0.3	0.3	0.2	0.2	0.2	0.3	0.4	0.3	0.25	0.2	0.2	0.35
Carbon/Nitrogen ratio (C/N)	12	10	9	7	7	7	5	12	9.5	7	7	6
CEC soil (cmolc/kg)	5	5	5	6	5	6	4	5	5	6	5	5
CEC clay (cmolc/kg)	21	19	18	17	18	17	19	21	18.5	17	18	18
ECEC (cmolc/kg)	4	4	4	5	7	7	7	4	4	5	7	7
TEB (cmolc/kg)	3	4	4	4	5	6	7	3	4	4	5	6.5
Base Saturation (% CEC soil)	80	76	76	76	77	76	77	80	76	76	77	76.5
Aluminium saturation (% ECEC)	0	5	0	7	0	0	11	0	2.5	7	0	5.5
Exchangeable Sodium Percentage (%)	2	2	3	3	3	3	2	2	2.5	3	3	2.5
Calcium Carbonate (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum content (% weight)	0	0	0	0	0	0	0	0	0	0	0	0
Electric Conductivity (dS/m)	0	0	0	0	0	0	0	0	0	0	0	0

Source: Derived from Harmonized World Soil Database v2.0 (HWSD)

Table 3.46 below presents the soil hydraulic properties derived for the five consolidated Haplic Lixisol layers used in AquaCrop. As the HWSD2.0 database does not provide the hydraulic parameters required by the model, specifically field capacity, wilting point, and saturated hydraulic conductivity, these values were estimated externally using a pedotransfer function based on the sand and clay content of each layer. The resulting hydraulic parameters for each consolidated layer are listed in Table 3.45 above and were applied directly in the AquaCrop simulations.

Table 3.46: Hydraulic Properties of Haplic Lixisols Soil Layers

	Dept layer D1	Dept layer D2 + D3	Dept layer D4	Dept layer D5	Dept layer D6 + D7
Permanent wilting point (%)	10.5	14.1	15.2	16.0	15.2
Field capacity (%)	19.1	22.9	24.1	24.9	24.0
Saturation (%)	42.3	45.4	46.3	46.8	46.3
Conductivity (mm/hr)	15.198	5.104	3.969	3.269	3.935
Conductivity (mm/day)	364.752	122.496	95.256	78.456	94.44

Source: Derived from the Soil Water Characteristics Hydraulic Properties Calculator from DYNSTEM (2025) based on equations obtained from Saxton et al. (1986)

3.2.3.7.2 Application of Soil Data in AquaCrop Simulations for the Tshiombo Irrigation Scheme

For the Tshiombo Irrigation Scheme, the only soil group identified in the main irrigation zone comprised Lixisols. Within this group, the sole soil unit present was the Haplic Lixisols. Consequently, the AquaCrop simulation for this scheme was conducted using soil data exclusively for the Haplic Lixisols unit. This approach ensures that the soil profile used in the simulation accurately reflects the dominant soil conditions of the irrigation zone. Figure 3.35 below provides a visual overview of the Haplic Lixisols soil profile employed in the AquaCrop model.

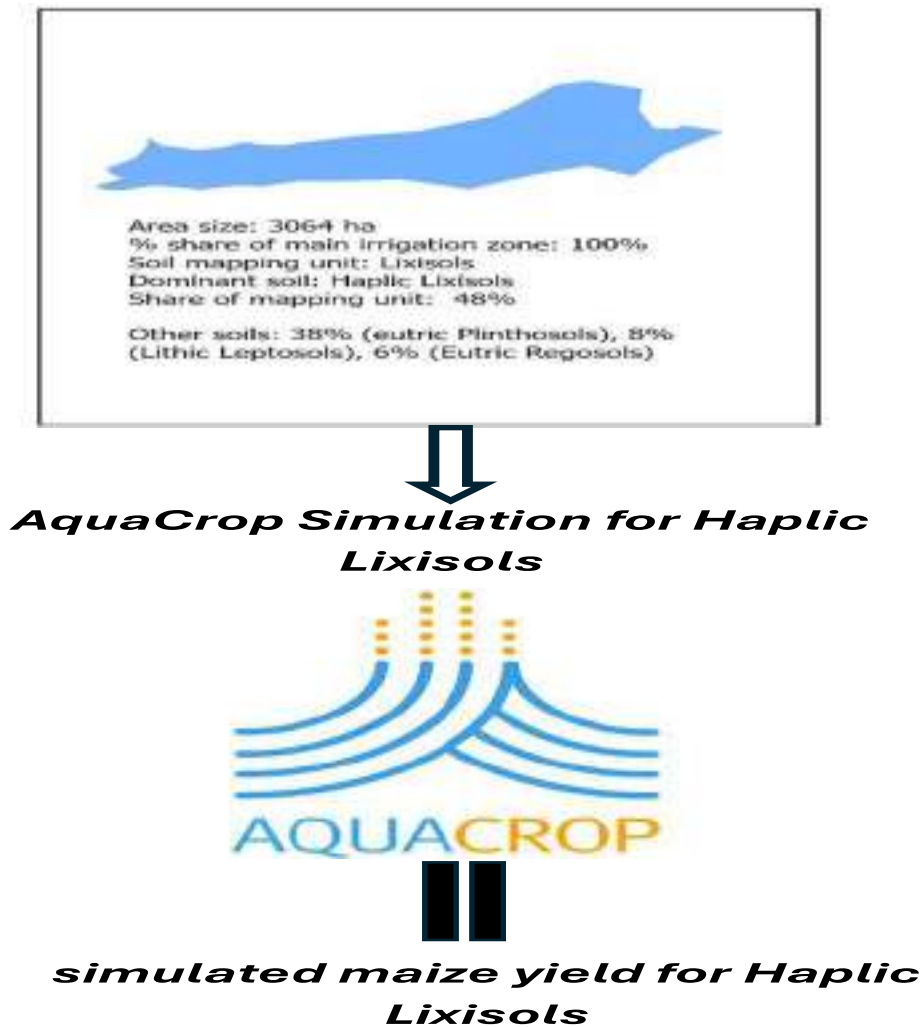


Figure 3.35: Summary of Soil Data Approach for AquaCrop Simulations in the Tshiombo Irrigation Scheme

Source: Project team compilation

3.2.3.8 Crop parameters

For the AquaCrop simulations, the default crop parameters incorporated into the model were utilised for maize, wheat, sugarcane, alfalfa/lucerne, and soybean. This was because the primary objective of this research is to develop an integrated framework that combines psychological, biophysical, and socio-economic aspects of food production in South Africa. As the focus was not on detailed crop calibration, employing the default parameters offered a straightforward and consistent starting point for the simulations (Raes et al., 2023).

3.2.3.9 Management data inputs

Data management practices were standardized mainly across the case studies to ensure comparability, while still allowing for adjustments based on locally relevant conditions, where necessary. Given this approach, the detailed data management inputs used in the AquaCrop simulations are presented within the respective case studies of Chapters 4-9, where they are contextualised in relation to each irrigation scheme and crop production system.

3.2.3.10 Irrigation scheduling

The irrigation schedules implemented in this study were established based on the gross irrigation requirements pertinent to each case study. These requirements are influenced by a combination of factors, including crop type, soil characteristics, and the climatic conditions prevailing in each irrigation area scheme.

Since these parameters vary across different study areas, detailed irrigation schedules are not presented here. Instead, the specific irrigation schedules used in the simulations are reported within each case study presented in Chapters 4 to 9, where they are contextualised based on local conditions and crop-specific requirements.

3.2.4 Social Accounting Matrix (SAM)

Before explaining the construction of the Social Accounting Matrix (SAM) for 2020, it is essential to formulate a general overview of SAM. In layman's terms, a SAM is a matrix that depicts the relationships between all the various role players in the national economy, including business sectors, households, and the government. It reflects all of the intersectoral relationships within the economy (Bahta, 2013; Arndt et al., 2020).

The most fundamental principles underlying a SAM are circular flows and double-entry bookkeeping. The concept of circular flows refers to a particular perspective from which an economic system is viewed and analysed. The various economic sectors, known as “activities” in a SAM, act as producers and sellers of goods and services, referred to as “commodities,” to households, enterprises, the government, and other producers in the economy. These institutions serve as the “purchasers” of these commodities. For their part, households, enterprises, and the government provide factor services to the various sectors, which then become the purchasers of these factors.

To allow a clear understanding of the basic concept of SAM, Table 3.47 below illustrates the fundamental concepts of SAM. This table captures all transfers within sectors and economic institutions. Productive

activities require inputs from the factor and commodity markets to produce goods and services that are distributed to households, the government, investors, and foreign entities. Breisinger et al. (2009) further explain that the goods and services produced by these activities are complemented by imports (M) and sold through the commodities market to households (C), government (G), investors (I), and foreigners (E). As indicated by the figure, each institution's expenditure becomes another institution's income. For example, household and government spending provide the income for the businesses that produce those goods and services. This income is crucial for businesses to continue operating and producing more. To ensure that money keeps circulating, other financial activities come into play, such as the taxes that households and businesses pay, which the government collects.

Breisinger et al. (2009) explained that activities are defined as entities that produce goods and services, while commodities are regarded as the goods and services produced by the activities. To illustrate, Table 3.47 below indicates that column 1 (C1) represents the activities that pay factors the wages, rent, and profits they generate during production. The payment is being made from activities to factors, and therefore, the value-added entry is made in the activity column and the factor row (R3-C1). Intermediate demand refers to payments made from activities to commodities (R2-C1). By summing the value added (R3-C1) and intermediate demand (R2-C1) results, the gross output is obtained. Commodities are either supplied domestically (R1-C2) or imported (R7-C2). Indirect sales taxes and import tariffs are paid on these commodities (R5-C2). Activities buy commodities to be used as intermediate inputs for production (R2-C1).

The final demand for commodities comprises household consumption spending (R2-C4), government consumption or recurrent expenditure (R2-C5), gross capital formation or investment (R2-C6), and export demand (R2-C7).

Table 3.47: The basic structure of a social accounting matrix (SAM)

	Activities C1	Commodities C2	Factors C3	Households C4	Government C5	Savings and investment C6	The rest of the world C7	Total
Activities R1		Domestic supply						Activity income
Commodities R2	Intermediate demand			Consumption spending (C)	Recurrent expenditure (G)	Investment demand (I)	Export earnings (E)	Total demand
Factors R3	Value-added							Total income factor
Households R4			Factor payments to households		Social transfers		Foreign remittances	Total household income
Government R5		Sales taxes and import tariffs		Direct taxes				Government income
Savings and investment R6				Private earnings	Fiscal surplus		Current account balance	Total savings
The rest of the world R7								Foreign exchange outflow
Total	Gross output	Total supply	Total factor spending	Total household spending	Government expenditure	Total investment spending	Foreign exchange inflow	

Source: Adapted from Breisinger et al. (2009)

To develop an integrated framework that combines psychological, biophysical, and socio-economic aspects of food production in South Africa, a Social Accounting Matrix (SAM) must be established. The SAM functions as both a database and a tool for partial equilibrium (multiplier analysis). In this particular project, after completing all the processes or stages outlined in Chapter 1 of the innovation section, the scenarios were derived from the AquaCrop model and simulated in the SAM to assess the broader economic and

social impacts of changes in water use behaviour, including the effects on socio-economic conditions at household, provincial, and regional (South Africa) levels.

The project team, with assistance from various stakeholders, particularly DALRRD, constructed the SAM for 2020 through using a variety of data sources, including, but not limited to, Supply and Use Tables, the South African Reserve Bank, Census Commercial Agriculture, Living Conditions Surveys, Regional Global Insight, Quarterly Labour Force Surveys, the General Household Survey, data on product and income taxes, data on exports and imports, and others.

The constructed SAM for 2020 comprises 265 accounts: 117 activities/industries (of which agricultural industries are disaggregated into 24 agricultural subsectors, including commodities/production used in this project, one for forestry, and fishing), 129 products/commodities (with agricultural commodities also disaggregated into 24 agricultural subsectors), one margin account, one account for capital, one account for land, four accounts for labour, four accounts for households, one enterprise, three tax accounts, one account for government, one account for investment/savings, change inventories, and one international trade (export/import) account.

A 2020 Macro-SAM for South Africa (R million) is available in Appendix E, Table E.1. A detailed disaggregation of commodities and production interests, such as maize, wheat, soybeans, lucerne, and sugarcane, will occur. Other variable interests, including households, labour, and land, will be disaggregated accordingly.

For this project, we applied for the disaggregated level of SAM, which consists of 265 accounts. The main disaggregated accounts include Lucern_Northern Cape, Maize_Free State, Sugar Cane_KZN, Wheat_North West, Soyabeans_North West, Maize_Small-Scale_Limpopo, Free State Labour, KwaZulu-Natal Labour, North West Labour, Limpopo Labour, land in South Africa, provinces, and irrigation schemes, as well as other accounts.

Given that the SAM needs disaggregation to meet the project's objectives, this disaggregation includes, but is not limited to, each irrigation scheme and food product incorporated into the project, utilising various sources of data. As a result of the disaggregation, the SAM Unbalanced must be balanced. A cross-entropy method is used to balance the SAM with GAMS software. The cross-entropy approach was employed to balance the SAM (Bahta et al., 2014; Fofana et al., 2008; Lee & Su, 2014; Robinson et al., 2000).

Balancing a SAM by using the cross-entropy (CE) approach is now a routine procedure in most SAM-based modelling applications. Robinson et al. (2000) emphasised that the CE technique is based on Shannon's (1948) information theory, which Theil (1967) applied to economics. The main idea is that the expected

information value of additional data can be expressed as a Kullback & Leibler (1951) cross-entropy distance “ $I(x: z)$ ” between the prior (x) and posterior (z) probability distributions of a set of “m” events, as explained in Equation 3.1:

$$-I(x: z) = \sum_{i=0}^m P_i \ln \frac{x_i}{z_i} \quad (3.1)$$

The goal of the CE problem is to determine the set of “xi” that minimises Equation (3.1) by utilising previous data knowledge. The objective in SAM estimation or updating is to construct a new SAM coefficient matrix “A*” that minimises the CE distance between itself and the prior (or initial and likely imbalanced) coefficient matrix “A”. This minimisation problem can be expressed as follows, if “a*ij” and “aij” are the respective elements of “A*” and “A”:

$$\text{Min} \left[\sum_i \sum_j a_{ij} \ln \frac{a^*_{ij}}{a_{ij}} \right] = \text{Subject to: } \sum_j a_{ij} y^*_j = y^*_i; \sum_j a_{ji} = 1 \text{ and } 0 \leq a_{ji} \leq 1 \quad (3.2)$$

After setting up the Lagrangian multiplier, the problem in Equation (3.2) does not have a closed-form solution and must be solved numerically. However, the ideal solution “a*ij” may be expressed as a function of both the Lagrange multipliers “T” associated with the row and column sums and the initial coefficient “aij”:

$$a^*_{ij} = \frac{a_{ij} \exp(\lambda_i y^*_j)}{\sum_{i,j} a_{ij} \exp(\lambda_i y^*_j)} \quad (3.3)$$

Robinson et al. (2000) compared Equation (3.3) to Bayes' rule, which states that the posterior distribution equals the sum of the prior distribution and the likelihood function, divided by a normalisation factor to convert relative probabilities to “absolute ones.” Consequently, Equation (3.3) can be viewed as an effective information processing rule that adheres to Zellner's information conservation principle (Zellner, 1962). It does not neglect any of the input data and yields accurate results. Robinson et al. (2000) justify their assertion that the CE estimator is consistent and exhibits maximum likelihood features under specific distributional assumptions.

Equation (3.2) further examines the fundamental minimisation issue by incorporating aggregation constraints and measurement errors. A typical aggregation constraint for k limitations can be expressed as follows:

$$\sum_i \sum_j g_{ij}^{(k)} t_j = y^{(k)} \quad (3.4)$$

where “gij” denotes an “n-by-n” aggregator matrix, consisting of ones for aggregate cells and zeros for all other cells. Assume there are “k” aggregation constraints in total. Similarly, measurement errors are accounted for in the following manner:

$$y = x + e \quad (3.5)$$

Where “y” is a vector of row sums, and “x”, measured with error “e”, is the vector of known column sums. The error is expressed as a weighted average of known constants “v_{i,w}”:

$$e_i = \sum_w w_{i,w} \cdot v_{i,w} \quad (3.6)$$

$$\sum_w w_{i,w} = 1 \text{ and } 0 \leq w_{i,w} \leq 1$$

The weights are treated as probabilities, which are estimated alongside the elements of the matrix “A*”. The estimation procedure employed in this study is based on five weights that are symmetrically distributed around zero. The minimisation problem in Equation (3.2) is solved, subject to Equations (3.4–3.6).

3.2.5 Ethical Considerations

The Project team was guided by several ethical considerations in collecting primary data: informed consent, privacy, and confidentiality. The Project team ensured that informed consent was obtained from each research participant before administering research instruments. An informed consent statement is designed to fully inform participants about what the research entails and its purpose. Strict adherence is enforced to guarantee that the privacy and confidentiality of participants are protected at all times. No personally identifiable information about the participants is disclosed to any third party.

Ethical clearance for the protocol followed during data collection was approved by the Research Ethics Committee at the University of the Free State, in accordance with the General/Human Research Ethics (GHREC) guidelines and regulations, Reference number UFS-HSD2023/1327. Participants took part voluntarily after the ethical principles were publicly declared. All participants were informed, and they completed and signed a consent form before actively participating in the study.

3.3 Method – Empirical Specifications

3.3.1 Theory of Planned Behaviour

To examine farmers' behaviours related to water use, this study utilised extended versions of the Theory of Planned Behaviour for three key behaviours. These comprised the adoption of water-saving technologies, the implementation of water-saving policies, and adaptation to climate variability. Each behavioural model

was constructed on the same theoretical foundation, incorporating the standard TPB constructs of attitude, subjective norms, and perceived behavioural control, along with additional context-specific variables where appropriate to enhance explanatory power. These models were employed across six different crops, resulting in a total of eighteen applications. However, as the theoretical structure and empirical approach remained consistent across all cases, it is unnecessary to present the specification for each model separately. Instead, the model for the adoption of water-saving technologies among commercial maize irrigators in the Orange Riet Irrigation Scheme is presented as a representative example to illustrate how the extended Theory of Planned Behaviour (TPB) framework was empirically applied.

3.3.2 Extended Theory of Planned Behaviour Model

Hair et al. (2021) provide a structured approach for conducting PLS-SEM analysis, which consists of the stages shown in Figure 3.36 below. For this study, only Stages 1, 2, 3, 4, 5a, 6, and 8 are relevant to achieving the research objectives. Specifically, all constructs in the TPB model are measured reflectively, making Stage 5b unnecessary. Additionally, the advanced PLS-SEM techniques in Stage 7 fall outside the scope of this study. The pertinent stages will be explained in detail in the following sections.

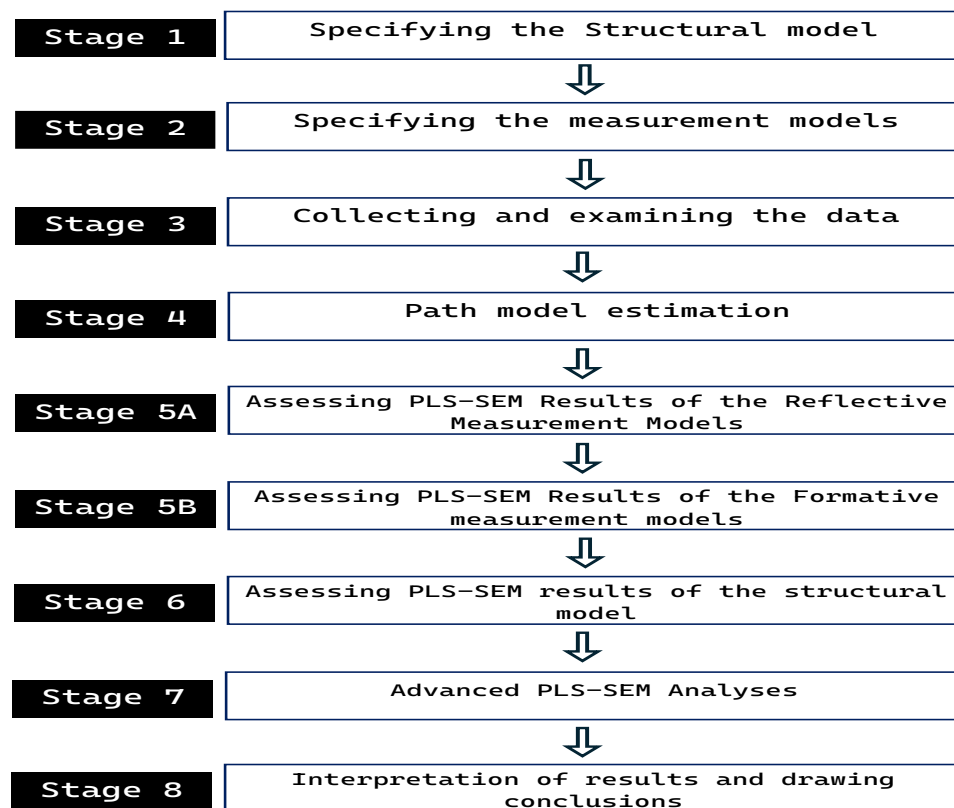


Figure 3.36: A systematic approach in applying partial Least Squares Structural Equation modelling (PLS-SEM)

Source: Adapted from Hair et al. (2021)

3.3.2.1 Specifying the structural model

According to Hair et al. (2021), an essential first step in any SEM analysis is to create a path model that clearly outlines the research hypotheses and visually represents the relationships among the variables under investigation. Path models generally consist of two elements: the structural model and the measurement models. Typically, path models include a structural model that outlines the causal relationships among latent variables, and measurement models that demonstrate how these variables are linked to their indicators.

To illustrate the distinction between the measurement and structural components of the behavioural models used in this project, the path model depicted in Figure 3.37 below provides a visual representation of the extended Theory of Planned Behaviour framework. Different shapes are employed to differentiate key elements in the model, with circles representing error terms. Rectangles represent observed measurement items, while diamonds denote additional constructs included in the extended framework. Ellipses represent the core TPB constructs: Attitudes (A_B), Subjective Norms (SN), Perceived Behavioural Control (PBC), and Intention (INT). The structural relationships between latent variables are illustrated using colour-coded paths, with each of the twelve constructs linked to its own set of measurement items via red paths.

In the structural model, constructs are further classified as exogenous or endogenous. Exogenous latent variables function solely as independent variables and possess only outgoing paths to other constructs. These are depicted as diamond shapes in the diagram. Ellipses represent endogenous latent variables and act as dependent variables, receiving paths from other constructs. As explained by Hair et al. (2021), constructs that serve as both predictors and outcomes, such as A_B , SN , and PBC , are also considered endogenous.

The model illustrated in Figure 3.37 below, derived from an analysis of water-saving technology adoption by commercial maize irrigators within the Orange Riet Irrigation Scheme, exemplifies the empirical specification approach that is consistently applied to all crops and behavioural scenarios in this project.

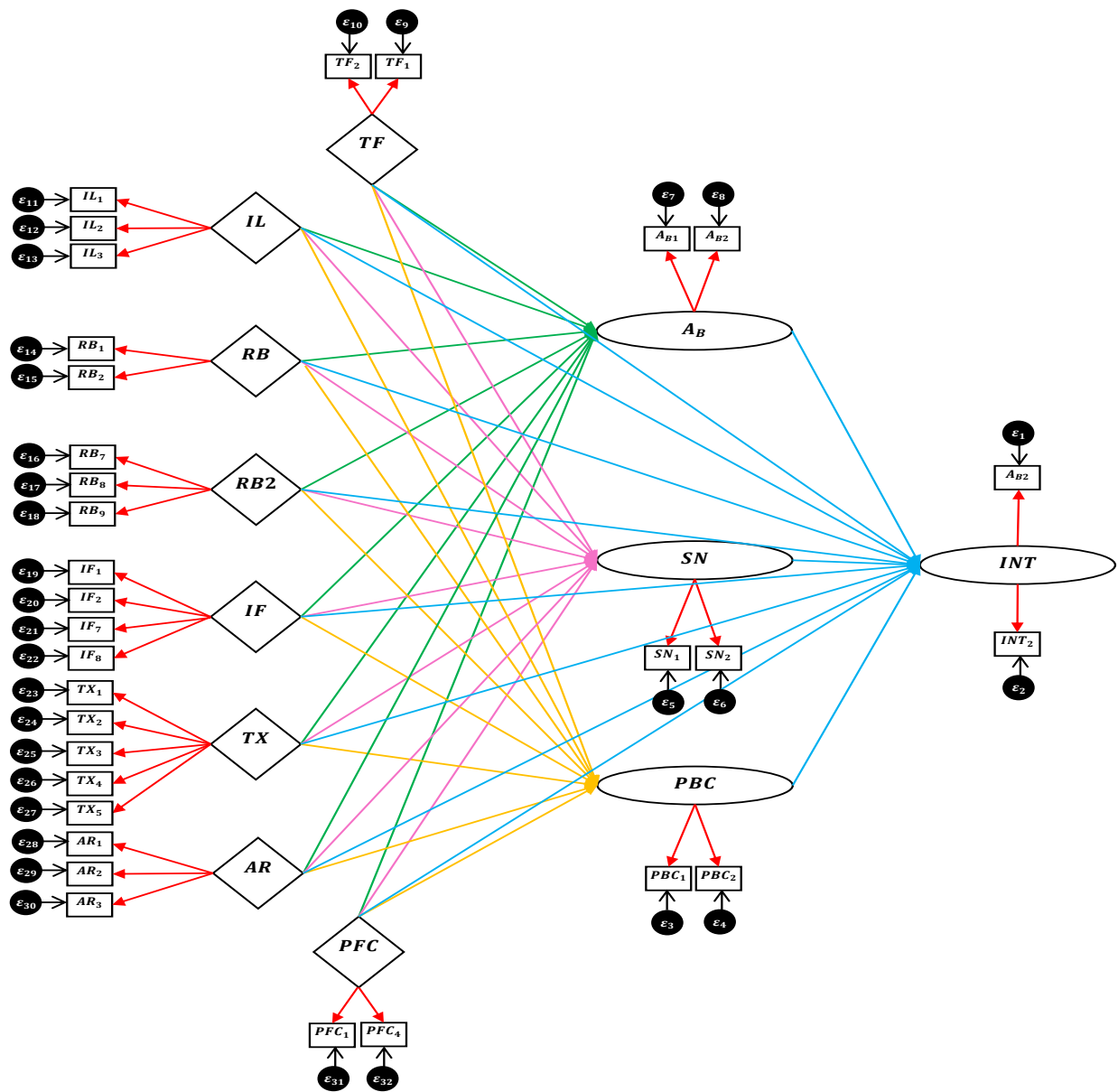


Figure 3.37: Integrated Structural and Measurement Model for Exploring Irrigators' Behaviour in Adopting Water-saving Technologies

Note:

- A circle represents an error term, a rectangle represents a measurable item, a diamond represents the additional constructs included, and an ellipse represents the standard TPB latent constructs.
- A_B -Attitudes; SN -Subjective norms; PBC -Perceived behavioural control; INT -Intentions; TF -Technical Factors; IL -Institutional and Legal Factors; RB -Perceived risks and benefits; $RB2$ -Perceived Risks from Load-shedding and Tariffs; IF -Informational factors; TX -Trust Factors; AR -Access to resources; PFC -Perceived financial costs.
- Red arrows represent the relationships in the measurement models, while blue, green, yellow, and pink arrows indicate the structural model relationships.

Source: Project team compilation

3.3.2.1.1 Structural Model Specification of Direct Effects

The structural model for the adoption of water-saving technologies is presented in Equations 3.7 to 3.10 below. These equations elucidate how behavioural intention and its associated factors are modelled, including both the standard TPB constructs and additional external factors. The arrows in Figure 3.37 above, coloured blue, green, pink, and orange, illustrate the relationships described by these equations. The model employs data derived from commercial maize farmers in the Orange Riet Irrigation Scheme as an example. The same approach is applied to other behaviours and crops within this research project.

$$A_B = \alpha_1 + \beta_{1,1}TF + \beta_{1,2}IF + \beta_{1,3}RB + \beta_{1,4}RB2 + \beta_{1,5}IL + \beta_{1,6}AR + \beta_{1,7}PFC + \beta_{1,8}TX + \varepsilon_1 \quad (3.7)$$

$$SN = \alpha_2 + \beta_{2,1}TF + \beta_{2,2}IF + \beta_{2,3}RB + \beta_{2,4}RB2 + \beta_{2,5}IL + \beta_{2,6}AR + \beta_{2,7}PFC + \beta_{2,8}TX + \varepsilon_2 \quad (3.8)$$

$$PBC = \alpha_3 + \beta_{3,1}TF + \beta_{3,2}IF + \beta_{3,3}RB + \beta_{3,4}RB2 + \beta_{3,5}IL + \beta_{3,6}AR + \beta_{3,7}PFC + \beta_{3,8}TX + \varepsilon_3 \quad (3.9)$$

$$INTEN_{WST} = \alpha_4 + \gamma_1 A_B + \gamma_2 SN + \gamma_3 PBC + \delta_1 TF + \delta_2 IF + \delta_3 RB + \delta_4 RB2 + \delta_5 IL + \delta_6 AR + \delta_7 PFC + \delta_8 TX + \varepsilon_4 \quad (3.10)$$

where:

- α_i Are intercepts for each endogenous construct equation;
- $\beta_{i,j}$ Coefficients capture the effects of the j -th exogenous variable on the i -th endogenous construct (Attitude, Subjective Norms, Perceived Behavioural Control);
- γ_i Coefficients capture the effects of the standard TPB (A_B , SN , PBC) on the intention to adopt water-saving technologies ($INTEN_{WST}$);
- δ_i Coefficients capture the direct effects of the exogenous variables on Behavioural Intention;
- ε_i Are disturbance (error) terms for each endogenous construct.

3.3.2.1.2 Structural Model Specification of Specific Indirect Effects

This section presents the specific indirect effects (**SIE**) of the exogenous constructs (**TF**, **IF**, **RB**, **RB2**, **IL**, **AR**, **PFC**, **TX**) on the endogenous construct $INTEN_{WST}$ via the mediating constructs A_B , SN , and PBC . Each specific indirect effect is represented as the product of the path from the exogenous variable to the mediator and the path from the mediator to the outcome.

$$SIE_{TF \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,1} \cdot \gamma_1 \quad (3.11)$$

$$SIE_{TF \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,1} \cdot \gamma_2 \quad (3.12)$$

$$SIE_{TF \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,1} \cdot \gamma_3 \quad (3.13)$$

$$SIE_{IF \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,2} \cdot \gamma_1 \quad (3.14)$$

$$SIE_{IF \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,2} \cdot \gamma_2 \quad (3.15)$$

$$SIE_{IF \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,2} \cdot \gamma_3 \quad (3.16)$$

$$SIE_{RB \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,3} \cdot \gamma_1 \quad (3.17)$$

$$SIE_{RB \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,3} \cdot \gamma_2 \quad (3.18)$$

$$SIE_{RB \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,3} \cdot \gamma_3 \quad (3.19)$$

$$SIE_{RB2 \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,4} \cdot \gamma_1 \quad (3.20)$$

$$SIE_{RB2 \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,4} \cdot \gamma_2 \quad (3.21)$$

$$SIE_{RB2 \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,4} \cdot \gamma_3 \quad (3.22)$$

$$SIE_{IL \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,5} \cdot \gamma_1 \quad (3.23)$$

$$SIE_{IL \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,5} \cdot \gamma_2 \quad (3.24)$$

$$SIE_{IL \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,5} \cdot \gamma_3 \quad (3.25)$$

$$SIE_{AR \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,6} \cdot \gamma_1 \quad (3.26)$$

$$SIE_{AR \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,6} \cdot \gamma_2 \quad (3.27)$$

$$SIE_{AR \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,6} \cdot \gamma_3 \quad (3.28)$$

$$SIE_{PFC \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,7} \cdot \gamma_1 \quad (3.29)$$

$$SIE_{PFC \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,7} \cdot \gamma_2 \quad (3.30)$$

$$SIE_{PFC \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,7} \cdot \gamma_3 \quad (3.31)$$

$$SIE_{TX \rightarrow A_B \rightarrow INTEN_{WST}} = \beta_{1,8} \cdot \gamma_1 \quad (3.32)$$

$$SIE_{TX \rightarrow SN \rightarrow INTEN_{WST}} = \beta_{2,8} \cdot \gamma_2 \quad (3.33)$$

$$SIE_{TX \rightarrow PBC \rightarrow INTEN_{WST}} = \beta_{3,8} \cdot \gamma_3 \quad (3.34)$$

3.3.2.1.3 Structural Model Specification of total indirect effects

This section presents the total indirect effects of each exogenous construct (**TF**, **IF**, **RB**, **RB2**, **IL**, **AR**, **PFC**, **X**) on the intention to adopt water-saving technologies ($INTEN_{WST}$). Total indirect effects represent the cumulative influence of a variable on the dependent variable ($INTEN_{WST}$) via all mediating pathways, specifically through Attitudes (**A_B**), Subjective Norms (**SN**), and Perceived Behavioural Control (**PBC**). Each total indirect effect is calculated by summing the products of the relevant path coefficients along each indirect path. These effects are critical for understanding how background factors shape behavioural intentions indirectly through the TPB mediators. Equations 3.35–3.42 specify the mathematical expressions of these total indirect effects for each exogenous construct.

$$TIE_{TF} = (\beta_{1,1} \cdot \gamma_1) + (\beta_{2,1} \cdot \gamma_2) + (\beta_{3,1} \cdot \gamma_3) \quad (3.35)$$

$$TIE_{IF} = (\beta_{1,2} \cdot \gamma_1) + (\beta_{2,2} \cdot \gamma_2) + (\beta_{3,2} \cdot \gamma_3) \quad (3.36)$$

$$TIE_{RB} = (\beta_{1,3} \cdot \gamma_1) + (\beta_{2,3} \cdot \gamma_2) + (\beta_{3,3} \cdot \gamma_3) \quad (3.37)$$

$$TIE_{RB2} = (\beta_{1,4} \cdot \gamma_1) + (\beta_{2,4} \cdot \gamma_2) + (\beta_{3,4} \cdot \gamma_3) \quad (3.38)$$

$$TIE_{IL} = (\beta_{1,5} \cdot \gamma_1) + (\beta_{2,5} \cdot \gamma_2) + (\beta_{3,5} \cdot \gamma_3) \quad (3.39)$$

$$TIE_{AR} = (\beta_{1,6} \cdot \gamma_1) + (\beta_{2,6} \cdot \gamma_2) + (\beta_{3,6} \cdot \gamma_3) \quad (3.40)$$

$$TIE_{PFC} = (\beta_{1,7} \cdot \gamma_1) + (\beta_{2,7} \cdot \gamma_2) + (\beta_{3,7} \cdot \gamma_3) \quad (3.41)$$

$$TIE_{TX} = (\beta_{1,8} \cdot \gamma_1) + (\beta_{2,8} \cdot \gamma_2) + (\beta_{3,8} \cdot \gamma_3) \quad (3.42)$$

3.3.2.1.4 Structural Model Specification: total effects

This section presents the total effects of each exogenous construct (**TF**, **IF**, **RB**, **RB2**, **IL**, **AR**, **PFC**, **TX**) on the intention to adopt water-saving technologies ($INTEN_{WST}$). A total effect is the sum of the direct effect and all indirect effects of a construct on the dependent variable. This provides a complete picture of the construct's overall influence on intention, accounting for both its immediate impact and the mediated pathways through Attitudes (**A_B**), Subjective Norms (**SN**), and Perceived Behavioural Control (**PBC**). Equations 37 to 44 present the total effect equations, combining the direct effect (δ_i) with all specific indirect components.

$$TE_{TF} = \delta_1 + (\beta_{1,1} \cdot \gamma_1) + (\beta_{2,1} \cdot \gamma_2) + (\beta_{3,1} \cdot \gamma_3) \quad (3.43)$$

$$TE_{IF} = \delta_2 + (\beta_{1,2} \cdot \gamma_1) + (\beta_{2,2} \cdot \gamma_2) + (\beta_{3,2} \cdot \gamma_3) \quad (3.44)$$

$$TE_{RB} = \delta_3 + (\beta_{1,3} \cdot \gamma_1) + (\beta_{2,3} \cdot \gamma_2) + (\beta_{3,3} \cdot \gamma_3) \quad (3.45)$$

$$TE_{RB2} = \delta_4 + (\beta_{1,4} \cdot \gamma_1) + (\beta_{2,4} \cdot \gamma_2) + (\beta_{3,4} \cdot \gamma_3) \quad (3.46)$$

$$TE_{IL} = \delta_5 + (\beta_{1,5} \cdot \gamma_1) + (\beta_{2,5} \cdot \gamma_2) + (\beta_{3,5} \cdot \gamma_3) \quad (3.47)$$

$$TE_{AR} = \delta_6 + (\beta_{1,6} \cdot \gamma_1) + (\beta_{2,6} \cdot \gamma_2) + (\beta_{3,6} \cdot \gamma_3) \quad (3.48)$$

$$TE_{PFC} = \delta_7 + (\beta_{1,7} \cdot \gamma_1) + (\beta_{2,7} \cdot \gamma_2) + (\beta_{3,7} \cdot \gamma_3) \quad (3.49)$$

$$TE_{TX} = \delta_8 + (\beta_{1,8} \cdot \gamma_1) + (\beta_{2,8} \cdot \gamma_2) + (\beta_{3,8} \cdot \gamma_3) \quad (3.50)$$

3.3.2.2 Specifying the measurement model

3.3.2.2.1 Intentions

The reflective measurement model for Intentions consists of two observed indicators (INT_1 and INT_2) that are influenced by the latent construct Intentions (INT). Thus, any alteration in the latent construct will result in a simultaneous change in its corresponding measurement items, which is the reason the arrows point from Intentions to the measurement items, as illustrated in Figure 3.38 below.

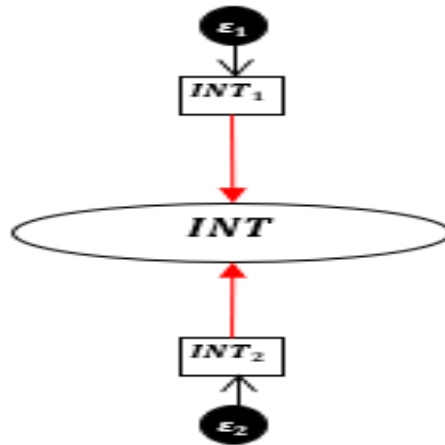


Figure 3.38: Reflective Measurement Model for the Latent Construct Intentions

Source: Project team compilation

Based on Figure 3.38 above, the equations representing the relationships between the latent construct intention (INT_1 and INT_2) and its indicators are presented in Equations 3.51–3.52:

$$INT_1 = \lambda_1 INT + \varepsilon_1 \quad (3.51)$$

$$INT_2 = \lambda_2 INT + \varepsilon_2 \quad (3.52)$$

where:

INT Latent construct for Intentions

INT_1, INT_2	Observed measurement items (indicators) for Intentions (INT)
λ_1, λ_2	Factor loadings representing the strength of the relationship between Intentions (INT) and its indicators (INT_1 and INT_2)
$\varepsilon_1, \varepsilon_2$	Measurement errors associated with INT_1 and INT_2

3.3.2.2.2 Attitudes

The reflective measurement model for Attitudes consists of two observed indicators (AB_1 and AB_2) the latent construct Attitudes influences that (A_B). If respondents' attitudes towards the adoption of water-saving technologies change, this will be reflected in the measurement items because of the model's reflective nature. The arrows pointing from Attitudes to the corresponding measurement items, as illustrated in Figure 3.39 below, represent this direct relationship between the latent construct and its indicators.

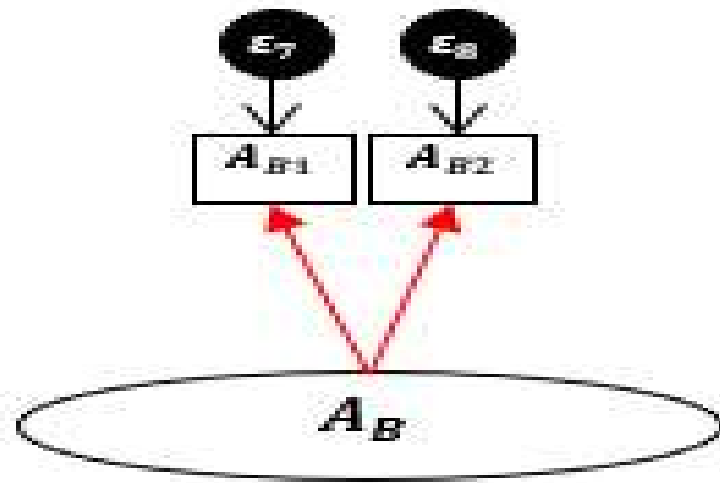


Figure 3.39: Reflective Measurement Model for the Latent Construct Attitudes (A_B)

Source: Project team compilation

The Equations (3.53–3.54) that represent this reflective measurement model for Attitudes are shown below, which detail the relationships between the latent construct and its two measurement items:

$$AB_1 = \lambda_3 A_B + \varepsilon_7 \quad (3.53)$$

$$AB_2 = \lambda_4 A_B + \varepsilon_8 \quad (3.54)$$

where:

A_B Latent construct for Attitudes

AB_1, AB_2	Observed measurement items (indicators) for Attitudes (A_B)
λ_3, λ_4	Factor loadings represent the strength of the relationship between A_B and its indicators (AB_1 and AB_2)
$\varepsilon_7, \varepsilon_8$	Measurement errors associated with AB_1 and AB_2

3.3.2.2.3 Subjective Norms

The reflective measurement model for Subjective Norms (SN) consists of two observed indicators (SN_1 and SN_2) that are influenced by the latent construct SN . The model is reflective, meaning that any changes in SN will be reflected in the measurement items, as shown in Figure 3.40 below. The arrows in the figure illustrate this relationship, pointing from SN to its respective indicators.

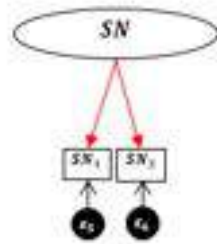


Figure 3.40: Reflective Measurement Model for the Latent Construct Subjective Norms (SN)

Source: Project team compilation

The Equations (3.55–3.56) that represent the reflective measurement model for SN , which define the relationships between the latent construct and its two measurement items, are as follows:

$$SN_1 = \lambda_5 SN + \varepsilon_5 \quad (3.55)$$

$$SN_2 = \lambda_6 SN + \varepsilon_6 \quad (3.56)$$

where:

SN	Latent construct for Subjective Norms
SN_1, SN_2	Observed measurement items (indicators) for SN
λ_5, λ_6	Factor loadings representing the strength of the relationship between SN and its indicators (SN_1 and SN_2)
$\varepsilon_5, \varepsilon_6$	Measurement errors associated with SN_1 and SN_2

3.3.2.2.4 Perceived Behavioural Control

The reflective measurement model for *PBC* consists of two observed indicators (*PBC*₁ and *PBC*₂) that are influenced by the latent construct *PBC*. Figure 3.41 below illustrates this relationship, with arrows indicating the direction of influence from *PBC* to its respective indicators.

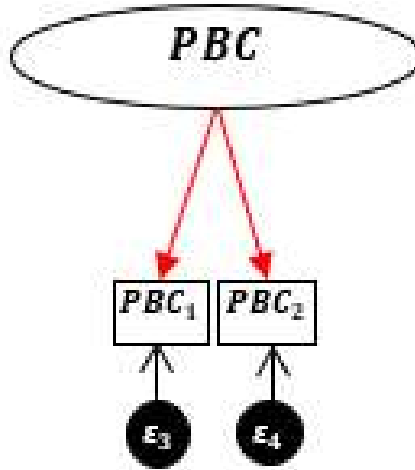


Figure 3.41: Reflective Measurement Model for the Latent Construct Perceived Behavioural Control (*PBC*)

Source: Project team compilation

The reflective measurement model for *PBC* is mathematically represented by Equations 3.57–3.58 below, which describe the relationships between the latent construct and its two measurement items:

$$PBC_1 = \lambda_7 PBC + \varepsilon_3 \quad (3.57)$$

$$PBC_2 = \lambda_8 PBC + \varepsilon_4 \quad (3.58)$$

where:

<i>PBC</i>	Latent construct for Perceived Behavioural Control
<i>PBC</i> ₁ , <i>PBC</i> ₂	Observed measurement items (indicators) for <i>PBC</i>
λ_7, λ_8	Factor loadings representing the strength of the relationship between <i>PBC</i> and its indicators (<i>PBC</i> ₁ and <i>PBC</i> ₂)
$\varepsilon_3, \varepsilon_4$	Measurement errors associated with <i>PBC</i> ₁ and <i>PBC</i> ₂

3.3.2.2.5 Technical factors

The reflective measurement model for Technical Factors (TF) consists of two observed indicators (TF_1 and TF_2) that are influenced by the latent construct T . This construct captures the technical aspects influencing the adoption of water-saving technologies. As with the other constructs, the model is reflective, so any change in TF will be reflected in its measurement items. The relationship between TF and its indicators is illustrated in Figure 3.42 below.

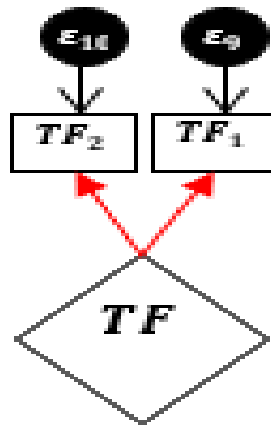


Figure 3.42: Reflective Measurement Model for the Latent Construct Technical Factors (TF)

Source: Project team compilation

The reflective measurement model for TF is mathematically represented by Equations 3.59–3.60, which define the relationships between the latent construct and its two measurement items:

$$TF_1 = \lambda_9 TF + \varepsilon_9 \quad (3.59)$$

$$TF_2 = \lambda_{10} TF + \varepsilon_{10} \quad (3.60)$$

where:

TF	Latent construct for Technical Factors
TF_1, TF_2	Observed measurement items (indicators) for TF
λ_9, λ_{10}	Factor loadings representing the strength of the relationship between TF and its indicators (TF_1 and TF_2)
$\varepsilon_9, \varepsilon_{10}$	Measurement errors associated with TF_1 and TF_2

3.3.2.2.6 Institutional and Legal Factors

The reflective measurement model for Institutional and Legal Factors (*IL*) consists of three observed indicators (IL_1 , IL_2 , and IL_3) that are influenced by the latent construct *IL*. This construct encompasses the institutional and legal factors that influence the adoption of water-saving technologies. As with other constructs, any change in *IL* will be reflected in its respective measurement items because of the reflective nature of the model. The relationship between *IL* and its indicators is illustrated in Figure 3.43 below.

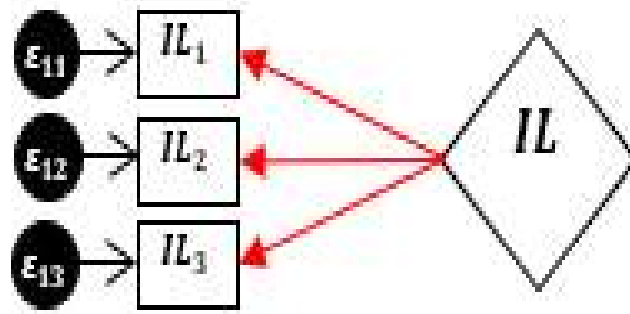


Figure 3.43: Reflective Measurement Model for the Latent Construct Institutional and Legal Factors (*IL*)

Source: Project team compilation

The reflective measurement model for *IL* is mathematically represented by Equations 3.61–3.63, defining the relationships between the latent construct and its three measurement items:

$$IL_1 = \lambda_{11}IL + \varepsilon_{11} \quad (3.61)$$

$$IL_2 = \lambda_{12}IL + \varepsilon_{12} \quad (3.62)$$

$$IL_3 = \lambda_{13}IL + \varepsilon_{13} \quad (3.63)$$

where:

IL	Latent construct for Institutional and Legal Factors
IL_1, IL_2, IL_3	Observed measurement items (indicators) for <i>IL</i>
$\lambda_{11}, \lambda_{12}, \lambda_{13}$	Factor loadings representing the strength of the relationship between <i>IL</i> and its indicators (IL_1 , IL_2 and IL_3)
$\varepsilon_{11}, \varepsilon_{12}, \varepsilon_{13}$	Measurement errors associated with IL_1 , IL_2 and IL_3

3.3.2.2.7 Perceived risks and benefits

The reflective measurement model for Perceived Risks and Benefits (RB) consists of two measurement items (RB_1 and RB_2), which act as indicators of the latent construct. Since the model is reflective, any alteration in RB will result in a corresponding change in its measurement items. The measurement model is illustrated in Figure 3.44 below.

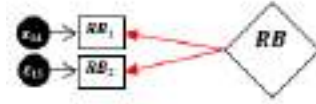


Figure 3.44: Reflective Measurement Model for the Latent Construct Perceived Risks and Benefits (RB)

Source: Project team compilation

The mathematical representation of the reflective measurement model for RB is provided in Equations 3.64–3.65, which define the relationships between the latent construct and its two measurement items:

$$RB_1 = \lambda_{14}RB + \varepsilon_{14} \quad (3.64)$$

$$RB_2 = \lambda_{15}RB + \varepsilon_{15} \quad (3.65)$$

where:

RB	Latent construct for Perceived Risks and Benefits
RB_1, RB_2	Observed measurement items (indicators) for RB
$\lambda_{14}, \lambda_{15}$	Factor loadings representing the strength of the relationship between RB and its indicators (RB_1 and RB_2)
$\varepsilon_{14}, \varepsilon_{15}$	Measurement errors associated with RB_1 and RB_2

3.3.2.2.8 Perceived Risks from Load-shedding and Tariffs

The reflective measurement model for Perceived Risk from Load-shedding and Tariffs ($RB2$) includes three measurement items (RB_7, RB_8 , and RB_9). This construct was included in the study to address specific factors such as load-shedding and rising tariffs. The measurement model is illustrated in Figure 3.45 below.

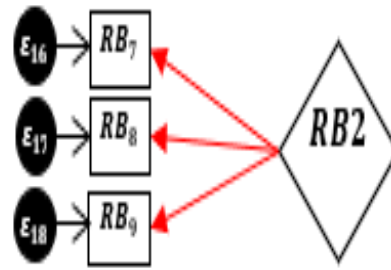


Figure 3.45: Reflective Measurement Model for the Latent Construct Perceived Risks from Load-shedding and Tariffs (*RB2*)

Source: Project team compilation

The Equations (3.66–3.68) for the reflective measurement model of *RB2*, which define the relationships between the latent construct and its three measurement items, are as follows.

$$RB_7 = \lambda_{16}RB2 + \varepsilon_{16} \quad (3.66)$$

$$RB_8 = \lambda_{17}RB2 + \varepsilon_{17} \quad (3.67)$$

$$RB_9 = \lambda_{18}RB2 + \varepsilon_{18} \quad (3.68)$$

where:

<i>RB2</i>	Latent construct for Perceived Risks from Load-shedding and Tariffs
<i>RB7</i> , <i>RB8</i> , <i>RB9</i>	Observed measurement items (indicators) for <i>RB2</i>
λ_{16} , λ_{17} , λ_{18}	Factor loadings representing the strength of the relationship between <i>RB2</i> and its indicators (<i>RB7</i> , <i>RB8</i> , and <i>RB9</i>)
ε_{16} , ε_{17} , ε_{18}	Measurement errors associated with <i>RB7</i> , <i>RB8</i> , and <i>RB9</i>

3.3.2.2.9 Informational factors

The reflective measurement model for Informational Factors (*IF*) consists of four measurement items (*IF1*, *IF2*, *IF7*, and *IF8*), which serve as indicators of the latent construct *IF*. The measurement model is illustrated in Figure 3.46 below.

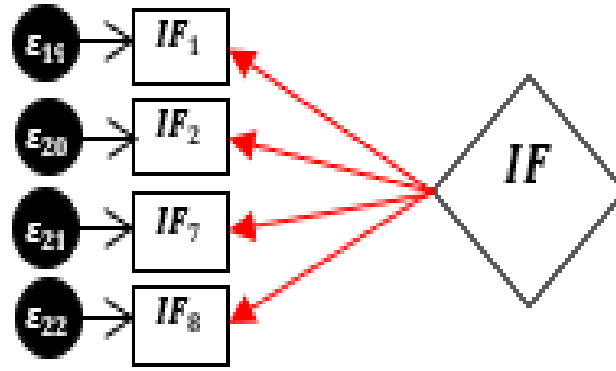


Figure 3.46: Reflective Measurement Model for the Latent Construct informational factors (*IF*)

Source: Project team compilation

The mathematical representation of the reflective measurement model for *IF* is provided in Equations 3.69–3.72, which define the relationships between the latent construct *IF* and its four measurement items:

$$IF_1 = \lambda_{19}IF + \varepsilon_{19} \quad (3.69)$$

$$IF_2 = \lambda_{20}IF + \varepsilon_{20} \quad (3.70)$$

$$IF_7 = \lambda_{21}IF + \varepsilon_{21} \quad (3.71)$$

$$IF_8 = \lambda_{22}IF + \varepsilon_{22} \quad (3.72)$$

where:

<i>IF</i>	Latent construct for Informational factors
<i>IF</i> ₁ , <i>IF</i> ₂ , <i>IF</i> ₇ , <i>IF</i> ₈	Observed measurement items (indicators) for <i>IF</i>
λ_{19} , λ_{20} , λ_{21} , λ_{22}	Factor loadings representing the strength of the relationship between <i>IF</i> and its indicators (<i>IF</i> ₁ , <i>IF</i> ₂ , <i>IF</i> ₇ , and <i>IF</i> ₈)
ε_{19} , ε_{20} , ε_{21} , ε_{22}	Measurement errors associated with <i>IF</i> ₁ , <i>IF</i> ₂ , <i>IF</i> ₇ , and <i>IF</i> ₈

3.3.2.2.10 Trust Factors

The reflective measurement model for Trust Factors (*TX*) consists of five dedicated measurement items (*TX*₁, *TX*₂, *TX*₃, *TX*₄, and *TX*₅), which serve as indicators of the latent construct Trust Factors. The measurement model is illustrated in Figure 3.47 below.

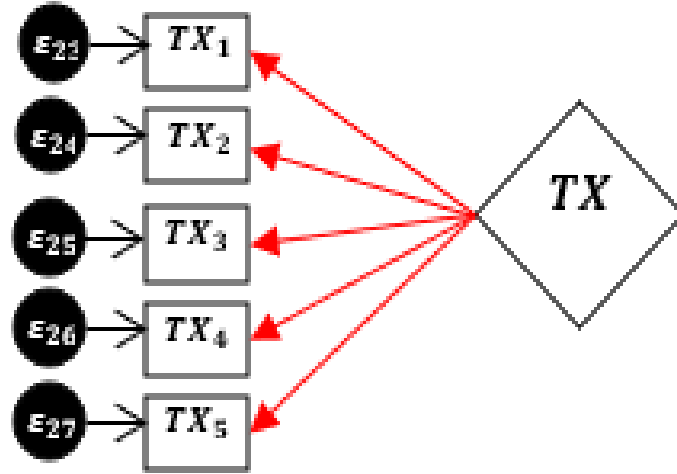


Figure 3.47: Reflective Measurement Model for the Latent Construct Trust Factors (TX)

Source: Project team compilation

The mathematical representation of the reflective measurement model for TX is provided in Equations 3.73–3.77, which define the relationships between the latent construct TX and its five measurement items.

$$TX_1 = \lambda_{23}TX + \varepsilon_{23} \quad (3.73)$$

$$TX_2 = \lambda_{24}TX + \varepsilon_{24} \quad (3.74)$$

$$TX_3 = \lambda_{25}TX + \varepsilon_{25} \quad (3.75)$$

$$TX_4 = \lambda_{26}TX + \varepsilon_{26} \quad (3.76)$$

$$TX_5 = \lambda_{27}TX + \varepsilon_{27} \quad (3.77)$$

where:

TX Latent construct for Informational factors

$TX_1, TX_2, TX_3, TX_4, TX_5$ Observed measurement items (indicators) for TX

$\lambda_{23}, \lambda_{24}, \lambda_{25}, \lambda_{26}, \lambda_{27}$ Factor loadings representing the strength of the relationship between TX and its indicators (TX_1, TX_2, TX_3, TX_4 , and TX_5)

$\varepsilon_{23}, \varepsilon_{24}, \varepsilon_{25}, \varepsilon_{26}, \varepsilon_{27}$ Measurement errors associated with TX_1, TX_2, TX_3, TX_4 , and TX_5

3.3.2.2.11 Access to Resources

The construct Access to Resources (AR) is measured using three distinct items (AR_1 , AR_2 , and AR_3), which represent key indicators of the construct. These measurement items reflect the respondents' access to necessary resources, as illustrated in the reflective measurement model shown in Figure 3.48 below.

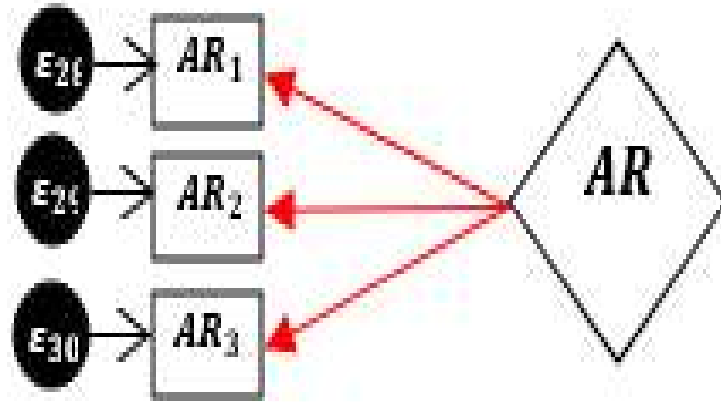


Figure 3.48: Reflective Measurement Model for the Latent Construct Access to Resources (AR)

Source: Project team compilation

The mathematical specification of the reflective measurement model for AR is provided in Equations 3.78–3.80, which define the relationships between the latent construct and its three measurement items.

$$AR_1 = \lambda_{28}AR + \varepsilon_{28} \quad (3.78)$$

$$AR_2 = \lambda_{29}AR + \varepsilon_{29} \quad (3.79)$$

$$AR_3 = \lambda_{30}AR + \varepsilon_{30} \quad (3.80)$$

where:

AR	Latent construct for Informational factors
AR_1, AR_2, AR_3	Observed measurement items (indicators) for AR
$\lambda_{28}, \lambda_{29}, \lambda_{30}$	Factor loadings representing the strength of the relationship between AR and its indicators (AR_1, AR_2 , and AR_3)
$\varepsilon_{28}, \varepsilon_{29}, \varepsilon_{30}$	Measurement errors associated with AR_1, AR_2 , and AR_3

3.3.2.2.12 Perceived financial cost

The reflective measurement model for Perceived Financial Cost (*PFC*) consists of two dedicated measurement items (PFC_1 and PFC_4), which serve as indicators of the latent construct Perceived Financial Cost. The measurement model is illustrated in Figure 3.49 below.

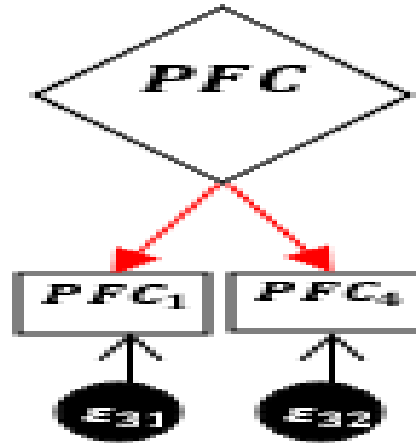


Figure 3.49: Reflective Measurement Model for the Latent Construct Perceived Financial Cost (*PFC*)

Source: Project team compilation

The mathematical specification of the reflective measurement model for Perceived Financial Costs (*PFC*) is provided in Equations 3.81–3.82, which define the relationships between the latent construct and its two measurement items.

$$PFC_1 = \lambda_{31}PFC + \varepsilon_{31} \quad (3.81)$$

$$PFC_4 = \lambda_{32}PFC + \varepsilon_{32} \quad (3.82)$$

where:

PFC	Latent construct for Informational factors
PFC_1, PFC_4	Observed measurement items (indicators) for <i>PFC</i>
$\lambda_{31}, \lambda_{32}$	Factor loadings representing the strength of the relationship between <i>PFC</i> and its indicators (PFC_1 and PFC_4)
$\varepsilon_{31}, \varepsilon_{32}$	Measurement errors associated with PFC_1 and PFC_4

3.3.3 Scenario formulations

This study integrates the Theory of Planned Behaviour (TPB) with AquaCrop simulations to evaluate the implications of varying levels of adoption of water use behaviours across the crop and water use behaviours considered in the scope of this project. Specifically, three adoption scenarios will be applied to evaluate the social and economic implications of farmers adopting water-saving behaviours. This project will apply three water use behaviour scenarios:

1. No Adoption
2. Partial Adoption
3. Full Adoption

These scenarios were chosen to capture a range of adoption levels, allowing for an analysis of the effects of different degrees of behaviour change on water use and crop performance. The No Adoption scenario serves as the baseline, reflecting the current irrigation practices with no changes in water use behaviour.

The Partial Adoption scenario represents a moderate shift, where some water use behaviours are adopted, leading to partial reductions in irrigation. The Full Adoption scenario assumes the complete adoption of specific water-use behaviours, reflecting the maximum potential for water use reduction. The TPB results do not determine which scenario will happen, but help to interpret how likely each one is, based on behavioural tendencies. While the scenarios remain the same across all crops, the TPB will provide insights into the underlying factors that drive different levels of adoption under each scenario, offering a better understanding of how these factors contribute to the changes in water use behaviour.

3.3.3.1 Water Saving Technology

While the scenarios remain the same across all crops, the TPB will provide insights into the underlying factors that drive different levels of adoption under each scenario, offering a better understanding of how these factors contribute to the changes in water use behaviour.

3.3.3.1.1 No Adoption (business as usual)

In this scenario, no water-saving technologies are adopted. Farmers are assumed to continue with current irrigation practices. The gross irrigation requirement is calculated for each crop and scheme based on local climatic and soil conditions. This total amount is then applied in fixed, evenly spaced intervals throughout the growing season, without adjusting for soil moisture or crop needs. This serves as the baseline scenario.

3.3.3.1.2 Partial Adoption

Partial Adoption reflects a shift towards more water-conscious irrigation behaviour. While the irrigation method (e.g. sprinkler) remains unchanged, scheduling becomes responsive to soil moisture conditions. Irrigation is triggered when a defined percentage of the readily available water (RAW) in the root zone has been depleted. This scenario simulates the use of basic soil moisture monitoring tools or sensors to guide irrigation timing.

3.3.3.1.3 Full Adoption

The Full Adoption scenario reflects both a change in irrigation timing and a shift to more efficient irrigation technology. As in the Partial Adoption case, irrigation is scheduled according to soil moisture depletion. In addition, sprinkler irrigation is replaced with drip irrigation, allowing for more precise and efficient water delivery. This scenario represents the highest level of behavioural and technological change.

3.3.3.2 Water Saving Policy

In semi-arid regions such as South Africa, various water-saving policies have been implemented to manage limited water resources, with water restrictions being particularly prominent during periods of severe drought. Between 2015 and 2018, the country experienced severe drought conditions, resulting in the imposition of stringent water restrictions in several agricultural regions. For example, during this period, the Western Cape agricultural sector faced reductions in water use of up to 60%. Specific areas experienced varying levels of restrictions, including a 50% reduction in the Breede Valley, a 60% reduction in the Berg River and Riviersonderend regions, and as high as 87% in the Lower Olifants River Valley during peak drought conditions. Given these historical water-saving efforts, we propose the following irrigation reduction scenarios, based on the adoption of water-saving policies:

- No Adoption (0% reduction): No changes in irrigation practices.
- Partial Adoption (30% reduction): A moderate level of water restriction, where policies are implemented to reduce irrigation water by 30%.
- Full Adoption (70% reduction): A high level of water restriction, reflecting severe drought conditions where irrigation water use is restricted by up to 70%.

3.3.3.3 Adaptation to Climate Variability

Adapting agricultural systems to climate variability requires a combination of water-saving and soil-conserving strategies. Among the most effective practices are mulching, weed management, and field surface improvements, which can significantly enhance crop resilience and optimise water use.

Mulching involves covering the soil surface with organic or inorganic materials to conserve soil moisture, regulate temperature, and reduce evaporation. Liao et al. (2022) highlighted the significant benefits of mulching in improving soil and plant conditions in water-limited environments. Their findings revealed that mulching, particularly with materials such as corn straw and horticultural fabric, increased soil water content and stabilised soil temperature, especially during the early growth stages.

El-Beltagi et al. (2022) demonstrated that mulching the soil surface provides essential benefits for sustainable crop management. Mulching effectively reduces soil evaporation and prevents erosion caused by wind or water. Furthermore, straw mulch moderates soil temperature during hot summers, preventing extreme topsoil temperatures that could hinder plant growth. Furthermore, Mostafa et al. (2023) demonstrated that applying plastic mulch-in-furrow (MF) and mulched-hole border (MB) irrigation systems resulted in significant water savings compared with non-mulched furrows (NMF). Specifically, water savings were 10.44% under MF and an impressive 46.3% under MB.

Weed management is another critical strategy for adapting agricultural systems to climate variability. Bajwa et al. (2015) highlighted the point that weeds pose a significant challenge to crop production, with improper management leading to substantial yield losses. The authors emphasised that factors such as intensive agricultural practices, shifting climatic conditions, and natural disasters significantly alter weed dynamics, necessitating the adaptation of weed management strategies.

Matloob et al. (2020) highlighted the increasing importance of weed management for sustainable crop production, particularly in light of climate uncertainty and food security concerns. Weeds compete for resources, disrupt crops, and heighten the incidence of pests and diseases, resulting in escalated management costs. Effective weed control is vital for preserving crop health and productivity amidst changing conditions. Consequently, adopting efficient weed management practices is essential, not only for optimising resource use but also for ensuring the resilience of crops in the face of variable climatic conditions.

Another critical strategy for adapting agricultural systems to climate variability is deficit irrigation. This practice involves applying water below the crop's full water requirement, optimising water use while maintaining acceptable crop yields. In a study by Mushtaq and Moghaddasi (2011), deficit irrigation was highlighted as being an effective adaptive strategy for climate variability and increasing environmental water demand. The study demonstrated that optimising irrigation practices through deficit irrigation could enhance water use efficiency, conserve water, and maximise benefits at the system level. By balancing environmental flows and net returns, deficit irrigation provides a sustainable solution for mitigating the impacts of climate variability, while maintaining agricultural productivity.

Similarly, Teshome et al. (2023) found that implementing deficit irrigation in green bean and sweet corn fields could significantly conserve water while achieving satisfactory crop yields. Barreales et al. (2023) found that the use of regulated deficit irrigation (RDI) under their experimental conditions helped to save irrigation water while promoting more sustainable almond production, demonstrating the potential of deficit irrigation to enhance water use efficiency and sustainability. Deficit irrigation is a promising strategy for adapting agricultural systems to climate variability by optimising water use and sustaining crop yields.

Considering the above literature, the following scenarios will be utilised for adapting to climate variability in the AquaCrop model:

1. No Adoption Scenario:

- This scenario assumes that no adaptive measures are implemented. The full irrigation requirement will be allocated based on the relevant Water Allocation Unit (WAU), without considering water-saving or soil-conserving practices.
- *Weed Management:* A moderate level of weed management is applied to minimise crop competition and optimise resource use.

2. Partial Adoption Scenario:

- *Mulching:* Mulching is applied at a moderate level to control soil temperature and moisture, as calculated in AquaCrop.
- *Weed Management:* A moderate level of weed management is applied to minimise crop competition and optimise resource use.
- *Deficit Irrigation:* Deficit irrigation is set at 20% below the gross irrigation requirement for the specific irrigation scheme. Irrigation intervals will be evenly distributed throughout the growing season.

3. Full Adoption Scenario:

- *Mulching:* Mulching is implemented at a significant level to maximise water retention and minimise evaporation, as optimised in AquaCrop.
- *Weed Management:* Weed management is implemented at the highest possible level to prevent competition and enhance crop resilience.
- *Deficit Irrigation:* Deficit irrigation is strategically utilised during the critical growth stages of the crop to optimise water use while maintaining acceptable yields, as determined by AquaCrop's simulation.

3.3.4 Multiplier Analysis (Partial Equilibrium Model)

The SAM framework will be crucial in understanding the social and economic implications of irrigators' changed water use behaviours in South Africa. The SAM framework was identified as suitable for achieving the project's aims, as it provides a comprehensive framework for assessing the social and economic implications of a particular event or activity (such as changed water use behaviour) by capturing inter-sectoral links and evaluating income distributions and social indicators. According to Bwanakare (2017), SAM aims to provide a highly detailed record that is consistent with the relationships between different economic agents, presenting the interactions among various entities in the economy.

The SAM (Semi-Input-Output model) is a partial equilibrium econometric model that measures the magnitudes of various types of multipliers. This is achieved by calculating sectoral contributions to the economy, including multipliers and other variables relevant to this study. A 2020 SAM was developed by a project team with the support of various stakeholders.

Samuelson (1970) defines the multiplier concept as follows: “ ‘the multiplier’ is the number by which the change in investment must be multiplied in order to present us with the resulting change in income.” Therefore, the multiplier concept can be described as representing the nature and extent of the impact of an autonomous change in a specific economic quantity on another economic quantity or other economic quantities, such as production or employment. To render the multiplier concept more general, investment and income can be substituted, respectively, by independent and dependent variables such as employment creation.

One of the multiplier models based on the combined SAM input-output table/model is the partial equilibrium model, utilised to assess the economic impacts of exogenous changes. According to Arndt et al. (2020), SAM analysis relies on three sets of assumptions. First, because prices are fixed, judgments regarding quantities are made based on value shares. Second, in the SAM columns, functional relationships are assumed to be linear. This implies, for instance, that Leontief production functions are employed in the activity columns, and that imports and domestic production are not substituted in the commodity columns (Leontief production functions are characterised by constant returns to scale, as well as the absence of substitution in factor and intermediate inputs). Third and finally, multiplier models are driven by prices and demand.

The Leontief inverse matrix and the technical input coefficients are utilised for this purpose. The amount of intermediate inputs that a particular sector requires from another industry to generate each country's currency is characterised as a technical coefficient (in monetary units), as indicated below.

$$\frac{X_{ij}}{X_j} = a_{ij} \quad (i = 1 \dots n) \text{ and } (j = 1 \dots n) \quad (3.86)$$

where “ a_{ij} ” is a production coefficient indicating the amount of sector “ i ’s” product needed to produce one unit of sector “ j ’s” product; “ X_{ij} ” represents the delivery of intermediate goods from sector “ i ” to sector “ j ”; “ X_j ” denotes total gross input (output of the different sectors). For specific elements in a transaction (equation 3.88) illustrated in Equation 3.87:

$$a_{11} = \frac{X_{11}}{X_1}; a_{12} = \frac{X_{12}}{X_2}; X_{1n} = \frac{X_{1n}}{X_n} \quad (3.87)$$

The technical coefficients matrix is a set of technical coefficients, often denoted by the capital letter “ A ”:

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdot & \cdot & \cdot & a_{1n} \\ a_{21} & a_{22} & & & & a_{2n} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ a_{n1} & a_{n2} & & & & a_{nn} \end{bmatrix} \quad (3.88)$$

where $(i = 1 \dots n)$ and $(j = 1 \dots n)$

The required output to meet a specified level of gross output can be shown as:

$$O = A^*X + n \quad (3.89)$$

where “ X ” denotes a vector of activity levels (in value terms) in an economy; “ A ” denotes the amounts of each activity used by another activity at rates that are assumed to be independent of the levels of activity in “ X ” (constant returns to scale); and “ O ” is a vector containing the intermediate demand for its output and the total final demand for its input. Total activity “ X ” satisfies endogenous “ AX ” and exogenous “ D ” uses. Assuming “ A ” is parametric, any change in “ D ” must be accommodated by a corresponding change in “ X ”:

$$X = AX + D \quad (3.90)$$

Solving for “ X ”, the relationship between “ D ” and the activity vector “ X ” is:

$$A^*X + D = X; \quad D = X - A^*X \quad (3.91)$$

Rearranging Equation 3.91:

$$D = (I - A)^*X \quad (3.92)$$

Thus:

$$X = (I - A) - 1 * D \text{ or } Ma * D \quad (3.93)$$

The term “(I-A)-1” or “Ma” is known as the Leontief inverse, also referred to as the multiplier matrix.

The theory regarding the multiplier concept is based on the technical coefficient matrix and the Leontief inverse. The multiplier is derived from the Leontief inverse, and the technical coefficient matrix is an essential component of it. The nature and extent of the impact of an autonomous change in a specific economic quantity on other economic quantities will be defined in terms of the multiplier concept.

3.3.5 Overview of Integrated Framework

This research developed an integrated framework to assess water use behaviours among food production farmers in South African irrigation schemes by combining psychological, biophysical, and socio-economic dimensions. The framework begins by employing the TPB to provide insights into the psychological conditions likely to occur under different adoption scenarios of water-saving practices. These scenarios subsequently inform the biophysical simulation stage, where AquaCrop models food production yields based on varying levels of water use that reflect the adoption scenarios. The simulated yield results are incorporated into a SAM to evaluate the broader economic and social impacts of changes in water use behaviours. Ultimately, the framework integrates these components to generate feedback aimed at supporting policy development and promoting sustainable water management in agriculture. This multi-stage approach is visually summarised above in Figure 1.2 in section 1.3, which outlines the four key stages of the integrated framework.

3.3.6 AquaCrop model

The original set of papers published at the model's release (Hsiao et al., 2009), Irrigation and Drainage Paper No. 66, “Crop Yield Response to Water” (Steduto et al., 2012), and the reference manual (Raes et al., 2023), which is updated regularly, provides details on the simulated processes in AquaCrop.

AquaCrop simulates crop growth and yield formation successively through several interconnected processes, organised into four steps, as highlighted in Chapter 2. These steps include crop development, transpiration, biomass production, and yield formation, each representing a key aspect of the model's framework.

3.3.6.1 Step 1: Simulation of green Canopy development

AquaCrop models foliage development by using green canopy cover (CC) rather than leaf area index (LAI), as described in the AquaCrop reference manual (Raes et al., 2023). CC represents the fraction of the soil surface covered by green canopy, ranging from zero before emergence to a maximum value (CC_X) that

depends on crop type and planting density. Canopy development is a key process in AquaCrop, as it has a direct influence on transpiration and biomass production (Vanuytrecht et al., 2014).

Under optimal conditions, canopy expansion is determined by three key parameters. The initial canopy cover after emergence (CC_0) defines the starting point of growth. The maximum canopy cover (CC_X) represents the highest fraction of ground coverage achieved under ideal conditions. The canopy growth coefficient (CGC) describes the rate at which the canopy expands between emergence and full development. As the crop matures, leaf senescence leads to a decline in canopy cover, which is represented by the canopy decline coefficient (CDC). These parameters are retrieved from the crop file at the beginning of the simulation.

Water stress affects canopy development by slowing expansion when root zone depletion reaches critical thresholds. The effect of water stress on canopy development is simulated by using a water stress coefficient for canopy expansion ($k_{s_{exp,w}}$), which reduces the effective CGC when root zone depletion reaches specific thresholds. If water stress becomes severe, canopy senescence is accelerated through the canopy senescence coefficient ($k_{s_{sen}}$), leading to an earlier and faster decline in CC .

Canopy development in AquaCrop is also influenced by air temperature, nutrient availability, and soil salinity. The effects of air temperature are simulated using growing degree days (GDD), along with base and upper temperature thresholds. Nutrient stress is modelled by using soil fertility coefficients, which reduce the maximum canopy cover (CC_X). Once CC_X is reached, the canopy declines at a steady rate. Soil salinity stress affects water availability in the root zone and similarly impacts canopy development, much like nutrient stress.

3.3.6.2 Step 2: Simulation of Crop Transpiration (Tr)

In AquaCrop, crop transpiration (Tr) is a crucial process in determining how much water the crop uses for growth. Transpiration is calculated by multiplying the evaporating power of the atmosphere (ET_0) by the crop coefficient ($K_{C_{Tr}}$), which is adjusted for canopy development, and then accounting for water stress (K_s) and temperature stress ($K_{s_{Tr}}$). The proportionality factor of crop transpiration in AquaCrop is known as $K_{C_{Tr,x}}$, being the coefficient that indicates when canopy expansion is complete ($CC = 1$) and without stress conditions. The crop transpiration coefficient ($K_{C_{Tr}} = K_{C_{Tr,x}} CC^*$) is proportional to the fractional canopy cover (CC) and is continuously adjusted based on the simulated canopy development. As the crop grows, $K_{C_{Tr,x}}$ is modified to account for the effects of ageing and senescence. Furthermore, CC is replaced by CC^* . Consider interrow micro-advection, which provides additional energy for transpiration, especially when canopy cover is incomplete. Interrow micro-advection refers to the process by which heat energy

from the soil and surrounding air is transferred to the crop canopy, thereby enhancing transpiration. Following these principles, Tr is determined by using Equation 3.83, as follows:

$$Tr = K_s K_{sTr} (K_{C_{Tr,x}} CC^*) ET_0 \quad (3.83)$$

where:

Tr	Crop transpiration
K_s	Water stresses
K_{sTr}	Temperature stress
$K_{C_{Tr,x}}$	Crop-specific transpiration coefficient at full canopy development
CC^*	Crop canopy cover adjusted for interrow micro-advection.
ET_0	Evaporating power of the atmosphere.

3.3.6.3 Step 3: Simulation of Above-Ground Biomass (B) Production

In AquaCrop, the simulation of above-ground biomass (B) relies on crop water productivity (WP), which indicates the quantity of dry matter produced per unit area per unit of water transpired. According to Raes et al. (2023), a highly linear relationship exists between biomass production and water consumption for a given species under specific climatic conditions. To ensure broad applicability across locations, seasons, and future climate conditions, AquaCrop employs a normalised water productivity (WP*) function, which accounts for variations in atmospheric CO₂ concentration and evaporative demand.

The normalisation of WP* is achieved through two key adjustments. First, evaporative demand is addressed by dividing daily Tr by the daily ET_0 , ensuring that varying climatic conditions do not disproportionately influence biomass production. Second, atmospheric CO₂ concentration is accounted for by setting a reference value of 369.41 ppm, based on measurements taken in 2000 at the Mauna Loa Observatory. Daily above-ground biomass production is calculated by multiplying WP* by the ratio of Tr to ET_0 (Raes et al., 2023):

$$B = WP^* \sum \left(\frac{Tr}{ET_0} \right) \quad (3.84)$$

where:

B	above-ground biomass production
WP^*	normalised water productivity

During the simulation, WP^* may be adjusted to account for variations in atmospheric CO_2 concentration, crop composition, and soil fertility. To correct for atmospheric CO_2 levels deviating from the reference value of 369.41 ppm, WP^* is multiplied by a correction factor, which is greater than 1 for elevated CO_2 levels and less than 1 for lower concentrations. Additionally, the type of biomass produced influences WP^* , as crops rich in lipids or proteins require more energy per unit dry weight than those composed primarily of carbohydrates, necessitating a reduction in WP^* through a specific adjustment factor. Lastly, soil fertility stress may reduce crop water productivity, which is simulated by using the soil fertility stress coefficient (Ks_{WP}), ranging from 1 (no fertility stress) to 0 (severe stress). If soil fertility does not constrain crop growth, WP^* remains unchanged.

3.3.6.4 Step 4: Simulation of Crop Yield (Y)

In AquaCrop, crop yield (Y) is simulated based on the Harvest Index (HI), which represents the fraction of total above-ground biomass (B) allocated to the harvested portion of the crop. Starting from flowering or tuber initiation, the HI gradually increases until it reaches its reference value (HI_0) at physiological maturity. However, if early canopy senescence shortens the grain-filling or tuber formation stage, HI may be reduced because of inadequate photosynthesis. For leafy vegetables, HI begins accumulating immediately after germination and quickly reaches its reference value. The final crop yield is obtained by multiplying B with the adjusted HI (Raes et al., 2023):

$$Y = f_{HI} HI_0 B \quad (3.85)$$

where:

Y Crop Yield

f_{HI} A multiplier that adjusts the reference HI according to the stresses experienced by the crop during the growing season

HI_0 The reference Harvest Index (HI) at physiological maturity

The stresses experienced by the crop throughout the growing season are considered by adjusting the Harvest Index using the multiplier f_{HI} , which accounts for the effects of water deficits and air temperature. The magnitude and timing of these stresses influence the Harvest Index, with potential positive ($f_{HI}>1$) or negative ($f_{HI}<1$) impacts on yield, depending on whether the stress occurs before yield formation, during flowering (affecting pollination), or during the yield formation phase.

3.3.7 Summary

This chapter establishes the conceptual and methodological foundation for this research project, which aims to develop an integrated framework that combines psychological, biophysical, and socio-economic dimensions to assess changes in water use behaviours across various irrigation schemes in South Africa. It emphasises the importance of integrating behavioural insights with crop modelling and economic impact analysis to inform agricultural water management strategies better.

Furthermore, this chapter outlines the methodology and data used to operationalise the integrated framework. It provides an overview of the data inputs and empirical specifications applied to each component of the framework, specifically the behavioural model based on the Theory of Planned Behaviour, the AquaCrop simulations for biophysical analysis, and the Social Accounting Matrix for economic evaluation. Together, these chapters provide the theoretical foundation, empirical justification, and methodological clarity required for the case study analyses presented in the following sections.

CHAPTER 4: CASE STUDY OF SMALLHOLDER FARMERS' MAIZE PRODUCTION IN THE TSHIOMBO IRRIGATION SCHEME, LIMPOPO PROVINCE

4.1 Overview

This section presents the empirical results derived from the application of the developed integrated framework to small-scale maize irrigators in the Tshiombo Irrigation Scheme. The results are structured to reflect the multi-dimensional nature of the framework, which combines psychological, biophysical, and socio-economic dimensions. First, the demographic, household, and farm characteristics of the sampled irrigators are described to provide contextual background. This is followed by the presentation of behavioural findings using the Theory of Planned Behaviour (TPB).

For each of the three water use behaviours considered (the adoption of water-saving technologies, the adoption of water-saving policies, and adaptation to climate variability), results are reported for both the standard TPB model and the augmented TPB model, as explained in detailed above. Thereafter, the behavioural findings are integrated into three behavioural adoption scenarios, which form the basis for subsequent crop simulation analysis. Using the AquaCrop model, changes in maize yields are estimated under each scenario. Finally, these yield changes are translated into economic outcomes through the use of a Social Accounting Matrix (SAM), allowing for an assessment of the broader socio-economic impacts associated with changes in water use behaviours.

4.2 Results

4.2.1 Demographic, Farm, and Household Characteristics of Respondents

The demographic, farm, and household profile of respondents in the Tshiombo Irrigation Scheme, as shown in Table 4.1 below, highlights several key characteristics. The sample is fairly balanced in terms of gender, with 53% of respondents being female and 47% male. Age distribution reveals that the majority of farmers are older, with 61% being aged 51 and above, reflecting an ageing farming population. In terms of education, most respondents (71%) have completed secondary education, while only a small percentage (11%) have obtained a diploma or higher education. Farming experience is substantial, with 75% of respondents having more than 10 years of experience, although most have less than 20 years (40%).

Interestingly, very few farmers (4%) engage in off-farm work, indicating a strong dependence on farming as their primary source of livelihood.

Table 4.1: Respondents' demographic, farm, and household profile

Variable	Classification	Frequency	Percentage (%)
Demographic profile			
Gender	Male	171	47%
	Female	195	53%
Age	21-30	10	3%
	31-40	37	10%
	41-50	94	26%
	51-60	110	30%
	61 and older	115	31%
Highest education level	Primary (Grade 1-7)	65	18%
	Secondary (grade 8-12)	260	71%
	Diploma	27	7%
	Undergraduate degree	14	4%
Farming experience	Less than 10	145	40%
	11-20	127	35%
	21-30	53	14%
	31-40	24	7%
	41-50	16	4%
	51-60	1	0,3%
Off-farm work	Yes	14	4%
	No	352	96%
Farm characteristics profile			
The land ownership type of the farm	Communal	15	4%
	Rented land	4	1%
	Customary land	347	95%
Farm located near modern medical facilities, populated areas, or markets	Yes	58	16%
	No	308	84%
Distance from markets	Less than 1 Km	10	3%
	1-5 Km	55	15%
	6-10 Km	8	2%
	11-15 Km	16	4%
	16-20 Km	60	16%
	More than 20 Km	217	59%
Succession plan	Yes	288	79%
	No	78	21%
Type of farming performed	Crop production	342	93%
	Mixed farming	24	7%
Rural flex irrigation times	Off-peak	63	17%
	Standard	101	28%
	Peak	145	40%

Variable	Classification	Frequency	Percentage (%)
Challenges ranked	All	57	16%
	Water scarcity	1	23%
	Climate change/variability	2	27%
	Lack of access to land	3	29%
	Lack of access to finance	4	24%
	Cost of water	5	27%
	Loadshedding	6	75%
Size of farm	Electricity	7	78%
	Less than 1 Ha	-	-
	1-1.5 Ha	353	96%
	1.51-2 Ha	11	3%
Household characteristics			
Age	More than 2 Ha	2	1%
	21-30	2	1%
	31-40	19	5%
	41-50	52	14%
	51-60	92	25%
Male members living in the household	61 and older	201	55%
	None	9	2%
	One	55	15%
	Two	102	28%
	Three	92	25%
	Four	68	19%
	Five	20	5%
	Six	16	4%
Female members living in the household	Seven	4	1%
	None	6	2%
	One	51	14%
	Two	134	37%
	Three	105	29%
	Four	50	14%
	Five	12	3%
	Six	5	1%
Male members living in the household are involved in agricultural activities on the farm	Seven	2	1%
	None	36	10%
	One	173	47%
	Two	133	36%
	Three	22	6%
	Four	1	0,3%
Female members living in the household are involved in agricultural activities on the farm	Five	1	0,3%
	None	32	9%
	One	221	60%
	Two	91	25%
	Three	17	5%

Variable	Classification	Frequency	Percentage (%)
	Four	4	1%
	Five	1	0,3%
Monthly household on-farm income	Less than R 1000	8	2%
	R 1000 - R 5000	72	20%
	R 5000 - R 10 000	69	19%
	R 10 000 - R 15 000	59	16%
	R 15 000 - R 20 000	31	8%
	More than R 20 000	127	35%
Monthly household off-farm income	Less than R 1000	86	23%
	R 1000 - R 5000	190	52%
	R 5000 - R 10 000	48	13%
	R 10 000 - R 15 000	13	4%
	R 15 000 - R 20 000	3	1%
	More than R 20 000	26	7%
Off-farm income	Yes	26	7%
	No	340	93%

Source: Project team compilation

The majority of farms in the Tshiombo Irrigation Scheme are located on customary land (95%), with only a small proportion being communal (4%) or rented (1%). Most farms are situated far from markets, with 59% of respondents indicating a distance greater than 20 km. Additionally, 79% of respondents reported having a succession plan in place. Crop production is the dominant activity, with 93% of respondents being involved. The most significant challenges, as ranked by farmers, are electricity issues (78%) and load shedding (75%).

The majority of the household heads are aged 61 and older. In terms of household composition, 47% of male members participate in agricultural activities, with the majority of households having one or two male members (15% and 28%, respectively). Among female members, 60% engage in agricultural activities, and the most significant proportion of female members in households is two (37%). The data also reveal that 35% of households earn more than R20,000 monthly from on-farm income, while off-farm income remains scarce, with only 7% of households reporting earnings exceeding R20,000. Notably, 93% of respondents do not engage in off-farm work, indicating a strong reliance on agricultural activities for household income.

The Respondents' Knowledge and Awareness of Climate Change/variability, as illustrated in Table 4.2 below, shows that a significant majority of respondents possess high or very high knowledge of climate change/variability, with 76% falling into these two categories. Only a small percentage reported very low (3%) or low (13%) awareness, while 8% indicated having an average understanding. These results suggest that the farmers in the Tshiombo Irrigation Scheme are generally well-informed about climate change/variability.

Table 4.2: Respondents' Knowledge and Awareness of Climate Change/Variability

	Classification	Frequency	Percentage (%)
Knowledge of climate change/variability	Very low	12	3%
	Low	49	13%
	Average	28	8%
	High	120	33%
	Very high	157	43%

Source: Project team compilation

4.2.2 Theory of Planned Behaviour

The findings derived from the standard Theory of Planned Behaviour model are presented first, followed by the results of the augmented model for the same behaviour, which incorporates additional constructs, as explained in Chapter 2 above.

4.2.2.1 Standard TPB Model for Adoption of Water-saving Technologies

4.2.2.1.1 Measurement Model Assessment Results

Before assessing the measurement and structural models for water-saving technology adoption among small-scale maize irrigators in the Tshiombo Irrigation Scheme, it is important to provide an overview of the initial path model, as shown in Figure 4.1 below for the standard TPB model and Figure 4.2 for the augmented TPB model. This model displays the relationships among the constructs and measurement items before any changes are made. It serves as a starting point, showing how the constructs are expected to relate to one another. During the assessment, some measurement items or constructs might be removed if they do not meet the necessary criteria.

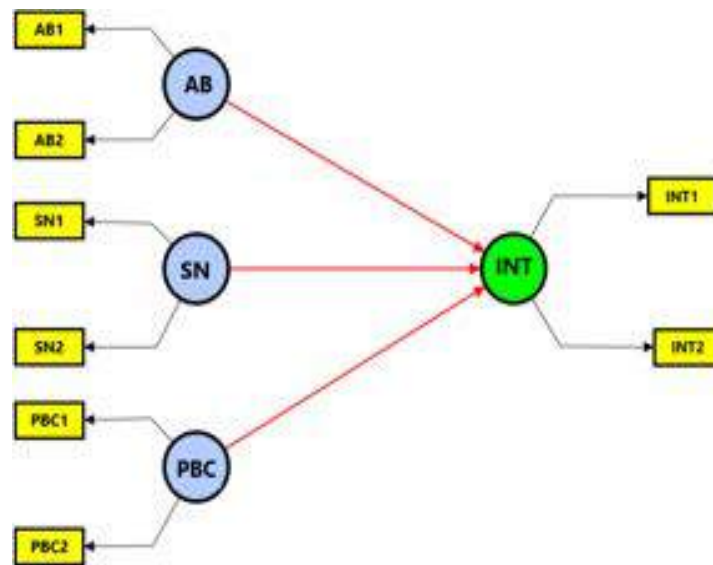


Figure 4.1: Initial Path Model of standard TPB for Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Tshiombo Irrigation Scheme

Source: Project team compilation

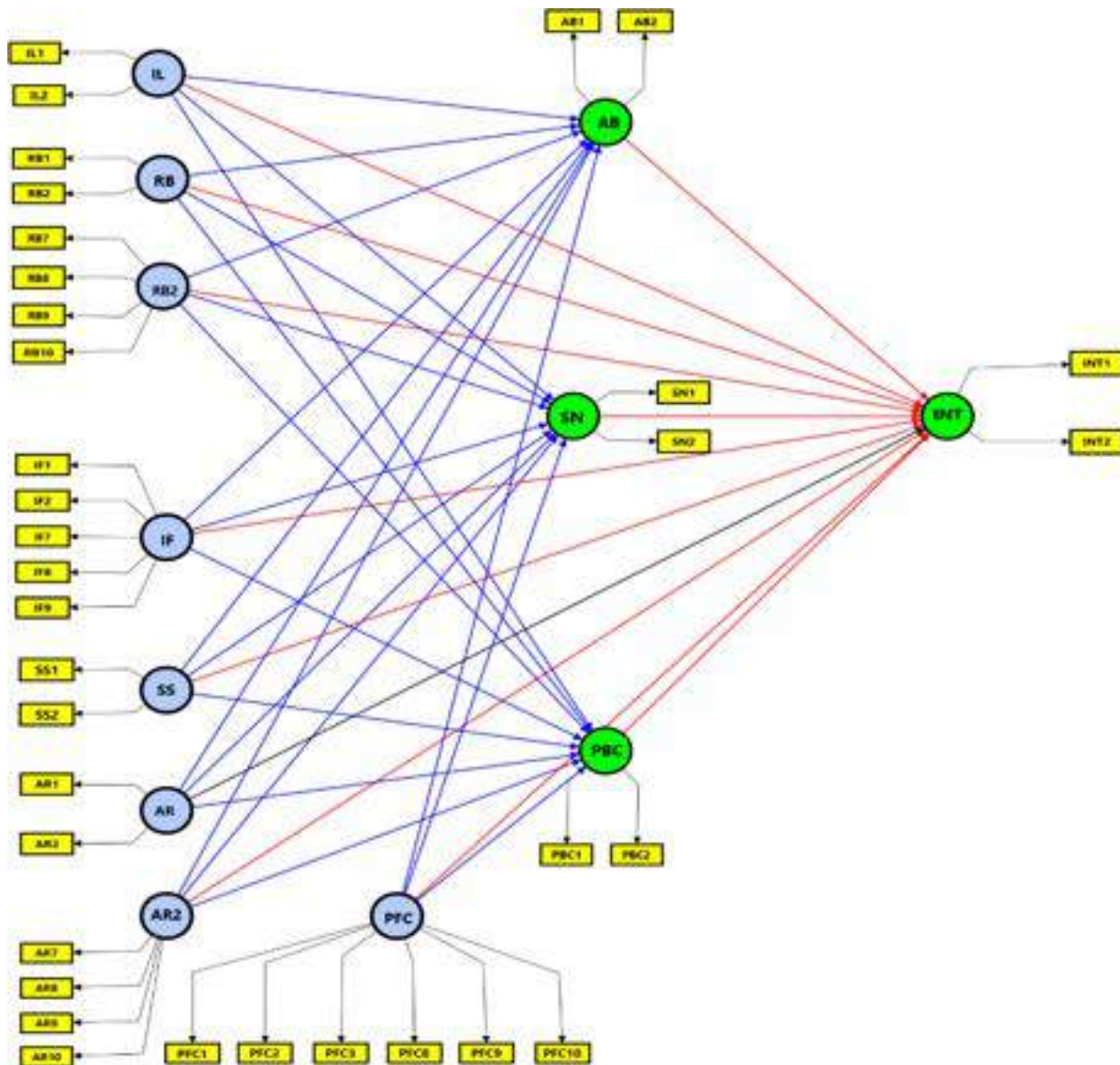


Figure 4.2: Initial Path Model of Augmented TPB Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Extended Model for the Tshiombo Irrigation Scheme

Source: Project team compilation

4.2.2.1.1.1 Indicator Reliability

The first step in assessing the measurement model for water-saving technology adoption among small-scale maize irrigators in the Tshiombo Irrigation Scheme is to evaluate the reliability of the indicators. According to the guidelines established by Hair and Alamer (2022), we aimed for outer loadings of 0.7 or higher to ensure strong reliability. Measurement items with loadings between 0.4 and 0.7 were considered for removal only if their exclusion improved internal consistency and convergent validity. In this assessment, only one indicator, INT_1 (intentions), had a loading below 0.4 and was therefore dropped from the model.

4.2.2.1.1.2 Internal Consistency Reliability

The next step in assessing the measurement model involved evaluating internal consistency through using composite reliability. Cronbach's alpha can sometimes underestimate reliability, especially when the number of items is small or when indicators have varying outer loadings. For this exploratory research, composite reliability values above 0.6 were considered acceptable, following the recommendations from Hair and Alamer (2022). Specifically, they suggest that acceptable values for exploratory research range from 0.60 to 0.70, while values between 0.70 and 0.90 are deemed satisfactory for more advanced research.

For the standard TPB model, all constructs had Cronbach's alpha and composite reliability scores above 0.6, except for the Attitudes (A_B) construct, which had a Cronbach's alpha score of 0.444. Composite reliability provides a more accurate measure, as it takes into account the individual outer loadings. Therefore, A_B meets the minimum internal consistency reliability criteria.

For the augmented TPB model, certain constructs, including Attitudes (A_B), Perceived Risks and Benefits (RB), Perceived Financial Costs (PFC), and Intentions (INT), had Cronbach's alpha values below 0.6. Composite reliability, which accounts for individual outer loadings, is a more accurate measure of reliability. Despite the lower Cronbach's alpha values, all constructs displayed composite reliability scores above 0.6. Therefore, the measurement models demonstrated acceptable internal consistency.

4.2.2.1.1.3 Convergent Validity

Next, convergent validity was assessed to ensure that the measurement items accurately represent their respective constructs. The results of the Standard TPB model revealed that all constructs with more than one measurement item had an Average Variance Extracted (AVE) above 0.5, indicating acceptable levels of convergent validity. Furthermore, the findings of the augmented TPB model also revealed that all constructs met this criterion, except for Informational Factors (IF), which initially had an AVE below 0.5. To improve the AVE for IF , measurement items IF_1 and IF_9 were removed, resulting in an AVE of 0.502, thus ensuring acceptable convergent validity for this construct.

4.2.2.1.1.4 Discriminant Validity

Discriminant validity was assessed by using both the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratios, as presented in Table 4.3 below for the standard TPB model. The initial estimation revealed that the HTMT ratio between attitudes (AB) and intentions (INT) exceeded 0.9, indicating a potential lack of discriminant validity. To address this, we examined the Variance Inflation Factor (VIF) values for both the inner (structural model) and outer models. No collinearity issues were found; however, to resolve the discriminant validity concerns, the measurement item with the lowest factor

loading for A_B (A_{B1}) was dropped. This adjustment improved the discriminant validity between A_B and INT .

The final Fornell-Larcker and HTMT ratios for discriminant validity are summarised in Table 4.3 below and demonstrate that both criteria are met. Specifically, the Fornell-Larcker criterion shows that the square root of the Average Variance Extracted (AVE) values (diagonal entries) is higher than the corresponding off-diagonal values, confirming adequate discriminant validity. Similarly, the HTMT ratios are below the threshold of 0.9, further supporting the discriminant validity of the measurement model.

Table 4.3: Fornell-Larcker Criterion and HTMT Ratios for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Fornell-Larcker Criterion					HTMT Ratio				
	A_B	INT	PBC	SN		A_B	SN	PBC	INT
A_B	1.000				A_B				
INT	0.746	1.000			INT	0.746			
PBC	0.124	0.131	0.843		PBC	0.129	0.128		
SN	0.203	0.174	0.022	0.850	SN	0.231	0.183	0.084	

Source: Project team compilation

After conducting all the assessments for the measurement model, the final results are summarised in Table 4.4 below. This table outlines the key findings related to indicator reliability, internal consistency, convergent validity, and discriminant validity for the measurement model.

Table 4.4: Summary of Results for the Reflective Measurement Model of Small-Scale Maize Irrigators' Adoption of Water-Saving Technologies in the Tshiombo Irrigation Scheme

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
<i>A_B</i>	<i>A_{B1}</i>	Dropped	N/A	N/A	N/A	Yes
	<i>A_{B2}</i>	0.959				
<i>SN</i>	<i>SN₁</i>	0.718	0.722	0.671	0.835	Yes
	<i>SN₂</i>	0.963				
<i>PBC</i>	<i>PBC₁</i>	0.682	0.710	0.677	0.826	Yes
	<i>PBC₂</i>	0.978				
<i>INT</i>	<i>INT₁</i>	Dropped	N/A	N/A	N/A	Yes
	<i>INT₂</i>	1.000				

Source: Project team compilation

For the augmented TPB, the initial HTMT estimates indicated potential discriminant validity issues between the Intentions (***INT***) construct and the Attitudes (***A_B***), Institutional and Legal Factors (***IL***), and Informational Factors (***IF***) constructs. To address these issues, the measurement item ***INT₂*** was removed from the construct ***INT*** (Intentions), which successfully addressed all concerns regarding the discriminant validity in the model.

Table 4.5 below presents the final Fornell-Larcker criterion results, while Table 4.6 below displays the final HTMT ratios. As shown in Table 4.7 below, the square root of the AVE (the diagonal values) is larger than the correlations between constructs (off-diagonal values), confirming discriminant validity. Additionally, the HTMT values in Table 4.6 below are all below the recommended threshold of 0.9, further supporting the model's discriminant validity.

Table 4.5: Fornell-Larcker Criterion for Discriminant Validity of the Extended Measurement Model for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

	<i>A_B</i>	<i>AR</i>	<i>AR2</i>	<i>IF</i>	<i>IL</i>	<i>INT</i>	<i>PBC</i>	<i>PFC</i>	<i>PFC2</i>	<i>RB</i>	<i>RB2</i>	<i>SN</i>	<i>SS</i>
<i>A_B</i>	0.801												
<i>AR</i>	-0.135	0.887											
<i>AR2</i>	0.089	0.136	0.708										
<i>IF</i>	0.050	0.127	0.233	0.661									
<i>IL</i>	0.123	0.037	0.171	0.194	0.853								
<i>INT</i>	0.064	0.154	0.202	0.653	0.345	1.000							
<i>PBC</i>	0.121	0.055	0.238	0.100	0.296	0.172	0.866						
<i>PFC</i>	-0.024	0.369	0.221	0.213	0.083	0.233	0.120	0.730					
<i>PFC2</i>	0.116	0.261	0.357	0.268	0.190	0.217	0.191	0.254	0.777				
<i>RB</i>	0.017	0.230	0.131	0.183	0.165	0.156	0.088	0.188	0.207	0.809			
<i>RB2</i>	0.160	0.006	0.363	0.230	0.220	0.239	0.218	0.188	0.311	0.241	0.735		
<i>SN</i>	0.188	-0.002	0.121	0.110	0.093	0.148	-0.051	0.005	0.126	0.068	0.160	0.867	
<i>SS</i>	0.206	-0.058	0.305	0.171	0.229	0.150	0.162	0.013	0.205	0.164	0.217	0.217	0.849

Source: Project team compilation

Table 4.6: HTMT Ratios for Discriminant Validity of the Extended Measurement Model for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

	<i>A_B</i>	<i>AR</i>	<i>AR2</i>	<i>IF</i>	<i>IL</i>	<i>INT</i>	<i>PBC</i>	<i>PFC</i>	<i>PFC2</i>	<i>RB</i>	<i>RB2</i>	<i>SN</i>	<i>SS</i>
<i>A_B</i>													
<i>AR</i>	0.260												
<i>AR2</i>	0.170	0.193											
<i>IF</i>	0.241	0.227	0.567										
<i>IL</i>	0.220	0.087	0.262	0.363									
<i>INT</i>	0.101	0.179	0.245	0.717	0.435								
<i>PBC</i>	0.210	0.077	0.333	0.249	0.448	0.194							
<i>PFC</i>	0.244	0.582	0.360	0.409	0.196	0.317	0.196						
<i>PFC2</i>	0.228	0.371	0.521	0.581	0.276	0.255	0.264	0.404					
<i>RB</i>	0.078	0.365	0.263	0.354	0.263	0.202	0.135	0.365	0.408				
<i>RB2</i>	0.263	0.057	0.540	0.499	0.325	0.280	0.317	0.304	0.451	0.436			
<i>SN</i>	0.341	0.099	0.199	0.248	0.139	0.180	0.084	0.094	0.171	0.131	0.226		
<i>SS</i>	0.393	0.089	0.483	0.321	0.367	0.191	0.248	0.173	0.320	0.302	0.330	0.327	

Source: Project team compilation

Following the evaluation of indicator reliability, internal consistency reliability, convergent validity, and discriminant validity, a summary of the final measurement model assessment results is provided in Table 4.7 below.

Table 4.7: Summary of Results for the Reflective Measurement Model of Small-Scale Maize Irrigators' Adoption of Water-Saving Technologies in the Extended Model for the Tshiombo Irrigation Scheme

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
<i>A_B</i>	<i>A_{B1}</i>	0.619	0.624	0.444	0.761	Yes
	<i>A_{B2}</i>	0.929				
<i>SN</i>	<i>SN₁</i>	0.861	0.752	0.671	0.859	Yes
	<i>SN₂</i>	0.874				
<i>PBC</i>	<i>PBC₁</i>	0.807	0.749	0.677	0.856	Yes
	<i>PBC₂</i>	0.920				
<i>SS</i>	<i>SS₁</i>	0.855	0.723	0.617	0.839	Yes
	<i>SS₂</i>	0.845				
<i>IL</i>	<i>IL₁</i>	0.729	0.729	0.628	0.843	Yes
	<i>IL₂</i>	0.628				
<i>RB</i>	<i>RB₁</i>	0.651	0.650	0.511	0.783	Yes
	<i>RB₂</i>	0.936				
<i>RB2</i>	<i>RB₇</i>	0.564	0.540	0.713	0.822	Yes
	<i>RB₈</i>	0.750				
	<i>RB₉</i>	0.828				
	<i>RB₁₀</i>	0.771				
<i>IF</i>	<i>IF₁</i>	Dropped	0.502	0.490	0.738	Yes
	<i>IF₂</i>	0.740				
	<i>IF₇</i>	0.577				
	<i>IF₈</i>	0.662				
	<i>IF₉</i>	Dropped				
<i>Ar2</i>	<i>AR₇</i>	0.610	0.500	0.664	0.799	Yes
	<i>AR₈</i>	0.712				
	<i>AR₉</i>	0.768				
	<i>AR₁₀</i>	0.728				
<i>AR</i>	<i>AR₁</i>	0.926	0.785	0.733	0.879	Yes
	<i>AR₂</i>	0.844				
<i>PFC2</i>	<i>PFC₈</i>	0.765	0.607	0.685	0.823	Yes
	<i>PFC₉</i>	0.815				
	<i>PFC₁₀</i>	0.757				
<i>PFC</i>	<i>PFC₁</i>	0.525	0.500	0.544	0.737	Yes
	<i>PFC₂</i>	0.740				
	<i>PFC₃</i>	0.806				
<i>INT</i>	<i>INT₁</i>	0.595	0.533	0.134	0.689	Yes
	<i>INT₂</i>	0.844				

Source: Project team compilation

4.2.2.1.2 Structural Model Assessment Results

4.2.2.1.2.1 Assessment of Collinearity Issues

The next step in the assessment involved evaluating the Variance Inflation Factor (VIF) values of the inner model, also known as the structural model. The results indicated that none of the structural paths exhibited VIF values above 3. This finding suggests that multicollinearity is not a concern within the model, ensuring the reliability of the path estimates

4.2.2.1.2.2 Significance and Relevance of Structural Relationships

The significance of the structural path relationships is assessed next. Figure 4.3 below presents an overview of the structural paths, including the coefficients and p-values associated with each relationship for the standard TPB model. Table 4.8 below offers a detailed summary of these statistics, highlighting the strength and significance of the connections between the constructs in the model.

The results presented in Appendix F, Table F.1, indicate the significance of the structural path relationships for the intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme. The path from Attitudes (A_B) to Intentions (INT) was significant and positive ($\beta = 0.736$, $p < 0.01$), demonstrating that positive attitudes significantly influence the intentions of small-scale maize irrigators to adopt water-saving technologies. In contrast, the paths from Subjective Norms (SN) to Intentions (INT) ($\beta = 0.041$, $p = 0.283$) and Perceived Behavioural Control (PBC) to Intentions (INT) ($\beta = 0.025$, $p = 0.457$) were not significant, indicating that these factors do not have a meaningful impact on the adoption intentions in this context.

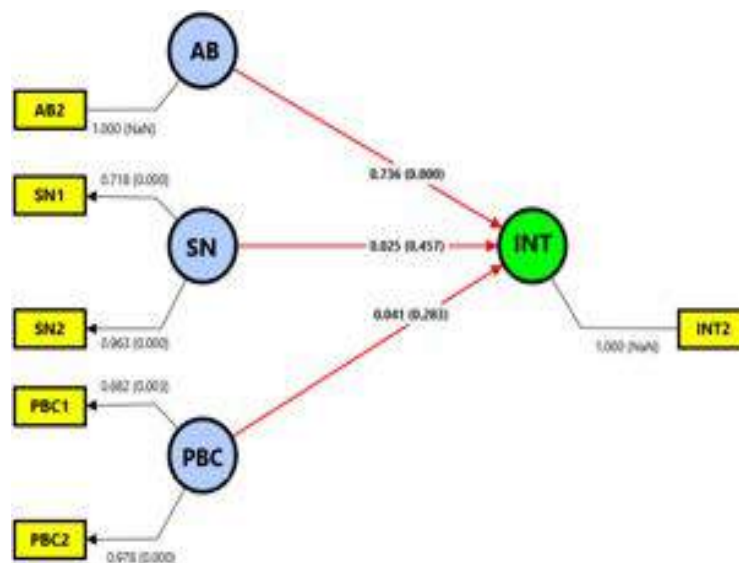


Figure 4.3: Path Analysis Findings of Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Tshiombo Irrigation Scheme

Source: Project team compilation

For the augmented or extended TPB model, which includes both mediating and direct relationships (unlike the standard TPB model), the significance of the structural relationships was assessed using a bootstrapping procedure. This method provides information on specific indirect effects, total indirect effects, direct effects, and total effects, offering a more complete understanding of the relationships between variables.

Figure 4.4 below provides a visual summary of the direct relationships in the model. The specific indirect effects are listed in Appendix F, Table F.2, the total indirect effects in Appendix F, Table F.3, the direct effects in Appendix F, Table F.4, and the total effects in Appendix F, Table F.5. This allows for a more detailed analysis to be made of how different factors influence small-scale maize irrigators' intentions to adopt water-saving technologies.

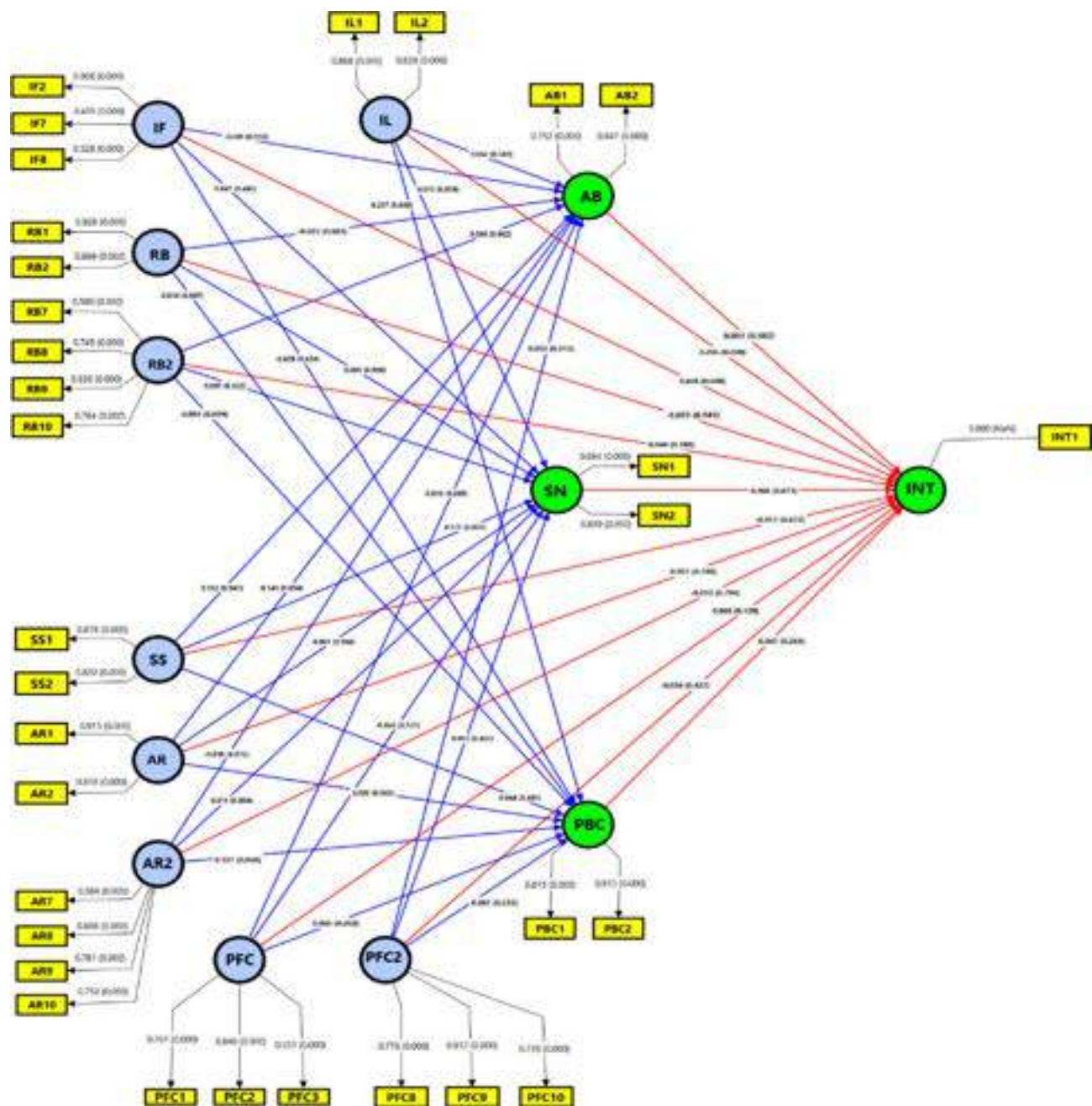


Figure 4.4: Path Analysis Results of the Extended Model on Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Tshiombo Irrigation Scheme

Source: Project team Compilation

Next, the specific indirect effects are presented in Appendix F, Table F.2. The results revealed that none of the specific indirect effects were statistically significant. This suggests that the mediating variables in the extended model do not have a notable influence on the relationships between the predictor variables and the intentions of small-scale maize irrigators to adopt water-saving technologies.

Next, Appendix F, Table F.3 presents the total indirect effects, and none of the total indirect effects were found to be significant. This indicates that, overall, the combined indirect pathways do not significantly impact the intentions of small-scale maize irrigators in the Tshiombo Irrigation Scheme to adopt water-saving technologies.

The results presented in Appendix F, Table F.4, reveal several significant direct relationships within the extended structural model. Access to Resources for Resilience (**AR2**) was found to have a positive and significant effect on Perceived Behavioural Control (**PBC**) ($\beta = 0.127$, $p < 0.05$), indicating that greater access to resources enhances irrigators' perceptions of control over adopting water-saving technologies. Informational Factors (**IF**) had a strong and significant influence on Intention (**INT**) ($\beta = 0.608$, $p < 0.01$), demonstrating that access to relevant information plays an essential role in shaping the intentions of small-scale irrigators to adopt water saving-technologies. Similarly, Institutional and Legal Factors (**IL**) positively affected both Intention (**INT**) ($\beta = 0.206$, $p < 0.01$) and Perceived Behavioural Control (**PBC**) ($\beta = 0.237$, $p < 0.01$), highlighting the importance of supportive policies and institutions in shaping adoption behaviour. Additionally, Perceived Social Support (**SS**) significantly influenced both Attitudes (**A_B**) ($\beta = 0.152$, $p < 0.05$) and Subjective Norms (**SN**) ($\beta = 0.171$, $p < 0.01$), indicating that social backing plays a critical role in forming positive attitudes and reinforcing social norms around the adoption of water-saving practices.

The total effects shown in Appendix F, Table F.5, are similar to the direct effects observed in the structural model, which is sensible, as only the direct effects were significant, and none of the indirect effects were found to be substantial.

4.2.2.1.2.3 Explanatory Power of the Model

For the standard TPB, the final step in evaluating the structural model involved assessing its explanatory power through the R^2 and f^2 statistics. The R^2 value was 0.558, with an adjusted R^2 of 0.555, indicating that the model explains approximately 55.8% of the variance in the intentions of small-scale maize irrigators to adopt water-saving technologies.

The f^2 Statistics further elucidate the impact of each construct on the model. Specifically, the effect size for Attitudes (**A_B**) was 1.155, suggesting a significant effect, while the f^2 values for Perceived Behavioural Control (**PBC**) and Subjective Norms (**SN**) were 0.004 and 0.001, respectively, indicating negligible effects. According to Hair & Alamer (2022), effect sizes can be classified as small (0.02), medium (0.15), or large (0.35). These results highlight the significant influence that attitudes have on the intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme.

The explanatory power of the extended/augmented TPB with the R^2 value for attitudes (A_B) is 0.083, the coefficient (0.083), indicates that the model explains 8.3% of the variance in attitudes towards water-saving technologies. The adjusted R^2 for attitudes is 0.060, reflecting a similar trend. In contrast, the intention (INT) to adopt water-saving technologies has a higher R^2 value of 0.518, suggesting that 51.8% of the variance in intentions is explained by the model, with an adjusted R^2 of 0.501.

The f^2 values of the extended TPB were 0.02, 0.15, and 0.35, indicating small, medium, and significant effects, respectively. The f^2 values for attitudes (A_B) are generally low, with AR showing a small effect size (0.017) and $AR2$ with no effect on A_B (0.000). For intentions (INT), the most significant effect comes from informational factors (IF), with an f^2 value of 0.655, indicating a significant effect. Other constructs such as perceived behavioural control (PBC) and subjective norms (SN) also have small to medium effect sizes, with values of 0.141 and 0.067, respectively.

4.2.2.2 Standard and augmented TPB Model for Adoption of Water Saving Policies

4.2.2.2.1 Measurement Model Assessment Results

When evaluating measurement and structural models in SmartPLS, it is often necessary to make adjustments to the initially planned model. This process is crucial for ensuring that the model accurately represents the underlying constructs and yields reliable results. Figures 4.5 and 4.6 below illustrate the initial measurement and structural models, respectively, prior to the assessment of the Standard and Augmented TPB models.

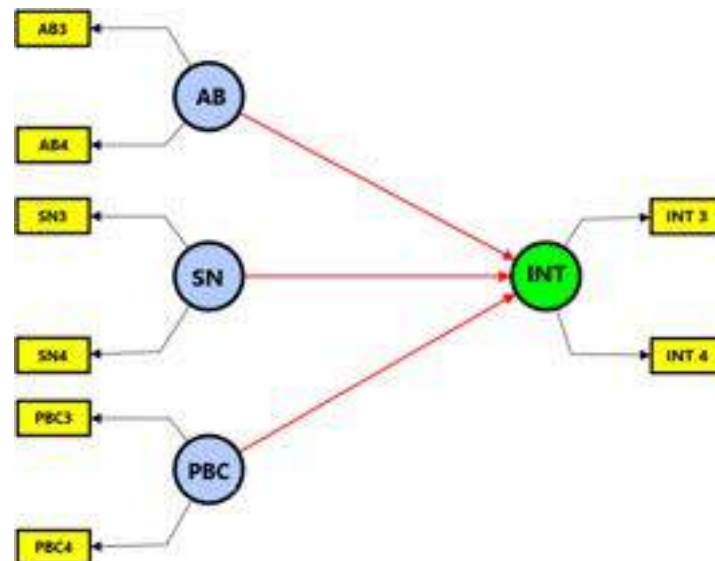


Figure 4.5: Initial Path Model of Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Source: Project team compilation

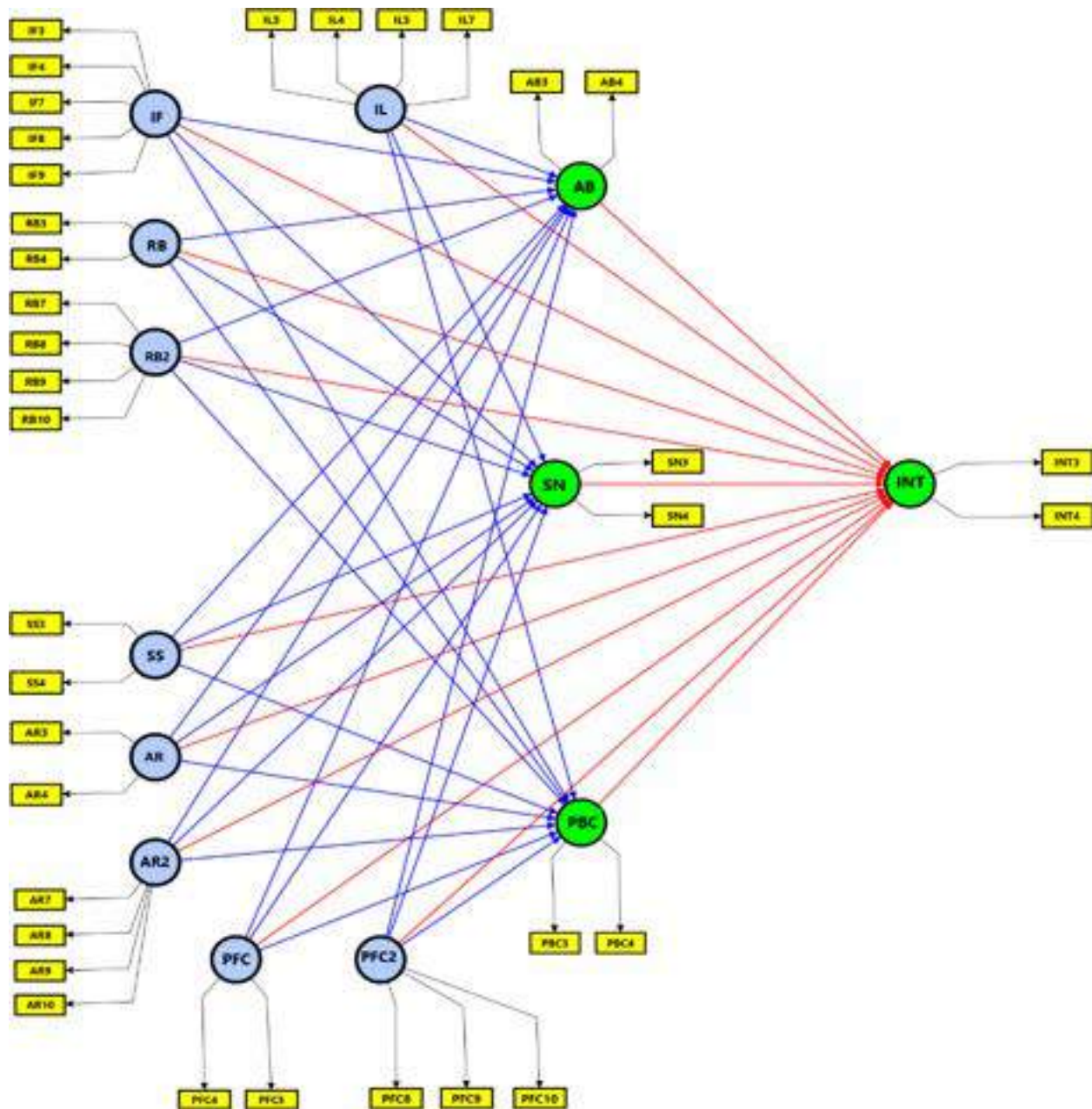


Figure 4.6: Initial Path Model of the Augmented Theory of Planned Behaviour for Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Source: Project team compilation

4.2.2.2.1.1 Indicator Reliability

The first step in assessing the measurement model for water-saving policy adoption among small-scale maize irrigators in the Tshiombo Irrigation Scheme is to evaluate the reliability of the indicators. Measurement items with loadings between 0.4 and 0.7 were considered for removal only if their exclusion improved internal consistency and convergent validity. Notably, none of the measurement items had loadings below 0.4, indicating that all items met the acceptable criteria for reliability.

4.2.2.2.1.2 Internal Consistency Reliability

Next, we assessed internal consistency reliability by using both Cronbach's alpha and composite reliability. Given the exploratory nature of this study, these lower thresholds were deemed appropriate. All constructs had Cronbach's alpha values for the standard TPB below 0.6. In contrast, composite reliability provides a more accurate measure, since it takes into account individual outer loadings. Importantly, all constructs exhibited composite reliability scores above 0.7, indicating strong internal consistency.

For the augmented TPB model, certain constructs, such as Attitudes (A_B), Perceived Social Support (SS), Perceived Risk and Benefits (RB), Access to Resources (AR), Perceived Financial Costs (PFC), and Intentions (INT), had Cronbach's alpha values below 0.6. However, all constructs showed composite reliability scores above 0.7. Composite reliability provides a more accurate measure, as it accounts for individual outer loadings.

4.2.2.2.1.3 Convergent Validity

All constructs demonstrated AVE values for both the standard and augmented TPB models exceeding 0.5, indicating that they explain a significant proportion of the variance in their respective indicators. For the augmented TPB, all constructs had AVE values above 0.5, except for Institutional and Legal Factors (IL) and Informational Factors (IF). To improve the AVE for IL , the measurement item with the lowest loading, IL_7 , was dropped, which successfully increased the AVE above 0.5.

For Informational Factors (IF), the initial step involved dropping IF_3 , the item with the lowest loading, but this did not raise the AVE above 0.5. Consequently, IF_8 , the next lowest loading item was dropped, but the AVE remained below 0.5. Finally, after dropping IF_9 , the AVE for the IF construct increased to an acceptable level above 0.5.

4.2.2.2.1.4 Discriminant Validity

Table 4.8 below indicates the standard TPB model of HTMT ratios, and the values should remain below 0.9 to confirm discriminant validity. The results indicate that both criteria are satisfied: the diagonal values are larger than the corresponding off-diagonal values for the Fornell-Larcker criterion, and all HTMT ratios are below the 0.9 threshold. This confirms that the constructs are distinct from one another, thereby ensuring the robustness of the measurement model.

Table 4.8: Fornell-Larcker Criterion and HTMT Ratios for Discriminant Validity of the Measurement Model for the Adoption of Water-Saving Policies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Fornell-Larcker Criterion					HTMT Ratio				
	<i>A_B</i>	<i>INT</i>	<i>PBC</i>	<i>SN</i>		<i>A_B</i>	<i>SN</i>	<i>PBC</i>	<i>INT</i>
<i>A_B</i>	0.763				<i>A_B</i>				
<i>INT</i>	0.319	0.777			<i>INT</i>	0.898			
<i>PBC</i>	0.273	0.387	0.850		<i>PBC</i>	0.576	0.827		
<i>SN</i>	0.269	0.327	0.191	0.845	<i>SN</i>	0.619	0.713	0.295	

Note: *A_B*- Attitudes, *INT*- Intentions, *PBC*-Perceived Behavioural Control, *SN*-Subjective Norms

Source: Project team compilation

For the augmented TPB model, the construct Intentions (INT) had discriminant validity issues with Access to Resources (AR), "Informational Factors" (IF), "Institutional and Legal Factors" (IL), and Perceived Financial Costs (PFC). To address these issues, we dropped the item *INT*₄, which successfully resolved all discriminant validity concerns. Table 4.9 below confirms that all values are below the 0.9 threshold, indicating that the model satisfies the discriminant validity criteria.

Table 4.9: Fornell-Larcker Criterion for the Extended Measurement Model of Small-Scale Maize Irrigators' Adoption of Water-Saving Policies in the Tshiombo Irrigation Scheme

	<i>A_B</i>	<i>AR</i>	<i>AR2</i>	<i>IF</i>	<i>IL</i>	<i>INT</i>	<i>PBC</i>	<i>PFC</i>	<i>PFC2</i>	<i>RB</i>	<i>RB2</i>	<i>SN</i>	<i>SS</i>
<i>A_B</i>	0.767												
<i>AR</i>	0.182	0.789											
<i>AR2</i>	0.133	0.227	0.706										
<i>IF</i>	0.240	0.298	0.325	0.766									
<i>IL</i>	0.340	0.255	0.235	0.336	0.743								
<i>INT</i>	0.238	0.198	0.281	0.326	0.761	1.000							
<i>PBC</i>	0.271	0.221	0.277	0.295	0.343	0.351	0.849						
<i>PFC</i>	0.255	0.317	0.249	0.286	0.349	0.293	0.289	0.816					
<i>PFC2</i>	0.153	0.262	0.356	0.291	0.285	0.256	0.229	0.208	0.781				
<i>RB</i>	0.216	0.275	0.177	0.242	0.245	0.162	0.178	0.291	0.129	0.785			
<i>RB2</i>	0.239	0.255	0.372	0.281	0.303	0.279	0.298	0.291	0.316	0.238	0.735		
<i>SN</i>	0.276	0.171	0.270	0.287	0.340	0.222	0.194	0.331	0.174	0.250	0.226	0.844	
<i>SS</i>	0.282	0.276	0.264	0.312	0.294	0.192	0.306	0.288	0.224	0.256	0.283	0.317	0.837

Source: Project team compilation

After completing the measurement model assessment, Table 4.10 below summarises the final results of the Standard TPB model and highlights the evaluations of indicator reliability, internal consistency, convergent validity, and discriminant validity for the measurement model.

Table 4.10: Summary of Results for the Reflective Measurement Model of Small-Scale Maize Irrigators' Adoption of Water Saving Policies in the Tshiombo Irrigation Scheme

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
<i>A_B</i>	<i>A_{B3}</i>	0.912	0.582	0.320	0.726	Yes
	<i>A_{B4}</i>	0.577				
<i>SN</i>	<i>SN₃</i>	0.882	0.714	0.603	0.833	Yes
	<i>SN₄</i>	0.806				
<i>PBC</i>	<i>PBC₃</i>	0.883	0.723	0.620	0.839	Yes
	<i>PBC₄</i>	0.817				
<i>INT</i>	<i>INT₃</i>	0.792	0.604	0.344	0.753	Yes
	<i>INT₄</i>	0.761				

Source: Project team compilation

The final HTMT ratios for the augmented TPB model are displayed in Tables 4.11 and 4.12 below, where all values are below the 0.9 threshold, indicating that the model satisfies the discriminant validity criteria.

Table 4.11: Fornell-Larcker Criterion for the Extended Measurement Model of Small-Scale Maize Irrigators' Adoption of Water-Saving Policies in the Tshiombo Irrigation Scheme

	<i>A_B</i>	<i>AR</i>	<i>AR2</i>	<i>IF</i>	<i>IL</i>	<i>INT</i>	<i>PBC</i>	<i>PFC</i>	<i>PFC2</i>	<i>RB</i>	<i>RB2</i>	<i>SN</i>	<i>SS</i>
<i>A_B</i>	0.767												
<i>AR</i>	0.182	0.789											
<i>AR2</i>	0.133	0.227	0.706										
<i>IF</i>	0.240	0.298	0.325	0.766									
<i>IL</i>	0.340	0.255	0.235	0.336	0.743								
<i>INT</i>	0.238	0.198	0.281	0.326	0.761	1.000							
<i>PBC</i>	0.271	0.221	0.277	0.295	0.343	0.351	0.849						
<i>PFC</i>	0.255	0.317	0.249	0.286	0.349	0.293	0.289	0.816					
<i>PFC2</i>	0.153	0.262	0.356	0.291	0.285	0.256	0.229	0.208	0.781				
<i>RB</i>	0.216	0.275	0.177	0.242	0.245	0.162	0.178	0.291	0.129	0.785			
<i>RB2</i>	0.239	0.255	0.372	0.281	0.303	0.279	0.298	0.291	0.316	0.238	0.735		
<i>SN</i>	0.276	0.171	0.270	0.287	0.340	0.222	0.194	0.331	0.174	0.250	0.226	0.844	
<i>SS</i>	0.282	0.276	0.264	0.312	0.294	0.192	0.306	0.288	0.224	0.256	0.283	0.317	0.837

Source: Project team compilation

Table 4.12: HTMT Ratios for the Extended Measurement Model of Small-Scale Maize Irrigators' Adoption of Water-Saving Policies are ensured in the Tshiombo Irrigation Scheme

	<i>A_B</i>	<i>AR</i>	<i>AR2</i>	<i>IF</i>	<i>IL</i>	<i>INT</i>	<i>PBC</i>	<i>PFC</i>	<i>PFC2</i>	<i>RB</i>	<i>RB2</i>	<i>SN</i>	<i>SS</i>
<i>A_B</i>													
<i>AR</i>	0.505												
<i>AR2</i>	0.290	0.444											
<i>IF</i>	0.724	0.823	0.750										
<i>IL</i>	0.767	0.524	0.353	0.760									
<i>INT</i>	0.410	0.301	0.340	0.601	0.884								
<i>PBC</i>	0.576	0.423	0.423	0.657	0.529	0.438							
<i>PFC</i>	0.584	0.716	0.429	0.715	0.626	0.417	0.513						
<i>PFC2</i>	0.290	0.488	0.521	0.646	0.443	0.299	0.346	0.344					
<i>RB</i>	0.531	0.713	0.344	0.727	0.517	0.236	0.333	0.623	0.260				
<i>RB2</i>	0.491	0.460	0.540	0.613	0.440	0.330	0.437	0.486	0.451	0.456			
<i>SN</i>	0.619	0.315	0.428	0.622	0.556	0.289	0.295	0.584	0.250	0.472	0.339		
<i>SS</i>	0.662	0.561	0.432	0.711	0.506	0.256	0.494	0.532	0.350	0.538	0.440	0.531	

Source: Project team compilation

Following the assessment of the measurement model, a summary of the final measurement model results is provided in Table 4.13 below. This table consolidates the outcomes of key reliability and validity checks, including indicator reliability, internal consistency reliability, convergent validity, and discriminant validity.

Table 4.13: Summary of Results for the Reflective Measurement Model of the Extended Theory of Planned Behaviour on the Adaptation of Water-Saving Policies by Small-Scale Maize Irrigators in the Tshiombo

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
<i>A_B</i>	<i>A_{B3}</i>	0.883	0.586	0.320	0.732	Yes
	<i>A_{B4}</i>	0.629				
<i>SN</i>	<i>SN₃</i>	0.887	0.712	0.603	0.832	Yes
	<i>SN₄</i>	0.799				
<i>PBC</i>	<i>PBC₃</i>	0.897	0.722	0.620	0.838	Yes
	<i>PBC₄</i>	0.798				
<i>SS</i>	<i>SS₃</i>	0.851	0.701	0.574	0.824	Yes
	<i>SS₄</i>	0.824				
<i>IL</i>	<i>IL₃</i>	0.696	0.560	0.612	0.792	Yes
	<i>IL₄</i>	0.685				

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
	<i>IL</i> ₅	0.839				
	<i>IL</i> ₇	Dropped				
RB	<i>RB</i> ₃	0.651	0.625	0.405	0.769	Yes
	<i>RB</i> ₄	0.899				
RB2	<i>RB</i> ₇	0.627	0.540	0.713	0.823	Yes
	<i>RB</i> ₈	0.754				
	<i>RB</i> ₉	0.810				
	<i>RB</i> ₁₀	0.739				
IF	<i>IF</i> ₃	Dropped	0.588	0.304	0.739	Yes
	<i>IF</i> ₄	0.845				
	<i>IF</i> ₇	0.677				
	<i>IF</i> ₈	Dropped				
	<i>IF</i> ₉	Dropped				
Ar2	<i>AR</i> ₇	0.639	0.500	0.664	0.799	Yes
	<i>AR</i> ₈	0.721				
	<i>AR</i> ₉	0.748				
	<i>AR</i> ₁₀	0.710				
AR	<i>AR</i> ₃	0.689	0.626	0.407	0.769	Yes
	<i>AR</i> ₄	0.877				
PFC2	<i>PFC</i> ₈	0.755	0.612	0.685	0.825	Yes
	<i>PFC</i> ₉	0.811				
	<i>PFC</i> ₁₀	0.777				
PFC	<i>PFC</i> ₄	0.780	0.659	0.501	0.793	Yes
	<i>PFC</i> ₅	0.850				
INT	<i>INT</i> ₃	1.000	N/A	N/A	N/A	Yes
	<i>INT</i> ₄	Dropped				

Source: Project team compilation

4.2.2.2.2 Structural Model Assessment Results

4.2.2.2.2.1 Assessment of Collinearity Issues

The first step in assessing the structural model involved evaluating collinearity issues among the inner paths. The results indicated that all Variance Inflation Factor (VIF) values for the inner paths were below 3. This finding suggests that there are no significant collinearity concerns within the model.

4.2.2.2.2 Significance and Relevance of Structural Relationships

Figure 4.7 below provides a visual overview of the structural paths, including the coefficients and corresponding p-values for the standard TPB model. Additionally, Table 4.19 below presents a detailed overview of these statistical results, offering insights into the strength and significance of the relationships among the constructs.

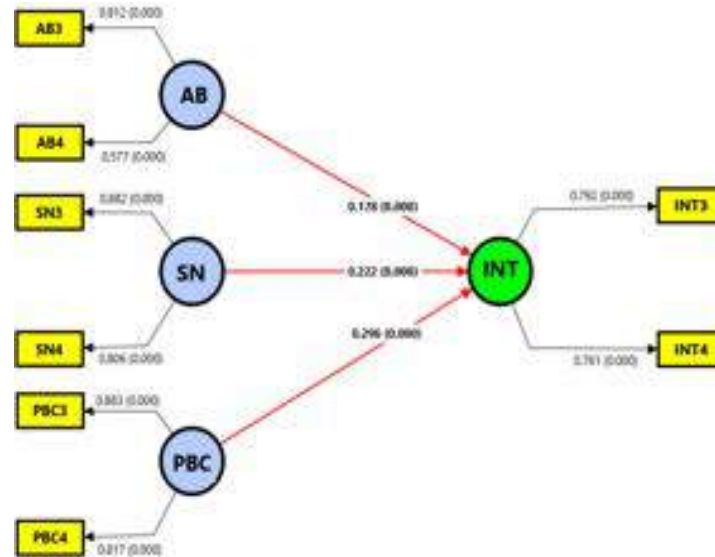


Figure 4.7: Path Analysis Findings of Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Source: Project team compilation

The results presented in Appendix F, Table F.6, demonstrate several significant direct effects in the structural model. The path from Attitudes (**AB**) to Intentions (**INT**) shows a positive and significant relationship ($\beta = 0.178$, $p < 0.01$), indicating that more favorable attitudes toward water-saving policies positively influence the intentions of small-scale maize irrigators in the Tshiombo Irrigation Scheme to adopt these practices.

Additionally, the path from Subjective Norms (**SN**) to Intentions (**INT**) also reveals a significant positive relationship ($\beta = 0.296$, $p < 0.01$), suggesting that the perceptions of social pressure and expectations from peers significantly impact the intention to adopt water-saving policies. Lastly, the path from Perceived Behavioural Control (**PBC**) to Intentions (**INT**) is significant and positive as well ($\beta = 0.222$, $p < 0.01$), indicating that the belief in one's ability to perform the behaviour significantly influences the intention to adopt these policies.

Since the augmented model includes mediating effects, the bootstrapping procedure provides results for specific indirect effects (Appendix F, Table F.7), total indirect effects (Appendix F, Table F.8), direct effects (Appendix F, Table F.9, and total effects (Appendix F Table F.10). Figure 4.8 below offers a visual representation of the direct impact (path coefficients) and their corresponding p-values.

Figure 4.8: Path Analysis Results of the Extended Model on Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Next is the evaluation of the specific indirect effects, as shown in Appendix F, Table F.7. The results revealed that none of the specific indirect effects were found to be significant. This indicates that, while mediating the relationships that were modelled, they did not demonstrate a statistically meaningful influence on the outcome variables in this context.

The total indirect effects, as presented in Appendix F, Table F.8, also showed that none of the total indirect effects were found to be significant. This is consistent with the findings for the specific indirect effects, further indicating that the mediating variables did not significantly contribute to the overall relationships in the model.

The direct effects analysis revealed several significant relationships among the constructs (Appendix F, Table F.9). Access to Resources for Resilience (**AR2**) positively and significantly influenced Subjective Norms (**SN**) ($\beta = 0.115$, $p < 0.05$), suggesting that improved access to resources enhances the perceived social expectations surrounding the adoption of water-saving technologies. Additionally, **AR2** had a positive and significant effect on Intentions (**INT**) ($\beta = 0.097$, $p < 0.05$), indicating that greater access to resources is associated with increased intentions to adopt water-saving practices.

Institutional and Legal Factors (**IL**) exhibited strong positive effects across multiple constructs, notably on Intentions (**INT**) ($\beta = 0.733$, $p < 0.001$), highlighting the point that supportive institutional and legal frameworks significantly drive the intentions of irrigators to adopt water-saving technologies. **IL** also positively influenced Attitudes (**A_B**) ($\beta = 0.209$, $p < 0.001$), suggesting that better institutional support fosters more favourable attitudes toward water-saving practices. Furthermore, **IL** positively impacted on Perceived Behavioural Control (**PBC**) ($\beta = 0.170$, $p < 0.01$), indicating that supportive legal environments enhance irrigators' perceptions of their ability to adopt these technologies.

Moreover, Perceived Financial Costs (**PFC**) had a significant positive effect on Subjective Norms (**SN**) ($\beta = 0.160$, $p < 0.01$), suggesting that perceptions of financial costs influence the social pressures experienced by irrigators regarding technology adoption. Perceived Behavioural Control (**PBC**) also demonstrated a positive relationship with Intentions (**INT**) ($\beta = 0.090$, $p < 0.05$), indicating that higher levels of perceived control correlate with greater intentions to adopt water-saving technologies.

Lastly, Perceived Social Support (**SS**) positively affected both Attitudes (**A_B**) ($\beta = 0.140$, $p < 0.05$) and Perceived Behavioural Control (**PBC**) ($\beta = 0.131$, $p < 0.05$), emphasising the role of social support in shaping attitudes and enhancing perceptions of control among irrigators. **SS** also positively influenced Subjective Norms (**SN**) ($\beta = 0.150$, $p < 0.01$), reinforcing the importance of perceived social support in driving the social expectations surrounding water-saving technology adoption.

The total effects shown in Appendix F, Table F.9 are consistent with the direct effects in Appendix F, Table F.10. This consistency is expected, since none of the indirect effects were significant. It suggests that the relationships among the constructs in the model are mainly direct. The absence of substantial indirect effects indicates that the main factors influencing the intentions of small-scale maize irrigators to adopt water-saving technologies are the direct connections between the key constructs, rather than through mediated pathways (A_B , SN , PBC).

4.2.2.2.3 Explanatory Power of the Model

The R^2 value was found to be 0.244, with an adjusted R^2 of 0.234 for the standard TPB model. This indicates that approximately 24.4% of the variance in the intentions to adopt water-saving policies among small-scale maize irrigators in the Tshiombo Irrigation Scheme can be explained by the model. On the other hand, the augmented TPB model, as indicated by the R^2 and f^2 statistics, showed that the intentions (INT) construct had the highest R^2 value of 0.609, with an adjusted R^2 of 0.596. This indicates that the model effectively captures the factors influencing small-scale maize irrigators' intentions to adopt water-saving Policies. In contrast, attitudes (A_B) had a lower R^2 value of 0.182, suggesting that the model explains less variance in attitudes compared with intention.

The f^2 Statistics of the standard TPB model further elucidate the effect sizes of the predictors. For Attitudes (A_B), the f^2 value is 0.037, suggesting a small effect size. The f^2 for Perceived Behavioural Control (PBC) is 0.105, which indicates a medium effect size, while the f^2 for Subjective Norms (SN) is 0.060, representing a small effect size. According to Hair and Alamer (2022), these classifications of effect sizes imply that, while the predictors do have some influence on the intentions to adopt water-saving policies, there remains substantial variance unexplained by the model, indicating potential areas for further exploration.

In the augmented TPB model, the f^2 Statistics reveal the effect sizes of different constructs on behavioral outcomes, and the values of 0.02, 0.15, and 0.35 denote small, medium, and large effects, respectively. Institutional and legal factors (IL) exhibited a tremendous effect on intentions (INT) with an f^2 value of 0.957, underscoring its significance in the model. In contrast, constructs such as access to resources for resilience ($AR2$) displayed minimal effects, with f^2 values close to zero, indicating limited impact on intentions and attitudes.

4.2.2.3 Augmented TPB Model for the adaptation towards climate variability

4.2.2.3.1 Measurement Model Assessment Results

Figure 4.9 below and Figure 4.10 below present the initial path model designed to assess the constructs related to small-scale farmers' adaptation to climate variability in the Tshiombo Irrigation Scheme for the

standard and augmented TPB models, respectively. This model encompasses the primary constructs of Attitudes, Subjective Norms, and Perceived Behavioural Control, each linked to the farmers' intention to adapt to climate variability. As the measurement and structural model assessments are conducted, this initial model may be subject to modifications, including the potential exclusion of constructs or measurement items that do not meet the established minimum requirements for validity and reliability.

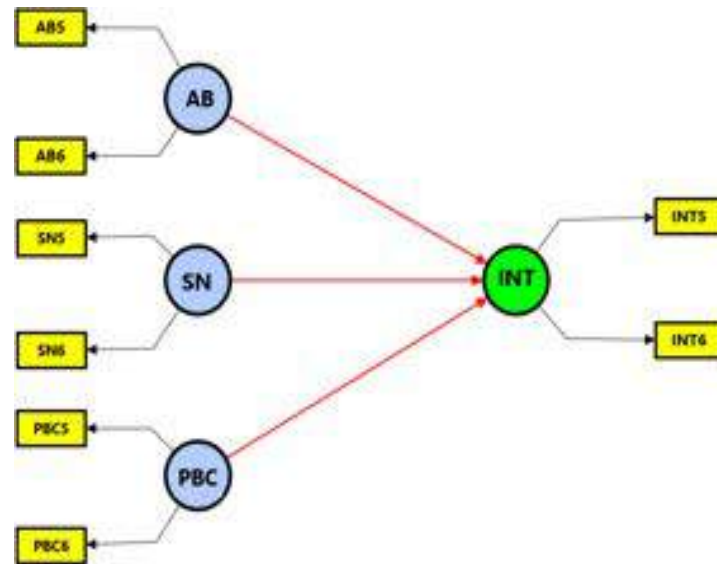


Figure 4.9: Initial Path Model of Small-Scale Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Source: Project team compilation

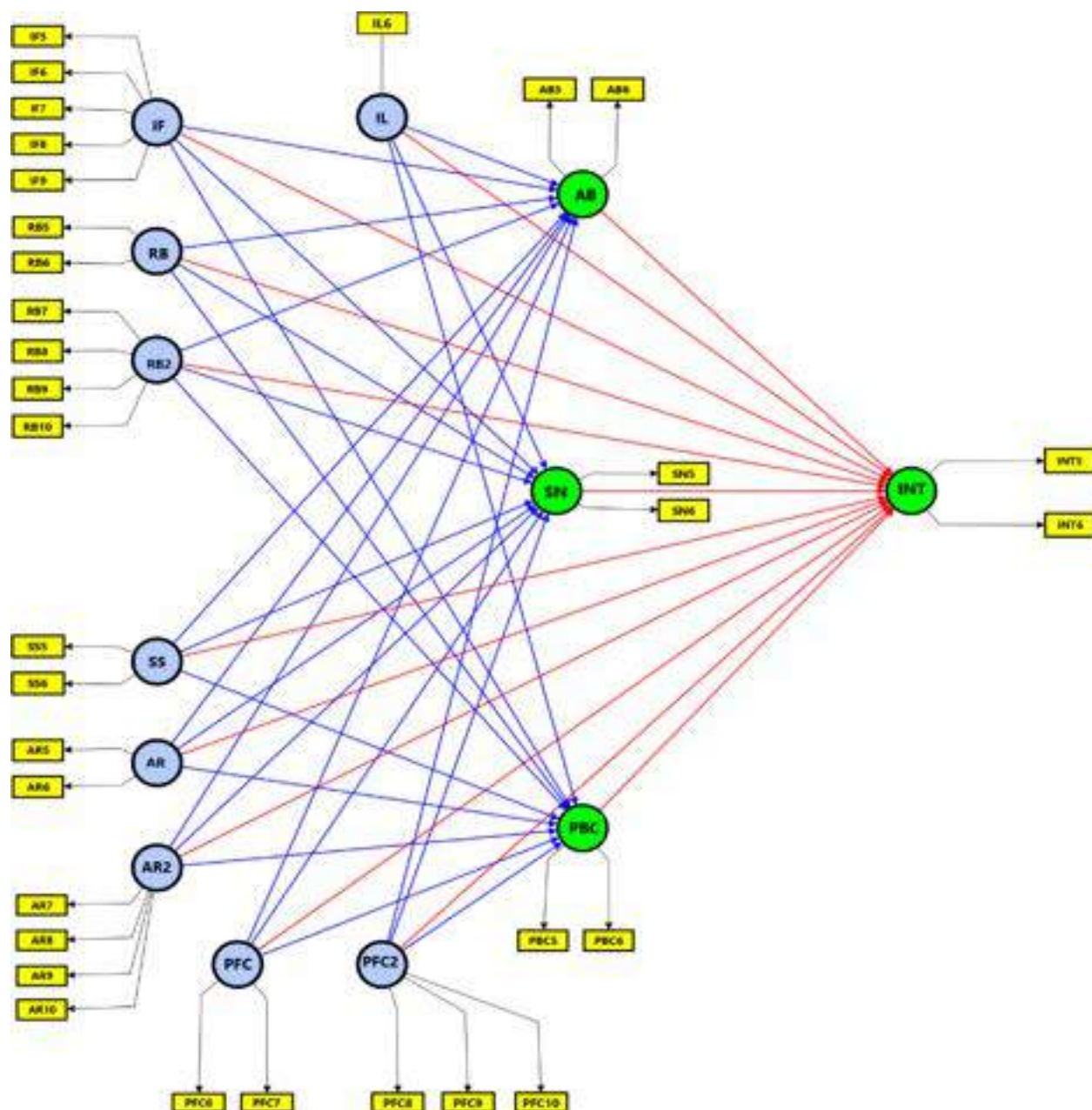


Figure 4.10: Initial Path Model of the Augmented Theory of Planned Behaviour for Small-Scale Maize Irrigators' Intentions for Adaptation Towards Climate variability in the Tshiombo Irrigation Scheme

Source: Project team compilation

4.2.2.3.1.1 Indicator Reliability

Loadings between 0.4 and 0.7 were considered for removal only if their exclusion improved internal consistency and convergent validity. Indicator reliability is crucial as it determines the extent to which the measurement items accurately reflect their respective latent constructs. After the initial estimation of the

model, it was found that the factor loadings for all constructs for the standard TPB model were above the threshold of 0.4, except for the measurement item A_{B6} , which registered a factor loading of 0.364. Given that this loading did not meet the acceptable threshold, the decision was made to drop A_{B6} from the model to enhance the overall reliability and validity of the constructs. For the augmented TPB model, the initial estimation of the path model indicated that none of the measurement items had loadings below 0.4.

4.2.2.3.1.2 Internal Consistency Reliability

For the standard TPB model, the internal consistency results show that all constructs have Cronbach's alpha and Composite Reliability values above the minimum threshold of 0.6, except for the Intention construct, which has a Cronbach's alpha of 0.485. However, Cronbach's alpha is known to underestimate reliability, particularly when the number of items is small or when indicators have varying outer loadings on the construct. Given this limitation, Composite Reliability offers a more accurate measure of internal consistency. In this study, all constructs, including Intention, meet the minimum requirement based on their Composite Reliability values.

For the augmented TPB model, some constructs, including Attitudes (A_B Perceived Risk and Benefits (RB), Access to Resources (AR), and Perceived Financial Costs (PFC) had Cronbach's Alpha values below 0.6. However, it is essential to note that all constructs achieved Composite Reliability scores above 0.6. It is also worth mentioning that Cronbach's Alpha may underestimate reliability, especially when there are few items or varying outer loadings. Composite Reliability provides a more accurate measure of internal consistency since it considers the individual outer loadings of each item within the construct.

4.2.2.3.1.3 Convergent Validity

For the standard TPB model, the attitudes construct does not have an AVE value owing to having only one measurement item; all other constructs demonstrated AVE values greater than 0.5, confirming that their indicators exhibit satisfactory levels of convergent validity. On the other hand, for the augmented TPB model, only one construct, Institutional and Legal Factors (IF), had an AVE below the acceptable threshold of 0.5. To improve the AVE, we first removed the measurement item with the lowest loading, IF_5 . However, this did not resolve the IF convergent issues. We then removed the next measurement item with the lowest loading, IF_9 . After making these changes, the AVE for the Institutional and Legal Factors (IF) increased above the threshold of 0.5, indicating that the construct has satisfactory convergent validity.

4.2.2.3.1.4 Discriminant Validity

As shown in Table 4.14 below, in the standard TPB model, the diagonal values (which represent the square roots of the AVEs) for each construct are greater than the off-diagonal values, confirming that the constructs are sufficiently distinct. Additionally, the HTMT ratio, which further evaluates discriminant validity,

indicates that the values are significantly below the threshold of 0.85 (or 0.9 in more lenient cases) for all pairs of constructs. This is also reflected in Table 4.16 below, where the HTMT ratios demonstrate acceptable levels of discriminant validity. Overall, these results indicate that the constructs are adequately distinct from one another.

Table 4.14: Fornell-Larcker Criterion and HTMT Ratios for Discriminant Validity of the Measurement Model for Small-Scale Maize Irrigators' Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Fornell-Larcker Criterion					HTMT Ratio				
	A_B	INT	PBC	SN		A_B	INT	PBC	SN
A_B	1.000				A_B				
INT	0.651	0.793			INT	0.779			
PBC	0.141	0.267	0.916		PBC	0.157	0.487		
SN	0.085	0.176	0.123	0.907	SN	0.096	0.298	0.155	

Note: A_B - Attitudes, INT - Intentions, PBC -Perceived Behavioural Control, SN -Subjective Norms

Source: Project team compilation

A summary of the final measurement model, including the results of the convergent validity, internal consistency reliability, and discriminant validity assessments, is provided in Table 4.15 below.

Table 4.15: Summary of Results for the Reflective Measurement Model of Small-Scale Maize Irrigators' Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
A_B	A_{B5}	1.000	N/A	N/A	N/A	Yes
	A_{B6}	Dropped				
SN	SN_5	0.907	0.824	0.786	0.903	Yes
	SN_6	0.908				
PBC	PBC_5	0.912	0.840	0.809	0.811	Yes
	PBC_6	0.921				
INT	INT_5	0.591	0.629	0.485	0.808	Yes
	INT_6	0.954				

Source: Project team compilation

For the augmented TPB model, the analysis revealed that the construct Intentions (INT) had discriminant validity issues with the constructs Attitudes (A_B), Institutional and Legal Factors (IF), and Perceived Financial Costs (PFC). To address this, we refined the model by dropping the measurement item INT_5 .

However, after this adjustment, there were still discriminant validity issues between Attitudes (A_B) and Intentions (INT). To resolve this, we removed the lowest loading measurement item from the Attitudes construct, which was A_{B6} . Following these adjustments, the model no longer exhibited any discriminant validity issues, indicating that the constructs are now distinct from one another. The final Fornell-Larcker values are presented in Table 4.16 below, while the final Heterotrait-Monotrait (HTMT) values are displayed in Table 4.17 below.

Table 4.16: Fornell-Larcker Criterion for the Extended Measurement Model of Small-Scale Maize Irrigators' Adaptation Towards Climate Variability in the Tshiombi Irrigation Scheme

	A_B	AR	$AR2$	IF	IL	INT	PBC	PFC	$PFC2$	RB	$RB2$	SN	SS
A_B	1.000												
AR	0.117	0.826											
$AR2$	0.133	0.245	0.707										
IF	0.163	0.283	0.377	0.728									
IL	0.182	0.233	0.235	0.284	1.000								
INT	0.695	0.233	0.286	0.717	0.272	1.000							
PBC	0.141	0.142	0.254	0.251	0.276	0.204	0.916						
PFC	0.189	0.264	0.344	0.358	0.267	0.319	0.291	0.805					
$PFC2$	0.146	0.219	0.350	0.336	0.220	0.254	0.303	0.421	0.784				
RB	0.158	0.226	0.346	0.360	0.254	0.297	0.286	0.264	0.282	0.815			
$RB2$	0.157	0.279	0.369	0.260	0.256	0.205	0.221	0.365	0.314	0.312	0.735		
SN	0.085	0.186	0.253	0.204	0.165	0.152	0.123	0.152	0.109	0.203	0.232	0.907	
SS	0.098	0.312	0.299	0.208	0.200	0.185	0.202	0.189	0.226	0.236	0.338	0.276	0.882

Source: Project team compilation

Table 4.17: HTMT Ratios for the Extended Measurement Model of Small-Scale Maize Irrigators' Adaptation Towards Climate Variability in the Tshiombi Irrigation Scheme

	A_B	AR	$AR2$	IF	IL	INT	PBC	PFC	$PFC2$	RB	$RB2$	SN	SS
A_B													
AR	0.154												
$AR2$	0.164	0.408											
IF	0.209	0.499	0.617										
IL	0.182	0.318	0.287	0.370									
INT	0.695	0.313	0.353	0.795	0.272								
PBC	0.157	0.222	0.345	0.387	0.308	0.227							
PFC	0.276	0.530	0.620	0.692	0.398	0.473	0.478						
$PFC2$	0.174	0.362	0.521	0.555	0.261	0.304	0.404	0.730					
RB	0.225	0.442	0.598	0.670	0.360	0.421	0.446	0.554	0.482				
$RB2$	0.184	0.457	0.540	0.446	0.297	0.242	0.286	0.638	0.451	0.522			
SN	0.096	0.286	0.346	0.314	0.186	0.172	0.155	0.244	0.148	0.327	0.304		
SS	0.113	0.512	0.437	0.312	0.235	0.218	0.263	0.335	0.323	0.390	0.470	0.370	

Source: Project team compilation

Table 4.18 below provides a summary of the final measurement model assessment results, which were obtained by assessing the indicator reliability, internal consistency reliability, convergent validity, and discriminant validity.

Table 4.18: Summary of Results for the Reflective Measurement Model of the Extended Theory of Planned Behaviour on making Adaptation Towards Climate variability by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant Validity
		Loadings	AVE	Cronbach's Alpha	Composite reliability	HTMT
		>0.4	>0.5	0.6-0.9	>0.6	Significantly lower than 0.85 (0.9)?
<i>A_B</i>	<i>A_{B5}</i>	1.000	N/A	N/A	N/A	Yes
	<i>A_{B6}</i>	Dropped				
<i>SN</i>	<i>SN₅</i>	0.911	0.823	0.786	0.787	Yes
	<i>SN₆</i>	0.904				
<i>PBC</i>	<i>PBC₅</i>	0.922	0.840	0.809	0.812	Yes
	<i>PBC₆</i>	0.910				
<i>SS</i>	<i>SS₅</i>	0.893	0.778	0.715	0.875	Yes
	<i>SS₆</i>	0.871				
<i>IL</i>	<i>IL₆</i>	1.000	N/A	N/A	N/A	Yes
<i>RB</i>	<i>RB₅</i>	0.787	0.664	0.496	0.798	Yes
	<i>RB₆</i>	0.842				
<i>RB2</i>	<i>RB₇</i>	0.649	0.540	0.713	0.823	Yes
	<i>RB₈</i>	0.744				
	<i>RB₉</i>	0.811				
	<i>RB₁₀</i>	0.727				
<i>IF</i>	<i>IF₅</i>	Dropped	0.529	0.597	0.768	Yes
	<i>IF₆</i>	0.751				
	<i>IF₇</i>	0.688				
	<i>IF₈</i>	0.653				
	<i>IF₉</i>	Dropped				
<i>Ar2</i>	<i>AR₇</i>	0.625	0.500	0.664	0.799	Yes
	<i>AR₈</i>	0.716				
	<i>AR₉</i>	0.747				
	<i>AR₁₀</i>	0.731				
<i>AR</i>	<i>AR₅</i>	0.813	0.683	0.536	0.811	Yes
	<i>AR₆</i>	0.840				
<i>PFC2</i>	<i>PFC₈</i>	0.753	0.610	0.685	0.824	Yes
	<i>PFC₉</i>	0.819				
	<i>PFC₁₀</i>	0.771				
<i>PFC</i>	<i>PFC₆</i>	0.802	0.649	0.460	0.787	Yes

	PFC_7	0.810				
INT	INT_5	0.855	N/A	N/A	N/A	Yes
	INT_6	Dropped				

Source: Project team compilation

4.2.2.3.2 Structural Model Assessment Results

The structural model assessment focuses on evaluating the relationships among the constructs related to small-scale farmers' adaptation to climate variability in Limpopo, Thohoyandou. This evaluation includes three key components: assessing collinearity issues, examining the significance of structural relationships, and determining the model's explanatory power.

4.2.2.3.2.1 Assessment of Collinearity Issues

The results indicated that none of the structural paths exhibited Variance Inflation Factor (VIF) values exceeding 3. This suggests that collinearity is not a concern in our model, allowing us to proceed with further analysis of the structural relationships.

4.2.2.3.2.2 Significance and Relevance of Structural Relationships

The next step in the analysis is to evaluate the hypothesised relationships between latent variables by examining the path coefficients (β) and their significance levels (p-values). A bootstrapping procedure with 10,000 resamples was conducted, using the percentile method to determine confidence intervals at a 5% significance level. This approach examines the confidence intervals by evaluating the lower 2.5% and upper 97.5% percentiles of the distribution to establish a 95% confidence interval for the coefficients. All hypotheses were evaluated using path coefficients (β), and only those with p values ≤ 0.05 were considered significant. The hypothesis testing results are shown in Figure 4.11 below and in Appendix F, Table F.11.

The results showed that attitudes significantly influence small-scale irrigators' intentions to adapt to climate variability. The path coefficient for the relationship between Attitude (A_B) and Intention (INT) was positive and significant ($\beta = 0.619$, $p < 0.01$), suggesting a strong positive relationship between favourable attitudes and the intention of small-scale farmers to adapt to climate variability. This indicates that, as farmers' attitudes become more positive, their intentions to adapt also increase significantly.

The results showed that subjective norms significantly influence small-scale irrigators' intentions to adapt to climate variability. The path coefficient for the relationship between Subjective norms (SN) and Intention (INT) was positive and significant ($\beta = 0.103$, $p < 0.01$), suggesting that the perceptions of others regarding adaptation behaviours can significantly impact individual farmers' intentions.

The results showed that perceived behavioural control significantly influences small-scale irrigators' intentions to adapt to climate variability. The path coefficient for the relationship between Perceived

behavioural control (*PBC*) and intention (*INT*) was positive and significant ($\beta = 0.167$, $p < 0.01$). This implies that, when farmers feel more in control of their ability to adapt to climate variability, their intentions to do so increase.

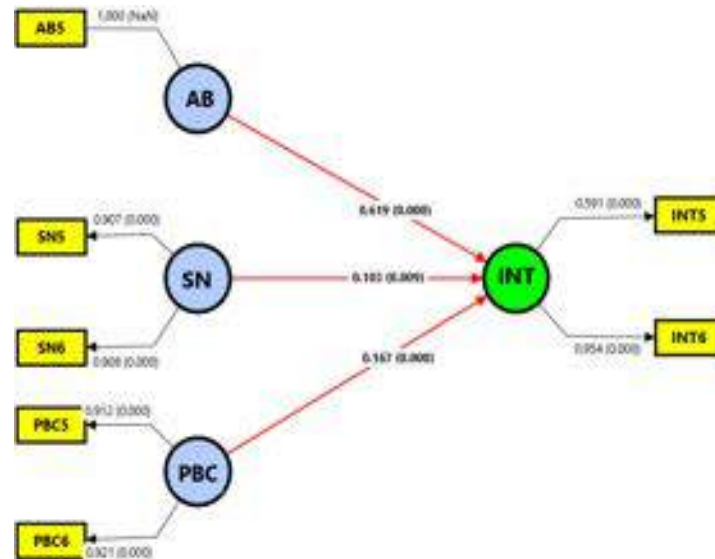


Figure 4.11: Path Analysis Findings of Small-Scale Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Source: Project team compilation

For the augmented TPB model, the bootstrapping procedure yielded specific indirect effects, total indirect effects, direct effects, and total effects, which are summarised in Appendix F, Tables F.12 to F.15. Figure 4.12 below provides a visual overview of the direct path coefficients, along with their corresponding p-values. This comprehensive analysis enables us to gain a deeper understanding of the relationships among the model's constructs.

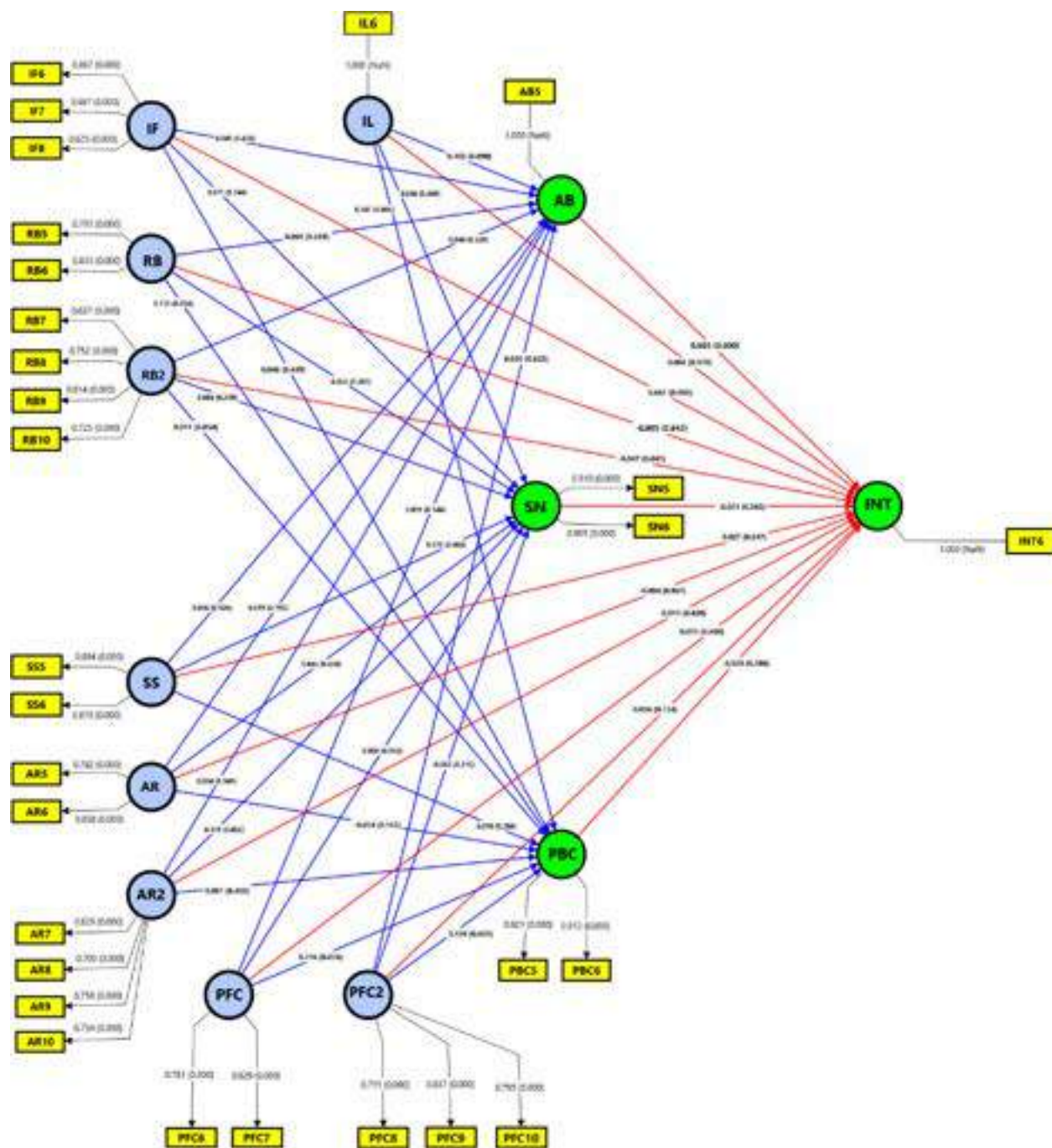


Figure 4.12: Path Analysis Results of the Extended Model on Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Source: Project team compilation

The specific indirect effects presented in Appendix F, Table F.12, indicated that none of these effects were statistically significant. This suggests that the mediating relationships between the constructs did not have a meaningful impact on small-scale maize irrigators' intentions to adapt to climate variability in the Tshiombo Irrigation scheme.

Similarly, the total indirect effects shown in Appendix F, Table F.13, also revealed that none of these effects were statistically significant. This indicates that the mediating relationships within the model did not significantly affect small-scale maize irrigators' intentions to adapt to climate variability in the Tshiombo Irrigation Scheme.

The results presented in Appendix F, Table F.14, reveal several significant direct relationships within the extended structural model. First, Attitudes (**A_B**) had a positive and significant effect on Intentions (**INT**) ($\beta = 0.603$, $p < 0.001$), suggesting that favourable attitudes towards climate variability adaptation significantly enhance the intentions of irrigators to adapt. Second, Institutional Factors (**IF**) also positively influenced Intentions (**INT**) ($\beta = 0.661$, $p < 0.001$), showing that institutional support and effective legal frameworks play a key role in motivating irrigators to adopt adaptive measures. Additionally, Institutional Factors (**IL**) positively impacted on Perceived Behavioural Control (**PBC**) ($\beta = 0.147$, $p < 0.01$), suggesting that favourable institutional conditions enhance irrigators' perceptions of their ability to implement adaptation strategies.

Perceived Financial Cost of Energy and Debt (**PFC2**) showed a positive effect on Perceived Behavioural Control (**PBC**) ($\beta = 0.139$, $p < 0.05$), suggesting that lower perceived financial costs make irrigators feel more capable of adopting adaptation practices. Furthermore, Perceived Risk and Benefits (**RB**) positively affected Perceived Behavioural Control (**PBC**) ($\beta = 0.132$, $p < 0.05$), implying that recognising the benefits of adaptation can enhance irrigators' confidence in their ability to adopt climate variability measures. Lastly, Perceived Social Support (**SS**) significantly influenced Subjective Norms (**SN**) ($\beta = 0.172$, $p < 0.01$), suggesting that social support plays a crucial role in shaping the normative beliefs of small-scale maize irrigators regarding adaptation to climate variability.

The total effects presented in Appendix F Table F.15 mirror the results of the direct impact, which is expected, given that only direct effects were found to be significant. None of the indirect effects had a significant impact, making the total effects consistent with the direct effect results. This reinforces the conclusion that the primary drivers of small-scale maize irrigators' intentions to adapt to climate variability in the Tshiombo Irrigation Scheme are based on direct influences.

4.2.2.3.2.3 Explanatory Power of the Model

The R^2 value of the standard TPB model indicates the proportion of variance in the dependent variable explained by the independent variables. At the same time, the F-squared statistic measures the effect size of each predictor construct on the outcome. The R^2 value of 0.466 indicates that approximately 46.6% of the variance in farmers' intentions to adapt to climate variability is explained by the constructs of attitudes, subjective norms, and perceived behavioural control. This suggests a moderate explanatory power of the

model, implying that the selected predictors account for a significant portion of the variation in intentions among small-scale farmers in Tshiombó.

On the other hand, the augmented TPB model illustrated that, for Intentions (*INT*), the model explains 87.6% of the variance, showing strong predictive power in determining the intentions of small-scale maize irrigators to adapt to climate variability. Attitudes (*A_B*) had a lower R^2 of 6.9%, while Perceived Behavioural Control (*PBC*) and Subjective Norms (*SN*) had R^2 values of 19.1% and 13.5%, respectively, indicating moderate explanatory power for these constructs.

In addition, f^2 values of the standard TPB model further illustrate that the individual effects of each predictor on the dependent variable were values of 0.02, 0.15, and 0.35, representing small, medium, and significant effects, respectively. The f^2 value for attitudes ($f^2 = 0.701$) indicates a large effect size, suggesting that *A_B* play a significant role in influencing farmers' intentions to adapt to climate variability. The f^2 value for *PBC* is 0.051, which is considered a small effect size, suggesting that, while *PBC* does influence intentions, its impact is relatively minor compared with attitudes. The f^2 value for *SN* is 0.019, which indicates a negligible effect size.

For the augmented TPB model, the effect sizes (f^2) reveal the individual contributions of exogenous variables to endogenous outcomes, Attitudes (*A_B*) and Institutional Factors (*IF*), both had significant effects on Intentions (*INT*), with f^2 values of 2.723 and 2.502, respectively, underscoring their critical roles in shaping adaptation intentions. Other variables, such as Perceived Financial Costs (*PFC2*) and Social Support (*SS*) had smaller effects on *PBC* and *SN*, with f^2 values of 0.017 and 0.027, indicating that, while they play a role, their impact is less substantial. Overall, the model provides a robust explanation of intentions to adapt, with smaller but notable contributions to perceived control and social norms.

4.2.3 AquaCrop Model Simulation

4.2.3.1 Net and Gross irrigation requirements for small-scale irrigators in the Tshiombó Irrigation Scheme

Before simulating scenarios, the net irrigation requirement for green maize production in the Tshiombó Irrigation Scheme must be established. This was achieved by using the AquaCrop model, which simulated scenarios based on local soil characteristics, weather data, and relevant crop parameters. Although green maize can be cultivated throughout most of the year in Tshiombó, planting is typically concentrated between July and September. According to van Averbé (2013), this window aligns with optimal growing conditions, as maize streak virus pressure declines, and conditions favour the development of large cobs. Planting during this period also reduces market competition with rainfed (dryland) maize. For this analysis, the planting date was fixed on 1 September, which falls within the commonly preferred planting window.

The net irrigation requirement was simulated annually for the period 2006 to 2022, providing insight into inter-annual variability. Table 4.19 below presents the net irrigation requirement for each year during this period, along with the multi-year average.

Table 4.19: Net Irrigation Requirement for green maize in the Tshiombo Irrigation Scheme

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Net irrigation requirement (mm)	147.5	28.8	126.1	122.7	142.1	57.6	42.5	117.1	173.6	204.1	124.4	121.1	159.3	149.1	84.7	69.9	52.3	113

Source: Project team compilation

Following Table 4.34, Equation 4.1 is presented, which was used to calculate the overall irrigation efficiency for the Tshiombo Irrigation Scheme. This calculation considers both conveyance efficiency (through lined canals) and field application efficiency (flood irrigation methods). According to Brouwer et al. (1989), surface irrigation methods such as border, furrow, or basin irrigation typically have a field application efficiency of 60%, while lined canals have a conveyance efficiency of 95%. Based on these values, the overall scheme irrigation efficiency is calculated using Equation 4.1, and the amount derived was 57%.

$$E = \frac{ec \times ea}{100} \quad (4.1)$$

where:

E Scheme irrigation efficiency (%)

ec Conveyance efficiency (%)

ea Field application efficiency (%)

$$E = \frac{95 \times 60}{100} = 57$$

Considering the overall scheme irrigation efficiency of 57%, Equation 4.2 below was used to calculate the gross irrigation requirement (GIR). The GIR is calculated as 198.2 mm, which is higher than the net irrigation requirement (NIR) of 113 mm presented in Table 4.19 above. This increase accounts for water losses that occur during conveyance and field application, meaning that more water must be applied at the source to ensure that the crop receives the required amount at the root zone.

$$GIR_g = \frac{NIR_n}{E} \quad (4.2)$$

$$GIR_g = \frac{113}{57}$$

$$GIR_g = 198.2 \text{ mm}$$

This 198.2 mm gross irrigation requirement will serve as the baseline for developing the irrigation schedules under the various water use behaviour scenarios simulated for the Tshiombo Irrigation Scheme.

4.2.3.2 The adoption of water-saving technologies

4.2.3.2.1 No-Adoption scenario

The first behavioural scenario assessed is the adoption of water-saving technologies. Under the no-adoption scenario, the full gross irrigation requirement (GIR) of 198.2 mm is applied evenly across the growing season, with 22 mm being used at each interval. Management practices are standardised across all three adoption scenarios to isolate the effect of irrigation behaviour. These practices include non-limiting soil fertility, 25% mulch cover, no runoff losses considered, and weed management set to typical practice. Table 4.20 below provides an overview of the irrigation schedule for the no-adoption scenario of water-saving technologies in the Tshiombo Irrigation Scheme.

Table 4.20: Irrigation Schedule for the No Adoption Scenario of Water-Saving Technologies in green maize production, Tshiombo Irrigation Scheme

Event	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Day Number	Net application
1	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10	22
2	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20	22
3	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30	22
4	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	40	22

5	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	50	22
6	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	60	22
7	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	70	22
8	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	80	22
9	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	90	22

Source: Project team compilation

Table 4.21 below presents the results of the AquaCrop simulations for the no adoption scenario of water-saving technologies in the Tshiombo Irrigation Scheme.

Table 4.21: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for green maize production in the Tshiombo Irrigation Scheme (No adoption of water-saving technologies)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
No adoption of water-saving technology	2006	15.084	3.838	198	1.52
	2007	14.906	3.876	198	1.74
	2008	15.160	3.942	198	1.82
	2009	14.943	3.834	198	1.62
	2010	15.236	3.926	198	1.60
	2011	15.204	3.953	198	1.94
	2012	15.285	3.974	198	2.03
	2013	14.930	3.790	198	1.45
	2014	15.020	3.706	198	1.47
	2015	13.912	2.934	198	1.06
	2016	15.346	2.877	198	1.20
	2017	15.311	3.981	198	1.75
	2018	15.129	3.920	198	1.68
	2019	15.605	3.351	198	1.42
	2020	15.382	3.962	198	1.88
	2021	12.592	3.274	198	1.82
	2022	15.595	4.055	198	2.09
	Average	14.98	3.72	198.00	1.65

Sources: Project team compilations

4.2.3.2.2 Partial Adoption scenario

For the partial adoption scenario, irrigation scheduling is based on soil moisture depletion. Specifically, an irrigation event is triggered whenever 70% of the readily available water is depleted. All management practices, including soil fertility (non-limiting), mulch cover (25%), runoff (not considered), and weed management, are kept consistent with the no adoption scenario. The results of the AquaCrop model simulation for this scenario are presented in Table 4.22 below.

Table 4.22: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for green maize production in the Tshiombo Irrigation Scheme (Partial adoption of water-saving technologies)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Partial adoption of water-saving technology	2006	15.174	3.945	195.3	1.55
	2007	14.906	3.876	113.5	1.78
	2008	15.160	3.942	156	1.88
	2009	14.962	3.890	164.7	1.57
	2010	15.254	3.966	158.7	1.60
	2011	15.204	3.953	86.0	2.11
	2012	15.285	3.974	92.5	2.11
	2013	15.024	3.907	155.1	1.44
	2014	15.272	3.971	210	1.48
	2015	15.490	4.028	230.1	1.35
	2016	15.529	3.028	160.2	1.21
	2017	15.311	3.981	158.1	1.79
	2018	15.167	3.944	206.0	1.64
	2019	15.647	3.409	175.3	1.51
	2020	15.397	4.003	129.4	1.90
	2021	12.592	3.274	113.9	1.93
	2022	15.595	4.055	84.8	2.18
	Average	15.12	3.83	152.33	1.71

Source: Project team compilations

4.2.3.2.3 Full adoption scenario

For the full adoption scenario, drip irrigation is adopted in place of flood irrigation to enhance water use productivity. Irrigation scheduling is based on soil moisture levels, with an irrigation event triggered when 70% of the readily available water is depleted. All other management practices remain consistent with the previous scenarios. The results of the AquaCrop model simulation for the full adoption scenario are presented in Table 4.23 below.

Table 4.23: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for green maize production in the Tshiombo Irrigation Scheme (Full adoption of water-saving technologies)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Full adoption of water-saving technology	2006	15.174	3.946	168	1.74
	2007	14.906	3.876	88.4	1.93
	2008	15.160	3.942	148.0	2.07
	2009	14.962	3.890	142.2	1.73
	2010	15.254	3.966	142.8	1.73
	2011	15.204	3.53	89.9	2.22
	2012	15.285	3.974	92.5	2.17
	2013	15.024	3.907	134.0	1.58
	2014	15.272	3.971	198.2	1.69
	2015	15.490	4.028	145.0	1.40
	2016	15.529	3.028	135.5	1.34
	2017	15.311	3.981	142.3	1.94
	2018	15.167	3.944	184.9	1.83
	2019	15.647	3.409	174.2	1.56
	2020	15.397	4.003	129.1	1.95
	2021	12.592	3.274	90.3	1.97
	2022	15.595	4.055	85.1	2.24
	Average	15.116	3.807	134.729	1.829

Source: Project team compilations

4.2.3.2.4 Summary of AquaCrop model Simulation Results for the Adoption of Water-saving Technologies

Table 4.24 below presents a summary of results for the various scenarios under the water use behaviour of adopting water-saving technologies in the Tshiombo Irrigation Scheme. The table compares yield outcomes across the ‘no adoption’, ‘partial adoption’, and ‘full adoption’ scenarios. The percentage change in yields for the partial and full adoption scenarios, relative to the no adoption baseline, will be used as input shocks in the Social Accounting Matrix (SAM) to assess broader socio-economic impacts.

Table 4.24: Summary of water saving technology adoption results for small-scale maize irrigators in the Tshiombo Irrigation Scheme

	No Adoption	Soil Moisture Sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	14.98	15.12	15.12
Yield (ton/ha)	3.72	3.83	3.81
% Change of yield compared to no adoption	-	3.09%	2.42%
Irrigation (mm)	108.00	156.55	144.73
WP_{ET} (Kg/m ³)	1.50	1.68	1.81

Source: Project team compilations

4.2.3.3 The adoption of Water-Saving Policies

4.2.3.3.1 No-Adoption scenario

The first scenario is the no adoption scenario. Under this scenario, the full gross irrigation requirement (GIR) of 198.2 mm is applied in equal intervals spaced 10 days apart, resulting in 22 mm per irrigation event. Since the irrigation schedule and simulation output for this scenario are identical to those for the no-adoption scenario of water-saving technologies discussed in the previous section, the results are not presented again here.

4.2.3.3.2 Partial Adoption scenario

In the partial adoption scenario, a 30% reduction in water use is imposed. As a result, only 138.7 mm of the total 198.2 mm gross irrigation requirement is allocated for maize production. This amount is distributed evenly over the season in 10-day intervals, with 15.41 mm intended per irrigation event. However, since AquaCrop's irrigation scheduling requires whole numbers, the amount was rounded down to 15 mm per interval. The irrigation schedule for this scenario is presented in Table 4.25 below.

Table 4.25: Irrigation Schedule for the Partial Adoption Scenario of Water-Saving Technologies in green maize production, Tshiombo Irrigation Scheme

Event	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Day Number	Net application (mm)
1	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10	15
2	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20	15
3	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30	15
4	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	40	15
5	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	50	15

6	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	60	15
7	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	70	15
8	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	80	15
9	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	90	15

Source: Project team compilation

Table 4.26 below presents the results of the AquaCrop model simulations for the partial adoption of water-saving policies by small-scale maize irrigators in the Tshiombo Irrigation Scheme. Simulations were conducted for each year from 2006 to 2022, and the table includes both the annual values and the average results for the AquaCrop model output metrics over these 17 years.

Table 4.26: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for green maize production in the Tshiombo Irrigation Scheme (Partial adoption of water-saving Policies)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Partial adoption of water-saving technology	2006	14.436	3.239	135	1.35
	2007	14.906	3.876	135	1.75
	2008	15.046	3.794	135	1.78
	2009	14.473	3.378	135	1.47
	2010	14.769	3.409	135	1.45
	2011	15.204	3.953	135	1.95
	2012	15.285	3.974	135	2.03
	2013	14.534	3.465	135	1.37
	2014	13.698	2.828	135	1.21
	2015	12.398	2.061	135	0.84
	2016	14.984	2.632	135	1.13
	2017	15.031	3.844	135	1.72
	2018	14.607	3.626	135	1.62
	2019	15.024	2.976	135	1.32
	2020	15.142	3.739	135	1.80
	2021	12.592	3.265	135	1.81
	2022	15.595	4.055	135	2.09
	Average	14.57	3.42	135.00	1.57

Sources: Project team compilation

4.2.3.3 Full adoption scenario

The final scenario involves the full adoption of water-saving policies, which entails a 70% reduction in water usage. This means that only 59.5 mm of the full gross irrigation requirement (198.2 mm) is available for maize production. This amount was distributed evenly across nine irrigation events, spaced 10 days apart. Dividing 59.5 mm by nine results in 6.6 mm per interval; however, since the AquaCrop model only accepts whole numbers, 6 mm was applied per interval. The irrigation schedule for this scenario is shown in Table 4.27 below.

Table 4.27: Irrigation Schedule for the full Adoption Scenario of Water-Saving Technologies in green maize production Tshiombo Irrigation Scheme

Event	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Day Number	Net application (mm)
1	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10	6
2	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20	6
3	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30	6
4	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	40	6
5	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	50	6
6	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	60	6
7	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	70	6

8	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	80	6
9	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	90	6

Source: Project team compilation

Table 4.28 below presents the AquaCrop model simulation results for the full adoption of water-saving policies scenario, showing the outcomes for small-scale maize irrigators in the Tshiombo Irrigation Scheme from 2006 to 2022.

Table 4.28: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for green maize production in the Tshiombo Irrigation Scheme (Full adoption of water-saving Policies)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Full adoption of water-saving technology	2006	11.571	1.958	54	0.99
	2007	14.906	3.876	54	1.82
	2008	13.638	3.085	54	1.66
	2009	12.481	2.266	54	1.13
	2010	12.797	2.386	54	1.20
	2011	15.127	3.870	54	2.04
	2012	15.280	3.973	54	2.07
	2013	13.422	2.699	54	1.17
	2014	9.274	1.420	54	0.80
	2015	8.027	0.963	54	0.47
	2016	13.093	1.919	54	0.94
	2017	13.636	3.085	54	1.57
	2018	12.239	2.273	54	1.25
	2019	12.775	1.997	54	1.04
	2020	14.444	3.184	54	1.65
	2021	12.381	3.078	54	1.82
	2022	15.508	4.032	54	2.14
	Average	12.98	2.71	54.00	1.40

Source: Project team compilation

4.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water Saving Policies

Table 4.29 below presents a summary of the results for the various scenarios involving the adoption of water-saving technologies policies in the Tshiombo Irrigation Scheme. The table compares yield outcomes across the no adoption, partial adoption, and full adoption scenarios. The percentage changes in yields for the partial and full adoption scenarios, relative to the no-adoption baseline, will be used as input shocks in the Social Accounting Matrix to assess broader socio-economic impacts.

Table 4.29: Summary of water saving technology adoption results for small-scale maize irrigators in the Tshiombo Irrigation Scheme

	No Adoption	Soil Moisture sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	14.98	14.57	2.71
Yield (ton/ha)	3.72	3.42	2.71
% Change of yield compared to no adoption	-	-8.04%	-27.11%
Irrigation (mm)	198.00	135.00	54.00
WP_{ET} (Kg/m ³)	1.65	1.57	1.40

Source: Project team compilation

4.2.3.4 The adaptation towards climate variability

4.2.3.4.1 No-Adaption scenario

The no-adaptation-to-climate-variability scenario assumes the full application of the previously calculated Gross Irrigation Requirement (GIR), distributed evenly throughout the season. Unlike the no-adoption scenarios for water-saving technologies and policies, this scenario excludes mulching and applies only moderate weed management, resulting in different soil water dynamics. Although the irrigation schedule remains unchanged, separate AquaCrop model simulations were conducted because of these management differences. The results are presented in Table 4.30 below.

Table 4.30: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Green Maize Production in the Tshiombo Irrigation Scheme (No Adaptation to Climate variability Scenario)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
No adoption of water-saving technology	2006	11.562	2.936	198	1.16
	2007	11.431	2.972	198	1.32
	2008	11.627	3.023	198	1.39
	2009	11.452	2.934	198	1.22
	2010	11.683	3.010	198	1.22
	2011	11.658	3.031	198	1.48
	2012	11.723	3.048	198	1.53
	2013	11.437	2.900	198	1.10
	2014	11.511	2.836	198	1.12
	2015	10.667	2.166	198	0.80
	2016	11.767	2.206	198	0.92
	2017	11.741	3.053	198	1.33
	2018	11.599	3.006	198	1.29
	2019	11.959	2.567	198	1.08
	2020	11.792	3.057	198	1.42
	2021	9.656	2.511	198	1.38
	2022	11.961	3.110	198	1.58
	Average	11.48	2.85	198.00	1.26

Source: Project team compilation

4.2.3.4.2 Partial Adaptation scenario

In this scenario, a 20% deficit irrigation strategy is implemented to simulate partial adaptation to climate variability. Mulching is maintained at a moderate level, along with moderate weed management. The Gross Irrigation Requirement (GIR) of 198.2 mm is decreased by 20%, resulting in an adjusted allocation of 158.6 mm. This volume is applied in equal irrigation intervals of 10 days. Dividing the total across the intervals yields 17.6 mm per event; however, since the AquaCrop model only accepts whole numbers, 17 mm was applied per interval to stay within the total water allocation. The irrigation schedule for this scenario is presented in Table 4.31 below.

Table 4.31: Irrigation Schedule for the Partial Adaptation Scenario to Climate Variability in Maize Production in the Tshiombo Irrigation Scheme

Event	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	17
2	20 June	20 June	20 June	20 June	20 June	20 June	20	17
3	30 June	30 June	30 June	30 June	30 June	30 June	30	17
4	10 July	10 July	10 July	10 July	10 July	10 July	40	17
5	20 July	20 July	20 July	20 July	20 July	20 July	50	17
6	30 July	30 July	30 July	30 July	30 July	30 July	60	17
7	9 August	9 August	9 August	9 August	9 August	9 August	70	17
8	19 August	19 August	19 August	19 August	19 August	19 August	80	17
9	29 August	29 August	29 August	29 August	29 August	29 August	90	17
10	8 September	8 September	8 September	8 September	8 September	8 September	100	17
11	18 September	18 September	18 September	18 September	18 September	18 September	110	17
12	28 September	28 September	28 September	28 September	28 September	28 September	120	17
13	8 October	8 October	8 October	8 October	8 October	8 October	130	17
14	18 October	18 October	18 October	18 October	18 October	18 October	140	17
15	28 October	28 October	28 October	28 October	28 October	28 October	150	17
16	7 November	7 November	7 November	7 November	7 November	7 November	160	17
17	17 November	17 November	17 November	17 November	17 November	17 November	170	17
18	27 November	27 November	27 November	27 November	27 November	27 November	180	17
19	7 December	7 December	7 December	7 December	7 December	7 December	190	17

Source: Project team compilation

The results for the partial adaptation to the climate variability scenario are presented in Table 4.32 below. AquaCrop model simulations were conducted for each year from 2006 to 2022, and the average values over this period were calculated and reported.

Table 4.32: Simulated biomass, yield, irrigation, and water productivity metrics for green maize production in the Tshiombo irrigation scheme (partial adaptation to climate variability scenario)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Partial adoption of water-saving technology	2006	11.349	2.712	153	1.11
	2007	11.431	2.972	153	1.36
	2008	11.603	2.989	153	1.40
	2009	11.256	2.736	153	1.19
	2010	11.504	2.793	153	1.18
	2011	11.658	3.031	153	1.52
	2012	11.723	3.048	153	1.59
	2013	11.241	2.739	153	1.09
	2014	10.897	2.399	153	1.01
	2015	9.941	1.781	153	0.72
	2016	11.597	2.088	153	0.90
	2017	11.654	3.011	153	1.35
	2018	11.406	2.907	153	1.29
	2019	11.741	2.406	153	1.06
	2020	11.678	2.926	153	1.43
	2021	9.656	2.511	153	1.42
	2022	11.961	3.110	153	1.63
	Average	11.31	2.72	153.00	1.25

Source: Project team compilation

4.2.3.4.3 Full adaptation scenario

The full adaptation to the climate variability scenario in the Tshiombo Irrigation Scheme includes high-level mulching (75% coverage), and weed management is implemented at the most intensive level to eliminate crop competition. A 30% deficit irrigation strategy is adopted, reducing the gross irrigation requirement from 198.2 mm to 138.7 mm. Water is applied strategically during the crop's critical growth stages to maximise efficiency and sustain acceptable yields. The irrigation schedule for this scenario is presented in Table 4.33 below.

Table 4.33: Irrigation schedule for the partial adaptation to climate variability scenario for green maize production at the Tshiombo Irrigation Scheme

Event	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Day Number	Net application (mm)
1	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10 Sept	10	15
2	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20 Sept	20	15
3	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30 Sept	30	15
4	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	10 Oct	40	15
5	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	20 Oct	50	15
6	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	30 Oct	60	15
7	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	9 Nov	70	15
8	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	19 Nov	80	15
9	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	29 Nov	90	15

Source: Project team compilation

The simulated results for the full adaptation strategy are presented in Table 4.34 below, based on AquaCrop model simulations conducted from 2006 to 2022. Average values across these metrics are also reported in the same table.

Table 4.34: Simulated metrics for biomass, yield, irrigation, and water productivity in green maize production within the Tshiombo Irrigation Scheme (Full Adaptation to Climate variability Scenario)

	Year	Biomass (ton/ha)	Dry Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)
Full adoption of water-saving technology	2006	15.012	3.794	138	1.59
	2007	14.906	3.876	138	1.83
	2008	15.157	3.941	138	1.90
	2009	14.958	3.875	138	1.69
	2010	15.226	3.938	138	1.69
	2011	15.204	3.953	138	2.05
	2012	15.284	3.974	138	2.15
	2013	14.912	3.796	138	1.51
	2014	14.670	3.572	138	1.50
	2015	13.665	2.759	138	1.09
	2016	15.455	2.950	138	1.26
	2017	15.238	3.962	138	1.82
	2018	14.005	3.880	138	1.75
	2019	15.601	3.380	138	1.49
	2020	15.388	3.982	138	1.96
	2021	12.587	3.260	138	1.90
	2022	15.595	4.055	138	2.18
	Average	14.87	3.70	138.00	1.73

Source: Project team compilation

4.2.3.5 Summary of AquaCrop Model Simulation Results for the Adaptation to Climate Variability

The summary of simulation results for the adaptation to climate variability scenarios is presented in Table 4.35 below. Each scenario was simulated annually from 2006 to 2022, with the results of the AquaCrop model averaged over these years. Table 4.35 displays these average results, comparing yield outcomes across the no-adoption, partial-adoption, and full-adoption scenarios. The percentage changes in yields for the partial and full adoption scenarios, relative to the no-adoption baseline, will be utilised as input shocks in the Social Accounting Matrix to assess broader socio-economic impacts.

Table 4.35: Summary of Adaptation to Climate variability Results for Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

	No Adoption	Soil Moisture sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	11.48	11.31	14.87
Yield (ton/ha)	2.85	2.72	3.70
% Change of yield compared with no adoption	-	-4.56%	30.15%
Irrigation (mm)	198.00	153.00	138.00
WP_{ET} (Kg/m ³)	1.26	1.25	1.73

Source: Project team compilations

4.2.4 Multiplier Analysis

In the preceding sections, the TPB model was used to analyse the psychological drivers influencing the intentions of smallholder irrigators to engage in three key water use behaviours in the Tshiombo Irrigation Scheme: the adoption of water-saving technologies, the implementation of water-saving policies, and adaptation to climate variability. Based on these behavioural insights, three scenarios were developed to reflect different levels of behavioural change: no adoption, partial adoption, and full adoption for each of the three behaviours. The TPB results provide insight into the psychological conditions under which each behavioural scenario is likely to occur. These scenarios were then simulated in the AquaCrop model to estimate the impact of each behaviour on crop yield. The simulations produced yield changes for each scenario, relative to the baseline of no adoption, enabling us to quantify the potential agronomic outcomes associated with varying levels of behavioural change. To understand the broader economic implications, the yield changes generated by the AquaCrop model were introduced as shocks into a Social Accounting Matrix (SAM) and analysed using a partial equilibrium model or multiplier analysis. This step allowed for an assessment to be made of how each scenario under each behaviour affects the broader economy as a ripple effect. The results of this analysis are presented in the following section, organised by behaviour and level of adoption.

As the no-adoption scenario serves as the baseline, it provides a reference yield against which the outcomes of the partial and full adoption scenarios are compared. Although the no-adoption scenario produces a yield, it does not signify a change and is therefore not included in the SAM results. The analysis focuses exclusively on the partial and full adoption scenarios, which illustrate the economic implications of changes in water use behaviour relative to the baseline.

4.2.4.1 Adoption of Water-saving Technologies

Table 4.36 below presents an overview of the key findings derived from the multiplier analysis. It summarises the estimated changes in yield and various economic indicators, including labour remuneration, gross operating surplus, household income, land return, and institutional income, under the partial and full adoption scenarios for each of the three water use behaviours. The percentages shown for each scenario indicate the change in yield relative to the no-adoption baseline. The table provides a comparative view of how different levels of behavioural change might influence broader economic outcomes for small-scale maize irrigators in the Tshiombo Irrigation Scheme. These results will be discussed in more detail in the subsections that follow.

Table 4.36: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Tshiombo Irrigation Scheme for Small-Scale Maize Irrigators

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (3.09%)	Full (2.42%)	Partial (-8.04%)	Full (-27.11%)	Partial (--4.56%)	Full (30,15%)
Maize small-scale Limpopo	31.99	26.35	13.77	13.78	13.77	77.1
Total labour remuneration in SA	10.05	8.03	8.22	2.31	3.25	25.31
Limpopo province generates labour return	0.85	0.49	1.2617	1.2619	1.2616	4.589
Gross operating surplus SA	11.83	9.45	5.5506	5.5516	5.5502	21.5
Household income for Limpopo	31.35	26.82	24.6	6.09	9.73	75.85
Land return in SA	1.98	1.45	7.0573	7.058	7.057	13.99
land return to irrigation in Limpopo	R101,070.64	R97,785.80	R110,417.22	R110,418.42	R110,416.73	R251,674.09
Institution income SA (enterprise + Household)	18.17	17.82	80.54	14.851	52.69	142.58
Household generating income SA	17.92	18.06	46.11	11.398	18.26	142.01
Value-added generating income SA (Labour + capital + land)	48.02	47.52	126.087	126.116	126.075	607.95

Source: Project team compilation

4.2.4.1.1 Partial Adoption

As indicated in Table 4.36 above, the effect of the partial adoption of water-saving technologies (irrigation scheduling based on soil moisture levels) increased smallholder maize yield in the Tshiombo Irrigation Scheme in the Vhembe District, Limpopo Province, resulting in an increase in maize output valued at R32 million within the Limpopo provincial economy.

The total labour remuneration was estimated to increase by R10 million in the South African economy, with Limpopo province generating a labour return of approximately R1 million and a gross operating surplus (capital) of R12 million. Most of the labour income was derived from the Western Cape province, followed by the Gauteng and Eastern Cape provinces.

Household income was estimated to increase by R18 million, contributing to the economy of Limpopo province. The overall land return was estimated to increase by R2 million in the South African economy, of which the return to irrigation in Limpopo was only R101 070.64. The highest return on irrigation in Limpopo province was observed in the Vhembe district, followed by the Capricorn and Sekhukhune districts.

Land is one of the critical assets in South Africa in both the agricultural and non-agricultural sectors. Land multipliers measure the value of returns from production activities in South Africa. Land multipliers indicate the value of land for every R1 million injected in production for a particular activity. The findings imply that, for every R1 million injected in South Africa for irrigation agricultural production, the total return values of agricultural land were worth R2 million, and in particular, land and return to irrigation in Limpopo were only R101 070.64.

In the case of institutional incomes (enterprises and households), the economy grew by R18 million. In contrast, households and value added (labour, capital, and land) generated incomes of only R18.17 million and R48 million in the South African economy, respectively.

The findings (value added) can be interpreted as a R1 million increase in demand for output from irrigation agriculture in South Africa. In contrast, the value added in the economy increases by R18.17 when injection occurs. When the institution's findings were interpreted, a R1 million injection into the irrigation agricultural industry led to an R18 million increase in income within the economy. The findings imply that complete or high water-saving irrigation techniques can improve water use productivity and maize yield. They can also stabilise yields needed for sustainable agriculture in response to climate variability and act as catalysts to enhance food security. This aligns with the National Development Plan (NDP) of South Africa and the Sustainable Development Goals (SDG 2), aimed at ending hunger and poverty. The findings of this study, aligned with those of Anjaly et al. (2024), indicate that implementing water-saving technology interventions, such as soil moisture techniques like eco-friendly straw mulching, contributes to better soil health and sustainable yield.

Furthermore, the findings of this study were largely consistent with the research conducted by Mudzielwana et al. (2022), which highlighted the importance of adopting irrigation systems to improve the livelihoods of most households in the Vhembe district, Limpopo province. Additionally, Pfunzo et al. (2024) indicated that irrigation is crucial, as it yields a better return on land for farmers. This further implies that policies should be implemented in ways that suit and support farmers in the Vhembe district communities in accessing all necessary resources to adopt proper irrigation systems, thereby improving and increasing yields for Smallholder maize, enhancing incomes, and achieving food security.

4.2.4.1.2 Full Adoption

As indicated in Table 4.36 above, the full adoption of water-saving technologies (irrigation scheduling based on soil moisture levels and the implementation of drip irrigation) resulted in an increased yield of smallholder maize in the Tshiombo Irrigation Scheme within the Vhembe District, Limpopo Province, leading to an enhancement of maize output by R26 million in the Limpopo provincial area economy.

The total labour remuneration in the South African economy was estimated to increase by R8 million, with Limpopo province contributing approximately R500 000 in labour returns and R9 million in gross operating surplus (capital). Most of the labour income was derived from the Western Cape, followed by Gauteng and the Eastern Cape.

Household income was estimated to increase by R18.06 million for the economy of Limpopo province. The overall land return was projected to rise by R1.45 million in South Africa's economy, of which the return from irrigation in Limpopo was only R97 785.80. The highest return on irrigation in the Limpopo district was observed in the Vhembe district, followed by the Capricorn and Sekhukhune districts within the Limpopo province's economy.

In the case of institutional incomes (enterprises and households), these are estimated at R17.82 million. In contrast, the households and value-added components (labour, capital, and land) generate incomes of only R18.06 million and R47.52 million in the economy of South Africa, respectively. The findings imply that complete or advanced water-saving irrigation techniques can improve water use productivity and maize yield. The findings of this study concur with those of the study conducted by Sacolo and Abidoye (2023) and Postel et al. (2001), who found that drip irrigation technology appears to be a viable option for smallholder farmers and is key to increasing crop production, incomes, alleviating a significant share of rural hunger and poverty, and enhancing household food security.

4.2.4.2 Adoption of Water-Saving Policies

4.2.4.2.1 Partial Adoption

As indicated in Table 4.36 above, the partial adoption of water-saving policies (a 30% water restriction in place) resulted in R11.20 million in maize output within the Limpopo provincial economy. The total labour remuneration was estimated at R6.58 million in the South African economy. Limpopo province contributes approximately R1.02 million in labour returns and a gross operating surplus (capital) of R4.46 million. Most of the labour income originates from the Western Cape, followed by the North West and Mpumalanga.

Household income was estimated at R36.68 million for the economy of the Limpopo province. The overall land return was estimated at R5.56 million in the economy of South Africa, of which the return to irrigation

in Limpopo amounted to only R88 380.60. The lowest return on irrigation in the Limpopo district was recorded in the Vhembe district, followed by the Capricorn and Sekhukhune districts within the Limpopo province economy.

Institutional incomes (enterprise and households) are valued at R64.43 million, while households and value added (labour, capital, and land) generate R36.68 million and R101.56 million in the South African economy, respectively. The findings of this study were mainly similar to those of the study conducted by Zhao and Li (2020), which found that water-saving policies significantly reduced water consumption; however, the effects differed between cities with varying water resource endowments, levels of economic development, and scales of urbanisation. Furthermore, the authors recommend that, in areas where water resource supply is insufficient, water-saving policies should be designed and implemented to suit local conditions, and it is also necessary to explore additional sources of water.

4.2.4.2.2 Full Adoption

As indicated in Table 4.36 above, the full adoption of water-saving policies (70% water restriction in place) resulted in R15.04 million in maize outputs in Limpopo within the provincial economy. The total labour remuneration was estimated at R2.55 million in the South African economy. Limpopo province generates a labour return of about R1.39 million and a gross operating surplus (capital) of R6.06 million. Most of the labour income comes from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R12.44 million for the Limpopo province's economy. The overall land return was estimated at R7.65 million in South Africa's economy, of which the return from irrigation in Limpopo was only R120 508.50. The lowest return on irrigation in the Limpopo district was found in the Vhembe irrigation district, followed by the Capricorn and Sekhukhune districts within the Limpopo province's economy.

In the case of institutional incomes (enterprise and households), these are valued at R16.16 million, while the households and value-added (labour, capital, and land) generate incomes of only R12.44 and R137.55 million in the economy of South Africa, respectively. The findings of this study concurred with those of Zhao and Li (2020), who found that water-saving policy significantly reduced water consumption, and the authors highlighted the point that, for areas where water resource supply is insufficient, water-saving policy should be designed and implemented to suit local conditions.

4.2.4.3 Adaptation to Climate Variability

4.2.4.3.1 Partial Adaption

As indicated in Table 4.36 above, the effect of partial adaptation to climate variability (applying a 20% deficit irrigation, with moderate mulching and moderate weed management) results in an output of R15.78 million in maize within the Limpopo provincial economy. The total labour remuneration generated is estimated at R3.72 million in the economy of South Africa, of which Limpopo province contributes a labour return of about R1.44 million and a gross operating surplus (capital) of R6.37 million. Most of the labour income comes from the Western Cape province, followed by North West and Mpumalanga provinces.

Household income was estimated at R11.17 million within the economy of Limpopo province. The overall land return was estimated at R8.09 million in South Africa's economy, with the return from irrigation in Limpopo amounting to only R126 507.92. The lowest return on irrigation in the Limpopo district was identified in the Vhembe district, followed by the Capricorn and Sekhukhune districts within the Limpopo province economy.

In the case of institutional incomes (enterprise and households), these are valued at R60.12 million. In contrast, the incomes generated from households and value added (labour, capital, and land) increased by R20.92 and R144.36 million in South Africa's economy, respectively. The findings of this study align with those of Etana et al. (2021), who confirmed that adaptation to climate variability contributes to livelihood improvement.

4.2.4.3.2 Full Adoption

As indicated in Table 4.36 above, the full adaptation to climate variability (30% deficit irrigation, with water applied strategically during the crop's critical growth stages, high-level mulching with 75% coverage, and an intensive weed management schedule) resulted in R75.11 million within the Limpopo provincial economy. The total labour remuneration was estimated at R24.66 million in the South African economy. Limpopo province generates a labour return of about R4.48 million and a gross operating surplus (capital) of R20.94 million. Most of the labour income came from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R73.65 million for the economy of Limpopo province. The overall estimated land return was R13.62 million in South Africa's economy, of which the return from irrigation in Limpopo amounted to only R245 006.01. The highest return on irrigation investment was observed in the Vhembe district, followed by the Capricorn and Sekhukhune districts, which collectively contribute significantly to the province's economy.

In the case of institutional incomes (enterprises and households), the estimated income is R139.30 million. The households and value added, which include labour, capital, and land, generate incomes of only R138.33 million and R592.28 million in South Africa's economy, respectively. The findings of this study, which align with those of Bedeke et al. (2019), indicate that the adoption of climate variability strategies that increase agricultural productivity while simultaneously building farmers' resilience has become a top policy priority in sub-Saharan African countries, including South Africa.

4.3 Discussions

The extended TPB model for the Tshiombo Irrigation Scheme indicates that the adoption of water-saving technologies is influenced by both farmers' psychological factors and structural support. Access to resources that build resilience enhances farmers' perceived behavioural control, making them more likely to adopt when they can manage risk and secure inputs. Informational factors have a substantial impact on intentions, underscoring the importance of farmer training and awareness. Institutional and legal factors bolster both intentions and control, suggesting that clear policies and secure land or water rights mitigate adoption barriers. Social support shapes attitudes and subjective norms, illustrating the point that peer influence and community networks foster behaviour change. These findings imply that full adoption is more likely to occur when farmers have access to information, institutional backing, and local support, while partial adoption may occur under weaker conditions.

The extended TPB model for the adoption of water-saving policies in the Tshiombo Irrigation Scheme indicates that access to resources and the enhancement of resilience positively influence intentions to adopt water-saving policies and subjective norms. Institutional and legal factors exert a strong positive effect on intentions, attitudes, and perceived behavioural control, suggesting that clear policies and supportive regulations are crucial for adoption. Perceived financial costs significantly affect subjective norms, highlighting the role of economic considerations in social pressure. Additionally, perceived behavioural control positively impacts intentions, while perceived social support influences attitudes, perceived control, and subjective norms. These results suggest that the adoption of water-saving policies hinges on a combination of internal motivation and external structural factors.

The extended TPB model for adaptation to climate variability in the Tshiombo Irrigation Scheme indicates that positive attitudes significantly enhance intentions to adapt. Institutional factors positively influence both intentions and perceived behavioural control, highlighting the importance of supportive policies and frameworks. Perceived financial costs associated with energy and debt, along with perceived risks and benefits, positively impact perceived behavioural control, suggesting that economic considerations and risk awareness play crucial roles in farmers' confidence to adapt. Additionally, perceived social support

profoundly shapes subjective norms, underlining the influence of community and peer networks on adaptive behaviours.

The AquaCrop model simulations, coupled with multiplier analysis, demonstrate a significant impact on the ripple effect of the economy in South Africa and its provinces. These gains are particularly noteworthy for smallholders in Limpopo, where even modest enhancements in productivity and resource utilisation can yield meaningful economic effects. These findings emphasise the necessity for carefully balancing water-saving policy implementation with economic sustainability, ensuring that behavioural interventions are supported by robust institutional frameworks, informational support, and resource access to mitigate the adverse effects on small-scale maize irrigators in the Tshiombo district municipality of Limpopo.

Last but not least, the integrated framework emphasised the point that, only through complete commitment to adaptation, supported by effective institutional frameworks, economic incentives, and social support, can farmers realise the full benefits in productivity and economic performance outcomes.

CHAPTER 5: CASE STUDY OF COMMERCIAL WHEAT PRODUCTION IN THE HARTBEESPOORT IRRIGATION SCHEME, NORTH WEST PROVINCE

5.1 Overview

This section presents the results for commercial wheat irrigators in the Hartbeespoort Irrigation Scheme, utilising the integrated framework developed in this project. It commences with the behavioural component, where results from both the standard and augmented versions of the Theory of Planned Behaviour are presented.

The section then presents the biophysical and economic components of the framework. Crop yield outcomes are simulated using the AquaCrop model under different behavioural scenarios that reflect varying levels of adoption. These simulated yield results are incorporated into a Social Accounting Matrix to assess the broader economic implications, including changes in income, output, and employment at the regional level.

5.2 Results

5.2.1 Demographic, Farm, and Household Characteristics of Respondents

Table 5.1 below presents an overview of the demographic, farm, and household characteristics of irrigators in the Hartbeespoort Irrigation Scheme. The entire sample consists of male respondents, with no female participation recorded. The age distribution reveals a broad range, with the largest age group being 41–50 years (31%), followed by those aged 61 and older (25%), indicating that the majority of respondents are middle-aged or older. Younger irrigators, aged 21–30, constitute a smaller proportion (6%).

Regarding education levels, the majority of respondents possess an undergraduate degree (55%), while 27% have completed secondary education, and 15% hold a diploma. A small percentage (2%) have obtained a master's degree, and no respondents reported holding a PhD or having only primary-level education.

In terms of health, most respondents rated their health as either good (48%) or excellent (44%), with very few reporting poor health (1%). These demographic variables offer insight into the profile of the irrigators, which is pertinent for understanding the adoption of water-saving technologies in this context.

Table 5.1: Demographic Profile of Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Variable	Classification	Frequency	Percentage (%)
Demographic Profile			
Gender	Male	124	100%
Age	21-30	8	6%
	31-40	26	21%
	41-50	38	31%
	51-60	21	17%
	61 and older	31	25%
Highest education level	Secondary (grade 8-12)	34	27%
	Diploma	19	15%
	Undergraduate degree	68	55%
	Masters	3	2%
Health Level	Poor	1	1%
	Average	10	8%
	Good	59	48%
	Excellent	54	44%
Farm characteristics			
The primary source of water used for irrigation	River	46	37%
	Dam	2	2%
	Canal	57	46%
	Borehole	4	3%
	River and dam water	2	2%
	River and canal water	5	4%
	River and borehole	5	4%
	Dam and canal water	1	1%
	Canal and borehole	2	2%
Type of farming performed	Crop production	97	78%
	Mixed farming	27	22%
Amount of agricultural land deeds owned	One	12	10%
	Two to five	44	35%
	More than five	68	55%
How scattered is the farmland from the main farm	Highly clustered together (1-5 km)	66	53%
	Moderately dispersed (6-10 km)	24	19%
	Highly dispersed (more than 10 km)	34	27%
Business structure of the farm operations	Sole proprietorship	32	26%
	Corporation	51	41%
	Partnership	6	5%
	Trust	26	21%
	Closed corporation	9	7%
The land ownership type of the farm	Sole owner	111	90%
	Lease	2	2%
	Combination of sole owner and lease	9	7%
	Communal	2	2%
	Less than 1 Km	80	65%

Variable	Classification	Frequency	Percentage (%)
Distance of the main irrigation land from the water source	1-3 Km	22	18%
	3-7 Km	11	9%
	7-10 Km	3	2%
	More than 10 Km	8	6%
Household characteristics			
Number of adults (18 years and older) living in the household	One	13	10%
	Two	100	81%
	Three or more	11	9%
Total individuals living in the household (adults + children)	One	11	9%
	Two	52	42%
	Three	18	15%
	Four or more	43	35%
Individuals in the household involved in farming activities	One	112	90%
	Two	8	6%
	Three or more	4	3%
Marital status	Married	115	93%
	Single	7	6%
	Divorced	1	1%
	Widowed	1	1%
Age of the head of the household	Less than 20	-	-
	20-30	8	6%
	31-40	26	21%
	41-50	38	31%
	51-60	21	17%
	61 and older	31	25%
Primary source of livelihood	Farmer/agricultural activities	121	98%
	Self-employed/business owner	3	2%
Off-farm income	Yes	18	15%
	No	106	85%

Sources: Project team compilation

Table 5.1 above outlines the farm characteristics of the irrigators participating in the Hartbeespoort Irrigation Scheme. Answers regarding the primary source of water utilised for irrigation reveal that canals are the most prevalent source (46%), followed closely by rivers (37%). Only a small proportion of respondents depend on dams (2%) or boreholes (3%), while a combination of various water sources is less common. In terms of farming practices, the majority of respondents (78%) are involved in crop production, whereas 22% engage in mixed farming, highlighting a concentration on crop cultivation in this area. The distance of farmland from the main farm is largely clustered, with 53% of respondents indicating that their farmland is situated within 1–5 km of the main farm. The business structure of farm operations shows that most respondents operate as corporations (41%) or sole proprietorships (26%), with partnerships and trusts comprising smaller proportions. Regarding land ownership, a significant majority (90%) are sole owners

of their land, while only 2% lease it. Furthermore, the distance of the main irrigation land from the water source indicates that 65% of respondents are located less than 1 km from the source, emphasising the potential ease of access to irrigation resources.

The household characteristics of respondents in the Hartbeespoort Irrigation Scheme are also presented in Table 5.1 above. A significant majority (81%) of households consist of two adults aged 18 years and older, with only 10% having one adult and 9% having three or more. Regarding total household size, 42% of respondents live in households with two individuals, while 35% report four or more members. A substantial majority (90%) of individuals in the household are involved in farming activities. The marital status of heads of households indicates that 93% are married, suggesting a stable family structure. The age distribution of heads of households reveals that 31% are aged 41–50, while 25% are 61 years or older. The primary source of livelihood for nearly all respondents (98%) is derived from farming or agricultural activities, with only 2% engaged in self-employment or business ownership. Additionally, a significant majority (85%) do not have off-farm income, indicating a reliance on agriculture as their primary income source.

5.2.2 Theory of Planned Behaviour

For wheat production, the focus is on the Hartbeespoort Irrigation Scheme in the North West province. In this context, the first behaviour to be modelled is the irrigators' intentions to adopt water-saving technologies by applying the standard Theory of Planned Behaviour (TPB). As the procedures – (measurement model (indicator reliability; internal consistency reliability, coverage validity, discriminant validity); structure model assessment (collinearity, significant relevance, hypothesis testing)) – of the standard and the augmented TPB are identical to those of the Tshiombo Irrigation Scheme, as indicated in Sections 4.2.2 to 4.2.2.1.2.3, only the main findings are presented in this section.

5.2.2.1 Standard TPB model – Adopt Water-Saving Technologies

The indicator of reliability for the adoption of water-saving technologies in the standard TPB model revealed that the measurement item for the construct 'Attitudes' had a factor loading of 0.171, which is below the acceptable threshold of 0.4. Consequently, this item was excluded from the analysis to enhance the reliability of the measurement model. All other measurement items across the remaining constructs displayed loadings above 0.4, indicating that they meet the criteria for indicator reliability.

Considering the internal consistency reliability of the Attitudes construct, it is not assessed, as it contains only one measurement item. The Subjective Norms (**SN**) construct had a Composite Reliability score of 0.709, which exceeds the recommended threshold of 0.6, indicating acceptable reliability. However, the Cronbach's alpha for **SN** was 0.265, which is notably low. This is not uncommon, particularly when

constructs contain few items or when item loadings vary significantly. Given that Composite Reliability offers a more accurate representation, **SN** meets the reliability standards.

For Perceived Behavioural Control (**PBC**), the Composite Reliability was 0.989, and Cronbach's alpha was 0.978. While these values indicate extremely high internal consistency, values above 0.90 (and especially above 0.95) may suggest that the items are semantically redundant, meaning they are rephrasing the same concept. To investigate this issue further, the Variance Inflation Factor (VIF) values were checked, and both **PBC** items had VIF values of 11.831, which significantly exceeds the acceptable threshold of 3. This suggests multicollinearity between the measurement items of the **PBC** construct, indicating redundancy and potential issues with the construct. Because of the high multicollinearity, the **PBC** measurement item with the lowest factor loading, PBC_1 , was dropped to improve model reliability and reduce redundancy.

The convergent validity shows that the AVE for Subjective Norm and Intention were both above the recommended threshold of 0.50, confirming acceptable convergent validity for these constructs. However, for Attitudes and Perceived Behavioural Control, the AVE could not be calculated, as these constructs had only one measurement item remaining after dropping items during the previous steps of the measurement model assessment.

The discriminant validity was assessed by using both the Fornell-Larcker Criterion and the HTMT Ratio. The square root of the AVE for each construct (diagonal values) is higher than its correlation with other constructs, confirming discriminant validity. Furthermore, the HTMT ratios for all construct pairs are significantly below the threshold of 0.85, further reinforcing adequate discriminant validity across the model. Furthermore, the reflective measurement model of results for Wheat Irrigators' Adoption of Water-Saving Technologies in the Hartbeespoort Irrigation Scheme outlines the convergent validity through indicator loadings and AVE values: the internal consistency reliability using Cronbach's alpha and composite reliability, and the discriminant validity confirmed by the HTMT ratios. This illustrates the robustness of the measurement model, with all constructs demonstrating adequate reliability and validity, except where items were dropped.

The structural model assessment checks for potential collinearity issues by examining the VIF values in the inner model. The VIF for the relationship between Attitudes and Intentions is 1.055, for Perceived Behavioural Control and Intentions, it is 1.043, and for Subjective Norms and Intentions, it is 1.025. Since all VIF values are below the threshold of 3, there are no collinearity concerns in the model.

The significance of the hypothesised relationships is assessed, with the results being provided in Figure 5.1 below and Appendix G, Table G.1. The relationship between attitudes (**A_B**) and intentions to adopt water-saving technologies are significant ($\beta = 0.211$, $p = 0.004$). This significantly positive effect indicates that

attitudes A_B have a positive and meaningful effect on the intention of wheat irrigators in the Hartbeespoort Irrigation Scheme, supporting the acceptance.

The relationship between subjective norms (SN) and the intention to adopt water-saving technologies was not significant ($\beta = 0.122$, $p = 0.422$), indicating that SN do not play an essential role in influencing the intentions of wheat irrigators in the Hartbeespoort Irrigation Scheme, leading to the rejection of H2.

The effect of perceived behavioural control (PBC) on intentions was significant ($\beta = 0.328$, $p = 0.001$). This substantial influence supports the acceptance of H3, indicating that PBC behaviour impacts positively on the intentions of wheat irrigators in the Hartbeespoort Irrigation Scheme to adopt water saving technology.

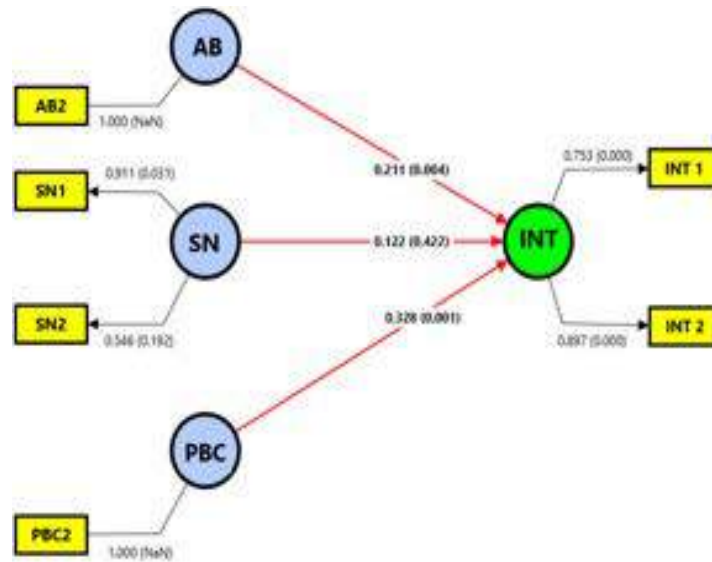


Figure 5.1: Path Analysis Findings of Wheat Irrigators' Intentions to Adopt Water-Saving Technologies in the Hartbeespoort Irrigation Scheme

Source: Project team compilations

The R^2 value is 0.193, indicating that approximately 19.3% of the variance in intentions to adopt water-saving technologies is explained by the constructs in the model. The obtained R^2 value of 0.193 may appear low, although, as noted by Ozili (2023), a low R^2 is acceptable in social science research. The primary aim in such studies is often to evaluate the significance of predictors, rather than to achieve high predictive accuracy. Ozili (2023) states that an R^2 of at least 0.1 is acceptable, provided that most predictors are statistically significant. This is the case in the path model applied to assess irrigators' adoption of water-saving technologies in the Hartbeespoort Irrigation Scheme. On the other hand, F^2 values of 0.02, 0.15, and 0.35 correspond to small, medium, and large effects, respectively. In this project, the F^2 value for attitudes is 0.053, indicating a small effect, while perceived behavioural control has a medium effect, with an F^2 value of 0.128. The F^2 value for subjective norms is 0.018, which is below the small effect threshold.

5.2.2.2 Augmented TPB model - Adopt Water-Saving Technologies

For the augmented TPB Model for the Adoption of Water-Saving Technologies, the reliability indicator indicated that certain measurement items were to be dropped for having loadings below 0.4: AB_1 (attitudes), IL_1 , IL_8 (institutional and legal factors), IF_7 , IF_8 (information factors), TX_3 , TX_5 (trust factors), AR_2 , AR_3 (Access to Resources).

The internal consistency reliability assessment indicates that the subjective norm (SN) and perceived financial cost (PFC) constructs had Cronbach's alpha scores below 0.6, and both had composite reliability scores above 0.6. It is important to note that Cronbach's alpha may underestimate reliability when there are few items or varying outer loadings. Composite reliability provides a more accurate measure, as it accounts for individual outer loadings.

For the PBC construct, the Cronbach's alpha and composite reliability were above 0.9, prompting an investigation into multicollinearity. The VIF values for PBC_1 and PBC_2 were 11.831, leading to the removal of PBC_1 because of its lower loading. A similar issue occurred with the technical factors construct (TF), resulting in the removal of TF_1 .

Next, convergent validity was assessed using the Average Variance Extracted (AVE) values. All constructs showed AVEs above 0.5, except for Perceived Risks from Load Shedding and Tariffs ($RB2$). The measurement item with the lowest loading, RB_8 , was first dropped, but the AVE remained below 0.5. Consequently, another item, RB_7 , was also removed, and this adjustment raised the AVE to exceed the 0.5 threshold, indicating acceptable convergent validity for the construct.

The discriminant validity results indicate that all HTMT ratios were below 0.9, except for Informational Factors (IF). Upon further investigation of the VIF values, it was found that the VIF values for the measurement items of IF were below 3. To address the issue, the measurement item with the lowest loading was dropped, but the HTMT ratio remained above 0.9. As a result, it was decided that the IF construct would be dropped from the model. Perceived Risks and Benefits (RB) also exhibited an HTMT ratio above 0.9. To resolve this, RB_2 , the measurement item with the lowest loading was removed, which successfully brought the HTMT ratio down below 0.9.

The structural relationships are reported by examining the total indirect effects (Appendix G, Table G.2), specific indirect effects (Appendix G, Table G.3), direct effects (Appendix G, Table G.4), and total effects (Appendix G, Table G.5). Unlike the standard TPB models estimated so far, which focused solely on direct effects because of the absence of mediating relationships, the extended TPB models incorporate both direct and indirect pathways.

In the analysis of specific indirect effects (Appendix G, Table G.2), none of the pathways were found to be significant, indicating that the examined constructs did not demonstrate meaningful indirect influences on the intentions to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme.

The total indirect effects assessed in Appendix G, Table G.3, similarly did not reveal any significant pathways. This finding suggests that the examined constructs did not exert a meaningful indirect influence on intentions to adopt water-saving technologies within the Hartbeespoort Irrigation Scheme. As a result, the relationships among these constructs may be predominantly direct, with no substantial mediation effects present in this model.

From the direct path analysis presented in Appendix G, Table G.4, perceived risks and benefits (**RB**) significantly influence attitudes (**AB**), with a coefficient of 0.256 and a p-value of 0.004 ($\beta = 0.256$, $p < 0.01$), indicating strong support for this relationship. Additionally, **RB** has a substantial positive effect on intentions, as evidenced by the coefficient of 0.529 and a highly significant p-value of 0.000 ($\beta = 0.529$, $p < 0.01$). The influence of RB extends to subjective norms (**SN**) as well, showing a positive relationship, with a coefficient of 0.179 and a p-value of 0.030 ($\beta = 0.179$, $p < 0.05$). Finally, technical factors (**TF**) also play a crucial role in shaping intentions, with a coefficient of 0.436 and a p-value of 0.000 ($\beta = 0.436$, $p < 0.01$), confirming the significance of this construct in the model.

The total effects, which represent the sum of direct and indirect effects, are presented in Appendix G, Table G.5. The results for total effects closely mirror those of the direct effects reported in Appendix G, Table G.4, indicating that the direct effects primarily influence the relationships among the constructs in the model. This similarity suggests that indirect effects play a minimal role in shaping the overall relationships, reinforcing the importance of direct paths in understanding irrigators' intentions to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme.

The explanatory power of the model for the Hartbeespoort Irrigation Scheme shows the variance explained (R^2) for each construct, and the model accounts for 70.2% of the variance in intentions to adopt water-saving technologies ($R^2 = 0.702$, adjusted $R^2 = 0.675$), demonstrating strong predictive power for the key outcome variable. However, the variance explained for the other constructs is lower: attitudes towards behaviour (**AB**) with $R^2 = 0.144$ (adjusted $R^2 = 0.093$), perceived behavioural control (**PBC**) with $R^2 = 0.144$ (adjusted $R^2 = 0.093$), and subjective norms (**SN**) with $R^2 = 0.196$ (adjusted $R^2 = 0.148$). This suggests that, while the model is effective in predicting intentions, it may require additional factors to explain more variance in the attitudes, **PBC**, and **SN** constructs within this scheme.

The f^2 Statistics measure values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. In this context, the f^2 value for perceived risks and benefits (**RB**) on intentions ($f^2=0.690$)

reflects a significant effect, as does the effect of technical factors (**TF**) on intentions ($f^2=0.521$). Moderate effects are seen for **RB** on attitudes ($f^2=0.062$), subjective norms ($f^2=0.033$), and **PBC** ($f^2=0.035$), while the remaining constructs show small or negligible effects. This classification highlights the dominant influence of RB and TF in shaping the adoption of water-saving technologies.

5.2.2.3 Standard TPB Model for Adoption of Water Saving Policies

The indicator reliability indicates that the measurement items **AB₄** and **INT₄** were identified with loadings below 0.4, leading to their removal from the model. Given the exploratory nature of this study, we considered these lower thresholds suitable. However, the construct for subjective norms exhibited a Cronbach's alpha of 0.003 and a composite reliability of 0.114, indicating very poor internal consistency. Based on these results, the appropriate course of action was to drop the construct entirely to ensure overall model reliability. For the Perceived Behavioural Control (**PBC**) construct, a Cronbach's alpha of 0.723 and composite reliability of 0.829 indicate strong internal consistency and reliability, which is in line with the recommended thresholds for exploratory research.

For convergent validity, the Perceived Behavioural Control (**PBC**) construct was the only one where the Average Variance Extracted (AVE) could be calculated, as the remaining constructs only had one measurement item each. The **PBC** construct's AVE value of 0.716 is above the 0.50 threshold, indicating that the construct explains a substantial portion of the variance in its indicators.

According to the Fornell-Larcker criterion, the square root of the AVE for each construct should be greater than the correlation between that construct and all other constructs; as a result, the square root of the AVE for **PBC** (0.846) was greater than its correlations with **AB** and **INT**, confirming sufficient discriminant validity. Additionally, the HTMT ratio values were below the recommended threshold of 0.90 for all construct pairs, further supporting adequate discriminant validity.

To evaluate collinearity, the Variance Inflation Factor (VIF) values of the inner model were examined. The results revealed that the VIF values for the relationships between Attitudes (**AB**) and Intentions and between Perceived Behavioural Control (**PBC**) and Intentions are below the recommended threshold of 3, indicating no critical collinearity issues within the model.

The results of the structural relationships are illustrated in Figure 5.2 below and Appendix G, Table G.6. The findings indicate that the relationship between Attitudes (**AB**) and Intentions (**INT**) is significant, showing that attitudes have a notable influence on the intentions of irrigators to adopt water-saving technologies ($\beta = -0.229$, $p < 0.01$). In contrast, the relationship between Perceived Behavioural Control (**PBC**) and Intentions (**INT**) is not significant, indicating that perceived behavioural control does not have a meaningful impact on the intentions to adopt water-saving technologies ($\beta = 0.027$, $p = 0.799$). Overall,

these results suggest that attitudes are crucial in influencing irrigators' intentions, while perceived behavioural control does not significantly contribute to this decision-making process.

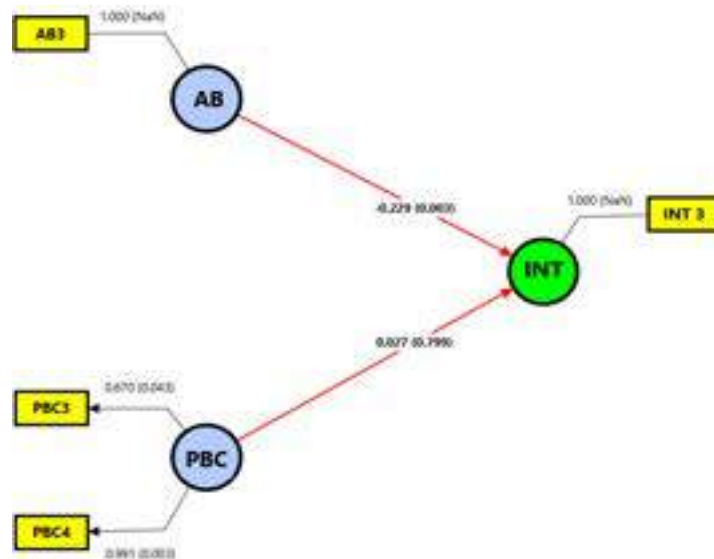


Figure 5.2: Path Analysis Findings of Wheat Irrigators' Intentions to Adopt Water-Saving Policies in the Hartbeespoort Irrigation Scheme

Source: Project team compilation

The R^2 value indicates the proportion of variance in the dependent variable (intentions to adopt water-saving policies) that the independent variables in the model can explain. Additionally, the f^2 statistic provides insights into the effect size of the predictors on the outcome variable, indicating how much the inclusion of a predictor variable improves the model fit. The R^2 value for intentions to adopt water-saving policies is 0.054, indicating that the independent variables account for a small portion of the variance in intentions. According to Ozili (2023), an R^2 of at least 0.1 is acceptable if most predictors are statistically significant, which is not the case in our study, as only one predictor was found to be statistically significant. The model's ability to predict intentions to adopt water-saving technologies is further limited, as highlighted by the low R^2 value. Additionally, the f^2 statistic for the attitude construct (A_B) is 0.055, suggesting a small effect size, while the f^2 statistic for perceived behavioural control (PBC) is negligible at 0.001. Throughout the measurement and structural model assessments, several measurement items and constructs were dropped because of issues related to reliability and validity. Consequently, these challenges contribute to the conclusion that the model is not well-fitted for effectively modelling intentions within the Hartbeespoort Irrigation Scheme.

5.2.2.4 Augmented TPB Model for Adoption of Water Saving Policies

Based on the indicator reliability assessment, the following measurement items were dropped: IL_7 and IL_8 (Institutional and Legal Factors), RB_9 (Perceived Risks from Load Shedding and Tariffs), IF_7

(Informational Factors), TX_3 and TX_5 (Trust Factors), AR_1 (Access to Resources), SN_4 (Subjective Norms), and INT_4 (Intentions).

All constructs had composite reliability scores above 0.60, indicating adequate internal consistency. However, certain constructs, including Attitudes (A_B), Institutional and Legal Factors (IL), Perceived Risks (RB), Perceived Risks from Load Shedding and Tariffs ($RB2$), and Access to Resources (AR), had Cronbach's alpha values below 0.60. It is worth noting that Cronbach's alpha can underestimate reliability, especially when the number of items is small or when indicators exhibit varying outer loadings.

For the extended model applied to water-saving policies adoption in the Hartbeespoort Irrigation Scheme, all the constructs had Average Variance Extracted (AVE) values above 0.5, confirming adequate convergent validity.

In this analysis, the square root of the AVE for each construct (diagonal values) is larger than the correlations between that construct and any other construct (off-diagonal values), indicating satisfactory discriminant validity for all constructs. HTMT values below the threshold of 0.90 are considered acceptable, indicating that the constructs are distinct from one another. Both assessments indicated no discriminant validity issues, as the Fornell-Larcker values met the required thresholds, and all HTMT ratios were below the critical value of 0.9, ensuring clear differentiation between constructs in the extended model.

The results indicated no collinearity problems, as all Variance Inflation Factor (VIF) values were below the threshold of 3 for each construct. This finding confirms the robustness of the structural model, allowing for a reliable analysis to be made of the relationships among the constructs.

In the extended model, Attitudes (A_B), Subjective Norms (SN), and Perceived Behavioural Control (PBC) act as mediators influencing intentions. Additionally, the extra constructs directly influence both intentions and the mediating constructs (A_B , SN , and PBC). Appendix G, Table G.7 presents the specific indirect effects, Appendix G, Table G.8 outlines the total indirect effects, Appendix G, Table G.9 details the direct effects, and Appendix G, Table G.10 summarises the total effects.

In Appendix G, Table G.7, the analysis of specific indirect effects reveals that none of these relationships is statistically significant. This indicates that the proposed mediation pathways between the additional constructs and intentions, via Attitudes (A_B), Subjective Norms (SN), and Perceived Behavioural Control (PBC), do not demonstrate a meaningful influence in this model.

In Appendix G, Table G.8, the assessment of total indirect effects reveals that none of these relationships is statistically significant. This finding indicates that the combined influence of the additional constructs on intentions, through the mediating variables (Attitudes, Subjective Norms, and Perceived Behavioural

Control), does not produce a meaningful impact on the intention to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme.

In the assessment of the direct effects (path coefficients) for the extended model, several significant relationships were identified, as shown in Appendix G, Table G.9. Access to Resources (**AR**) negatively influenced Intentions (**INT**) ($\beta = -0.093$, $p < 0.05$). Informational Factors (**IF**) significantly affected Attitudes (**AB**) ($\beta = -0.245$, $p < 0.05$) and had a strong positive influence on Intentions (**INT**) ($\beta = 0.795$, $p < 0.01$). Institutional and Legal Factors (**IL**) positively impacted on Perceived Behavioural Control (**PBC**) ($\beta = 0.169$, $p < 0.05$) and Subjective Norms (**SN**) ($\beta = 0.199$, $p < 0.05$). Lastly, Trust Factors (**TF**) significantly influenced Intentions (**INT**) ($\beta = 0.637$, $p < 0.01$). These findings underscore the critical roles that these constructs play in shaping the intentions to adopt water-saving technologies within the Hartbeespoort Irrigation Scheme.

Appendix G, Table G.10 illustrates the total effects, which represent the sum of direct and indirect effects. As anticipated, the result for the total effects is relatively similar to the results for the direct effects presented in Appendix G, Table G.9. This similarity arises because the indirect effects were found to be insignificant, indicating that they do not contribute meaningfully to the overall model. Consequently, it is expected that the total effects will predominantly be driven by direct effects, emphasising the importance of direct relationships in understanding the adoption of water-saving policies in the Hartbeespoort Irrigation Scheme.

The explanatory power of the extended model presents the variance explained (R^2) for each construct in the model. Notably, Intentions (**INT**) exhibited a strong explanatory power with an R^2 value of 0.886, indicating that the model can account for a significant portion of the variance in intentions to adopt water-saving policies. In contrast, Access to Resources (**AB**) had an R^2 value of 0.146, while Subjective Norms (**SN**) and Perceived Behavioural Control (**PBC**) showed R^2 values of 0.153 and 0.069, respectively, indicating modest explanatory power.

In evaluating the effect sizes (f^2) of key constructs on behavioural outcomes, values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. Information Factors (**IF**) and Trust Factors (**TF**) exhibit large and medium effect sizes on Intentions (**INT**) with f^2 values of 4.613 and 3.367, respectively. This indicates a significant influence of these constructs on the intention to adopt water-saving policies. Meanwhile, the other constructs show varying levels of effect sizes.

5.2.2.5 Standard TPB Model for the adaptation towards climate variability

The initial estimation of the path model of indicator reliability revealed that none of the measurement items had loadings below 0.7. All Cronbach's alphas for Internal consistency and composite reliability scores were above the minimum threshold of 0.6 for all constructs.

Convergent validity was assessed through using Average Variance Extracted (AVE), with a minimum threshold set at 0.5. All constructs demonstrated an AVE above this threshold, suggesting that the constructs explain more than 50% of the variance in their respective measurement items.

The HTMT ratio analysis indicates that values below the recommended threshold of 0.90 signify adequate discriminant validity among constructs. The results suggest that the square root of the AVEs (along the diagonal) for each construct is greater than their respective correlations with other constructs. This confirms that each construct is sufficiently distinct from the others. Furthermore, the HTMT ratios are below the 0.90 threshold, further supporting the conclusion of adequate discriminant validity among the constructs in the model.

The first step in the structural model assessment involved evaluating potential collinearity issues by analysing the Variance Inflation Factor (VIF) values. The results indicated that the VIF values for all constructs in the inner model were below the recommended threshold of 3, suggesting that collinearity is not a concern in this model.

The structural relationships were assessed, and the results are illustrated in Figure 5.3 below and summarised in Appendix G, Table G.11. The relationship between attitudes towards behaviour (***A_B***) and intentions (***INT***) were found to be significant, indicating that more favourable attitudes positively influence intentions to adopt climate variability measures ($\beta = 0.318$, $p < 0.01$). In contrast, the effect of subjective norms (***SN***) on intentions was not statistically significant, suggesting that perceived social pressure did not strongly influence intentions to adopt climate variability adaptations ($\beta = 0.140$, $p = 0.150$). Similarly, the relationship between perceived behavioural control (***PBC***) and intentions was also found to be non-significant, implying that the perceived ability to perform climate adaptation behaviours did not significantly affect intentions ($\beta = 0.058$, $p = 0.584$).

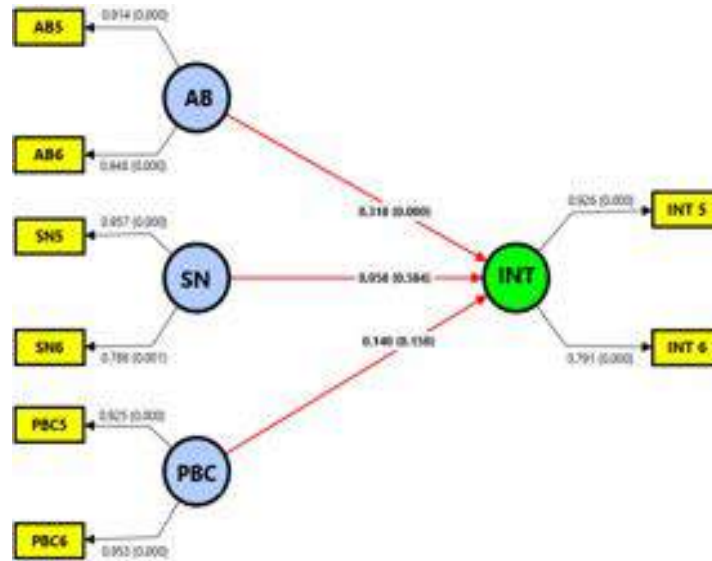


Figure 5.3: Path Analysis Findings of Wheat Irrigators' Intentions for Adaptation Towards Climate Variability in the Hartbeespoort Irrigation Scheme

Source: project team compilation

The R^2 value for intentions is 0.155, with an adjusted R^2 of 0.134. While this R^2 value might seem modest, it is deemed acceptable in social science research, as highlighted by Ozili (2023). The primary focus is often on assessing the significance of predictors, rather than on achieving high predictive accuracy.

In terms of effect sizes, the f^2 values indicate the strength of the relationships between constructs. Specifically, the F^2 value for attitudes towards behaviour (**AB**) is 0.105, which suggests a small effect size. In contrast, the F^2 values for perceived behavioural control (**PBC**) and subjective norms (**SN**) are 0.022 and 0.003, respectively, indicating a small effect size for **PBC** and a negligible effect size for **SN**.

These results imply that, while attitudes significantly influence intentions, the other variables included in the model may have limited explanatory power. Furthermore, the low f^2 values for **PBC** and **SN** suggest that additional external variables not accounted for in the model may play a role in influencing intentions to adapt to climate variability in the Hartbeespoort Irrigation Scheme.

5.2.2.6 Augmented TPB Model for the adaptation towards climate variability

Several items with loadings below 0.4 were removed from the model, including **IL₆** and **IL₈** (institutional and legal factors), **RB₁₀** (perceived risks from load shedding and tariffs), **IF₇** (informational factors), and **TX₂** and **TX₃** (trust factors) for indicator reliability.

The internal consistency and reliability of the construct for Trust Factors (**TX**) initially had both a Cronbach's alpha and composite reliability score below the minimum threshold of 0.6. To address this issue,

we removed **TX₅**, which had the lowest factor loading. This adjustment resulted in an improved Cronbach's alpha and composite reliability scores, bringing them above the required minimum threshold. Furthermore, the constructs for Perceived Financial Cost (**PFC**), Access to Resources (**AR**), and Technical Factors (**TF**) exhibited Cronbach's alpha scores below 0.6, while their composite reliability scores remained above this threshold. The remaining constructs achieved both Cronbach's alpha and composite reliability scores above 0.6, indicating satisfactory internal consistency and reliability.

All constructs in this study initially had Average Variance Extracted (AVE) values above 0.5; the constructs for Perceived Risks from Load Shedding and Tariffs (**RB2**) and Access to Resources (**AR**) fell below this threshold. For the construct 'Perceived Risks from Load Shedding' (**RB2**), various scenarios for dropping measurement items were explored. It was found that removing the item with the lowest loading, **RB₇**, resulting in the remaining measurement items' loadings also dropping below 0.4, and the AVE of the **RB2** remained below 0.5. Ultimately, the measurement item **RB₉** was dropped instead, which resulted in improved loadings for the remaining two items (**RB₇** and **RB₈**), bringing the AVE above 0.5, thus improving the convergent validity of the construct **RB2**.

For the construct 'Access to Resources' (**AR**), the AVE was initially below 0.5. After reviewing the factor loadings, we dropped **AR₃**, which had the lowest loading. This adjustment improved the overall loadings of the remaining items and resulted in the AVE exceeding the 0.5 threshold, thus enhancing the construct's convergent validity.

The HTMT ratio for Informational Factors (**IF**) on Intentions (**INT**) exceeded 0.9, suggesting potential discriminant validity issues. We first checked the Variance Inflation Factor (VIF) values for both the inner and outer models, and no collinearity problems were found between **IF** and **INT**. We then explored different scenarios where specific **IF** measurement items were dropped to improve the HTMT ratio. However, despite various adjustments, the HTMT ratio did not improve significantly. As a result, we ultimately decided to remove the Informational Factors (**IF**) construct from the model.

For the construct 'Perceived Risks and Benefits' (**RB**), the HTMT ratio exceeded 0.9. We therefore investigated the issue further and found no VIF problems. To address the HTMT concern, we dropped the measurement item with the lowest factor loading (**RB₆**) from the **RB** construct. This adjustment successfully reduced the HTMT ratio to below the threshold of 0.9, improving discriminant validity.

The results indicated no collinearity problems, as all VIF values were below the threshold of 3 for each construct. This finding confirms the robustness of the structural model, allowing for a reliable analysis of the relationships among the constructs.

The next step in the analysis is to evaluate the hypothesised relationships between latent variables by examining the path coefficients (β) and their significance levels (p-values). A bootstrapping procedure with 10,000 resamples was conducted, using the percentile method to determine confidence intervals at a 5% significance level. This approach examines the confidence intervals by evaluating the lower 2.5% and upper 97.5% percentiles of the distribution to establish a 95% confidence interval for the coefficients. All hypotheses were evaluated using path coefficients (β), and only those with p values ≤ 0.05 were considered significant.

During the attempt to run the bootstrapping procedure, we encountered an issue where NaN (Not a Number) values were returned, indicating that the model struggled to find a feasible solution. Upon investigation, we discovered that dropping the Perceived Risks from Load Shedding and Tariffs (RB2) construct allowed the bootstrapping procedure to derive a feasible solution successfully. Further examination of the RB2 construct revealed that the two measurement items, RB7 and RB8, both had VIF values exceeding 3, indicating significant multicollinearity. We initially attempted to drop one of the measurement items, but still received NaN values when rerunning the bootstrapping procedure. Consequently, we decided to remove the entire RB2 construct from the model, which resolved the issue and enabled the successful execution of the bootstrapping procedure.

The results obtained by the bootstrapping procedure include specific indirect effects (Appendix G, Table G.12), total indirect effects (Appendix G, Table G.13), direct effects (Appendix G, Table G.14), and total effects (Appendix G, Table G.15). The specific indirect effects provide insights into how mediators influence the relationships between constructs. In contrast, the total indirect effects aggregate these influences. The total effects, which combine both direct and indirect effects, are nearly identical to the direct effects, as most indirect effects were found to be insignificant.

The specific indirect effects presented in Appendix G, Table G.12 for the model investigating irrigators' intentions to adapt to climate variability in the Hartbeespoort Irrigation Scheme indicated that none of these effects were statistically significant. This suggests that the mediating variables did not significantly influence the relationships between the independent and dependent variables.

The total indirect effects, as shown in Appendix G, Table G.13, were also found to be insignificant. This further reinforces the finding that the mediating variables in the model did not play a significant role in explaining the relationships between the predictors and irrigators' intentions to adapt to climate variability in the Hartbeespoort Irrigation Scheme. Consequently, indirect influences appear to have a minimal impact on the overall model.

The direct effects (path coefficients) presented in Appendix G, Table G.14, revealed several significant relationships. The relationship between attitudes (***A_B***) and intentions (***INT***) were significant ($\beta = 0.163$, $p < 0.01$), indicating that more favourable attitudes towards climate variability adaptation positively influence intentions to adopt such measures. Additionally, the influence of institutional and legal factors (***IL***) on subjective norms (***SN***) was also significant ($\beta = 0.255$, $p < 0.05$), suggesting that institutional support enhances social pressure to adapt. Moreover, the perceived risks from load shedding and tariffs (***RB***) had a substantial effect on intentions (***INT***) ($\beta = 0.545$, $p < 0.01$), highlighting the importance of these perceived risks in driving adaptive intentions. The relationship between perceived risks (***RB***) and perceived behavioural control (***PBC***) was significant as well ($\beta = 0.247$, $p < 0.05$), indicating that higher perceived risks are associated with a greater sense of control over adaptation efforts. Lastly, technical factors (***TF***) significantly influenced intentions (***INT***) ($\beta = 0.397$, $p < 0.001$), emphasising the role of technical support and resources in shaping the intentions of irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme.

The total effects, which represent the sum of both direct and indirect effects, are presented in Appendix G, Table G.15. The results indicated that the total effects closely mirrored the direct effects (Appendix G, Table G.14, reinforcing our findings that stated that none of the indirect effects were significant (Appendix G, Table G.12 and Appendix G, Table G.13). The total effects primarily reflect the direct relationships observed in the analysis, highlighting the strong and direct influence of the various constructs on irrigators' intentions to adapt to climate variability within the Hartbeespoort Irrigation Scheme.

Notably, the intention to adapt (***INT***) had a strong explanatory power, with an R^2 value of 0.695, suggesting that approximately 69.5% of the variance in intentions can be explained by the model. The adjusted R^2 for intentions was 0.671, indicating a good fit after accounting for the number of predictors. In contrast, the constructs for attitudes (***A_B***), perceived behavioural control (***PBC***), and subjective norms (***SN***) showed lower explanatory power, with R^2 values of 0.099, 0.199, and 0.144, respectively. These findings highlight the point that, while the model effectively captures the variance in intentions to adapt to climate variability, the influence of attitudes, perceived behavioural control, and subjective norms remains comparatively limited.

The effect size (f^2) values of 0.02, 0.15, and 0.35 correspond to small, medium, and large effects, respectively. The results indicate that the construct for perceived risks from load shedding and tariffs (***RB2***) has a substantial impact on the intention to adapt (***INT***), with an f^2 value of 0.721, indicating a significant effect. This suggests that perceptions of risks significantly influence the intentions of irrigators to adopt adaptive behaviours toward climate variability.

In addition, the trust factors (*TF*) also showed a medium effect on *INT*, with an f^2 value of 0.427. This emphasises the importance of trust in influencing behavioural outcomes related to climate variability adaptation. The other constructs exhibited small to negligible effects on the outcome variables, with f^2 values generally below 0.15.

5.2.3 AquaCrop Model Simulation

5.2.3.1 Net and Gross Irrigation Requirements for commercial wheat irrigators in the Hartbeespoort irrigation scheme

According to the AquaCrop Model Reference Manual (Raes et al., 2023), the NIR is the amount of water needed to maintain soil moisture above a specified depletion threshold, thereby preventing significant water stress. The AquaCrop model estimates the NIR based on crop water uptake and soil moisture balance, but does not account for conveyance losses or irrigation inefficiencies. In contrast, the GIR represents the total water applied to the field to meet the NIR, incorporating losses from evaporation, deep percolation, runoff, and inefficiencies in the irrigation system (Savva & Frenken, 2002). Table 5.2 below illustrates the NIR for the Hartbeespoort Irrigation Scheme, presented for the two weather stations used in the simulations, and considers the three dominant soil types occurring in the main irrigation zone of the scheme.

Table 5.2: Net Irrigation Requirement for Dominant Soil Types in the Main Irrigation Zone of the Hartbeespoort Irrigation Scheme

		Station name: Wildebeesthoek Coordinates: 25°40'06.6"S 28°02'03.1"E			Station name: Brits Coordinates: 25°35'29.0"S 27°46'07.4"E			Average
		2016	2017	2018	2011	2012	2013	
Net irrigation requirement	Eutric Plinthosols	442.0	391.0	431.6	377.7	260.7	382.7	380.95
	Calcic Vertisols	455.0	397.1	444.7	385.2	275.4	388.4	390.97
	Ferric Luvisols	459.3	411.4	446.9	397.9	275.3	401.9	398.78
	Average	452.1	399.83	441.07	386.93	270.47	391	390.23

Source: Project team compilation

By utilising Equation 4.1 ($\frac{95 \times 75}{100} = 71.25$) and Equation 4.2 (adapted from Savva & Frenken, 2002), the efficiency and the gross irrigation requirement (GIR) were calculated, respectively. As the net irrigation requirement (NIR) does not account for application efficiency or conveyance losses, it was assumed for purposes of this study that most irrigation in the Hartbeespoort Irrigation Scheme is carried out using sprinkler systems and that water is distributed via lined canals. The lined canals are assumed to have a

conveyance efficiency of 95%, and the sprinkler systems an application efficiency of 75%. To ensure that the irrigation planning accounts for a worst-case scenario, the NIR values from the year with the highest irrigation demand (NIR 2016 = 452.1 mm) were used to calculate the GIR. The year 2016 was selected based on the lowest recorded rainfall and the highest crop water requirements across the three dominant soil types in the Hartbeespoort Irrigation Scheme.

A conveyance efficiency of 95% was assumed for the lined canals, and an application efficiency of 75% was assumed for the sprinkler irrigation systems used in the Hartbeespoort Irrigation Scheme. Based on these assumptions, the combined overall irrigation efficiency was calculated as 71.25% by using Equation 4.1, as indicated above. This overall irrigation efficiency of 71.25% was then used in Equation 4.2 ($\frac{452.1}{71.25} = 634.53$) to calculate the gross irrigation requirement (GIR).

The net and gross irrigation requirements for the production year 2016, which had the highest net irrigation requirement on average, were 452.10 mm and the corresponding gross irrigation requirement on average was 634.53 mm.

5.2.3.2 The adoption of water-saving technologies

5.2.3.2.1 No adoption scenario

In the AquaCrop model simulations for commercial wheat irrigators in the Hartbeespoort Irrigation Scheme, the “No Adoption” scenario represents a baseline condition where farmers do not implement any water-saving technologies. Management practices were standardised across all scenarios to isolate the effect of irrigation scheduling alone. Specifically, soil fertility was set as non-limiting, 25% mulch cover was applied, runoff was not considered, and weed management was assumed to be optimal.

For this scenario, wheat is assumed to be planted on 1 June. Irrigation is applied at regular 10-day intervals throughout the growing season. This results in a total of 19 irrigation events. To remain within the gross irrigation requirement (GIR) of 634 mm, each event delivers 33 mm of water. This is slightly below the calculated 33.36 mm per interval to ensure the seasonal total is not exceeded. This uniform irrigation strategy reflects conventional practices where water is applied without reference to crop development stages or soil moisture status. Table 5.3 below provides a detailed breakdown of the irrigation schedule used in this scenario.

Table 5.3: Irrigation Schedule for the No Adoption Scenario of Water-Saving Technologies in Wheat Production in the Hartbeespoort Irrigation Scheme

Event	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	33
2	20 June	20 June	20 June	20 June	20 June	20 June	20	33
3	30 June	30 June	30 June	30 June	30 June	30 June	30	33
4	10 July	10 July	10 July	10 July	10 July	10 July	40	33
5	20 July	20 July	20 July	20 July	20 July	20 July	50	33
6	30 July	30 July	30 July	30 July	30 July	30 July	60	33
7	9 August	9 August	9 August	9 August	9 August	9 August	70	33
8	19 August	19 August	19 August	19 August	19 August	19 August	80	33
9	29 August	29 August	29 August	29 August	29 August	29 August	90	33
10	8 September	8 September	8 September	8 September	8 September	8 September	100	33
11	18 September	18 September	18 September	18 September	18 September	18 September	110	33
12	28 September	28 September	28 September	28 September	28 September	28 September	120	33
13	8 October	8 October	8 October	8 October	8 October	8 October	130	33
14	18 October	18 October	18 October	18 October	18 October	18 October	140	33
15	28 October	28 October	28 October	28 October	28 October	28 October	150	33
16	7 November	7 November	7 November	7 November	7 November	7 November	160	33
17	17 November	17 November	17 November	17 November	17 November	17 November	170	33
18	27 November	27 November	27 November	27 November	27 November	27 November	180	33
19	7 December	7 December	7 December	7 December	7 December	7 December	190	33

Source: Project team compilation

The results for the scenario of the non-adoption of water-saving technologies for commercial wheat irrigators are presented in Table 5.4 below. AquaCrop model simulations were conducted for each dominant soil unit occurring in the main irrigation zone, and a weighted average of the AquaCrop model result metrics was calculated based on the area covered by each dominant soil unit.

Table 5.4: AquaCrop Simulation Results for the No-Adoption Scenario of water-saving technologies for the Dominant Soil Types of the Main Irrigation Zone of the Hartbeespoort Irrigation Scheme

Soil type		No Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	22.31	22.51	22.85	23.32	23.49	23.49	22.99
	Yield (ton/ha)	10.71	10.81	10.97	11.21	11.28	11.28	11.04
	Irrigation (mm)	627.00	627.00	627.00	627.00	627.00	627.00	627.00
	WP_{ET} (Kg/m ³)	1.58	1.68	1.59	1.52	1.59	1.58	1.59
Calcic Vertisols	Biomass (ton/ha)	22.31	22.51	22.85	23.32	23.49	23.49	22.99
	Yield (ton/ha)	10.71	10.81	10.97	11.21	11.28	11.28	11.04
	Irrigation (mm)	627.00	627.00	627.00	627.00	627.00	627.00	627.00
	WP_{ET} (Kg/m ³)	1.55	1.64	1.55	1.50	1.55	1.54	1.56
Ferric Luvisols	Biomass (ton/ha)	22.31	22.51	22.85	23.29	23.49	23.48	22.99
	Yield (ton/ha)	10.71	10.81	10.97	11.24	11.28	11.28	11.05
	Irrigation (mm)	627.00	627.00	627.00	627.00	627.00	627.00	627.00
	WP_{ET} (Kg/m ³)	1.59	1.69	1.60	1.54	1.60	1.59	1.60
Weighted Average	Biomass (ton/ha)	22.31	22.51	22.85	23.32	23.49	23.48	22.99
	Yield (ton/ha)	10.71	10.81	10.97	11.21	11.28	11.28	11.04
	Irrigation (mm)	627.00	627.00	627.00	627.00	627.00	627.00	627.00
	WP_{ET} (Kg/m ³)	1.56	1.66	1.57	1.51	1.57	1.56	1.57

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Eutric Cambisols contributing 26%, Calcic Vertisols 64%, and Ferric Luvisols 10%.

Source: Project team compilation

5.2.3.2.2 Partial adoption scenario

In the partial adoption scenario, it is assumed that commercial wheat irrigators in the Hartbeespoort Irrigation Scheme make use of soil moisture monitoring technology, such as soil moisture probes, to guide irrigation decisions. Unlike the no adoption scenario, where irrigation is applied on a fixed schedule, no fixed interval is used here. Instead, irrigation is triggered whenever 70% of the Readily Available Water (RAW) in the root zone is depleted. This threshold reflects a typical management strategy for maintaining crop performance while improving water use efficiency.

As with all scenarios, key management practices in the AquaCrop model were kept constant to isolate the effect of irrigation scheduling. These include non-limiting soil fertility, 25% mulch cover, no runoff, and perfect weed control. This simulation approach is intended to represent a more responsive and efficient irrigation strategy associated with partial adoption of water-saving technologies. It captures how the timing and volume of irrigation events adjust dynamically, based on real-time soil moisture conditions, which may lead to fewer but better-targeted applications of water. The results of the AquaCrop model simulation for this scenario are presented in Table 5.5 below. Outputs are provided for each of the dominant soil types found in the main irrigation zone. In addition, a weighted average for each simulated metric (such as yield,

biomass, and water productivity) was calculated based on the proportional area covered by each soil unit in the zone.

Table 5.5: Irrigation Schedule for the Partial Adoption Scenario of Water-Saving Technologies in Wheat Production in the Hartbeespoort Irrigation Scheme

Soil type		Partial Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	22.30	22.49	22.82	23.30	23.46	23.46	22.97
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.27	11.27	11.03
	Irrigation (mm)	474.10	374.90	386.80	477.90	479.30	467.40	443.40
	WP_{ET} (Kg/m ³)	1.71	1.85	1.73	1.63	1.74	1.73	1.73
Calcic Vertisols	Biomass (ton/ha)	22.28	22.48	22.81	23.28	23.44	23.45	22.96
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.26	11.03
	Irrigation (mm)	828.80	616.30	837.70	1011.80	925.50	918.60	856.45
	WP_{ET} (Kg/m ³)	1.69	1.83	1.72	1.60	1.71	1.70	1.71
Ferric Luvisols	Biomass (ton/ha)	22.29	22.49	22.82	23.29	23.45	23.46	22.97
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.27	11.03
	Irrigation (mm)	459.40	366.60	450.70	517.60	450.20	444.10	448.10
	WP_{ET} (Kg/m ³)	1.71	1.84	1.72	1.63	1.73	1.72	1.73
Weighted Average	Biomass (ton/ha)	22.29	22.48	22.81	23.28	23.45	23.45	22.96
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.27	11.03
	Irrigation (mm)	699.64	528.57	681.77	823.57	761.96	753.84	708.22
	WP_{ET} (Kg/m ³)	1.70	1.84	1.72	1.61	1.72	1.71	1.72

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Eutric Cambisols contributing 26%, Calcic Vertisols 64%, and Ferric Luvisols 10%.

Source: Project team compilation

5.2.3.2.3 Full adoption scenario

The full adoption scenario builds on the partial adoption scenario by maintaining soil moisture-based irrigation scheduling, while upgrading the irrigation method from sprinkler to drip irrigation. This change is intended to simulate the effects of adopting a high-productivity irrigation system in combination with sensor-based scheduling. All other management parameters in the AquaCrop model remain consistent with the previous scenarios: soil fertility is non-limiting, mulch cover is set at 25%, runoff is not considered, and weed management is assumed to be optimal.

The results of the AquaCrop model simulation for the full adoption scenario are presented in Table 5.6 below, showing outputs for each of the dominant soil types in the main irrigation zone. A weighted average was also calculated for each output metric, based on the area share of each soil unit, providing an overall estimate of system performance under full adoption conditions.

Table 5.6: Irrigation Schedule for the Full Adoption Scenario of Water-Saving Technologies in Wheat Production in the Hartbeespoort Irrigation Scheme

		Full Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	22.30	22.49	22.82	23.29	23.46	23.46	22.97
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.27	11.27	11.03
	Irrigation (mm)	382.90	369.10	385.80	470.60	466.80	467.70	423.82
	WP_{ET} (Kg/m ³)	1.74	1.87	1.73	1.66	1.77	1.74	1.75
Calcic Vertisols	Biomass (ton/ha)	22.29	22.48	22.81	23.28	23.44	23.45	22.96
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.26	11.03
	Irrigation (mm)	831.80	627.30	826.10	924.20	917.70	1008.70	855.97
	WP_{ET} (Kg/m ³)	1.72	1.84	1.73	1.63	1.74	1.72	1.73
Ferric Luvisols	Biomass (ton/ha)	22.29	22.49	22.82	23.29	23.45	23.46	22.97
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.27	11.03
	Irrigation (mm)	448.40	298.00	452.30	514.50	445.90	435.40	432.42
	WP_{ET} (Kg/m ³)	1.74	1.87	1.75	1.66	1.77	1.75	1.76
Weighted Average	Biomass (ton/ha)	22.29	22.48	22.81	23.28	23.45	23.45	23.03
	Yield (ton/ha)	10.71	10.80	10.96	11.19	11.26	11.27	11.06
	Irrigation (mm)	676.75	527.24	674.24	765.29	753.29	810.71	672.93
	WP_{ET} (Kg/m ³)	1.73	1.85	1.73	1.64	1.75	1.73	1.68

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Eutric Cambisols contributing 26%, Calcic Vertisols 64%, and Ferric Luvisols 10%.

Source: Project team compilation

5.2.3.2.4 Summary of AquaCrop Simulation Results for the Adoption of Water-saving Technologies

The AquaCrop model simulations were run for three scenarios representing different levels of water-saving technology adoption. For each scenario, weighted averages of key metrics were calculated using the area share of each soil unit in the main irrigation zone of the Hartbeespoort Irrigation Scheme. Table 5.7 below presents the weighted average results for grain yield, biomass, irrigation applied, and water productivity. It also shows the changes in yield under partial and full adoption as compared with the no-adoption scenario. These yield differences are essential for the next step in the framework, where changes in agricultural output are fed into the Social Accounting Matrix to assess broader economic impacts.

Table 5.7: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	22.99	11.04	627.00	1.57	Baseline (0%)
	Partial adoption	22.96	11.03	708.22	1.72	-0.11%
	Full Adoption	23.03	11.07	672.93	1.68	0.27%

Source: Project team compilation

5.2.3.3 The adoption of water-saving policies

5.2.3.3.1 No adoption scenario

The first adoption scenario simulates the application of water-saving policies through optimised irrigation scheduling, where the Gross Irrigation Requirement (GIR) of 634 mm is applied in equal increments throughout the growing season. Specifically, irrigation events are scheduled at 10-day intervals, each supplying 33.36 mm. However, because of the AquaCrop's model restriction to integer input values for irrigation amounts, each interval was limited to 33 mm, ensuring that the total GIR does not exceed the allocated 634 mm.

This irrigation schedule mirrors what was used in the scenario of the non-adoption of water-saving technologies. As such, neither the schedule nor the AquaCrop results are presented again, as they are identical. All scenarios under the adoption of water-saving policies were simulated using consistent management assumptions. Soil fertility was assumed to be non-limiting, mulch cover was set at 25%, runoff was not included in the water balance, and weed management was assumed to be perfect.

5.2.3.3.2 Partial adoption scenario

The partial adoption scenario simulates the implementation of a 30% water-use restriction as part of water-saving policy adoption. Under this restriction, only 443.8 mm of the original Gross Irrigation Requirement (GIR) of 634 mm is available for irrigation during the wheat-growing season in the Hartbeespoort Irrigation Scheme.

This total volume was distributed evenly across 10-day intervals, resulting in 19 irrigation events. Each event was scheduled to apply 23.25 mm of water. However, because of the AquaCrop's model requirement for integer input values, the amount was rounded down to 23 mm per interval to ensure the total volume did not exceed the 443.8 mm limit. The resulting irrigation schedule is presented in Table 5.8 below.

Table 5.8: Irrigation Schedule for the Partial Adoption Scenario of Water-Saving Policies in Wheat Production in the Hartbeespoort Irrigation Scheme

Event	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	23
2	20 June	20 June	20 June	20 June	20 June	20 June	20	23
3	30 June	30 June	30 June	30 June	30 June	30 June	30	23
4	10 July	10 July	10 July	10 July	10 July	10 July	40	23
5	20 July	20 July	20 July	20 July	20 July	20 July	50	23
6	30 July	30 July	30 July	30 July	30 July	30 July	60	23
7	9 August	9 August	9 August	9 August	9 August	9 August	70	23
8	19 August	19 August	19 August	19 August	19 August	19 August	80	23
9	29 August	29 August	29 August	29 August	29 August	29 August	90	23
10	8 September	8 September	8 September	8 September	8 September	8 September	100	23
11	18 September	18 September	18 September	18 September	18 September	18 September	110	23
12	28 September	28 September	28 September	28 September	28 September	28 September	120	23
13	8 October	8 October	8 October	8 October	8 October	8 October	130	23
14	18 October	18 October	18 October	18 October	18 October	18 October	140	23
15	28 October	28 October	28 October	28 October	28 October	28 October	150	23
16	7 November	7 November	7 November	7 November	7 November	7 November	160	23
17	17 November	17 November	17 November	17 November	17 November	17 November	170	23
18	27 November	27 November	27 November	27 November	27 November	27 November	180	23
19	7 December	7 December	7 December	7 December	7 December	7 December	190	23

Source: Project team compilation

Table 5.9 below presents the AquaCrop model simulation results for the partial adoption scenario of water-saving policies by wheat irrigators in the Hartbeespoort Irrigation Scheme. Simulations were conducted separately for each dominant soil type in the main irrigation zone, and a weighted average for each AquaCrop model output metric was calculated based on the proportional area covered by each soil unit.

Table 5.9: Irrigation Schedule for the Partial Adoption Scenario of Water-Saving Policies in Wheat Production in the Hartbeespoort Irrigation Scheme

Soil type		Partial Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	21.903	22.513	22.351	21.769	22.852	22.932	22.39
	Yield (ton/ha)	10.479	10.811	10.741	10.415	10.888	10.98	10.72
	Irrigation (mm)	437	437	437	437	437	437	437.00
	WP_{ET} (Kg/m ³)	1.58	1.68	1.59	1.5	1.58	1.58	1.59
Calcic Vertisols	Biomass (ton/ha)	22	22.513	22.579	22.102	22.946	23.016	22.53
	Yield (ton/ha)	10.54	10.811	10.859	10.591	10.947	11.015	10.79
	Irrigation (mm)	437	437	437	437	437	437	437.00
	WP_{ET} (Kg/m ³)	1.55	1.64	1.55	1.48	1.54	1.54	1.55
Ferric Luvisols	Biomass (ton/ha)	21.024	22.511	21.533	20.549	22.037	22.085	21.62
	Yield (ton/ha)	10.012	10.814	10.305	10.033	10.432	10.55	10.36
	Irrigation (mm)	437	437	437	437	437	437	437.00
	WP_{ET} (Kg/m ³)	1.59	1.7	1.59	1.53	1.58	1.59	1.60
Weighted Average	Biomass (ton/ha)	21.88	22.51	22.42	21.86	22.83	22.90	22.40
	Yield (ton/ha)	10.47	10.81	10.77	10.49	10.88	10.96	10.73
	Irrigation (mm)	437	437	437	437	437	437	437.00
	WP_{ET} (Kg/m ³)	1.56	1.66	1.56	1.49	1.55	1.56	1.56

Source: Project team's compilation

5.2.3.3.3 Full adoption scenario

The full adoption scenario models the implementation of water-saving policies that impose a 70% restriction on irrigation water use. As a result, the Gross Irrigation Requirement (GIR) of 634 mm is reduced to 190.2 mm for the wheat-growing season in the Hartbeespoort Irrigation Scheme. This reduced volume is distributed evenly across 10-day intervals throughout the season. Each irrigation event applies 10 mm of water, resulting in a consistent irrigation schedule that aligns with AquaCrop's model input requirements. Table 5.10 below presents the irrigation schedule used under the full adoption of water-saving policies.

Table 5.10: Irrigation Schedule for the Full Adoption Scenario of Water-Saving Policies in Wheat Production in the Hartbeespoort Irrigation Scheme

	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	10
2	20 June	20 June	20 June	20 June	20 June	20 June	20	10
3	30 June	30 June	30 June	30 June	30 June	30 June	30	10
4	10 July	10 July	10 July	10 July	10 July	10 July	40	10
5	20 July	20 July	20 July	20 July	20 July	20 July	50	10
6	30 July	30 July	30 July	30 July	30 July	30 July	60	10
7	9 August	9 August	9 August	9 August	9 August	9 August	70	10
8	19 August	19 August	19 August	19 August	19 August	19 August	80	10
9	29 August	29 August	29 August	29 August	29 August	29 August	90	10
10	8 September	8 September	8 September	8 September	8 September	8 September	100	10
11	18 September	18 September	18 September	18 September	18 September	18 September	110	10
12	28 September	28 September	28 September	28 September	28 September	28 September	120	10
13	8 October	8 October	8 October	8 October	8 October	8 October	130	10
14	18 October	18 October	18 October	18 October	18 October	18 October	140	10
15	28 October	28 October	28 October	28 October	28 October	28 October	150	10
16	7 November	7 November	7 November	7 November	7 November	7 November	160	10
17	17 November	17 November	17 November	17 November	17 November	17 November	170	10
18	27 November	27 November	27 November	27 November	27 November	27 November	180	10
19	7 December	7 December	7 December	7 December	7 December	7 December	190	10

Source: Project team compilation

Table 5.11 below presents the AquaCrop model simulation results for the full adoption of water-saving policies scenario. Simulations were conducted for each dominant soil type in the main irrigation zone of the Hartbeespoort Irrigation Scheme. A weighted average of the AquaCrop model output metrics was then calculated based on the proportion of area covered by each dominant soil unit within the irrigation zone.

Table 5.11: Irrigation Schedule for the Full Adoption Scenario of Water-Saving Policies in Wheat Production in the Hartbeespoort Irrigation Scheme

Soil type		No Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	16.11	20.20	16.65	15.23	16.42	16.31	16.82
	Yield (ton/ha)	7.50	9.99	7.83	5.95	7.57	7.49	7.72
	Irrigation (mm)	190.00	190.00	190.00	190.00	190.00	190.00	190.00
	WP_{ET} (Kg/m ³)	1.48	1.74	1.49	1.12	1.45	1.44	1.45
Calcic Vertisols	Biomass (ton/ha)	16.48	20.02	16.64	15.34	16.23	15.82	16.75
	Yield (ton/ha)	7.73	9.87	7.86	6.68	7.45	7.24	7.81
	Irrigation (mm)	190.00	190.00	190.00	190.00	190.00	190.00	190.00
	WP_{ET} (Kg/m ³)	1.47	1.70	1.46	1.22	1.40	1.38	1.44
Ferric Luvisols	Biomass (ton/ha)	14.60	18.94	14.84	13.27	14.53	14.71	15.15
	Yield (ton/ha)	6.51	9.37	5.40	3.59	6.40	6.58	6.31
	Irrigation (mm)	190.00	190.00	190.00	190.00	190.00	190.00	190.00
	WP_{ET} (Kg/m ³)	1.39	1.73	1.12	0.73	1.33	1.36	1.28
Weighted Average	Biomass (ton/ha)	16.19	19.95	16.46	15.11	16.11	15.84	16.61
	Yield (ton/ha)	7.55	9.85	7.61	6.18	7.38	7.24	7.64
	Irrigation (mm)	190.00	190.00	190.00	190.00	190.00	190.00	190.00
	WP_{ET} (Kg/m ³)	1.46	1.71	1.43	1.15	1.41	1.39	1.43

Source: Project team compilation

5.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water Saving policies

The AquaCrop model simulations were run for three scenarios representing different levels of adaptation towards water saving policies. For each scenario, weighted averages of key metrics were calculated using the area share of each soil unit in the main irrigation zone of the Hartbeespoort Irrigation Scheme. Table 5.12 below presents the weighted average results for grain yield, biomass, irrigation applied, and water productivity. It also shows the changes in yield under partial and full adoption, as compared with the no adoption scenario. These yield differences are essential for the next step in the framework, where changes in agricultural output are fed into the Social Accounting Matrix through partial equilibrium or multiplier analyses to assess broader economic impacts.

Table 5.12: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption	No Adoption	22.99	11.04	627.00	1.57	Baseline (0%)
	Partial adoption	22.40	10.73	437.00	1.56	-2.91%
	Full Adoption	16.61	7.24	190.00	1.39	-52.53%

Source: Project team compilation

5.2.3.4 The adaptation towards climate variability

5.2.3.4.1 No adaptation scenario

The no adaptation scenario to climate variability assumes that the full Gross Irrigation Requirement (GIR), as previously calculated, is applied evenly across the growing season. No water-saving practices such as mulching are implemented, and only moderate weed management is used, allowing for some crop competition. Unlike the no-adoption scenarios for water-saving technologies and policies, this scenario excludes mulching, which affects the soil water balance. As a result, separate AquaCrop model simulations were necessary, even though the irrigation schedule is the same as that used in the no adoption scenarios for water-saving technologies and policies. Therefore, the irrigation schedule is not reproduced here. Table 5.13 below presents the AquaCrop model simulation results for the scenario of no adaptation to climate variability.

Table 5.13: Irrigation Schedule for No Adoption Scenario (2018–2023) for the adaptation towards climate variability in the Hartbeespoort Irrigation Scheme

Soil type		No Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	17.28	17.447	17.707	18.076	18.212	18.203	17.82
	Yield (ton/ha)	8.393	8.475	8.604	8.794	8.849	8.844	8.66
	Irrigation (mm)	627	627	627	627	627	627	627.00
	WP_{ET} (Kg/m ³)	1.22	1.3	1.23	1.18	1.23	1.22	1.23
Calcic Vertisols	Biomass (ton/ha)	17.28	17.447	17.707	18.077	18.212	18.203	17.82
	Yield (ton/ha)	8.393	8.475	8.603	8.792	8.849	8.844	8.66
	Irrigation (mm)	627	627	627	627	627	627	627.00
	WP_{ET} (Kg/m ³)	1.19	1.26	1.19	1.15	1.19	1.19	1.20
Ferric Luvissols	Biomass (ton/ha)	17.28	17.447	17.706	17.968	18.211	18.202	17.80
	Yield (ton/ha)	8.393	8.476	8.606	8.777	8.849	8.846	8.66
	Irrigation (mm)	627	627	627	627	627	627	627.00
	WP_{ET} (Kg/m ³)	1.23	1.31	1.24	1.19	1.24	1.23	1.24
Weighted Average	Biomass (ton/ha)	17.28	17.45	17.71	18.07	18.21	18.20	17.82
	Yield (ton/ha)	8.39	8.48	8.60	8.79	8.85	8.84	8.66
	Irrigation (mm)	627.00	627.00	627.00	627.00	627.00	627.00	627.00
	WP_{ET} (Kg/m ³)	1.20	1.28	1.21	1.16	1.21	1.20	1.21

Source: Project team compilation

5.2.3.4.2 Partial adaptation scenario

The partial adaptation scenario to climate variability involves applying a 20% deficit irrigation, with mulching set at a moderate level and moderate weed management applied. This means the GIR of 634.5 mm is reduced by 20%, resulting in 507.2 mm being used over the growing season. Irrigation events are spaced at 10-day intervals, with 26.69 mm scheduled per interval. However, since the AquaCrop model only accepts integer values for irrigation amounts, each event was rounded down to 26 mm to ensure the total seasonal irrigation remains within the 507.2 mm limit. Table 5.14 below presents the irrigation schedule for the partial adaptation scenario to climate variability.

Table 5.14: Irrigation Schedule for the Partial Adaptation Scenario to Climate Variability in Wheat Production in the Hartbeespoort Irrigation Scheme

Event	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	26
2	20 June	20 June	20 June	20 June	20 June	20 June	20	26
3	30 June	30 June	30 June	30 June	30 June	30 June	30	26
4	10 July	10 July	10 July	10 July	10 July	10 July	40	26
5	20 July	20 July	20 July	20 July	20 July	20 July	50	26
6	30 July	30 July	30 July	30 July	30 July	30 July	60	26
7	9 August	9 August	9 August	9 August	9 August	9 August	70	26
8	19 August	19 August	19 August	19 August	19 August	19 August	80	26
9	29 August	29 August	29 August	29 August	29 August	29 August	90	26
10	8 September	8 September	8 September	8 September	8 September	8 September	100	26
11	18 September	18 September	18 September	18 September	18 September	18 September	110	26
12	28 September	28 September	28 September	28 September	28 September	28 September	120	26
13	8 October	8 October	8 October	8 October	8 October	8 October	130	26
14	18 October	18 October	18 October	18 October	18 October	18 October	140	26
15	28 October	28 October	28 October	28 October	28 October	28 October	150	26
16	7 November	7 November	7 November	7 November	7 November	7 November	160	26
17	17 November	17 November	17 November	17 November	17 November	17 November	170	26
18	27 November	27 November	27 November	27 November	27 November	27 November	180	26
19	7 December	7 December	7 December	7 December	7 December	7 December	190	26

Source: Project team compilation

Table 5.15 below presents the simulation results for the partial adaptation to climate variability scenario, where simulations were conducted for each of the dominant soil types occurring in the main irrigation zone of the Hartbeespoort Irrigation Scheme. A weighted average was then calculated for the AquaCrop model results, based on the proportion of the area covered by each dominant soil unit in the main irrigation zone.

Table 5.15: Irrigation Schedule for the Partial Adoption Scenario of Climate Variability in Wheat Production in the Hartbeespoort Irrigation Scheme

Soil type		No Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	17.24	17.45	17.71	17.68	18.17	18.18	17.74
	Yield (ton/ha)	8.37	8.48	8.62	8.61	8.82	8.84	8.62
	Irrigation (mm)	494.00	494.00	494.00	494.00	494.00	494.00	494.00
	WP_{ET} (kg/m ³)	1.26	1.34	1.27	1.22	1.26	1.26	1.27
Calcic Vertisols	Biomass (ton/ha)	17.26	17.45	17.71	17.83	18.20	18.18	17.77
	Yield (ton/ha)	8.38	8.48	8.61	8.70	8.84	8.84	8.64
	Irrigation (mm)	494.00	494.00	494.00	494.00	494.00	494.00	494.00
	WP_{ET} (kg/m ³)	1.24	1.32	1.24	1.20	1.24	1.24	1.25
Ferric Luvisols	Biomass (ton/ha)	16.99	17.45	17.41	16.90	17.89	17.90	17.42
	Yield (ton/ha)	8.22	8.48	8.48	8.14	8.64	8.69	8.44
	Irrigation (mm)	494.00	494.00	494.00	494.00	494.00	494.00	494.00
	WP_{ET} (kg/m ³)	1.27	1.35	1.28	1.21	1.27	1.27	1.28
Weighted Average	Biomass (ton/ha)	17.23	17.45	17.68	17.70	18.16	18.16	17.73
	Yield (ton/ha)	8.36	8.48	8.60	8.62	8.82	8.82	8.62
	Irrigation (mm)	494.00	494.00	494.00	494.00	494.00	494.00	494.00
	WP_{ET} (kg/m ³)	1.25	1.33	1.25	1.21	1.25	1.25	1.26

source: Project team compilation

5.2.3.4.3 Full adaptation scenario

In this scenario, mulching is applied extensively to maximise soil moisture retention and reduce evaporation, as optimised in the AquaCrop model. Weed management is implemented at the highest level to prevent crop competition and improve crop resilience to climate variability. Additionally, a 30% deficit irrigation strategy is adopted, where only 444 mm of water is available for irrigation throughout the growing season, compared with the full gross irrigation requirement of 634.5 mm. Water is strategically applied during the crop's critical growth stages to optimise use, while maintaining acceptable yields. Table 5.16 below provides an overview of the irrigation events and the volumes of water applied, highlighting the increased amounts applied during the most sensitive stages of crop development.

Table 5.16: Irrigation Schedule for the Full Adaptation Scenario to Climate Variability in Wheat Production in the Hartbeespoort Irrigation Scheme

Event	2011	2012	2013	2016	2017	2018	Day Number	Net application (mm)
1	10 June	10 June	10 June	10 June	10 June	10 June	10	15
2	20 June	20 June	20 June	20 June	20 June	20 June	20	15
3	30 June	30 June	30 June	30 June	30 June	30 June	30	15
4	10 July	10 July	10 July	10 July	10 July	10 July	40	15
5	20 July	20 July	20 July	20 July	20 July	20 July	50	15
6	30 July	30 July	30 July	30 July	30 July	30 July	60	20
7	9 August	9 August	9 August	9 August	9 August	9 August	70	20
8	19 August	19 August	19 August	19 August	19 August	19 August	80	20
9	29 August	29 August	29 August	29 August	29 August	29 August	90	30
10	8 September	8 September	8 September	8 September	8 September	8 September	100	30
11	18 September	18 September	18 September	18 September	18 September	18 September	110	30
12	28 September	28 September	28 September	28 September	28 September	28 September	120	35
13	8 October	8 October	8 October	8 October	8 October	8 October	130	40
14	18 October	18 October	18 October	18 October	18 October	18 October	140	40
15	28 October	28 October	28 October	28 October	28 October	28 October	150	40
16	7 November	7 November	7 November	7 November	7 November	7 November	160	34
17	17 November	17 November	17 November	17 November	17 November	17 November	170	15
18	27 November	27 November	27 November	27 November	27 November	27 November	180	10
19	7 December	7 December	7 December	7 December	7 December	7 December	190	5

Source: Project team compilation

The results for the full adaptation to climate variability in the Hartbeespoort irrigation scheme are presented in Table 5.17 below. The AquaCrop model simulations were conducted for each dominant soil unit occurring in the main irrigation zone of the Hartbeespoort irrigation scheme. A weighted average for each AquaCrop model metric was then obtained, based on the area covered by each dominant soil unit within the main irrigation zone.

Table 5.17: Irrigation Schedule for the Full Adoption Scenario of Water-Saving Policies in Wheat Production in the Hartbeespoort Irrigation Scheme

Soil type		Full Adoption Scenario						
		2011	2012	2013	2016	2017	2018	Average
Eutric Plinthosols	Biomass (ton/ha)	22.31	22.51	22.84	23.09	23.47	23.47	22.95
	Yield (ton/ha)	10.71	10.81	10.98	11.15	11.27	11.28	11.03
	Irrigation (mm)	444.00	444.00	444.00	444.00	444.00	444.00	444.00
	WP_{ET} (Kg/m ³)	1.64	1.74	1.65	1.59	1.64	1.64	1.65
Calcic Vertisols	Biomass (ton/ha)	22.31	22.51	22.84	23.25	23.46	23.47	22.97
	Yield (ton/ha)	10.71	10.81	10.98	11.23	11.27	11.28	11.05
	Irrigation (mm)	444.00	444.00	444.00	444.00	444.00	444.00	444.00
	WP_{ET} (Kg/m ³)	1.63	1.72	1.63	1.58	1.62	1.62	1.63
Ferric Luvisols	Biomass (ton/ha)	22.30	22.51	22.81	22.46	23.37	23.41	22.81
	Yield (ton/ha)	10.71	10.81	10.99	10.92	11.23	11.28	10.99
	Irrigation (mm)	444.00	444.00	444.00	444.00	444.00	444.00	444.00
	WP_{ET} (Kg/m ³)	1.65	1.75	1.66	1.61	1.65	1.65	1.66
Weighted Average	Biomass (ton/ha)	22.31	22.51	22.84	23.13	23.45	23.47	22.95
	Yield (ton/ha)	10.71	10.81	10.98	11.18	11.26	11.28	11.04
	Irrigation (mm)	444.00	444.00	444.00	444.00	444.00	444.00	444.00
	WP_{ET} (Kg/m ³)	1.63	1.73	1.64	1.59	1.63	1.63	1.64

Source: Project team compilation

5.2.3.4.4 Summary of AquaCrop model Simulation Results for the adaptation towards climate variability

As with the previous simulations, each scenario was simulated for all dominant soil units occurring within the main irrigation zone of the Hartbeespoort Irrigation Scheme. A weighted average was then calculated based on the area covered by each soil unit in the main irrigation zone to reflect overall scheme-level outcomes.

Table 5.18 below presents the weighted average results for the three adaptation scenarios: no adaptation, partial adaptation, and full adaptation to climate variability. In the final column, the percentage change in yield is shown relative to the no-adaptation scenario. These yield change percentages will be used as exogenous shocks in the Social Accounting Matrix (SAM) through multiplier analysis to assess the broader economic implications of adapting irrigation practices in response to climate variability.

Table 5.18: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	17.82	8.66	627.00	1.21	Baseline (0%)
	Partial adoption	17.73	8.62	494.00	1.26	-0.49%
	Full Adoption	22.95	11.04	444.00	1.64	21.55%

Source: Project team compilation

5.2.4 Multiplier Analysis

In the preceding sections, the integrated framework developed for this study was applied to assess the drivers of water use behaviour among commercial wheat irrigators in the Hartbeespoort Irrigation Scheme.

5.2.4.1 Adoption of water-saving technologies

Table 5.19 below gives a summary of the economic impacts simulated for the Hartbeespoort Irrigation Scheme.

Table 5.19: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Hartbeespoort Irrigation Scheme for Commercial Wheat Irrigators

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (-0.11%)	Full (0.27%)	Partial (-2.91%)	Full (-52.53%)	Partial (-0.49%)	Full (21.55%)
Wheat in the Northwest	10.35	12.11	21.68	16.28	7.95	40.25
Total labour remuneration in SA	3.01	31.09	15.35	2.75	25.85	113.67
Northwest province generates labour return	1.77	2.5	3.75	0.59	1.37	4.76
Gross operating surplus SA	2.86	24.69	6.51	4.13	2.22	90.26
Household income for the Northwest	8.99	79.15	42.32	5.63	29.91	289.3
Land return in SA	3.67	17.76	7.68	5.3	2.82	59.01
land return to irrigation in the Northwest	R98,982.90	R136,967.90	R270,743.30.42	R143,179.37	R76, 050.96	R263 025.9
Institution income SA (enterprise + Household)	31.99	78.52	99.68	11.35	72.71	454.73
Household generating income SA	14.06	123.7	62.03	8.79	58.97	452.37
Value-added generating income SA (Labour + capital + land)	65.51	217.23	137.54	94.7	50.36	769.15

Source: Project team compilation

5.2.4.1.1 Partial adoption

As indicated in Table 5.19 above, the effect of the partial adoption of Water-Saving Technologies results in R10.35 million in wheat output in the economy of the Northwest province. The total labour remuneration

was estimated to be R3.01 million in the economy of South Africa, of which the Northwest province generates a labour return of about R1.77 million and a gross operating surplus of R2.86 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R8.99 million, which was earned in the economy of Northwest province. The overall land return was estimated at R3.67 million in the economy of South Africa, of which the return to irrigation in the Northwest was only R98 982.90. The highest return on irrigation in the province of Northwest was found in the Modiri irrigation district, followed by the Ruth irrigation and Kenneth Kaunda irrigation districts in the economy of Northwest province.

In the case of institutional incomes (enterprise and households), these were estimated at R31.99 million. The households and value added generated (labour, capital, and land) were R14.06 million and R65.51 million in the economy of South Africa, respectively. The findings of this study concur with those of Lakhia et al. (2024), which indicated that the use of precision irrigation water-saving systems for efficient water management under climate variability is one of the recommended approaches by researchers. It can mitigate the adverse effects of a changing climate and help to enhance water use efficiency, crop yield, and environmental footprints. As the water scarcity problem intensifies as a result of climate variability and population growth, the precision irrigation water-saving systems are poised to play a critical role in optimising and modernising water usage, increasing water use efficiency, and reducing environmental footprints, thus ensuring sustainable agriculture development.

5.2.4.1.2 Full adoption

As indicated in Table 5.19 above, the full adaptation towards climate variability, represented by irrigation scheduling based on soil moisture levels accompanied by the adoption of drip irrigation, resulted in R12.11 million wheat output in the economy of the Northwest province. The total labour remuneration was estimated at R31.09 million in the economy of South Africa, of which Northwest province generates a labour return of about R2.5 million and a gross operating surplus (capital) of R24.69 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated to be R79.15 million towards the economy of the Northwest province. The overall land return was estimated at R17.76 million in the economy of South Africa, of which the return to irrigation in the Northwest was only R136 967.90. The highest return on irrigation in the province of North West was found in the Modiri irrigation district, followed by the Ruth irrigation and Kenneth Kaunda irrigation districts in the economy of North West province.

Regarding institutional incomes (enterprise and households), these were estimated at R78.652 million. The households and value added (labour, capital, and land) generated incomes of only R12.70 million and R217.23 million in the economy of South Africa, respectively. The findings of this study align with those of Postel et al. (2001), who found that drip irrigation technology is a key to increasing crop production and incomes, alleviating a significant share of hunger and poverty, and enhancing household food security. Furthermore, Anjaly et al. (2024) indicated that implementing the water-saving technology interventions, such as soil moisture techniques like eco-friendly straw mulching, contributes to better soil health and sustainable yields.

5.2.4.2 Adoption of water-saving policies

5.2.4.2.1 Partial adoption

As indicated in Table 5.19 above, the partial adoption of the water saving policies scenario, where a 30% water restriction is in place, results in a R21.68 million wheat yield in the Hartbeespoort Irrigation Scheme in the North West province. The total labour remuneration was estimated at R15.35 million in the economy of South Africa, of which the North West province generates a labour return of about R3.75 million and a gross operating surplus (capital) of R6.51 million in the economy. Most of the labour income increase was derived in the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R42.32 million in the economy of North West province. The overall land return was estimated at R7.68 million in the economy of South Africa, of which the return to irrigation in the North West was only R270 743.30. The highest return on irrigation in the district of the North West was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of North West province.

The institutional incomes (enterprise and households) were estimated at R99.68 million. The households and value added (labour, capital, and land) generate incomes of R62.03 and R137.54 million in the economy of South Africa, respectively. The findings of this study aligned with those of Islam et al. (2022), which showed that the introduction of adaptation measures and strategies significantly increased both the yield and wheat productivity.

5.2.4.2.2 Full adoption

As indicated in Table 5.19 above, the full adoption of the water-saving policies scenario, which involved a 70% water restriction, resulted in a R16.28 million wheat yield in the Hartbeespoort Irrigation Scheme in the North West province. The total labour remuneration was estimated at R2.75million in the economy of South Africa, of which the North West province generates a labour return of more than half a million and

gross operating surplus (capital) of R4.13 million in the economy. Most of the labour income is derived from the Western Cape, followed by the North West and Mpumalanga provinces.

Household income was estimated at R5.63 million towards the economy of North West province. The overall land return was estimated at R5.30 million in the economy of South Africa, of which the return to irrigation in North West was only R143 179.37. The highest return on irrigation in the North West province was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of North West province.

Regarding institutional incomes (enterprise and households), these were estimated at R11.35 million. The households and value added (labour, capital, and land) generate incomes of only R8.79 and R94.70 million in the economy of South Africa. As indicated above in this sub-section, the findings of this study concur with the findings of Islam et al (2022), which showed that introducing adaptation measures and strategies significantly increased both the yield and wheat productivity.

5.2.4.3 Adaptation towards climate variability

5.2.4.3.1 Partial adaption

As indicated in Table 5.19 above, the partial adoption of the climate variability scenario, which involved applying a 20% deficit irrigation strategy along with moderate mulching and moderate weed management, resulted in a R7.95 million wheat output in the Hartbeespoort Irrigation Scheme in the North West province. The total labour remuneration was estimated at R25.85 million in the economy of South Africa, of which the North West province generates a labour return of about R1.37million and a gross operating surplus (capital) of R2.22 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R29.91 million for the economy of the North West province. The overall land return was estimated at R2.82 million in the economy of South Africa, of which the return to irrigation in the North West was only R76 050.96. The highest return on irrigation in the province of the North West was found in the Bojanala irrigation district, followed by the Ruth and Modiri irrigation districts in the province.

Institutional incomes (enterprise and households) were valued at R 72.71 million. The households and value added (labour, capital, and land) generate incomes of R72.71 and R50.36 million in the economy of South Africa, respectively. The findings of this study aligned with those of Challinor et al. (2014), which highlighted the point that, without adaptation to climate variability, losses in aggregate production are expected for wheat, rice, and maize in both temperate and tropical regions by 2 °C of local warming. Crop-level adaptations increased simulated yields.

5.2.4.3.2 Full Adaption

As indicated in Table 5.19 above, the full adaptation towards climate variability scenario, which involved applying a 30% deficit irrigation strategy with water applied strategically during the crop's critical growth stages, high level mulching with 75% coverage and an intense weed management schedule, resulted in R40.25 million in commercial wheat output in the Hartbeespoort Irrigation Scheme in the North West province economy. The total labour remuneration was estimated at R113.67 million in the economy of South Africa, of which the North West province generates a labour return of about R4.76 million and a gross operating surplus (capital) of R90.26 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R457.73 million towards the economy of North West province. The overall land return was estimated at R59.01 million in the economy of South Africa, of which the return to irrigation in the North West was only R263 025.90. The highest return on irrigation in the province of the North West was found in the Bojanala irrigation district, followed by the Modiri irrigation and Ruth districts in the economy of the North West province.

Institutional incomes (enterprise and households) were estimated at R452.37 million. The households and value added (labour, capital, and land) generate incomes of R452.37 and R769.15 million in South Africa's economy, respectively. As indicated above in this sub-section, the findings of this study aligned with those of Challinor et al. (2014), which highlighted the point that, without adaptation to climate variability, losses in aggregate production are expected for wheat, rice, and maize in both temperate and tropical regions by 2 °C of local warming. Crop-level adaptations increased simulated yields.

5.3 Discussions

In the Hartbeespoort Irrigation Scheme, the extended TPB results show that perceived risks and benefits significantly influence farmers' attitudes, intentions, and subjective norms toward adopting water-saving technologies. This suggests that adoption is more likely to occur when farmers believe that the benefits of the technologies outweigh the potential disadvantages. Technical factors also have a strong influence on intention, shaping how farmers assess the practicality and effectiveness of the technologies. These psychological conditions indicate that adoption is most likely when farmers see both clear benefits and technical feasibility. However, the AquaCrop simulations reveal only minimal changes in yield. Partial adoption results in a slight decrease of 0.11%, while full adoption leads to a slight increase of 0.27%. Despite limited improvements in yield, both scenarios show notable gains in water productivity when compared with the no-adoption case. The Social Accounting Matrix results confirm this trend, with only minor changes in socio-economic indicators. This suggests that, while the technologies help to improve

water use productivity at the farm level, they do not lead to significant wider economic benefits unless accompanied by broader structural support.

The extended TPB results reveal that informational factors play a critical role in shaping attitudes and intentions to adopt water-saving policies, with strong positive effects on intentions. However, access to resources was found to influence intentions negatively, suggesting that farmers who face resource constraints are less likely to support restrictive policies. Trust factors also emerged as a strong positive driver of intention, while institutional and legal factors enhanced both perceived control and social pressure. These psychological conditions indicate that the adoption of water-saving policies is more likely to occur when farmers trust the system, have access to clear and persuasive information, and perceive supportive legal and institutional structures, despite the burden of resource constraints. However, the AquaCrop model simulations show significant yield penalties associated with both levels of policy adoption. Partial adoption involving a 30% water restriction results in a 2.91% decrease in wheat yield, while full adoption with a 70% restriction leads to a sharp 52.53% decline. These yield shocks translate into severe socio-economic consequences in the SAM results. Adaptations have a substantial impact on the socio-economic variables. These results suggest that, without compensatory support mechanisms, the economic costs of strict water-saving policies can be severe, undermining farmer livelihoods and broader regional welfare.

In the Hartbeespoort Irrigation Scheme, adaptation towards climate variability is strongly influenced by a combination of psychological and contextual factors. The extended TPB model shows that favourable attitudes significantly drive intentions to adopt adaptive practices, while institutional and legal support strengthens social norms that encourage adaptation. Perceived risks from external pressures such as load shedding and tariffs have a powerful effect on intentions and also increase perceived behavioural control, meaning that farmers who recognise these risks feel more capable of responding. Technical factors further reinforce intention, indicating that access to technical resources and solutions is a key enabler of adaptive behaviour. These psychological conditions point to a context where farmers are likely to adopt adaptive strategies when they perceive risks as being serious, have the technical means to act, and receive institutional reinforcement. From a biophysical perspective, the AquaCrop model results show minimal yield impact under partial adaptation, but significant yield increases under full adaptation. Notably, the SAM results reveal the broader socioeconomic gains where full adaptation increases wheat output and boosts labour remuneration in South Africa and household income in the North West province, as well as lifts land returns and institutional incomes significantly. These findings confirm that, under the right psychological and structural conditions, full adaptation not only enhances productivity but also delivers widespread economic benefits, thus making a compelling case for investment in long-term climate resilience.

CHAPTER 6: CASE STUDY OF COMMERCIAL MAIZE PRODUCTION IN THE ORANGE-RIET IRRIGATION SCHEME, FREE STATE PROVINCE

6.1 Overview

This section presents the results for commercial maize irrigators in the Orange Riet Irrigation Scheme based on the integrated framework developed in this project, TPB, AquaCrop model simulation, and multiplier analysis. The results begin with a summary of the demographic, farm, and household characteristics of the irrigators who participated in the study. These characteristics provide essential context for understanding the behavioural and system-level outcomes that follow.

6.2 Results

6.2.1 Demographic, Farm, and Household Characteristics of Respondents

Table 6.1 below presents the demographic profile of the 131 respondents in this study. The sample exclusively consists of male irrigators. This could be attributable to the socio-cultural dynamics of the region or the nature of the irrigation activities being predominantly managed by men. Age distribution is varied, with the majority of respondents being between 41 and 50 years old (30.53%) and the smallest group being under 20 years old. Moreover, more than half of the respondents have attained an undergraduate degree (54.20%), indicating a relatively high level of educational attainment within the sample. A significant portion had also completed secondary education (28.24%) and attained diplomas (15.27%). The presence of respondents with master's degrees (2.29%) further highlights the educational diversity within the group. In terms of health level, a substantial proportion of respondents rate their health as good (49.62%) or excellent (41.22%), suggesting that the majority of the sample considers themselves to be in good or excellent health.

Furthermore, Table 6.1 outlines the farm characteristics of the respondents, providing insight into the irrigation practices, type of farming, land ownership, and business structures prevalent among the sample. A significant majority of respondents use river water (38%) or canal water (37%) for irrigation, with a notable preference for these sources over other options. Crop production is the dominant type of farming performed (74.05%), with a smaller proportion engaging in mixed agriculture (25.95%). The absence of exclusive livestock production suggests that the region's farming activities are predominantly oriented towards crop cultivation. Regarding land ownership, most respondents own more than five land deeds

(58.02%), indicating substantial landholdings. This is complemented by a high proportion of sole ownership (86.26%), reflecting a prevalent ownership model in the region. The distance of the main irrigation land from the water source shows that a majority of respondents (64.12%) have their land less than 1 km from the water source. The variety noted in the business structures, with a majority operating as corporations (39.69%) and sole proprietorships (19.85%), indicates a diverse approach to farm management.

Table 6.1: Demographic, farm, and household Profile of Maize Irrigators in the Orange-Riet Irrigation Scheme

Variable	Classification	Frequency	Percentage (%)
Demographic profile			
Gender	Male	131	100%
Age	21-30	10	7.63%
	31-40	27	20.61%
	41-50	40	30.53%
	51-60	33	25.19%
	61 and older	21	16.03%
	Secondary (grade 8-12)	37	28.24%
	Diploma	20	15.27%
	Undergraduate degree	71	54.20%
	Master's	3	2.29%
Health Level	Poor	4	3.05%
	Average	8	6.11%
	Good	65	49.62%
	Excellent	54	41.22%
Farm Profile			
The primary source of water used for irrigation	River	50	38%
	Dam	3	2%
	Canal	49	37%
	Borehole	6	5%
	River and dam water	3	2%
	River and canal water	8	6%
	River and borehole	9	7%
	Dam and canal water	1	1%
	Canal and borehole	2	2%
Type of farming performed	Crop production	97	74.05%
	Mixed farming	34	25.95%
Amount of agricultural land deeds owned	One	14	10.69%
	Two to five	41	31.23%
	More than five	76	58.02%
How scattered is the farmland from the main farm	Highly clustered together (1-5 km)	63	48.09%
	Moderately dispersed (6-10 km)	28	21.37%
	Highly dispersed (more than 10 km)	40	30.54%
	Sole proprietorship	26	19.85%

Variable	Classification	Frequency	Percentage (%)
Demographic profile			
Business structure of the farm operations	Corporation	52	39.69%
	Partnership	5	3.82%
	Trust	37	28.24%
	Closed corporation	11	8.40%
The land ownership type of the farm	Sole owner	113	86.26%
	Lease	2	1.53%
	Combination of sole owner and lease	16	12.21%
Distance of the main irrigation land from the water source	Less than 1 Km	84	64.12%
	1-3 Km	23	17.56%
	3-7 Km	11	8.40%
	7-10 Km	2	1.52%
	More than 10 Km	11	8.40%
Household Characteristics			
Number of adults (18 years and older) living in the household	One	13	9.92%
	Two	105	80.15%
	Three or more	13	9.92%
Total individuals living in the household (adults + children)	One	8	6.11%
	Two	49	37.40%
	Three	23	17.56%
	Four or more	51	38.93%
Individuals in the household involved in farming activities	One	119	90.84%
	Two	8	6.11%
	Three or more	4	3.05%
Marital status	Married	123	93.89%
	Single	6	4.58%
	Divorced	1	0.76%
	Widowed	1	0.76%
	20-30	9	6.87%
	31-40	27	20.61%
	41-50	40	30.53%
	51-60	34	25.95%
	61 and older	21	16.03%
Primary source of livelihood	Farmer/agricultural activities	128	97.71%
	Self-employed/business owner	3	2.29%
Off-farm income	Yes	16	12.21%
	No	115	87.79%

Source: Project team compilation

Table 6.1 above also presents an overview of the household characteristics of the respondents, revealing key aspects such as household size, the role of household members in farming, and the primary source of livelihood. The majority of respondents live in households with two adults (80.15%), and the most common household size overall is four or more individuals (38.93%). Most respondents (90.84%) have only one

individual involved in farming activities, suggesting that a single person per household predominantly manages farming. The marital status of respondents shows a high prevalence of married individuals (93.89%). The age distribution of household heads is relatively balanced, with a significant proportion falling between 41 and 50 years old (30.53%) and between 31 and 40 years old (20.61%). Nearly all respondents (97.71%) rely on farming or agricultural activities as their primary source of livelihood. In addition, a substantial majority of respondents (87.79%) do not have any off-farm income, while only a minority (12.21%) have additional sources of revenue.

6.2.2 Theory of Planned Behaviour

As indicated above, the procedures are identical and thus only the main findings are presented in this section.

6.2.2.1 Standard TPB Model for Adoption of Water-saving Technologies

The indicator reliability estimation revealed that all measurement items for all constructs had loadings above 0.4. Internal consistency reliability assessment indicates that the Attitudes construct, Cronbach's alpha was 0.212, and for Subjective Norms, it was 0.308, both of which are below the acceptable threshold of 0.70, indicating low reliability. However, Cronbach's alpha is known to underestimate reliability, particularly when the number of items is small or when indicators have varying outer loadings on the construct. The composite reliability values, which take into account the individual outer loadings of the indicators, provide a more accurate assessment. In this study, the composite reliability for Attitudes was 0.690 and for Subjective Norms was 0.743. Given the exploratory nature of our research, these slightly lower thresholds were deemed appropriate for evaluating internal consistency.

For the Perceived Behavioural Control (PBC) construct, both the Cronbach's alpha and the composite reliability were above 0.95, suggesting the presence of redundant items. High-reliability values above 0.95 may indicate that the measurement items on a specific construct are too similar, which could inflate reliability measures and potentially compromise the content validity of the construct, as noted by Hair and Alamer (2022). The high Variance Inflation Factor (VIF) values for the two PBC items (both at 16.889) further indicated multicollinearity, implying that the items were not contributing unique information. To address this, the item with the lowest factor loading (PBC_2), was removed to improve the construct's validity and maintain its conceptual integrity.

For the convergent validity, the AVE for constructs with multiple indicators, the AVE values exceeded the minimum threshold of 0.50, with Attitudes at 0.548 and Subjective Norms at 0.591, confirming that these constructs adequately explain the variance in their indicators. Since the construct PBC is measured with only one item, its AVE could not be calculated.

The HTMT Ratio analysis indicates that values below the recommended threshold of 0.90 signify adequate discriminant validity among constructs. Initially, the HTMT value between Attitudes (A_B) and Intention (INT) was calculated at 1.07, suggesting a potential overlap between these constructs. Upon investigation, the first Attitude item (A_{B1}) had a moderate factor loading of 0.5 and correlations with INT_1 (0.256) and INT_2 (0.397). Although not excessively high, these correlations indicated that A_{B1} was not sufficiently distinct from the Intention construct, inflating the HTMT value. To address this issue, A_{B1} was removed, and after recalculating, the HTMT values confirmed that the constructs were now distinct from each other.

Upon recalculating the VIF values, the results confirm that collinearity is not a concern in the adjusted model. The VIF values are 1.145 for Attitude to Intention, 1.075 for Subjective Norms to Intention, and 1.069 for Behavioural Control to Intention. These values are well below the threshold of 3, indicating that multicollinearity is not an issue.

The significance of the hypothesised relationships between latent variables was identified by examining the path coefficients (β) and their significance levels (p -values), for which a bootstrapping procedure with 10,000 resamples was conducted, using the percentile method to determine confidence intervals at a 5% significance level. This approach examines the confidence intervals by evaluating the lower 2.5% and upper 97.5% percentiles of the distribution to establish a 95% confidence interval for the coefficients. All hypotheses were evaluated using path coefficients (β), and only those with p values ≤ 0.05 were considered significant. The hypothesis testing results are shown in Figure 6.1 below and Appendix H, Table H.1.

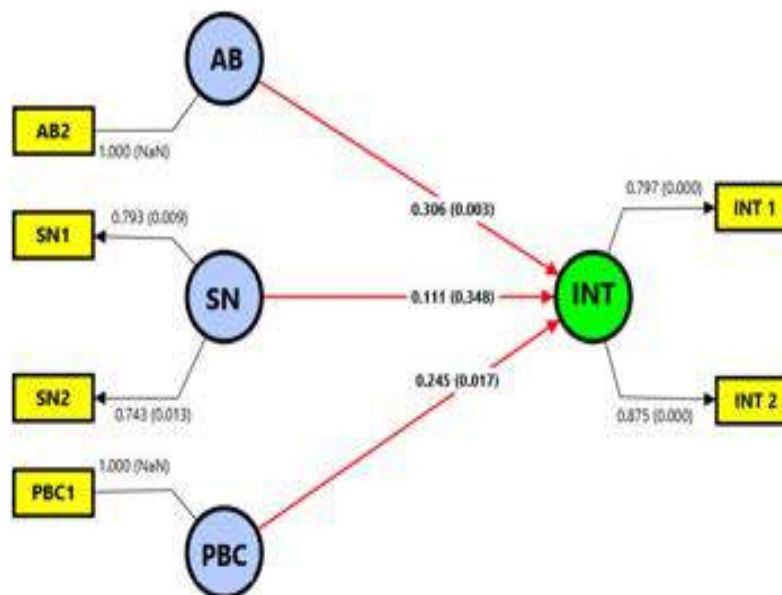


Figure 6.1: Path Analysis Findings of Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Orange-Riet Irrigation Scheme

Sources: Project team Compilations

The first hypothesis (H1), which proposed that attitudes significantly influence irrigators' intentions to implement water-saving technologies in the Orange-Riet Irrigation Scheme, was supported. The path coefficient for the relationship between Attitude (A_B) and Intention (INT) was positive and significant ($\beta = 0.306, p < 0.01$), indicating that a more favourable attitude towards water-saving technologies is associated with a higher intention to adopt these technologies among irrigators in the Orange-Riet irrigations scheme.

The second hypothesis (H2) stated that subjective norms significantly influence irrigators' intentions to adopt water-saving technologies in the Orange-Riet Irrigation Scheme. This hypothesis was also supported. The path coefficient for the relationship between Subjective Norms (SN) and Intention (INT) was significant ($\beta = 0.245, p < 0.05$), suggesting that social pressures or perceived expectations from others positively impact irrigators' intentions to adopt water-saving technologies.

The third hypothesis (H3), which proposed that perceived behavioural control significantly influences irrigators' intentions to adopt water-saving technologies in the Orange-Riet Irrigation Scheme, was rejected. The path coefficient for the relationship between Perceived Behavioural Control (PBC) and Intention (INT) was not significant ($\beta = 0.111, p = 0.354$). This indicates that the perceived ease or difficulty of adopting water-saving technologies does not significantly impact the intention to adopt these technologies among irrigators.

The R^2 value for the model was 0.225, indicating that approximately 22.5% of the variance in intentions to adopt water-saving technologies can be explained by the constructs in the model. While the obtained R^2 value may seem low, Ozili (2023) argues that a low R^2 is acceptable in social science research, as the primary goal is often to assess the significance of predictors, rather than to achieve high predictive accuracy. According to Ozili (2023), an R^2 of at least 0.1 is acceptable if most predictors are statistically significant, which is the case in our study. Thus, the important relationships found among the constructs support the model's validity, despite the modest R^2 value.

The F^2 statistic measures the change in the R^2 value when a specific Predictor construct is omitted from the model. In this study, the effect size for Attitudes (A_B) on Intentions (INT) is 0.105, indicating a small to medium effect, suggesting that attitudes have a meaningful influence on intentions to adopt water-saving technologies. Conversely, the effect size for Perceived Behavioural Control (PBC) is 0.072, reflecting a small effect, indicating a minor impact in this model. Subjective Norms (SN) showed a negligible effect size of 0.015, highlighting its limited influence on intentions. These findings underscore the varying degrees of influence that different factors exert on the intention to adopt water-saving technologies.

6.2.2.2 Augmented TPB Model for Adoption of Water-saving Technologies

Several measurement items were dropped to ensure the robustness of our measurement from the augmented model. For the construct of institutional and legal factors, items IL_1 and IL_8 were removed. The perceived risks and benefits construct saw the removal of RB_{10} , while for information factors, IF_7 was dropped. Lastly, in the access to resources construct, items AR_2 and AR_3 were excluded.

For the construct “Trust Factors” (TX) the composite reliability and Cronbach’s alpha were below the recommended threshold of 0.6. Various combinations of measurement items were dropped, and by removing TX_3 and TX_5 , the highest internal consistency was achieved. This adjustment resulted in acceptable levels of Cronbach’s alpha and composite reliability for the remaining items.

In the case of the “Perceived behavioural control” (PBC) construct, both the Cronbach’s alpha and the composite reliability exceeded 0.95, indicating redundancy. To address this, the VIF values of the inner model were inspected, revealing that the two measurement items had VIF values above 3. As a result, the measurement item PBC_2 was dropped to reduce multicollinearity and improve the model’s reliability.

The analysis of the construct “Technical Factors” (TF) showed that the Cronbach’s alpha and the composite reliability scores exceeded 0.9, indicating strong internal consistency. However, since high-reliability values can sometimes indicate redundancy, the VIF values for the two measurement items were inspected in the inner model. The analysis revealed VIF values above 3, signalling potential collinearity issues. As a result, the measurement item with the lowest factor loading, TF_2 , was dropped to improve the model’s performance.

The remaining constructs exhibited favourable levels of internal consistency reliability. This indicates that the measurement items for these constructs consistently capture the intended concepts, supporting the reliability and validity of the overall measurement model.

In terms of convergent validity, all constructs with multiple measurement items demonstrated Average Variance Extracted (AVE) values exceeding 0.5, which implies that the constructs are adequately capturing the intended variance, further supporting the validity of the measurement model.

The HTMT values exceeded the 0.90 threshold for several constructs, particularly between Attitudes (A_B) and Intentions (INT), Risk and Benefits (RB) and Intentions (INT), and Informational Factors (IF) and Intentions (INT). Given that the prior steps of the measurement model confirmed acceptable reliability and that VIF values for both the measurement and structural models were below 3, we decided to address the discriminant validity issues by removing items with the lowest loadings.

First, we dropped A_{B1} (measurement item one from Attitudes) and recalculated the HTMT values, which subsequently improved, with Attitudes and Intentions falling below the 0.90 threshold. Next, we focused on the **RB** construct. By removing the measurement item with the lowest loading (**RB2**), the HTMT value for **RB** with **INT** also dropped below 0.90, thus resolving the issue. For the **IF** construct, despite attempts to improve discriminant validity by removing specific measurement items, the HTMT values remained above 0.90 in relation to **INT**. Therefore, to maintain the overall model's validity, we decided to exclude the Informational Factors construct from the model. The results revealed that all VIF values were below the accepted threshold of 3, indicating that collinearity is not a concern in this model and allowing for the continued assessment of the structural relationships.

In contrast, the augmented TPB model incorporates additional constructs that function as extended constructs that mediate the relationships between the original TPB constructs (attitudes, subjective norms, and PBC) and intentions. As a result, the bootstrapping analysis for this model yields not only path coefficients, but also total indirect effects, specific indirect effects, and total effects. Total indirect effects measure the overall impact of one construct on another through one or more mediating variables. Specific indirect effects focus on the contribution of a single pathway from a predictor to an outcome through a specific mediator. Total effects combine both direct and indirect effects of one construct on another, whereas the path coefficients only reflect the direct effects between constructs. Appendix H, Table H.2, presents the results for the specific indirect effects of the augmented TPB model concerning the adoption of water-saving technology in the Orange-Riet Irrigation Scheme. The analysis reveals that none of the proposed specific indirect effects are statistically significant, as indicated by the p-values exceeding the conventional threshold of 0.05 for all hypotheses. These findings suggest that the additional constructs included in the augmented TPB model do not significantly mediate the relationships between the original TPB constructs and intentions within this specific context.

Appendix H, Table H.3, summarises the total indirect effects of various constructs on the intention to adopt water-saving technologies in the Orange-Riet Irrigation Scheme. It should be recalled that the total indirect effects show the overall impact of each predictor on the outcome (intention) through all mediators combined. The results indicate that none of the total indirect effects were statistically significant, as all hypotheses were rejected, based on the corresponding p-values exceeding the conventional threshold of 0.05.

Appendix H, Table H.4, illustrates the direct effects (path coefficients) of the augmented TPB model on the intentions to adopt water-saving technologies in the Orange-Riet Irrigation Scheme. The path coefficients represent the direct strength and direction of the relationships between the constructs in the model.

Among the various hypotheses tested, only five paths yielded statistically significant results. The path from Access to Resources (**AR**) to **PBC** shows a substantial adverse effect ($\beta = -0.160$, $p < 0.05$). Another significant relationship is observed from **RB** to Attitude (**A_B**) ($\beta = 0.288$, $p < 0.01$), indicating that perceptions of risk and benefit positively shape farmers' attitudes toward adopting water-saving technologies. The path from Risk and Benefits (**RB**) to Intention (**INT**) shows a strong positive effect ($\beta = 0.522$, $p < 0.01$), suggesting that the perceived risks and benefits significantly influence farmers' intentions to adopt water-saving technologies. The path from Technical Factors (**TF**) to **INT** also reflects a significant positive coefficient ($\beta = 0.538$, $p < 0.01$), indicating that technical factors strongly influence farmers' intentions. Furthermore, the relationship between **TF** and Perceived Behavioural Control (**PBC**) is significant ($\beta = 0.257$, $p < 0.01$), implying that technical factors positively impact farmers' perceived control over their ability to adopt these technologies. Appendix H, Table H.5, presents the total effects within the model. Total effects in a structural model represent the overall impact of an independent variable on a dependent variable, accounting for both direct and indirect paths.

In the extended TPB model, R^2 values are presented for attitudes (0.21), subjective norms (0.13), perceived behavioural control (0.24), and intentions (0.76). The f^2 Statistical values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. As a result, the Perceived Risks and Benefits (**RB**) construct shows a significant impact on Intention (**INT**) ($f^2 = 0.925$) and a negligible effect on Attitudes (**A_B**) ($f^2 = 0.095$). Similarly, Technical Factors (**TF**) have a significant effect on Intention ($f^2 = 0.976$) and a medium effect on Perceived Behavioural Control (**PBC**) ($f^2 = 0.075$). Access to Resources (**AR**) exhibits small effects on **PBC** ($f^2 = 0.032$) and Subjective Norms (**SN**) ($f^2 = 0.023$), while its effect on Attitudes is minimal ($f^2 = 0.009$). Additionally, Perceived Financial Costs (**PFC**) show small effects on **PBC** and **INT**. Overall, **RB** and **TF** demonstrate strong influences, particularly on **INT**, while other constructs show smaller impacts.

6.2.2.3 Standard TPB Model for Adoption of Water Saving Policies

For the TPB model, assessing irrigators' intentions to adopt water-saving technologies, the majority of factor loadings for the measurement items were above the minimum threshold of 0.4. However, two measurement items were below this threshold. SN_4 from the subjective norms construct, with a factor loading of 0.190, and INT_4 from the intentions construct, with a factor loading of 0.128. As a result, these two measurement items were dropped from the analysis.

Since the constructs of subjective norms and perceived behavioural control each have only one measurement item, the Cronbach's alpha and composite reliability could not be calculated for these

constructs⁴. However, for attitudes and perceived behavioural control, which each have two measurement items, the Cronbach's alpha and composite reliability values exceeded the minimum threshold of 0.6. The AVE values exceeded the minimum threshold of 0.5, with attitudes (*A_B*) with an AVE value of 0.61, and perceived behavioural control (*PBC*) with an AVE value of 0.636.

The Fornell-Larcker criterion analysis indicates a satisfactory level of discriminant validity among the constructs in the model. The values on the diagonal (0.781, 1.000, 0.798, 1.000) represent the square roots of the AVEs for constructs *A_B*, *INT*, *PBC*, and *SN*, respectively. The off-diagonal values represent the correlations between the constructs. The Fornell-Larcker Criterion indicates that all constructs exhibit discriminant validity, as the square root of the AVE for each construct is greater than the correlations with any other construct. Furthermore, the results of the HTMT ratio analysis indicate satisfactory discriminant validity among the constructs, indicating that all HTMT values are below the threshold of 0.9, and the low HTMT ratios confirm that the constructs are measuring different concepts and are not too highly correlated with each other.

Collinearity occurs when predictor variables are highly correlated, which can distort the estimated path coefficients and reduce the model's explanatory power. To address this, the Variance Inflation Factor (VIF) was calculated for each construct. A VIF value below 3 indicates that collinearity is not a concern, ensuring the stability and reliability of the model's estimates. The VIF values are 1.051 for Attitude to Intention, 1.053 for Subjective Norms to Intention, and 1.049 for Perceived Behavioural Control to Intention.

The next step in the analysis is to evaluate the hypothesised relationships between latent variables by examining the path coefficients (β) and their significance levels (p-values). The hypothesis testing results are shown in Figure 6.2 below and Appendix H, Table H.6.

The first hypothesis (H106), which proposed that attitudes significantly influence irrigators' intentions to implement water-saving polices in the Orange-Riet Irrigation Scheme, was supported. The path coefficient for the relationship between Attitude (*A_B*) and Intention (*INT*) was positive and significant ($\beta = 0.306$, $p < 0.01$), indicating that a more favourable attitude towards water-saving polices is associated with a higher intention to adopt these technologies among irrigators in the Orange-Riet Irrigation Scheme.

The second hypothesis (H107) stated that subjective norms significantly influence irrigators' intentions to adopt water-saving polices in the Orange-Riet Irrigation Scheme. This hypothesis was also supported. The path coefficient for the relationship between Subjective Norms (*SN*) and Intention (*INT*) was significant (β

⁴ Cronbach's alpha and composite reliability cannot be calculated for a single measurement item construct because these measures require multiple items to assess the internal consistency of a construct.

= 0.245, $p < 0.05$), suggesting that social pressures or perceived expectations from others positively impact irrigators' intentions to adopt water-saving technologies.

The third hypothesis (H108), which proposed that perceived behavioural control significantly influences irrigators' intentions to adopt water-saving policies in the Orange-Riet Irrigation Scheme, was rejected. The path coefficient for the relationship between Perceived Behavioural Control (*PBC*) and Intention (*INT*) was not significant ($\beta = 0.111$, $p = 0.354$). This indicates that the perceived ease or difficulty of adopting water-saving technologies does not significantly impact the intention to adopt these technologies among irrigators.

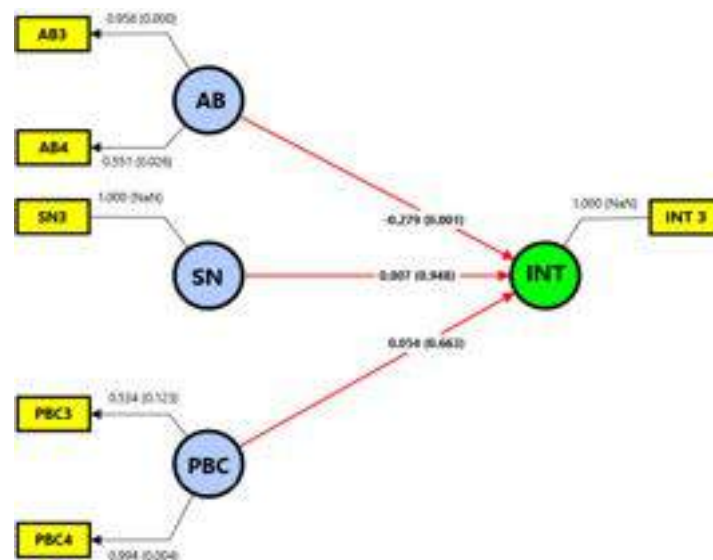


Figure 6.2: Path Analysis Findings of Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Orange-Riet Irrigation Scheme

Source: Project team compilation

The R^2 value for the model was 0.087, indicating that approximately 8.7% of the variance in the intentions to adopt water-saving technologies can be explained by the constructs in the model.

In this study, the effect size for Attitudes (*A_B*) on Intentions (*INT*) is 0.082, indicating a small effect, suggesting that attitudes have a meaningful, albeit modest, influence on intentions to adopt water-saving technologies. Conversely, the effect size for Perceived Behavioural Control (*PBC*) is 0.003, reflecting a negligible effect, indicating minimal impact in this model. Subjective Norms (*SN*) showed an effect size of 0.000, highlighting its limited influence on intentions.

Overall, these findings underscore that, while attitudes are a significant predictor, the model's low R^2 value indicates that there are likely additional factors influencing the intention to adopt water-saving technologies that are not captured in this study.

6.2.2.4 Augmented TPB Model for Adoption of Water Saving Policies

These measurement items included IL_8 from the Institutional and Legal Factors construct (**IL**), IF_7 from the Informational Factors construct (**IF**), and TX_3 and TX_5 from the Trust Factors construct (**TF**). We also eliminated AR_2 and AR_3 from the Access to Resources construct (**AR**), SN_4 from Subjective Norms (**SN**), INT_4 from Intentions (**INT**), and RB_{10} from Perceived Risks from Load Shedding and Tariffs (**RB₂**) using indicator reliability assessment as indicated above.

Given the exploratory nature of our study, we considered these slightly lower thresholds appropriate for evaluating internal consistency. All constructs demonstrated acceptable internal consistency reliability, except for **A_B**, **RB**, **TX**, and **PFC**, which had Cronbach's alpha values below 0.6. However, Cronbach's alpha is known to underestimate reliability, particularly when the number of items is small or when outer loadings vary. Composite reliability, which accounts for the outer loadings of individual indicators, offered a more accurate measure, with values for **A_B**, **RB**, **TX**, **IL**, and **PFC** all exceeded the 0.6 threshold, confirming an acceptable level of reliability.

All constructs demonstrated a measure, the extent to which a construct explains the variance of its indicators using Average Variance Extracted (AVE), of above 0.5, except for the construct Institutional and Legal Factors (**IL**), which showed an AVE of 0.498. Upon further inspection of **IL**'s measurement items, the item with the lowest loading (IL_7), was removed. After this adjustment, the AVE of **IL** improved to 0.681.

All constructs displayed favourable discriminant validity, with the square root of the AVE for each construct exceeding its correlations with other constructs. The HTMT values, with a threshold of 0.90, are applied to assess discriminant validity, as recommended by Hair and Alamer (2022). All HTMT values confirm that the constructs in this study demonstrate adequate discriminant validity.

The first step in assessing the structural model for intentions to adopt water-saving policies in the Orange-Riet Irrigation Scheme involved checking for collinearity issues by examining the VIF values. The results showed that all VIF values between the constructs in the extended model were below the threshold of 3, indicating that collinearity is not a concern.

The Path Analysis Results of the Extended Model on Irrigators' Intentions to Adopt Water-Saving Policies in the Orange-Riet Irrigation Scheme reveal the relationships between constructs. The extended model includes additional constructs that mediate the relationships between the original TPB constructs (attitudes, subjective norms, and PBC) and intentions. Consequently, the bootstrapping analysis yields not only path coefficients but also total indirect effects, specific indirect effects, and total effects. The specific indirect effects are presented in Table 6.8 below, the total direct effects in Table 6.9 below, the direct effects (path

coefficients) in Table 6.10 below, and the total effects (sum of direct and indirect effects) in Appendix H, Table H.7.

Appendix H, Table H.7 indicates that none of the hypothesised relationships achieved statistical significance, as all p-values exceeded the conventional significance level of 0.05. This suggests that the extended constructs do not significantly mediate the relationships between the original TPB constructs and the intentions of irrigators to adopt water-saving policies in the Orange-Riet Irrigation Scheme.

As presented in Appendix H, Table H.8, the analysis of total indirect effects in the augmented TPB model reveals that none of the hypothesised relationships achieved statistical significance. All p-values for the total indirect effects exceed the standard significance threshold of 0.05. The total indirect effects represent the combined influence of the mediating constructs on the intention to adopt water-saving policies. Consequently, the null hypotheses for all total indirect effects are retained, indicating that the assessed mediating effects do not significantly influence the relationship between the constructs and the intention to adopt water-saving policies in the Orange-Riet Irrigation Scheme.

As shown in Appendix H, Table H.9, the analysis of direct effects in the augmented TPB model identifies several significant relationships between the constructs and the intention to adopt water-saving policies in the Orange-Riet Irrigation Scheme. Among the various hypotheses tested, several paths yielded statistically significant results. The path from Access to Resources (**AR**) to intention (**INT**) shows a significant negative effect ($\beta = -0.077$, $p < 0.05$), suggesting that increased access to resources may have an adverse impact on the intention to adopt water-saving policies.

A strong negative relationship is observed from Information Factors (**IF**) to attitudes (**AB**) ($\beta = -0.357$, $p < 0.01$), indicating that negative perceptions of farmer influence significantly hinder attitudes toward adopting these policies. Additionally, the path from Institutional and Legal Factors (**IL**) to perceived behavioural control (**PBC**) is significant ($\beta = 0.379$, $p < 0.01$), implying that positive influences from institutional and legal frameworks enhance farmers' perceived control over their ability to adopt water-saving policies. The relationship between Perceived Financial Costs (**PFC**) and intention (**INT**) also reflects a substantial positive effect ($\beta = 0.712$, $p < 0.01$), suggesting that favourable perceptions of financial costs significantly increase the likelihood of adoption.

Furthermore, the path from Institutional and Legal Factors (**IL**) to subjective norms (**SN**) shows a notable positive coefficient ($\beta = 0.340$, $p < 0.01$), indicating that institutional influences significantly shape farmers' subjective norms regarding the adoption of water-saving policies. Lastly, the relationship between Perceived Risks and Benefits (**RB**) and subjective norms (**SN**) is significant ($\beta = -0.189$, $p < 0.05$),

suggesting that perceptions of risk and benefits negatively influence the subjective norms surrounding the adoption of these policies.

The analysis of total effects (Appendix H, Table H.10), which includes both direct and indirect effects, shows that the results are nearly identical to the path coefficients (Appendix H, Table H.9). This is expected because the specific and total indirect effects were statistically insignificant. Thus, the direct effects are the main contributors to the relationships in the model. This alignment between total effects and path coefficients highlights the importance of these direct relationships, suggesting that they are the key drivers in influencing water-saving policy adoption in the Orange-Riet Irrigation Scheme. At the same time, the indirect pathways appear less relevant.

In the context of the Orange-Riet Irrigation Scheme and the adoption of water-saving policies, the explanatory power of the extended TPB model is reflected in the R^2 values. It demonstrates strong predictive capabilities, particularly in relation to Intention (*INT*), which has an R^2 value of 0.915, indicating that approximately 91.5% of the variance in irrigators' intentions to adopt water-saving policies can be explained by the model.

For the other constructs, Attitude (*A_B*) has an R^2 value of 0.204, indicating a modest explanatory capacity, while Perceived Behavioural Control (*PBC*) and Subjective Norms (*SN*) exhibit R^2 values of 0.196 and 0.231, respectively. These values indicate that, while these constructs contribute to the overall model, their individual explanatory power is comparatively lower than that of the Intention construct. The adjusted R^2 values also reflect a similar trend, with *INT* maintaining a substantial adjusted value of 0.907, reinforcing the reliability of the model's predictive power.

The (f^2) of key constructs indicated that the Perceived Financial Costs (*PFC*) construct has a substantial impact on Intention (*INT*) ($f^2 = 5.561$), indicating that financial perceptions significantly influence farmers' intentions. Similarly, Perceived Risks and Benefits (*RB*) also shows a substantial effect on *INT* ($f^2 = 4.226$), highlighting its importance in shaping intentions.

Institutional and Legal Factors (*IL*) positively affect Perceived Behavioural Control (*PBC*) ($f^2 = 0.174$), suggesting their relevance in farmers' perceptions of adoption capability. Information Factors (*IF*) moderately influence Attitude (*A_B*) ($f^2 = 0.126$), indicating that available information can impact attitudes. Overall, the analysis emphasises the significant roles of financial, risk, and institutional factors in promoting the adoption of water-saving policies.

6.2.2.5 Standard TPB Model for the adaptation towards climate variability

The initial estimation of the path model of indicator reliability indicated that all measurement items for the constructs had factor loadings exceeding 0.7. With the factor loadings meeting the threshold, we proceeded to assess internal consistency reliability. All constructs met the minimum thresholds for internal consistency reliability, with Cronbach's Alpha values ranging from 0.637 to 0.897, and Composite Reliability values exceeding 0.8, for all constructs. This indicates that each construct exhibits acceptable internal consistency.

The AVE indicates that all constructs display AVE values above the recommended threshold, with values ranging from 0.726 to 0.907, confirming that the constructs demonstrate adequate convergent validity.

The Fornell-Larcker criterion, where all diagonal values (the square roots of AVE) are higher than the inter-construct correlations, confirms adequate discriminant validity. The HTMT ratio also indicated that all values fell below the 0.85 threshold, further confirming that each construct is sufficiently distinct from the others in the model.

The VIF values of the inner model were evaluated, with results showing that the VIF values are 1.237 for Attitudes to Intention, 1.231 for Subjective Norms to Intention, and 1.034 for Perceived Behavioural Control to Intention. Since all values are well below the recommended threshold of 3, we can conclude that multicollinearity is not a concern in this model, allowing for a reliable interpretation of the path coefficients in subsequent analyses. After confirming the absence of multicollinearity, the next step was to assess the significance and relevance of the structural relationships.

The hypothesised relationships between latent variables were examined by evaluating the path coefficients (β) and their significance levels (p -values). A bootstrapping procedure with 10,000 resamples was conducted, using the percentile method to determine confidence intervals at a 5% significance level. This approach examines the confidence intervals by evaluating the lower 2.5% and upper 97.5% percentiles of the distribution to establish a 95% confidence interval for the coefficients. All hypotheses were evaluated using path coefficients (β), and only those with p values ≤ 0.05 were considered significant. The hypothesis testing results are shown in Figure 6.3 below and Appendix H, Table H.11.

Attitudes were found to significantly influence irrigators' intentions to adapt to climate variability in the Orange-Riet Irrigation Scheme. The path coefficient for the relationship between Attitude (A_B) and Intention (INT) was positive and significant ($\beta = 0.303$, $p < 0.01$). This strong, positive, and considerable effect suggests that those farmers in the Orange-Riet Irrigation Scheme with more favourable attitudes towards climate variability adaptation are significantly more likely to intend to adopt adaptive practices.

Subjective norms were also found to significantly influence irrigators' intentions to adapt to climate variability in the Orange-Riet Irrigation Scheme. This hypothesis was also supported at a 10% significance level. The path coefficient for the relationship between Subjective Norms (*SN*) and Intention (*INT*) was significant ($\beta = 0.153, p < 0.1$). The positive and significant effect of Subjective norms implies that farmers who perceive social pressure or encouragement from their community, peers, or family members are somewhat more likely to intend to adopt climate adaptation practices. The relatively weaker significance implies that, while social influence plays a role, it may not be the dominant factor in driving intentions in this region.

Perceived behavioural control, however, did not significantly influence irrigators' intentions to adapt to climate variability in the Orange-Riet Irrigation Scheme. The path coefficient for the relationship between Perceived Behavioural Control (*PBC*) and Intention (*INT*) was not significant ($\beta = 0.096, p = 0.272$). This suggests that farmers' perceived ability to adopt adaptive practices does not significantly affect their intention to adapt.

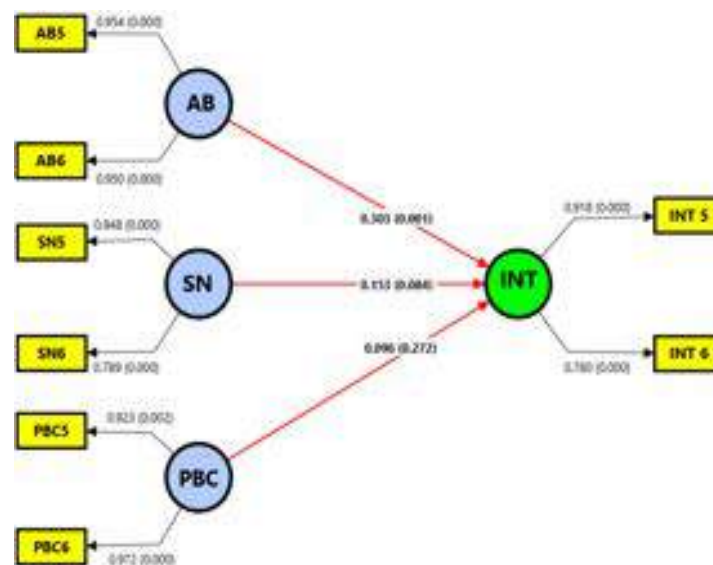


Figure 6.3: Path Analysis Findings of Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Orange-Riet Irrigation Scheme

Source: Project team compilation

The R^2 value for farmers' intention to adapt to climate variability was 0.178, suggesting that 17.8% of the variance in the intentions to adapt to climate variability is explained by the predictor variables in the model. While the obtained R^2 value may seem low, Ozili (2023) argues that a low R^2 is acceptable in social science research, as the primary goal is often to assess the significance of predictors, rather than to achieve high predictive accuracy. According to Ozili (2023), an R^2 of at least 0.1 is acceptable if most predictors are

statistically significant, which is the case in our study. Thus, the significant relationships found among the constructs support the model's validity, despite the modest R^2 value.

In this study, the effect size for Attitudes (A_B) on Intentions (INT) is 0.09, which falls between the thresholds for a small and medium effect size. This suggests that, while the effect of attitudes is not significant, it has a noticeable and meaningful influence on farmers' intention to adapt to climate variability. Conversely, the effect size for Perceived Behavioural Control (PBC) is 0.011, reflecting a negligible effect, indicating minimal impact in this model. Subjective Norms (SN) showed an effect size of 0.023, just above the threshold for a small effect size. This implies that subjective norms have a minimal but still detectable impact on the intention to adapt to climate variability.

6.2.2.6 Augmented TPB Model for the adaptation towards climate variability

Several measurement items with loadings below 0.4 were removed, including IL_6 and IL_8 (Institutional and Legal Factors), RB_{10} (Perceived Risks from Load Shedding and Tariffs), IF_7 (Informational Factors), TX_1 , TX_2 , TX_3 , and TX_4 (Trust Factors), as well as PFC_3 (Perceived Financial Cost), confirming the indicator of reliability at an acceptable level.

Given the exploratory nature of our study, we deemed these slightly lower thresholds to be appropriate for evaluating internal consistency (acceptable values for exploratory research range from 0.60 to 0.70, while satisfactory values for more advanced research fall between 0.70 and 0.90). Although certain constructs, specifically Access to Resources (AR) and Trust Factors (TF), had Cronbach's alpha values below 0.60, all constructs exhibited composite reliability scores exceeding 0.70. It is important to note that Cronbach's alpha can underestimate reliability, particularly when the number of items is small or when indicators have varying outer loadings on the construct. The composite reliability values, which account for the individual outer loadings of the indicators, offer a more accurate assessment of internal consistency—convergent Validity.

In the extended model for climate variability adaptation, all constructs had AVE values above 0.5, confirming that they demonstrate sufficient convergent validity. The Fornell-Larcker criterion was used to assess discriminant validity, as shown where each construct's square root of the AVE (diagonal values) exceeds its correlations with other constructs, confirming that each construct is distinct and measures a unique concept in the model. The HTMT ratio revealed that Informational Factors (IF) had a value higher than 0.9 with Intention (INT), prompting a closer examination of the measurement items. After removing the items with the lowest loadings and checking the VIF values, which showed no multicollinearity issues, we decided to drop the IF construct entirely.

Similarly, the Risk and Benefits (*RB*) construct exhibited an HTMT value above 0.9 with INT. Removing the lowest-loading item, *RB*₆, brought the HTMT value below the 0.9 threshold, ensuring acceptable discriminant validity. All remaining constructs demonstrated HTMT values below 0.9, confirming adequate discriminant validity for the rest of the model.

The results showed that all constructs had VIF values below the threshold of 3, indicating no collinearity issues within the structural model for climate variability adaptation in the Orange-Riet Irrigation Scheme.

In the standard TPB model, the focus is primarily on reporting direct relationships (path coefficients) between constructs, as the model is designed to evaluate the direct impact of attitudes, subjective norms, and perceived behavioural control on behavioural intentions. However, in the extended model for climate variability adaptation, additional constructs are included. This complexity introduces indirect relationships between variables, which might influence the outcomes through mediating constructs. Therefore, to capture the full scope of these interactions, we report not only the direct effects (Appendix H, Table H.12) but also the specific indirect effects (Appendix H, Table H.13), total indirect effects (Appendix H, Table H.14), and total effects (Appendix H, Table H.15).

Appendix H, Table H.12 presents these results for the specific indirect effects. In the extended model for climate variability adaptation in the Orange-Riet Irrigation Scheme, the results indicate that none of the specific indirect effects are significant. This finding suggests that the influence of certain constructs on behavioural outcomes occurs primarily through direct pathways, rather than through indirect routes.

The results presented in Appendix H, Table H.13, indicate that all total indirect effects in the extended model for climate variability adaptation in the Orange-Riet Irrigation Scheme are insignificant. This suggests that, similar to the specific indirect effects, the constructs in the model do not exert a meaningful influence on behavioural outcomes through indirect channels.

The analysis of the extended model for climate variability adaptation in the Orange-Riet Irrigation Scheme revealed several significant direct effects, shown in Appendix H, Table H.14. The effect of attitudes towards behaviour (*A_B*) on intentions (*INT*) was found to be significant, with a coefficient of 0.168 ($\beta = 0.168$, $p = 0.05$). Additionally, perceived financial costs (*PFC*) significantly influenced subjective norms (*SN*), showing a coefficient of 0.193 ($\beta = 0.193$, $p < 0.05$).

Moreover, perceived risks and benefits (*RB*) had a substantial impact on intentions (*INT*), with a coefficient of 0.581 ($\beta = 0.581$, $p < 0.001$). The relationship between perceived risks from load shedding and tariffs (*RB*₂) and attitudes (*A_B*) was also significant, yielding a coefficient of -0.178 ($\beta = -0.178$, $p < 0.05$). Trust factors (*TF*) positively influence attitudes (*A_B*), with a coefficient of 0.216 ($\beta = 0.216$, $p < 0.05$).

Furthermore, trust factors (*TF*) significantly affected intentions (*INT*) as well, showing a coefficient of 0.415 ($\beta = 0.415$, $p < 0.001$). These results highlight the key role of attitudes, perceived financial costs, and trust factors in the decision-making process regarding climate variability adaptation in this context.

The total effects, which represent the sum of direct and indirect effects, are presented in Appendix H, Table H.15. The analysis of total direct and total indirect effects in the extended model for climate variability adaptation in the Orange-Riet Irrigation Scheme revealed results consistent with the direct effects, as none of the specific or total indirect effects were found to be significant. This outcome is logical, indicating that the direct relationships exhibit greater explanatory power within this context.

For attitudes towards behaviours (*A_B*), the R^2 value was 0.149, with an adjusted R^2 of 0.100. The intention construct (*INT*) demonstrated a higher explanatory power, with an R^2 value of 0.732 and an adjusted R^2 of 0.710, suggesting that a significant proportion of the variance in intentions to adapt to climate variability is accounted for by the model. The perceived behavioural control (*PBC*) construct had an R^2 value of 0.096 (adjusted $R^2 = 0.044$), while subjective norms (*SN*) explained 0.123 of the variance (adjusted $R^2 = 0.073$).

According to the guidelines proposed by Cohen (1988), effect sizes can be classified as small (0.02), medium (0.15), and large (0.35). The effect Size (f^2) analysis reveals that Perceived Risks and Benefits (*RB*) and Trust Factors (*TF*) exert a considerable influence on irrigators' Intentions (*INT*) to adapt to climate variability.

6.2.3 AquaCrop Model Simulation

This section presents the simulation results obtained from the AquaCrop model for the commercial maize producers in the Orange-Riet Irrigation Scheme.

6.2.3.1 Net and Gross Irrigation Requirements for Commercial Maize in the Orange-Riet Irrigation Scheme

According to the AquaCrop Reference Manual Raes et al. (2023), the NIR is the amount of water needed to maintain soil moisture above a specified depletion threshold, preventing significant water stress. AquaCrop estimates the NIR based on crop water uptake and soil moisture balance, but does not account for conveyance losses or irrigation inefficiencies. In contrast, the GIR represents the total water applied to the field to meet the NIR, incorporating losses from evaporation, deep percolation, runoff, and inefficiencies in the irrigation system (Savva and Frenken, 2002). Table 6.2 below presents the net irrigation requirements for the dominant soil types within the main irrigation zone of the Orange-Riet Irrigation Scheme.

Table 6.2: Net Irrigation Requirement for Dominant Soil Types in the Main Irrigation Zone of the Orange-Riet Irrigation Scheme (2018–2023)

		Production year					
		2018/19	2019/20	2020/21	2021/22	2022/23	Average
Net Irrigation Requirement (mm)	Chromic Cambisols	249.8	123.1	108.0	256.4	233.7	194.2
	Petric Calcisols	233.4	122.4	112.8	259.5	233.8	192.4
	Eutric Cambisols	241.4	123.3	113.7	260.0	236.6	195.0
	Average	241.5	122.9	111.5	258.6	234.7	193.9

Source: Project team compilation

By utilising Equation 4.1 ($\frac{95 \times 73.67}{100} = 69.99$) and Equation 4.2 (adapted from Savva & Frenken, 2002), the efficiency and the gross irrigation requirement (GIR) were calculated, respectively. The net irrigation requirement (NIR) does not account for application efficiency or conveyance losses, hence it is assumed that most irrigation in the Orange-Riet Irrigation Scheme, the majority of irrigation, occurs under centre pivot sprinkler systems. However, since water in this scheme is transported via canals, additional losses occur as a result of seepage and conveyance inefficiencies. To account for these factors, the efficiency for the Orange-Riet Irrigation Scheme is adjusted to 73.67%, reflecting the combined losses in water transport and application.

The lined canals are assumed to have a conveyance efficiency of 95%, and the sprinkler systems an application efficiency of 73.67%. To ensure the irrigation planning accounts for a worst-case scenario, the NIR values from the year with the highest irrigation demand (NIR 2021/22 = 258.6 mm) were used to calculate the GIR. The year 2021/22 was selected based on the lowest recorded rainfall and highest crop water requirements across the three dominant soil types in the Orange-Riet Irrigation Scheme. This overall irrigation efficiency of 69.99% was then used in Equation 4.2 ($\frac{258.6}{69.99} = 369.50$) to calculate the gross irrigation requirement (GIR). The net and gross irrigation requirements for the production year 2021/22, which had the highest net irrigation requirement on average, were 258.6 mm and the corresponding gross irrigation requirement on average was 369.5 mm.

6.2.3.2 The adoption of water-saving technologies

6.2.3.2.1 No adoption scenario

For the no-adoption scenario, an irrigation schedule was established in AquaCrop to simulate irrigation events occurring every 10th day after planting (Planting date = 1st of December). Specifically, 13 irrigation events were scheduled throughout the maize growing cycle, with 28 mm applied per irrigation event. This approach results in a total of approximately 364 mm, closely aligning with the allocated 369.5 mm of irrigation water for the no-adoption scenario. Table 6.3 below provides a detailed overview of the irrigation schedule and its application within the simulations.

Table 6.3: Irrigation Schedule for No Adoption Scenario (2018–2023) for the adoption of water-saving technologies in the Orange-Riet Irrigation Scheme

Event	2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Day Number	Net application (mm)
1	10 December 2018	10 December 2019	10 December 2020	10 December 2021	10 December 2022	10	28
2	20 December 2018	20 December 2019	20 December 2020	20 December 2021	20 December 2022	20	28
3	30 December 2018	30 December 2019	30 December 2020	30 December 2021	30 December 2022	30	28
4	9 January 2019	9 January 2020	9 January 2021	9 January 2022	9 January 2023	40	28
5	19 January 2019	19 January 2020	19 January 2021	19 January 2022	19 January 2023	50	28
6	29 January 2019	29 January 2020	29 January 2021	29 January 2022	29 January 2023	60	28
7	8 February 2019	8 February 2020	8 February 2021	8 February 2022	8 February 2023	70	28
8	18 February 2019	18 February 2020	18 February 2021	18 February 2022	18 February 2023	80	28
9	28 February 2019	28 February 2020	28 February 2021	28 February 2022	28 February 2023	90	28
10	10 March 2019	9 March 2020	10 March 2021	10 March 2022	10 March 2023	100	28
11	20 March 2019	19 March 2020	20 March 2021	20 March 2022	20 March 2023	110	28
12	30 March 2019	29 March 2020	30 March 2021	30 March 2022	30 March 2023	120	28
13	9 April 2019	8 April 2020	9 April 2021	9 April 2022	9 April 2023	130	28

Source: Project team compilation

For the no-adoption scenario, the simulation was done for all three soil types occurring in the main irrigation zone, as shown in Table 6.4 below. A weighted average was then calculated for each metric across the three soil types, based on the percentage area that each dominant soil type covers in the main irrigation zone. In the last column of Table 6.4, an average was calculated for every metric for each soil type, as well as for the weighted average metrics across the three soil types. The average of the weighted averages for each

metric, calculated across the years, serves as a fair representative value for the no-adoption scenario simulation results. The weighted averages are used in the Social Accounting Matrix through multiplier analysis.

Table 6.4: AquaCrop model Simulation Results for the No-Adoption Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		No Adoption Scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chronic Cambisols	Biomass (ton/ha)	29.727	30.527	30.581	30.415	30.496	30.3492
	Yield (ton/ha)	14.109	14.673	14.680	14.650	14.651	14.5526
	Irrigation (mm)	364	364	364	364	364	364
	WP_{ET} (Kg/m ³)	2.42	2.81	3.01	2.72	2.65	2.722
Petric Calcisols	Biomass (ton/ha)	29.232	30.514	30.577	30.408	30.493	30.2448
	Yield (ton/ha)	14.075	14.669	14.678	14.649	13.650	14.3442
	Irrigation (mm)	364	364	364	364	364	364
	WP_{ET} (Kg/m ³)	2.42	2.81	3.01	2.72	2.65	2.722
Eutric Cambisols	Biomass (ton/ha)	29.048	30.473	30.571	30.388	30.478	30.1916
	Yield (ton/ha)	13.993	14.650	14.675	14.644	14.643	14.521
	Irrigation (mm)	364	364	364	364	364	364
	WP_{ET} (Kg/m ³)	2.40	2.78	2.99	2.70	2.64	2.702
Weighted Average	Biomass (ton/ha)	29.475	30.512	30.578	30.407	30.491	30.29258
	Yield (ton/ha)	14.075	14.667	14.678	14.648	14.469	14.5075
	Irrigation (mm)	364	364	364	364	364	364
	WP_{ET} (Kg/m ³)	2.42	2.80	3.01	2.72	2.65	2.7172

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chronic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.2.2 Partial adoption scenario

Recall that the irrigation schedule for the partial adoption scenario is based on soil moisture conditions, where an irrigation event is triggered when 70% of the Readily Available Water (RAW) has been depleted. Table 6.5 below presents the simulation results for this scenario across the five marketing years for each soil type. A weighted average for each metric calculated in the AquaCrop model was determined, taking into account the area covered by each dominant soil type in the main irrigation zone. The average values of these weighted metrics, particularly yield, are of significant importance. This yield will be compared with the yield from the no adoption scenario, and the percentage change will be simulated in the Social Accounting Matrix through multiplier analysis.

Table 6.5: AquaCrop Simulation Results for the Partial Adoption Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		Partial adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	29.986	29.934	30.547	30.209	30.178	30.1708
	Yield (ton/ha)	14.410	14.368	14.675	14.501	14.497	14.4902
	Irrigation (mm)	301.3	199.0	236.3	302.5	344.8	276.78
	WP_{ET} (Kg/m ³)	2.48	2.94	3.06	2.83	2.79	2.82
Petric Calcisols	Biomass (ton/ha)	29.866	29.941	30.550	30.201	30.202	30.152
	Yield (ton/ha)	14.336	14.372	14.678	14.499	14.511	14.4792
	Irrigation (mm)	334.7	199.7	222.4	287.1	341.1	277
	WP_{ET} (Kg/m ³)	2.50	2.94	3.11	2.83	2.78	2.832
Eutric Cambisols	Biomass (ton/ha)	29.882	29.837	30.541	30.216	30.142	30.1236
	Yield (ton/ha)	14.359	14.322	14.673	14.512	14.468	14.4668
	Irrigation (mm)	197.4	194.8	231.2	280.2	303.5	241.42
	WP_{ET} (Kg/m ³)	2.46	2.91	3.04	2.82	2.74	2.794
Weighted Average	Biomass (ton/ha)	29.93944	29.91198	30.5461	30.20924	30.17368	30.15609
	Yield (ton/ha)	14.38444	14.35768	14.67506	14.50328	14.49256	14.4826
	Irrigation (mm)	282.376	198.118	232.574	294.376	334.222	268.3332
	WP_{ET} (Kg/m ³)	2.4788	2.9328	3.0642	2.8276	2.7762	2.81592

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.2.3 Full adoption scenario

In the full adoption scenario, drip irrigation is implemented, and irrigation events are triggered when 70% of the Readily Available Water (RAW) in the soil has been depleted. Table 6.6 below presents the AquaCrop model simulation results for this scenario across the five marketing years for each of the dominant soil types in the main irrigation zone. As with the previous scenarios (Tables 6.4 and 6.5 above), a weighted average for each metric was calculated, accounting for the area covered by each dominant soil type in the main irrigation zone. The average values of these weighted metrics, with particular emphasis on yield, are critical in understanding the outcomes of the full adoption scenario. This yield will be compared with the yield of the no-adoption scenario, and the percentage change in yield will be incorporated into the Social Accounting Matrix through a multiplier analysis.

Table 6.6: AquaCrop Simulation Results for the Full Adoption Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		Full Adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	30.026	29.934	30.550	30.209	30.315	30.2068
	Yield (ton/ha)	14.416	14.368	14.676	14.501	14.560	14.5042
	Irrigation (mm)	296.6	199.0	236.3	302.0	351.0	276.98
	WP_{ET} (Kg/m ³)	2.65	2.94	3.15	2.83	2.84	2.882
Petric Calcisols	Biomass (ton/ha)	30.027	29.941	30.555	30.203	30.320	30.2092
	Yield (ton/ha)	14.416	14.372	14.681	14.500	14.565	14.5068
	Irrigation (mm)	298.7	199.7	222.3	286.6	339.6	269.38
	WP_{ET} (Kg/m ³)	2.65	2.94	3.16	2.83	2.84	2.884
Eutric Cambisols	Biomass (ton/ha)	29.941	29.836	30.547	30.220	30.233	30.1554
	Yield (ton/ha)	14.375	14.321	14.676	14.514	14.523	14.4818
	Irrigation (mm)	300.3	198.7	231.2	278.2	341.8	270.04
	WP_{ET} (Kg/m ³)	2.64	2.92	3.14	2.83	2.82	2.87
Weighted Average	Biomass (ton/ha)	30.006	29.912	30.550	30.211	30.296	30.1949
	Yield (ton/ha)	14.406	14.357	14.677	14.504	14.552	14.49929
	Irrigation (mm)	297.87	199.05	232.56	293.52	346.74	273.9464
	WP_{ET} (Kg/m ³)	2.65	2.94	3.15	2.83	2.84	2.87948

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.2.4 Summary of AquaCrop Simulation Results for the Adoption of Water-saving Technologies

Table 6.7 below summarises the representative weighted average metrics for the adoption scenarios in the main irrigation zone. While there is a slight decrease in yield for both the partial adoption (-0.17%) and full adoption (-0.05%) scenarios compared with the no-adoption baseline, both adoption scenarios show improvements in water productivity. Additionally, less water was used for irrigation, indicating that, despite the small yield reductions, the adoption of water-saving technologies enhances water productivity, making them a viable strategy for achieving more sustainable irrigation in the Orange-Riet Irrigation Scheme.

Table 6.7: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	30.29258	14.5075	364	2.7172	Baseline (0%)
	Partial adoption	30.15609	14.4826	268.3332	2.81592	-0.17%
	Full Adoption	30.1949	14.49929	273.9464	2.87948	-0.05%

Source: Project team compilation

The slight changes in yield observed for the partial adoption (-0.17%) and full adoption (-0.05%) scenarios will be simulated in the SAM to illustrate the socio-economic implications of these yield changes. These variations in yield will provide valuable insights into how different adoption scenarios might affect the broader socio-economic outcomes.

6.2.3.3 The adoption of water-saving policies

6.2.3.3.1 No adoption scenario

For the non-adoption scenario of water-saving policies, it is assumed that no water restrictions are in place. This means that the full gross irrigation requirement (369 mm) is applied in equal amounts at evenly spaced intervals throughout the growing season. Since this setup is identical to the no adoption scenario for water-saving technologies (the previous water use behaviour), the irrigation schedule and resulting outputs will be the same. Therefore, it will not be simulated again. The non-adoption scenarios for water-saving policies and water-saving technologies are functionally equivalent. As a result, only the partial and full adoption scenarios for water saving policies will be simulated and analysed.

6.2.3.3.2 Partial adoption scenario

For the partial adoption scenario of water-saving policies, it is assumed that a 30% water restriction is imposed. This means that only 258 mm of water is available for irrigation, which is 30% less than the full gross irrigation requirement of 369 mm. When divided over 13 intervals, this results in approximately 19.8 mm per interval. Since the AquaCrop's model irrigation schedule only accepts whole numbers, the amount was rounded down to 19 mm per interval to ensure the total irrigation does not exceed 258 mm. This water is applied in equal amounts at evenly spaced intervals throughout the maize growing season. Table 6.8 below presents the irrigation schedule for the partial adoption of water-saving policies in the Orange-Riet Irrigation Scheme.

Table 6.8: Irrigation Schedule for No Adoption Scenario (2018–2023) for the adoption of water-saving polices in the Orange-Riet Irrigation Scheme

Event	2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Day Number	Net application (mm)
1	10 December 2018	10 December 2019	10 December 2020	10 December 2021	10 December 2022	10	19
2	20 December 2018	20 December 2019	20 December 2020	20 December 2021	20 December 2022	20	19
3	30 December 2018	30 December 2019	30 December 2020	30 December 2021	30 December 2022	30	19
4	9 January 2019	9 January 2020	9 January 2021	9 January 2022	9 January 2023	40	19
5	19 January 2019	19 January 2020	19 January 2021	19 January 2022	19 January 2023	50	19
6	29 January 2019	29 January 2020	29 January 2021	29 January 2022	29 January 2023	60	19
7	8 February 2019	8 February 2020	8 February 2021	8 February 2022	8 February 2023	70	19
8	18 February 2019	18 February 2020	18 February 2021	18 February 2022	18 February 2023	80	19
9	28 February 2019	28 February 2020	28 February 2021	28 February 2022	28 February 2023	90	19
10	10 March 2019	9 March 2020	10 March 2021	10 March 2022	10 March 2023	100	19
11	20 March 2019	19 March 2020	20 March 2021	20 March 2022	20 March 2023	110	19
12	30 March 2019	29 March 2020	30 March 2021	30 March 2022	30 March 2023	120	19
13	9 April 2019	8 April 2020	9 April 2021	9 April 2022	9 April 2023	130	19

Source: Project team compilation

Table 6.9 below presents the results for the partial adoption of water-saving policies in the Orange-Riet Irrigation Scheme for each dominant soil type. It also includes a weighted average obtained by considering the area covered by each soil type.

Table 6.9: AquaCrop Simulation Results for the partial adoption of water-saving policies Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		Partial Adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	27.229	30.444	30.575	29.115	30.245	29.5216
	Yield (ton/ha)	13.129	14.663	14.677	14.091	14.557	14.2234
	Irrigation (mm)	247	247	247	247	247	247
	WP_{ET} (Kg/m ³)	2.40	2.83	3.00	2.73	2.67	2.726
Petric Calcisols	Biomass (ton/ha)	27.350	30.387	30.570	28.179	30.158	29.3288
	Yield (ton/ha)	13.185	14.637	14.676	13.634	14.516	14.1296
	Irrigation (mm)	247	247	247	247	247	247
	WP_{ET} (Kg/m ³)	2.41	2.83	3.01	2.69	2.67	2.722
Eutric Cambisols	Biomass (ton/ha)	26.934	30.341	30.558	27.973	30.070	29.1752
	Yield (ton/ha)	12.987	14.615	14.670	13.537	14.474	14.0566
	Irrigation (mm)	247	247	247	247	247	247
	WP_{ET} (Kg/m ³)	2.38	2.81	2.99	2.66	2.65	2.698
Weighted Average	Biomass (ton/ha)	27.17998	30.40902	30.57002	28.67244	30.18734	29.40376
	Yield (ton/ha)	13.105	14.6468	14.67514	13.87578	14.5297	14.166484
	Irrigation (mm)	247	247	247	247	247	247
	WP_{ET} (Kg/m ³)	2.397	2.8252	2.9994	2.706	2.6652	2.71856

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.3.3 Full adoption scenario

In the full adoption scenario of water-saving policies, it is assumed that a strict water restriction of 70% is enforced. This means that only 110 mm of the total gross irrigation requirement of 369.5 mm is available for irrigation. To accommodate this limitation, the 110 mm is divided into equal intervals and applied evenly throughout the maize growing season. Specifically, 8 mm of irrigation is used during each of the 13 intervals, which are spaced ten days apart. Table 6.10 below presents the irrigation schedule implemented under this scenario for the full adoption of water-saving policies in the Orange-Riet Irrigation Scheme.

Table 6.10: Irrigation Schedule for No Adoption Scenario (2018–2023) for the adoption of water-saving technologies in the Orange-Riet Irrigation Scheme

Event	2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Day Number	Net application (mm)
1	10 December 2018	10 December 2019	10 December 2020	10 December 2021	10 December 2022	10	8
2	20 December 2018	20 December 2019	20 December 2020	20 December 2021	20 December 2022	20	8
3	30 December 2018	30 December 2019	30 December 2020	30 December 2021	30 December 2022	30	8
4	9 January 2019	9 January 2020	9 January 2021	9 January 2022	9 January 2023	40	8
5	19 January 2019	19 January 2020	19 January 2021	19 January 2022	19 January 2023	50	8
6	29 January 2019	29 January 2020	29 January 2021	29 January 2022	29 January 2023	60	8
7	8 February 2019	8 February 2020	8 February 2021	8 February 2022	8 February 2023	70	8
8	18 February 2019	18 February 2020	18 February 2021	18 February 2022	18 February 2023	80	8
9	28 February 2019	28 February 2020	28 February 2021	28 February 2022	28 February 2023	90	8
10	10 March 2019	9 March 2020	10 March 2021	10 March 2022	10 March 2023	100	8
11	20 March 2019	19 March 2020	20 March 2021	20 March 2022	20 March 2023	110	8
12	30 March 2019	29 March 2020	30 March 2021	30 March 2022	30 March 2023	120	8
13	9 April 2019	8 April 2020	9 April 2021	9 April 2022	9 April 2023	130	8

Source: Project team compilation

Table 6.11 below presents the AquaCrop model simulation results for the full adoption scenario of water saving policies for each dominant soil type occurring in the main irrigation zone of the Orange-Riet Irrigation Scheme. It also includes the weighted average based on the area covered by each dominant soil type within the main irrigation zone.

Table 6.11: AquaCrop model Simulation Results for the full adoption of water-saving policies Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

		Full Adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	21.428	26.738	30.526	21.525	23.422	24.7278
	Yield (ton/ha)	10.314	12.891	14.658	10.388	11.21	11.8922
	Irrigation (mm)	104	104	104	104	104	104
	WP_{ET} (Kg/m ³)	2.2	2.73	3.01	2.47	2.47	2.576
Petric Calcisols	Biomass (ton/ha)	21.673	26.549	30.506	21.078	22.829	24.527
	Yield (ton/ha)	10.435	12.8	14.649	10.153	10.916	11.7906
	Irrigation (mm)	104	104	104	104	104	104
	WP_{ET} (Kg/m ³)	2.22	2.72	3.01	3.45	2.45	2.77
Eutric Cambisols	Biomass (ton/ha)	20.95	25.58	30.503	20.974	22.46	24.0934
	Yield (ton/ha)	10.085	12.332	14.648	10.114	10.745	11.5848
	Irrigation (mm)	104	104	104	104	104	104
	WP_{ET} (Kg/m ³)	2.15	2.65	3	2.43	2.39	2.524
Weighted Average	Biomass (ton/ha)	21.35738	26.42606	30.51688	21.3123	23.08438	24.5394
	Yield (ton/ha)	10.28082	12.74046	14.65398	10.27994	11.04548	11.800136
	Irrigation (mm)	104	104	104	104	104	104
	WP_{ET} (Kg/m ³)	2.1916	2.709	3.0076	2.6368	2.4472	2.59844

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water Saving Policies

Table 6.12 below presents the weighted average AquaCrop model simulation results for each scenario under the adoption of water saving policies, taking into account the variation in dominant soil types within the main irrigation zone of the Orange-Riet Irrigation Scheme. The percentage change in yield relative to the no adoption scenario will be used as a yield shock in the Social Accounting Matrix through a multiplier analysis.

Table 6.12: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	30.29	14.51	364.00	2.72	Baseline (0%)
	Partial adoption	29.40	14.17	247.00	2.72	-2.35%
	Full Adoption	24.54	11.80	104.00	2.60	-18.66%

Source: Project team compilation

6.2.3.4 The adaptation towards climate variability

6.2.3.4.1 No adaptation scenario

In the no-adaption scenario, it is assumed that the full gross irrigation requirement, as calculated earlier in the report, is allocated and irrigated evenly throughout the growing season. No water-saving practices, such as mulching, are implemented, and only moderate weed management is applied to reduce crop competition. Irrigation is applied at regular intervals based on the gross irrigation requirement (369.5 mm), with events spaced ten days apart. The total gross irrigation requirement is divided equally across these intervals, resulting in 28 mm per irrigation event. Since the no-adaptation-to-climate-variability scenario follows the same irrigation schedule and assumptions as the no-adoption scenario for water-saving technologies does, the irrigation schedule is not reproduced here.

6.2.3.4.2 Partial adaptation scenario

In the partial adoption scenario, a combination of moderate water-saving practices and deficit irrigation is applied to adapt to climate variability. Mulching is implemented at a moderate level to regulate soil temperature and retain soil moisture, as modelled in the AquaCrop model. Moderate weed management is also applied to reduce crop competition and enhance water use efficiency.

Under this scenario, deficit irrigation is applied at 20 % below the full gross irrigation requirement. This equates to 295 mm of irrigation water available for the season, based on a 20 % reduction from the full gross requirement of 369.5 mm. When distributed across 13 intervals, this results in approximately 22.69 mm per interval. To ensure the total does not exceed the available 295 mm, the irrigation depth was rounded down to 22 mm per interval. Irrigation events are spaced evenly throughout the maize growing season. Table 6.13 below provides an overview of the irrigation schedule for the partial adaptation toward the climate variability scenario.

Table 6.13: Irrigation Schedule for No Adoption Scenario (2018–2023) for the adaptation towards climate variability in the Orange-Riet Irrigation Scheme

Event	2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Day Number	Net application (mm)
1	10 December 2018	10 December 2019	10 December 2020	10 December 2021	10 December 2022	10	22
2	20 December 2018	20 December 2019	20 December 2020	20 December 2021	20 December 2022	20	22
3	30 December 2018	30 December 2019	30 December 2020	30 December 2021	30 December 2022	30	22
4	9 January 2019	9 January 2020	9 January 2021	9 January 2022	9 January 2023	40	22
5	19 January 2019	19 January 2020	19 January 2021	19 January 2022	19 January 2023	50	22
6	29 January 2019	29 January 2020	29 January 2021	29 January 2022	29 January 2023	60	22
7	8 February 2019	8 February 2020	8 February 2021	8 February 2022	8 February 2023	70	22
8	18 February 2019	18 February 2020	18 February 2021	18 February 2022	18 February 2023	80	22
9	28 February 2019	28 February 2020	28 February 2021	28 February 2022	28 February 2023	90	22
10	10 March 2019	9 March 2020	10 March 2021	10 March 2022	10 March 2023	100	22
11	20 March 2019	19 March 2020	20 March 2021	20 March 2022	20 March 2023	110	22
12	30 March 2019	29 March 2020	30 March 2021	30 March 2022	30 March 2023	120	22
13	9 April 2019	8 April 2020	9 April 2021	9 April 2022	9 April 2023	130	22

Source: Project team compilation

Table 6.14 below provides an overview of the results simulated in the AquaCrop model for the partial adaptation to the climate variability scenario.

Table 6.14: AquaCrop model Simulation Results for the partial adaptation towards climate variability Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		Partial adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	21.864	23.434	23.482	23.078	23.410	23.05
	Yield (ton/ha)	10.543	11.275	11.272	11.160	11.256	11.10
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	1.89	2.20	2.36	2.14	2.08	2.13
Petric Calcisols	Biomass (ton/ha)	21.856	23.426	23.479	22.937	23.410	23.02
	Yield (ton/ha)	10.533	11.275	11.271	11.097	11.256	11.09
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	1.89	2.20	2.36	2.14	2.08	2.13
Eutric Cambisols	Biomass (ton/ha)	21.676	23.396	23.476	22.932	23.385	22.97
	Yield (ton/ha)	10.450	11.260	11.269	11.096	11.247	11.06
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	1.88	2.18	2.35	2.13	2.06	2.12
Weighted Average	Biomass (ton/ha)	21.82	23.42	23.48	23.02	23.40	23.03
	Yield (ton/ha)	10.52	11.27	11.27	11.13	11.25	11.09
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	1.89	2.20	2.36	2.14	2.08	2.13

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.4.3 Full adaptation scenario

In the full adaptation scenario, mulching is implemented at a significant level to maximise soil moisture retention and minimise evaporation, as optimised in the AquaCrop model. Weed management is applied at the highest possible level to prevent crop competition and enhance resilience to climate variability. Additionally, a 30% deficit irrigation strategy is followed, meaning that, from the full gross irrigation requirement of 634.5 mm, only 444 mm is available for irrigation throughout the growing season. However, water is strategically applied during the crop's critical growth stages to optimise water use, while maintaining acceptable yields. Table 6.15 below provides an overview of the irrigation events and the amounts of water applied, highlighting the increased volumes during the most sensitive stages of crop development.

Table 6.15: Irrigation Schedule for full Adoption Scenario (2018–2023) for the adaptation towards climate variability in the Orange-Riet Irrigation Scheme

Event	2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Day Number	Net application (mm)
1	10 December 2018	10 December 2019	10 December 2020	10 December 2021	10 December 2022	10	6
2	20 December 2018	20 December 2019	20 December 2020	20 December 2021	20 December 2022	20	8
3	30 December 2018	30 December 2019	30 December 2020	30 December 2021	30 December 2022	30	10
4	9 January 2019	9 January 2020	9 January 2021	9 January 2022	9 January 2023	40	30
5	19 January 2019	19 January 2020	19 January 2021	19 January 2022	19 January 2023	50	30
6	29 January 2019	29 January 2020	29 January 2021	29 January 2022	29 January 2023	60	30
7	8 February 2019	8 February 2020	8 February 2021	8 February 2022	8 February 2023	70	40
8	18 February 2019	18 February 2020	18 February 2021	18 February 2022	18 February 2023	80	40
9	28 February 2019	28 February 2020	28 February 2021	28 February 2022	28 February 2023	90	30
10	10 March 2019	9 March 2020	10 March 2021	10 March 2022	10 March 2023	100	10
11	20 March 2019	19 March 2020	20 March 2021	20 March 2022	20 March 2023	110	8
12	30 March 2019	29 March 2020	30 March 2021	30 March 2022	30 March 2023	120	8
13	9 April 2019	8 April 2020	9 April 2021	9 April 2022	9 April 2023	130	8

Source: Project team compilation

Table 6.16 below presents the simulation results for the full adaptation to the climate variability scenario for maize production in the Orange-Riet Irrigation Scheme. Simulations were conducted for each dominant soil unit occurring within the main irrigation zone. A weighted average for each metric was then calculated based on the proportion of the area that each dominant soil unit occupies within this zone. This approach ensures that the results accurately reflect the variability in soil characteristics across the irrigated landscape.

Table 6.16: AquaCrop model Simulation Results for the Full adaptation towards climate variability Scenario for the Dominant Soil Types of the Main Irrigation Zone of the Orange-Riet Irrigation Scheme

Soil type		Full adoption scenario					
		2018/19 marketing year	2019/20 marketing year	2020/21 marketing year	2021/22 marketing year	2022/23 marketing year	Average
Chromic Cambisols	Biomass (ton/ha)	27.974	30.352	30.553	30.276	30.304	29.89
	Yield (ton/ha)	13.481	14.586	14.666	14.585	14.564	14.38
	Irrigation (mm)	258	258	258	258	258	258.00
	WP_{ET} (Kg/m ³)	2.56	2.95	3.15	2.88	2.82	2.87
Petric Calcisols	Biomass (ton/ha)	27.940	30.352	30.548	30.273	30.300	29.88
	Yield (ton/ha)	13.449	14.588	14.664	14.587	14.561	14.37
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	2.56	2.96	3.15	2.89	2.82	2.88
Eutric Cambisols	Biomass (ton/ha)	27.641	30.290	30.546	30.220	30.127	29.76
	Yield (ton/ha)	13.313	14.559	1.663	14.566	14.480	11.72
	Irrigation (mm)	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	2.54	2.94	3.13	2.87	2.79	2.85
Weighted Average	Biomass (ton/ha)	27.89	30.34	30.55	30.26	30.26	29.86
	Yield (ton/ha)	13.43	14.58	11.54	14.58	14.54	13.74
	Irrigation (mm)	286.00	286.00	286.00	286.00	286.00	286.00
	WP_{ET} (Kg/m ³)	2.56	2.95	3.15	2.88	2.81	2.87

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Chromic Cambisols contributing 58%, Petric Calcisols 18%, and Eutric Cambisols 24%.

Source: Project team compilation

6.2.3.4.4 Summary of AquaCrop Model Simulation Results for the adaptation towards climate variability

Table 6.17 below provides a summary of the AquaCrop model simulations for commercial maize production in the Orange-Riet Irrigation Scheme. The table indicates the weighted average results obtained from each adaptation scenario, considering the dominant soil types in the main irrigation zone. The percentage change in yield compared with the no adoption scenario, which serves as the baseline, will be used as a yield shock input in the Social Accounting Matrix through multiplier analysis.

Table 6.17: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	23.20	11.16	364.00	2.06	Baseline (0%)
	Partial adoption	23.03	11.09	286.00	2.13	-0.63%
	Full Adoption	29.86	13.74	258.00	2.87	23.08%

Source: Project team compilation

6.2.4 Multiplier Analysis

This section presents the Social Accounting Matrix results for the Orange-Riet Irrigation Scheme, focusing on commercial maize producers. The analysis highlights how different levels of adoption influence regional and national economic indicators by capturing the ripple effects throughout the economy. Table 6.18 below presents an overview of the Multiplier Analysis results across each water use behaviour.

Table 6.18: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Orange-Riet Irrigation Scheme

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (-0.17%)	Full (-0.05%)	Partial (-2.35%)	Full (-18.66%)	Partial (-0.63%)	Full (23.08%)
Maize Free State	27.1	14.06	37.4	29.53	9.98	38.97
Total labour remuneration in SA	22.38	41.46	30.92	23.46	8.36	92.56
Free State province generates labour return	5.37	6.19	6.93	2.53	1.02	47.82
Gross operating surplus SA	10.51	3.52	13.54	4.83	1.82	26.98
Household income for the Free State	65.56	32.75	86.4	69.38	25.18	93.76
Land return in SA	14.46	6.03	18.42	6.83	2.74	17.59
land returned to irrigation in the Free State	R111,770.89	R51, 319.08	R143,255.9	R51,787.3	R23,248.08	R129,431.8
Institution income SA (enterprise + Household)	109.78	28.18	129,56	31.58	11.73	147.86
Household generating income SA	103.32	26.58	113,58	29.21	10.79	146.92
Value-added generating income SA (Labour + capital + land)	218.87	99.48	216,23	112.63	43.58	757.39

Source: Project team compilation

6.2.4.1 Adoption of water-saving technologies

6.2.4.1.1 Partial adoption

As indicated in Table 6.18, the effect of the Soil Moisture Sensor on the adaptation of water saving technology resulted in R27.10 million maize output in the Orange-Riet irrigation Scheme, Free State province. The total labour remuneration was estimated at R22.38 million in the economy of South Africa,

of which the Free State province generates a labour return of about R5.37 million and gross operating surplus (capital) of R10.51 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R65.56 million for the economy of the Free State province. The overall land return was estimated at R14.46 million in the economy of South Africa, of which the return to irrigation in the Free State was only R111 770.89. The highest return on irrigation in the province of the Free State was found in the Fezile Dabi irrigation district, followed by Lejweleputswa irrigation and Xhariep irrigation districts in the economy of Free State province.

Institutional incomes (enterprise and households) were estimated at R109.78 million in the economy. The households and value added (labour, capital, and land) generate incomes of only R103.32 and R218.87 million, respectively, in the economy of South Africa. The findings of this study concurred with those of Anjaly et al. (2024), which indicated that implementing water-saving technology interventions, such as soil moisture techniques like eco-friendly straw mulching, contribute to better soil health and sustainable yield.

6.2.4.1.2 Full adoption

As indicated in Table 6.18, the effect of the drip irrigation adaptation of water saving technology resulted in R14.06 million maize output in the Orange-Riet irrigation Scheme and to the economy of the Free State province. The total labour remuneration was estimated at R 41.46 million in the economy of South Africa, of which the Free State province generates a labour return of about R6.19 million and a gross operating surplus (capital) of R3.52 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R37.756 million towards the economy of Free State province. The overall land return was estimated at R6.03 million in the economy of South Africa, of which the return to irrigation in the Free State was only R51 319.08. The highest return on irrigation in the province of the Free State was found in the Fezile Dabi irrigation district, followed by the Lejweleputswa and Xhariep irrigation districts in the economy of Free State province.

Institutional incomes (enterprise and households) were valued at R28.18 million. The households and value added (labour, capital, and land) generate incomes estimated at R26.58 and R99.48 million in the economy of South Africa, respectively. This finding aligned with that of Pronti et al. (2024), which indicated that, to ensure food security in a context of increasing water use and demand and growing climatic variability, more crop per drop is required.

6.2.4.2 Adoption of water-saving policies

6.2.4.2.1 Partial adoption

As indicated in Table 6.18, the effect of the adoption of water saving policies resulted in R37.4 million of maize in the Orange-Riet Irrigation Scheme and to the economy of Free State province. The total labour remuneration was estimated at R30.92 million in the economy of South Africa, of which the Free State province generates a labour return of about R6.93 million and gross operating surplus (capital) of R13.54 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R86.4 million towards the economy of the Free State province. The overall land return was estimated at R18.42 million in the economy of South Africa, of which the return to irrigation in the Free State was only R143 255.90. The highest return on irrigation in the province of the Free State was found in the Fezile Dabi irrigation district, followed by the Lejweleputswa and Xhariep irrigation districts in the economy of Free State province.

Institutional incomes (enterprise and households) were valued at R129.56 million. The households and value added (labour, capital, and land) generate incomes estimated at R113.58 and R216.10 million in the economy of South Africa, respectively. The findings of this study concurred with those of Yang et al. (2022a), which showed that, through water-saving policies and measures, the effective utilisation coefficient of agricultural irrigation water has increased, and water-saving policies have been implemented well. It has guidance on water-saving reform work in other places.

6.2.4.2.2 Full adoption

As indicated in Table 6.18, the effect of the adoption of water saving policies resulted in R29.53 million in the maize output and in the economy of the Free State province. The total labour remuneration was estimated at R23.46 million in the economy of South Africa, of which the Free State province generates a labour return of about R2.53 million and a gross operating surplus (capital) of R4.83 million in the economy. Most of the labour income is derived from the Western Cape, followed by the North West and Mpumalanga provinces.

Household income was estimated at R69.38 million for the economy of the Free State province. The overall land return was estimated at R6.83 million in the economy of South Africa, of which the return to irrigation in the Free State was only R51,787.30. The highest return on irrigation in the Free State province was found in the Thaba Mofutsanyane irrigation district, followed by the Fezile Dabi and Xhariep irrigation districts in the economy of the Free State province.

Institutional incomes (enterprise and households) were valued at R31.58million. The households and value added (labour, Capital, and land) generated incomes of around R29.82 and R112.63 million in the economy of South Africa, respectively. As indicated above in this section, the findings of this study aligned with those of Yang et al. (2022a), which showed that, through water-saving policies and measures, the effective utilisation coefficient of agricultural irrigation water has increased, and water-saving policies have been implemented well, providing guidance on water-saving reform work in other places

6.2.4.3 Adaptation towards climate variability

6.2.4.3.1 Partial Adaption

As indicated in Table 6.18, the effect of adaptation towards climate variability resulted in R9.98 million in maize output in the Orange-Riet Irrigation Scheme and the Free State province economy. The total labour remuneration was estimated at R8.36 million in the economy of South Africa, of which the Free State province generates a labour return of about R1.02 million and a gross operating surplus (capital) of R1.82 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R25.18 million towards the economy of the Free State province. The overall land return was estimated at R2.74 million in the economy of South Africa, of which the return to irrigation in the Free State was only R23 248.08. The highest return on irrigation in the province of the Free State was found in the Fezile Dabi irrigation district, followed by the Lejweleputswa and Xhariep irrigation districts in the economy of the Free State province.

Institutional incomes (enterprise and households) were estimated at R11.73 million. The households and value added (labour, capital, and land) generate incomes of around R 10.79 and R43.58 million in the economy of South Africa, respectively. This finding aligned with that of Challinor et al. (2014), which highlighted that, without adaptation to climate variability, losses in aggregate production are expected for wheat, rice, and maize in both temperate and tropical regions by 2 °C of local warming. Crop-level adaptations increase simulated yields.

6.2.4.3.2 Full Adaption

As indicated in Table 6.18, the effect of adaptation towards climate variability resulted in R38.97 million in maize output in the Orange-Riet Irrigation Scheme and the Free State province economy. The total labour remuneration was estimated at R92.56 million in the economy of South Africa, of which the Free State province generates a labour return of about R47.82 million and a gross operating surplus (capital) of R26.98 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R93.76 million towards the economy of the Free State province. The overall land return was estimated at R17.59 million in the economy of South Africa, of which the return to irrigation in the Free State was only R129 431.8. The highest return on irrigation in the province of the Free State was found in the Fezile Dabi irrigation district, followed by the Lejweleputswa and Xhariep irrigation districts in the economy of the Free State province.

Institutional incomes (enterprise and households) were valued at R147.8651 million. The households and value added (labour, capital, and land) generate incomes estimated at R146.92 and R757.39 million in the economy of South Africa, respectively. As highlighted above in this sub-section, the findings of this study aligned with the findings of Challinor et al. (2014), which indicated that, without adaptation to climate variability, losses in aggregate production are expected for wheat, rice, and maize in both temperate and tropical regions by 2 °C of local warming. Crop-level adaptations increase simulated yields.

6.3 Discussions

The extended TPB model for the adoption of water-saving technologies among commercial maize irrigators in the Orange-Riet Irrigation Scheme suggests that farmers' intentions and perceived control are influenced mainly by perceptions of risk and benefit, as well as by technical factors. Access to resources, however, appears to have a negative influence on perceived behavioural control, indicating potential constraints or challenges, despite resource availability. These psychological conditions imply that varying levels of adoption are linked to how farmers evaluate the risks and benefits of technologies and their confidence in managing technical aspects.

Partial adoption might occur when farmers recognise some benefits, but remain uncertain about technical control or face resource-related challenges. In contrast, full adoption is more likely to happen when technical confidence is higher and perceived risks and benefits strongly motivate intentions. The AquaCrop model simulations show that partial adoption results in improved water productivity, while full adoption leads to even better water productivity. The social accounting matrix results demonstrate only minor economic impacts as a result of the relatively small changes in yield compared with the no adoption scenario. Since the adoption of water-saving technologies resulted in only minimal yield increases, the broader social and economic impacts were also limited. However, at the farm level, these technologies play an essential role in improving water productivity, rendering them valuable for sustainable water management.

The extended TPB results suggest that farmers' intentions and perceptions regarding water-saving policies are influenced by complex and sometimes conflicting factors. For instance, increased access to resources unexpectedly reduces intention to adopt these policies, which might indicate that better-resourced farmers

feel less pressure to change behaviour. Negative perceptions influenced by information factors lower positive attitudes towards policy adoption, potentially reflecting scepticism or resistance among farmers. However, strong institutional and legal support enhances perceived control and social norms, which are essential for fostering adoption intentions. Positive views of financial costs further encourage adoption. These psychological and structural dynamics help to explain the adoption levels observed in the AquaCrop model scenarios.

The extended TPB results for adaptation to climate variability in the Orange-Riet Irrigation Scheme highlight key psychological drivers that influence farmers' intentions and behaviours. Positive attitudes toward adaptation, bolstered by trust factors, along with strong perceptions of risks and benefits, are associated with higher intentions to adapt fully. Conversely, concerns about financial costs and specific risks, such as load shedding, negatively influence attitudes, potentially limiting adoption. These psychological conditions suggest that partial adaptation may occur when trust and perceived benefits are moderate. Still, financial concerns and risk perceptions persist, whereas full adaptation requires stronger positive attitudes and trust, alongside minimised financial worries. Correspondingly, the AquaCrop model simulations indicate a fluctuation of yields under different adaptation scenarios. These agronomic outcomes translate into significant socio-economic impacts, as shown in the multiplier analysis results and are reflected by output, labour remuneration, household income, land returns, and overall value-added income within the Free State economy. These results clearly highlight the point that farmers need to fully commit to adapting to climate variability to realise the agronomic and socio-economic benefits fully.

CHAPTER 7: CASE STUDY OF COMMERCIAL LUCERNE PRODUCTION IN THE KAKAMAS IRRIGATION SCHEME, NORTHERN CAPE PROVINCE

7.1 Overview

This section presents the results for commercial lucerne irrigators in the Kakamas Irrigation Scheme, based on the integrated framework developed in this project. The analysis begins by describing the demographic farm and household characteristics of the participating irrigators. These characteristics help to frame the behavioural and system-level results that follow by offering insights into the broader production and decision-making environment.

7.2 Results

7.2.1 Demographic, Farm, and Household Characteristics of Respondents

The demographic, farm, and household profile of respondents in the Kakamas Irrigation Scheme is presented in Table 7.1 below. All respondents were male (100%), with the majority aged between 51 and 60 years (31%), followed by 41–50 years (25%) and 31–40 years (20%), while only 4% were in the 21–30 age group. In terms of education, most respondents had an undergraduate degree (46%), 38% had completed secondary education, and 15% held a diploma. A small percentage (1%) had a master's degree, and none had only a primary education or a PhD. Regarding health status, 55% of respondents reported being in good health, 34% excellent health, 9% average, and only 2% poor health.

The majority of respondents in the Kakamas Irrigation Scheme (62%) primarily use canal water for irrigation, with a smaller percentage relying on river water (24%) and other mixed sources such as river and canal water (8%). Crop production dominates the farming activities (78%), with some engaging in mixed farming (21%). Most respondents own more than five agricultural land deeds (42%), with their farmland typically being highly clustered within 1–5 km of the main farm (69%). Sole proprietorship (36%) and corporations (34%) are the most common business structures used, and 92% of respondents are sole owners of their land. Additionally, 81% of the irrigation land is located less than 1 km from the primary water source.

A significant majority (81%) of households consist of two adults, aged 18 years and older, while 12% have three or more adults. When considering total household size, 35% have four or more individuals, with 42% comprising two individuals. All household heads are male, and a large proportion (92%) of households involve only one person in farming activities. Most respondents are married (93%), and the age distribution

of household heads is relatively even, with 31% aged 51–60 and 21% aged 61 and older. The primary source of livelihood for respondents is self-employment or business ownership (98%), with only 2% relying on farming activities. Furthermore, 18% of respondents reported having off-farm income.

Table 7.1: Demographic, farm, and household Profile of Respondents in the Kakamas Irrigation Scheme

Variable	Classification	Frequency	Percentage (%)
Demographic			
Gender	Male	170	100%
Age	21-30	6	4%
	31-40	34	20%
	41-50	42	25%
	51-60	53	31%
	61 and older	35	21%
	Secondary (grade 8-12)	65	38%
	Diploma	25	15%
	Undergraduate degree	78	46%
	Masters	2	1%
Health Level	Poor	3	2%
	Average	16	9%
	Good	93	55%
	Excellent	58	34%
Farm characteristics			
The primary source of water used for irrigation	River	40	24%
	Dam	4	2%
	Canal	105	62%
	River and dam water	1	1%
	River and canal water	13	8%
	River and borehole	5	3%
	Dam and canal water	1	1%
	Canal and borehole	1	1%
Type of farming performed	Crop production	133	78%
	Livestock production	1	1%
	Mixed farming	36	21%
Amount of agricultural land deeds owned	One	35	21%
	Two to five	63	37%
	More than five	72	42%
How scattered is the farmland from the main farm	Highly clustered together (1-5 km)	118	69%
	Moderately dispersed (6-10 km)	26	15%
	Highly dispersed (more than 10 km)	26	15%
Business structure of the farm operations	Sole proprietorship	62	36%
	Corporation	57	34%
	Partnership	5	3%
	Trust	36	21%

Variable	Classification	Frequency	Percentage (%)
Demographic			
The land ownership type of the farm	Closed corporation	10	6%
	Sole owner	156	92%
	Lease	2	1%
	Combination of sole owner and lease	12	7%
Distance of the main irrigation land from the water source	Less than 1 Km	138	81%
	1-3 Km	20	12%
	3-7 Km	5	3%
	7-10 Km	-	-
	More than 10 Km	7	4%
Household characteristics			
Number of adults (18 years and older) living in the household	One	12	7%
	Two	137	81%
	Three or more	21	12%
Total individuals living in the household (adults + children)	One	9	5%
	Two	71	42%
	Three	31	18%
	Four or more	59	35%
Individuals in the household involved in farming activities	One	156	92%
	Two	11	6%
	Three or more	3	2%
Marital status	Married	158	93%
	Single	9	5%
	Divorced	2	1%
	Widowed	1	1%
Age of the head of the household	Less than 20	-	-
	20-30	6	4%
	31-40	34	20%
	41-50	42	25%
	51-60	53	31%
	61 and older	35	21%
Primary source of livelihood	Farmer/agricultural activities	4	2%
	Self-employed/business owner	166	98%
Off-farm income	Yes	31	18%
	No	139	82%

Sources: Project team Compilation

7.2.2 Theory of Planned Behaviour

7.2.2.1 Standard TPB Model for Adoption of Water-Saving Technologies

None of the measurement items had factor loadings below the acceptable threshold of 0.4, indicating that all items met the necessary reliability standards. Although some constructs, such as Attitudes (A_B) and Subjective Norms (SN), had relatively low Cronbach's alpha values, all constructs achieved composite reliability scores above 0.7, indicating adequate internal consistency. However, Perceived Behavioural Control (PBC) recorded a high score above 0.9. Consequently, the measurement item for PBC with the lowest factor loading (PBC_1) was dropped to enhance the model's overall reliability.

All constructs with more than one measurement item achieved an AVE value above the acceptable threshold of 0.5. This indicates that these constructs effectively capture a significant amount of variance from their respective measurement items, supporting the convergent validity of the model. The Fornell-Larcker results suggest that the square root of the Average Variance Extracted (AVE) values (diagonal values) are higher than the correlations between the constructs. This supports the discriminant validity of the model and the HTMT results, where all values are below the recommended threshold of 0.9. This further confirms that the constructs are distinct from one another, establishing adequate discriminant validity in the measurement model.

The structural model assessment commenced with the evaluation of the Variance Inflation Factor (VIF) values for the inner model. VIF is an important metric used to detect multicollinearity among the constructs in the model. In this analysis, all VIF values were found to be below the threshold of 3, indicating that multicollinearity is not a concern in this model. Figure 7.1 below provides an overview of the path coefficients along with their respective p-values, offering a visual representation of the relationships within the model. Additionally, Appendix I, Table I.1. presents a detailed summary of these statistics, including the path coefficients, t-values, and p-values for each path relationship.

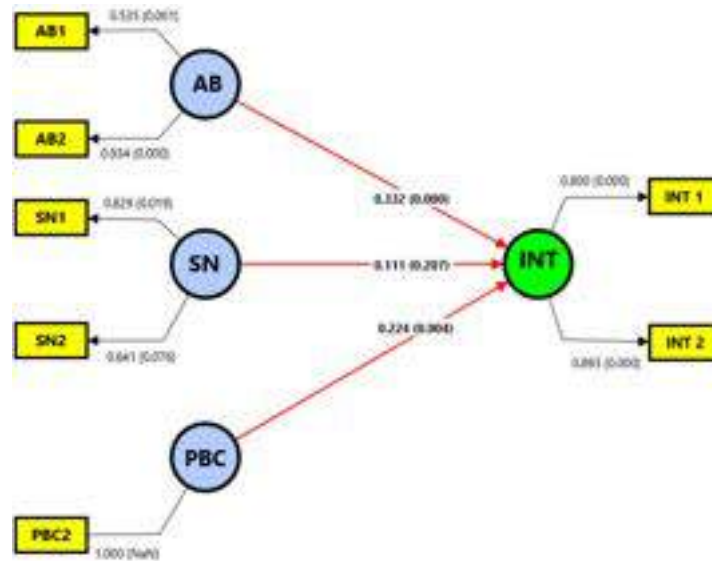


Figure 7.1: Path Analysis Findings of Lucerne Irrigators' Intentions to Adopt Water-Saving Technologies in the Kakamas Irrigation Scheme

Source: Project team compilation

Appendix I, Table I.1 represents the hypothesis testing results for the structural model, detailing the relationships between attitudes, subjective norms, perceived behavioural control, and intentions in the context of lucerne irrigators in the Kakamas Irrigation Scheme. The path from Attitudes (A_B) to Intentions (INT) was significant and positive ($\beta = 0.332$, $p < 0.01$), as shown in the table, indicating that attitudes towards water-saving technologies positively influence the intentions of lucerne irrigators in the Kakamas Irrigation Scheme to adopt these technologies. Similarly, the relationship between Subjective Norms (SN) and Intentions (INT) was also significant and positive ($\beta = 0.224$, $p < 0.05$), suggesting that social pressures and expectations from others play an essential role in shaping the intentions of these irrigators. In contrast, the path from Perceived Behavioural Control (PBC) to Intentions (INT) was not statistically significant ($\beta = 0.111$, $p = 0.207$), indicating that the perceived ability of lucerne irrigators to implement water-saving technologies does not significantly influence their intentions to adopt such practices.

The R^2 value for intentions was 0.200, with an adjusted R^2 of 0.186, indicating that the model explains approximately 20% of the variance in irrigators' intentions to adopt water-saving technologies. The f^2 Statistics for the predictor variables were as follows: attitudes (A_B) ($f^2 = 0.134$), perceived behavioural control (PBC) ($f^2 = 0.061$), and subjective norms (SN) ($f^2 = 0.015$). The results indicate that attitudes (A_B) have a small effect on intentions (INT), as the f^2 value is less than 0.15. Similarly, perceived behavioural control (PBC) and subjective norms (SN) exhibit negligible effects, further suggesting a limited influence on the adoption of water-saving technologies among lucerne irrigators.

7.2.2.2 Augmented TPB Model for Adoption of Water-Saving Technologies

The specific measurement items, including **IL**₁ (Institutional and Legal Factors), **RB**₁₀ (Perceived Risks from Load Shedding and Tariffs), **IF**₇ and **IF**₈ (Informational Factors), **TX**₃ (Trust Factors), and **AR**₁ (Access to Resources), were removed owing to outer loadings below 0.4 to ensure an indicator of reliability.

The primary focus of this assessment was placed on the composite reliability score as a reliable estimate of internal consistency, as this indicates the importance of using composite reliability for a more accurate assessment. Notably, several constructs exhibited Cronbach's alpha scores below 0.6, including Attitudes (**A_B**), Institutional and Legal Factors (**IL**), Trust Factors (**TX**), Access to Resources (**AR**), Perceived Financial Cost (**PFC**), and Subjective Norms (**SN**). Despite these low alpha values, all constructs maintained composite reliability scores above 0.6.

Additionally, certain constructs demonstrated excessively high composite reliability scores exceeding 0.9, indicating potential redundancy among measurement items. For Technical Factors (**TF**), **TF**₁ was dropped as it had the lowest loading on the construct. In the case of **RB2** (Perceived Risks from Load Shedding and Tariffs), **RB**₇ was initially dropped, but the composite score remained above 0.9, leading to the removal of **RB**₉ as well. Lastly, for Perceived Behavioural Control (**PBC**), **PBC**₁ was dropped since it had the lowest loading on the construct among the two measurement items.

In this analysis, all constructs exhibited AVE values above 0.5, except for Trust Factors (**TX**). By dropping **TX**₅, the AVE for the Trust Factors construct improved, resulting in a value equal to 0.5. This adjustment ensured that the construct met the minimum requirement for discriminant validity, reinforcing the robustness of the measurement model.

The initial estimation of the HTMT ratios revealed that Intentions (**INT**) exhibited discriminant validity issues with both Informational Factors (**IF**) and Institutional and Legal Factors (**IL**). Further investigation indicated that dropping **IL**₁ resolved this issue completely. Additionally, Perceived Risks and Benefits (**RB**) also faced discriminant validity challenges with INT. However, this was addressed by removing **RB2**, which successfully resolved the discriminant validity issue. Furthermore, the square root of the AVE (shown as diagonal values) is larger than the correlations between constructs (off-diagonal values). Similarly, the final HTMT ratios are below the threshold of 0.9, thereby affirming adequate discriminant validity among the constructs in the model.

Variance Inflation Factor (VIF) values were calculated to identify any potential issues with multicollinearity among the constructs. The analysis revealed that none of the inner path VIF values exceeded the threshold of 3, indicating that collinearity was not a concern in this model.

The significance of the extended model's structural relationships is presented, highlighting the presence of mediating relationships. The bootstrapping procedure results in a detailed report detailing specific indirect effects, total indirect effects, direct effects, and total effects. This differs from the standard Theory of Planned Behaviour (TPB) model, where only direct effects were reported because of the absence of mediating variables. The specific indirect effects are summarised in Appendix I, Table I.2, revealing that none of these specific indirect effects were statistically significant. This indicates that the mediating variables (*A_B*, *SN*, and *PBC*) did not significantly influence the relationships between the additional constructs and Intention (*INT*) in this extended model.

The total indirect effects are presented in Appendix I, Table I.3, where the results indicate that none of these effects were statistically significant. This finding supports the results in Appendix I, Table I.2, which is that the mediating variables (*A_B*, *SN*, and *PBC*) did not contribute significantly to the relationships between the additional constructs and Intention (*INT*).

The direct effects are summarised in Appendix I, Table I.4. Firstly, the path from Informational Factors (*IF*) to Attitudes (*A_B*) is positive and significant ($\beta = 0.242$, $p < 0.05$). This indicates that greater access to information positively influences the attitudes of lucerne irrigators toward adopting water-saving technologies. Secondly, the relationship between Informational Factors (*IF*) and Intention (*INT*) is also positive and significant ($\beta = 0.545$, $p < 0.01$). This suggests that, as informational factors improve, the intention to adopt water-saving technologies increases significantly among the irrigators. Lastly, the path from Perceived Risks and Benefits (*RB*) to Intention (*INT*) is significant and strong ($\beta = 0.646$, $p < 0.01$). This indicates that higher perceived benefits relative to risks strongly enhance the intention to adopt water-saving technologies among lucerne irrigators. The total effects are presented in Appendix I, Table I.5, and closely resemble the direct effects. This consistency is sensible, as none of the indirect effects were found to be significant.

The results show an R^2 of 0.177 for Attitudes (*A_B*), suggesting that approximately 17.7% of the variance in attitudes toward adopting water-saving technologies can be explained by the model. The Intention (*INT*) construct demonstrates a remarkably high R^2 of 0.959, indicating that 95.9% of the variance in intentions to adopt water-saving technologies is accounted for by the model. This suggests a strong predictive power concerning intentions. Conversely, the R^2 values for Perceived Behavioural Control (*PBC*) and Subjective Norms (*SN*) are relatively low at 0.120 and 0.118, respectively, indicating that these constructs explain only a small portion of the variance in their respective outcomes.

The effect sizes for the Informational Factors (*IF*) and Perceived Risks and Benefits (*RB*) on Intentions (*INT*) reveal substantial influence. The f^2 value for *IF* on *INT* is 5.088, indicating a large effect size. This

suggests that Informational Factors play a significant role in shaping intentions to adopt water-saving technologies. Similarly, the f^2 value for **RB** on **INT** is 7.144, also reflecting a large effect size. This result indicates that perceived risks and benefits significantly influence intentions to adopt water-saving technologies.

7.2.2.3 Standard TPB Model for Adoption of Water-Saving Policies

In this case, **SN₃** was the only measurement item with a loading below 0.4 and was subsequently dropped from the model to ensure indicator reliability. Both Attitude (**A_B**) and Intention (**INT**) had Cronbach's alphas below 0.6. Their composite reliability scores were above 0.6, aligning with the suggestion by Hair and Alamer (2022) that composite reliability is a better measure in such cases. For Perceived Behavioural Control (**PBC**), both Cronbach's alpha and composite reliability were above 0.6, indicating sufficient internal consistency.

All constructs demonstrated sufficient convergent validity, with AVE values exceeding the recommended threshold of 0.5. This indicates that the constructs explain more than half of the variance of their respective indicators. For the Fornell-Larcker criterion, the square root of the AVE (represented by the diagonal values) must be greater than the correlations between the constructs, and this criterion has been satisfied, as the diagonal values exceed the correlations. Additionally, the HTMT values fall below the threshold of 0.9, further confirming discriminant validity. Ultimately, the results imply that the constructs are sufficiently distinct from each other. The results indicated that all VIF values were below the threshold of 3, suggesting that multicollinearity is not a concern in this model.

Figure 7.2 below provides a visual overview of the path analysis, highlighting the estimated path coefficients and their corresponding p-values.

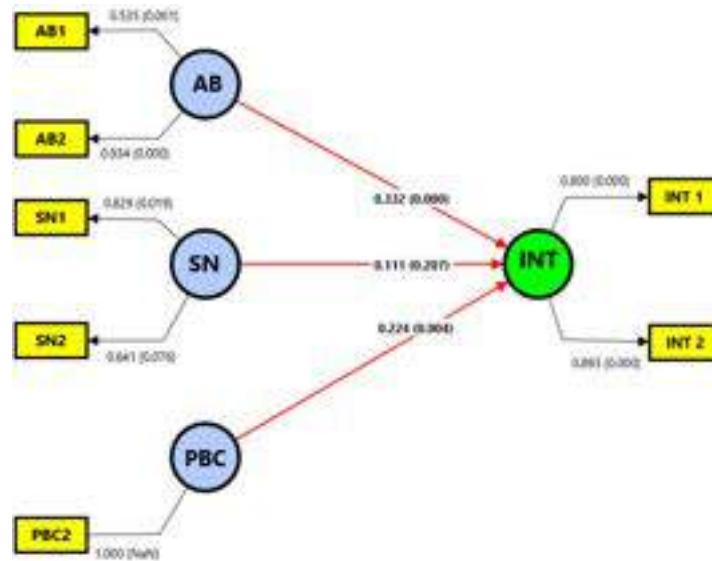


Figure 7.2: Path Analysis Findings of Lucerne Irrigators' Intentions to Adopt Water-Saving Policies in the Kakamas Irrigation Scheme

Source: Project team compilation

Appendix I, Table I.6 offers a more detailed summary of these statistics, including the path coefficients, standard errors, t-values, and p-values for each relationship in the model. The path from Attitudes (A_B) to Intentions (INT) was significant but negative ($\beta = -0.201$, $p < 0.05$), indicating that attitudes towards water-saving policies have an important, though negative, influence on the intentions of lucerne irrigators in the Kakamas Irrigation Scheme to adopt these policies. The path from Subjective Norms (SN) to Intentions (INT) was significant and positive ($\beta = 0.219$, $p < 0.01$), suggesting that perceived social pressure from essential others positively influences lucerne irrigators' intentions to adopt water-saving policies. In contrast, the path from Perceived Behavioural Control (PBC) to Intentions (INT) was not significant ($\beta = 0.141$, $p = 0.113$), indicating that perceived control over adopting water-saving policies does not have a statistically significant influence on the intentions of lucerne irrigators in the Kakamas Irrigation Scheme.

The R^2 value for Intentions (INT) was 0.103, with an adjusted R^2 of 0.087, indicating a modest level of explanatory power. The obtained R^2 value may appear low. However, as noted by Ozili (2023), a low R^2 is acceptable in social science research. The primary aim in such studies is often to evaluate the significance of predictors, rather than to achieve high predictive accuracy.

The f^2 values for the constructs influencing intentions were as follows: Attitudes (A_B) had an effect size of 0.043, Perceived Behavioural Control (PBC) had an effect size of 0.053, and Subjective Norms (SN) had an effect size of 0.021.

7.2.2.4 Augmented TPB Model for Adoption of Water-Saving Policies

In this assessment, several measurement items were removed because of outer loadings below 0.4. These items include **IL**₇ (Institutional and Legal Factors), **RB**₁₀ (Perceived Risks from Load Shedding and Tariffs), **IF**₇ (Informational Factors), **TX**₃ and **TX**₅ (Trust Factors), **PFC**₄ (Perceived Financial Cost), **INT**₄ (intentions) and **SN**₄ (Subjective Norms). Removing these items enhanced the overall reliability of the model without compromising its validity.

Several constructs, including Attitudes (**A_B**), Institutional and Legal Factors (**IL**), Perceived Risks (**RB**), Informational Factors (**IF**), Access to Resources (**AR**), and Intention (**INT**), had Cronbach's alpha values below 0.6. However, all these constructs had composite reliability scores above 0.6, meeting the acceptable threshold for reliability. The **RB** construct, with a composite reliability score over 0.9, indicated redundancy among its measurement items. Initially, **RB**₇ was removed, but this did not bring the score below 0.9. Consequently, the next lowest-loading item, **RB**₉, was also removed to resolve the issue.

All constructs had AVE values above 0.5, except for Institutional and Legal Factors (**IL**) and Access to resources (**AR**). To address this, **IL**₈, which had the lowest loading on the construct, was removed. After this adjustment, the AVE for **IL** improved to a value above 0.6, meeting the acceptable threshold. For Access to resources (**AR**), **AR**₁ removed, which improved the AVE value of **AR** above 0.5.

The HTMT estimation revealed a discriminant validity issue between Informational Factors (**IF**) and Intention (**INT**). After exploring various solutions by dropping measurement items from **IF**, it was determined that removing **IF**₄ and **IF**₈ effectively resolved this issue. Additionally, discriminant validity concerns arose between Perceived Risks (**RB**) and Perceived Financial Cost (**PFC**). However, after thorough exploration, it was concluded that no feasible solution could address these issues. Consequently, the decision was made to remove both **RB** and **PFC** from the model. Similarly, the final HTMT ratios show that all values fall below the threshold of 0.9, indicating no further discriminant validity issues after the modifications.

The Variance Inflation Factor (VIF) values were examined for the inner model to identify any potential collinearity issues among the inner paths. All VIF values were found to be below the threshold of 3, indicating that collinearity was not a concern in the model.

The significance of the structural relationships was assessed, and the result for the specific indirect effects is presented in Appendix I, Table I.7. At the same time, Appendix I, Table I.8 outlines the total indirect effects. Additionally, Appendix I, Table I.9 details the direct effects, and Appendix I, Table I.10 presents the total effects.

Appendix I, Table I.8 presents the total indirect effects, revealing that none of these effects achieved statistical significance. This suggests that the indirect pathways explored in the model did not have a meaningful impact on the lucerne irrigators' intentions to adopt water-saving policies.

The results presented in Appendix I, Table I.9, highlight several significant direct effects in the structural model. The path from Informational Factors (**IF**) to Attitudes (**A_B**) reveals a significant negative relationship ($\beta = -0.244$, $p < 0.05$), suggesting that higher levels of informational factors are associated with less favourable attitudes toward the adoption of water-saving policies. Additionally, the relationship between Informational Factors (**IF**) to intention (**INT**) shows a significant positive effect ($\beta = 0.450$, $p < 0.01$), indicating that increased informational factors correlate with a higher intention to adopt water-saving policies. Furthermore, the direct path from Institutional and Legal Factors (**IL**) to Subjective Norms (**SN**) is significant ($\beta = 0.223$, $p < 0.01$), suggesting that stronger institutional and legal frameworks positively influence subjective norms related to the adoption of water-saving policies. The direct effect of Trust Factors (**TF**) on intention (**INT**) is also significant ($\beta = 0.497$, $p < 0.01$), indicating that greater trust in factors related to water-saving policies enhances the intention to adopt these practices. Lastly, the path from Trust Factors (**TF**) to Subjective Norms (**SN**) shows a significant positive effect ($\beta = 0.283$, $p < 0.01$), suggesting that increased trust in water-saving practices positively influences the subjective norms surrounding their adoption.

The total effects, as shown in Appendix I, Table I.10, mirror the results of the direct impact found in Appendix I, Table I.9 above. This similarity is expected and sensible, since none of the indirect effects were found to be significant. Therefore, the overall influence of the exogenous variables on the endogenous variables is primarily driven by the direct paths observed in the model.

The intention construct (**INT**), which is the primary focus of the model, shows an R^2 of 0.429, indicating that the model explains approximately 42.9% of the variance in intention. The other constructs (**A_B**, **PBC**, and **SN**) display much lower R^2 values, with adjusted R^2 values as low as 0.046 for **PBC**. Despite these low R^2 values, it is important to note, as emphasised by Ozili (2023), that in social science research, lower R^2 values are often acceptable. This is because the main aim is not necessarily to achieve high predictive accuracy, but to examine the significance and strength of the relationships between predictors and outcomes.

According to Hair and Alamer (2022), effect sizes (f^2) can be classified as small (0.02), medium (0.15), or large (0.35). For instance, **IF** has a medium effect size of 0.281 on intention (**INT**), highlighting its substantial impact. Additionally, **TF** also demonstrates a significant effect on intention ($f^2 = 0.406$), indicating its critical role in shaping behavioural outcomes. On the other hand, smaller effects were

observed for other relationships, such as *IL* on *SN* ($f^2 = 0.051$), which still falls into the small-to-medium range, and *TX* on *SN* ($f^2 = 0.080$).

7.2.2.5 Standard TPB Model for the adaptation towards climate variability

In the indicator reliability evaluation, all measurement items achieved factor loadings higher than 0.7, indicating strong indicator reliability. All measurement items exhibited both Cronbach's alpha and composite reliability scores above 0.6. However, attitudes (*A_B*) and perceived behavioural control (*PBC*) showed composite reliability scores exceeding 0.9, indicating redundancy among the measurement items for these constructs. To address this, we dropped the measurement items with the lowest loadings for each construct, specifically *A_{B5}* and *PBC₅*, to improve the overall model.

The Average Variance Extracted (AVE) indicates that all constructs with more than two measurement items achieved values exceeding the 0.5 threshold. The Fornell-Larcker values which require the square root of the AVE (represented by the diagonal values) to be greater than the correlations between constructs. This condition has been met, confirming that each construct is distinct from the others. Furthermore, the HTMT ratios were below this threshold, further validating the discriminant validity of the constructs within the model for lucerne irrigators' adaptation to climate variability in the Kakamas Irrigation Scheme.

The VIF values for all paths in the inner model (structural model) were below the threshold of 3, indicating that collinearity is not a concern and that the constructs in the model are distinct and independent in predicting the outcomes.

An overview of the path model results, including path coefficients and p-values, is illustrated in Figure 7.3 below. A detailed breakdown of these statistics is provided in Appendix I, Table I.11, where each path's significance, coefficient values, and p-values are presented to evaluate the relationships between the constructs.

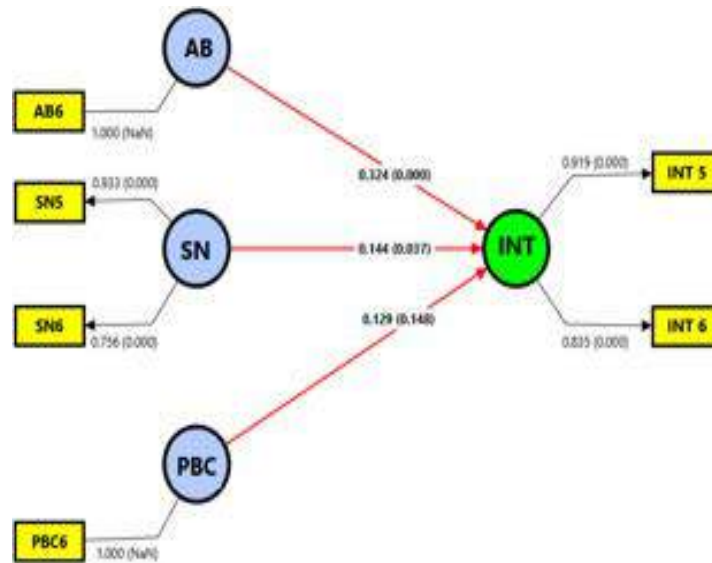


Figure 7.3: Path Analysis Findings of Lucerne Irrigators' Intentions for Adaptation Towards Climate Variability in the Kakamas Irrigation Scheme

Source: Project team compilation

The structural model results reveal varying levels of significance for the hypothesised relationships. The path from Attitudes (A_B) to Intentions (INT) was significant and positive ($\beta = 0.324$, $p < 0.01$), indicating that attitudes positively influence the intentions of lucerne irrigators in the Kakamas Irrigation Scheme to adopt climate variability. The path from Subjective Norms (SN) to Intentions (INT) was not significant ($\beta = 0.129$, $p = 0.148$), suggesting that subjective norms did not have a notable impact on the adoption intentions in this context. The path from Perceived Behavioural Control (PBC) to Intentions (INT) was significant and positive ($\beta = 0.144$, $p < 0.05$), indicating that perceived behavioural control had a positive influence on the intentions of irrigators to adopt Climate variability.

The R^2 for Intentions (INT) was 0.186, with an adjusted R^2 of 0.171. This indicates that the model explains 18.6% of the variance in intentions to adopt water-saving policies among lucerne irrigators in the Kakamas Irrigation Scheme. However, as noted by Ozili (2023), a low R^2 is acceptable in social science research, where the primary goal is often to assess the significance of the predictors, rather than to focus on high predictive accuracy.

Additionally, the f^2 values for the model's constructs were calculated to determine their effect sizes. Attitudes (A_B) had an f^2 of 0.118, reflecting a small to medium effect on Intentions (INT). Perceived Behavioural Control (PBC) had an f^2 of 0.019, and Subjective Norms (SN) had an f^2 of 0.024, both classified as small effects. According to Hair and Alamer (2022), effect sizes of 0.02 are small, 0.15 are medium, and 0.35 are large, indicating that Attitudes had the most notable impact on intentions, while PBC and SN had relatively smaller influences.

7.2.2.6 Augmented TPB Model for the adaptation towards climate variability

During this assessment, several measurement items were removed because of outer loadings below 0.4 in order to ensure the reliability of the indicators. The following measurement items were dropped: **TF**₆ (Technical Factors), **IL**₆ (Institutional and Legal Factors), **RB**₁₀ (Perceived Risks from Load Shedding and Tariffs), **IF**₇ and **IF**₈ (Informational Factors), **TX**₃ and **TX**₅ (Trust Factors), and **PFC**₃ (Perceived Financial Cost).

In this assessment, several constructs displayed Cronbach's Alpha values exceeding 0.9, indicating redundancy among their measurement items. For the Attitude construct (**AB**), **AB**₅ was dropped to resolve this redundancy, as it had the lowest factor loading among the measurement items. For the Perceived Behavioural Control construct (**PBC**), **PBC**₅ was removed for the same reason. In the case of the Risk Behaviour construct (**RB2**), **RB**₇ was initially dropped, but since this action did not lower the construct's composite score to below 0.9, the decision was made to drop it subsequently **RB**₉. Lastly, for the Informational Factors construct (**IF**), **IF**₆ was removed as it had the lowest factor loading among the measurement items.

All the constructs in the measurement model for lucerne irrigators' adaptation to climate variability showed Average Variance Extracted (AVE) values above the threshold of 0.5, indicating that each construct explained more than 50% of the variance in its respective indicators. This suggests that the measurement model has satisfactory convergent validity.

The discriminant validity was assessed. Initially, intention (**INT**) showed discriminant validity issues with informational factors (**IF**) and institutional and legal factors (**IL**). To resolve these issues, **INT**₆ was dropped from the model. After this adjustment, no further discriminant validity issues were present. The VIF values of the inner model were examined, and the results revealed that none of the inner paths had a VIF value above 3, indicating no significant collinearity issues within the model.

The initial estimation of the bootstrapping procedure resulted in NaN values, indicating that there was no feasible solution. However, considering that a thorough process had already been followed during both the measurement and structural model assessments, and given that no collinearity issues were present, the next step was to explore whether dropping specific constructs could resolve the NaN problem. The results revealed that dropping the IF construct resolved the issue. The issue with IF might be attributable to its limited contribution to the variance explained in the endogenous variables, meaning that it could have had weak predictive power or influence on the key outcomes in the model.

The results for the specific indirect effects are detailed in Appendix I, Table I.12, and none of these effects were found to be significant. This suggests that no individual intermediary relationships between the

constructs have a statistically significant influence on lucerne irrigators' intentions to adapt to climate variability in the Kakamas irrigation scheme. The total indirect effects are shown in Appendix I, Table I.13, direct effects are summarised in Appendix I, Table I.14, and the total effects are presented in Appendix I, Table I.15.

The results of the total indirect effects, presented in Table Appendix I, Table I.13, show that several indirect relationships are significant. Specifically, perceived financial costs (**PFC**) were found to have a substantial and positive total indirect effect ($\beta = 0.043$, $p < 0.05$), suggesting that financial concerns indirectly influence the intention to adapt to climate variability (**INT**) through the mediating variables (**A_B**, **SN**, **PBC**). Similarly, Perceived Risks and Benefits (**RB**) show a significant and positive total indirect effect ($\beta = 0.041$, $p < 0.05$), indicating that perceived risks and benefits also exert an indirect effect on irrigators' intention to adapt to climate variability via the mediating constructs (**A_B**, **SN**, **PBC**). Additionally, trust factors (**TX**) showed a significant total indirect effect ($\beta = 0.053$, $p < 0.05$), highlighting that trust indirectly influences the intention to adapt. These findings underscore the role of mediating factors in translating these variables into an intention to adapt to climate variability. These findings suggest that, while the specific indirect effects were not significant, the combined indirect effects through the mediators (**A_B**, **SN**, **PBC**) play a meaningful role in influencing intention.

The direct effects presented in Appendix I, Table I.14, show several significant relationships. Attitudes (**A_B**) have a positive and significant direct effect on the intention to adapt to climate variability ($\beta = 0.136$, $p < 0.05$), highlighting that favourable attitudes drive adaptation intentions (**INT**). Perceived financial costs (**PFC**) significantly influence subjective norms (**SN**) ($\beta = 0.256$, $p < 0.01$), indicating that financial concerns shape social expectations regarding adaptation behaviour.

Perceived risks (**RB**) have a positive direct effect on attitudes (**A_B**) ($\beta = 0.210$, $p < 0.05$) and on the intention to adapt ($\beta = 0.196$, $p < 0.01$), showing that risk perceptions play a direct role in shaping both attitudes and intentions. Technical factors (**TF**) also show significant effects on attitudes ($\beta = 0.244$, $p < 0.01$) and a notably strong effect on intention ($\beta = 0.731$, $p < 0.01$), indicating that technical considerations are a key driver of adaptation behaviour. Finally, trust factors (**TX**) significantly influence both attitudes ($\beta = 0.225$, $p < 0.05$) and subjective norms (**SN**) ($\beta = 0.249$, $p < 0.01$), underscoring the importance of trust in shaping beliefs and social pressure toward climate variability adaptation.

The total effects shown in Appendix I, Table I.15, are similar to the direct effects, with only slight differences in the coefficients. While the direct effects highlight significant relationships between variables, the total effects consider both direct and indirect influences. This similarity indicates that the direct effects play an important role in explaining the overall model. Significant total indirect effects further highlight the

connections among these variables and their relevance to climate variability adaptation behaviour. The model explains (R^2) 20.6% of the variance in attitudes (A_B) and 79.1% in intentions (INT), indicating strong explanatory power for intentions. In contrast, perceived behavioural control (PBC) accounts for only 2.9%, and subjective norms (SN) for 17.0%.

The effect sizes (f^2) results indicate that technical factors (TF) have a substantial impact on intentions (INT) with a large effect size of 2.093, emphasising their critical role in driving adaptive behaviour. Perceived risks (RB) also show a medium effect size on intentions (0.159), suggesting that risk perceptions significantly influence adaptive behaviours. In contrast, perceived financial costs (PFC) and trust factors (TX) demonstrate small to medium effects across various constructs. Overall, these findings highlight the varying degrees of influence that different factors have on attitudes and intentions towards climate variability adaptation.

7.2.3 AquaCrop Model Simulation

7.2.3.1 Net and Gross Irrigation requirements for commercial lucerne irrigators in the Kakamas Irrigation Scheme

The net irrigation requirement and all scenarios simulated for lucerne production in the Kakamas Irrigation Scheme were performed under the following assumptions:

Cultivation Period:

- Lucerne is cultivated for five consecutive years before being replanted.
- Replanting occurs on 15 April of the sixth year.

Planting and harvesting schedule:

- Planting takes place in the fall, just before winter, to minimise weed competition and ensure optimal establishment.
- In planting years, planting occurs on 15 April, and harvesting begins on 1 August to give the crop sufficient time to establish itself. Subsequent harvests occur at 30-day intervals.
- In non-planting years, harvesting begins in line with the growth cycle, which starts when the temperature criterion is met.

Growth Cycle Criteria in Non-Planting Years:

- The growth cycle restarts when the daily average temperature reaches or exceeds 18 °C for five consecutive days.

- This restart condition is evaluated annually during the 1 August to 29 October window.
- The growth cycle ends when the daily average temperature drops below 18 °C for five consecutive days.
- This end condition is assessed between 1 April and 1 June.

The net irrigation requirement (NIR) for lucerne was calculated for the three main soil units found within the primary irrigation zone of the Kakamas Irrigation Scheme, based on long-term climate data covering the period from 2000 to 2023. The results, presented in Table 7.2 below, show apparent variation in NIR across soil types.

Table 7.2: Net Irrigation Requirement for lucerne production in the Kakamas Irrigation Scheme

Crop Cycle Year	Calendar Year	Restart date	End date	Net irrigation requirement			
				Ferralic Arenosols	Eutric Fluvisols	Chromic Cambisols	Average
1	2000/01 (Planting year)	15 April 2000	23 April 2001	1246.5	725.3	651.2	874.333
2	2001/02	10 August 2001	10 May 2002	877.9	887.9	973.1	912.967
3	2002/03	7 September 2002	15 May 2003	1101.8	1087.9	1102.9	1097.533
4	2003/04	16 September 2003	1 June 2004	932.1	924.7	988.6	948.467
5	2004/05	1 September 2004	27 April 2005	922.4	915.8	949.0	929.067
1	2005/06 (Planting year)	15 April 2005	27 April 2006	1020.1	608.7	528.8	719.200
2	2006/07	7 September 2006	1 May 2007	988.7	996.9	1031.6	1005.733
3	2007/08	23 August 2007	1 June 2008	966.9	926.0	971.9	954.933
4	2008/09	9 October 2008	4 May 2009	814.4	757.3	764.1	778.600
5	2009/10	2 September 2009	1 June 2010	966.7	953.4	1017.8	979.300
1	2010/11(Planting year)	15 April 2010	30 April 2011	1085.1	550.6	441.2	692.300
2	2011/12	10 September 2011	23 May 2011	910.6	904.1	923.2	912.633
3	2012/13	19 September 2012	23 April 2013	826.6	817.9	835.4	826.633
4	2013/14	5 October 2013	14 May 2014	879.7	858.3	909.2	882.400
5	2014/15	8 September 2014	20 April 2015	1002.3	987.7	1023.7	1004.567
1	2015/16(Planting year)	15 April 2015	29 May 2016	1058.3	674.2	619.1	783.867
2	2016/17	30 August 2016	17 May 2017	1054.4	1021.8	1093.1	1056.433
3	2017/18	13 September 2017	17 May 2018	1008.3	973.6	1022.0	1001.300
4	2018/19	26 September 2018	1 June 2019	1006.2	937.3	1034.8	992.767
5	2019/20	26 August 2019	18 May 2020	1014.0	1025.4	1067.3	1035.567
1	2020/21(Planting year)	15 April 2020	11 May 2021	979	507.9	401.1	629.333
2	2021/22	14 September 2021	12 May 2022	767.9	742.7	787.0	765.867
3	2022/23	19 September 2022	17 May 2023	944.4	941.2	971.6	952.400
Average Net irrigation requirement (mm)				972.80	857.68	874.25	901.58

Source: Project team compilation

The gross irrigation requirement (GIR) was calculated, as the net irrigation requirement (NIR) does not account for application efficiency or conveyance losses. It is assumed that most irrigation in the Kakamas Irrigation Scheme is carried out by using flood irrigation methods, such as border irrigation. That water is distributed via open canal systems. According to Brouwer et al. (1989), surface irrigation methods, such as border, furrow, or basin irrigation, typically have a field application efficiency of 60%, while lined canals have a conveyance efficiency of 95%.

By utilising Equation 4.1 ($\frac{95 \times 60}{100} = 57$) and Equation 4.2 ($\frac{1097.53}{57} = 1925.49$), the efficiency and the gross irrigation requirement (GIR) were calculated, respectively. This overall irrigation efficiency of 57% was then used to calculate the gross irrigation requirement (GIR). To ensure the irrigation planning accounts for a worst-case scenario, the NIR values from the year with the highest irrigation demand (NIR 2002/03 = 1097.53 mm) were used to calculate the GIR, as indicated in Table 7.2 above, in Row 3. This year was selected based on the lowest recorded rainfall and the highest crop water requirements across the three dominant soil types in the Kakamas Irrigation Scheme.

The net and gross irrigation requirements for the production year 2002/03, which had the highest net irrigation requirement on average, were 1097.5 mm and the corresponding gross irrigation requirement on average was 1925.49 mm.

7.2.3.2 The adoption of water-saving technologies

7.2.3.2.1 No-Adoption scenario

In the No Adoption scenario of water-saving technologies, simulations were conducted for lucerne production in the Kakamas Irrigation Scheme for each production year from 2000/01 to 2022/23. The results of these simulations are presented in Table 7.3 below. Under this scenario, the full Gross Irrigation Requirement of 1925.5 mm is evenly distributed across the growing season, with irrigation intervals occurring every 10 days. Irrigation is performed using flood irrigation. The total irrigation applied in each production year is slightly less than 1925.5 mm, as the irrigation amount per interval is rounded down to the nearest whole number when the division of total irrigation by the number of intervals results in a decimal value, ensuring that the total irrigation applied does not exceed the specified requirement.

Table 7.3: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of No Adoption of Water-saving Technologies

								Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	52	1924	9	18.926	18.926	1.46	18.948	18.948	1.32	18.884	18.884	1.28	18.913	18.913	1.30
2	2001/02	10 Aug 2001	10 May 2002	28	68	1904	9	20.134	20.134	1.96	20.210	20.210	1.80	19.867	19.867	1.73	20.025	20.025	1.77
3	2002/03	7 Sep 2002	15 May 2003	25	77	1925	8	19.546	19.546	1.81	18.863	18.863	1.60	19.276	19.276	1.60	19.104	19.104	1.61
4	2003/04	16 Sep 2003	1 June 2004	26	74	1924	8	20.959	20.959	1.89	21.167	21.167	2.74	18.819	18.819	1.56	19.912	19.912	2.09
5	2004/05	1 Sep 2004	27 April 2005	23	83	1909	7	17.753	17.753	1.73	17.013	17.103	1.51	17.833	17.833	1.53	17.472	17.472	1.53
1	2005/06	15 Apr 2005	27 April 2006	37	52	1924	9	19.440	19.440	1.55	19.459	19.451	1.39	19.451	19.451	1.35	19.454	19.454	1.37
2	2006/07	7 Sep 2006	1 May 2007	23	83	1909	7	17.561	17.561	1.75	17.641	17.641	1.62	17.308	17.308	1.56	17.461	17.461	1.59
3	2007/08	23 Aug 2007	1 June 2008	28	68	1904	9	22.088	22.088	1.90	22.179	22.179	1.74	21.848	21.848	1.68	22.000	22.000	1.71
4	2008/09	9 Oct 2008	4 May 2009	20	96	1920	6	21.101	21.101	1.68	21.112	21.112	1.65	21.242	21.242	1.64	21.181	21.181	1.65
5	2009/10	2 Sep 2009	1 June 2010	27	71	1917	9	21.117	21.117	1.84	21.218	21.218	1.71	21.218	21.218	1.65	21.215	21.215	1.68
1	2010/11	15 Apr 2010	30 April 2011	38	50	1900	10	21.704	21.704	1.63	21.719	21.719	1.47	21.706	21.706	1.43	21.712	21.712	1.45
2	2011/12	10 Sep 2011	23 May 2011	25	77	1925	8	19.351	19.351	1.85	19.433	19.433	1.69	19.130	19.130	1.63	19.269	19.269	1.66
3	2012/13	19 Sep 2012	23 April 2013	21	91	1911	7	18.635	18.635	1.74	18.890	18.890	1.65	18.211	19.211	1.61	18.521	18.521	1.63
4	2013/14	5 Oct 2013	14 May 2014	22	87	1914	7	18.223	18.223	1.66	18.321	18.321	1.61	18.122	18.122	1.58	18.212	18.212	1.60
5	2014/15	8 Sep 2014	20 April 2015	22	87	1914	7	18.001	18.001	1.70	18.012	18.012	1.67	18.012	18.012	1.57	18.012	18.012	1.62
1	2015/16	15 Apr 2015	29 May 2016	41	47	1927	11	24.482	24.482	1.87	24.449	24.449	1.67	24.458	24.458	1.61	24.455	24.455	1.64
2	2016/17	30 Aug 2016	17 May 2017	26	74	1924	8	20.821	20.821	1.91	20.912	20.912	1.75	20.571	20.571	1.68	20.728	20.728	1.72
3	2017/18	13 Sep 2017	17 May 2018	24	80	1920	8	18.711	18.711	1.91	18.789	18.789	1.75	18.491	18.491	1.69	18.628	18.628	1.72
4	2018/19	26 Sep 2018	1 June 2019	24	80	1920	8	19.395	19.395	1.97	20.239	20.239	1.86	19.568	19.568	1.73	19.855	19.855	1.79
5	2019/20	26 Aug 2019	18 May 2020	24	80	1920	8	21.358	21.358	1.97	21.454	21.454	1.8	21.454	21.454	1.73	21.451	21.451	1.77
1	2020/21	15 Apr 2020	11 May 2021	39	49	1911	10	22.128	22.128	1.72	22.145	22.145	1.55	22.142	22.142	1.49	22.143	22.143	1.52
2	2021/22	14 Sep 2021	12 May 2022	24	80	1920	8	18.484	18.484	1.99	18.550	18.550	1.82	18.254	18.254	1.75	18.391	18.391	1.79
3	2022/23	19 Sept 2022	17 May 2023	24	80	1920	8	19.399	19.399	1.98	19.485	19.485	1.80	19.110	19.110	1.71	19.283	19.283	1.76
Average				27.30	73.30	1916.78	8.22	19.97	19.97	1.80	20.01	20.01	1.70	19.78	19.83	1.60	19.886	19.886	1.65

Sources: Project team compilation

7.2.3.2.2 Partial Adoption scenario

For the Partial Adoption scenario in the Kakamas Irrigation Scheme, irrigation scheduling is based on soil moisture thresholds. Specifically, when 70% of the soil's Readily Available Water (RAW) is depleted, irrigation is triggered to replenish the soil back to field capacity. Although the scheduling follows a soil-

moisture-based strategy, irrigation is still carried out using traditional flood irrigation methods. The simulation results for each production year under this scenario are presented in Table 7.4 below.

Table 7.4: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Partial Adoption of Water-Saving Technologies

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Cuttings	Ferralic Arenosols				Eutric Fluvisols				Chromic Cambisols				Weighted average			
					Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	9	22.309	22.309	1124.2	1.83	22.327	22.327	1134.4	1.81	22.312	22.312	1142.2	1.79	22.318	22.318	1138.2	1.80
2	2001/02	10 Aug 2001	10 May 2002	9	18.767	18.767	706.5	2.31	21.260	21.20	768.7	2.22	21.231	21.231	931.2	2.17	21.165	21.165	853.1	2.20
3	2002/03	7 Sep 2002	15 May 2003	8	20.137	20.137	972.0	1.91	22.232	22.323	901.9	2.07	20.228	20.228	1034.5	1.84	21.100	21.100	974.6	1.94
4	2003/04	16 Sep 2003	1 June 2004	8	23.136	20.136	787.5	2.13	23.241	23.241	771.7	2.14	23.320	23.320	762.8	2.09	23.280	23.280	767.5	2.11
5	2004/05	1 Sep 2004	27 April 2005	7	20.366	20.366	801.7	1.98	20.346	20.346	884.6	1.91	20.324	20.324	895.9	1.88	20.335	20.335	888.0	1.90
1	2005/06	15 Apr 2005	27 April 2006	9	22.997	22.997	947.7	1.94	23.020	23.020	1001.7	1.86	22.965	22.965	998.2	1.84	22.990	22.990	998.1	1.85
2	2006/07	7 Sep 2006	1 May 2007	7	18.153	18.153	755	2.21	19.134	19.134	902.7	1.87	19.249	19.249	903.3	1.83	19.164	19.164	898.3	1.86
3	2007/08	23 Aug 2007	1 June 2008	9	23.551	23.551	800.1	2.14	23.380	23.380	771.6	2.09	23.416	23.416	925.8	2.03	23.405	23.405	854.5	2.06
4	2008/09	9 Oct 2008	4 May 2009	6	16.426	16.426	709.3	1.88	16.396	16.396	772.9	1.84	16.402	16.402	777.8	1.81	16.400	16.400	773.5	1.83
5	2009/10	2 Sep 2009	1 June 2010	9	22.566	22.566	858.9	2.07	22.515	22.515	907.5	2.02	22.578	22.578	900.0	1.99	22.550	22.550	902.0	2.01
1	2010/11	15 Apr 2010	30 April 2011	10	24.863	24.863	987.1	2.05	24.954	24.954	911.6	2.02	24.991	24.991	1056.5	1.97	24.971	24.971	991.0	1.99
2	2011/12	10 Sep 2011	23 May 2011	8	20.111	20.111	765.3	2.01	21.169	21.169	904.3	2.00	21.230	21.230	893.2	1.97	21.168	21.168	894.0	1.98
3	2012/13	19 Sep 2012	23 April 2013	7	17.071	17.071	777.0	1.83	17.107	17.107	753.5	1.79	17.102	17.102	767.9	1.76	17.103	17.103	761.9	1.78
4	2013/14	5 Oct 2013	14 May 2014	7	17.784	17.784	787.3	1.89	17.702	17.702	785.0	1.84	17.690	17.690	794.1	1.82	17.698	17.698	789.9	1.83
5	2014/15	8 Sep 2014	20 April 2015	7	17.891	17.891	846.8	1.79	17.850	17.850	857.4	1.76	17.837	17.837	868.8	1.73	17.844	17.844	863.1	1.75
1	2015/16	15 Apr 2015	29 May 2016	11	28.237	28.237	979.7	2.32	27.991	27.991	1064.0	2.28	28.417	28.417	1072.7	2.28	28.225	28.225	601.3	2.28
2	2016/17	30 Aug 2016	17 May 2017	8	19.541	19.541	711.4	2.22	22.379	22.379	899.1	2.06	22.406	22.406	886.1	2.05	22.303	22.303	886.2	2.06
3	2017/18	13 Sep 2017	17 May 2018	8	20.797	20.797	866.4	2.12	20.809	20.809	914.6	2.10	20.810	20.810	917.8	2.05	20.809	20.809	914.8	2.07
4	2018/19	26 Sep 2018	1 June 2019	8	21.523	21.523	906.0	2.17	21.458	21.458	909.7	2.13	21.418	21.418	894.4	2.13	21.439	21.439	901.4	2.13
5	2019/20	26 Aug 2019	18 May 2020	8	22.850	22.850	987.5	2.18	22.934	22.934	885.9	2.11	22.905	22.905	1035.7	2.06	22.916	22.916	968.8	2.09
1	2020/21	15 Apr 2020	11 May 2021	10	26.326	26.326	977.4	2.21	26.390	26.390	881.5	2.18	26.357	26.357	1029.0	2.15	26.370	26.370	963.0	2.17
2	2021/22	14 Sep 2021	12 May 2022	8	21.001	21.001	721.3	2.20	20.807	20.807	653.2	2.15	20.799	20.799	663.1	2.11	20.809	20.809	660.6	2.13
3	2022/23	19 Sept 2022	17 May 2023	8	21.268	21.268	794.8	2.23	21.244	21.244	778.5	2.19	21.217	21.217	784.4	2.16	21.230	21.230	782.2	2.18
Average				8.22	21.20	21.07	850.91	2.07	21.59	21.59	861.45	2.02	21.53	21.53	910.23	1.98	21.55	21.55	870.70	2.00

Source: Project team compilation

7.2.3.2.3 Full Adoption scenario

For the Full Adoption scenario involving the adoption of both soil moisture sensors and drip irrigation in the Kakamas Irrigation Scheme, irrigation is triggered when 70% of the soil's Readily Available Water (RAW) is depleted, and the soil is then irrigated back to field capacity. In this scenario, irrigation is performed via drip irrigation, marking a transition from the flood irrigation method used in the No Adoption and Partial Adoption scenarios. The simulation results for the various production years under this scenario are presented in Table 7.5 below.

Table 7.5: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Full Adoption of Water-Saving Technologies

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Cuttings	Ferralic Arenosols				Eutric Fluvisols				Chromic Cambisols				Weighted average			
					Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	Total Irrigation amount (mm)	WP _{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	9	22.286	22.286	1048.5	1.95	17.864	17.864	763.7	1.88	17.538	17.538	772.8	1.83	17.83	17.83	777.59	1.86
2	2001/02	10 Aug 2001	10 May 2002	9	21.938	21.938	806	2.40	18.676	18.676	637.0	2.46	18.969	18.969	647.3	2.44	18.94	18.94	647.85	2.45
3	2002/03	7 Sep 2002	15 May 2003	8	22.095	22.095	973.0	2.20	17.320	17.320	770.3	2.04	17.985	17.985	783.3	2.09	17.83	17.83	783.65	2.07
4	2003/04	16 Sep 2003	1 June 2004	8	23.156	23.156	793.4	2.26	18.594	18.594	651.1	2.07	17.790	17.790	771.7	2.09	18.31	18.31	719.73	2.09
5	2004/05	1 Sep 2004	27 April 2005	7	20.318	20.318	784.0	2.07	18.321	18.321	641.0	2.06	19.312	9.312	750.2	2.01	18.91	18.91	703.59	2.03
1	2005/06	15 Apr 2005	27 April 2006	9	23.021	23.021	955.7	2.01	18.422	18.422	642.7	1.89	17.991	17.991	654.2	1.81	18.34	18.34	658.76	1.85
2	2006/07	7 Sep 2006	1 May 2007	7	19.201	19.201	794.8	2.01	18.771	18.771	630.12	1.99	18.808	18.808	655.3	1.95	19.90	19.90	648.74	2.05
3	2007/08	23 Aug 2007	1 June 2008	9	23.580	23.580	792.5	2.22	20.766	20.766	646.4	2.21	21.043	21.043	649.4	2.19	21.00	21.00	652.64	2.20
4	2008/09	9 Oct 2008	4 May 2009	6	16.433	16.433	717.4	1.97	20.876	20.876	663.0	2.20	19.058	19.058	667.8	2.02	19.80	19.80	667.28	2.10
5	2009/10	2 Sep 2009	1 June 2010	9	22.595	22.595	876.0	2.17	19.998	19.998	628.0	2.20	19.975	19.975	638.6	2.18	20.07	20.07	641.51	2.19
1	2010/11	15 Apr 2010	30 April 2011	10	24.967	24.967	892.2	2.17	20.468	20.468	655.9	2.05	19.990	19.990	659.2	1.99	21.00	21.00	665.16	2.10
2	2011/12	10 Sep 2011	23 May 2011	8	21.167	21.167	790.3	2.15	20.111	20.111	621.3	2.23	19.335	19.335	677.0	1.98	20.26	20.26	656.28	2.09
3	2012/13	19 Sep 2012	23 April 2013	7	17.122	17.122	688.8	1.94	20.001	20.001	639.5	2.11	20.053	20.053	661.0	2.01	19.94	19.94	652.50	2.05
4	2013/14	5 Oct 2013	14 May 2014	7	17.802	17.802	785.6	1.97	19.981	19.981	655.5	2.04	20.001	20.001	690.0	2.00	19.92	19.92	677.97	2.02
5	2014/15	8 Sep 2014	20 April 2015	7	17.856	17.856	861.7	1.89	20.001	20.001	680.3	1.95	18.032	18.032	712.3	1.99	19.42	19.42	703.07	1.97
1	2015/16	15 Apr 2015	29 May 2016	11	28.167	28.167	917.9	2.50	23.139	23.139	656.4	2.38	22.719	22.719	815.8	2.33	23.08	23.08	749.44	2.36
2	2016/17	30 Aug 2016	17 May 2017	8	22.363	22.363	883.5	2.23	19.375	19.375	636.6	2.28	19.574	19.574	769.7	2.25	19.58	19.58	715.20	2.26
3	2017/18	13 Sep 2017	17 May 2018	8	20.793	20.793	805.0	2.26	19.231	19.231	647.7	2.02	19.821	19.821	740.5	2.12	20.13	20.13	702.03	2.08
4	2018/19	26 Sep 2018	1 June 2019	8	21.489	21.489	799.1	2.33	19.220	19.220	651.8	2.05	20.436	20.436	723.6	2.41	19.94	19.94	694.65	2.25
5	2019/20	26 Aug 2019	18 May 2020	8	22.853	22.853	886.5	2.29	20.024	20.024	641.3	2.37	20.041	20.041	785.0	2.35	20.15	20.15	725.48	2.36
1	2020/21	15 Apr 2020	11 May 2021	10	26.288	26.288	876.8	2.34	21.000	21.000	662.2	2.22	20.634	20.634	664.0	2.16	20.97	20.97	669.98	2.19

2	2021/22	14 Sep 2021	12 May 2022	8	20.706	20.706	630.4	2.30	20.155	20.155	630.5	2.31	19.550	19.550	715.0	2.06	19.91	19.91	675.41	2.18
3	2022/23	19 Sept 2022	17 May 2023	8	21.163	21.163	817.8	2.32	20.010	20.010	649.0	2.01	20.583	20.583	733.578	2.10	20.35	20.35	699.32	2.07
Average				8.22	21.84	21.84	833.78	2.17	19.67	19.67	656.58	2.13	19.80	19.37	710.32	2.12	19.81	19.81	690.77	2.12

Source: Project team compilation

7.2.3.2.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water-saving Technologies

Table 7.6 below presents the summary of results for the various scenarios under the water use behaviour of adopting water-saving technologies in the Kakamas Irrigation Scheme. The table compares yield outcomes across the no adoption, partial adoption, and full adoption scenarios. The percentage changes in yields for the partial and full adoption scenarios, relative to the no adoption baseline, will be used as input shocks in the Social Accounting Matrix through multiplier analysis to assess broader socio-economic impacts.

Table 7.6: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Lucerne Production in the Kakamas Irrigation Scheme for the adoption of water-saving technologies

	No Adoption	Soil Moisture sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	19.8864668	21.55	19.81
Yield (ton/ha)	19.8864668	21.55	19.81
% Change of yield compared to no adoption	-	8.35%	-8.08%
Irrigation (mm)	1916.78	870.70	690.77
WP_{ET} (Kg/m ³)	1.65	2.00	2.12

Source: Project team compilation

7.2.3.3 The adoption of water-saving policies

7.2.3.3.1 No-Adoption scenario

The No Adoption scenario will not be simulated, as it is identical to the no adoption scenario previously simulated under the adoption of water-saving policies, where the net gross irrigation requirement of 1925.5 mm is applied in equal increments at 10-day intervals throughout the growing season.

7.2.3.3.2 Partial Adoption scenario

For the partial adoption of water-saving policies scenario, it is assumed that a 30% water restriction is implemented. As a result, the net gross irrigation requirement of 1925.5 mm, which is allocated under no restriction, is reduced to 1347.9 mm ($1925.5 \times (1 - 0.3) = 1347.9$) of water to be irrigated throughout the

growing season in 10-day intervals. The results of the simulation for the partial adoption scenario of water-saving policies are presented in Table 7.7 below.

Table 7.7: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Partial Adoption of Water-Saving Policies

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
								Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	36	1332	9	15.072	15.072	1.42	15	15	1.23	14.182	14.182	1.15	14.57	14.57	1.18
2	2001/02	10 Aug 2001	10 May 2002	28	48	1344	9	17.651	17.651	1.93	18.771	18.771	1.8	18.17	18.17	1.71	18.42	18.42	1.74
3	2002/03	7 Sep 2002	15 May 2003	25	53	1325	8	15.78	15.78	1.79	17.089	17.089	1.62	16.237	16.237	1.57	16.59	16.59	1.59
4	2003/04	16 Sep 2003	1 June 2004	26	51	1326	8	17.928	17.928	1.79	18.463	18.463	1.67	16.745	16.745	1.62	17.53	17.53	1.64
5	2004/05	1 Sep 2004	27 April 2005	23	58	1334	7	18.566	18.566	1.81	19.001	19.001	1.7	18.761	18.761	1.71	18.86	18.86	1.71
1	2005/06	15 Apr 2005	27 April 2006	37	36	1332	9	16.692	16.92	1.53	17.697	17.691	1.35	17.128	17.128	1.27	17.36	17.36	1.30
2	2006/07	7 Sep 2006	1 May 2007	23	58	1334	7	16.522	16.522	1.63	18.781	18.781	1.55	17.835	17.835	1.54	18.21	18.21	1.55
3	2007/08	23 Aug 2007	1 June 2008	28	48	1344	9	20.019	20.019	1.88	20.032	20.032	1.71	20.297	20.297	1.67	20.17	20.17	1.69
4	2008/09	9 Oct 2008	4 May 2009	20	67	1340	6	18.353	18.353	1.79	18.883	18.883	1.8	18.141	18.141	1.71	18.47	18.47	1.73
5	2009/10	2 Sep 2009	1 June 2010	27	49	1323	9	18.984	18.984	1.84	18.991	18.991	1.67	19.165	9.165	1.62	19.08	19.08	1.64
1	2010/11	15 Apr 2010	30 April 2011	38	35	1330	10	19.408	19.408	1.62	19.121	19.121	1.44	18.262	18.262	1.36	18.67	18.67	1.39
2	2011/12	10 Sep 2011	23 May 2011	25	53	1325	8	17.335	17.335	1.63	17.944	17.944	1.51	17.899	17.899	1.54	17.90	17.90	1.54
3	2012/13	19 Sep 2012	23 April 2013	21	64	1344	7	18.111	18.111	1.69	18.789	16.789	1.63	18.335	18.335	1.65	18.53	18.53	1.65
4	2013/14	5 Oct 2013	14 May 2014	22	61	1342	7	18.897	18.897	1.71	19.419	19.419	1.74	18.811	18.811	1.72	19.08	19.08	1.72
5	2014/15	8 Sep 2014	20 April 2015	22	61	1342	7	19.117	19.117	1.81	17.055	17.055	1.55	18.599	18.599	1.33	17.94	17.94	1.40
1	2015/16	15 Apr 2015	29 May 2016	41	32	1312	11	21.762	21.762	1.86	20.505	20.505	1.58	19.09	19.09	1.45	19.79	19.79	1.50
2	2016/17	30 Aug 2016	17 May 2017	26	51	1326	8	18.533	18.533	1.89	18.536	18.536	1.72	17.701	17.701	1.66	18.09	18.09	1.69
3	2017/18	13 Sep 2017	17 May 2018	24	56	1344	8	19.589	19.589	1.75	19.014	19.014	1.68	18.899	18.899	1.61	18.97	18.97	1.63
4	2018/19	26 Sep 2018	1 June 2019	24	56	1344	8	19.119	19.119	1.69	20.045	20.045	1.65	18.453	18.453	1.71	19.17	19.17	1.70
5	2019/20	26 Aug 2019	18 May 2020	24	56	1344	8	18.991	18.991	1.73	18.769	18.769	1.63	19.401	19.401	1.71	19.11	19.11	1.69
1	2020/21	15 Apr 2020	11 May 2021	39	34	1326	10	20.181	20.181	1.72	20.099	20.099	1.52	19.148	19.148	1.41	19.60	19.60	1.45
2	2021/22	14 Sep 2021	12 May 2022	24	56	1344	8	17.231	17.231	1.68	19.901	19.901	1.66	18.529	18.529	1.62	19.09	19.09	1.63
3	2022/23	19 Sept 2022	17 May 2023	24	56	1344	8	18.231	18.231	1.75	18.566	18.566	1.71	17.014	17.014	1.65	17.73	17.73	1.67
Average				27.30	51.09	1334.83	8.22	18.35	18.36	1.74	18.72	18.63	1.61	18.12	17.69	1.56	18.39	18.39	1.58

Source: Project team compilation

7.2.3.3.3 Full adoption scenario

For the full adoption of the water-saving policies scenario in the Kakamas Irrigation Scheme, a 70% water restriction is imposed. Consequently, the gross irrigation requirement of 1925.5 mm, which is allocated for irrigation under no restriction, is reduced to 577.7 mm ($1925.5 \times (1 - 0.7) = 577.7$). This 577.7 mm will be evenly distributed throughout the growing season in intervals spaced 10 days apart. The results of the simulation under the full adoption of water-saving policies scenario in the Kakamas Irrigation Scheme are presented in Table 7.8 below.

Table 7.8: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Full Adoption of Water-Saving Policies

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
								Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	15	555	9	7.457	7.457	0.93	8.338	8.338	0.90	7.028	7.028	0.75	7.614	7.614	0.821
2	2001/02	10 Aug 2001	10 May 2002	28	20	560	9	9.926	9.926	1.36	10.987	10.987	1.30	9.185	9.185	0.81	9.995	9.995	1.041
3	2002/03	7 Sep 2002	15 May 2003	25	23	575	8	11.628	11.628	1.30	12.561	12.561	1.36	11.007	11.007	1.28	11.705	11.705	1.316
4	2003/04	16 Sep 2003	1 June 2004	26	22	572	8	15.744	15.744	1.75	16.887	16.887	1.67	15.747	15.747	1.59	16.245	16.245	1.630
5	2004/05	1 Sep 2004	27 April 2005	23	25	575	7	13.889	13.889	1.51	14.551	14.551	1.55	13.443	13.443	1.21	13.941	13.941	1.368
1	2005/06	15 Apr 2005	27 April 2006	37	15	555	9	9.871	9.871	1.30	11.269	11.269	1.20	13.521	13.521	1.40	12.422	12.422	1.309
2	2006/07	7 Sep 2006	1 May 2007	23	25	575	7	11.558	11.558	0.98	12.654	12.654	1.05	11.135	11.135	0.91	11.812	11.812	0.973
3	2007/08	23 Aug 2007	1 June 2008	28	20	560	9	13.382	13.382	1.51	15.232	15.232	1.50	14.204	14.204	1.60	14.627	14.627	1.553
4	2008/09	9 Oct 2008	4 May 2009	20	28	560	6	12.210	12.210	1.19	13.589	13.589	1.45	12.350	12.350	1.13	12.887	12.887	1.272
5	2009/10	2 Sep 2009	1 June 2010	27	21	567	9	13.815	13.815	1.59	11.699	11.699	1.20	12.552	12.552	1.28	12.220	12.220	1.255
1	2010/11	15 Apr 2010	30 April 2011	38	15	570	10	12.422	12.422	1.32	13.205	13.205	1.25	11.741	11.741	1.11	12.402	12.402	1.178
2	2011/12	10 Sep 2011	23 May 2011	25	23	575	8	11.531	11.531	1.05	12.891	12.891	1.42	12.351	12.351	1.19	12.561	12.561	1.286
3	2012/13	19 Sep 2012	23 April 2013	21	27	567	7	13.890	13.890	1.35	14.112	14.112	1.38	13.618	13.618	1.24	13.842	13.842	1.305
4	2013/14	5 Oct 2013	14 May 2014	22	26	572	7	13.325	13.325	1.25	13.898	13.898	1.26	12.543	12.543	1.30	13.160	13.160	1.281
5	2014/15	8 Sep 2014	20 April 2015	22	26	572	7	11.311	11.311	1.20	10.881	10.881	1.14	10.331	10.331	1.10	10.602	10.602	1.121
1	2015/16	15 Apr 2015	29 May 2016	41	14	574	11	11.574	11.574	1.30	12.685	12.685	1.27	9.834	9.834	0.99	11.134	11.134	1.122
2	2016/17	30 Aug 2016	17 May 2017	26	22	572	8	10.995	10.995	1.02	11.011	11.011	1.08	10.558	10.558	0.95	10.770	10.770	1.009
3	2017/18	13 Sep 2017	17 May 2018	24	24	576	8	11.641	11.641	0.92	11.121	11.121	0.95	11.513	11.513	0.98	11.346	11.346	0.965
4	2018/19	26 Sep 2018	1 June 2019	24	24	576	8	8.890	8.890	0.98	9.571	9.571	1.12	8.35	8.35	0.77	8.900	8.900	0.930
5	2019/20	26 Aug 2019	18 May 2020	24	24	576	8	9.301	9.301	1.31	11.780	11.780	1.29	12.205	12.205	1.33	11.927	11.927	1.312
1	2020/21	15 Apr 2020	11 May 2021	39	14	546	10	12.805	12.805	1.36	14.807	14.807	1.35	11.608	11.608	1.12	13.043	13.043	1.228

2	2021/22	14 Sep 2021	12 May 2022	24	24	576	8	12.311	12.311	1.43	11.441	11.441	1.21	11.325	11.325	1.01	11.407	11.407	1.111
3	2022/23	19 Sept 2022	17 May 2023	24	24	576	8	10.882	10.882	1.00	12.329	12.329	1.34	9.735	9.735	1.02	10.904	10.904	1.159
Average				27.30	21.78	568.78	8.22	11.75	11.75	1.25	12.50	12.50	1.27	11.56	11.56	1.12	11.98	11.98	1.20

Source: Project team compilation

7.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water-Saving Policies

Table 7.9 below summarises the results for the various scenarios simulated for the adoption of water-saving policies in the Kakamas Irrigation Scheme.

Table 7.9: Results for the various scenarios simulated for the adoption of water-saving policies in the Kakamas Irrigation Scheme

	No Adoption	Soil Moisture sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	19.89	18.39	11.98
Yield (ton/ha)	19.89	18.39	11.98
% Change of yield compared to no adoption	-	-8.15%	-66.04%
Irrigation (mm)	1916.78	1334.83	568.78
WP_{ET} (Kg/m ³)	1.65	1.58	1.20

Source: Project team compilation

7.2.3.4 The adaptation towards climate variability

7.2.3.4.1 No-Adaption scenario

The no-adaptation scenario to climate variability assumes that the full Gross Irrigation Requirement (GIR), as previously calculated, is applied evenly across the growing season. Because of the perennial nature and regrowth characteristics of lucerne, no mulching is implemented in this scenario, as it is not agronomically suitable. Weed management is set to poor, allowing for significant weed-crop competition. Although the irrigation schedule remains the same as in the no-adoption scenario for water-saving technologies and policies, separate AquaCrop model simulations were required to account for the exclusion of mulching and the impact of poor weed control. Table 7.10 below presents the AquaCrop model simulation results for the no-adaptation to climate variability scenario.

Table 7.10: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of No-Adaptation to Climate variability

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
								Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	52	1924	9	12.289	12.289	0.98	13.073	13.073	0.91	12.814	12.814	0.88	12.91	12.91	0.90
2	2001/02	10 Aug 2001	10 May 2002	28	68	1904	9	13.275	13.275	1.32	13.564	13.564	1.21	13.145	13.145	1.16	13.33	13.33	1.19
3	2002/03	7 Sep 2002	15 May 2003	25	77	1925	8	12.341	12.341	0.99	13.060	13.060	1.11	12.189	12.189	1.03	12.57	12.57	1.06
4	2003/04	16 Sep 2003	1 June 2004	26	74	1924	8	13.191	13.191	1.17	13.953	13.953	1.15	13.472	13.472	1.10	13.67	13.67	1.12
5	2004/05	1 Sep 2004	27 April 2005	23	83	1909	7	12.110	12.110	1.02	11.867	11.867	1.05	11.303	11.303	1.00	11.57	11.57	1.02
1	2005/06	15 Apr 2005	27 April 2006	37	52	1924	9	12.540	12.540	1.03	12.295	12.295	0.93	13.216	13.216	0.91	12.79	12.79	0.92
2	2006/07	7 Sep 2006	1 May 2007	23	83	1909	7	12.781	12.781	1.11	11.906	11.906	1.09	11.483	11.483	1.05	11.71	11.71	1.07
3	2007/08	23 Aug 2007	1 June 2008	28	68	1904	9	14.824	14.824	1.28	14.699	14.699	1.16	14.421	14.421	1.12	14.56	14.56	1.14
4	2008/09	9 Oct 2008	4 May 2009	20	96	1920	6	12.578	12.578	1.22	12.234	12.234	1.18	12.982	12.982	1.15	12.64	12.64	1.17
5	2009/10	2 Sep 2009	1 June 2010	27	71	1917	9	13.977	13.997	1.21	13.983	13.983	1.13	13.688	13.688	1.09	13.83	13.83	1.11
1	2010/11	15 Apr 2010	30 April 2011	38	50	1900	10	13.865	13.865	1.09	13.821	13.821	1.01	14.412	14.412	0.97	14.14	14.14	0.99
2	2011/12	10 Sep 2011	23 May 2011	25	77	1925	8	12.456	12.456	1.05	13.176	13.176	1.15	12.702	12.702	1.10	12.90	12.90	1.12
3	2012/13	19 Sep 2012	23 April 2013	21	91	1911	7	13.917	13.917	1.15	12.546	12.546	1.01	14.112	14.112	1.05	13.42	13.42	1.04
4	2013/14	5 Oct 2013	14 May 2014	22	87	1914	7	12.879	12.879	0.97	12.581	12.581	0.95	13.559	13.559	1.10	13.11	13.11	1.03
5	2014/15	8 Sep 2014	20 April 2015	22	87	1914	7	13.960	13.960	1.01	13.561	13.561	0.99	14.221	14.221	1.18	13.92	13.92	1.09
1	2015/16	15 Apr 2015	29 May 2016	41	47	1927	11	15.791	15.1791	1.24	16.673	16.673	1.13	16.347	16.147	1.08	16.47	16.47	1.11
2	2016/17	30 Aug 2016	17 May 2017	26	74	1924	8	14.825	14.825	1.15	14.047	14.047	1.18	13.670	13.670	1.14	13.87	13.87	1.16
3	2017/18	13 Sep 2017	17 May 2018	24	80	1920	8	13.555	13.555	1.21	12.674	12.674	1.19	14.142	14.142	1.10	13.48	13.48	1.14
4	2018/19	26 Sep 2018	1 June 2019	24	80	1920	8	12.581	12.581	1.11	13.084	13.084	1.21	12.525	12.525	1.14	12.77	12.77	1.17
5	2019/20	26 Aug 2019	18 May 2020	24	80	1920	8	13.671	13.671	1.01	14.194	14.194	1.19	13.846	13.846	1.15	13.99	13.99	1.16
1	2020/21	15 Apr 2020	11 May 2021	39	49	1911	10	14.346	14.346	1.16	15.482	15.482	1.07	15.109	15.109	1.02	15.25	15.25	1.05
2	2021/22	14 Sep 2021	12 May 2022	24	80	1920	8	13.895	13.895	1.34	12.615	12.615	1.24	12.711	12.711	1.04	12.71	12.71	1.14
3	2022/23	19 Sept 2022	17 May 2023	24	80	1920	8	14.687	14.687	1.12	13.010	13.010	1.20	12.583	12.583	1.14	12.84	12.84	1.17
Average				27.30	73.30	1916.78	8.22	13.49	13.47	1.13	13.40	13.40	1.11	13.42	13.41	1.07	13.41	13.41	1.09

Source: Project team compilation

7.2.3.4.2 Partial Adaptation scenario

Under the partial adaptation to climate variability scenario, weed management is set to moderate, and a 20% deficit irrigation strategy is implemented. This reduces the net irrigation requirement of 1925.5 mm to 1540.4 mm ($1925.5 \times 0.8 = 1540.4$ mm), which is applied evenly at 10-day intervals throughout the growing season. Table 7.11 below presents the results obtained from the simulation conducted for the partial adaptation scenario.

Table 7.11: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Partial Adaptation to Climate Variability

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
								Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP_{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	41.00	1517.00	9	14.872	14.872	1.24	12.156	12.156	0.89	12.446	12.446	0.89	12.3965	12.3965	0.9011
2	2001/02	10 Aug 2001	10 May 2002	28	55.00	1540.00	9	16.426	16.426	1.63	16.391	16.391	1.48	16.201	16.201	1.41	16.2911	16.2911	1.4476
3	2002/03	7 Sep 2002	15 May 2003	25	61.00	1525.00	8	15.600	15.600	1.47	15.035	15.035	1.29	15.615	15.615	1.30	15.3613	15.3613	1.3010
4	2003/04	16 Sep 2003	1 June 2004	26	59.00	1534.00	8	16.694	16.694	1.53	16.717	16.717	1.39	16.714	16.714	1.35	16.7147	16.7147	1.3732
5	2004/05	1 Sep 2004	27 April 2005	23	67.00	1541.00	7	13.731	13.731	1.35	14.135	14.135	1.27	14.373	14.373	1.25	14.2487	14.2487	1.2619
1	2005/06	15 Apr 2005	27 April 2006	37	41.00	1517.00	9	15.976	15.976	1.31	13.360	13.360	0.96	13.246	13.246	0.93	13.3825	13.3825	0.9552
2	2006/07	7 Sep 2006	1 May 2007	23	66.00	1518.00	7	14.151	14.151	1.44	14.161	14.161	1.32	14.160	14.160	1.28	14.1602	14.1602	1.3025
3	2007/08	23 Aug 2007	1 June 2008	28	55.00	1540.00	9	17.702	17.702	1.54	17.771	17.771	1.41	17.714	17.714	1.37	17.7385	17.7385	1.3929
4	2008/09	9 Oct 2008	4 May 2009	20	77.00	1540.00	6	16.592	16.592	1.54	16.321	16.321	1.50	16.320	16.320	1.47	16.3291	16.3291	1.4853
5	2009/10	2 Sep 2009	1 June 2010	27	57.00	1539.00	9	17.685	17.685	1.56	16.861	16.861	1.37	16.854	16.854	1.33	16.8835	16.8835	1.3548
1	2010/11	15 Apr 2010	30 April 2011	38	40.00	1520.00	10	17.859	17.859	1.36	14.788	14.788	1.01	14.701	14.701	0.98	14.8393	14.8393	1.0052
2	2011/12	10 Sep 2011	23 May 2011	25	61.00	1525.00	8	15.676	15.676	1.52	15.690	15.690	1.38	15.690	15.690	1.34	15.6896	15.6896	1.3632
3	2012/13	19 Sep 2012	23 April 2013	21	73.00	1533.00	7	16.721	16.721	1.45	16.352	16.352	1.30	16.511	16.511	1.28	16.4482	16.4482	1.2941
4	2013/14	5 Oct 2013	14 May 2014	22	70.00	1540.00	7	16.995	16.995	1.40	16.554	16.554	1.25	16.545	16.545	1.23	16.5632	16.5632	1.2441
5	2014/15	8 Sep 2014	20 April 2015	22	70.00	1540.00	7	17.852	17.852	1.59	17.231	17.231	1.53	17.431	17.431	1.56	17.3570	17.3570	1.5479
1	2015/16	15 Apr 2015	29 May 2016	41	37.00	1517.00	11	19.792	19.792	1.56	16.465	16.465	1.15	16.188	16.188	1.11	16.4235	16.4235	1.1418
2	2016/17	30 Aug 2016	17 May 2017	26	59.00	1534.00	8	16.804	16.804	1.56	16.815	16.815	1.43	16.813	16.813	1.38	16.8136	16.8136	1.4076
3	2017/18	13 Sep 2017	17 May 2018	24	64.00	1536.00	8	15.078	15.078	1.56	15.088	15.088	1.43	15.088	15.088	1.38	15.0877	15.0877	1.4076
4	2018/19	26 Sep 2018	1 June 2019	24	64.00	1536.00	8	15.561	15.561	1.60	15.572	15.572	1.45	17.295	17.295	1.41	16.4876	16.4876	1.4335
5	2019/20	26 Aug 2019	18 May 2020	24	64.00	1536.00	8	17.060	17.060	1.59	17.073	17.073	1.45	17.073	17.073	1.39	17.0726	17.0726	1.4226
1	2020/21	15 Apr 2020	11 May 2021	39	39.00	1521.00	10	18.378	18.378	1.44	15.213	15.213	1.06	15.154	15.154	1.02	15.2822	15.2822	1.0508
2	2021/22	14 Sep 2021	12 May 2022	24	64.00	1536.00	8	14.994	14.994	1.63	14.999	14.999	1.48	14.999	14.999	1.44	14.9988	14.9988	1.4635

3	2022/23	19 Sept 2022	17 May 2023	24	64.00	1536.00	8	15.508	15.508	1.61	15.515	15.515	1.45	15.515	15.515	1.39	15.5148	15.5148	1.4232
Average				27.304	58.609	1531.348	8.217	16.4220	16.4220	1.4991	15.6636	15.6636	1.3152	15.7672	15.7672	1.2822	15.7428	15.7428	1.3035

Source: Project team compilation

7.2.3.4.3 Full adaptation scenario

Under the full adaptation to the climate variability scenario, weed management is set to be perfect in the AquaCrop model, and a 30% deficit irrigation strategy is implemented. This reduces the net irrigation requirement from 1925.5 mm to 1347.9 mm ($1925.5 \times 0.7 = 1347.9$ mm). The irrigation method is changed from surface border irrigation to sprinkler irrigation. While strategic irrigation based on critical growth stages was applied for other crops, this was not feasible for lucerne because of variability in production start and end dates, which are determined by a temperature criterion and vary across years. To maintain consistency, the total irrigation depth of 1347.9 mm was applied at fixed 10-day intervals throughout the season. Table 7.12 below presents the simulation results for the Kakamas Irrigation Scheme under the full adaptation to the climate variability scenario.

Table 7.12: Simulation Results for Lucerne Production in the Kakamas Irrigation Scheme under the Scenario of Full Adaptation towards climate variability

Crop Cycle Year	Calendar Year	Restart date	End date	Number of Irrigation Intervals	Irrigation amount per interval (mm)	Total Irrigation amount (mm)	Number of Cuttings	Ferralic Arenosols			Eutric Fluvisols			Chromic Cambisols			Weighted Average		
								Biomass (ton/ha)	Dry Yield (ton/ha)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP _{ET} (Kg/m ³)	Biomass (ton/ha)	Dry Yield (ton/ha)	WP _{ET} (Kg/m ³)
1	2000/01	15 Apr 2000	23 Apr 2001	37	36.00	1332.00	9	19.364	19.364	1.58	16.938	16.938	1.29	16.629	16.629	1.24	16.851	16.851	1.273
2	2001/02	10 Aug 2001	10 May 2002	28	48.00	1344.00	9	19.827	19.827	1.98	19.620	19.620	1.78	19.951	19.951	1.72	19.803	19.803	1.754
3	2002/03	7 Sep 2002	15 May 2003	25	53.00	1325.00	8	19.016	19.016	1.81	19.031	19.031	1.64	18.991	18.991	1.60	19.009	19.009	1.624
4	2003/04	16 Sep 2003	1 June 2004	26	51.00	1326.00	8	20.402	20.402	1.87	20.442	20.442	1.71	20.434	20.434	1.66	20.436	20.436	1.689
5	2004/05	1 Sep 2004	27 April 2005	23	58.00	1334.00	7	17.411	17.411	1.74	17.331	17.331	1.56	17.324	17.324	1.51	17.330	17.330	1.539
1	2005/06	15 Apr 2005	27 April 2006	37	36.00	1332.00	9	21.091	21.091	1.70	18.930	18.930	1.40	18.577	18.577	1.34	18.811	18.811	1.378
2	2006/07	7 Sep 2006	1 May 2007	23	58.00	1334.00	7	17.145	17.415	1.75	17.159	17.159	1.59	17.156	17.156	1.55	17.157	17.157	1.574
3	2007/08	23 Aug 2007	1 June 2008	28	48.00	1344.00	9	21.677	21.677	1.89	21.690	21.690	1.73	21.674	21.674	1.68	21.681	21.681	1.709
4	2008/09	9 Oct 2008	4 May 2009	20	67.00	1340.00	6	22.867	22.867	1.93	22.001	22.001	1.78	21.780	21.780	1.72	21.911	21.911	1.753
5	2009/10	2 Sep 2009	1 June 2010	27	49.00	1323.00	9	20.664	20.664	1.85	20.678	20.678	1.69	20.605	20.605	1.64	20.639	20.639	1.669
1	2010/11	15 Apr 2010	30 April 2011	38	35.00	1330.00	10	24.277	24.277	1.81	21.100	21.100	1.49	20.396	20.396	1.42	20.827	20.827	1.463
2	2011/12	10 Sep 2011	23 May 2011	25	53.00	1325.00	8	18.981	18.981	1.84	18.999	18.999	1.67	18.996	18.996	1.63	18.997	18.997	1.654
3	2012/13	19 Sep 2012	23 April 2013	21	64.00	1344.00	7	20.819	20.819	1.92	20.635	20.635	1.88	20.115	20.115	1.86	20.364	20.364	1.871
4	2013/14	5 Oct 2013	14 May 2014	22	61.00	1342.00	7	22.534	22.534	1.87	21.553	21.553	1.78	21.443	21.443	1.71	21.526	21.526	1.746
5	2014/15	8 Sep 2014	20 April 2015	22	61.00	1342.00	7	21.876	21.876	1.86	21.557	20.557	1.68	20.176	20.176	1.72	20.833	20.833	1.707

1	2015/16	15 Apr 2015	29 May 2016	41	32.00	1312.00	11	25.833	25.833	1.88	22.848	22.828	1.66	21.634	21.634	1.55	22.298	22.298	1.609
2	2016/17	30 Aug 2016	17 May 2017	26	51.00	1326.00	8	20.358	20.358	1.90	20.363	20.363	1.74	20.321	20.321	1.68	20.341	20.341	1.713
3	2017/18	13 Sep 2017	17 May 2018	24	56.00	1344.00	8	18.368	18.368	1.90	18.383	18.383	1.74	18.381	18.381	1.68	18.381	18.381	1.713
4	2018/19	26 Sep 2018	1 June 2019	24	56.00	1344.00	8	18.937	18.937	1.96	18.950	18.950	1.77	18.947	18.947	1.71	18.948	18.948	1.744
5	2019/20	26 Aug 2019	18 May 2020	24	56.00	1344.00	8	20.940	20.940	1.97	20.956	20.956	1.78	20.950	20.950	1.72	20.952	20.952	1.754
1	2020/21	15 Apr 2020	11 May 2021	39	34.00	1326.00	10	25.001	25.001	1.90	20.044	20.044	1.57	21.512	21.512	1.49	20.982	20.982	1.538
2	2021/22	14 Sep 2021	12 May 2022	24	56.00	1344.00	8	18.142	18.142	1.98	18.148	18.148	1.79	18.148	18.148	1.75	18.148	18.148	1.775
3	2022/23	19 Sept 2022	17 May 2023	24	56.00	1344.00	8	18.932	18.932	1.97	18.941	18.941	1.77	18.939	18.939	1.71	18.940	18.940	1.744
Average				27.304	51.087	1334.826	8.217	20.629	20.641	1.863	19.839	19.795	1.673	19.699	19.699	1.621	19.790	19.790	1.652

Source: Project team compilation

7.2.3.4.4 Summary of AquaCrop Model Simulation Results for the Adaptation towards Climate Variability

Table 7.13 below presents the results of the different adaptation behaviour scenarios towards climate variability for lucerne production in the Kakamas Irrigation Scheme, including the No-Adaptation, Partial Adaptation, and Full Adaptation scenarios.

Table 7.13: Summary of Average Biomass, Yield, Irrigation, and Water Productivity for Lucerne Production under Different Adaptation Scenarios towards Climate variability in the Kakamas Irrigation Scheme

	No Adoption	Soil Moisture sensor	Drip + Soil Moisture sensor
Biomass (ton/ha)	13.41	15.74	19.79
Yield (ton/ha)	13.41	15.74	19.79
% Change of yield compared to no adoption	-	17.38%	47.56%
Irrigation (mm)	1916.78	1531.35	1334.83
WP_{ET} (Kg/m ³)	1.09	1.30	1.65

Source: Project team compilation

7.2.4 Multiplier Analysis

This section presents the results of the multiplier analysis based on changes in lucerne yield obtained from AquaCrop model simulations. In the analysis, only the yield changes from the partial and full scenarios are used, as these reflect the impact of changing behaviour. The no-adoption scenario serves as the reference point and is therefore not included in the multiplier analysis results. Table 7.14 below presents the main multiplier results for all three behaviours under both partial and full adoption scenarios.

Table 7.14: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Kakamas Irrigation Scheme for commercial lucerne irrigators

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (+8.35%)	Full (-8.08%)	Partial (-8.15%)	Full (-66.04%)	Partial (+17.38%)	Full (+47.56%)
Maize small-scale Limpopo	22.78	21.38	21.74	104.05	416.59	989.21
Total labour remuneration in SA	35.99	14.64	34.18	77.53	105.75	186.44
Limpopo province generates labour return	6.76	6.85	2.67	5.15	12.49	34.18
Gross operating surplus SA	9.86	3.86	3.2	7.06	59.9	153.31
Household income for Limpopo	93.41	33.08	74.41	190.17	382.32	846.69
Land return in SA	11.79	2.99	4.1	8.89	39.13	97.98
land return to irrigation in Limpopo	R176, 665.9	R24, 7355.56	R61, 498.21	R133,317.38	R485,227.75	R1, 316,870.0
Institution income SA (enterprise + Household)	37.24	16.88	22.82	76.86	333.24	908.95
Household generating income SA	31.43	15.73	20.79	70.65	298.89	878.27
Value-added generating income SA (Labour + capital + land)	189.42	79.92	73.25	138.77	172.14	470.52

Source: Project team compilation

7.2.4.1 Adoption of water-saving technologies

7.2.4.1.1 Partial Adoption

As indicated in Table 7.14, the partial adoption of water-saving technologies based on irrigation scheduling using soil moisture levels resulted in a R22.78 million lucerne output in the Kakamas Irrigation Scheme and in the economy of the Northern Cape (NC) province of South Africa. The total labour remuneration was estimated at R35.99 million in South Africa, of which NC province generates a labour return of about R6.76 million and a gross operating surplus (capital) of R9.86 million. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R 93.41 million towards the economy of the NC province. The overall land return was estimated at R11.79 million in the economy of South Africa, of which the return to irrigation in NC was only R176 665.90. The highest return on irrigation in the province of NC was found in the Namakwa irrigation district, followed by ZF Mgcawu and Frances Baard irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) were valued at R37.24 million. The households and value added (labour, capital, and land) generate incomes of only R31.43 and R189.42 million in the economy of

South Africa, respectively. The findings of this study are in line with those of Anjaly et al. (2024), which indicated that implementing water-saving technology interventions, such as soil moisture techniques like eco-friendly straw mulching, contribute to better soil health and sustainable yield.

7.2.4.1.2 Full Adoption

As indicated in Table 7.14, the full adoption scenario involving the use of drip irrigation and irrigation scheduling based on soil moisture levels resulted in R21.38 million output of Lucerne in the Kakamas irrigation scheme in the Northern Cape province. The total labour remuneration was estimated at R14.64 million in the economy of South Africa, of which NC province generates a labour return of about R6.85 million and gross operating surplus (capital) of R3.86 million in the economy. Most of the labour income was derived from the Western Cape province, followed by North West and Mpumalanga provinces.

Household income was estimated at R33.08 million for the economy of the NC province. The overall land return was estimated at R2.99 million in the economy of South Africa, of which the return to irrigation in NC was only R24 755, 56. The highest return on irrigation in the province of NC was found in the Namakwa irrigation district, followed by ZF Mgcawu and Frances Baard irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) were estimated at R 16.88 million. The households and value added (labour, capital, and land) generate incomes of R 15.73 and R79.92 million in the economy of South Africa, respectively. The findings of this study are in line with those of Anjaly et al. (2024), who indicated that implementing water-saving technology interventions, such as drip irrigation, contributes to sustainable yield.

7.2.4.2 Adoption of water-saving policies

7.2.4.2.1 Partial Adoption

As indicated in Table 7.14, the effect of the adoption of water-saving policies resulted in R21.74 million output of lucerne in the Kakamas Irrigation Scheme and in the Northern Cape province economy. The total labour remuneration was estimated at R34.18 million in South Africa. The NC province generates a labour return of about R2.67 million and a gross operating surplus (capital) of R3.20 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R74.41 million towards the economy of the NC province. The overall land return was estimated at R4.1 million in the economy of South Africa, of which the return to irrigation in the NC was only R61 493.21. The highest return on irrigation in the province of NC was found in the

Namakwa irrigation district, followed by ZF Mgcawu and Frances Baard irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) valued at R22.82 million in the economy. The households and value added (labour, capital, and land) generated incomes of R20.79 and R73.25 million in the economy of South Africa, respectively. The findings of this study aligned with those of Adegbo et al. (2019), Challinor et al. (2014), and Jing et al. (2024), which highlighted the point that, without adaptation to climate variability, losses in aggregate production are expected in crops, while farmers who had adopted adaptation strategies would gain higher yields. Such adaptation strategies include innovative irrigation strategies alongside soil water conservation methods that collectively enhance water retention and efficiency.

7.2.4.2.2 Full Adoption

As indicated in Table 7.14 above, the effect of the adoption of water-saving policies resulted in R104.05 million output of lucerne in the Kakamas Irrigation Scheme and the Northern Cape province economy. The total labour remuneration was estimated at R77.53 million in the economy of South Africa, of which the NC province generates a labour return of about R5.15 million and a gross operating surplus (capital) of R7.06 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R185.10 million towards the economy of the NC province. The overall land return was estimated at R8.89 million in the economy of South Africa, of which the return to irrigation in NC was R133 317.38. The highest return on irrigation in the province of NC was found in the Namakwa irrigation district, followed by the Frances Baard and Pixley Ka Seme irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) were valued at R76.86 million in the economy of South Africa, while the households and value added (labour, capital, and land) generated incomes of R70.65 and R138.77 million in the economy of South Africa, respectively. As indicated above in this sub-section, the findings of this study concurred with those of Adegbo et al. (2019), Challinor et al. (2014), and Jing et al. (2024), which highlighted the point that, without adaptation to climate variability, losses in aggregate production are expected in crops, while farmers who had adopted adaptation strategies would gain higher yields. Such adaptation strategies include innovative irrigation strategies alongside soil water conservation methods that collectively enhance water retention and efficiency.

7.2.4.3 Adaptation towards climate variability

7.2.4.3.1 Partial Adaption

As indicated in Table 7.14 above, the effect of adaptation towards climate variability resulted in a R989.21 million output of lucerne in the Kakamas Irrigation Scheme and the NC province economy. The total labour remuneration was estimated at R105.75 million in the economy of South Africa, of which the NC province generated a labour return of about R12.49 million and a gross operating surplus (capital) of R59.90 million in the economy of South Africa. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R382.32 million towards the economy of the NC province. The overall land return was estimated at R39.1396 million in the economy of South Africa, of which the return to irrigation in NC was R485 227.75. The highest return on irrigation in the province of NC was found in the Namakwa irrigation district, followed by the ZF Mgcawu and Frances Baard irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) were estimated at a value of R333.24 in the economy. The households and value added (labour, capital, and land) generated incomes of R298.89 and R172.14 million in the economy of South Africa, respectively. The finding of this study is aligned with those of Zhao and Li (2015), who stated that crop production may have been affected and will continue to be considerably affected by increases in the frequency and intensity of extreme environmental conditions attributable to climate variability.

7.2.4.3.2 Full Adaption

As indicated in Table 7.14 above, the effect of adaptation towards climate variability resulted in a R989.21 million lucerne output in the Kakamas Irrigation Scheme and the Northern Cape province economy. The total labour remuneration was estimated at R186.44 million in the economy of South Africa, of which the NC province generates a labour return of about R34.18 million and a gross operating surplus (capital) of R153.31 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R846.69 million towards the economy of the NC province. The overall land return was calculated to R97.98 million in the economy of South Africa, of which the return to irrigation in the NC R1, 316.870.0 million. The highest return on irrigation in the province of NC was found in the Namakwa irrigation district, followed by the ZF Mgcawu and Frances Baard irrigation districts in the economy of NC province.

Institutional incomes (enterprise and households) were valued at R908.95 million to the economy of South Africa, while the households and value added (labour, capital, and land) generated incomes of R878.27 and R470.52 million in the economy of South Africa, respectively.

7.3 Discussions

The extended TPB model reveals that commercial lucerne irrigators' adoption decisions around water-saving technologies are primarily driven by access to information and their perceptions of the risks and benefits associated with these technologies. The model suggests that no adoption is most likely under psychological conditions where irrigators perceive high risks or limited benefits, and where they lack sufficient access to reliable and relevant information. In such cases, attitudes remain weak, and intention to adopt is low.

Partial adoption, such as shifting to soil moisture-based irrigation scheduling while continuing with flood irrigation systems, occurs under more favourable psychological conditions. Here, irrigators exhibit more positive attitudes toward water-saving practices and show strong intention to adopt, likely because they perceive clear benefits and have access to practical, decision-enabling information. This is consistent with the simulation results showing an increase in yields under different adaptation scenarios. The introduction of associated yield changes into the economic system, through the multiplier analysis adaptation of other scenarios, leads to positive ripple effects across household income, labour remuneration, land returns, and institutional income with different amounts. These findings show that adoption outcomes are shaped by both the psychological framing of technologies and the tangible agronomic and economic impacts they are expected to generate.

The extended TPB model shows that a complex mix of psychological drivers shapes the adoption of water-saving policies among lucerne irrigators. Interestingly, increased access to information appears to reduce positive attitudes toward such policies, likely because policy information is often framed around restrictions, trade-offs, or compliance burdens. Despite this, information still strengthens intention to adopt, possibly reflecting a sense of necessity or inevitability. High trust in institutions and the policy process significantly boosts both intention and subjective norms, indicating that farmers are more likely to comply when they believe the system is fair and reliable.

Strong institutional and legal frameworks also help to reinforce these social pressures. Under these conditions, no adoption is most likely when trust is low and institutional influence is weak, leading to both poor attitudes and weak normative pressure. Partial or cautious adoption, such as accepting moderate water restrictions, occurs when trust is higher and intention is supported by stronger norms, even if attitudes remain mixed. Full adoption, under severe restrictions, is made economically and psychologically unviable

despite strong institutional pressure or trust. When such restrictions are applied, the resulting yield shocks trigger widespread negative effects across the agricultural economy, reducing land returns, household income, and institutional revenues. These findings underscore how the adoption of policy-driven practices depends not just on awareness or enforcement, but also on the perceived fairness, practicality, and economic consequences of the policies themselves.

The extended TPB model highlights the point that the indirect influence of financial concerns, perceived risks and benefits, and trust largely drives adaptation to climate variability among lucerne irrigators. While these factors do not directly influence intention, they exert meaningful indirect effects by shaping attitudes, perceived behavioural control, and subjective norms. In other words, farmers are more likely to intend to adapt when they perceive the financial trade-offs as manageable, the benefits as tangible, and the actors involved as trustworthy, all filtered through a sense of personal capability and social expectation. Under weak psychological conditions, such as low trust, high perceived costs, and low perceived control, no adaptation is likely, as farmers lack the motivation or confidence to change. Partial adaptation, such as improving weed management and applying moderate deficit irrigation, aligns with moderately positive attitudes and intention, and is supported by the simulated yield increase.

In contrast, full adaptation, including a switch to sprinkler irrigation and more aggressive deficit strategies, requires stronger perceived benefits and trust, alongside high self-efficacy and normative support. This scenario is associated with a significant increase in yields, reinforcing its perceived value. When these yield gains are introduced into the economic system, they generate substantial positive ripple effects in land returns, household income, and institutional revenues. These results demonstrate how psychological readiness, combined with clear agronomic and economic gains, can significantly drive adaptation behaviours in response to climate variability.

CHAPTER 8: CASE STUDY OF COMMERCIAL SOYBEAN PRODUCTION IN THE HARTBEESPOORT IRRIGATION SCHEME, NORTH WEST PROVINCE

8.1 Overview

This section presents the results for soybeans production in the Hartbeespoort Irrigation Scheme, following the procedures and methodologies outlined above.

8.2 Results

8.2.1 Demographic, Farm, and Household Characteristics of Respondents

The demographic, farm and households' profile of soybean irrigators in the Hartbeespoort Irrigation Scheme is summarised in Table 8.1 below. The age distribution reveals that 34% of the irrigators are 61 years or older, while younger age groups (less than 30) are absent. In terms of level of education, 41% hold undergraduate degrees, suggesting a generally educated group, though only 2% have attained a master's degree. Health levels are predominantly positive, with 59% rating their health as good.

A significant majority rely on canals as their primary irrigation source (78%), with only a few using rivers (11%) or dams (3%). Most irrigators engage in crop production (86%), with a smaller proportion practising mixed farming (14%). In terms of land ownership, the majority own two to five hectares (56%), and most farmland is highly clustered, situated within 1–5 km from the main farm (75%). The business structure is predominantly sole proprietorship (42%), although corporations also constitute a notable portion (34%). Land ownership is primarily individual, with the majority of irrigators being sole owners (92%). Furthermore, a significant number of respondents have their main irrigation land located less than 1 km from their water source (80%), indicating ease of access to irrigation facilities.

The majority of households consist of two adults (81%), and the most common number of people living in each household is two (53%). A large majority (84%) have only one person involved in farming activities. The majority of respondents are married (89%), indicating stable family structures. In terms of age, heads of households are fairly evenly spread out, with 34% being aged 61 and older, and 28% between 41 and 50 years. Almost all respondents (97%) rely on farming or agricultural activities as their primary source of income, although 16% also have some income from other jobs.

Table 8.1: Demographic Profile of Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Variable	Classification	Frequency	Percentage (%)
Demographic			
Gender	Male	64	100%
Age	31-40	10	16%
	41-50	18	28%
	51-60	14	22%
	61 and older	22	34%
Highest education level	Secondary (grade 8-12)	27	41%
	Diploma	10	16%
	Undergraduate degree	26	41%
	Masters	1	2%
Health Level	Poor	1	2%
	Average	6	9%
	Good	38	59%
	Excellent	19	30%
Farm characteristics			
The primary source of water used for irrigation	River	7	11%
	Dam	2	3%
	Canal	50	78%
	River and dam water	1	2%
	River and canal water	2	3%
	River and borehole	2	3%
Type of farming performed	Crop production	55	86%
	Mixed farming	9	14%
Amount of agricultural land deeds owned	One	7	11%
	Two to five	36	56%
	More than five	21	33%
How scattered is the farmland from the main farm	Highly clustered together (1-5 km)	48	75%
	Moderately dispersed (6-10 km)	7	11%
	Highly dispersed (more than 10 km)	9	14%
	Sole proprietorship	27	42%

Variable	Classification	Frequency	Percentage (%)
Demographic			
Business structure of the farm operations	Corporation	22	34%
	Partnership	4	6%
	Trust	9	14%
	Closed corporation	2	3%
The land ownership type of the farm	Sole owner	59	92%
	Lease	1	2%
	Combination of sole owner and lease	3	5%
	Communal	1	2%
Distance of the main irrigation land from the water source	Less than 1 Km	51	80%
	1-3 Km	6	9%
	3-7 Km	3	5%
	7-10 Km	1	2%
	More than 10 Km	3	5%
Household characteristics			
Number of adults (18 years and older) living in the household	One	6	9%
	Two	52	81%
	Three or more	6	9%
Total individuals living in the household (adults + children)	One	7	11%
	Two	34	53%
	Three	7	11%
	Four or more	16	25%
	Female	-	-
Individuals in the household involved in farming activities	One	54	84%
	Two	7	11%
	Three or more	3	5%
Marital status	Married	57	89%
	Single	3	5%
	Divorced	2	3%
	Widowed	2	3%
Age of the head of the household	31-40	10	16%
	41-50	18	28%

Variable	Classification	Frequency	Percentage (%)
Demographic			
	51-60	14	22%
	61 and older	22	34%
Primary source of livelihood	Farmer/agricultural activities	62	97%
	Self-employed/business owner	2	3%
Off-farm income	Yes	10	16%
	No	54	84%

Sources: Project team compilation

8.2.2 Theory of Planned Behaviour

8.2.2.1 Standard TPB Model for Adoption of Water-saving Technologies

Measurement item SN_2 had a loading below 0.4 and was consequently dropped from the model to enhance its robustness and ensure the reliability of indicators. The internal consistency reliability results revealed that the Perceived Behavioural Control (**PBC**) construct showed a composite reliability score above 0.95, which is considered high.

In addition to the **PBC** construct, both Attitudes (**AB**) and Intention (**INT**) had Cronbach's alpha values below 0.6. However, their composite reliability scores were above 0.6. Given that Cronbach's alpha tends to underestimate reliability when the number of items is small or when outer loadings vary, it was not relied on as the primary indicator. Instead, composite reliability, which accounts for the outer loadings of individual indicators, was used as a more accurate measure of internal consistency for these constructs.

The Average Variance Extracted (AVE) revealed that all constructs with more than one measurement item exhibited an AVE higher than 0.5, indicating that these constructs accounted for over 50% of the variance in their respective indicators. This demonstrates satisfactory convergent validity, suggesting that the items were adequately correlated with their underlying constructs.

In the Fornell-Larcker test, the square root of the AVE for each construct (diagonal values) was larger than the correlations between that construct and any other construct (off-diagonal values), indicating satisfactory discriminant validity. Regarding the HTMT criterion, values below 0.90 are generally acceptable, showing that the constructs are distinct from each other. Initially, the HTMT ratio between **INT** (Intention) and **AB** (Attitude) was above 0.90, suggesting a potential overlap between the two constructs. This high HTMT ratio can arise when constructs are conceptually similar or closely related, leading to high correlations between their indicators. To address this, we further investigated the VIF values of both the inner model (structural model constructs) and outer model (measurement items), but found no issues with collinearity.

Thus, we decided to drop the lowest loading measurement item (A_{B1}) from the AB construct. After doing so, the HTMT ratio between INT and AB fell below 0.90, ensuring acceptable discriminant validity across the model. The VIF values for all constructs were found to be below 3, indicating that collinearity is not a concern.

During the analysis, attempts to run the bootstrapping procedure for hypothesis testing resulted in non-viable solutions, yielding "NaN" (Not a Number) values. This issue is likely attributed to significant alterations made to the model during the measurement and structural model assessments. As measurement items were dropped to enhance the model's reliability and validity, the structural relationships may have been disrupted, leading to complications in estimating a feasible solution for bootstrapping. As part of the project's scope, we will also estimate extended Theory of Planned Behaviour (TPB) models to analyse soybean irrigators' intentions to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme.

8.2.2.2 Augmented TPB Model for Adoption of Water-saving Technologies

Several measurement items, owing to their loadings falling below the acceptable threshold of 0.4, were removed, including A_{B1} (Attitudes), SN_1 (Subjective Norms), IL_2 (Institutional and Legal Factors), IF_7 and IF_8 (Informational Factors), TX_3 and TX_5 (Trust Factors), AR_1 (Access to Resources), and PFC_1 (Perceived Financial Cost). These adjustments were necessary to ensure that the model maintains robust reliability and validity in the subsequent analysis.

Some constructs, such as Institutional, Perceived Risks from Load Shedding and Tariffs ($RB2$), and Legal Factors (IL), and Access to Resources (AR), had Cronbach's alpha values below 0.6. However, both constructs exhibited composite reliability scores above 0.6, which is more appropriate for this exploratory study. In contrast, composite reliability provides a more accurate assessment of internal consistency, as it accounts for the individual outer loadings of the indicators. Therefore, we rely on composite reliability scores to validate the internal consistency of these constructs.

The composite reliability score for Perceived Behavioural Control (PBC) was notably high at 0.993, indicating potential redundancy among the measurement items. To address this, we examined the Variance Inflation Factor (VIF) values for the PBC measurement items and found both exceeded the threshold of 3. Consequently, it was decided to drop the PBC measurement item with the lowest loading (PBC_1) to enhance the model's robustness.

All constructs had an AVE above the minimum threshold of 0.5, except for the construct Perceived Risks from Load Shedding and Tariffs ($RB2$). To address this, we dropped the measurement item from $RB2$ with the lowest factor loading (RB_8), which subsequently improved the AVE for $RB2$ to exceed the 0.5 threshold. This adjustment ensured that all constructs met the required standard for convergent validity.

The HTMT ratio revealed that the construct Institutional and Legal Factors (**IL**) had an HTMT ratio above 0.9 with several other constructs. After inspecting the VIF values of both the inner and outer models and confirming no collinearity issues, we dropped **IL₁**, the measurement item with the lowest factor loading. Recalculating the HTMT ratios showed that the discriminant validity issue for **IL** was resolved.

However, the construct Informational Factors (**IF**) also showed an HTMT ratio above 0.9 with Intentions (**INT**). Since no collinearity issues were present, we dropped the lowest loading **IF** item. Despite this, the HTMT ratio remained above 0.9, so we ultimately decided to drop **IF** from the model to ensure discriminant validity. After making these adjustments, the final Fornell-Larcker criterion results and HTMT ratios confirmed that discriminant validity was adequately established. All the Variance Inflation Factor (VIF) values were below the acceptable threshold of 3, indicating no significant collinearity issues within the model.

During the initial attempt to perform bootstrapping, the analysis resulted in "NaN" values, indicating a problem with the model. To find a feasible solution, various options were explored by adjusting measurement items and constructs. It became evident that the removal of **RB2** was the key issue, as its complete removal allowed SmartPLS to execute the bootstrapping procedure without further complications successfully.

The specific indirect effects (Appendix J, Table J.1) were examined for soybean irrigators' intentions to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme. These effects capture how additional constructs, such as trust or access to resources, indirectly influence intentions through their effects on attitudes, perceived behavioural control, and subjective norms. The results revealed that none of these specific indirect effects had a significant impact, indicating that the additional constructs did not significantly influence soybean irrigators' intentions through the mediation of attitudes, **PBC**, or **SN**.

The total indirect effects, as presented in Appendix J, Table J.2, reflect the overall influence of the additional constructs on soybean irrigators' intentions to adopt water-saving technologies through the combined mediating effects of attitudes, perceived behavioural control, and subjective norms. Similar to the specific indirect effects, none of the total indirect effects were found to be significant.

The total direct effects are summarised in Appendix J, Table J.3, and the results revealed several significant relationships. Institutional and Legal Factors (**IL**) had a negative effect on subjective norms (**SN**) ($\beta = -0.285$, $p < 0.05$). Perceived Risks (**RB**) showed a positive effect on both attitudes (**A_B**) ($\beta = 0.278$, $p < 0.05$) and intentions (**INT**) ($\beta = 0.539$, $p < 0.05$). Additionally, Technical Factors (**TF**) positively influenced intentions (**INT**) ($\beta = 0.560$, $p < 0.05$). These findings suggest that perceived risks and benefits and Technical Factors play an important role in shaping attitudes and intentions. In contrast, institutional and

legal factors negatively impact subjective norms among soybean irrigators in the Hartbeespoort Irrigation Scheme.

Appendix J, Table J.4 reflects the total effects, which represent the sum of the direct and indirect effects. The results for the total effects are relatively consistent with the path coefficients (direct effects), which is sensible, given that none of the indirect effects were found to be significant. This alignment suggests that the direct effects primarily drive the overall relationships in the model, reinforcing the findings regarding the intentions of soybean irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme.

The (R^2) results indicate that attitudes (A_B) account for 22.7% of the variance in their respective construct, with an adjusted R^2 of 14.5%. Intentions (INT) show a higher explanatory power, with an R^2 of 67.8% and an adjusted R^2 of 62.4%. Perceived Behavioural Control (PBC) accounts for 12.5% of the variance (adjusted R^2 of 3.2%), while Subjective Norms (SN) explain 32.0% of the variance, with an adjusted R^2 of 24.8%. These findings highlight the varying levels of explanatory power of different constructs within the model, emphasising the significance of intentions in predicting water-saving technology adoption among soybean irrigators.

In the context of the Hartbeespoort Irrigation Scheme, the effect sizes (f^2) value for the resource barriers (RB) construct shows a small effect size of 0.095 for attitudes (A_B), but has a substantial effect of 0.758 on intentions (INT), highlighting its significant influence. Similarly, the technical factors (TF) exhibit an impressive f^2 value of 0.903 for intentions, indicating a significant effect as well. In contrast, other constructs, like perceived behavioural control (PBC) and subjective norms (SN), present smaller f^2 values, suggesting their limited impact on behavioural outcomes.

8.2.2.3 Standard TPB Model for Adoption of Water Saving Policies

Items with loadings below 0.4 were immediately removed because of their insufficient contribution and reliability. As a result, A_{B4} and INT_4 , which had loadings below 0.4, were dropped from the model to ensure the reliability of indicators. All constructs with multiple measurement items had composite reliability scores above 0.6. However, the construct SN had a Cronbach's alpha below 0.6. It is essential to recognise that Cronbach's alpha may underestimate reliability when there are few items or varying outer loadings. Therefore, despite SN 's low Cronbach's alpha, the satisfactory composite reliability score deems the construct reliable.

All constructs with more than one measurement item displayed AVE values above 0.6, indicating satisfactory convergent validity.

In the Fornell-Larcker analysis, the square root of the AVE for each construct exceeded the correlations with other constructs, confirming satisfactory discriminant validity. The HTMT ratio values were below the threshold of 0.90, indicating that the constructs are sufficiently distinct from each other. Both criteria were met.

The results indicate that the Variance Inflation Factor (VIF) values for all constructs in the inner model are below the threshold of 3. This suggests that there are no significant collinearity problems, ensuring the stability and reliability of the structural model estimates.

A visual overview of the structural relationships is provided in Figure 8.1 below, with a detailed summary presented Appendix J, Table J.5. None of the structural relationships were found to be significant, meaning that none of the predictor variables (Attitudes, Subjective Norms, and Perceived Behavioural Control) had a considerable influence on soybean irrigators' intentions to adopt water-saving polices in the Hartbeespoort Irrigation Scheme.

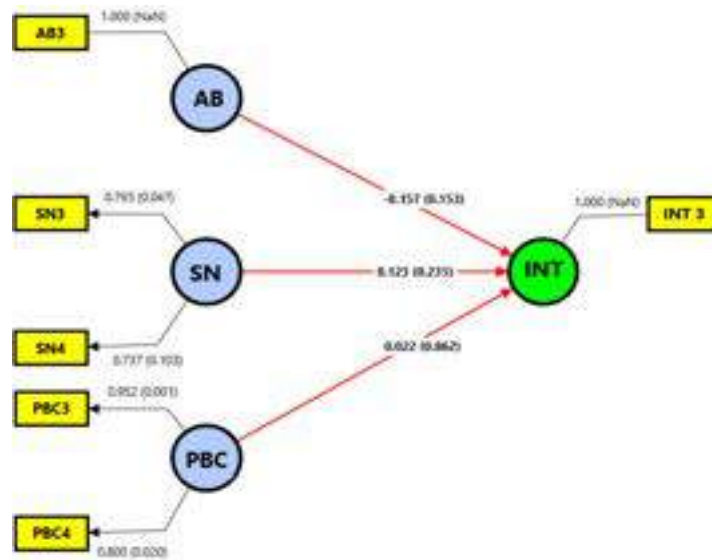


Figure 8.1: Path Analysis Findings of Soybean Irrigators' Intentions to Adopt Water-Saving Policies in the Hartbeespoort Irrigation Scheme

Source: Project team Compilation

The path from Attitudes (AB) to Intentions (INT) was negative and non-significant ($\beta = -0.157$, $p = 0.153$), indicating that attitudes towards adopting water-saving polices did not significantly influence soybean irrigators' intentions in the Hartbeespoort Irrigation Scheme. Similarly, the relationship between Subjective Norms (SN) and Intentions (INT) was positive but non-significant ($\beta = 0.123$, $p = 0.235$), suggesting that social pressure did not play a significant role in shaping irrigators' intentions. Lastly, Perceived Behavioural Control (PBC) did not show a substantial effect on Intentions (INT) ($\beta = 0.022$, $p = 0.174$), indicating that

perceived control over adopting water saving policies had no considerable impact. All hypotheses were therefore rejected.

The R^2 value for intentions (*INT*) was 0.047, indicating that the model explains only 4.7% of the variance in soybean irrigators' intentions to adopt water-saving policies. Additionally, the f^2 values for Attitudes (*A_B*), Perceived Behavioural Control (*PBC*), and Subjective Norms (*SN*) were 0.023, 0.000, and 0.015, respectively. These low values align with the non-significance of the relationships, suggesting that other variables beyond *A_B*, *PBC*, and *SN* might influence soybean irrigators' intentions to adopt water-saving policies in the Hartbeespoort Irrigation Scheme.

8.2.2.4 Augmented TPB Model for Adoption of Water Saving Policies

The following items were dropped because of their low loadings: *A_{B4}* (Attitudes), *IL₈* (Institutional and Legal Factors), *RB₈* and *RB₉* (Perceived Risks from Load Shedding and Tariffs), *IF₇* (Informational Factors), *TX₂* and *TX₃* (Trust Factors), *INT₃* (Intentions) and *AR₁* (Access to Resources). Removing these items helps to refine the model by ensuring that only reliable indicators are retained. These items had low loadings because they exhibited weak correlations with their respective constructs, indicating they were not strong indicators of the underlying factor they were intended to measure.

The Subjective Norms (*SN*) construct had both a Cronbach's alpha and composite reliability score below 0.4. To maintain the construct within the structural model, we dropped the measurement item with the lowest loading to improve reliability. Additionally, the Perceived Risks from Load Shedding and Tariffs (*RB2*) construct showed Cronbach's alpha and composite reliability scores above 0.9, which indicated overly high internal consistency, possibly signifying redundancy among the items. By dropping *RB₈*, we brought the internal consistency reliability of the *RB2* construct down to more acceptable levels.

The remaining constructs showed Cronbach's alpha values below 0.6 in some cases. In contrast, composite reliability provides a more accurate assessment of internal consistency, as it accounts for the individual outer loadings of the indicators. Therefore, we relied on composite reliability scores to validate the internal consistency of these constructs, and all constructs had composite reliability scores above 0.6, indicating acceptable reliability.

Convergent validity is assessed by examining the Average Variance Extracted (AVE) values, with a minimum threshold of 0.5 indicating that the construct explains at least 50% of the variance in its items. In our analysis, all constructs displayed AVE values above this threshold, confirming adequate convergent validity. Initially, when estimating the HTMT ratios, we identified *RB2* as a problematic construct because of its HTMT values exceeding 0.9 with various other constructs. To address this, we dropped the *RB₁₀* measurement item, which resolved the discriminant validity issues for *RB2*. All remaining constructs

demonstrated favourable HTMT ratios below 0.9. This indicates that the constructs are distinct and not overly correlated with one another. In terms of the Fornell-Larcker criterion, the square root of the AVE for each construct was larger than the correlations with other constructs. This confirms that the constructs share more variance with their own indicators than with other constructs, further supporting discriminant validity.

The VIF values between constructs in the inner model are below 3, indicating that there are no collinearity issues present. This suggests that the predictor constructs are sufficiently independent, allowing for reliable estimation of the path coefficients in the model.

In this analysis, the measurement model was rigorously assessed, and collinearity was thoroughly examined in both the measurement and structural models. Despite these efforts, the bootstrapping procedure yielded NaN results, indicating a lack of feasible solutions for the extended model focused on the adoption of water-saving policies. This outcome suggests that one or more bootstrapping samples did not lead to valid solutions, preventing the calculation of reliable parameter estimates. Given the comprehensive nature of this investigation and the fact that this model is part of a broader project involving the estimation of 30 models, it is reasonable to conclude that the specific characteristics of the data or model configuration may have contributed to this issue. Overall, the rigorous application of established assessment techniques reinforces the credibility of the findings obtained from the other models within this research project.

8.2.2.5 Standard TPB Model for the adaptation towards climate variability

None of the measurement items had loadings below 0.6, indicating sufficient indicator reliability for all items. All constructs demonstrated Cronbach's alpha and composite reliability scores above the minimum threshold of 0.6. However, the construct Perceived Behavioural Control (**PBC**) exhibited a composite reliability score of 0.937. Values exceeding 0.90, especially those approaching or exceeding 0.95, may indicate redundancy among indicators, suggesting that some items may not contribute unique value and could be measuring similar aspects of the construct. To address this potential redundancy, we inspected the VIF values for the two measurement items associated with **PBC**, which both exceeded 3. Consequently, we decided to drop the item with the lowest factor loading, specifically **PBC₆**, to enhance the construct's validity and reliability.

All constructs exceeded this threshold, indicating satisfactory convergent validity. This demonstrates that the constructs effectively capture the intended underlying theoretical concepts. The square root of the AVE is larger than the correlations, satisfying the Fornell-Larcker criterion. Additionally, the HTMT ratios are below 0.90, further indicating that the constructs are distinct from one another and exhibit adequate

discriminant validity. All Variance Inflation Factor (VIF) values for the inner model (structural model) are below the threshold of 3, indicating that collinearity is not a concern in this analysis.

An overview of the path coefficient results is provided in Figure 8.2 below, with a detailed summary presented in Appendix J, Table J.6. It is evident that none of the predictor variables had a significant effect on the intentions of soybean irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme.

The path from Attitudes (A_B) to Intentions (INT) was positive but non-significant ($\beta = 0.228$, $p = 0.225$), suggesting that attitudes towards adapting to climate variability did not significantly influence the intentions of soybean irrigators in the Hartbeespoort Irrigation Scheme.

The relationship between Subjective Norms (SN) and Intentions (INT) was also positive and non-significant ($\beta = 0.035$, $p = 0.870$). This indicates that the perceived social pressures to adopt climate variability measures did not have a meaningful impact on the intentions of the irrigators.

Lastly, the path from Perceived Behavioural Control (PBC) to Intentions (INT) was positive and non-significant ($\beta = 0.135$, $p = 0.553$). This suggests that the irrigators' perceived ability to adopt climate variability adaptation strategies did not significantly affect their intentions in the Hartbeespoort Irrigation Scheme. Overall, the results indicate that none of the predictor variables significantly influenced the intentions of soybean irrigators to adapt to climate variability.

The R^2 statistic for intentions (INT) was found to be 0.097, indicating a relatively low level of explained variance. Additionally, the F^2 values for the constructs are as follows: 0.048 for Attitudes (A_B), 0.001 for Subjective Norms (SN) and 0.017 for Perceived Behavioural Control (PBC). These values suggest that the adaptation to climate variability among soybean irrigators in the Hartbeespoort Irrigation Scheme is influenced by other variables not included in the model. Consequently, the model did not perform well in predicting the climate variability of these irrigators.

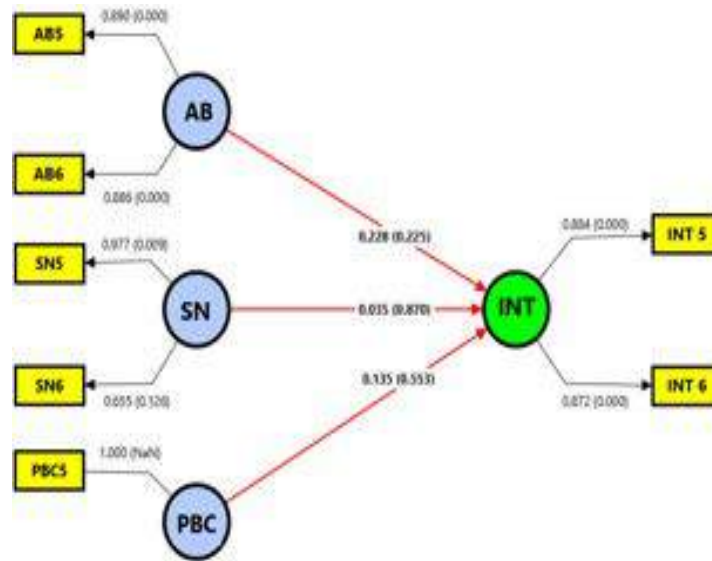


Figure 8.2: Path Analysis Findings of Soybean Irrigators' Intentions for Adaptation Towards Climate Variability in the Hartbeespoort Irrigation Scheme

Source: Project team Compilation

8.2.2.6 Augmented TPB Model for the adaptation towards climate variability

The following items were dropped: **RB₉** (Perceived Risks from Load Shedding and Tariffs), **IF₇** (Informational Factors), and **TX₃** and **TX₅** (Trust Factors) to ensure reliability indicators. Given the exploratory nature of this study, these slightly lower thresholds were deemed appropriate. Although the constructs **IL**, **AR**, and **RB2** had Cronbach's alpha scores below 0.6, all three exhibited composite reliability scores above 0.6, which indicates acceptable internal consistency.

Furthermore, it was noted that **PBC** (Perceived Behavioural Control) had a composite reliability score above 0.9. Consequently, we inspected the VIF values of the two measurement items dedicated to **PBC** and found their VIF values exceeded 3, indicating potential multicollinearity issues. Therefore, we dropped **PBC₅** to address this concern. For the remaining constructs, the internal consistency reliability was found to be acceptable, as evidenced by composite reliability scores exceeding the 0.6 threshold.

All constructs displayed AVE values above the threshold of 0.5, except for **IL**, **RB2**, and **AR**. Low convergent validity implies that the indicators (or measurement items) of a construct are not adequately capturing the underlying concept they are supposed to measure. For these problematic constructs (**IL**, **RB2**, and **AR**), we explored whether the convergent validity could be improved through the removal of certain measurement items that may have weakened the overall construct validity.

For **RB2** (Perceived Risks from Load Shedding and Tariffs), we found that the only way to improve the AVE above 0.5 is by dropping the measurement item **RB₁₀**. However, dropping **RB₁₀** also caused the

composite reliability score of **RB2** to rise above 0.9, indicating that the two remaining measurement items, **RB₇** and **RB₈**, were too closely related, potentially leading to redundancy in the construct. Consequently, we decided to drop **RB₈**, as it had the lowest factor loading compared with **RB₇**. For **AR** (Access to Resources), we found that, by dropping the measurement item with the lowest factor loading, **AR₃**, the AVE of the construct improved to exceed 0.5, enhancing its convergent validity. For **IL** (Institutional and Legal Factors), dropping **IL₈** improved the AVE of the construct to exceed 0.5, thus enhancing its convergent validity.

Three constructs had HTMT ratios above 0.90, indicating potential discriminant validity issues. These were Informational Factors (**IF**) with Intentions (**INT**), Perceived Financial Constraints (**PFC**) with Access to Resources (**AR**), and Subjective Norms (**SN**) with Institutional and Legal Factors (**IL**). These elevated HTMT values (HTMT >0.9) suggest a possible overlap between these constructs. Firstly, we inspected the VIF values in the measurement model and found no collinearity issues. Therefore, we explored the construct Informational Factors (**IF**) by removing the measurement item with the lowest factor loading, but this did not reduce the HTMT ratio below 0.90. To maintain the model's integrity, we decided to drop **IF** completely. For Perceived Financial Constraints (**PFC**), dropping **PFC₃** improved the HTMT ratio below 0.90. Similarly, for Subjective Norms (**SN**), we dropped **SN₆** because of its low factor loading, which also brought the HTMT ratio below 0.90, the results revealed no collinearity problems, indicating that the inner model is free from multicollinearity concerns.

In the analysis, we aimed to evaluate the hypothesised relationships between the latent variables by examining the path coefficients (β) and their significance levels (p-values). To achieve this, we conducted a bootstrapping procedure with 10,000 resamples, using the percentile method to determine confidence intervals at a 5% significance level. This method involves evaluating the lower 2.5% and upper 97.5% percentiles of the distribution to establish a 95% confidence interval for the coefficients. All hypotheses were assessed based on path coefficients (β), with significance determined at p values ≤ 0.05 .

However, during the initial attempt to run the bootstrapping procedure, we encountered a NaN (Not a Number) result, indicating that the model could not find a feasible solution. Upon investigation, we discovered that dropping the **RB2** construct from the model resolved this issue. The NaN result often occurs when the model is over-parameterised or when certain constructs do not contribute adequately to the overall model fit, leading to invalid solutions.

While we verified that the measurement and structural models were adequate and met reliability and validity criteria, the inclusion of **RB2** might have introduced complexity that hindered model estimation. By removing **RB2**, we allowed the model to stabilise, enabling it to compute the path coefficients successfully

and yielding valid results for further analysis. The bootstrapping procedure subsequently yielded the specific indirect effect (Appendix J, Table J.7), total indirect effect (Appendix J, Table J.8), direct effect (Appendix J, Table J.9), and total effect (Appendix J, Table J.10), providing comprehensive insights into the relationships among the constructs. Appendix J, Table J.7 presents the specific indirect effects, revealing that none of these effects were found to be significant. This indicates that the hypothesised mediating relationships among the constructs did not reach statistical significance in this analysis. Appendix J, Table J.8 displays the results of the total indirect effects, indicating that none of these effects were found to be significant. This suggests that the overall mediating relationships among the constructs did not achieve statistical significance in this analysis.

Appendix J, Table J.9 presents the results of the direct effects, indicating several statistically significant relationships. The effect of Institutional and Legal factors (**IL**) on Subjective Norms (**SN**) was found to be substantial with a path coefficient of -0.490 ($p < 0.01$), suggesting a negative relationship between these constructs. Additionally, Perceived Risks from Load Shedding and Tariffs (**RB**) positively influenced Intentions (**INT**), with a path coefficient of 0.559 ($p < 0.01$), indicating a significant positive effect. Trust Factors (**TF**) also demonstrated a significant positive effect on Intentions, with a path coefficient of 0.438 ($p < 0.01$).

Appendix J, Table J.10 displays the results of the total effects, which represent the sum of both direct and indirect effects. Notably, the total effects are nearly identical to the direct effects, which is sensible given that none of the indirect effects were found to be significant. This reinforces the notion that the relationships among the constructs are primarily driven by direct influences, further supporting the findings of the direct effects.

The construct Intentions (**INT**) demonstrated a high R^2 value of 0.656, indicating that it accounts for a significant portion of the variance in the adaptation towards climate variability within the Hartbeespoort Irrigation Scheme. This suggests that the model effectively predicts farmers' intentions to adopt adaptive practices. In comparison, the other constructs exhibited lower R^2 values: Subjective Norms (**SN**) had an R^2 of 0.299, Perceived Behavioural Control (**PBC**) had an R^2 of 0.206, and Attitudes (**A_B**) had the lowest R^2 of 0.171. These findings imply that, while the model successfully captures the intentions of farmers, there are likely other variables influencing attitudes, subjective norms, and perceived behavioural control that are not accounted for in the model.

The effect size (f^2) value of the Resource Benefit (**RB**) construct has a substantial effect on Intentions (**INT**), with an f^2 value of 0.695, indicating a large effect size. Other constructs, such as Institutional and legal factors (**IL**) and Attitude (**A_B**), display small to medium effect sizes across different outcomes, with

f^2 values of 0.097 for IL impacting on A_B and 0.092 for Access to Resources (AR) impacting on A_B . However, most other relationships exhibit small effect sizes, indicating a less pronounced influence on the respective behavioural outcomes.

8.2.3 AquaCrop Model Simulation

8.2.3.1 Net and Gross Irrigation Requirements for Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme

The AquaCrop model estimates the NIR based on crop water uptake and soil moisture balance, but does not account for conveyance losses or irrigation inefficiencies. In contrast, the GIR represents the total water applied to the field to meet the NIR, incorporating losses from evaporation, deep percolation, runoff, and inefficiencies in the irrigation system. To estimate the irrigation water allocation for soybean production in the Hartbeespoort Irrigation Scheme, we utilised weather data from two stations provided by the Agricultural Research Council (ARC), namely Wildebeesthoek (25°40'06.6"S, 28°02'03.1"E) and Brits (25°35'29.0"S, 27°46'07.4"E). These were the only stations available for the study area, and the data covered limited time periods from 2015 to 2019 for Wildebeesthoek and from 2010 to 2014 for Brits. Table 8.2 below presents the net irrigation requirements calculated in the AquaCrop model for each of the dominant soil types found in the main irrigation zone of the Hartbeespoort Irrigation Scheme.

Table 8.2: Net Irrigation Requirement for Dominant Soil Types in the Main Irrigation Zone of the Hartbeespoort Irrigation Scheme for Soybean Production

		Station name: Wildebeesthoek Coordinates: 25°40'06.6"S 28°02'03.1"E				Station name: Brits Coordinates: 25°35'29.0"S 27°46'07.4"E				Average
		2015/16 production year	2016/17 production year	2017/18 production year	2018/19 production year	2010/11 production year	2011/12 production year	2012/13 production year	2013/14 production year	
Net irrigation requirement	Eutric Plinthosols	134.8	0	197.7	84.2	83.4	162.4	199.7	66.3	116.1
	Calcic Vertisols	157.9	74.1	208.7	182.1	83.1	168.7	209.7	74.2	144.8
	Ferric Luvisols	145.6	8.9	216.6	93.4	104.5	183.6	219.1	84.3	132.0
	Average	146.1	27.7	207.7	119.9	90.3	171.6	209.5	74.9	131.0

Source: Project team compilation

Next, the gross irrigation requirement (GIR) was calculated, as the net irrigation requirement (NIR) does not account for application efficiency or conveyance losses. It is assumed that most irrigation in the Hartbeespoort Irrigation Scheme is carried out by using sprinkler systems and that water is distributed via

lined canals. Therefore, by utilising Equation 4.1 ($\frac{95 \times 75}{100} = 71.25$) and Equation 4.2 (adapted from Savva & Frenken, 2002), the efficiency and the gross irrigation requirement (GIR) were calculated, respectively. The lined canals were assumed to have a conveyance efficiency of 95%, and an application efficiency of 75% was assumed for the sprinkler irrigation systems used in the Hartbeespoort Irrigation Scheme. Based on these assumptions, the combined overall irrigation efficiency was calculated at 71.25% by using Equation 4.1 as indicated above. To ensure the irrigation planning accounts for a worst-case scenario, the NIR values from the year with the highest irrigation demand (NIR 2012/13 = 209.5 mm) as indicated in the above table were used to calculate the GIR by utilising Equation 4.2 ($\frac{209.5}{71.25} = 294.04$).

The net and gross irrigation requirements for the production year 2012/13, which had the highest net irrigation requirement, on average, were 209.5 mm (Table 8.2) and the corresponding gross irrigation requirement on the adoption of water-saving technologies (294.04 mm).

8.2.3.1.1 No adoption scenario

In the AquaCrop simulations for commercial soybean irrigators in the Hartbeespoort Irrigation Scheme, the “No Adoption” scenario (Table 8.3 below) represents a baseline condition where farmers do not implement any water-saving technologies. Management practices were standardised across all scenarios to isolate the effect of irrigation scheduling alone. Specifically, soil fertility was set as non-limiting, 25% mulch cover was applied, runoff was not considered, and weed management was assumed to be optimal.

Table 8.3 Irrigation Schedule for the No Adoption Scenario of Water-Saving Technologies for Soybean Production in the Hartbeespoort Irrigation Scheme

Event	2010/11 marketin g year	2011/12 marketin g year	2012/13 marketin g year	2013/14 marketin g year	2015/16 marketin g year	2016/17 marketin g year	2017/18 marketin g year	2018/19 marketin g year	Day Number	Net application (mm)
1	24 Nov 2010	24 Nov 2011	24 Nov 2012	24 Nov 2013	24 Nov 2014	24 Nov 2015	24 Nov 2016	24 Nov 2017	10	22
2	4 Dec 2010	4 Dec 2011	4 Dec 2012	4 Dec 2013	4 Dec 2014	4 Dec 2015	4 Dec 2016	4 Dec 2017	20	22
3	14 Dec 2010	14 Dec 2011	14 Dec 2012	14 Dec 2013	14 Dec 2014	14 Dec 2015	14 Dec 2016	14 Dec 2017	30	22
4	24 Dec 2010	24 Dec 2011	24 Dec 2012	24 Dec 2013	24 Dec 2014	24 Dec 2015	24 Dec 2016	24 Dec 2017	40	22
5	3 Jan 2011	3 Jan 2012	3 Jan 2013	3 Jan 2014	3 Jan 2015	3 Jan 2014	3 Jan 2017	3 Jan 2018	50	22
6	13 Jan 2011	13 Jan 2012	13 Jan 2013	13 Jan 2014	13 Jan 2015	13 Jan 2015	13 Jan 2017	13 Jan 2018	60	22
7	23 Jan 2011	23 Jan 2012	23 Jan 2013	23 Jan 2014	23 Jan 2015	23 Jan 2015	23 Jan 2017	23 Jan 2018	70	22

Event	2010/11 marketin g year	2011/12 marketin g year	2012/13 marketin g year	2013/14 marketin g year	2015/16 marketin g year	2016/17 marketin g year	2017/18 marketin g year	2018/19 marketin g year	Day Number	Net application (mm)
8	2 Feb 2011	2 Feb 2012	2 Feb 2013	2 Feb 2014	2 Feb 2015	2 Feb 2015	2 Feb 2017	2 Feb 2018	80	22
9	12 Feb 2011	12 Feb 2012	12 Feb 2013	12 Feb 2014	12 Feb 2015	12 Feb 2015	12 Feb 2017	12 Feb 2018	90	22
10	22 Feb 2011	22 Feb 2012	22 Feb 2013	22 Feb 2014	22 Feb 2015	22 Feb 2015	22 Feb 2017	22 Feb 2018	100	22
11	4 Mar 2011	3 Mar 2012	4 Mar 2013	4 Mar 2014	4 Mar 2015	3 Mar 2015	4 Mar 2017	4 Mar 2018	110	22
12	14 Mar 2011	13 Mar 2012	14 Mar 2013	14 Mar 2014	14 Mar 2015	13 Mar 2015	14 Mar 2017	14 Mar 2018	120	22
13	24 Mar 2011	23 Mar 2012	24 Mar 2013	24 Mar 2014	24 Mar 2015	23 Mar 2015	24 Mar 2017	24 Mar 2018	130	22

Source: Project team compilation

Table 8.4 below presents the results for the no-adoption scenario of water-saving technologies for soybean production in the Hartbeespoort Irrigation Scheme.

Table 8.4: Summary of Results under the No-Adoption Scenario for Water-Saving Technology among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

No Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	12.176	12.241	12.301	12.358	12.461	12.545	12.453	12.642	12.40
	Yield (ton/ha)	4.778	4.802	4.825	4.848	4.889	4.921	4.897	4.960	4.87
	Irrigation (mm)	286	286	286	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	0.91	0.83	0.82	0.88	0.86	0.95	0.89	0.88	0.88
Calcic Vertisols	Biomass (ton/ha)	12.115	12.233	12.295	12.358	12.442	12.541	12.396	12.615	12.37
	Yield (ton/ha)	4.769	4.799	4.824	4.848	4.884	4.920	4.889	4.953	4.86
	Irrigation (mm)	286	286	286	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	0.89	0.81	0.80	0.86	0.84	0.92	0.87	0.85	0.86
Ferric Luvvisols	Biomass (ton/ha)	12.170	12.238	12.265	12.351	12.451	12.543	12.223	12.628	12.36
	Yield (ton/ha)	4.776	4.801	4.808	4.845	4.886	4.920	4.889	4.956	4.86
	Irrigation (mm)	286	286	286	286	286	286	286	286	286.00
	WP_{ET} (Kg/m ³)	0.92	0.84	0.82	0.88	0.87	0.95	0.90	0.88	0.88
Weighted Average	Biomass (ton/ha)	12.14	12.24	12.29	12.36	12.45	12.54	12.39	12.62	12.38
	Yield (ton/ha)	4.77	4.80	4.82	4.85	4.89	4.92	4.89	4.96	4.86
	Irrigation (mm)	286.00	286.00	286.00	286.00	286.00	286.00	286.00	286.00	286.00
	WP_{ET} (Kg/m ³)	0.90	0.82	0.81	0.87	0.85	0.93	0.88	0.86	0.86

Source: Project team compilation

8.2.3.1.2 Partial adoption scenario

For the partial adoption scenario, it is assumed that commercial soybean irrigators in the Hartbeespoort Irrigation Scheme schedule irrigation based on soil moisture levels, rather than following a fixed schedule. Unlike the no-adoption scenario, where irrigation is applied at set intervals, irrigation in this scenario is triggered whenever 70% of the readily available water (RAW) in the root zone is depleted. Key management practices in the AquaCrop model were kept constant to isolate the effect of irrigation scheduling. These include non-limiting soil fertility, 25% mulch cover, no runoff, and perfect weed control. The results of the AquaCrop model simulation for this scenario are presented in Table 8.5 below. Outputs are provided for each of the dominant soil types found in the main irrigation zone. In addition, a weighted average for each simulated metric (such as yield, biomass, and water productivity) was calculated based on the proportional area covered by each soil unit in the zone.

Table 8.5: Summary of Results under the Partial-Adoption Scenario for Water-Saving Technology among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Partial Adoption Scenario										
Soil		2010/11 marketing year	2011/12 marketing year	2012/13 marketing year	2013/14 marketing year	2015/16 marketing year	2016/17 marketing year	2017/18 marketing year	2018/19 marketing year	Average
Eutric Plinthosols	Biomass (ton/ha)	12.066	12.196	12.275	12.348	12.401	12.397	12.536	12.527	12.343
	Yield (ton/ha)	4.870	4.890	4.818	4.944	4.878	4.907	4.926	4.945	4.897
	Irrigation (mm)	108.700	180.800	270.100	97.000	158.500	82.600	300.900	196.800	174.425
	WP_{ET} (Kg/m ³)	0.960	0.860	0.800	0.880	0.870	0.980	0.880	0.870	0.888
Calcic Vertisols	Biomass (ton/ha)	12.087	12.166	12.258	12.343	12.328	12.241	12.512	12.456	12.299
	Yield (ton/ha)	4.868	4.887	4.814	4.883	4.878	4.921	4.923	4.953	4.891
	Irrigation (mm)	222.300	390.500	492.290	175.500	251.500	88.000	424.400	259.800	288.036
	WP_{ET} (Kg/m ³)	0.910	0.840	0.780	0.860	0.840	0.970	0.870	0.850	0.865
Ferric Luvissols	Biomass (ton/ha)	12.095	12.151	12.254	12.348	12.368	12.436	12.517	12.503	12.334
	Yield (ton/ha)	4.768	4.786	4.814	4.884	4.877	4.904	4.924	4.948	4.863
	Irrigation (mm)	173.400	223.100	2281.200	130.000	192.000	86.000	298.600	195.900	447.525
	WP_{ET} (Kg/m ³)	0.920	0.870	0.810	0.890	0.860	0.960	0.890	0.870	0.884
Weighted Average	Biomass (ton/ha)	12.082	12.172	12.262	12.345	12.351	12.301	12.519	12.479	12.314
	Yield (ton/ha)	4.859	4.878	4.815	4.895	4.878	4.917	4.924	4.951	4.889
	Irrigation (mm)	187.874	319.238	613.412	150.540	221.370	86.396	379.710	237.030	274.446
	WP_{ET} (Kg/m ³)	0.924	0.848	0.788	0.868	0.850	0.972	0.875	0.857	0.873

Source: Project team compilation

8.2.3.1.3 Full adoption scenario

The full adoption scenario represents the most advanced water management strategy simulated for commercial soybean irrigators in the Hartbeespoort Irrigation Scheme. It builds on the partial adoption scenario by maintaining soil moisture-based irrigation scheduling, while upgrading the irrigation method

from sprinkler to drip irrigation. This change is intended to simulate the effects of adopting a high-productivity irrigation system in combination with sensor-based scheduling. All other management parameters in the AquaCrop model remain consistent with the previous scenarios. The results of the AquaCrop model simulations for the full adoption scenario are presented in Table 8.6 below, showing outputs for each of the dominant soil types in the main irrigation zone. A weighted average was also calculated for each output metric, based on the area share of each soil unit, providing an overall estimate of system performance under full adoption conditions.

Table 8.6: Summary of Results under the full-Adoption Scenario for Water-Saving Technology among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Full Adoption Scenario										
		2010/11 r	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	12..140	12.196	12.275	12.348	12.406	12.405	12.536	12.527	12.385
	Yield (ton/ha)	4.871	4.890	4.818	4.844	4.978	4.906	4.926	4.945	4.897
	Irrigation (mm)	108.700	180.800	259.000	84.500	158.500	82.600	289.200	183.000	168.288
	WP_{ET} (Kg/m ³)	0.950	0.870	0.820	0.890	0.880	0.990	0.910	0.890	0.900
Calcic Vertisols	Biomass (ton/ha)	12.120	12.166	12.257	12.343	12.332	12.259	12.512	12.504	12.312
	Yield (ton/ha)	4.869	4.887	4.814	4.843	4.978	4.921	4.923	4.947	4.898
	Irrigation (mm)	222.300	390.700	475.200	175.500	250.600	88.000	406.300	216.600	278.150
	WP_{ET} (Kg/m ³)	0.920	0.840	0.800	0.870	0.860	0.980	0.890	0.850	0.876
Ferric Luvisols	Biomass (ton/ha)	12.101	12.151	12.254	12.348	12.369	12.322	12.519	12.506	12.321
	Yield (ton/ha)	4.868	4.886	4.814	4.944	4.977	4.916	4.924	4.947	4.910
	Irrigation (mm)	149.000	223.100	270.900	117.800	179.100	67.400	223.700	182.800	176.725
	WP_{ET} (Kg/m ³)	0.960	0.880	0.820	0.900	0.890	1.000	0.920	0.890	0.908
Weighted Average	Biomass (ton/ha)	12.106	12.155	12.255	12.347	12.358	12.304	12.517	12.505	12.318
	Yield (ton/ha)	4.868	4.886	4.814	4.915	4.977	4.917	4.924	4.947	4.906
	Irrigation (mm)	170.176	271.518	329.920	134.469	199.756	73.351	276.451	192.564	206.026
	WP_{ET} (Kg/m ³)	0.948	0.868	0.814	0.891	0.881	0.994	0.911	0.878	0.898

Note: The weighted average values were calculated based on the proportional area coverage of each soil type in the main irrigation zone, with Eutric Cambisols contributing 26%, Calcic Vertisols 64%, and Ferric Luvisols 10%.

Source: Project team compilation

8.2.3.1.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water-Saving Technologies

AquaCrop model simulations were run for three scenarios representing different levels of water saving technology adoption, and the results are presented in Table 8.7 below. For each scenario, weighted averages of key metrics were calculated by using the area share of each soil unit in the main irrigation zone of the Hartbeespoort Irrigation Scheme. It also shows the change in yield under partial and full adoption compared with the no-adoption scenario.

Table 8.7: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				% Change in Yield Compared to No Adoption
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	
Adoption scenario	No Adoption	12.38	4.86	286.00	0.86	Baseline (0%)
	Partial adoption	12.31	4.89	274.45	0.87	0.61%
	Full Adoption	12.32	4.91	206.03	0.90	0.95%

Source: Project team compilation

8.2.3.2 The adoption of water-saving policies

8.2.3.2.1 No-adoption scenario

For the no-adoption scenario of water-saving policies, it is assumed that no water restrictions are in place. This means that the full gross irrigation requirement (294.04 mm) is applied in equal amounts at evenly spaced intervals throughout the growing season. Since this setup is identical to the no-adoption scenario for water-saving technologies, the irrigation schedule and resulting outputs will be the same. Therefore, it will not be simulated again. The non-adoption scenarios for water-saving policies and water-saving technologies are functionally equivalent. As a result, only the partial and full adoption scenarios for water-saving policies will be simulated and analysed.

8.2.3.2.2 Partial adoption scenario

For the partial adoption scenario of water-saving policies, it is assumed that a 30% water restriction is imposed. This means that only 205.8 mm of water is available for irrigation, which is 30% less than the full gross irrigation requirement of 294.04 mm. When divided over 13 intervals, this results in approximately 15.8 mm per interval. Since the Aqua Crop's model irrigation schedule only accepts whole numbers, the amount was rounded down to 15 mm per interval to ensure the total irrigation does not exceed 205.8 mm. This water is applied in equal amounts at evenly spaced intervals throughout the maize growing season. Table 8.8 below presents the irrigation schedule for the partial adoption of water-saving policies in the Hartbeespoort Irrigation Scheme.

Table 8.8: Irrigation Schedule for the Partial Adoption Scenario of Water-Saving policies for Soybean Production in the Hartbeespoort Irrigation Scheme

Event	2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Day Number	Net application (mm)
1	24 Nov 2010	24 Nov 2011	24 Nov 2012	24 Nov 2013	24 Nov 2014	24 Nov 2015	24 Nov 2016	24 Nov 2017	10	15
2	4 Dec 2010	4 Dec 2011	4 Dec 2012	4 Dec 2013	4 Dec 2014	4 Dec 2015	4 Dec 2016	4 Dec 2017	20	15
3	14 Dec 2010	14 Dec 2011	14 Dec 2012	14 Dec 2013	14 Dec 2014	14 Dec 2015	14 Dec 2016	14 Dec 2017	30	15
4	24 Dec 2010	24 Dec 2011	24 Dec 2012	24 Dec 2013	24 Dec 2014	24 Dec 2015	24 Dec 2016	24 Dec 2017	40	15
5	3 Jan 2011	3 Jan 2012	3 Jan 2013	3 Jan 2014	3 Jan 2015	3 Jan 2014	3 Jan 2017	3 Jan 2018	50	15
6	13 Jan 2011	13 Jan 2012	13 Jan 2013	13 Jan 2014	13 Jan 2015	13 Jan 2015	13 Jan 2017	13 Jan 2018	60	15
7	23 Jan 2011	23 Jan 2012	23 Jan 2013	23 Jan 2014	23 Jan 2015	23 Jan 2015	23 Jan 2017	23 Jan 2018	70	15
8	2 Feb 2011	2 Feb 2012	2 Feb 2013	2 Feb 2014	2 Feb 2015	2 Feb 2015	2 Feb 2017	2 Feb 2018	80	15
9	12 Feb 2011	12 Feb 2012	12 Feb 2013	12 Feb 2014	12 Feb 2015	12 Feb 2015	12 Feb 2017	12 Feb 2018	90	15
10	22 Feb 2011	22 Feb 2012	22 Feb 2013	22 Feb 2014	22 Feb 2015	22 Feb 2015	22 Feb 2017	22 Feb 2018	100	15
11	4 Mar 2011	3 Mar 2012	4 Mar 2013	4 Mar 2014	4 Mar 2015	3 Mar 2015	4 Mar 2017	4 Mar 2018	110	15
12	14 Mar 2011	13 Mar 2012	14 Mar 2013	14 Mar 2014	14 Mar 2015	13 Mar 2015	14 Mar 2017	14 Mar 2018	120	15
13	24 Mar 2011	23 Mar 2012	24 Mar 2013	24 Mar 2014	24 Mar 2015	23 Mar 2015	24 Mar 2017	24 Mar 2018	130	15

Source: Project team compilation

Table 8.9 below presents the results for the partial adoption of water-saving policies in the Hartbeespoort Irrigation Scheme for each dominant soil type. It also includes a weighted average obtained by considering the area covered by each soil type.

Table 8.9: Summary of Results under the Partial Adoption Scenario for Water-Saving policies among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Partial Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	12.128	12.234	12.200	12.349	12.450	12.540	12.123	12.627	12.331
	Yield (ton/ha)	4.770	4.700	4.776	4.845	4.786	4.719	4.868	4.855	4.790
	Irrigation (mm)	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000
	WP_{ET} (Kg/m ³)	0.920	0.840	0.810	0.870	0.860	0.950	0.900	0.880	0.879
Calcic Vertisols	Biomass (ton/ha)	12.003	12.222	12.211	12.349	12.417	12.505	11.967	12.546	12.278
	Yield (ton/ha)	4.777	4.796	4.782	4.745	4.779	4.810	4.827	4.846	4.795
	Irrigation (mm)	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000
	WP_{ET} (Kg/m ³)	0.900	0.810	0.790	0.860	0.840	0.920	0.870	0.850	0.855
Ferric Luvisols	Biomass (ton/ha)	12.095	12.149	11.887	12.273	12.419	12.534	11.461	12.604	12.178
	Yield (ton/ha)	4.761	4.757	4.612	4.815	4.878	4.917	4.581	4.950	4.784
	Irrigation (mm)	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000
	WP_{ET} (Kg/m ³)	0.930	0.840	0.810	0.880	0.870	0.950	0.880	0.890	0.881
Weighted Average	Biomass (ton/ha)	12.068	12.170	11.981	12.295	12.418	12.526	11.607	12.587	12.207
	Yield (ton/ha)	4.774	4.767	4.763	4.778	4.791	4.797	4.813	4.859	4.793
	Irrigation (mm)	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000
	WP_{ET} (Kg/m ³)	0.908	0.821	0.797	0.865	0.848	0.931	0.879	0.862	0.864

Source: Project team compilation

8.2.3.2.3 Full adoption scenario

For the full adoption scenario of water-saving policies, it is assumed that a 70% water restriction is imposed. This means that only 88 mm of water is available for irrigation, which is 30% less than the full gross irrigation requirement of 294.04 mm. When divided over 13 intervals, this results in approximately 6.8 mm per interval. Since AquaCrop's model irrigation schedule only accepts whole numbers, the amount was rounded down to 6 mm per interval to ensure the total irrigation does not exceed 88 mm. This water is applied in equal amounts at evenly spaced intervals throughout the maize growing season. Table 8.10 below presents the irrigation schedule for the partial adoption of water-saving policies in the Hartbeespoort Irrigation Scheme.

Table 8.10: Irrigation Schedule for the Full Adoption Scenario of Water-Saving policies for Soybean Production in the Hartbeespoort Irrigation Scheme

Event	2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Day Number	Net application (mm)
1	24 Nov 2010	24 Nov 2011	24 Nov 2012	24 Nov 2013	24 Nov 2014	24 Nov 2015	24 Nov 2016	24 Nov 2017	10	6
2	4 Dec 2010	4 Dec 2011	4 Dec 2012	4 Dec 2013	4 Dec 2014	4 Dec 2015	4 Dec 2016	4 Dec 2017	20	6
3	14 Dec 2010	14 Dec 2011	14 Dec 2012	14 Dec 2013	14 Dec 2014	14 Dec 2015	14 Dec 2016	14 Dec 2017	30	6
4	24 Dec 2010	24 Dec 2011	24 Dec 2012	24 Dec 2013	24 Dec 2014	24 Dec 2015	24 Dec 2016	24 Dec 2017	40	6
5	3 Jan 2011	3 Jan 2012	3 Jan 2013	3 Jan 2014	3 Jan 2015	3 Jan 2014	3 Jan 2017	3 Jan 2018	50	6
6	13 Jan 2011	13 Jan 2012	13 Jan 2013	13 Jan 2014	13 Jan 2015	13 Jan 2015	13 Jan 2017	13 Jan 2018	60	6
7	23 Jan 2011	23 Jan 2012	23 Jan 2013	23 Jan 2014	23 Jan 2015	23 Jan 2015	23 Jan 2017	23 Jan 2018	70	6
8	2 Feb 2011	2 Feb 2012	2 Feb 2013	2 Feb 2014	2 Feb 2015	2 Feb 2015	2 Feb 2017	2 Feb 2018	80	6
9	12 Feb 2011	12 Feb 2012	12 Feb 2013	12 Feb 2014	12 Feb 2015	12 Feb 2015	12 Feb 2017	12 Feb 2018	90	6
10	22 Feb 2011	22 Feb 2012	22 Feb 2013	22 Feb 2014	22 Feb 2015	22 Feb 2015	22 Feb 2017	22 Feb 2018	100	6
11	4 Mar 2011	3 Mar 2012	4 Mar 2013	4 Mar 2014	4 Mar 2015	3 Mar 2015	4 Mar 2017	4 Mar 2018	110	6
12	14 Mar 2011	13 Mar 2012	14 Mar 2013	14 Mar 2014	14 Mar 2015	13 Mar 2015	14 Mar 2017	14 Mar 2018	120	6
13	24 Mar 2011	23 Mar 2012	24 Mar 2013	24 Mar 2014	24 Mar 2015	23 Mar 2015	24 Mar 2017	24 Mar 2018	130	6

Source: Project team compilation

Table 8.11 below presents the results for the full adoption of water-saving policies in the Hartbeespoort Irrigation Scheme for each dominant soil type. It also includes a weighted average obtained by considering the area covered by each soil type.

Table 8.11: Summary of Results under the full-Adoption Scenario for Water-Saving policies among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Full Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	11.995	11.090	11.602	12.245	12.163	12.457	10.464	12.524	11.818
	Yield (ton/ha)	4.564	4.366	4.461	4.084	3.771	3.905	3.068	3.964	4.023
	Irrigation (mm)	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000
	WP_{ET} (Kg/m ³)	0.910	0.790	0.800	0.820	0.760	0.870	0.710	0.700	0.795
Calcic Vertisols	Biomass (ton/ha)	11.856	11.849	11.608	12.257	12.088	12.286	10.523	12.275	11.843
	Yield (ton/ha)	4.578	4.615	4.278	4.126	3.760	3.920	3.100	3.955	4.042
	Irrigation (mm)	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000
	WP_{ET} (Kg/m ³)	0.830	0.820	0.830	0.770	0.740	0.760	0.800	0.780	0.791
Ferric Luvulisols	Biomass (ton/ha)	11.740	11.472	10.918	11.922	11.737	12.415	9.271	12.441	11.490
	Yield (ton/ha)	4.292	4.398	4.082	4.120	3.800	3.905	3.546	4.128	4.034
	Irrigation (mm)	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000
	WP_{ET} (Kg/m ³)	0.960	0.840	0.770	0.780	0.740	0.710	0.710	0.730	0.780
Weighted Average	Biomass (ton/ha)	11.881	11.614	11.537	12.220	12.072	12.343	10.382	12.356	11.801
	Yield (ton/ha)	4.546	4.529	4.306	4.114	3.767	3.915	3.136	3.975	4.036
	Irrigation (mm)	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000
	WP_{ET} (Kg/m ³)	0.864	0.814	0.816	0.784	0.745	0.784	0.768	0.754	0.791

Source: Project team compilation

8.2.3.2.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water Saving Policies

AquaCrop model simulations were run for three scenarios representing different levels of water saving policy adoption. For each scenario, weighted averages of key metrics were calculated using the area share of each soil unit in the main irrigation zone of the Hartbeespoort Irrigation Scheme, as indicated in Table 8.12 below.

Table 8.12: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	12.38	4.86	286.00	0.86	Baseline (0%)
	Partial adoption	4.79	4.79	195.00	-0.86	-1.38%
	Full Adoption	11.80	4.04	78.00	0.79	-16.96%

Source: Project team compilation

8.2.3.3 The adaptation towards climate variability

8.2.3.3.1 No adaptation scenario

The no adaptation scenario to climate variability assumes that the full Gross Irrigation Requirement (GIR) of 294.04 mm is applied evenly across the growing season. No water-saving practices such as mulching are implemented, and only moderate weed management is used, allowing for some crop competition. Unlike the no-adoption scenarios for water-saving technologies and policies, this scenario excludes mulching, which affects the soil water balance. As a result, separate AquaCrop model simulations were necessary, even though the irrigation schedule is the same as that used in the no-adoption scenarios for water-saving technologies and policies. Therefore, the irrigation schedule is not reproduced here. Table 8.13 below presents the AquaCrop model simulation results for the no-adaptation to climate variability scenario.

Table 8.13: Summary of Results under the No-Adaptation Scenario to Climate variability among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

No Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	9.367	9.423	9.469	9.514	9.593	9.656	9.603	9.726	9.544
	Yield (ton/ha)	3.674	3.696	3.714	3.732	3.763	3.788	3.767	3.815	3.744
	Irrigation (mm)	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000
	WP_{ET} (Kg/m ³)	0.690	0.630	0.620	0.640	0.650	0.710	0.670	0.660	0.659
Calcic Vertisols	Biomass (ton/ha)	9.303	14.000	9.463	9.513	9.573	9.643	9.554	9.696	10.093
	Yield (ton/ha)	3.649	3.693	3.712	3.732	3.755	3.783	3.748	3.803	3.734
	Irrigation (mm)	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000
	WP_{ET} (Kg/m ³)	0.670	0.610	0.600	0.660	0.630	0.690	0.650	0.640	0.644
Ferric Luvisols	Biomass (ton/ha)	9.363	9.419	9.441	9.585	9.585	9.653	9.425	9.713	9.523
	Yield (ton/ha)	3.673	3.695	3.700	3.760	3.760	3.786	3.697	3.810	3.735
	Irrigation (mm)	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000
	WP_{ET} (Kg/m ³)	0.700	0.640	0.620	0.660	0.660	0.720	0.670	0.670	0.668
Weighted Average	Biomass (ton/ha)	9.326	12.352	9.462	9.520	9.579	9.647	9.554	9.706	9.893
	Yield (ton/ha)	3.658	3.694	3.711	3.735	3.758	3.785	3.748	3.807	3.737
	Irrigation (mm)	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000	286.000
	WP_{ET} (Kg/m ³)	0.678	0.618	0.607	0.655	0.638	0.698	0.657	0.648	0.650

Source: Project team compilation

8.2.3.3.2 Partial adaptation scenario

Under the partial adaptation to climate variability scenario, weed management is set to moderate, and a 20% deficit irrigation strategy is implemented. This reduces the gross irrigation requirement of 294.04 mm to 235.232 mm ($294.04 \times 0.8 = 235.232$ mm), which is applied evenly at 10-day intervals throughout the growing season. Table 8.14 below presents the irrigation schedule for the partial adaptation towards climate variability of soybean production in the Hartbeespoort Irrigation Scheme.

Table 8.14: Irrigation Schedule for the Partial Adaptation Scenario towards climate variability of Soybean Production in the Hartbeespoort Irrigation Scheme

Event	2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Day Number	Net application (mm)
1	24 Nov 2010	24 Nov 2011	24 Nov 2012	24 Nov 2013	24 Nov 2014	24 Nov 2015	24 Nov 2016	24 Nov 2017	10	18
2	4 Dec 2010	4 Dec 2011	4 Dec 2012	4 Dec 2013	4 Dec 2014	4 Dec 2015	4 Dec 2016	4 Dec 2017	20	18
3	14 Dec 2010	14 Dec 2011	14 Dec 2012	14 Dec 2013	14 Dec 2014	14 Dec 2015	14 Dec 2016	14 Dec 2017	30	18
4	24 Dec 2010	24 Dec 2011	24 Dec 2012	24 Dec 2013	24 Dec 2014	24 Dec 2015	24 Dec 2016	24 Dec 2017	40	18
5	3 Jan 2011	3 Jan 2012	3 Jan 2013	3 Jan 2014	3 Jan 2015	3 Jan 2014	3 Jan 2017	3 Jan 2018	50	18
6	13 Jan 2011	13 Jan 2012	13 Jan 2013	13 Jan 2014	13 Jan 2015	13 Jan 2015	13 Jan 2017	13 Jan 2018	60	18
7	23 Jan 2011	23 Jan 2012	23 Jan 2013	23 Jan 2014	23 Jan 2015	23 Jan 2015	23 Jan 2017	23 Jan 2018	70	18
8	2 Feb 2011	2 Feb 2012	2 Feb 2013	2 Feb 2014	2 Feb 2015	2 Feb 2015	2 Feb 2017	2 Feb 2018	80	18
9	12 Feb 2011	12 Feb 2012	12 Feb 2013	12 Feb 2014	12 Feb 2015	12 Feb 2015	12 Feb 2017	12 Feb 2018	90	18
10	22 Feb 2011	22 Feb 2012	22 Feb 2013	22 Feb 2014	22 Feb 2015	22 Feb 2015	22 Feb 2017	22 Feb 2018	100	18
11	4 Mar 2011	3 Mar 2012	4 Mar 2013	4 Mar 2014	4 Mar 2015	3 Mar 2015	4 Mar 2017	4 Mar 2018	110	18
12	14 Mar 2011	13 Mar 2012	14 Mar 2013	14 Mar 2014	14 Mar 2015	13 Mar 2015	14 Mar 2017	14 Mar 2018	120	18
13	24 Mar 2011	23 Mar 2012	24 Mar 2013	24 Mar 2014	24 Mar 2015	23 Mar 2015	24 Mar 2017	24 Mar 2018	130	18

Source: Project team compilation

Table 8.15 below presents the AquaCrop model simulation results for the partial adaptation towards the climate variability scenario in the Hartbeespoort Irrigation Scheme for soybean production.

Table 8.15: Summary of Results under the Partial Adaptation Scenario to Climate Variability among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Partial Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	10.476	10.548	10.584	10.648	10.738	10.811	10.635	10.890	10.666
	Yield (ton/ha)	4.160	4.195	4.208	4.236	4.268	4.301	4.201	4.329	4.237
	Irrigation (mm)	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000
	WP_{ET} (Kg/m ³)	0.800	0.730	0.710	0.760	0.750	0.830	0.770	0.770	0.765
Calcic Vertisols	Biomass (ton/ha)	10.404	10.640	10.593	10.649	10.717	10.801	10.584	10.852	10.655
	Yield (ton/ha)	4.115	4.190	4.207	4.236	4.256	4.294	4.175	4.305	4.222
	Irrigation (mm)	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000
	WP_{ET} (Kg/m ³)	0.770	0.710	0.690	0.750	0.730	0.810	0.750	0.740	0.744
Ferric Luvisols	Biomass (ton/ha)	10.469	10.542	10.433	10.433	10.722	10.808	10.265	10.875	10.568
	Yield (ton/ha)	4.155	4.191	4.129	4.129	4.259	4.299	4.024	4.320	4.188
	Irrigation (mm)	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000
	WP_{ET} (Kg/m ³)	0.800	0.740	0.710	0.710	0.760	0.830	0.750	0.770	0.759
Weighted Average	Biomass (ton/ha)	10.429	10.606	10.575	10.627	10.723	10.804	10.565	10.864	10.649
	Yield (ton/ha)	4.131	4.191	4.199	4.225	4.259	4.296	4.167	4.313	4.223
	Irrigation (mm)	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000	234.000
	WP_{ET} (Kg/m ³)	0.781	0.718	0.697	0.749	0.738	0.817	0.755	0.751	0.751

Source: Project team compilation

8.2.3.3.3 Full adaptation scenario

The full adaptation to the climate variability scenario in the Hartbeespoort Irrigation Scheme includes high-level mulching (75% coverage), and weed management is implemented at the most intensive level to eliminate crop competition. A 30% deficit irrigation strategy is adopted, reducing the full gross irrigation requirement of 294 mm to 205 mm. Water is applied strategically during the crop's critical growth stages to maximise productivity. The irrigation schedule for this scenario is presented in Table 8.16 below.

Table 8.16: Irrigation Schedule for the full Adaptation Scenario towards climate variability of Soybean Production in the Hartbeespoort Irrigation Scheme

Event	2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Day Number	Net application (mm)
1	24 Nov 2010	24 Nov 2011	24 Nov 2012	24 Nov 2013	24 Nov 2014	24 Nov 2015	24 Nov 2016	24 Nov 2017	10	5
2	4 Dec 2010	4 Dec 2011	4 Dec 2012	4 Dec 2013	4 Dec 2014	4 Dec 2015	4 Dec 2016	4 Dec 2017	20	5
3	14 Dec 2010	14 Dec 2011	14 Dec 2012	14 Dec 2013	14 Dec 2014	14 Dec 2015	14 Dec 2016	14 Dec 2017	30	5
4	24 Dec 2010	24 Dec 2011	24 Dec 2012	24 Dec 2013	24 Dec 2014	24 Dec 2015	24 Dec 2016	24 Dec 2017	40	10
5	3 Jan 2011	3 Jan 2012	3 Jan 2013	3 Jan 2014	3 Jan 2015	3 Jan 2014	3 Jan 2017	3 Jan 2018	50	15
6	13 Jan 2011	13 Jan 2012	13 Jan 2013	13 Jan 2014	13 Jan 2015	13 Jan 2015	13 Jan 2017	13 Jan 2018	60	20
7	23 Jan 2011	23 Jan 2012	23 Jan 2013	23 Jan 2014	23 Jan 2015	23 Jan 2015	23 Jan 2017	23 Jan 2018	70	35
8	2 Feb 2011	2 Feb 2012	2 Feb 2013	2 Feb 2014	2 Feb 2015	2 Feb 2015	2 Feb 2017	2 Feb 2018	80	35
9	12 Feb 2011	12 Feb 2012	12 Feb 2013	12 Feb 2014	12 Feb 2015	12 Feb 2015	12 Feb 2017	12 Feb 2018	90	35
10	22 Feb 2011	22 Feb 2012	22 Feb 2013	22 Feb 2014	22 Feb 2015	22 Feb 2015	22 Feb 2017	22 Feb 2018	100	25
11	4 Mar 2011	3 Mar 2012	4 Mar 2013	4 Mar 2014	4 Mar 2015	3 Mar 2015	4 Mar 2017	4 Mar 2018	110	5
12	14 Mar 2011	13 Mar 2012	14 Mar 2013	14 Mar 2014	14 Mar 2015	13 Mar 2015	14 Mar 2017	14 Mar 2018	120	5
13	24 Mar 2011	23 Mar 2012	24 Mar 2013	24 Mar 2014	24 Mar 2015	23 Mar 2015	24 Mar 2017	24 Mar 2018	130	5

Source: Project team compilation

The results for the full adaptation scenario to climate variability are presented in Table 8.17 below, based on AquaCrop model simulations across the three dominant soil types in the main irrigation zone of the Hartbeespoort Irrigation Scheme.

Table 8.17: Summary of Results under the Full Adaptation Scenario to Climate variability among Commercial Soybean Farmers in the Hartbeespoort Irrigation Scheme

Full Adoption Scenario										
Soil		2010/11	2011/12	2012/13	2013/14	2015/16	2016/17	2017/18	2018/19	Average
Eutric Plinthosols	Biomass (ton/ha)	12.061	12.228	0.040	12.355	12.442	12.532	12.169	12.596	10.803
	Yield (ton/ha)	4.770	4.798	4.825	4.847	4.884	4.917	4.885	4.949	4.859
	Irrigation (mm)	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
	WP_{ET} (Kg/m ³)	0.980	0.880	0.850	0.940	0.900	1.010	0.950	0.930	0.930
Calcic Vertisols	Biomass (ton/ha)	12.004	122.230	12.229	12.356	12.426	12.505	12.170	12.524	26.056
	Yield (ton/ha)	4.777	4.799	4.825	4.847	4.881	4.910	4.878	4.947	4.858
	Irrigation (mm)	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
	WP_{ET} (Kg/m ³)	0.970	0.870	0.840	0.930	0.880	0.990	0.940	0.910	0.916
Ferric Luvissols	Biomass (ton/ha)	11.999	12.214	12.261	12.346	12.412	12.519	11.628	12.565	12.243
	Yield (ton/ha)	4.778	4.794	4.806	4.843	4.879	4.913	4.659	4.946	4.827
	Irrigation (mm)	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
	WP_{ET} (Kg/m ³)	0.990	0.890	0.860	0.940	0.900	1.010	0.930	0.930	0.931
Weighted Average	Biomass (ton/ha)	12.018	82.628	9.063	12.355	12.429	12.513	12.116	12.547	20.709
	Yield (ton/ha)	4.775	4.798	4.823	4.847	4.882	4.912	4.858	4.947	4.855
	Irrigation (mm)	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
	WP_{ET} (Kg/m ³)	0.975	0.875	0.845	0.934	0.887	0.997	0.942	0.917	0.921

Source: Project team compilation

8.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adaptation towards Climate Variability

AquaCrop model simulations were run for three scenarios representing different levels of adaptation to climate variability, as illustrated in Table 8.18 below.

Table 8.18: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				% Change in Yield Compared to No Adoption
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	
Adoption scenario	No Adoption	9.89	3.74	286.00	0.65	Baseline (0%)
	Partial adoption	10.65	4.22	234.00	0.92	13.00%
	Full Adoption	20.71	4.86	205.00	0.92	29.93%

Source: Project team compilation

8.2.4 Multiplier Analysis

This section presents the economic implications of behavioural responses to climate variability among commercial soybean irrigators in the Hartbeespoort Irrigation Scheme. These scenarios were simulated in the AquaCrop model to estimate the resulting changes in soybean yield. The model outputs provided a quantifiable basis for assessing how different levels of adaptation could affect productivity. The changes in yield were then applied as shocks to a Social Accounting Matrix through multiplier analysis in order to explore the broader economic consequences. This approach allows us to move beyond farm-level agronomic outcomes to assess the wider impact across the economy, accounting for the ripple effect. The results of the multiplier analysis are presented in Table 8.19 below.

Table 8.19: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Hartbeespoort Irrigation Scheme for Commercial Soybean Irrigators

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (+0.61%)	Full (+0.95%)	Partial (-1.38%)	Full (-16.96%)	Partial (+13%)	Full (+29.93%)
Soybean in the Northwest	19.12	14.63	8.15	25.03	19.42	293.64
Total labour remuneration in SA	13.22	7.02	4.67	6.39	16.76	222.76
Northwest province generates labour return	2.35	3.01	1.89	3.2	5.4	12.54
Gross operating surplus SA	12.81	5.92	1.42	16.93	16.18	32.69
Household income for the Northwest	39.89	14.75	9.89	22.78	17.47	401.17
Land return in SA	8.67	3.68	1.69	21.5	20.38	22.24
land returns to irrigation in the West	R338,652.6	R118,950.88	R78,235.6	R210,380.96	R450,559.60	R3,669,113.0
Institution income SA (enterprise + Household)	52.87	20.05	16.25	42.63	39.17	765.14
Household generating income SA	51.83	19.95	15.82	39.63	27.3	341.17
Value-added generating income SA (Labour + capital + land)	340.18	114.92	89.50	187.63	238.18	772.11

Source: Project team compilation

8.2.4.1 Adoption of Water-saving Technologies

8.2.4.1.1 Partial Adoption

As indicated in Table 8.19 above, the partial water saving technology scenario where soil moisture levels inform irrigation scheduling results in R19.12 million output of soybeans in the northern part of the Hartbeespoort Irrigation Scheme and in the economy of Northwest province. The total labour remuneration was estimated at R13.22 million in the economy of South Africa, of which the Northwest province generates a labour return of about R2.35 million and a gross operating surplus (capital) of R12.81 million in the economy of South Africa. Most of the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R39.89 million for the economy of North West province. The overall land return was estimated to increase by R8.67 million in the economy of South Africa, of which the return to irrigation in Northwest was only R338 652.60. The highest return on irrigation in the province of Northwest was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of Northwest province.

Institutional incomes (enterprise and households) were valued at R52.87 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes valued at R51.83 and R340.18 million in the economy of South Africa, respectively. The findings of this study concurred with those of Anjaly et al. (2024), which indicated that implementing water-saving technology interventions, such as soil moisture techniques like eco-friendly straw mulching, contribute to better soil health and sustainable yields.

8.2.4.1.2 Full Adoption

As indicated in Table 8.19 above, the full adoption of water-saving technologies, which include irrigation scheduling based on varying soil moisture levels and a shift from sprinkler to drip irrigation, increases commercial soybean output by R14.63 million in the northern part of the Hartbeespoort Irrigation Scheme and in the economy of the Northwest province. The total labour remuneration was estimated at R7.02 million in the economy of South Africa, of which the Northwest province generates labour return of about R3.01 million and gross operating surplus (capital) of R5.92 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R14.75 million towards the economy of Northwest province. The overall land return was estimated at R3.68 million in the economy of South Africa, of which the return to irrigation in Northwest was only R118 950.88. The highest return on irrigation in the province of Northwest was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of Northwest province.

Institutional incomes (enterprise and households) were valued at R20.05 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R19.95 and R114.92 million in the economy of South Africa, respectively. The findings of this study concurred with those of Postel et al. (2001), which found that drip irrigation technology appears to be a viable option for smallholder farmers and is a key to increasing crop production and incomes, alleviating a significant share of rural hunger and poverty, and enhancing household food security.

8.2.4.2 Adoption of Water Saving Policies

8.2.4.2.1 Partial Adoption

As indicated in Table 8.19 above, the partial adoption of water saving policies resulted in R8.15 million in soybean output in the Hartbeespoort Irrigation Scheme and in the Northwest province economy. The total labour remuneration was estimated to be R4.67million in the economy of South Africa, of which the Northwest province generates a labour return of about R1.89 million and a gross operating surplus (capital) of R1.42 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R9.89 million in the economy of the Northwest province. The overall land return was estimated at R1.69 million in the economy of South Africa, of which the return to irrigation in the Northwest was only R78 235.60. The highest return on irrigation in the province of the Northwest was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of Northwest province.

Institutional incomes (enterprise and households) were valued at R16.25 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R15.82 and R89.50 million in the economy of South Africa, respectively. The finding of this study is aligned with those of Adegbo et al. (2019), who found that farmers who adopted adaptation strategies would have gained lower yields if they had not adopted them. Those who did not adopt a strategy would have gained higher yields than if they had.

8.2.4.2.2 Full Adoption

As indicated in Table 8.19 above, the full adoption of water-saving policies entailed a R25.03million output of soybeans in the Hartbeespoort Irrigation Scheme and in the economy of the Northwest province. The total labour remuneration was estimated at R6.39 million in the economy of South Africa, of which the Northwest province generates a labour return of about R3.2 million and a gross operating surplus (capital) of R16.93 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R22.78 million towards the economy of the Northwest province. The overall land return was estimated at R21.5 million in the economy of South Africa, of which the return to irrigation in Northwest was only R210 380.96. The highest return on irrigation in a district of the Northwest province was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of NNorthwestprovince.

Institutional incomes (enterprises and households) were valued at R42.63 million in the economy of South Africa. The households and value added (labour, capital, and land) generate incomes valued at R42.63 and R187.63 million in the economy of South Africa, respectively. As indicated in this sub-section above, the findings of this study concurred with those of Adego et al. (2019), who found that farmers who adopted adaptation strategies would have gained lower yields if they had not adopted them. Those who did not adopt a strategy would have gained a higher yield than if they had.

8.2.4.3 Adaptation to Climate Variability

8.2.4.3.1 Partial Adaption

As indicated in Table 8.19 above, the partial adaptation to climate variability, which entails improved water management and deficit irrigation, resulted in a R19.42 million output of soybeans in the Hartbeespoort Irrigation Scheme and in the Northwest province economy. The total labour remuneration was estimated at R16.76 million in the economy of South Africa, of which the Northwest province generated a labour return of about R5.40 million and a gross operating surplus (capital) of R16.18 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R17.47 million towards the economy of the Northwest province. The overall land return was estimated at R20.38 million in the economy of South Africa, of which the return to irrigation in Northwest was R450 559.33. The highest return on irrigation in the province of the Northwest was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of the NNorthwestprovince.

Institutional incomes (enterprise and households) were valued at R39.17million in the economy of South Africa. The households and value added (labour, capital, and land) generate incomes of R27.30 and R238.18 million in the economy of South Africa, respectively. The finding of this study is aligned with those of Zhu et al. (2024), who found that climate variability impacts soybean production mainly in terms of yield and quality. Rising temperatures negatively affect soybean growth, development, and yield.

8.2.4.3.2 Full Adaption

As indicated in Table 8.19 above, the full adaptation to climate variability, which entails perfect weed management, deficit irrigation, and irrigation applied strategically during the crop's critical growth stages, resulted in a R293.64 million soybean output in the northern part of the Hartbeespoort Irrigation Scheme and in the economy of Northwest province. The total labour remuneration was estimated at R222.76 million in the economy of South Africa, of which the Northwest province generates a labour return of about R12.54 million and a gross operating surplus (capital) of R32.69 million in the economy of South Africa. Most of

the labour income was derived from the Western Cape province, followed by the Northwest and Mpumalanga provinces.

Household income was estimated at R401.97 million towards the economy of Northwest province. The overall land return was estimated at R22.24 million in the economy of South Africa, of which the return to irrigation in the Northwest was R3 669 113.00. The highest return on irrigation in the province of the Northwest was found in the Bojanala irrigation district, followed by the Modiri and Ruth irrigation districts in the economy of the NNorthwestprovince.

Institutional incomes (enterprise and households) were valued at R765.14 million in the economy of South Africa. The households and value added (labour, capital, and land) generate incomes of R341.17 and R772.11 million in the economy of South Africa, respectively. As indicated above in this sub-section, the findings of this study concurred with those of Zhu et al. (2024), who found that climate variability impacts soybean production mainly in terms of yield and quality. Rising temperatures negatively affect soybean growth, development, and yield.

8.3 Discussions

The TPB results indicate that the intention to adopt water-saving technologies among commercial soybean irrigators in the Hartbeespoort Irrigation Scheme is strongly influenced by perceived risks and technical factors, both positively shaping intentions, while institutional and legal factors negatively impact subjective norms. This suggests that farmers are more likely to adopt these technologies when they perceive clear benefits and have confidence in their technical feasibility. However, they might be discouraged by institutional barriers or a lack of social support. Under these psychological conditions, a no-adoption scenario would prevail where barriers dominate, while partial adoption occurs when perceived risks and technical factors encourage some uptake.

Corresponding Aqua Crop model simulations show that different adoption scenarios lead to an increase in soybean yield with varying rand value as a ripple effect through multiplier analysis across the economy, including increases in soybean output in the Northwest province, total labour remuneration, and gross operating surplus in South Africa, as well as enhanced household income and land returns, both nationally and regionally. This demonstrates that psychological drivers of technology adoption not only affect farm-level productivity but also have broader economic implications for the province and country.

For the behaviour of adapting to climate variability, the extended Theory of Planned Behaviour model identified several important psychological drivers among commercial soybean irrigators in the Hartbeespoort Irrigation Scheme. Institutional and legal factors were found to influence perceived social

pressure to adopt the behaviour negatively. At the same time, perceptions of risk related to issues such as load shedding and tariffs encouraged farmers to consider adaptive practices. Trust in relevant institutions and technologies also played a key role in shaping farmers' willingness to adapt. These psychological conditions suggest that adaptation is more likely when farmers feel supported by reliable systems and when they recognise the risks of inaction.

CHAPTER 9: CASE STUDY OF COMMERCIAL SUGARCANE PRODUCTION IN THE IMPALA IRRIGATION SCHEME, KWAZULU-NATAL PROVINCE

9.1 Overview

This section presents the results generated through the application of the integrated framework developed in this project, focusing on commercial sugarcane producers in the Impala Irrigation Scheme. The analysis begins with a summary of the demographic, farm, and household characteristics of the irrigators who participated in the study.

9.2 Results

9.2.1 Demographic, Farm, and Household Characteristics of Respondents

The demographic profile of respondents in the Impala Irrigation Scheme, as shown in Table 9.1 below, highlights several key characteristics. All respondents were male, indicating a male-dominated farming environment. The age distribution suggests a significant proportion of older farmers, with 33.33% being aged 61 years and older. Regarding education, respondents exhibited a high level of educational attainment: 37.0% held diplomas, and 33.3% had undergraduate degrees. Additionally, health levels were reported as good (53.7%) or excellent (33.3%) among the respondents.

The primary source of irrigation water was predominantly from canals, with 67% of respondents relying on this method. Other sources included dams (7%) and a combination of river and dam or canal water (4% each). Most respondents (81.5%) engaged in crop production, while 18.5% practised mixed farming. Regarding land ownership, 50% of respondents owned between two and five agricultural plots, and 42.6% owned more than five. The majority of farmland (44.4%) was highly clustered together, located within 1–5 km of each other. In terms of business structure, 39% operated as corporations, and 41% managed their farms as trusts, indicating a diversity in farm management practices. Most respondents (79.6%) were sole owners of their land, with 70.4% having irrigation land located less than 1 km from their water source.

The majority of households (70.4%) had only one adult member aged 18 years and older, with 46.3% of households consisting of two individuals when accounting for both adults and children. In terms of involvement in farming activities, 59.3% of respondents reported that only one individual in the household participated, while 33.3% had two individuals engaged in farming. Marital status data indicated that 94.4% of respondents were married, highlighting the prevalence of stable family structures in the community. The

age distribution of household heads showed that 29.6% were aged 41–50 years, with a significant portion (33.3%) being 61 years or older. This suggests a mature demographic within farming leadership. The primary source of livelihood for most respondents (87%) was agriculture, underscoring the community's reliance on farming for economic stability. Furthermore, a majority (65%) of households reported having no off-farm income, which might indicate limited diversification of income sources within the community.

Table 9.1: Respondents’ demographic, farm, and households profile

Variable	Classification	Frequency	Percentage (%)
Demographic profile			
Gender	Male	54	100%
Age	31-40	7	12,96%
	41-50	16	29,63%
	51-60	13	24,07%
	61 and older	18	33,33%
Highest education level	Secondary (grade 8-12)	16	29,6%
	Diploma	20	37,0%
	Undergraduate degree	18	33,3%
	Average	7	13,0%
	Good	29	53,7%
	Excellent	18	33,3%
Farm characteristics profile			
The primary source of water used for irrigation	River	3	6%
	Dam	4	7%
	Canal	36	67%
	River and dam water	2	4%
	River and canal water	3	6%
	Dam and canal water	4	7%
	Canal and borehole	2	4%
Type of farming performed	Crop production	44	81,5%
	Mixed farming	10	18,5%
Amount of agricultural land deeds owned	One	4	7,4%
	Two to five	27	50,0%
	More than five	23	42,6%
	Highly clustered together (1-5 km)	24	44,4%

How scattered is the farmland from the main farm	Moderately dispersed (6-10 km)	13	24,1%
	Highly dispersed (more than 10 km)	17	31,5%
Business structure of the farm operations	Sole proprietorship	8	15%
	Corporation	21	39%
	Partnership	2	4%
	Trust	22	41%
	Closed corporation	1	2%
The land ownership type of the farm	Sole owner	43	79,6%
	Lease	0	0%
	Combination of sole owner and lease	11	20,4%
Distance of the main irrigation land from the water source	Less than 1 Km	38	70,4%
	1-3 Km	10	18,5%
	3-7 Km	3	5,6%
	7-10 Km	1	1,9%
	More than 10 Km	2	3,7%
Household characteristics			
Number of adults (18 years and older) living in the household	One	38	70,4%
	Two	10	18,5%
	Three or more	3	5,6%
Total individuals living in the household (adults + children)	One	4	7,4%
	Two	25	46,3%
	Three	8	14,8%
	Four or more	17	31,5%
Individuals in the household involved in farming activities	One	32	59,3%
	Two	18	33,3%
	Three or more	4	7,4%
Marital status	Married	51	94,4%
	Single	2	3,7%
	Widowed	1	1,9%
Age of the head of the household	31-40	27	12,96%
	41-50	40	29,63%

	51-60	33	24,07%
	61 and older	21	33,33%
Primary source of livelihood	Farmer/agricultural activities	47	87,0%
	Self-employed/business owner	7	13,0%
Off-farm income	Yes	19	35%
	No	35	65%

Sources: Project team Compilations

9.2.2 Theory of Planned Behaviour

9.2.2.1 Standard TPB Model for Adoption of Water-Saving Technologies

None of the measurement items displayed outer loadings below 0.6, suggesting that all items contributed adequately to the construct being measured and indicated the reliability of the indicators. Given the exploratory nature of this study, we found these lower thresholds appropriate. While the constructs of Attitude (A_B), Subjective Norms (SN), Perceived Behavioural Control (PBC), and Intentions (INT) had Cronbach's alpha values below 0.60; all exhibited composite reliability scores above 0.70. It is important to note that Cronbach's alpha may underestimate reliability when constructs have few items or varying outer loadings. Composite reliability provides a more accurate assessment by accounting for individual outer loadings. Considering that we relied on two measurement items per construct because of the broad scope of this project, it is reasonable to conclude that the Cronbach's alpha values reflected an underestimation of internal consistency reliability.

All constructs demonstrated AVE values above 0.5. This indicates that the constructs successfully capture a significant portion of the variance in their respective measurement items. Initial estimations revealed that Subjective Norms (SN) had discriminant validity issues with the constructs of Intention (INT) and Attitude (A_B). To investigate possible collinearity issues, we examined the inner and outer model Variance Inflation Factor (VIF) values, which indicated no significant problems. Consequently, we removed the measurement item with the lowest factor loading (SN_2) from the Subjective Norms construct and recalculated the HTMT and Fornell-Larcker values. This adjustment resolved the discriminant validity issues, as the HTMT values fell below the 0.90 threshold.

The results indicated that all VIF values were below the threshold of 3, suggesting that there are no significant collinearity concerns among the constructs in the model. Figure 9.1 below provides a visual representation of the relationships among the constructs within the structural model, showing the path coefficients and significance levels. Appendix K, Table K.1 presents a detailed overview of the path

coefficients, including their values, t-statistics, and p-values, which provide insights into the significance of each relationship.

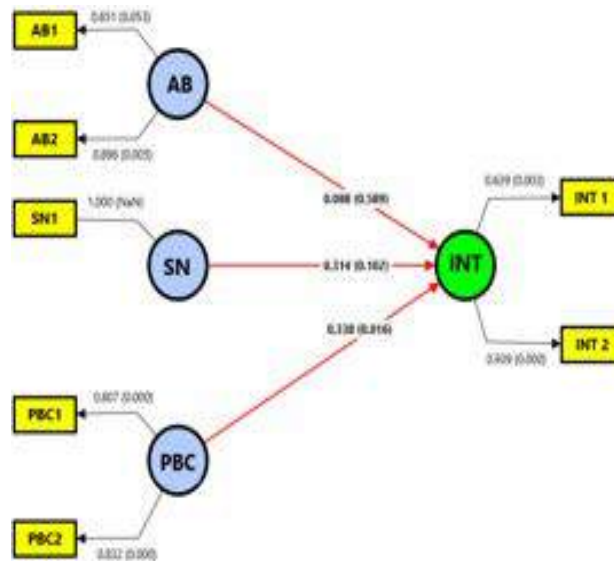


Figure 9.1: Path Analysis Findings of Sugarcane Irrigators' Intentions to Adopt Water-Saving Technologies in the Impala Irrigation Scheme

Source: Project team compilation

Appendix K, Table K.1 provides a detailed overview of the path coefficients derived from the structural model assessment. The path from Attitudes (**AB**) to Intentions (**INT**) was positive but non-significant ($\beta = 0.088$, $p = 0.589$), indicating that attitudes towards adopting water-saving technologies did not significantly influence sugarcane irrigators' intentions in the Impala Irrigation Scheme. In contrast, the relationship between Subjective Norms (**SN**) and Intentions (**INT**) was positive and significant ($\beta = 0.338$, $p < 0.05$), suggesting that social pressure played an important role in shaping irrigators' intentions. Lastly, Perceived Behavioural Control (**PBC**) had a positive but non-significant effect on Intentions (**INT**) ($\beta = 0.314$, $p = 0.102$), indicating that perceived control over adopting these technologies did not have a substantial impact.

The R^2 value for intentions (**INT**) is 0.275, with an adjusted R^2 of 0.232. These values indicate that approximately 27.5% of the variance in irrigators' intentions to adopt water-saving technologies can be explained by the model. The effect size (f^2) value of Attitudes (**AB**) is 0.009, suggesting a negligible effect. In contrast, both Subjective Norms (**INT**) at 0.130 and Perceived Behavioural Control (**PBC**) at 0.136 indicate medium effect sizes.

9.2.2.2 Augmented TPB Model for Adoption of Water-Saving Technologies

Several measurement items were dropped because their loadings fell below the acceptable threshold of 0.4. Specifically, the following measurement items were excluded: **IL**₁ (Institutional and Legal Factors), **IF**₇ (Informational Factors), **TX**₃ (Trust Factors), and **PFC**₁ (Perceived Financial Cost) to ensure internal reliability.

Most constructs had composite reliability scores above 0.60, indicating adequate internal consistency. However, the construct Access to Resources (**AR**) initially had a composite score below 0.60, but after dropping **AR**₁, the score improved above the acceptable threshold. Additionally, the construct Technical Factors (**TF**) had a score above 0.90, indicating potential over-reliability, which was resolved by dropping **TF**₁, the item with the lowest factor loading among the two measurement items for **TF**. Furthermore, the construct Perceived Risks from Load Shedding and Tariffs (**RB**₂) also had a composite score above 0.9, indicating redundancy among measurement items. To improve the composite reliability score and reduce redundancy, the measurement items RB8 and RB10 were dropped from the model.

All constructs show AVE values exceeding the 0.5 threshold, and so the results indicate that the constructs sufficiently explain over half of the variance in their indicators, ensuring satisfactory convergent validity. The HTMT ratio suggests that the construct Subjective Norms (**SN**) showed discriminant validity issues, with an HTMT ratio above 0.9 when compared with Attitudes (**A_B**), Access to Resources (**AR**), Institutional and Legal Factors (**IL**), and Intentions (**INT**). To address this, the measurement item with the lowest factor loading on **SN** (**SN**₁) was removed, which successfully resolved the issue. However, the construct Risk-Benefit (**RB**) exhibited an HTMT ratio higher than 0.9 with both Institutional and Legal Factors (**IL**) and Intentions (**INT**). Dropping the measurement item with the lowest factor loading on IL did not resolve the issue, leading to the complete exclusion of RB from the model.

Similarly, Institutional and Legal Factors (**IL**) had HTMT ratios above 0.9 with Attitudes (**A_B**) and Access to Resources (**AR**). After removing the measurement item with the lowest loading on **IL** (**IL**₈), the discriminant validity issues for **IL** were resolved.

Informational Factors (**IF**) also displayed discriminant validity issues, with an HTMT ratio exceeding 0.9 with Access to Resources (**AR**). Initially, the lowest-loading item on **IF** (**IF**₈) was dropped, but this did not improve the HTMT ratio. Subsequently, **IF**₁ was also removed, yet the issue persisted, leading to the complete exclusion of **IF** from the model.

Finally, Access to Resources (**AR**) showed an HTMT ratio higher than 0.9 with Attitudes (**A_B**). To address this, the lowest-loading measurement item on **AR** (**AR₃**) was removed, resolving the discriminant validity concerns for this construct.

The Variance Inflation Factor (VIF) values indicated that none of the paths in the structural model exhibited a VIF value exceeding 3. This suggests that collinearity is not a concern in the model. We also examine the structural path relationships for sugarcane irrigators in the Impala Irrigation Scheme regarding the adoption of water-saving technologies. Using the extended TPB model, we assess both direct and indirect effects, which differ from the standard TPB model that only considers direct effects owing to the lack of mediating relationships.

The specific indirect effects are presented in Appendix K, Table K.2. In this analysis, none of the specific indirect effects were found to be statistically significant. This suggests that, while the direct relationships among the constructs are essential, the mediating pathways through which attitudes, subjective norms, and perceived behavioural control influence the intention to adopt water-saving technologies do not have a significant impact in this context.

Similar to the specific indirect effects (Appendix K, Table K.3), none of the total indirect effects were found to be statistically significant. This indicates that the combined influence of the mediators in the model does not significantly affect the intention to adopt water-saving technologies among sugarcane irrigators in the Impala irrigation scheme.

The analysis of direct effects is presented in Appendix K, Table K.4, where two paths were found to be statistically significant. The influence of perceived financial cost (**PFC**) on attitudes (**A_B**) is negative ($\beta = -0.334, p < 0.05$), indicating that higher perceived financial costs are associated with less favourable attitudes toward the adoption of water-saving technologies. Conversely, technical factors (**TF**) positively influence intentions (**INT**) ($\beta = 0.411, p < 0.05$), suggesting that favourable technical factors significantly enhance the intentions of irrigators to adopt these technologies.

The total effects presented in Appendix K, Table K.5, exhibit a similar pattern to the direct effects, which is expected given that only the direct effects showed a significant influence. This similarity reinforces the idea that the primary drivers of irrigators' intentions to adopt water-saving technologies are the direct relationships established in the model. As such, the total effects further emphasise the importance of addressing perceived financial costs and technical factors in efforts to promote the adoption of these technologies among sugarcane irrigators.

For the construct of attitudes (A_B), the R^2 value is 0.262, with an adjusted R^2 of 0.168, indicating a moderate level of variance is explained. The intention (INT) construct shows a stronger R^2 of 0.591 and an adjusted R^2 of 0.507, suggesting that the model explains a significant portion of the variance in irrigators' intentions to adopt water-saving technologies. Perceived behavioural control (PBC) and subjective norms (SN) exhibit lower R^2 values of 0.229 (adjusted R^2 of 0.130) and 0.199 (adjusted R^2 of 0.096), respectively, indicating limited explanatory power for these constructs.

The effect size (f^2) value for perceived financial cost (PFC) has a moderate effect on attitudes (A_B) with an f^2 value of 0.143 and a small effect on intentions (INT) at 0.065. Technical factors (TF) exhibit a significant effect on intentions (INT), with an f^2 value of 0.312, underscoring its significance in shaping irrigators' intentions to adopt water-saving technologies. Other constructs, such as attitudes (A_B) and subjective norms (SN), demonstrate small to negligible effects across various outcomes.

9.2.2.3 Standard TPB Model for Adoption of Water-Saving Policies

Measurement item INT_3 was dropped from the construct Intentions, and SN_3 was removed from the construct Subjective Norms as a result of having factor loadings below 0.4 to ensure the reliability of the indicators. The construct Attitudes (A_B) had a Cronbach's alpha below 0.6 but achieved a composite reliability score above 0.7. According to Hair and Alamer (2022), composite reliability provides a more accurate assessment when there are few items or varying outer loadings, making it a more suitable measure of internal consistency in this context. Perceived Behavioural Control (PBC) showed both Cronbach's alpha and composite reliability scores above 0.7. For the remaining constructs, Intentions (INT) and Subjective Norms (SN), only one measurement item was retained for each; therefore, Cronbach's alpha and composite reliability could not be calculated for them.

The AVE values were above the recommended threshold of 0.5, indicating satisfactory convergent validity. For the HTMT ratios, all values are below the threshold of 0.9, indicating adequate discriminant validity. Moreover, the Fornell-Larcker criterion shows that the square root of the AVE for each construct (diagonal values) is larger than the correlations between constructs, further confirming that discriminant validity has been established. Both the Fornell-Larcker criterion and the HTMT ratio support the discriminant validity of the constructs in this study, affirming that the measures of Attitude (A_B), Intention (INT), Perceived Behavioural Control (PBC), and Subjective Norms (SN) are adequately distinct from one another.

The assessment of the VIF values for each path in the structural model revealed that all values are below 3, indicating that there are no significant collinearity issues present in the structural model.

The significance and relevance of the structural relationships were evaluated. Figure 9.2 below presents an overview of the path coefficients and p-values for each path in the inner model. Additionally, Appendix K, Table K.6 provides a detailed summary of these results.

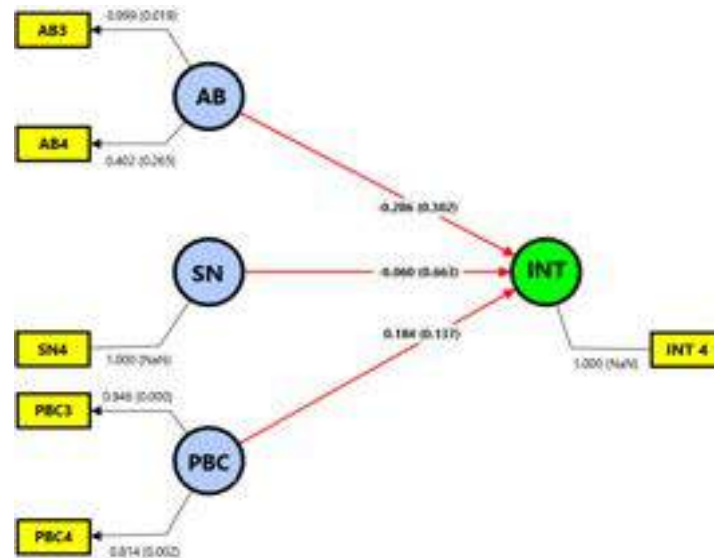


Figure 9.2: Path Analysis Findings of Sugarcane Irrigators' Intentions to Adopt Water-Saving Policies in the Impala Irrigation Scheme

Source: Project team compilation

As presented in Appendix K, Table K.6, the path from Attitudes (A_B) to Intentions (INT) was negative and non-significant ($\beta = -0.286$, $p = 0.302$), indicating that attitudes towards adopting water-saving policies did not significantly influence irrigators' intentions. The path from Subjective Norms (SN) to Intentions (INT) was also negative and non-significant ($\beta = -0.060$, $p = 0.663$), suggesting that social pressures did not play a significant role in shaping intentions. Lastly, the path from Perceived Behavioural Control (PBC) to Intentions (INT) was positive but non-significant ($\beta = 0.184$, $p = 0.137$), indicating that perceived ease of performing the behaviour did not significantly affect the intentions of irrigators.

The coefficient of determination (R^2) for Intentions (INT) was found to be 0.125, with an adjusted R^2 of 0.073. In terms of effect sizes, the F^2 statistic for the relationship between Attitudes (A_B) and Intentions (INT) was 0.091, indicating a small effect size. The effect size for Perceived Behavioural Control (PBC) on Intentions was 0.038, also reflecting a small effect. Conversely, the F^2 value for Subjective Norms (SN) on Intentions was 0.004, suggesting a negligible effect.

9.2.2.4 Augmented TPB Model for Adoption of Water-Saving Policies

The measurement items excluded from the model, to ensure the reliability of the indicators, included *INT*₃ (intentions), *IL*₇ (institutional and legal factors), *RB*₄ (perceived risks and benefits), *IF*₇ and *IF*₈ (informational factors), *TX*₃ (trust factors), *AR*₁ and *AR*₂ (access to resources), and *PFC*₄ (perceived financial cost).

Some constructs, like attitudes (*A_B*) and institutional and legal factors (*IL*), had Cronbach's alpha values below 0.6, but achieved composite reliability scores above 0.6. This indicates the importance of using composite reliability to achieve a more accurate assessment. Additionally, the construct for perceived risks from load shedding and tariffs (*RB2*) showed a composite reliability score above 0.9, indicating that the measurement items may be redundant. Removing item *RB*₈ resolved this issue, and the composite reliability score is now below 0.9. The construct *TF* also had a Composite reliability score above 0.9; therefore, we dropped the measurement item *TF*₃.

All constructs with more than one measurement item achieved an AVE above 0.5, except for the construct of institutional and legal factors (*IL*). To improve the AVE for *IL*, measurement item *IL*₈, which had the lowest factor loading among all measurement items for this construct, was removed. After this adjustment, the AVE for *IL* was successfully increased above the 0.5 threshold. No discriminant validity issues remained in the model assessing sugarcane irrigators' intentions to adopt water-saving policies in the Impala Irrigation Scheme. The results for VIF indicated that all paths in the inner model had Variance Inflation Factor (VIF) values below 3, suggesting that collinearity is not a concern in this model.

Initially, during the attempt to perform the bootstrap procedure, a NaN (Not a Number) result was obtained, indicating that the bootstrapping could not find a feasible solution. Given that we had conducted a rigorous evaluation of both the measurement and structural models and found no collinearity issues in either the inner (structural) or outer (measurement) model, we decided to explore the option of dropping constructs to address this problem. Upon removing the construct Perceived Risks and Benefits (*RB*) from our model, the issue was resolved, and the bootstrapping process was executed successfully, without any further complications.

Since mediating effects are involved in our extended model, we report on the specific indirect effects in Appendix K, Table K.7, which indicate that none of the indirect effects were statistically significant. This means that the mediating variables (*A_B*, *SN*, and *PBC*) in the extended model did not significantly impact the relationships between independent and dependent variables.

The results for the total indirect effects, shown in Appendix K, Table K.8, revealed that none of the effects were statistically significant. This suggests that the mediating constructs (*A_B*, *SN*, and *PBC*) did not

significantly mediate the overall indirect relationships between the additional predictors and the intention to adopt water-saving policies in the model.

According to the results presented in Appendix K, Table K.9, several direct paths were found to be significant in the model. The path from Access to Resources (*AR*) to Attitudes (*A_B*) was negative and significant ($\beta = -0.444$, $p < 0.01$), indicating that limited access to resources negatively influenced sugarcane irrigators' attitudes towards adopting water-saving technologies. Additionally, the direct path from Perceived Financial Cost (*PFC*) to Intentions (*INT*) was positive and highly significant ($\beta = 0.708$, $p < 0.01$), suggesting that lower perceived financial costs played a substantial role in shaping irrigators' intentions to adopt water-saving policies. Finally, the path from Trust (*TX*) to Intentions (*INT*) was also positive and significant ($\beta = 0.283$, $p < 0.05$), indicating that higher levels of trust contributed to stronger intentions to adopt these technologies in the Impala Irrigation Scheme.

The total effects presented in Appendix K, Table K.10, reflect a similar pattern to the direct effects, which is logical, given that the indirect effects were not significant. Since the total effects account for both direct and indirect effects, the lack of substantial indirect effects means that the total effects primarily align with the direct effects.

The results indicate that the R^2 for Intentions (*INT*) is 0.707, suggesting a strong explanatory power in predicting the intention to adopt water-saving policies among sugarcane irrigators in the Impala Irrigation Scheme. The adjusted R^2 for *INT* is 0.639, indicating that a substantial portion of the variance in intentions can be attributed to the model. For the remaining endogenous constructs, the R^2 values show moderate to weak explanatory power. The construct Attitudes (*A_B*) has an R^2 of 0.358 (adjusted R^2 of 0.261), Subjective Norms (*SN*) has an R^2 of 0.379 (adjusted R^2 of 0.285), and Perceived Behavioural Control (*PBC*) has a low R^2 of 0.182 (adjusted R^2 of 0.057).

The f^2 values indicate the strength of the relationships. For the intentions (*INT*), the strongest effect is seen from Task Factors (*TF*) with an f^2 value of 0.312, indicating a large effect size. Additionally, the construct Perceived Financial Costs (*PFC*) also shows a medium effect size on *INT* with an f^2 of 0.065. Overall, the results from both tables highlight the model's capacity to explain the variance in the dependent constructs, particularly in relation to intentions to adopt water-saving policies.

9.2.2.5 Standard TPB Model for the adaptation towards climate variability

The initial estimation revealed that all measurement items had loadings above 0.7, indicating strong indicator reliability for the constructs measured. Given the exploratory nature of this study, we considered these lower thresholds to be suitable. All constructs demonstrated Cronbach's alpha and composite reliability scores above 0.6, indicating adequate internal consistency reliability for the measurement model.

All constructs had Average Variance Extracted (AVE) values above 0.5. This suggests that the constructs explain a significant amount of the variance in their respective measurement items, confirming that the measurement model possesses good convergent validity.

The Fornell-Larcker Criterion indicates that the diagonal values, representing the square root of the Average Variance Extracted (AVE), are larger than the off-diagonal correlation values between the constructs. This demonstrates that each construct shares more variance with its indicators than with other constructs. Moreover, the HTMT ratios confirm that all values are below the threshold of 0.9, indicating acceptable discriminant validity.

The structural model assessment begins with evaluating collinearity in the structural model. We calculated the Variance Inflation Factor (VIF) values for each path in the inner model. The results revealed that all paths in the inner model had VIF values below the threshold of 3, indicating no significant collinearity issues.

Figure 9.3 below presents the path coefficients and p-values of the inner model, illustrating the relationships among the constructs. Additionally, Appendix K, Table K. 11 provides a detailed overview of the hypothesis testing results, summarising the path relationships and their significance levels.

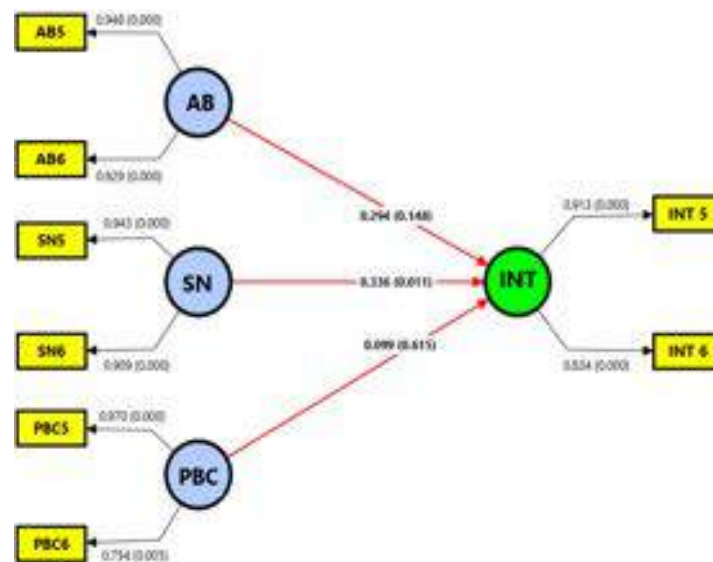


Figure 9.3: Path Analysis Findings of Sugarcane Irrigators' Intentions for Adaptation Towards Climate Variability in the Impala Irrigation Scheme

Source: Project team compilation

Appendix K, Table K. 11 presents the hypothesis testing results for the structural model. The path from Attitudes (**AB**) to Intentions (**INT**) was positive but non-significant ($\beta = 0.294$, $p = 0.148$), indicating that attitudes towards adopting water-saving technologies did not significantly influence irrigators' intentions in

the Impala Irrigation Scheme. Similarly, the relationship between Subjective Norms (*SN*) and Intentions (*INT*) was positive and significant ($\beta = 0.336$, $p < 0.01$), suggesting that social pressures had a significant impact on shaping irrigators' intentions to adopt climate variability. Lastly, Perceived Behavioural Control (*PBC*) did not show a substantial effect on Intentions (*INT*) ($\beta = 0.099$, $p = 0.615$), indicating that perceived control over adopting climate variability had no considerable impact on irrigators' intentions in this context.

The R^2 value for intentions (*INT*) was 0.302, with an adjusted R^2 of 0.260. While these values may seem low, Ozili (2023) argues that, in social science research, a low R^2 can be acceptable, as the focus often lies on assessing the significance of predictors, rather than achieving high predictive accuracy. The f^2 value for Attitudes (*AB*) on intentions was 0.087, indicating a small effect. For Perceived Behavioural Control (*PBC*) on intentions, the f^2 value was 0.010, representing an insignificant effect. In contrast, the f^2 value for Subjective Norms (*SN*) on intentions was 0.151, indicating a medium effect.

9.2.2.6 Augmented TPB Model for the adaptation towards climate variability

The following items were dropped owing to loadings below 0.4, in order to ensure the reliability of the indicators: *IL6* (Institutional and Legal Factors), *IF₇* (Informational Factors), *TX₃* (Trust Factors), *AR₁* and *AR₂* (Access to Resources), and *PFC₃* (Perceived Financial Costs). Among the constructs, only Institutional and Legal Factors (*IL*) had a Cronbach's alpha below 0.6, while all constructs achieved composite reliability scores above 0.7. The composite score for Perceived Risks from Load Shedding and Tariffs (*RB2*) was notably high. However, dropping the measurement item *RB₈* improved the score, while keeping it below 0.9.

All constructs demonstrated acceptable convergent validity, with AVE values exceeding the threshold of 0.5. The Fornell-Larcker criterion requires that the square root of the Average Variance Extracted (AVE) for each construct should be greater than its correlations with other constructs, ensuring that each construct shares more variance with its own indicators than with those of other constructs. HTMT evaluates discriminant validity by comparing the ratio of between-construct correlations (heterotrait-heteromethod) to within-construct correlations (monotrait-heteromethod), with values below 0.90 indicating acceptable discriminant validity.

Initially, the HTMT ratios indicated a discriminant validity issue between the Informational Factors (*IF*) and Intentions (*INT*). We assessed the outer value correlations and found that all Variance Inflation Factor (VIF) values were below the acceptable threshold of 3. Consequently, we explored the possibility of dropping measurement items from the *IF* construct and determined that removing *IF₅* and *IF₆* effectively resolved the discriminant validity issue. Similar to the Informational Factors (*IF*) construct, the Perceived

Risks and Benefits (**RB**) also exhibited discriminant validity issues with Intentions (**INT**). We did not identify any collinearity issues and therefore resolved the discriminant validity issue by dropping **RB**₅.

The results revealed that all VIF values were below the threshold of 3, indicating that collinearity was not a concern in the model. The structural model assessment was conducted using bootstrapping procedures, given the extended model's inclusion of mediating relationships. The results are reported in Tables Appendix K, Table K. 12-K.15. The specific indirect effects are presented in Table Appendix K, Table K. 12, and the results indicate that none of these specific indirect effects were statistically significant. This suggests that the mediating constructs (**A_B**, **SN**, and **PBC**) did not significantly influence the relationships between the predictor variables and the intention to adapt to climate variability among sugarcane irrigators in the Impala Irrigation Scheme.

The total indirect effects are presented in Appendix K, Table K. 13, and the results show that none of these total indirect effects were statistically significant. This further indicates that the mediating constructs did not play an essential role in influencing the relationships between the predictors and the intention to adapt to climate variability among sugarcane irrigators in the Impala Irrigation Scheme.

The results presented in Appendix K, Table K.14, reveal several significant direct paths. The path from Institutional and Legal Factors (**IL**) to Subjective Norms (**SN**) was found to be substantial and positive ($\beta = 0.526$, $p < 0.01$), indicating that institutional and legal factors have a strong influence on the social norms surrounding the adaptation to climate variability among sugarcane irrigators. Additionally, the direct effect of Perceived Financial Costs (**PFC**) on Perceived Behavioural Control (**PBC**) was negative and significant ($\beta = -0.336$, $p < 0.01$), suggesting that higher perceived financial costs negatively impact farmers' perceived ability to control their adaptation behaviours.

Furthermore, Technical Factors (**TF**) exhibited a significant positive effect on Intentions (**INT**) ($\beta = 0.356$, $p < 0.01$), highlighting the importance of trust in influencing the intentions of sugarcane irrigators to adapt to climate variability. Technical Factors (**TF**) also significantly influenced Subjective Norms (**SN**) ($\beta = 0.423$, $p < 0.01$), reinforcing the role of trust in shaping social perceptions. Finally, the path from Trust Factors (**TX**) to Attitudes (**A_B**) was significant and positive ($\beta = 0.356$, $p < 0.05$), indicating that trust positively affects the attitudes of sugarcane irrigators towards adapting to climate variability. A summary of direct effects is illustrated in Table 9.16 below.

The total effects, presented in Appendix K, Table K.15, closely resemble the results of the direct effects because of the absence of significant indirect effects in the model. This suggests that the main influences on sugarcane irrigators' intentions to adapt to climate variability in the Impala Irrigation Scheme come from direct pathways.

The R^2 values explain 70.7% of the variance in intentions (*INT*) to adapt to climate variability in the Impala Irrigation Scheme, suggesting strong explanatory power. However, for constructs like Perceived Behavioural Control (*PBC*), the adjusted R^2 value is relatively low (0.057), indicating limited explanatory power for that construct. The f^2 statistic value of Technical Factors (*TF*) exhibits a medium effect on intentions (*INT*) to adapt to climate variability ($f^2 = 0.274$) and on subjective norms (*SN*) ($f^2 = 0.265$), indicating the importance of TF in shaping these constructs. Additionally, Institutional and Legal Factors (*IL*) show a medium effect on SN ($f^2 = 0.310$). However, most other constructs, such as Perceived Financial Costs (*PFC*) and Attitudes (*A_B*), show small effect sizes across the different endogenous variables, reflecting a more limited influence in the model.

9.2.3 AquaCrop Model Simulation

9.2.3.1 Net and Gross Irrigation Requirements for Commercial Sugarcane Irrigators in the Impala Irrigation Scheme

The weather data for the study period, spanning from 2004 to 2011, was obtained from the Agricultural Research Council (ARC), as this was the only period for which data were available. Using this data, the net irrigation requirement for sugarcane was calculated annually, based on the identified soil properties and climate conditions. Table 9.2 below provides an overview of the net irrigation requirement (NIR) for sugarcane production in the Impala Irrigation Scheme across the dominant soil units identified in the main irrigation zone of the Impala Irrigation Scheme.

Next, the Gross Irrigation Requirement (GIR) was calculated, as the Net Irrigation Requirement (NIR) does not account for application efficiency or conveyance losses. It is assumed that most irrigation in the Impala Irrigation Scheme is carried out by using sprinkler systems and that water is distributed via lined canals. Therefore, by utilising Equation 4.1 ($\frac{95 \times 75}{100} = 71.25$) and Equation 4.2 (adapted from Savva & Frenken, 2002), the efficiency and the Gross Irrigation Requirement (GIR) were calculated, respectively. The lined canals are assumed to have a conveyance efficiency of 95%, and the sprinkler systems an application efficiency of 75%. To ensure the irrigation planning accounts for a worst-case scenario, the NIR values from the year with the highest irrigation demand (NIR 2005/06 = 560.9 mm) were used to calculate the GIR.

This overall irrigation efficiency of 71.25% was then used in Equation 4.2 ($\frac{560.9}{71.25} = 787.2$) to calculate the Gross Irrigation Requirement (GIR). The Net and Gross Irrigation Requirements for the 2005/06 production year, which had the highest net irrigation requirement on average, were 560.90 (Table 9.2- production year of 2005/06) and 787.20 mm, respectively, as the basis for the different adoption scenarios that were simulated.

Table 9.2: Net Irrigation Requirements for Sugarcane Production in the Impala Irrigation Scheme

		Production year							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Net Irrigation Requirement (mm)	Dystric Leptosols	495.3	562.4	227.4	411.6	460.3	315.9	377.9	407.3
	Dystric Regosols	484.4	551.9	211.9	398.3	449.5	294.7	354.1	392.1
	Eutric Planosols	502.6	567.8	240.2	417.0	464.5	327.5	385.4	415.0
	Chromic Cambisols	495.8	561.4	232.8	394.4	489.7	335.7	344.9	407.8
	Average	494.5	560.9	228.1	405.3	466.0	318.5	365.6	405.5

Source: Project team compilation

9.2.3.2 The adoption of water-saving technologies

9.2.3.2.1 No adoption scenario

For the no-adoption scenario of water-saving technologies in the Impala Irrigation Scheme for sugarcane production, the full gross irrigation requirement of 787.2 mm was applied consistently throughout the growing season. Irrigation events were scheduled at equal intervals of 10 days, resulting in a total of 36 applications. Dividing the total gross irrigation requirement by the number of intervals gives an application depth of 21.86 mm per interval. However, this was rounded down to 21 mm per interval to comply with the AquaCrop Model requirement for integer input values. Management practices were kept consistent across all scenarios in order to isolate the effect of irrigation scheduling alone. In this scenario, soil fertility was assumed to be non-limiting, a mulch cover of 25% was applied, surface runoff was not considered, and weed management was assumed to be optimal. Table 9.3 below provides the irrigation schedule applied under the no-adoption scenario of water-saving technologies in the Impala Irrigation Scheme.

Table 9.3: Irrigation Schedule for the No-Adoption Scenario of Water-Saving Technologies in Sugarcane Production in the Impala Irrigation Scheme

Event	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Day Number	Net applicati on (mm)
1	10 Feb 2004	10 Feb 2005	10 Feb 2006	10 Feb 2007	10 Feb 2008	10 Feb 2009	10 Feb 2010	10	21
2	20 Feb 2004	20 Feb 2005	20 Feb 2006	20 Feb 2007	20 Feb 2008	20 Feb 2009	20 Feb 2010	20	21
3	1 Mar 2004	2 Mar 2005	2 Mar 2006	2 Mar 2007	1 Mar 2008	2 Mar 2009	2 Mar 2010	30	21
4	11 Mar 2004	12 Mar 2005	12 Mar 2006	12 Mar 2007	11 Mar 2008	12 Mar 2009	12 Mar 2010	40	21
5	21 Mar 2004	22 Mar 2005	22 Mar 2006	22 Mar 2007	21 Mar 2008	22 Mar 2009	22 Mar 2010	50	21
6	31 Mar 2004	1 Apr 2005	1 Apr 2006	1 Apr 2007	31 Mar 2008	1 Apr 2009	1 Apr 2010	60	21
7	10 Apr 2004	11 Apr 2005	11 Apr 2006	11 Apr 2007	10 Apr 2008	11 Apr 2009	11 Apr 2009	70	21
8	20 Apr 2004	21 Apr 2005	21 Apr 2006	21 Apr 2007	20 Apr 2008	21 Apr 2009	21 Apr 2010	80	21
9	30 Apr 2004	1 May 2005	1 May 2006	1 May 2007	30 Apr 2008	1 May 2009	1 May 2010	90	21
10	10 May 2004	11 May 2005	11 May 2006	11 May 2007	10 May 2008	11 May 2009	11 May 2010	100	21
11	20 May 2004	21 May 2005	21 May 2006	21 May 2007	20 May 2008	21 May 2009	21 May 2010	110	21
12	30 May 2004	31 May 2005	31 May 2006	31 May 2007	30 May 2008	31 May 2009	31 May 2010	120	21
13	9 Jun 2004	10 Jun 2005	10 Jun 2006	10 Jun 2007	9 Jun 2008	10 Jun 2009	10 Jun 2010	130	21
14	19 Jun 2004	20 Jun 2004	20 Jun 2006	20 Jun 2007	19 Jun 2008	20 Jun 2009	20 Jun 2010	140	21
15	29 Jun 2004	30 Jun 2005	30 Jun 2006	30 Jun 2007	29 Jun 2008	30 Jun 2009	30 Jun 2010	150	21
16	9 Jul 2004	10 Jul 2005	10 Jul 2006	10 Jul 2007	9 Jul 2008	10 Jul 2009	10 Jul 2010	160	21
17	19 Jul 2004	20 Jul 2005	20 Jul 2006	20 Jul 2007	19 Jul 2008	20 Jul 2009	20 Jul 2010	170	21
18	29 Jul 2004	30 Jul 2005	30 Jul 2006	30 Jul 2007	29 Jul 2008	30 Jul 2009	30 Jul 2010	180	21
19	8 August 2004	9 August 2005	9 August 2006	9 August 2007	8 August 2008	9 August 2009	9 August 2010	190	21
20	18 Aug 2004	19 Aug 2005	19 Aug 2006	19 Aug 2007	18 Aug 2008	19 Aug 2009	19 Aug 2010	200	21
21	28 Aug 2004	29 Aug 2005	29 Aug 2006	29 Aug 2007	28 Aug 2008	29 Aug 2009	29 Aug 2010	210	21
22	7 Sep 2004	8 Sep 2005	8 Sep 2006	8 Sep 2007	7 Sep 2008	8 Sep 2009	8 Sep 2010	220	21
23	17 Sep 2004	18 Sep 2005	18 Sep 2006	18 Sep 2007	17 Sep 2008	18 Sep 2009	18 Sep 2010	230	21
24	27 Sep 2004	28 Sep 2005	28 Sep 2006	28 Sep 2007	27 Sep 2008	28 Sep 2009	28 Sep 2010	240	21
25	7 Oct 2004	8 Oct 2005	8 Oct 2006	8 Oct 2007	7 Oct 2008	8 Oct 2009	8 Oct 2010	250	21
26	17 Oct 2004	18 Oct 2005	18 Oct 2006	18 Oct 2007	17 Oct 2008	18 Oct 2009	18 Oct 2010	260	21
27	27 Oct 2004	28 Oct 2005	28 Oct 2006	28 Oct 2007	27 Oct 2008	28 Oct 2009	28 Oct 2010	270	21
28	6 Nov 2004	7 Nov 2005	7 Nov 2006	7 Nov 2007	6 Nov 2008	7 Nov 2009	7 Nov 2010	280	21
29	16 Nov 2004	17 Nov 2005	17 Nov 2006	17 Nov 2007	16 Nov 2008	17 Nov 2009	17 Nov 2010	290	21
30	26 Nov 2004	27 Nov 2005	27 Nov 2006	27 Nov 2007	26 Nov 2008	27 Nov 2009	27 Nov 2010	300	21
31	6 Dec 2004	7 Dec 2005	7 Dec 2006	7 Dec 2007	6 Dec 2008	7 Dec 2009	7 Dec 2010	310	21
32	16 Dec 2004	17 Dec 2005	17 Dec 2006	17 Dec 2007	16 Dec 2008	17 Dec 2009	17 Dec 2010	320	21
33	26 Dec 2004	27 Dec 2005	27 Dec 2006	27 Dec 2007	26 Dec 2008	27 Dec 2009	27 Dec 2010	330	21
34	5 Jan 2005	6 Jan 2006	6 Jan 2007	6 Jan 2008	5 Jan 2009	6 Jan 2010	6 Jan 2011	340	21
35	15 Jan 2005	16 Jan 2006	16 Jan 2007	16 Jan 2008	15 Jan 2009	16 Jan 2010	16 Jan 2011	350	21
36	25 Jan 2005	26 Jan 2006	26 Jan 2007	26 Jan 2008	25 Jan 2009	26 Jan 2010	26 Jan 2011	360	21

Source: Project team compilation

Table 9.4 below presents the simulated biomass, yield, irrigation, and water productivity metrics for sugarcane production in the Impala Irrigation Scheme under the No-Adoption Scenario for water-saving technologies.

Table 9.4: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (No-Adoption Scenario for Water-Saving Technologies)

Soil		No Adoption Scenario							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Dystric Leptosols	Biomass (ton/ha)	77.450	81.757	78.215	77.655	80.752	77.508	78.592	78.85
	Yield (ton/ha)	26.199	27.703	26.465	26.264	27.351	26.208	26.586	26.68
	Irrigation (mm)	756	756	756	756	756	756	756	756.00
	WP_{ET} (Kg/m ³)	2.55	2.73	2.75	2.84	2.86	2.80	2.75	2.75
Dystric Regosols	Biomass (ton/ha)	77.450	81.757	78.215	77.658	80.752	77.508	78.602	78.85
	Yield (ton/ha)	26.199	27.703	26.465	26.265	27.351	26.208	26.588	26.68
	Irrigation (mm)	756	756	756	756	756	756	756	756.00
	WP_{ET} (Kg/m ³)	2.55	2.73	2.75	2.84	2.86	2.80	2.74	2.75
Eutric Planosols	Biomass (ton/ha)	77.450	81.757	78.215	77.650	80.752	77.508	78.591	78.85
	Yield (ton/ha)	26.199	27.703	26.465	26.262	27.351	26.208	26.585	26.68
	Irrigation (mm)	756	756	756	756	756	756	756	756.00
	WP_{ET} (Kg/m ³)	2.56	2.75	2.77	2.86	2.87	2.81	2.76	2.77
Chromic Cambisols	Biomass (ton/ha)	77.450	81.757	78.215	77.659	80.752	77.508	78.604	78.85
	Yield (ton/ha)	26.199	27.703	26.465	26.265	27.351	26.208	26.588	26.68
	Irrigation (mm)	756	756	756	756	756	756	756	756.00
	WP_{ET} (Kg/m ³)	2.53	2.71	2.72	2.79	2.82	2.77	2.71	2.72
Weighted Average	Biomass (ton/ha)	77.45	81.76	78.22	77.66	80.75	77.51	78.60	78.85
	Yield (ton/ha)	26.20	27.70	26.47	26.26	27.35	26.21	26.59	26.68
	Irrigation (mm)	756.00	756.00	756.00	756.00	756.00	756.00	756.00	756.00
	WP_{ET} (Kg/m ³)	2.54	2.73	2.74	2.82	2.84	2.79	2.73	2.74

Source: Project team compilation

9.2.3.2.2 Partial adoption scenario

The partial adoption of water-saving technologies in the Impala Irrigation Scheme involved irrigation scheduling based on soil moisture levels. Specifically, irrigation was triggered once 70% of the readily available water (RAW) in the root zone had been depleted, and water was then applied to restore the soil moisture to field capacity. Key management practices in the AquaCrop model were kept constant across all scenarios in order to isolate the effect of irrigation scheduling alone. These included non-limiting soil fertility, 25% mulch cover, no surface runoff, and optimal weed control. Table 9.5 below presents the AquaCrop model simulation results for the partial adoption scenario of water-saving technologies. Simulations were conducted separately for each of the dominant soil units occurring within the main irrigation zone of the Impala Irrigation Scheme. A weighted average for the AquaCrop model output metrics

was then calculated based on the proportion of the area covered by each soil unit within the main irrigation zone.

Table 9.5: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (Partial Adoption Scenario for Water-Saving Technologies)

Soil		Partial Adoption Scenario						2010/11	Average
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10		
Dystric Leptosols	Biomass (ton/ha)	77.45	81.757	78.209	77.636	80.747	77.507	78.613	78.85
	Yield (ton/ha)	26.499	27.703	26.663	26.76	27.35	26.907	26.589	26.92
	Irrigation (mm)	611.6	568.3	339.3	464.3	529.3	402.7	439.6	479.30
	WP_{ET} (Kg/m ³)	2.58	2.74	2.78	2.95	2.94	2.84	2.77	2.80
Dystric Regosols	Biomass (ton/ha)	77.45	81.757	78.212	77.64	80.747	77.507	78.613	78.85
	Yield (ton/ha)	26.199	27.702	26.464	26.261	27.35	26.207	26.589	26.68
	Irrigation (mm)	565.2	581.6	327.1	470.6	487.4	387.7	422.2	463.11
	WP_{ET} (Kg/m ³)	2.58	2.74	2.8	2.97	2.95	2.84	2.79	2.81
Eutric Planosols	Biomass (ton/ha)	77.45	81.757	78.209	77.645	80.747	77.506	78.612	78.85
	Yield (ton/ha)	26.499	27.703	26.463	26.462	27.45	26.507	26.589	26.81
	Irrigation (mm)	558.9	638	318.2	473.5	556.6	369.8	415.1	475.73
	WP_{ET} (Kg/m ³)	2.59	2.75	2.79	2.97	2.95	2.85	2.79	2.81
Chromic Cambisols	Biomass (ton/ha)	77.45	81.757	78.214	77.648	80.745	77.507	78.613	78.85
	Yield (ton/ha)	26.599	27.703	26.464	26.262	27.349	26.208	26.589	26.74
	Irrigation (mm)	736	813.7	384.8	621.9	707.5	563.3	560.6	626.83
	WP_{ET} (Kg/m ³)	2.66	2.8	2.8	2.94	2.95	2.8	2.76	2.82
Weighted Average	Biomass (ton/ha)	77.45	81.76	78.21	77.65	80.75	77.51	78.61	78.85
	Yield (ton/ha)	26.54	27.70	26.48	26.37	27.38	26.36	26.59	26.77
	Irrigation (mm)	660.84	726.24	356.96	554.24	633.95	479.75	497.44	558.49
	WP_{ET} (Kg/m ³)	2.63	2.78	2.80	2.95	2.95	2.82	2.77	2.81

Source: Project team compilation

9.2.3.2.3 Full adoption scenario

The full adoption scenario of water-saving technologies in the Impala Irrigation Scheme follows the same irrigation scheduling approach as for the partial adoption scenario. The key difference is that drip irrigation was used instead of sprinkler irrigation. As with the other scenarios, key management practices in the AquaCrop model were kept constant in order to isolate the effect of irrigation scheduling and irrigation method. These included non-limiting soil fertility, 25% mulch cover, no surface runoff, and optimal weed control. Table 9.6 below presents the AquaCrop model simulation results for the full adoption scenario of water-saving technologies.

Table 9.6: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (Full Adoption Scenario for Water-Saving Technologies)

Soil type		Full Adoption Scenario						Average
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	
Dystric Leptosols	Biomass (ton/ha)	77.45	81.757	78.209	77.636	80.744	77.507	78.85
	Yield (ton/ha)	26.199	27.703	26.463	26.26	27.349	26.207	26.68
	Irrigation (mm)	610.3	566.2	326.6	461.9	533.2	400.9	474.40
	WP_{ET} (Kg/m ³)	2.59	2.76	2.83	2.99	2.96	2.86	2.83
Dystric Regosols	Biomass (ton/ha)	77.45	81.757	78.212	77.641	80.749	77.507	78.85
	Yield (ton/ha)	26.199	27.703	26.464	26.261	27.35	26.207	26.68
	Irrigation (mm)	564.7	580.4	326.7	473.2	485.3	391.6	463.17
	WP_{ET} (Kg/m ³)	2.59	3.76	2.82	2.99	2.96	2.85	2.97
Eutric Planosols	Biomass (ton/ha)	77.45	81.757	78.209	77.644	80.746	77.506	78.85
	Yield (ton/ha)	26.199	27.703	26.463	26.262	27.35	26.207	26.68
	Irrigation (mm)	569.4	636.3	307.4	483.3	557.7	367.7	475.49
	WP_{ET} (Kg/m ³)	2.6	2.78	2.84	3.0	2.97	2.87	2.84
Chromic Cambisols	Biomass (ton/ha)	78.54	81.757	79.214	79.648	80.745	77.507	79.43
	Yield (ton/ha)	26.799	27.903	26.764	26.562	27.949	27.208	27.25
	Irrigation (mm)	735.2	810.4	381.4	616.5	706	534.2	620.17
	WP_{ET} (Kg/m ³)	2.57	2.74	2.79	2.96	2.95	2.81	2.80
Weighted Average	Biomass (ton/ha)	78.05	81.76	78.76	78.75	80.75	77.51	79.17
	Yield (ton/ha)	26.53	27.81	26.63	26.43	27.68	26.76	27.00
	Irrigation (mm)	663.63	723.65	350.60	554.34	633.69	463.13	554.36
	WP_{ET} (Kg/m ³)	2.58	2.81	2.81	2.98	2.96	2.84	2.83

Source: Project team compilation

9.2.3.2.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water-saving Technologies

AquaCrop model simulations were run for three scenarios representing different levels of water-saving technology adoption. For each scenario, weighted averages of key metrics were calculated using the area share of each soil unit in the main irrigation zone of the Impala Irrigation Scheme. Table 9.7 below presents the weighted average results for grain yield, biomass, irrigation applied, and water productivity. It also shows the changes in yield under partial and full adoption compared with the no-adoption scenario.

Table 9.7: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	78.85	26.68	756.00	2.74	Baseline (0%)
	Partial adoption	78.85	26.77	558.49	2.81	0.34%
	Full Adoption	79.17	27.00	554.36	2.83	1.18%

Source: Project team compilation

9.2.3.3 The adoption of water-saving policies

9.2.3.3.1 No-adoption scenario

For the no-adoption scenario of water-saving policies, it is assumed that no water restrictions are in place. This means that the full gross irrigation requirement of 787.2 mm is applied in equal amounts at evenly spaced intervals throughout the growing season. Since this setup is identical to the no-adoption scenario for water-saving technologies (the previous water use behaviour), the irrigation schedule and resulting outputs will be the same. Therefore, it will not be simulated again. The no-adoption scenarios for water-saving policies and water-saving technologies are functionally equivalent. As a result, only the partial and full adoption scenarios for water-saving policies will be simulated and analysed.

9.2.3.3.2 Partial adoption scenario

For the partial adoption scenario of water-saving policies, it is assumed that a 30% water restriction is imposed. This means that only 551.04 mm of water is available for irrigation, which is 30 % less than the full gross irrigation requirement of 787.2 mm. When divided over 36 intervals, this results in approximately 15.3 mm per interval. Since the AquaCrop's Model irrigation schedule only accepts whole numbers, the amount was rounded down to 15 mm per interval to ensure the total irrigation does not exceed 551.04 mm. This water is applied in equal amounts at evenly spaced intervals throughout the growing season. Table 9.8 below presents the irrigation schedule for the partial adoption of water-saving policies in the Impala Irrigation Scheme.

Table 9.8: Irrigation Schedule for the No Adoption Scenario of Water-Saving polices in Sugarcane Production in the Impala Irrigation Scheme

Event	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Day Number	Net applicati on (mm)
1	10 Feb 2004	10 Feb 2005	10 Feb 2006	10 Feb 2007	10 Feb 2008	10 Feb 2009	10 Feb 2010	10	15
2	20 Feb 2004	20 Feb 2005	20 Feb 2006	20 Feb 2007	20 Feb 2008	20 Feb 2009	20 Feb 2010	20	15
3	1 Mar 2004	2 Mar 2005	2 Mar 2006	2 Mar 2007	1 Mar 2008	2 Mar 2009	2 Mar 2010	30	15
4	11 Mar 2004	12 Mar 2005	12 Mar 2006	12 Mar 2007	11 Mar 2008	12 Mar 2009	12 Mar 2010	40	15
5	21 Mar 2004	22 Mar 2005	22 Mar 2006	22 Mar 2007	21 Mar 2008	22 Mar 2009	22 Mar 2010	50	15
6	31 Mar 2004	1 Apr 2005	1 Apr 2006	1 Apr 2007	31 Mar 2008	1 Apr 2009	1 Apr 2010	60	15
7	10 Apr 2004	11 Apr 2005	11 Apr 2006	11 Apr 2007	10 Apr 2008	11 Apr 2009	11 Apr 2009	70	15
8	20 Apr 2004	21 Apr 2005	21 Apr 2006	21 Apr 2007	20 Apr 2008	21 Apr 2009	21 Apr 2010	80	15
9	30 Apr 2004	1 May 2005	1 May 2006	1 May 2007	30 Apr 2008	1 May 2009	1 May 2010	90	15
10	10 May 2004	11 May 2005	11 May 2006	11 May 2007	10 May 2008	11 May 2009	11 May 2010	100	15
11	20 May 2004	21 May 2005	21 May 2006	21 May 2007	20 May 2008	21 May 2009	21 May 2010	110	15
12	30 May 2004	31 May 2005	31 May 2006	31 May 2007	30 May 2008	31 May 2009	31 May 2010	120	15
13	9 Jun 2004	10 Jun 2005	10 Jun 2006	10 Jun 2007	9 Jun 2008	10 Jun 2009	10 Jun 2010	130	15
14	19 Jun 2004	20 Jun 2004	20 Jun 2006	20 Jun 2007	19 Jun 2008	20 Jun 2009	20 Jun 2010	140	15
15	29 Jun 2004	30 Jun 2005	30 Jun 2006	30 Jun 2007	29 Jun 2008	30 Jun 2009	30 Jun 2010	150	15
16	9 Jul 2004	10 Jul 2005	10 Jul 2006	10 Jul 2007	9 Jul 2008	10 Jul 2009	10 Jul 2010	160	15
17	19 Jul 2004	20 Jul 2005	20 Jul 2006	20 Jul 2007	19 Jul 2008	20 Jul 2009	20 Jul 2010	170	15
18	29 Jul 2004	30 Jul 2005	30 Jul 2006	30 Jul 2007	29 Jul 2008	30 Jul 2009	30 Jul 2010	180	15
19	8 August 2004	9 August 2005	9 August 2006	9 August 2007	8 August 2008	9 August 2009	9 August 2010	190	15
20	18 Aug 2004	19 Aug 2005	19 Aug 2006	19 Aug 2007	18 Aug 2008	19 Aug 2009	19 Aug 2010	200	15
21	28 Aug 2004	29 Aug 2005	29 Aug 2006	29 Aug 2007	28 Aug 2008	29 Aug 2009	29 Aug 2010	210	15
22	7 Sep 2004	8 Sep 2005	8 Sep 2006	8 Sep 2007	7 Sep 2008	8 Sep 2009	8 Sep 2010	220	15
23	17 Sep 2004	18 Sep 2005	18 Sep 2006	18 Sep 2007	17 Sep 2008	18 Sep 2009	18 Sep 2010	230	15
24	27 Sep 2004	28 Sep 2005	28 Sep 2006	28 Sep 2007	27 Sep 2008	28 Sep 2009	28 Sep 2010	240	15
25	7 Oct 2004	8 Oct 2005	8 Oct 2006	8 Oct 2007	7 Oct 2008	8 Oct 2009	8 Oct 2010	250	15
26	17 Oct 2004	18 Oct 2005	18 Oct 2006	18 Oct 2007	17 Oct 2008	18 Oct 2009	18 Oct 2010	260	15
27	27 Oct 2004	28 Oct 2005	28 Oct 2006	28 Oct 2007	27 Oct 2008	28 Oct 2009	28 Oct 2010	270	15
28	6 Nov 2004	7 Nov 2005	7 Nov 2006	7 Nov 2007	6 Nov 2008	7 Nov 2009	7 Nov 2010	280	15
29	16 Nov 2004	17 Nov 2005	17 Nov 2006	17 Nov 2007	16 Nov 2008	17 Nov 2009	17 Nov 2010	290	15
30	26 Nov 2004	27 Nov 2005	27 Nov 2006	27 Nov 2007	26 Nov 2008	27 Nov 2009	27 Nov 2010	300	15
31	6 Dec 2004	7 Dec 2005	7 Dec 2006	7 Dec 2007	6 Dec 2008	7 Dec 2009	7 Dec 2010	310	15
32	16 Dec 2004	17 Dec 2005	17 Dec 2006	17 Dec 2007	16 Dec 2008	17 Dec 2009	17 Dec 2010	320	15
33	26 Dec 2004	27 Dec 2005	27 Dec 2006	27 Dec 2007	26 Dec 2008	27 Dec 2009	27 Dec 2010	330	15
34	5 Jan 2005	6 Jan 2006	6 Jan 2007	6 Jan 2008	5 Jan 2009	6 Jan 2010	6 Jan 2011	340	15
35	15 Jan 2005	16 Jan 2006	16 Jan 2007	16 Jan 2008	15 Jan 2009	16 Jan 2010	16 Jan 2011	350	15
36	25 Jan 2005	26 Jan 2006	26 Jan 2007	26 Jan 2008	25 Jan 2009	26 Jan 2010	26 Jan 2011	360	15

Source: Project team compilation

The results for the partial adoption of water saving policies are presented in Table 9.9 below for the four dominant soil units occurring in the main irrigation zone of the Impala Irrigation Scheme, as well as a weighted average based on the area covered by each dominant soil unit within the main irrigation zone.

Table 9.9: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (Partial Adoption Scenario for Water-Saving policies)

Soil type		Partial Adoption Scenario							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Dystic Leptosols	Biomass (ton/ha)	75.304	78.241	78.215	74.896	80.577	77.742	77.586	77.51
	Yield (ton/ha)	24.448	26.472	26.465	25.300	27.290	26.115	26.234	26.05
	Irrigation (mm)	540	540	540	540	540	540	540	540.00
	WP_{ET} (Kg/m ³)	2.56	2.74	2.76	2.84	2.88	2.80	2.76	2.76
Dystic Regosols	Biomass (ton/ha)	76.403	79.506	78.215	76.266	80.751	77.508	78.194	78.12
	Yield (ton/ha)	25.833	26.916	26.465	25.778	27.351	26.208	26.445	26.43
	Irrigation (mm)	540	540	540	540	540	540	540	540.00
	WP_{ET} (Kg/m ³)	2.56	2.74	2.75	2.85	2.87	2.80	2.75	2.76
Eutric Planosols	Biomass (ton/ha)	74.396	77.548	78.215	74.289	80.378	75.728	77.137	76.81
	Yield (ton/ha)	25.130	26.230	26.465	25.089	26.220	25.931	26.077	25.88
	Irrigation (mm)	540	540	540	540	540	540	540	540.00
	WP_{ET} (Kg/m ³)	2.55	2.76	2.77	2.85	2.88	2.80	2.77	2.77
Chromic Cambisols	Biomass (ton/ha)	76.920	80.070	78.215	76.555	80.750	77.508	77.508	78.22
	Yield (ton/ha)	26.014	27.113	26.465	25.880	26.321	26.208	26.208	26.32
	Irrigation (mm)	540	540	540	540	540	540	540	540.00
	WP_{ET} (Kg/m ³)	2.54	2.72	2.73	2.70	2.84	2.77	2.77	2.72
Weighted Average	Biomass (ton/ha)	75.96	79.09	78.22	75.68	80.62	76.96	77.43	77.71
	Yield (ton/ha)	25.60	26.77	26.47	25.58	26.42	26.11	26.18	26.16
	Irrigation (mm)	540	540	540	540	540	540	540	540.00
	WP_{ET} (Kg/m ³)	2.55	2.74	2.75	2.77	2.86	2.78	2.77	2.74

Source: Project team compilation

9.2.3.3.3 Full adoption scenario

For the full adoption scenario of water-saving policies, it is assumed that a 70% water restriction is imposed. This means that only 236.16 mm of water is available for irrigation, which is 30% less than the full gross irrigation requirement of 787.2 mm. When divided over 36 intervals, this results in approximately 6.8 mm per interval. Since the AquaCrop's Model irrigation schedule only accepts whole numbers, the amount was rounded down to 6 mm per interval to ensure the total irrigation does not exceed 236.16 mm. This water is applied in equal amounts at evenly spaced intervals throughout the maize growing season. Table 9.10 below presents the irrigation schedule for the full adoption of water-saving policies in the Impala Irrigation Scheme.

Table 9.10: Irrigation Schedule for the full Adoption Scenario of Water-Saving policies in Sugarcane Production in the Impala Irrigation Scheme

Event	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Day Number	Net applicati on (mm)
1	10 Feb 2004	10 Feb 2005	10 Feb 2006	10 Feb 2007	10 Feb 2008	10 Feb 2009	10 Feb 2010	10	6
2	20 Feb 2004	20 Feb 2005	20 Feb 2006	20 Feb 2007	20 Feb 2008	20 Feb 2009	20 Feb 2010	20	6
3	1 Mar 2004	2 Mar 2005	2 Mar 2006	2 Mar 2007	1 Mar 2008	2 Mar 2009	2 Mar 2010	30	6
4	11 Mar 2004	12 Mar 2005	12 Mar 2006	12 Mar 2007	11 Mar 2008	12 Mar 2009	12 Mar 2010	40	6
5	21 Mar 2004	22 Mar 2005	22 Mar 2006	22 Mar 2007	21 Mar 2008	22 Mar 2009	22 Mar 2010	50	6
6	31 Mar 2004	1 Apr 2005	1 Apr 2006	1 Apr 2007	31 Mar 2008	1 Apr 2009	1 Apr 2010	60	6
7	10 Apr 2004	11 Apr 2005	11 Apr 2006	11 Apr 2007	10 Apr 2008	11 Apr 2009	11 Apr 2009	70	6
8	20 Apr 2004	21 Apr 2005	21 Apr 2006	21 Apr 2007	20 Apr 2008	21 Apr 2009	21 Apr 2010	80	6
9	30 Apr 2004	1 May 2005	1 May 2006	1 May 2007	30 Apr 2008	1 May 2009	1 May 2010	90	6
10	10 May 2004	11 May 2005	11 May 2006	11 May 2007	10 May 2008	11 May 2009	11 May 2010	100	6
11	20 May 2004	21 May 2005	21 May 2006	21 May 2007	20 May 2008	21 May 2009	21 May 2010	110	6
12	30 May 2004	31 May 2005	31 May 2006	31 May 2007	30 May 2008	31 May 2009	31 May 2010	120	6
13	9 Jun 2004	10 Jun 2005	10 Jun 2006	10 Jun 2007	9 Jun 2008	10 Jun 2009	10 Jun 2010	130	6
14	19 Jun 2004	20 Jun 2004	20 Jun 2006	20 Jun 2007	19 Jun 2008	20 Jun 2009	20 Jun 2010	140	6
15	29 Jun 2004	30 Jun 2005	30 Jun 2006	30 Jun 2007	29 Jun 2008	30 Jun 2009	30 Jun 2010	150	6
16	9 Jul 2004	10 Jul 2005	10 Jul 2006	10 Jul 2007	9 Jul 2008	10 Jul 2009	10 Jul 2010	160	6
17	19 Jul 2004	20 Jul 2005	20 Jul 2006	20 Jul 2007	19 Jul 2008	20 Jul 2009	20 Jul 2010	170	6
18	29 Jul 2004	30 Jul 2005	30 Jul 2006	30 Jul 2007	29 Jul 2008	30 Jul 2009	30 Jul 2010	180	6
19	8 August 2004	9 August 2005	9 August 2006	9 August 2007	8 August 2008	9 August 2009	9 August 2010	190	6
20	18 Aug 2004	19 Aug 2005	19 Aug 2006	19 Aug 2007	18 Aug 2008	19 Aug 2009	19 Aug 2010	200	6
21	28 Aug 2004	29 Aug 2005	29 Aug 2006	29 Aug 2007	28 Aug 2008	29 Aug 2009	29 Aug 2010	210	6
22	7 Sep 2004	8 Sep 2005	8 Sep 2006	8 Sep 2007	7 Sep 2008	8 Sep 2009	8 Sep 2010	220	6
23	17 Sep 2004	18 Sep 2005	18 Sep 2006	18 Sep 2007	17 Sep 2008	18 Sep 2009	18 Sep 2010	230	6
24	27 Sep 2004	28 Sep 2005	28 Sep 2006	28 Sep 2007	27 Sep 2008	28 Sep 2009	28 Sep 2010	240	6
25	7 Oct 2004	8 Oct 2005	8 Oct 2006	8 Oct 2007	7 Oct 2008	8 Oct 2009	8 Oct 2010	250	6
26	17 Oct 2004	18 Oct 2005	18 Oct 2006	18 Oct 2007	17 Oct 2008	18 Oct 2009	18 Oct 2010	260	6
27	27 Oct 2004	28 Oct 2005	28 Oct 2006	28 Oct 2007	27 Oct 2008	28 Oct 2009	28 Oct 2010	270	6
28	6 Nov 2004	7 Nov 2005	7 Nov 2006	7 Nov 2007	6 Nov 2008	7 Nov 2009	7 Nov 2010	280	6
29	16 Nov 2004	17 Nov 2005	17 Nov 2006	17 Nov 2007	16 Nov 2008	17 Nov 2009	17 Nov 2010	290	6
30	26 Nov 2004	27 Nov 2005	27 Nov 2006	27 Nov 2007	26 Nov 2008	27 Nov 2009	27 Nov 2010	300	6
31	6 Dec 2004	7 Dec 2005	7 Dec 2006	7 Dec 2007	6 Dec 2008	7 Dec 2009	7 Dec 2010	310	6
32	16 Dec 2004	17 Dec 2005	17 Dec 2006	17 Dec 2007	16 Dec 2008	17 Dec 2009	17 Dec 2010	320	6
33	26 Dec 2004	27 Dec 2005	27 Dec 2006	27 Dec 2007	26 Dec 2008	27 Dec 2009	27 Dec 2010	330	6
34	5 Jan 2005	6 Jan 2006	6 Jan 2007	6 Jan 2008	5 Jan 2009	6 Jan 2010	6 Jan 2011	340	6
35	15 Jan 2005	16 Jan 2006	16 Jan 2007	16 Jan 2008	15 Jan 2009	16 Jan 2010	16 Jan 2011	350	6
36	25 Jan 2005	26 Jan 2006	26 Jan 2007	26 Jan 2008	25 Jan 2009	26 Jan 2010	26 Jan 2011	360	6

Source: Project team compilation

Next, the results for the full adoption of water-saving policies are presented in Table 9.11 below for the four dominant soil units occurring in the main irrigation zone of the Impala Irrigation Scheme, as well as a weighted average based on the area covered by each dominant soil unit within the main irrigation zone.

Table 9.11: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (full Adoption Scenario for Water-Saving policies)

Soil type		Full Adoption Scenario							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Dystric Leptosols	Biomass (ton/ha)	54.732	54.667	76.334	54.542	62.511	67.385	64.622	62.11
	Yield (ton/ha)	18.248	18.222	25.806	18.227	20.967	22.666	21.700	20.83
	Irrigation (mm)	216	216	216	216	216	216	216	216.00
	WP_{ET} (Kg/m ³)	2.35	2.49	2.79	2.56	2.85	2.66	2.67	2.62
Dystric Regosols	Biomass (ton/ha)	57.172	57.038	77.351	55.094	65.555	70.115	67.375	64.24
	Yield (ton/ha)	19.102	19.051	26.162	18.385	22.032	23.620	22.659	21.57
	Irrigation (mm)	216	216	216	216	216	216	216	216.00
	WP_{ET} (Kg/m ³)	2.39	2.53	2.79	2.54	2.90	2.70	2.71	2.65
Eutric Planosols	Biomass (ton/ha)	53.532	53.805	75.430	54.337	61.963	65.697	63.510	61.18
	Yield (ton/ha)	17.829	17.920	25.490	18.189	20.776	22.077	21.312	20.51
	Irrigation (mm)	216	216	216	216	216	216	216	216.00
	WP_{ET} (Kg/m ³)	2.34	2.50	2.80	2.59	2.85	2.63	2.67	2.63
Chromic Cambisols	Biomass (ton/ha)	58.479	57.290	77.629	33.477	64.718	70.668	67.752	61.43
	Yield (ton/ha)	19.560	19.140	26.260	10.810	21.739	23.814	22.791	20.59
	Irrigation (mm)	216	216	216	216	216	216	216	216.00
	WP_{ET} (Kg/m ³)	2.38	2.47	2.76	2.46	2.85	2.70	2.66	2.61
Weighted Average	Biomass (ton/ha)	56.53	55.95	76.81	42.92	63.70	68.79	66.13	61.55
	Yield (ton/ha)	18.88	18.67	25.97	14.14	21.38	23.16	22.22	20.63
	Irrigation (mm)	216	216	216	216	216	216	216	216.00
	WP_{ET} (Kg/m ³)	2.37	2.48	2.78	2.51	2.85	2.67	2.67	2.62

Source: Project team compilation

9.2.3.3.4 Summary of AquaCrop Model Simulation Results for the Adoption of Water Saving Policies

The AquaCrop model simulations were run for three scenarios representing different levels of adaptation towards water saving policies. Table 9.12 below presents the weighted average results for grain yield, biomass, irrigation applied, and water productivity. It also shows the changes in yield under partial and full adoption compared with the no-adoption scenario.

Table 9.12: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	% Change in Yield Compared to No Adoption
Adoption scenario	No Adoption	78.85	26.68	756.00	2.74	Baseline (0%)
	Partial adoption	77.71	26.16	540.00	2.74	-2.00%
	Full Adoption	61.55	20.63	216.00	2.62	-29.32%

Source: Project team compilation

9.2.3.4 The adaptation towards climate variability

9.2.3.4.1 No-adaptation scenario

The no-adaptation scenario to climate variability assumes that the full gross irrigation requirement of 787.2 mm is applied uniformly throughout the growing season. In this scenario, no water-saving measures such as mulching are implemented, and only moderate weed management is practised, allowing some level of competition with the crop. Unlike the no-adoption scenarios for water-saving technologies and policies, this scenario does not include mulching, which has a direct impact on the soil water balance. As a result, separate AquaCrop model simulations were required, despite the irrigation schedule being identical to that used in the no-adoption scenarios for water-saving technologies and policies. Table 9.13 below presents the AquaCrop model simulation results for the scenario of no adaptation to climate variability in the Impala Irrigation Scheme.

Table 9.13: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (No adaptation towards climate variability)

Soil type		No Adaptation Scenario						2010/11	Average
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10		
Dystric Leptosols	Biomass (ton/ha)	59.154	62.430	59.740	59.314	61.668	59.205	60.024	60.22
	Yield (ton/ha)	19.975	21.118	20.177	20.025	20.851	19.983	20.269	20.34
	Irrigation (mm)	756.0	756.0	756.0	756.0	756.0	756.0	756.0	756.00
	WP_{ET} (Kg/m ³)	1.92	2.06	2.07	2.14	2.16	2.12	2.07	2.08
Dystric Regosols	Biomass (ton/ha)	59.157	62.430	59.740	59.318	61.668	59.205	60.034	60.22
	Yield (ton/ha)	19.975	21.118	20.177	20.026	20.851	19.983	20.271	20.34
	Irrigation (mm)	756.0	756.0	756.0	756.0	756.0	756.0	756.0	756.00
	WP_{ET} (Kg/m ³)	1.92	2.06	2.07	2.14	2.16	2.11	2.07	2.08
Eutric Planosols	Biomass (ton/ha)	59.152	62.429	59.740	59.311	61.668	59.205	60.023	60.22
	Yield (ton/ha)	19.975	21.118	20.177	20.023	20.851	19.983	20.269	20.34
	Irrigation (mm)	756	756.0	756.0	756.0	756.0	756.0	756.0	756.00
	WP_{ET} (Kg/m ³)	1.93	2.07	2.09	2.16	2.18	2.13	2.09	2.09
Chromic Cambisols	Biomass (ton/ha)	59.156	62.430	59.740	59.318	61.668	59.205	60.034	60.22
	Yield (ton/ha)	19.975	21.118	20.177	20.026	20.851	19.983	20.271	20.34
	Irrigation (mm)	756.0	756.0	756.0	756.0	756.0	756.0	756.0	756.00
	WP_{ET} (Kg/m ³)	1.90	2.04	2.05	2.11	2.13	2.08	2.04	2.05
Weighted Average	Biomass (ton/ha)	59.15	62.43	59.74	59.32	61.67	59.21	60.03	60.22
	Yield (ton/ha)	19.98	21.12	20.18	20.02	20.85	19.98	20.27	20.34
	Irrigation (mm)	756.00	756.00	756.00	756.00	756.00	756.00	756.00	756.00
	WP_{ET} (Kg/m ³)	1.91	2.05	2.07	2.13	2.15	2.10	2.06	2.07

Source: Project team compilation

9.2.3.4.2 Partial adaptation scenario

Under the partial adaptation to climate variability scenario, weed management is set to moderate, and a 20% deficit irrigation strategy is implemented. This reduces the gross irrigation requirement of 787.2 mm to 629.76 mm, which is applied evenly at 10-day intervals throughout the growing season. Table 9.14 below presents the irrigation schedule for the partial adaptation towards climate variability of sugarcane production in the Impala Irrigation Scheme.

Table 9.14: Irrigation Schedule for the partial adaptation towards climate variability in Sugarcane Production in the Impala Irrigation Scheme

Event	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Day Number	Net applicati on (mm)
1	10 Feb 2004	10 Feb 2005	10 Feb 2006	10 Feb 2007	10 Feb 2008	10 Feb 2009	10 Feb 2010	10	17
2	20 Feb 2004	20 Feb 2005	20 Feb 2006	20 Feb 2007	20 Feb 2008	20 Feb 2009	20 Feb 2010	20	17
3	1 Mar 2004	2 Mar 2005	2 Mar 2006	2 Mar 2007	1 Mar 2008	2 Mar 2009	2 Mar 2010	30	17
4	11 Mar 2004	12 Mar 2005	12 Mar 2006	12 Mar 2007	11 Mar 2008	12 Mar 2009	12 Mar 2010	40	17
5	21 Mar 2004	22 Mar 2005	22 Mar 2006	22 Mar 2007	21 Mar 2008	22 Mar 2009	22 Mar 2010	50	17
6	31 Mar 2004	1 Apr 2005	1 Apr 2006	1 Apr 2007	31 Mar 2008	1 Apr 2009	1 Apr 2010	60	17
7	10 Apr 2004	11 Apr 2005	11 Apr 2006	11 Apr 2007	10 Apr 2008	11 Apr 2009	11 Apr 2009	70	17
8	20 Apr 2004	21 Apr 2005	21 Apr 2006	21 Apr 2007	20 Apr 2008	21 Apr 2009	21 Apr 2010	80	17
9	30 Apr 2004	1 May 2005	1 May 2006	1 May 2007	30 Apr 2008	1 May 2009	1 May 2010	90	17
10	10 May 2004	11 May 2005	11 May 2006	11 May 2007	10 May 2008	11 May 2009	11 May 2010	100	17
11	20 May 2004	21 May 2005	21 May 2006	21 May 2007	20 May 2008	21 May 2009	21 May 2010	110	17
12	30 May 2004	31 May 2005	31 May 2006	31 May 2007	30 May 2008	31 May 2009	31 May 2010	120	17
13	9 Jun 2004	10 Jun 2005	10 Jun 2006	10 Jun 2007	9 Jun 2008	10 Jun 2009	10 Jun 2010	130	17
14	19 Jun 2004	20 Jun 2004	20 Jun 2006	20 Jun 2007	19 Jun 2008	20 Jun 2009	20 Jun 2010	140	17
15	29 Jun 2004	30 Jun 2005	30 Jun 2006	30 Jun 2007	29 Jun 2008	30 Jun 2009	30 Jun 2010	150	17
16	9 Jul 2004	10 Jul 2005	10 Jul 2006	10 Jul 2007	9 Jul 2008	10 Jul 2009	10 Jul 2010	160	17
17	19 Jul 2004	20 Jul 2005	20 Jul 2006	20 Jul 2007	19 Jul 2008	20 Jul 2009	20 Jul 2010	170	17
18	29 Jul 2004	30 Jul 2005	30 Jul 2006	30 Jul 2007	29 Jul 2008	30 Jul 2009	30 Jul 2010	180	17
19	8 August 2004	9 August 2005	9 August 2006	9 August 2007	8 August 2008	9 August 2009	9 August 2010	190	17
20	18 Aug 2004	19 Aug 2005	19 Aug 2006	19 Aug 2007	18 Aug 2008	19 Aug 2009	19 Aug 2010	200	17
21	28 Aug 2004	29 Aug 2005	29 Aug 2006	29 Aug 2007	28 Aug 2008	29 Aug 2009	29 Aug 2010	210	17
22	7 Sep 2004	8 Sep 2005	8 Sep 2006	8 Sep 2007	7 Sep 2008	8 Sep 2009	8 Sep 2010	220	17
23	17 Sep 2004	18 Sep 2005	18 Sep 2006	18 Sep 2007	17 Sep 2008	18 Sep 2009	18 Sep 2010	230	17
24	27 Sep 2004	28 Sep 2005	28 Sep 2006	28 Sep 2007	27 Sep 2008	28 Sep 2009	28 Sep 2010	240	17
25	7 Oct 2004	8 Oct 2005	8 Oct 2006	8 Oct 2007	7 Oct 2008	8 Oct 2009	8 Oct 2010	250	17
26	17 Oct 2004	18 Oct 2005	18 Oct 2006	18 Oct 2007	17 Oct 2008	18 Oct 2009	18 Oct 2010	260	17
27	27 Oct 2004	28 Oct 2005	28 Oct 2006	28 Oct 2007	27 Oct 2008	28 Oct 2009	28 Oct 2010	270	17
28	6 Nov 2004	7 Nov 2005	7 Nov 2006	7 Nov 2007	6 Nov 2008	7 Nov 2009	7 Nov 2010	280	17
29	16 Nov 2004	17 Nov 2005	17 Nov 2006	17 Nov 2007	16 Nov 2008	17 Nov 2009	17 Nov 2010	290	17
30	26 Nov 2004	27 Nov 2005	27 Nov 2006	27 Nov 2007	26 Nov 2008	27 Nov 2009	27 Nov 2010	300	17
31	6 Dec 2004	7 Dec 2005	7 Dec 2006	7 Dec 2007	6 Dec 2008	7 Dec 2009	7 Dec 2010	310	17
32	16 Dec 2004	17 Dec 2005	17 Dec 2006	17 Dec 2007	16 Dec 2008	17 Dec 2009	17 Dec 2010	320	17
33	26 Dec 2004	27 Dec 2005	27 Dec 2006	27 Dec 2007	26 Dec 2008	27 Dec 2009	27 Dec 2010	330	17
34	5 Jan 2005	6 Jan 2006	6 Jan 2007	6 Jan 2008	5 Jan 2009	6 Jan 2010	6 Jan 2011	340	17
35	15 Jan 2005	16 Jan 2006	16 Jan 2007	16 Jan 2008	15 Jan 2009	16 Jan 2010	16 Jan 2011	350	17
36	25 Jan 2005	26 Jan 2006	26 Jan 2007	26 Jan 2008	25 Jan 2009	26 Jan 2010	26 Jan 2011	360	17

Source: Project team compilation

Table 9.15 below presents the results of the partial adaptation towards climate variability from the AquaCrop model simulations for each dominant soil type. The weighted average is also shown, based on

the relative area covered by each dominant soil type within the main irrigation zone of the Impala Irrigation Scheme.

Table 9.15: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (partial Adaptation scenario towards climate variability)

Soil type		Partial Adaptation Scenario							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Dystic Leptosols	Biomass (ton/ha)	59.043	61.825	59.74	59.042	61.668	59.206	59.995	60.07
	Yield (ton/ha)	19.935	20.906	20.177	19.929	20.851	19.983	20.257	20.29
	Irrigation (mm)	612	612	612	612	612	612	612	612.00
	WP_{ET} (Kg/m ³)	1.97	2.11	2.13	2.2	2.2	2.17	2.12	2.13
Dystic Regosols	Biomass (ton/ha)	59.151	62.261	59.74	59.312	61.668	59.205	60.043	60.20
	Yield (ton/ha)	19.973	21.059	20.177	20.024	20.851	19.983	20.272	20.33
	Irrigation (mm)	612	612	612	612	612	612	612	612.00
	WP_{ET} (Kg/m ³)	1.97	2.11	2.12	2.19	2.2	2.17	2.12	2.13
Eutric Planosols	Biomass (ton/ha)	58.886	61.494	59.74	58.788	61.667	59.19	59.871	59.95
	Yield (ton/ha)	19.881	21.791	21.17	21.841	20.851	19.978	20.214	20.82
	Irrigation (mm)	612	612	612	612	612	612	612	612.00
	WP_{ET} (Kg/m ³)	1.98	2.12	2.14	2.2	2.2	2.17	2.13	2.13
Chromic Cambisols	Biomass (ton/ha)	61.157	62.371	61.74	60.317	61.668	59.205	60.043	60.93
	Yield (ton/ha)	19.975	21.098	21.177	21.025	20.851	19.983	20.727	20.69
	Irrigation (mm)	612	612	612	612	612	612	612	612.00
	WP_{ET} (Kg/m ³)	1.96	2.09	2.11	2.16	2.18	2.14	2.09	2.10
Weighted Average	Biomass (ton/ha)	60.16	62.04	60.84	59.68	61.67	59.20	59.98	60.51
	Yield (ton/ha)	19.94	21.30	21.04	21.15	20.85	19.98	20.50	20.68
	Irrigation (mm)	612	612	612	612	612	612	612	612.00
	WP_{ET} (Kg/m ³)	1.97	2.10	2.12	2.18	2.19	2.15	2.11	2.12

Source: Project team compilation

9.2.3.4.3 Full adaptation scenario

For the full adoption scenario of climate variability, it is assumed that a 70% water restriction is imposed. This means that only 551.04 mm of water is available for irrigation, which is 30% less than the full gross irrigation requirement of 787.2 mm. The irrigation amounts per interval were strategically divided to apply more water during crucial growing periods. The irrigation scheduling for the full adaptation towards climate variability is shown in Table 9.16 below.

Table 9.16: Irrigation Schedule for the full adaptation towards climate variability in Sugarcane Production in the Impala Irrigation Scheme

Event	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Day Number	Net applicati on (mm)
1	10 Feb 2004	10 Feb 2005	10 Feb 2006	10 Feb 2007	10 Feb 2008	10 Feb 2009	10 Feb 2010	10	5
2	20 Feb 2004	20 Feb 2005	20 Feb 2006	20 Feb 2007	20 Feb 2008	20 Feb 2009	20 Feb 2010	20	5
3	1 Mar 2004	2 Mar 2005	2 Mar 2006	2 Mar 2007	1 Mar 2008	2 Mar 2009	2 Mar 2010	30	6
4	11 Mar 2004	12 Mar 2005	12 Mar 2006	12 Mar 2007	11 Mar 2008	12 Mar 2009	12 Mar 2010	40	10
5	21 Mar 2004	22 Mar 2005	22 Mar 2006	22 Mar 2007	21 Mar 2008	22 Mar 2009	22 Mar 2010	50	15
6	31 Mar 2004	1 Apr 2005	1 Apr 2006	1 Apr 2007	31 Mar 2008	1 Apr 2009	1 Apr 2010	60	15
7	10 Apr 2004	11 Apr 2005	11 Apr 2006	11 Apr 2007	10 Apr 2008	11 Apr 2009	11 Apr 2009	70	25
8	20 Apr 2004	21 Apr 2005	21 Apr 2006	21 Apr 2007	20 Apr 2008	21 Apr 2009	21 Apr 2010	80	25
9	30 Apr 2004	1 May 2005	1 May 2006	1 May 2007	30 Apr 2008	1 May 2009	1 May 2010	90	25
10	10 May 2004	11 May 2005	11 May 2006	11 May 2007	10 May 2008	11 May 2009	11 May 2010	100	20
11	20 May 2004	21 May 2005	21 May 2006	21 May 2007	20 May 2008	21 May 2009	21 May 2010	110	20
12	30 May 2004	31 May 2005	31 May 2006	31 May 2007	30 May 2008	31 May 2009	31 May 2010	120	20
13	9 Jun 2004	10 Jun 2005	10 Jun 2006	10 Jun 2007	9 Jun 2008	10 Jun 2009	10 Jun 2010	130	20
14	19 Jun 2004	20 Jun 2004	20 Jun 2006	20 Jun 2007	19 Jun 2008	20 Jun 2009	20 Jun 2010	140	20
15	29 Jun 2004	30 Jun 2005	30 Jun 2006	30 Jun 2007	29 Jun 2008	30 Jun 2009	30 Jun 2010	150	20
16	9 Jul 2004	10 Jul 2005	10 Jul 2006	10 Jul 2007	9 Jul 2008	10 Jul 2009	10 Jul 2010	160	20
17	19 Jul 2004	20 Jul 2005	20 Jul 2006	20 Jul 2007	19 Jul 2008	20 Jul 2009	20 Jul 2010	170	20
18	29 Jul 2004	30 Jul 2005	30 Jul 2006	30 Jul 2007	29 Jul 2008	30 Jul 2009	30 Jul 2010	180	20
19	8 August 2004	9 August 2005	9 August 2006	9 August 2007	8 August 2008	9 August 2009	9 August 2010	190	20
20	18 Aug 2004	19 Aug 2005	19 Aug 2006	19 Aug 2007	18 Aug 2008	19 Aug 2009	19 Aug 2010	200	20
21	28 Aug 2004	29 Aug 2005	29 Aug 2006	29 Aug 2007	28 Aug 2008	29 Aug 2009	29 Aug 2010	210	20
22	7 Sep 2004	8 Sep 2005	8 Sep 2006	8 Sep 2007	7 Sep 2008	8 Sep 2009	8 Sep 2010	220	20
23	17 Sep 2004	18 Sep 2005	18 Sep 2006	18 Sep 2007	17 Sep 2008	18 Sep 2009	18 Sep 2010	230	20
24	27 Sep 2004	28 Sep 2005	28 Sep 2006	28 Sep 2007	27 Sep 2008	28 Sep 2009	28 Sep 2010	240	20
25	7 Oct 2004	8 Oct 2005	8 Oct 2006	8 Oct 2007	7 Oct 2008	8 Oct 2009	8 Oct 2010	250	15
26	17 Oct 2004	18 Oct 2005	18 Oct 2006	18 Oct 2007	17 Oct 2008	18 Oct 2009	18 Oct 2010	260	15
27	27 Oct 2004	28 Oct 2005	28 Oct 2006	28 Oct 2007	27 Oct 2008	28 Oct 2009	28 Oct 2010	270	15
28	6 Nov 2004	7 Nov 2005	7 Nov 2006	7 Nov 2007	6 Nov 2008	7 Nov 2009	7 Nov 2010	280	10
29	16 Nov 2004	17 Nov 2005	17 Nov 2006	17 Nov 2007	16 Nov 2008	17 Nov 2009	17 Nov 2010	290	10
30	26 Nov 2004	27 Nov 2005	27 Nov 2006	27 Nov 2007	26 Nov 2008	27 Nov 2009	27 Nov 2010	300	10
31	6 Dec 2004	7 Dec 2005	7 Dec 2006	7 Dec 2007	6 Dec 2008	7 Dec 2009	7 Dec 2010	310	10
32	16 Dec 2004	17 Dec 2005	17 Dec 2006	17 Dec 2007	16 Dec 2008	17 Dec 2009	17 Dec 2010	320	10
33	26 Dec 2004	27 Dec 2005	27 Dec 2006	27 Dec 2007	26 Dec 2008	27 Dec 2009	27 Dec 2010	330	10
34	5 Jan 2005	6 Jan 2006	6 Jan 2007	6 Jan 2008	5 Jan 2009	6 Jan 2010	6 Jan 2011	340	5
35	15 Jan 2005	16 Jan 2006	16 Jan 2007	16 Jan 2008	15 Jan 2009	16 Jan 2010	16 Jan 2011	350	5
36	25 Jan 2005	26 Jan 2006	26 Jan 2007	26 Jan 2008	25 Jan 2009	26 Jan 2010	26 Jan 2011	360	5

Source: Project team compilation

The AquaCrop model simulation results for the full adaptation towards climate variability are shown in Table 9.17 below. Simulations were carried out for each dominant soil type in the main irrigation zone of

the Impala Irrigation Scheme. A weighted average of the AquaCrop results was calculated across these dominant soil units based on the area covered by each soil type within the main irrigation zone.

Table 9.17: Simulated Biomass, Yield, Irrigation, and Water Productivity Metrics for Sugarcane Production in the Impala Irrigation Scheme (full Adoption Scenario for climate variability)

Soil type		Full Adaptation							
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Average
Dystic Leptosols	Biomass (ton/ha)	77.436	81.737	78.215	77.385	80.752	77.508	78.698	78.82
	Yield (ton/ha)	26.194	27.696	26.465	26.183	27.351	26.208	26.588	26.67
	Irrigation (mm)	551.0	551.0	551.0	551.0	551.0	551.0	551.0	551.00
	WP_{ET} (Kg/m ³)	2.64	2.81	2.84	2.95	2.96	2.89	2.84	2.85
Dystic Regosols	Biomass (ton/ha)	77.450	81.757	78.215	77.582	80.752	77.508	78.613	78.84
	Yield (ton/ha)	26.199	27.703	26.465	26.243	27.351	26.208	26.589	26.68
	Irrigation (mm)	551.0	551.0	551.0	551.0	551.0	551.0	551.0	551.00
	WP_{ET} (Kg/m ³)	2.63	2.80	2.84	2.95	2.96	2.89	2.83	2.84
Eutric Planosols	Biomass (ton/ha)	77.793	81.701	78.215	77.038	80.750	77.507	78.604	78.80
	Yield (ton/ha)	26.180	27.684	26.465	26.076	27.351	26.208	26.588	26.65
	Irrigation (mm)	551.0	551.0	551.0	551.0	551.0	551.0	551.0	551.00
	WP_{ET} (Kg/m ³)	2.64	2.84	2.85	2.96	2.96	2.89	2.85	2.86
Chromic Cambisols	Biomass (ton/ha)	77.450	81.757	78.215	77.618	80.752	77.508	78.613	78.84
	Yield (ton/ha)	26.199	27.703	36.465	26.253	27.351	26.208	26.589	28.11
	Irrigation (mm)	551.0	551.0	551.0	551.0	551.0	551.0	551.0	551.00
	WP_{ET} (Kg/m ³)	2.62	2.79	2.82	2.93	2.94	2.87	2.81	2.83
Weighted Average	Biomass (ton/ha)	77.56	81.74	78.22	77.41	80.75	77.51	78.62	78.83
	Yield (ton/ha)	26.19	27.70	31.97	26.19	27.35	26.21	26.59	27.46
	Irrigation (mm)	551	551	551	551	551	551	551	551.00
	WP_{ET} (Kg/m ³)	2.63	2.81	2.83	2.94	2.95	2.88	2.83	2.84

Source: Project team compilation

9.2.3.4.4 Summary of AquaCrop Model Simulation Results for the adaptation towards climate variability

The final summary of the AquaCrop model simulation results for the adaptation to the climate variability scenario is presented in Table 9.18 below, and it also presents the weighted average results for the three adaptation scenarios: no adaptation, partial adaptation, and full adaptation to climate variability. In the final column, the percentage change in yield is shown relative to the no-adaptation scenario. These yield change percentages will be used as exogenous shocks in the Social Accounting Matrix (SAM) through multiplier analysis to assess the broader economic implications of adapting irrigation practices in response to climate variability.

Table 9.18: Summary of Representative Weighted Average Metrics for Adoption Scenarios

		Representative Weighted Average Metrics for Adoption Scenarios in the Main Irrigation Zone				% Change in Yield Compared to No Adoption
		Biomass (ton/ha)	Yield (ton/ha)	Irrigation (mm)	WP_{ET} (Kg/m ³)	
Adoption scenario	No Adoption	60.22	20.34	756.00	2.05	Baseline (0%)
	Partial adoption	60.51	20.68	612.00	2.12	1.67%
	Full Adoption	78.83	27.46	551.00	2.84	34.97%

Source: Project team compilation

9.2.4 Multiplier Analysis

This section explores the economic effects of how commercial sugarcane irrigators in the Impala Irrigation Scheme respond to climate variability. Table 9.19 provides a summary of the multiplier analysis results, showing the economic impacts of increased adaptation among commercial sugarcane irrigators.

Table 9.19: Summary of Key Economic Impacts under Partial and Full Adoption Scenarios for Water Use Behaviours in the Impala Irrigation Scheme for Commercial Sugarcane Irrigators

Variable	Adoption of Water-Saving Technologies		Adoption of Water-Saving Policies		Adaptation to Climate Variability	
	Partial (+0.34%)	Full (+1.18%)	Partial (-2.0%)	Full (-29.32%)	Partial (+1.67%)	Full (+34.97%)
<i>Sugar cane in KZN</i>	27.53	95.54	3,62	33.70	62.57	283.13
Total labour remuneration in SA	15.26	85.03	1,63	18.69	34.67	152.88
<i>KZN province generates labour return</i>	4.31	16.77	0.59	2. 66	6.84	30.9
Gross operating surplus SA	9.06	65.76	2,16	5.564	26.81	111.35
Household income for KZN	35.66	87.62	4,09	43.67	72.02	306.66
Land return in SA	11.44	14.51	3,48	7.066	17.42	76.82
land return to irrigation in KZN	R145,012.68	R404,667.12	R28, 748.73	R89,528.08	R165,017.2	R746,787.10
Institution income SA (enterprise + Household)	65.76	103.28	14,26	108.15	R108.44	521.76
Household generating income SA	60.18	98.56	9,54	73.72	R106.98	498.28
value added generating income SA (Labour + capital + land)	185.69	195.86	69,58	126.49	R618.14	398.68

Source: Project team compilation

9.2.4.1 Adoption of water-saving technologies

9.2.4.1.1 Partial Adoption

As shown in Table 9.19 above, the partial adoption of water-saving technologies, which involves irrigation scheduling based on soil moisture levels, led to a R27.53 million output in commercial sugarcane yield attributed to improved water management. This could be attributed to the use of precision irrigation systems across the Impala Irrigation Scheme in KwaZulu-Natal, which resulted in enhanced sugarcane output and improved the provincial economy. The total labour remuneration was estimated at R15.26 million in the

economy of South Africa, of which the KZN province generates a labour return of about R4.31 million and a gross operating surplus (capital) of R9.06 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West, Mpumalanga, and Eastern Cape provinces.

Household income was estimated at R35.66 million for the economy of KZN province. The overall land return was estimated at R11.44 million in the economy of South Africa, of which the return to irrigation in KZN was only R145 012.68. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district.

Institutional incomes (enterprise and households) were valued at R65.76 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R60.18 and R185.69 million in the economy of South Africa, respectively. As indicated above in this sub-section, the findings of this study concurred with those of Anjaly et al. (2024), which stated that implementing water-saving technologies or interventions improves yield and produces quality canes, ultimately enhancing the livelihoods of sugarcane farmers and minimising detrimental environmental impacts.

9.2.4.1.2 Full Adoption

As indicated in Table 9.19 above, the effect of irrigation scheduling based on soil moisture levels and the adoption of drip irrigation, moving away from conventional sprinkler systems, led to a R95.54 million output in commercial sugarcane in the Impala Irrigation Scheme and in the KwaZulu-Natal economy, which could be attributed to improved water management. The total labour remuneration was estimated at R85.03 million in the economy of South Africa, of which KZN province generates a labour return of about R16.77 million and a gross operating surplus (capital) of R65.76 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West, Mpumalanga, and Eastern Cape provinces.

Household income was estimated at R87.62 million towards the economy of KZN province. The overall land return was estimated at R14.51 million in the economy of South Africa, of which the return to irrigation in KZN was only R404 667.12. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district, followed by another district of the KZN irrigation district in the economy of KZN province.

Institutional incomes (enterprise and households) were valued at R103.28 million in the economy of South Africa. The households and value added (labour, Capital, and land) generated incomes of R98.56 and R195.86 million in the economy of South Africa, respectively. The findings of this study concurred with those of Anjaly et al. (2024), which indicated that implementing water-saving technology interventions, such as drip irrigation and soil moisture techniques like eco-friendly straw mulching, contribute to better

soil health and sustainable cane yields. Furthermore, Shroff and Varun Miglani (2024) highlighted the point that, after the adoption of drip irrigation, farmers experienced higher yields and profits and saved water across sugarcane production.

9.2.4.2 Adoption of water-saving policies

9.2.4.2.1 Partial Adoption

As indicated in Table 9.19 above, the partial adoption of water-saving policies led to a R3.62 million output of sugarcane in the Impala Irrigation Scheme and in the KwaZulu-Natal economy. The total labour remuneration was estimated at R1.63 million in the economy of South Africa, of which the KZN province generates a labour return of about R0.59 million and a gross operating surplus (capital) of R2.16 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R4.09 million towards the economy of KZN province. The overall land return was estimated at R3.48 million in the economy of South Africa, of which the return to irrigation in the KZN was R28,748.73. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district, followed by other districts of KZN irrigation in the economy of KZN province.

Institutional incomes (enterprise and households) were valued at 14.26 million in the economy of South Africa. Households and value added (labour, capital, and land) generated incomes of R9.54 and R69.58 million in the economy of South Africa, respectively. The findings of this study aligned with those of Jing et al. (2024), which showed that innovative irrigation strategies, alongside soil water conservation methods, collectively enhanced water retention and efficiency.

9.2.4.2.2 Full Adoption

As indicated in Table 9.19 above, the full adoption of water-saving policies resulted in a R33.70 million output of sugarcane in the Impala Irrigation Scheme and in the economy of KwaZulu-Natal. The total labour remuneration was estimated at R 18.69 million in the economy of South Africa, of which the KZN province generates a labour return of about R2.66 million and a gross operating surplus (capital) of R5.55 million in the economy. Most of the labour income was derived from the Western Cape, followed by the North West and Mpumalanga provinces.

Household income was estimated at R 43.67 million towards the economy of the KZN province. The overall land return was estimated at R 7.07 million in the economy of South Africa, of which the return to irrigation in KZN was R89 528.08. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district of KZN.

Institutional incomes (enterprise and households) were valued at R108.15 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R73.72 and R126.49 million in the economy of South Africa, respectively. As indicated above in this sub-section, the findings of this study concurred with those of Jing et al. (2024), which showed that innovative irrigation strategies, alongside soil water conservation methods, collectively enhance water retention and efficiency.

9.2.4.3 Adaptation towards climate variability

9.2.4.3.1 Partial Adaption

As indicated in Table 9.19 above, the effect of partial adaptation to climate variability, which involved a deficit irrigation strategy, moderate weed management, and moderate mulching, led to a R62.57 million output of sugarcane in the Impala Irrigation Scheme and into the economy of KwaZulu-Natal. The total labour remuneration was estimated at R34.67 million in the economy of South Africa, of which the KZN province generates labour return of about R6.84 million and gross operating surplus (capital) of R26.81 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R 106.98 million towards the economy of the KZN province. The overall land return was estimated at R72.02 million in the economy of South Africa, of which the return to irrigation in KZN was R165 017.20. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district of KZN.

Institutional incomes (enterprise and households) were valued at R108.44 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R106.98 and R618.14 million in the economy of South Africa, respectively. The findings of this study are in line with those of Zhao and Li (2015), which indicated that sugarcane production may have been affected and will continue to be considerably affected by increases in the frequency and intensity of extreme environmental conditions attributable to climate variability, and that the degree of the impact of climate variability on sugarcane is associated with geographic location and adaptive capacity.

9.2.4.3.2 Full Adaption

As indicated in Table 9.19 above, the effect of full adaptation towards climate variability, which involved effective weed management, significant mulching, and irrigation applied strategically at critical growing stages of the plant, led to R283.13 million output of sugarcane in the Impala Irrigation Scheme and the economy of KwaZulu-Natal. The total labour remuneration was estimated at R152.88 million in South Africa, of which the KZN province generates labour return of about R30.9million, and gross operating

surplus (capital) of R111.35 million in the economy. Most of the labour income was derived from the Western Cape province, followed by the North West and Mpumalanga provinces.

Household income was estimated at R306.66 million towards the economy of KZN province. The overall land return was estimated at R76.82 million in the economy of South Africa, of which the return to irrigation in the KZN was R746 787.10. The highest return on irrigation in the district of KZN was found in the Zululand irrigation district, followed by other districts of KZN irrigation in the economy of KZN province.

Institutional incomes (enterprise and households) were valued at R521.76 million in the economy of South Africa. The households and value added (labour, capital, and land) generated incomes of R498.28 and R398.68 million in the economy of South Africa, respectively. As indicated above in this sub-section, the finding of this study aligned with that of Zhao and Li (2015), which stated that sugarcane production may have been affected and will continue to be considerably affected by increases in the frequency and intensity of extreme environmental conditions attributable to climate variability, and that the degree of the impact on climate variability on sugarcane is associated with geographic location and adaptive capacity.

9.3 Discussions

The TPB results indicate that perceived financial cost negatively affects attitudes towards adopting water-saving technologies, meaning that higher expected expenses reduce favourable views on adoption. However, technical factors have a positive effect on intentions, showing that, when irrigators perceive the technology as technically suitable, their willingness to adopt increases. This suggests that, while cost concerns may limit adoption, practical feasibility encourages it.

The TPB results reveal that limited access to resources negatively influences attitudes towards adopting water-saving policies among sugar cane irrigators. This suggests that when resources are scarce or difficult to obtain, irrigators are less favourable towards adopting these policies. On the other hand, lower perceived financial costs strongly increase intentions to adopt, indicating that affordability plays a critical role in decision-making. Additionally, higher levels of trust further encourage intentions to implement water-saving policies, highlighting the importance of confidence in institutions or policy frameworks. However, this combination of psychological barriers and economic trade-offs suggests that, while cost and trust are essential for adoption, the adverse impacts on yields pose challenges for the widespread uptake of restrictive water saving policies.

The TPB findings indicate that institutional and legal factors strongly influence social norms around adapting to climate variability among sugar cane irrigators. This means that supportive policies and regulations could encourage wider social acceptance of adaptation measures. Higher perceived financial

costs reduce farmers' perceived control over adaptation behaviours, highlighting cost as a key barrier. Technical factors positively affect both intentions and social norms, showing that trust in technology and expertise plays a crucial role in motivating adaptation. Additionally, trust factors directly improve attitudes towards adaptation, reinforcing the psychological readiness of irrigators to respond to climate risks.

The AquaCrop model simulations show that different scenarios of adoption of technologies result in an increase in sugar cane yield with varying Rand values. The ripple effect and multiplier analysis reveal significant positive ripple effects throughout the economy, including improvements in sugar cane output in KwaZulu-Natal, national labour remuneration, provincial labour returns, gross operating surplus, household incomes in KwaZulu-Natal, land returns, institutional income, and overall value added from labour, capital, and land. This suggests that overcoming financial barriers and building institutional support and trust could drive meaningful adaptation, which in turn boosts productivity and generates widespread economic benefits.

CHAPTER 10: SUMMARY, CONCLUSIONS, RECOMMENDATIONS, LIMITATIONS, AND FURTHER STUDIES

10.1 Overview

This project addressed the need to take a practical, methodological approach to integrate different dimensions of agricultural systems and to understand how behavioural change among actors influences system outcomes. While many frameworks exist conceptually, few offer the practical tools needed for application. This project filled that gap by developing and applying an integrated framework combining psychological, biophysical, social, and economic dimensions systematically.

10.2 Summary of Results

10.2.1 The adoption of water-saving technologies

A combination of psychological, biophysical, and economic factors shaped the adoption of water-saving technologies across the irrigation schemes. From a psychological perspective, many farmers expressed willingness to adopt these technologies when they perceived clear benefits and felt confident in their ability to apply them. However, concerns about financial risk, uncertainty around short-term outcomes, and limited control over decisions reduced their intention to adopt in some areas. The biophysical analysis using the AquaCrop model indicated that, while water productivity generally improved with these technologies, the effects on yield varied. The economic simulations reflected this variability: adoption often led to moderate gains in gross output and household income, but these benefits were dependent on actual yield responses and farmers' ability to access markets, especially for smallholder farmers, as increasing yield without having access to markets would not be fruitful. Adoption is more likely to succeed where the technical solution fits the local context, where there is institutional support, and where farmers have viable market opportunities.

Key takeaways

- Positive technical attitudes comprised the strongest and most consistent driver of adoption intention.
- Perceived control and autonomy supported adoption, where farmers felt capable and supported
- Water productivity generally improved with the adoption across schemes
- Yield gains were not guaranteed and depended on local conditions
- Economic benefits depended on both yield effects and market conditions.

10.2.2 The adoption of water-saving policies

Regarding the adoption of water-saving policies, the analysis across the case studies revealed that institutional and legal factors consistently played a positive role in shaping farmers' intentions, attitudes, and perceived behavioural control. In contrast, access to resources and informational factors showed mixed or even negative effects, with negative relationships with intention or attitudes observed in several schemes, such as commercial wheat, maize, lucerne, and sugarcane production. Trust emerged as a strong, positive predictor of intentions in multiple schemes (e.g. Hartbeespoort wheat and Kakamas lucerne). At the same time, perceived financial cost tended to positively influence intentions, suggesting that affordability perceptions boost willingness to adopt. From the AquaCrop simulations, a clear trend emerged where partial adoption resulted in modest yield reduction, which translated into ripple effects in the broader economy, thus emphasising that aggressive water-restriction, if not economically compensated or technically supported, might undermine both farm-level viability and regional economic stability.

Key takeaways

- Institutional and legal support was the most consistent driver of adoption intentions and perceived control.
- Trust and financial cost perceptions encouraged adoption, while resource access and information had mixed effects.
- Yield drops triggered ripple effects on local and regional economies.
- Balanced policies are needed to align water savings with farm productivity and economic stability.

10.2.3 The Adaptation towards climate variability

Regarding the adaptation towards climate variability, the analysis across the case studies revealed that attitudes, institutional and legal factors, trust, and technical considerations consistently had positive and significant effects on farmers' intentions and perceived behavioural control. Perceived financial costs and social support also influenced behavioural constructs, although their effects varied by scheme and crop. AquaCrop model simulations indicated that partial adaptation often caused small yield fluctuations. A significant ripple effect in the broader economy accompanied these biophysical improvements under full adaptation. Overall, the integrated framework highlights the point that successful climate adaptation depends on favourable behavioural drivers, supported by enabling institutional and technical conditions, leading to meaningful yield gains and positive economic outcomes.

Key takeaways

- Attitudes, institutional/legal factors, and trust consistently drive adaptation intentions and perceived control.
- Perceived financial costs and social support positively influence adaptation, but vary by scheme.
- Partial adaptation causes yield fluctuations.
- Full adaptation leads to substantial yield increases across crops and schemes.
- Yield gains derived from full adaptation generate strong, positive economic ripple effects.
- Effective adaptation requires combining behavioural drivers with institutional and technical support to maximise productivity and economic benefits.

10.3 Conclusions

Overall, the project highlights the point that fostering effective water management and practice requires not only promoting favourable attitudes and intentions but also strengthening institutional support, reducing financial barriers, enhancing trust, and providing technical resources. Such a holistic perspective is essential for building resilient agricultural systems that are capable of withstanding future climate challenges. We conclude that this project benefits the farmers and different stakeholders from different perspectives, as discussed below.

We disseminated the findings through popular articles (3 published) in non-technical language, media platforms (two interviews on TV), and presenting at five national and international conferences, scientific publications (5 articles), and one conference proceedings. Besides this, the project empowered students, and among the project team, 1 Honours degree student and 2 Master's degree students graduated with distinction. At the same time, 1 PhD candidate will graduate on the 11th of December 2025. The project team disseminated information and engaged with stakeholders (smallholder maize irrigator farmers, extension officers, members of DAARLD, and the DAARLD Deputy Director of the province concerned) regarding the findings of the project in non-technical language on the 1st of April 2025 in Thohoyandou, Limpopo Province. This was to enhance the project's implementation and knowledge utilisation, which is an iterative process aimed at achieving societal impacts. It was a success, and the findings of the project were validated. Figure 10.1 below illustrates stakeholder engagements.





Figure 10.1: Stakeholder engagements

Furthermore, the project proposes that a financial modality should be developed to enhance the adaptability of different types of technology. This is because, without a support mechanism, the economic costs of water-saving technologies could undermine farmer livelihoods and broader regional welfare. Furthermore, the project concludes that, with the right psychological and structural conditions, full adaptation not only improves productivity but also delivers widespread economic benefits, making a compelling case for investment in long-term climate resilience.

10.4 Recommendations

This project makes it clear that changes in water use behaviour at the farm level do not happen in isolation. They create significant ripple effects across the biophysical environment, social and economic conditions, and psychological drivers within irrigation schemes. All stakeholders, farmers, irrigation boards, and extension officers must shift from a retrospective mindset that focuses on fixing problems after they happen to a prospective approach that anticipates these complex impacts before recommendations or policies are put in place.

Extension officers play a key role in translating knowledge into practice on the ground. This project shows that extension services need to move away from simply reacting to problems as they arise. Instead, extension officers should provide farmers with proactive advice that considers the complex interactions between psychological, social, economic, and environmental factors. Farmers need to be made aware that changes to water use have broader consequences than just immediate gains or losses in yield or costs. Extension officers should encourage farmers to participate in adaptive learning cycles. This means they

continuously observe, learn from outcomes, and adjust their behaviours accordingly. Promoting ongoing engagement between all stakeholders by using the integrated framework would improve the resilience and sustainability of irrigation schemes.

The main lesson derived from this research is that change in water use behaviour is not a simple matter of technical adjustment or individual choice. It is a complex issue embedded in a dynamic system where physical, social, economic, and psychological factors interact in often unpredictable ways.

Educational campaigns and training sessions could highlight potential cost savings and productivity improvements, which could assist in creating positive attitudes toward the adoption of technologies. A practical approach could be to leverage major agricultural exhibitions, such as Nampo Harvest Day, Nampo Cape, and Agri-Expo, which could serve as effective platforms for these educational efforts, providing opportunities for live demonstrations and direct producer engagement.

Adopting different water technologies needs finance, especially for smallholder farmers. Given this fact, the project team recommended that the South African government and various stakeholders should introduce a Grameen Bank modality⁵, which has proved effective in different parts of the world. To be successful, commitment from relevant stakeholders and behavioural changes by farmers are needed.

10.5 Limitations and Further Research

The point is highlighted that there is a complexity of water-use behaviours in agricultural settings. It is crucial to acknowledge the limitations of existing behavioural models in capturing this complexity. Academically, the recognition of these complexities in human decision-making is evident, with various studies augmenting traditional behavioural models by integrating additional constructs.

Because of the broad scope and the large number of behaviours studied, the project questionnaire used a minimal number of measurement items according to the Theory of Planned Behaviour construct. While this approach facilitated data collection across multiple dimensions, it limits the depth and robustness of the psychological measurement. Future research should include more items per construct to improve construct validity and reliability.

⁵ Grameen Bank is a microfinance organisation founded by Prof. Muhammed Yonus, which provides loans without collateral. Reaching the needy through village banks (VBs) and group-based lending programmes provides a self-sustainable means of enhancing farmers' entrepreneurship, with community engagement and the adoption of water saving technology. Group lending, referred to as non-individual credit, given to group of farmers establishes a solidarity group in the form of a credit union, where cooperative associations, users' societies and others play a significant role in securing, managing, efficiently utilising, and paying off credit on time.

Irrigation schedules, management practices, and behavioural change scenarios in the AquaCrop model simulations were intentionally kept simple to maintain comparability and focus across case studies. However, this simplification may under-represent the complexity of real-world farmer decision-making. Future research should aim to incorporate more refined and context-specific scenario designs to reflect adaptive behaviour in diverse production settings better.

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Appendices A-K

Appendix A- Measurement of TPB Model- Commercial Farmers

Table A.1: Measurement Items for the Attitudes Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	A_{B_1}	Maximising production and farm efficiency is more important than adopting water-saving technologies.
	A_{B_2}	Conserving water should not be prioritised over adopting water-saving technologies.
Adoption of water-saving policies	A_{B_3}	I follow water-saving policies only during droughts.
	A_{B_4}	There is no need to adopt water-saving policies to protect water resources.
Adaptation towards climate variability	A_{B_5}	I follow the prescribed irrigation practices from the water user association or governing bodies to adapt to climate variability.
	A_{B_6}	Using prescribed irrigation practices from my water user association or governing bodies will save me time and money when adapting to climate variability.

Source: Project team compilation

Table A.2: Measurement Items for the Subjective Norms Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	SN_1	My family strongly encourages me to use water-saving technologies.
	SN_2	People in my area seem willing to use water-saving technologies.
Adoption of water-saving policies	SN_3	Important people (my neighbours and leaders in the community) support and promote water-saving policies.
	SN_4	I feel pressured by society to adopt water-saving policies.
Adaptation towards climate variability	SN_5	Other farmers and industry professionals strongly encourage me to take action against climate variability.
	SN_6	There is increasing pressure from my community to adjust my farming practices in response to climate variability.

Source: Project team compilation

Table A.3: Measurement Items for the Perceived Behavioural Control Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	PBC_1	I am confident in my current abilities to use water-saving technologies effectively.
	PBC_2	I'm confident in my ability to learn and use water-saving technologies.
Adoption of water-saving policies	PBC_3	I have the skills to adopt and implement water-saving policies.
	PBC_4	I have the necessary resources and knowledge to comply with water-saving policies.
Adaptation towards climate variability	PBC_5	I feel I can adapt my farming practices to climate variability.
	PBC_6	I can make the necessary changes to my farming in response to climate variability.

Source: Project team compilation

Table A.4: Measurement Items for the Technical Factors Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	TF_1	I attended training on how to utilise water-saving technologies.
	TF_2	I gained a deeper understanding of water-saving technologies during the training sessions.
Adoption of water-saving policies	TF_3	I receive support from the government for implementing water-saving policies.
	TF_4	I have attended government training that focuses on water-saving policies.
Adaptation towards climate variability	TF_5	I attended specific training on how to adapt to climate variability.
	TF_6	Technical training taught me how to adapt my farming to climate variability.

Source: Project team compilation

Table A.5: Measurement Items for the Institutional and Legal Factors Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	<i>IL₁</i>	The government supports and encourages farmers to use water-saving technologies.
	<i>IL₂</i>	The water user association and governing bodies support and encourage farmers to use water-saving technologies.
Adoption of water-saving policies	<i>IL₃</i>	I am familiar with the water-saving rules, regulations, and policies in my area.
	<i>IL₄</i>	The farmers' association in my area helps me to implement water-saving policies.
	<i>IL₇</i>	I am aware of the policies listed on the information page.
Adaptation towards climate variability	<i>IL₅</i>	The farmers' association in my area helps me adapt to climate variability.
	<i>IL₆</i>	The government's training and awareness programmes help me adapt to climate variability.
General (applies to all behaviours)	<i>IL₈</i>	Obtaining water rights is a challenge for my farming operations.

Source: Project team compilation

Table A.6: Measurement Items for the Perceived Risks and Benefits Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	RB_1	The risk of water scarcity motivates me to use water-saving technologies.
	RB_2	Water-saving technologies can reduce the risk of water scarcity.
Adoption of water-saving policies	RB_3	I will adopt water-saving policies because they can prevent potential financial losses.
	RB_4	Water-saving policies can help mitigate the risk of water scarcity and enhance irrigation efficiency.
Adaptation towards climate variability	RB_5	Adjusting my irrigation to account for climate variability will help mitigate the risks associated with it.
	RB_6	The risks associated with climate variability motivate me to modify my irrigation practices.

Source: Project team compilation

Table A.7: Measurement Items for the Perceived Risks from Load-shedding and Tariffs Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	<i>RB₇</i>	I am concerned about how load-shedding can affect my irrigation practices and water management.
	<i>RB₈</i>	I consider load-shedding a threat to my farm's overall productivity and profitability.
	<i>RB₉</i>	The increase in electricity and water tariffs is a threat to my farm.
	<i>RB₁₀</i>	Land reform is a significant risk to the future of my farm.

Source: Project team compilation

Table A.8: Measurement Items for the Informational Factors Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	IF_1	I am seeking information on emerging water-saving technologies.
	IF_2	I am searching for information on water-saving technologies before implementing them.
Adoption of water-saving policies	IF_3	I believe that information on water-saving policies is crucial for their success on my farm.
	IF_4	I assess the reliability and quality of information on water-saving policies before I adopt them.
Adaptation towards climate variability	IF_5	My decisions about my irrigation are influenced by information about the impacts of climate variability.
	IF_6	I look at the reliability and quality of information on climate variability before adapting to it.
General (applies to all behaviours)	IF_7	The Department of Agriculture, district municipalities, and other government agencies provide me with important information for my irrigation practices.
	IF_8	I receive important information and training for my irrigation practices from non-governmental agricultural organizations such as Grain SA, the Lucerne Trust, Potato SA, etc.

Source: Project team compilation

Table A.9: Measurement Items for the Trust Factors Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	TX_1	I have confidence in the people responsible for water management in my scheme.
	TX_2	I trust other farmers in the community to manage water sustainably.
	TX_3	I have confidence in the government's policies and actions for sustainable water management.
	TX_4	I have confidence in the people involved with water management in my scheme to facilitate communication and collaboration among the different stakeholders.
	TX_5	I rely on the advice of non-governmental agricultural organizations (Grain SA, Potato SA, Lucerne Trust, etc.) to improve my irrigation practices.

Source: Project team compilation

Table A.10: Measurement Items for the Access to Resources Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	AR_1	I have sufficient access to financial resources for my farming operations.
	AR_2	I have easy access to the markets for the crops I produce under irrigation.
	AR_3	I can easily utilise risk management tools such as insurance and SAFEX to manage farming-related risks.

Source: Project team compilation

Table A.11: Measurement Items for the Perceived Financial Costs Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	PFC_1	The cost of water-saving technologies is a challenge for my irrigation activities.
Adoption of water-saving policies	PFC_2	The cost of implementing water-saving policies is a challenge for my irrigation activities.
Adaptation towards climate variability	PFC_3	The cost of adapting to climate variability is a challenge for my irrigation activities.
General (applies to all behaviours)	PFC_4	The cost of alternative energy sources (solar power) is too high for me to switch from my current electricity provider.

Source: Project team compilation

Table A.12: Measurement Items for the Intentions Construct (Commercial Farmers, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	IN_1	I am currently intending to adopt water-saving technologies in my irrigation activities.
	INT_2	I plan to adopt water-saving technologies in my irrigation activities in the near future.
Adoption of water-saving policies	INT_3	I am currently intending to implement water-saving policies in my irrigation practices.
	INT_4	I plan to implement water-saving policies in my irrigation practices in the near future.
Adaptation towards climate variability	INT_5	I am currently planning to adopt measures to adapt to the impacts of climate variability on my irrigation activities.
	INT_6	I plan to adopt measures to adapt to the impacts of climate variability on my irrigation activities in the near future.

Source: Project team compilation

Table A.13: Measurement Items for Household, Farm, and Farmer Characteristics (Commercial Farmers, Socio-economic Variables)

Your gender?	Male		Female		Other	
Your age in years?						
Highest level of education?	Primary (Grade 1-7)	Secondary (Grade 8-12)	Diploma	Degree	Masters	PhD
Do you have any off-farm income? (If yes, specify)	Yes			No		
If yes, please specify						
Health Level	Poor	Average		Good	Excellent	
What is the size of your irrigation land (Hectares)?						
What is the size of the rest of your agricultural land (hectares)?						
What is the primary source of water used for irrigation?	River water	Dam water		Canal water	Borehole water	
If other, please specify						
What is the total amount of agricultural land deeds that you own?	One		Two to five		More than five	
How scattered is your farmland from your main farm?	Highly clustered together (1–5 Km)		Moderately dispersed (5–10 Km)		Highly dispersed (10 or more Km)	
What type of farming do you primarily do on your farm?	Crop production		Livestock production		Mixed farming	
Specify the crops or livestock that you farm.						
What is the business structure of your farming operation?	Sole proprietorship		Corporation		Partnership	
If other, please specify						
How far is your farm from the water source you use for irrigation?	Less than 1 Km	1-3 Km	3-7 Km	7-10 Km	More than 10 Km	
What is the land ownership type for your farm?	I am the sole owner	I lease my land		A combination of sole ownership and leasehold		communal
How many adults 18 years and older live in your home?	One		Two		Three or more	
How many people live in your home, including adults and children?	One	Two		Three	Four or more	
Please indicate the age of the head of your household.						
Please indicate the gender of the head of your household.	Male		Female		Other	
How many individuals in your household are involved in your farming activities?	One		Two		Three or more	
Please indicate your marital status.	Married	Single	Divorced	Widowed	Other	
What is your main occupation or primary source of livelihood?	Farmer/agricultural activities		Self-employed/business owner		Other	
If other, please specify						

Source: Project team compilation

Appendix B- Measurement of TPB Model- Smallholder Farmers

Table B.1: Measurement Items for the Attitudes Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	A_{B1}	Using water-saving tools (technologies) will enable me to use less water on my farm.
	A_{B2}	Water-saving tools (technologies) can improve irrigation for sustainable farming.
Adoption of water-saving policies	A_{B3}	I support the implementation of water-saving rules (policies) to make sure farmers use water well and protect water resources in our district.
	A_{B4}	It is important to implement water-saving rules (policies) to save water and secure the future of farming in our area.
Adaptation towards climate variability	A_{B5}	It is essential to adapt my irrigation methods (drip, sprinkler, pivot, flood, etc.) to account for climate variability, ensuring the future success of my farm.
	A_{B6}	It is easy for me to adjust my irrigation practices to mitigate the effects of climate variability.

Source: Project team compilation

Table B.2: Measurement Items for the Subjective Norms Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	SN_1	Important people like my family and friends think that using water-saving tools (technologies) is a smart way to use water efficiently/wisely.
	SN_2	Important people like my family and friends would support my use of water-saving tools (technologies) for irrigation to save water.
Adoption of water-saving policies	SN_3	I feel that many farmers in my community are getting encouragement from others to follow water-saving rules (policies).
	SN_4	I believe agricultural experts (extension officers) would support the implementation of water-saving rules (policies) for irrigation.
Adaptation towards climate variability	SN_5	I believe that important people in my community expect me to change how I use water to address climate variability.
	SN_6	The opinions of significant figures in my farming community may influence how I use water due to climate variability.

Source: Project team compilation

Table B.3: Measurement Items for the Perceived Behavioural Control Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	PBC_1	I am confident in my ability to use water-saving tools (technologies) on my own when irrigating on my farm.
	PBC_2	I believe that I can learn about new water-saving tools (technologies) available in the market.
Adoption of water-saving policies	PBC_3	I think I can follow the water-saving rules (policies) set by the government/authorities.
	PBC_4	I believe I can adjust my crop irrigation methods to comply with water-saving rules (policies).
Adaptation towards climate variability	PBC_5	I can adjust my irrigation practices to mitigate the effects of climate variability.
	PBC_6	I know that I can learn about new methods to adjust to climate variability.

Source: Project team compilation

Table B.4: Measurement Items for the Access to Resources Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	AR_1	It is easy for me to get money or a loan to buy water-saving tools (technologies) for my farm.
	AR_2	I can easily find and contact sellers who offer water-saving tools (technologies).
Adoption of water-saving policies	AR_3	I can easily find information about water conservation, climate variability, and water-saving rules (policies) at various sources, including radio, TV, cooperatives, community organisations, influential figures, and others.
	AR_4	I am familiar with various coping strategies for addressing climate variability, including selling personal property, diversification, breeding cattle, implementing drought-resistant crops, migration, and selling livestock, among others.
Adaptation towards climate variability	AR_5	It is easy for me to obtain financial assistance or insurance to mitigate risks related to climate variability.
	AR_6	I can easily get assistance or advice from experts on how to adapt to climate variability.

Source: Project team compilation

Table B.5: Measurement Items for the Access to Resources for Resilience Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	AR_7	I have easy access to the market from my current location, allowing me to sell my farming products.
	AR_8	I have sufficient resources in general (cattle, furniture, machinery, etc.) to cope with climate variability, policy changes, and others.
	AR_9	I have easy access to water resources to use for irrigation on my farm.
	AR_{10}	I have access to safety nets, including government grants, insurance, assistance from other farmers, government subsidies, relief subsidies, and credit and other resources.

Source: Project team compilation

Table B.6: Measurement Items for the Institutional Factors Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	IL_1	Assistance from experts (extension officers) helps me use water-saving tools (technologies) on my farm.
	IL_2	I often ask for the support of extension agents/officers to help me implement water-saving tools (technologies) on my farm.
Adoption of water-saving policies	IL_3	I'm aware of the water-saving policies and rules (policies) made by the government authorities to save water.
	IL_4	The availability and help of the government and non-government organisations (AFASA, Grain SA, BKB, etc.) will not affect my decision to follow water-saving rules (policies).
	IL_7	I am aware of the rules (policies) that are listed on the information page.
	IL_8	I am implementing the rules (policies) listed on the information page.
Adaptation towards climate variability	IL_5	Government policies and support have improved my ability to handle water shortages.
	IL_6	Better support from the government would make it easier for me to deal with the effects of climate variability.

Source: Project team compilation

Table B.7: Measurement Items for the Perceived Social Support Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	SS_1	I can depend on other farmers (part of a cooperative, social networks, church, stokvel, and others) to teach me about saving water tools (technologies).
	SS_2	Talking to other farmers (part of a cooperative, social network, church, stokvel, and others) about farming in general affects my choice to use water-saving tools (technologies).
Adoption of water-saving policies	SS_3	I think farmers (part of a cooperative, social network, church, stokvel, and others) in my area work together to follow water-saving rules (policies) and help each other.
	SS_4	The advice of respected elders in the community about water-saving rules (policies) is essential to me.
Adaptation towards climate variability	SS_5	I believe my family, friends, and neighbours would provide me with practical support and ideas to mitigate the effects of climate variability on my farm.
	SS_6	I can rely on a good support network (part of a cooperative, social network, church, stokvel, and others) to help me with the challenges caused by climate variability on my farm.

Source: Project team compilation

Table B.8: Measurement Items for the Perceived Financial Costs Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	PFC_1	The cost of buying water-saving tools (technologies) affects my decision to use them.
	PFC_2	The ongoing costs for maintaining or subscribing to water-saving tools (technologies) play a role in my decision to use them.
	PFC_3	The government gives me financial support to buy water-saving tools (technologies).
Adoption of water-saving policies	PFC_4	The costs of complying with water-saving rules (policies) affect my decision to adopt them.
	PFC_5	I want to use water-saving rules (policies) because they can save me money.
Adaptation towards climate variability	PFC_6	The costs involved in addressing climate variability on my farm may impact my adaptation to it.
	PFC_7	If the long-term costs of adapting to climate variability are high, I might not persist in such efforts.

Source: Project team compilation

Table B.9: Measurement Items for the Construct Perceived Financial Costs Related to Energy and Debt (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	PFC_8	The cost of alternative energy sources (solar power and generators) is too high for me to move away from my current electricity supplier.
	PFC_9	To reduce electricity cost, I consider off-peak, regular, and peak times of rural flex during the day when irrigating.
	PFC_{10}	The level of my farm debt is a challenge for my farming operations.

Source: Project team compilation

Table B.10: Measurement Items for the Informational Factors Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	IF_1	I can get reliable information about water-saving tools (technologies) when I need it (access to information).
	IF_2	Understanding the benefits and how to use water-saving tools (technologies) influences my decision to use them.
Adoption of water-saving policies	IF_3	I can find information about different water-saving rules (policies) and how they might help me.
	IF_4	Information sessions about water-saving rules (policies) will help me understand and adopt these rules (guidelines).
Adaptation towards climate variability	IF_5	I can access information and predictions about the weather that could help me deal with climate variability.
	IF_6	Information about the various methods to adapt to climate variability will motivate me to use these methods.
	IF_7	I have access to information about water-saving tools, rules, and climate variability, but it is too difficult for me to understand.
General (applies to all behaviours)	IF_8	I have enough knowledge to successfully adapt to climate variability and implement water-saving tools (technologies) and rules (policies) on my farm.
	IF_9	I have access to early warning information regarding climate variability, drought, floods, heat waves, and other natural disasters.

Source: Project team compilation

Table B.11: Measurement Items for the Perceived Risks and Benefits Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	RB_1	I think using water-saving tools (technologies) will help me irrigate better.
	RB_2	I am bothered by the potential drawbacks of using water-saving tools (technologies).
Adoption of water-saving policies	RB_3	Following water-saving rules (policies) can help me use water better on my farm.
	RB_4	I'm worried about the potential drawbacks/risks associated with following water-saving rules (policies) on my farm.
Adaptation towards climate variability	RB_5	I am aware of the benefits of adapting my farming practices to climate variability.
	RB_6	I'm worried about the potential drawbacks and risks associated with adapting to climate variability on my farm.

Source: Project team compilation

Table B.12: Measurement Items for the Construct Perceived Risks Related to Tariffs and Load-shedding (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
General (applies to all behaviours)	RB_7	The increase in tariffs (cost) of water and electricity is a threat to my farm.
	RB_8	I view load-shedding as a threat and challenge to my farming operations.
	RB_9	Load-shedding affects the productivity and profitability of my farming operations.
	RB_{10}	Electricity price increases negatively affect the productivity and profitability of my farming operations.

Source: Project team compilation

Table B.13: Measurement Items for the Intentions Construct (Small-scale Irrigators, Augmented TPB Model)

Targeted Water Use Behaviour	Symbol	Measuring item
Adoption of water-saving technologies	<i>INT₁</i>	I am currently intending to adopt water-saving technologies in my irrigation activities.
	<i>INT₂</i>	I plan to adopt water-saving technologies in my irrigation activities in the near future.
Adoption of water-saving policies	<i>INT₃</i>	I am currently intending to implement water-saving policies in my irrigation practices.
	<i>INT₄</i>	I plan to implement water-saving policies in my irrigation practices in the near future.
Adaptation towards climate variability	<i>INT₅</i>	I am currently planning to adopt measures to adapt to the impacts of climate variability on my irrigation activities.
	<i>INT₆</i>	I plan to adopt measures to adapt to the impacts of climate variability on my irrigation activities in the near future.

Source: Project team compilation

Table B.14: Measurement Items for Household, Farm, and Farmer Characteristics (Small-scale Irrigators, Socio-economic Variables)

Your gender?	Male		Female		Other	
Your age in years?						
Highest education level?	Primary (Grade 1-7)	Secondary (Grade 8-12)	diploma	Degree	Masters	PhD
Do you have any off-farm income?	Yes			No		
If yes, specify:						
How many years have you been farming (experience)?						
Do you engage in any off-farm work?	Yes			No		
If yes, specify:						
Rate your level of knowledge about climate variability.	Very low	low	Average	High	Very high	
What is the ownership status of your land?	Communal land	Rented land	Customary land	Purchased land	Other	
If other, specify						
Is your farm located near modern medical facilities, populated areas, or markets?	Yes			No		
How far is your farm from the nearest markets where you buy or sell agricultural products?	Less than 1 km	1-5km	5-10km	10-15km	15-20km	More than 20km
Do you have someone in mind to take over your farm in the future (a succession plan)?	Yes			No		
Please select the category that best describes your farm based on its primary agricultural activities or specialisation.	Crop production		Livestock production		Mixed farming	
Specify the crops or livestock that you farm.						
Indicate the gender of the head of your household.						
How many male members live in your household?						
How many female members live in your household?						
How many male members of your household are involved in agricultural activities on your farm/communal land?						
How many female members of your household are involved in agricultural activities on your farm/communal land?						
What is your monthly household's on-farm income?	Less than R1 000	R1 000 - R5 000	R5 000- R10 000	R10 000- R15 000	R15 000- R20 000	R20 000 or more
What is your monthly household off-farm income?	Less than R1 000	R1 000 - R5 000	R5 000- R10 000	R10 000- R15 000	R15 000- R20 000	R20 000 or more
During which rural flex time slots do you irrigate on your farm?	Off-peak		Standard		Peak	All of them
Rank these challenges on your farm from 1 to 6	Electricity cost	Cost of water	Lack of finance	Lack of access to land	Climate variability	Water scarcity
Rank from 1 to 6:						
Describe the size of your farm in hectares.						

Source: Project team compilation

Appendix C 1- Hypotheses- Commercial Farmers

C 1.1: Hypotheses for the Orange-Riet Irrigation Scheme - Adoption of Water-Saving Technologies

Table C.1: Standard TPB Hypotheses for Adoption of Water Saving Technologies by Commercial Maize Farmers in the Orange Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H2	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H3	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.2: Augmented TPB hypotheses for the direct predictors of intentions of commercial maize irrigators to adopt water-saving technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H4	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H5	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving technology.
H6	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technology.
H7	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H8	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving technology.
H9	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving technology.
H10	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving technology.
H11	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H12	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H13	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving technology.
H14	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technology.
H15	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving technology.
H16	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving technology.
H17	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving technology.
H18	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving technology.
H19	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H20	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H21	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H22	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H23	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H24	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H25	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H26	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H27	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H28	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving technology.
H29	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving technology.
H30	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving technology.
H31	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving technology.
H32	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving technology.
H33	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving technology.
H34	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving technology.
H35	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving technology.
H36	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving technology.
H37	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving technology.
H38	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving technology.

Source: Project team compilation

Table C.3: Augmented TPB hypotheses for the specific indirect effects on intentions of commercial maize irrigators to adopt water-saving technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H39	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H40	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H41	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H42	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H43	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H44	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H45	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H46	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H47	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H48	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H49	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H50	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H51	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H52	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H53	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H54	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H55	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving technologies.
H56	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H57	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H58	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving technologies.
H59	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H60	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving technologies.
H61	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H62	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.4: Augmented TPB hypotheses for the total indirect effects on intentions of commercial maize irrigators to adopt water-saving technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H63	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving technology.
H64	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technology.
H65	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technology.
H66	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving technology.
H67	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving technology.
H68	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving technology.
H69	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving technology.
H70	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technology.

Source: Project team compilation

Table C.5: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial maize irrigators to adopt water-saving technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Brief description
H71	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H72	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technology.
H73	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technology.
H74	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H75	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H76	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving technologies.
H77	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving technology.
H78	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H79	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H80	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the adoption of water-saving technology.
H81	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H82	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H83	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H84	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving technologies.
H85	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the adoption of water-saving technology.
H86	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H87	$TX \Rightarrow PBC$	Trust factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H88	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H89	$PFC \Rightarrow PBC$	The perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H90	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H91	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H92	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H93	$RB \Rightarrow PBC$	Perceived risks and benefits have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H94	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H95	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technology.
H96	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving technology.
H97	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technology.
H98	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technology.
H99	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving technology.
H100	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technology.
H101	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving technology.
H102	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving technology.
H103	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving technology.
H104	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technology.
H105	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technology.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 1.2: Hypotheses for the Orange-Riet Irrigation Scheme - Water Saving Policies

Table C.6: Standard TPB Hypotheses for Adoption of Water Saving Policies by Commercial Maize Farmers in the Orange Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H106	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H107	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H108	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.7: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on intentions of commercial maize irrigators to adopt water-saving policies in the Orange-Riet Irrigation Scheme.

Hypothesis	Relation	Hypothesised Relationship
H109	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H110	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving policies.
H111	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H112	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H113	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving policies.
H114	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving policies.
H115	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving policies.
H116	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H117	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H118	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving policies.
H119	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H120	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving policies.
H121	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving policies.
H122	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving policies.
H123	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving policies.
H124	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H125	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H126	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H127	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H128	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H129	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H130	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H131	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H132	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H133	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving policies.
H134	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving policies.
H135	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving policies.
H136	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving policies.
H137	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving policies.
H138	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving policies.
H139	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving policies.
H140	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving policies.
H141	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving policies.
H142	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving policies.
H143	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving policies.

Source: Project team compilation

Table C.8: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on intentions of commercial maize irrigators to adopt water-saving policies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H144	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving policies.
H145	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H146	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H147	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving policies.
H148	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H149	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H150	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H151	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H152	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving policies.
H153	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H154	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H155	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving policies.
H156	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H157	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H158	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H159	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H160	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving policies.
H161	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H162	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H163	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving policies.
H164	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H165	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving policies.
H166	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H167	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.

Source: Project Team compilation

Table C.9: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial maize irrigators to adopt water-saving policies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H168	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving policies.
H169	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H170	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H171	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving policies.
H172	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving policies.
H173	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving policies.
H174	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving policies.
H175	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.

Source: Project Team compilation

Table C.10: Summary of Hypotheses on Total Effects (Direct and Indirect) of Additional and Standard Constructs on the Intentions of commercial maize irrigators to adopt water-saving policies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Brief description
H176	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H177	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H178	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H179	$TF \Rightarrow A_B$	Technical factors have a significant influence on attitudes regarding the adoption of water-saving policies.
H180	$IL \Rightarrow A_B$	Institutional and legal factors have a significant influence on attitudes regarding the adoption of water-saving policies.
H181	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving policies.
H182	$RB \Rightarrow A_B$	Perceived risks and benefits have a significant influence on attitudes regarding the adoption of water-saving policies.
H183	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H184	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H185	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the adoption of water-saving policies.
H186	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H187	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H188	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H189	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving policies.
H190	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving policies.
H191	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H192	$TX \Rightarrow PBC$	Trust factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H193	$AR \Rightarrow PBC$	Access to resources has an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H194	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H195	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H196	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H197	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H198	$RB \Rightarrow PBC$	Perceived risks and benefits have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H199	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H200	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H201	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving policies.
H202	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H203	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H204	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving policies.
H205	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H206	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving policies.
H207	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving policies.
H208	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving policies.
H209	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H210	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 1.3: Hypotheses for the Orange-Riet Irrigation Scheme – Adaptation to Climate Variability

Table C.11: Standard TPB Hypotheses for Adaptation to Climate Variability by Commercial Maize Farmers in the Orange Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H211	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H212	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H213	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.12: Augmented TPB hypotheses for the direct predictors of intentions of commercial maize irrigators to adapt to climate variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H214	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H215	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes toward the intention to adapt to climate variability.
H216	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward the intention to adapt to climate variability.
H217	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H218	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H219	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes toward the intention to adapt to climate variability.
H220	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes toward the intention to adapt to climate variability.
H221	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H222	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H223	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the intention to adapt to climate variability.
H224	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H225	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H226	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H227	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H228	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H229	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H230	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H231	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H232	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H233	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H234	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H235	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H236	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H237	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H238	$A_B \rightarrow INT$	Attitudes directly predict intentions to adapt to climate variability.
H239	$TX \rightarrow INT$	Trust factors directly predict intentions to adapt to climate variability.
H240	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adapt to climate variability.
H241	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adapt to climate variability.
H242	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adapt to climate variability.
H243	$SN \rightarrow INT$	Subjective norms directly predict intentions to adapt to climate variability.
H244	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adapt to climate variability.
H245	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adapt to climate variability.
H246	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adapt to climate variability.
H247	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adapt to climate variability.
H248	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adapt to climate variability.

Source: Project team compilation

Table C.13: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on intentions of commercial maize irrigators to adapt to climate variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H249	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adapt to climate variability.
H250	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H251	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H252	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adapt to climate variability.
H253	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H254	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H255	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H256	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H257	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adapt to climate variability.
H258	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H259	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H260	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adapt to climate variability.
H261	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H262	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H263	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H264	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H265	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adapt to climate variability.
H266	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H267	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H268	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adapt to climate variability.
H269	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adapt to climate variability.
H270	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adapt to climate variability.
H271	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H272	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.

Source: Project team compilation

Table C.14: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on intentions of commercial maize irrigators to adapt to climate variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H273	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adapt to climate variability.
H274	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H275	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H276	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adapt to climate variability.
H277	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adapt to climate variability.
H278	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adapt to climate variability.
H279	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adapt to climate variability.
H280	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.

Source: Project team compilation

Table C.15: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial maize irrigators to adapt to climate variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Brief description
H281	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H282	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H283	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H284	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H285	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H286	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes toward the intention to adapt to climate variability.
H287	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H288	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H289	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H290	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the intention to adapt to climate variability.
H291	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H292	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H293	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms related to the intention to adapt to climate variability.
H294	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H295	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H296	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H297	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H298	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H299	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H300	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H301	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H302	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H303	$RB \Rightarrow PBC$	Perceived risks and benefits have a significant influence on perceived behavioural control regarding adaptation to climate variability.
H304	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H305	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H306	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adapt to climate variability.
H307	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H308	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H309	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adapt to climate variability.
H310	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H311	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adapt to climate variability.
H312	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adapt to climate variability.
H313	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adapt to climate variability.
H314	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H315	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included

Source: Project team compilation

C 2.1: Hypotheses of Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme - Adoption of Water-Saving Technologies

Table C.16: Standard TPB Hypotheses for Adoption of Water Saving Technologies by Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H316	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H317	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H318	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.17: Augmented TPB hypotheses for the direct predictors of intentions of commercial wheat irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H319	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H320	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving technology.
H321	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technology.
H322	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H323	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving technology.
H324	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving technology.
H325	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving technology.
H326	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H327	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H328	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving technology.
H329	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technology.
H330	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving technology.
H331	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving technology.
H332	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving technology.
H333	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving technology.
H334	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H335	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H336	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H337	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H338	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H339	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H340	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H341	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H342	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H343	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving technology.
H344	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving technology.
H345	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving technology.
H346	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving technology.
H347	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving technology.
H348	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving technology.
H349	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving technology.
H350	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving technology.
H351	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving technology.
H352	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving technology.
H353	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving technology.

Source: Project team compilation

Table C.18: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H354	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H355	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H356	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H357	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H358	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H359	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H360	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H361	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H362	$T\mathbf{X} \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H363	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H364	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H365	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H366	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H367	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H368	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H369	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H370	$T\mathbf{X} \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving technologies.
H371	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H372	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H373	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving technologies.
H374	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H375	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving technologies.
H376	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H377	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.19: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H378	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving technology.
H379	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technology.
H380	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technology.
H381	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving technology.
H382	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving technology.
H383	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving technology.
H384	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving technology.
H385	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technology.

Source: Project team compilation

Table C.20: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H386	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H387	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technology.
H388	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technology.
H389	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H390	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H391	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving technology.
H392	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving technology.
H393	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H394	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H395	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the adoption of water-saving technology.
H396	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H397	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H398	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H399	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving technology.
H400	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving technology.
H401	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H402	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H403	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H404	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H405	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H406	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H407	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H408	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H409	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H410	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technology.
H411	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving technology.
H412	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technology.
H413	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technology.
H414	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving technology.
H415	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technology.
H416	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving technology.
H417	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving technology.
H418	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving technology.
H419	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technology.
H420	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technology.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 2.2: Hypotheses of Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme - Adoption of Water Saving Policies

Table C.21: Standard TPB Hypotheses for Adoption of Water Saving Policies by Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H421	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H422	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H423	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.22: Augmented TPB hypotheses for the direct predictors of intentions of commercial wheat irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H424	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H425	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving policies.
H426	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H427	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H428	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H429	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving policies.
H430	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving policies.
H431	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H432	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H433	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving policies.
H434	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H435	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving policies.
H436	$IL \rightarrow SN$	Institutional and legal factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H437	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving policies.
H438	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving policies.
H439	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H440	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H441	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H442	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H443	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H444	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H445	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H446	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H447	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H448	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving policies.
H449	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving policies.
H450	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving policies.
H451	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving policies.
H452	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving policies.
H453	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving policies.
H454	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving policies.
H455	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving policies.
H456	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving policies.
H457	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving policies.
H458	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving policies.

Source: Project team compilation

Table C.23: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H459	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving policies.
H460	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H461	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H462	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving policies.
H463	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H464	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H465	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H466	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H467	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving policies.
H468	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H469	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H470	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving policies.
H471	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H472	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H473	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H474	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H475	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving policies.
H476	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H477	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H478	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving policies.
H479	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H480	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving policies.
H481	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H482	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.

Source: Project team compilation

Table C.24: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H483	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving policies.
H484	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H485	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H486	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving policies.
H487	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving policies.
H488	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving policies.
H489	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving policies.
H490	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.

Source: Project team compilation

Table C.25: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial wheat irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H491	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H492	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H493	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H494	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H495	$IL \Rightarrow A_B$	Institutional and legal factors have a significant influence on attitudes regarding the adoption of water-saving policies.
H496	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving policies.
H497	$RB \Rightarrow A_B$	Perceived risks and benefits have a significant influence on attitudes regarding the adoption of water-saving policies.
H498	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H499	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H500	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the adoption of water-saving policies.
H501	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H502	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H503	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H504	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving policies.
H505	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the adoption of water-saving policies.
H506	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H507	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H508	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H509	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H510	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H511	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H512	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H513	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H514	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H515	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H516	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving policies.
H517	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H518	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H519	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving policies.
H520	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H521	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving policies.
H522	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving policies.
H523	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving policies.
H524	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H525	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 2.3: Hypotheses of Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme - Adaptation to Climate Variability

Table C.26: Standard TPB Hypotheses for Adaptation to Climate Variability by Commercial Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H526	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H527	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H528	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.27: Augmented TPB hypotheses for the direct predictors of intentions of commercial wheat irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H529	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H530	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes toward the intention to adapt to climate variability.
H531	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward the intention to adapt to climate variability.
H532	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H533	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H534	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes toward the intention to adapt to climate variability.
H535	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes toward the intention to adapt to climate variability.
H536	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H537	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H538	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the intention to adapt to climate variability.
H539	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H540	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H541	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H542	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H543	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H544	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H545	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H546	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H547	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H548	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H549	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H550	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H551	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H552	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H553	$A_B \rightarrow INT$	Attitudes directly predict intentions to adapt to climate variability.
H554	$TX \rightarrow INT$	Trust factors directly predict intentions to adapt to climate variability.
H555	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adapt to climate variability.
H556	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adapt to climate variability.
H557	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adapt to climate variability.
H558	$SN \rightarrow INT$	Subjective norms directly predict intentions to adapt to climate variability.
H559	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adapt to climate variability.
H560	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adapt to climate variability.
H561	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adapt to climate variability.
H562	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adapt to climate variability.
H563	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adapt to climate variability.

Source: Project team compilation

Table C.28: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H564	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adapt to climate variability.
H565	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H566	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H567	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adapt to climate variability.
H568	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H569	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H570	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H571	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H572	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adapt to climate variability.
H573	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H574	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H575	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adapt to climate variability.
H576	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H577	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H578	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H579	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H580	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adapt to climate variability.
H581	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H582	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H583	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adapt to climate variability.
H584	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adapt to climate variability.
H585	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adapt to climate variability.
H586	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H587	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.

Source: Project team compilation

Table C.29: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial wheat irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H588	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adapt to climate variability.
H589	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H590	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H591	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adapt to climate variability.
H592	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adapt to climate variability.
H593	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adapt to climate variability.
H594	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adapt to climate variability.
H595	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.

Source: Project team compilation

Table C.30: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial wheat irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H596	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H597	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H598	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H599	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H600	$IL \Rightarrow A_B$	Institutional and legal factors have a significant influence on attitudes toward adapting to climate variability.
H601	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes toward the intention to adapt to climate variability.
H602	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H603	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H604	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H605	$AR \Rightarrow SN$	Access to resources is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H606	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H607	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H608	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms related to the intention to adapt to climate variability.
H609	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H610	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H611	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H612	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H613	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H614	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H615	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H616	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H617	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H618	$RB \Rightarrow PBC$	Perceived risks and benefits have a significant influence on perceived behavioural control regarding adaptation to climate variability.
H619	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H620	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H621	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adapt to climate variability.
H622	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H623	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H624	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adapt to climate variability.
H625	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H626	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adapt to climate variability.
H627	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adapt to climate variability.
H628	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adapt to climate variability.
H629	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H630	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 3.1: Hypotheses of Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme - Adoption of Water Saving Technologies

Table C.31: Standard TPB Hypotheses for Adoption of Water Saving Technologies by Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H631	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H632	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H633	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.32: Augmented TPB hypotheses for the direct predictors of intentions of commercial soybean irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H634	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H635	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving technology.
H636	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technology.
H637	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H638	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving technology.
H639	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving technology.
H640	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving technology.
H641	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H642	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H643	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving technology.
H644	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technology.
H645	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving technology.
H646	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving technology.
H647	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving technology.
H648	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving technology.
H649	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H650	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H651	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H652	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H653	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H654	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H655	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H656	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H657	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H658	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving technology.
H659	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving technology.
H660	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving technology.
H661	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving technology.
H662	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving technology.
H663	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving technology.
H664	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving technology.
H665	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving technology.
H666	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving technology.
H667	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving technology.
H668	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving technology.

Source: Project team compilation

Table C.33: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H669	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H670	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H671	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H672	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H673	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H674	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H675	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H676	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H677	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H678	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H679	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H680	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H681	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H682	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H683	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H684	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H685	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving technologies.
H686	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H687	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H688	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving technologies.
H689	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H690	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving technologies.
H691	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H692	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.34: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H693	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving technology.
H694	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technology.
H695	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technology.
H696	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving technology.
H697	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving technology.
H698	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving technology.
H699	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving technology.
H700	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technology.

Source: Project team compilation

Table C.35: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H701	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H702	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technology.
H703	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technology.
H704	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H705	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H706	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving technology.
H707	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving technology.
H708	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H709	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H710	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the adoption of water-saving technology.
H711	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H712	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H713	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H714	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving technology.
H715	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the adoption of water-saving technology.
H716	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H717	$TX \Rightarrow PBC$	Trust factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H718	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H719	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H720	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H721	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H722	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H723	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H724	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H725	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technology.
H726	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving technology.
H727	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technology.
H728	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technology.
H729	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving technology.
H730	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technology.
H731	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving technology.
H732	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving technology.
H733	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving technology.
H734	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technology.
H735	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technology.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 3.2: Hypotheses of Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme - Adoption of Water Saving Policies

Table C.36: Standard TPB Hypotheses for Adoption of Water Saving Policies by Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H736	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H737	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H738	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.37: Augmented TPB hypotheses for the direct predictors of intentions of commercial soybean irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H739	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H740	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving policies.
H741	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H742	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H743	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H744	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving policies.
H745	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving policies.
H746	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H747	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H748	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving policies.
H749	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H750	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving policies.
H751	$IL \rightarrow SN$	Institutional and legal factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H752	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving policies.
H753	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving policies.
H754	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H755	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H756	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H757	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H758	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H759	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H760	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H761	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H762	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H763	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving policies.
H764	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving policies.
H765	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving policies.
H766	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving policies.
H767	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving policies.
H768	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving policies.
H769	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving policies.
H770	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving policies.
H771	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving policies.
H772	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving policies.
H773	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving policies.

Source: Project team compilation

Table C.38: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H774	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving policies.
H775	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H776	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H777	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving policies.
H778	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H779	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H780	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H781	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H782	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving policies.
H783	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H784	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H785	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving policies.
H786	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H787	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H788	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H789	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H790	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving policies.
H791	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H792	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H793	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving policies.
H794	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H795	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving policies.
H796	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H797	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.

Source: Project team compilation

Table C.39: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H798	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving policies.
H799	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H800	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H801	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving policies.
H802	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving policies.
H803	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving policies.
H804	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving policies.
H805	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.

Source: Project team compilation

Table C.40: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adopt water-saving policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H806	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H807	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H808	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H809	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H810	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H811	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving policies.
H812	$RB \Rightarrow A_B$	Perceived risks and benefits have a significant influence on attitudes regarding the adoption of water-saving policies.
H813	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H814	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H815	$AR \Rightarrow SN$	Access to resources has an overall influence on subjective norms regarding the adoption of water-saving policies.
H816	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H817	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H818	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H819	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving policies.
H820	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving policies.
H821	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H822	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H823	$AR \Rightarrow PBC$	Access to resources has an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H824	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H825	$TF \Rightarrow PBC$	Technical factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H826	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H827	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H828	$RB \Rightarrow PBC$	Perceived risks and benefits have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H829	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H830	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H831	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving policies.
H832	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H833	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H834	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving policies.
H835	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H836	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving policies.
H837	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving policies.
H838	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving policies.
H839	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H840	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included

Source: Project team compilation

C 3.3: Hypotheses of Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme - Adoption of Climate Variability

Table C.41: Standard TPB Hypotheses for Adaptation to Climate Variability by Commercial Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H841	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H842	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H843	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.42: Augmented TPB hypotheses for the direct predictors of intentions of commercial soybean irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H844	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H845	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes toward the intention to adapt to climate variability.
H846	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward the intention to adapt to climate variability.
H847	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H848	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes toward the intention to adapt to climate variability.
H849	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes toward the intention to adapt to climate variability.
H850	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes toward the intention to adapt to climate variability.
H851	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H852	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H853	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the intention to adapt to climate variability.
H854	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H855	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H856	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H857	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H858	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H859	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H860	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H861	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H862	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H863	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H864	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H865	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H866	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H867	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H868	$A_B \rightarrow INT$	Attitudes directly predict intentions to adapt to climate variability.
H869	$TX \rightarrow INT$	Trust factors directly predict intentions to adapt to climate variability.
H870	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adapt to climate variability.
H871	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adapt to climate variability.
H872	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adapt to climate variability.
H873	$SN \rightarrow INT$	Subjective norms directly predict intentions to adapt to climate variability.
H874	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adapt to climate variability.
H875	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adapt to climate variability.
H876	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adapt to climate variability.
H877	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adapt to climate variability.
H878	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adapt to climate variability.

Source: Project team compilation

Table C.43: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H879	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adapt to climate variability.
H880	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H881	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H882	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adapt to climate variability.
H883	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H884	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H885	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H886	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H887	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adapt to climate variability.
H888	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H889	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H890	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adapt to climate variability.
H891	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H892	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H893	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H894	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H895	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adapt to climate variability.
H896	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H897	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H898	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adapt to climate variability.
H899	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adapt to climate variability.
H900	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adapt to climate variability.
H901	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H902	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.

Source: Project team compilation

Table C.44: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial soybean irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H903	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adapt to climate variability.
H904	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H905	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H906	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adapt to climate variability.
H907	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adapt to climate variability.
H908	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adapt to climate variability.
H909	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adapt to climate variability.
H910	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.

Source: Project team compilation

Table C.45: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial soybean irrigators to adapt to climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Brief description
H911	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H912	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H913	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H914	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H915	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H916	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes toward the intention to adapt to climate variability.
H917	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H918	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H919	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H920	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the intention to adapt to climate variability.
H921	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H922	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H923	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H924	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H925	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H926	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H927	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H928	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H929	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H930	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H931	$I \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H932	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H933	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H934	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H935	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H936	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adapt to climate variability.
H937	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H938	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H939	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adapt to climate variability.
H940	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H941	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adapt to climate variability.
H942	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adapt to climate variability.
H943	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adapt to climate variability.
H944	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H945	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.

Source: Project team compilation

C 4.1: Hypotheses of Commercial Sugarcane Irrigators in the Impala Irrigation Scheme - Adoption of Water Saving Technologies

Table C.46: Standard TPB Hypotheses for Adoption of Water Saving Technologies by Commercial Sugarcane Irrigators in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H946	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H947	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H948	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.47: Augmented TPB hypotheses for the direct predictors of intentions of commercial sugarcane irrigators to adopt water-saving technologies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H949	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H950	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving technology.
H951	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technology.
H952	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H953	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving technology.
H954	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving technology.
H955	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving technology.
H956	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H957	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H958	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving technology.
H959	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technology.
H960	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving technology.
H961	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving technology.
H962	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving technology.
H963	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving technology.
H964	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H965	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H966	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H967	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H968	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H969	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H970	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H971	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H972	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H973	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving technology.
H974	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving technology.
H975	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving technology.
H976	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving technology.
H977	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving technology.
H978	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving technology.
H979	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving technology.
H980	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving technology.
H981	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving technology.
H982	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving technology.
H983	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving technology.

Source: Project team compilation

Table C.48: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving technologies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H984	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H985	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H986	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H987	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H988	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H989	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H990	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H991	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H992	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H993	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H994	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H995	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H996	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H997	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H998	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H999	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H1000	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving technologies.
H1001	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H1002	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1003	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving technologies.
H1004	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H1005	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving technologies.
H1006	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H1007	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.49: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving technologies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1008	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving technology.
H1009	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technology.
H1010	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technology.
H1011	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving technology.
H1012	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving technology.
H1013	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving technology.
H1014	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving technology.
H1015	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technology.

Source: Project team compilation

Table C.50: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving technologies in the Impala Irrigation Scheme

Hypothesis	Relation	Brief description
H1016	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1017	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technology.
H1018	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technology.
H1019	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1020	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1021	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving technologies.
H1022	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving technology.
H1023	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1024	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H1025	$AR \Rightarrow SN$	Access to resources is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H1026	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H1027	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the adoption of water-saving technology.
H1028	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving technologies.
H1029	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving technologies.
H1030	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the adoption of water-saving technology.
H1031	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1032	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1033	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H1034	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H1035	$TF \Rightarrow PBC$	Technical factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1036	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving technology.
H1037	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H1038	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H1039	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1040	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technology.
H1041	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving technology.
H1042	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technology.
H1043	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technology.
H1044	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving technology.
H1045	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technology.
H1046	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving technology.
H1047	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving technology.
H1048	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving technology.
H1049	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technology.
H1050	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technology.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included.; Source: Project team compilation

C 4.2: Hypotheses of Commercial Sugarcane Irrigators in the Impala Irrigation Scheme - Adoption of Water Saving Policies

Table C.51: Standard TPB Hypotheses for Adoption of Water Saving Policies by Commercial Sugarcane Irrigators in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1051	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H1052	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H1053	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.52: Augmented TPB hypotheses for the direct predictors of intentions of commercial sugarcane irrigators to adopt water-saving policies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1054	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1055	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving policies.
H1056	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1057	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1058	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving policies.
H1059	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving policies.
H1060	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving policies.
H1061	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1062	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1063	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving policies.
H1064	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1065	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving policies.
H1066	$IL \rightarrow SN$	Institutional and legal factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1067	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving policies.
H1068	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving policies.
H1069	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1070	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1071	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1072	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1073	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1074	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H1075	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1076	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H1077	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1078	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving policies.
H1079	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving policies.
H1080	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving policies.
H1081	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving policies.
H1082	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving policies.
H1083	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving policies.
H1084	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving policies.
H1085	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving policies.
H1086	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving policies.
H1087	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving policies.
H1088	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving policies.

Source: Project team compilation

Table C.53: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving policies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1089	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving policies.
H1090	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1091	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1092	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving policies.
H1093	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1094	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H1095	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1096	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H1097	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving policies.
H1098	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1099	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1100	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving policies.
H1101	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1102	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H1103	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1104	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H1105	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving policies.
H1106	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H1107	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1108	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving policies.
H1109	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1110	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving policies.
H1111	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1112	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.

Source: Project team compilation

Table C.54: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving policies in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1113	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving policies.
H1114	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H1115	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H1116	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving policies.
H1117	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving policies.
H1118	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving policies.
H1119	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving policies.
H1120	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.

Source: Project team compilation

Table C.55: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adopt water-saving policies in the Impala Irrigation Scheme

Hypothesis	Relation	Brief description
H1121	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1122	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1123	$PFC \Rightarrow A_B$	The perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1124	$TF \Rightarrow A_B$	Technical factors have a significant influence on attitudes regarding the adoption of water-saving policies.
H1125	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1126	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving policies.
H1127	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving policies.
H1128	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1129	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H1130	$AR \Rightarrow SN$	Access to resources has an overall influence on subjective norms regarding the adoption of water-saving policies.
H1131	$PFC \Rightarrow SN$	The perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1132	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1133	$IL \Rightarrow SN$	Institutional and legal factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H1134	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1135	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1136	$IF \Rightarrow SN$	Information factors have a significant influence on subjective norms regarding the adoption of water-saving policies.
H1137	$TX \Rightarrow PBC$	Trust factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H1138	$AR \Rightarrow PBC$	Access to resources has a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H1139	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1140	$TF \Rightarrow PBC$	Technical factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1141	$IL \Rightarrow PBC$	Institutional and legal factors have a significant influence on perceived behavioural control regarding the adoption of water-saving policies.
H1142	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H1143	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H1144	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1145	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H1146	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving policies.
H1147	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H1148	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H1149	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving policies.
H1150	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H1151	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving policies.
H1152	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving policies.
H1153	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving policies.
H1154	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H1155	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.

The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included. Source: Project team compilation

C 4.1: Hypotheses of Commercial Sugarcane Irrigators in the Impala Irrigation Scheme - Adoption of Climate Variability

Table C.56: Standard TPB Hypotheses for Adaptation to Climate Variability by Commercial Sugarcane Irrigators in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1156	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H1157	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H1158	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.57: Augmented TPB hypotheses for the direct predictors of intentions of commercial sugarcane irrigators to adapt to climate variability in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1159	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1160	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes toward the intention to adapt to climate variability.
H1161	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward the intention to adapt to climate variability.
H1162	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1163	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1164	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes toward the intention to adapt to climate variability.
H1165	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes toward the intention to adapt to climate variability.
H1166	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1167	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1168	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1169	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1170	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1171	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H1172	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1173	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H1174	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1175	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1176	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1177	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1178	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1179	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H1180	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1181	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H1182	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1183	$A_B \rightarrow INT$	Attitudes directly predict intentions to adapt to climate variability.
H1184	$TX \rightarrow INT$	Trust factors directly predict intentions to adapt to climate variability.
H1185	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adapt to climate variability.
H1186	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adapt to climate variability.
H1187	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adapt to climate variability.
H1188	$SN \rightarrow INT$	Subjective norms directly predict intentions to adapt to climate variability.
H1189	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adapt to climate variability.
H1190	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adapt to climate variability.
H1191	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adapt to climate variability.
H1192	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adapt to climate variability.
H1193	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adapt to climate variability.

Source: Project team compilation

Table C.58: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adapt to climate variability in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1194	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adapt to climate variability.
H1195	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H1196	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1197	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adapt to climate variability.
H1198	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1199	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H1200	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1201	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H1202	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adapt to climate variability.
H1203	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H1204	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1205	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adapt to climate variability.
H1206	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1207	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H1208	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1209	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H1210	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adapt to climate variability.
H1211	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H1212	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H1213	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adapt to climate variability.
H1214	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1215	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adapt to climate variability.
H1216	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1217	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.

Source: Project team compilation

Table C.59: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adapt to climate variability in the Impala Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1218	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adapt to climate variability.
H1219	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H1220	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H1221	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adapt to climate variability.
H1222	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adapt to climate variability.
H1223	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adapt to climate variability.
H1224	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adapt to climate variability.
H1225	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.

Source: Project team compilation

Table C.60: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial sugarcane irrigators to adapt to climate variability in the Impala Irrigation Scheme

Hypothesis	Relation	Brief description
H1226	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1227	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1228	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1229	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1230	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1231	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes toward the intention to adapt to climate variability.
H1232	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H1233	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1234	$TX \Rightarrow SN$	Trust factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1235	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1236	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1237	$TF \Rightarrow SN$	Technical factors have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1238	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1239	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1240	$RB \Rightarrow SN$	Perceived risks and benefits have a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1241	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1242	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1243	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1244	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1245	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1246	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1247	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1248	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H1249	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1250	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H1251	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adapt to climate variability.
H1252	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H1253	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H1254	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adapt to climate variability.
H1255	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H1256	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adapt to climate variability.
H1257	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adapt to climate variability.
H1258	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adapt to climate variability.
H1259	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H1260	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.

Source: Project team compilation

C 5.1: Hypotheses of Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme - Adoption of Water Saving Technologies

Table C.61: Standard TPB Hypotheses for Adoption of Water Saving Technologies by Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1261	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H1262	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H1263	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.62: Augmented TPB hypotheses for the direct predictors of intentions of commercial lucerne irrigators to adopt water-saving technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1264	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H1265	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving technology.
H1266	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technology.
H1267	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H1268	$IL \rightarrow A_B$	Institutional and legal factors are direct predictors of attitudes regarding the adoption of water-saving technology.
H1269	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving technology.
H1270	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving technology.
H1271	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technology.
H1272	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H1273	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving technology.
H1274	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technology.
H1275	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving technology.
H1276	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the adoption of water-saving technology.
H1277	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving technology.
H1278	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving technology.
H1279	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technology.
H1280	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H1281	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H1282	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H1283	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H1284	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H1285	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving technology.
H1286	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving technology.
H1287	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technology.
H1288	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving technology.
H1289	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving technology.
H1290	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving technology.
H1291	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving technology.
H1292	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving technology.
H1293	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving technology.
H1294	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving technology.
H1295	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving technology.
H1296	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving technology.
H1297	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving technology.
H1298	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving technology.

Source: Project team compilation

Table C.63: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1299	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H1300	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H1301	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1302	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H1303	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H1304	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H1305	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H1306	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H1307	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving technologies.
H1308	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H1309	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1310	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving technologies.
H1311	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H1312	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving technologies.
H1313	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H1314	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H1315	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving technologies.
H1316	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H1317	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1318	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving technologies.
H1319	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving technologies.
H1320	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving technologies.
H1321	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving technologies.
H1322	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.64: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1323	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving technology.
H1324	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technology.
H1325	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technology.
H1326	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving technology.
H1327	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving technology.
H1328	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving technology.
H1329	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving technology.
H1330	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technology.

Source: Project team compilation

Table C.65: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Brief description
H1331	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1332	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technology.
H1333	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technology.
H1334	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1335	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1336	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving technology.
H1337	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving technology.
H1338	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technology.
H1339	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1340	$AR \Rightarrow SN$	Access to resources is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H1341	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technology.
H1342	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1343	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1344	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1345	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1346	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving technology.
H1347	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1348	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H1349	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technology.
H1350	$TF \Rightarrow PBC$	Technical factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1351	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1352	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H1353	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving technology.
H1354	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technology.
H1355	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technology.
H1356	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving technology.
H1357	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technology.
H1358	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technology.
H1359	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving technology.
H1360	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technology.
H1361	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving technology.
H1362	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving technology.
H1363	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving technology.
H1364	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technology.
H1365	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technology.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included; Source: Project team compilation

C 5.2: Hypotheses of Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme - Adoption of Water Saving Policies

Table C.66: Standard TPB Hypotheses for Adoption of Water Saving Policies by Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1366	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H1367	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H1368	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.67: Augmented TPB hypotheses for the direct predictors of intentions of commercial lucerne irrigators to adopt water-saving policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1369	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1370	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes regarding the adoption of water-saving policies.
H1371	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1372	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1373	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1374	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes regarding the adoption of water-saving policies.
H1375	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes regarding the adoption of water-saving policies.
H1376	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1377	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1378	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the adoption of water-saving policies.
H1379	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1380	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the adoption of water-saving policies.
H1381	$IL \rightarrow SN$	Institutional and legal factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1382	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the adoption of water-saving policies.
H1383	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the adoption of water-saving policies.
H1384	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1385	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1386	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1387	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1388	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1389	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H1390	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the adoption of water-saving policies.
H1391	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the adoption of water-saving policies.
H1392	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1393	$A_B \rightarrow INT$	Attitudes directly predict intentions to adopt water-saving policies.
H1394	$TX \rightarrow INT$	Trust factors directly predict intentions to adopt water-saving policies.
H1395	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adopt water-saving policies.
H1396	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adopt water-saving policies.
H1397	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adopt water-saving policies.
H1398	$SN \rightarrow INT$	Subjective norms directly predict intentions to adopt water-saving policies.
H1399	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adopt water-saving policies.
H1400	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adopt water-saving policies.
H1401	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adopt water-saving policies.
H1402	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adopt water-saving policies.
H1403	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adopt water-saving policies.

Source: Project team compilation

Table C.68: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1404	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adopt water-saving policies.
H1405	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1406	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1407	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adopt water-saving policies.
H1408	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1409	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H1410	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1411	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H1412	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adopt water-saving policies.
H1413	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1414	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1415	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adopt water-saving policies.
H1416	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1417	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adopt water-saving policies.
H1418	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1419	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H1420	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adopt water-saving policies.
H1421	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H1422	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1423	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adopt water-saving policies.
H1424	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adopt water-saving policies.
H1425	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adopt water-saving policies.
H1426	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adopt water-saving policies.
H1427	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.

Source: Project team compilation

Table C.69: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1428	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adopt water-saving policies.
H1429	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H1430	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H1431	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adopt water-saving policies.
H1432	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adopt water-saving policies.
H1433	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adopt water-saving policies.
H1434	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adopt water-saving policies.
H1435	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.

Source: Project team compilation

Table C.70: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adopt water-saving policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Brief description
H1436	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1437	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1438	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1439	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1440	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1441	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes regarding the adoption of water-saving policies.
H1442	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes regarding the adoption of water-saving policies.
H1443	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1444	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1445	$AR \Rightarrow SN$	Access to resources has an overall influence on subjective norms regarding the adoption of water-saving policies.
H1446	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1447	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1448	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1449	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1450	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1451	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1452	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1453	$AR \Rightarrow PBC$	Access to resources has an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1454	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1455	$TF \Rightarrow PBC$	Technical factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1456	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1457	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H1458	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the adoption of water-saving policies.
H1459	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1460	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H1461	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adopt water-saving policies.
H1462	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H1463	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H1464	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adopt water-saving policies.
H1465	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H1466	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adopt water-saving policies.
H1467	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adopt water-saving policies.
H1468	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adopt water-saving policies.
H1469	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H1470	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.

⇒) signifies the total effect, indicating that both direct and indirect paths are included

Source: Project team compilation

C 5.3: Hypotheses of Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme - Adoption of Climate Variability

Table C.71: Standard TPB Hypotheses for Adaptation to Climate Variability by Commercial Lucerne Irrigators in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1471	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H1472	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H1473	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.72: Augmented TPB hypotheses for the direct predictors of intentions of commercial lucerne irrigators to adapt to climate variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1474	$TX \rightarrow A_B$	Trust factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1475	$AR \rightarrow A_B$	Access to resources has a direct influence on attitudes toward the intention to adapt to climate variability.
H1476	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward the intention to adapt to climate variability.
H1477	$TF \rightarrow A_B$	Technical factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1478	$IL \rightarrow A_B$	Institutional and legal factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1479	$RB_2 \rightarrow A_B$	Perceived risks from load-shedding and tariffs have a direct influence on attitudes toward the intention to adapt to climate variability.
H1480	$RB \rightarrow A_B$	Perceived risks and benefits are direct predictors of attitudes toward the intention to adapt to climate variability.
H1481	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward the intention to adapt to climate variability.
H1482	$TX \rightarrow SN$	Trust factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1483	$AR \rightarrow SN$	Access to resources has a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1484	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1485	$TF \rightarrow SN$	Technical factors have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1486	$IL \rightarrow SN$	Institutional and legal factors are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H1487	$RB_2 \rightarrow SN$	Perceived risks from load-shedding and tariffs have a direct influence on subjective norms regarding the intention to adapt to climate variability.
H1488	$RB \rightarrow SN$	Perceived risks and benefits are direct predictors of subjective norms regarding the intention to adapt to climate variability.
H1489	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the intention to adapt to climate variability.
H1490	$TX \rightarrow PBC$	Trust factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1491	$AR \rightarrow PBC$	Access to resources has a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1492	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1493	$TF \rightarrow PBC$	Technical factors have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1494	$IL \rightarrow PBC$	Institutional and legal factors are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H1495	$RB_2 \rightarrow PBC$	Perceived risks from load-shedding and tariffs have a direct influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1496	$RB \rightarrow PBC$	Perceived risks and benefits are direct predictors of perceived behavioural control regarding the intention to adapt to climate variability.
H1497	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the intention to adapt to climate variability.
H1498	$A_B \rightarrow INT$	Attitudes directly predict intentions to adapt to climate variability.
H1499	$TX \rightarrow INT$	Trust factors directly predict intentions to adapt to climate variability.
H1500	$AR \rightarrow INT$	Access to resources has a direct influence on intentions to adapt to climate variability.
H1501	$PFC \rightarrow INT$	Perceived financial cost directly predicts intentions to adapt to climate variability.
H1502	$TF \rightarrow INT$	Technical factors have a direct influence on intentions to adapt to climate variability.
H1503	$SN \rightarrow INT$	Subjective norms directly predict intentions to adapt to climate variability.
H1504	$IL \rightarrow INT$	Institutional and legal factors have a direct influence on intentions to adapt to climate variability.
H1505	$RB_2 \rightarrow INT$	Perceived risk from load-shedding and tariffs has a direct influence on intentions to adapt to climate variability.
H1506	$RB \rightarrow INT$	Perceived risks and benefits directly predict intentions to adapt to climate variability.
H1507	$IF \rightarrow INT$	Information factors have a direct influence on intentions to adapt to climate variability.
H1508	$PBC \rightarrow INT$	Perceived behavioural control directly predicts intentions to adapt to climate variability.

Source: Project team compilation

Table C.73: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adapt to climate variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1509	$TX \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between trust factors and intentions to adapt to climate variability.
H1510	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H1511	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1512	$TF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between technical factors and intentions to adapt to climate variability.
H1513	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1514	$RB_2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H1515	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1516	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H1517	$TX \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between trust factors and intentions to adapt to climate variability.
H1518	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H1519	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1520	$TF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between technical factors and intentions to adapt to climate variability.
H1521	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1522	$RB_2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks from load-shedding and tariffs and intentions to adapt to climate variability.
H1523	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1524	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H1525	$TX \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between trust factors and intentions to adapt to climate variability.
H1526	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H1527	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H1528	$TF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between technical factors and intentions to adapt to climate variability.
H1529	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional and legal factors and intentions to adapt to climate variability.
H1530	$RB_2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the effect of perceived risks from load-shedding and tariffs on intentions to adapt to climate variability.
H1531	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risks and benefits and intentions to adapt to climate variability.
H1532	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.

Source: Project team compilation

Table C.74: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adapt to climate variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1533	$TX \rightarrow INT$	Trust factors indirectly contribute to intentions to adapt to climate variability.
H1534	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H1535	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H1536	$TF \rightarrow INT$	Technical factors indirectly contribute to intentions to adapt to climate variability.
H1537	$IL \rightarrow INT$	Institutional and legal factors indirectly contribute to intentions to adapt to climate variability.
H1538	$RB_2 \rightarrow INT$	Perceived risks from load-shedding and tariffs indirectly contribute to intentions to adapt to climate variability.
H1539	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to intentions to adapt to climate variability.
H1540	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.

Source: Project team compilation

Table C.75: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of commercial lucerne irrigators to adapt to climate variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Brief description
H1541	$TX \Rightarrow A_B$	Trust factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1542	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1543	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1544	$TF \Rightarrow A_B$	Technical factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1545	$IL \Rightarrow A_B$	Institutional and legal factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1546	$RB_2 \Rightarrow A_B$	Perceived risks from load-shedding and tariffs have an overall influence on attitudes toward the intention to adapt to climate variability.
H1547	$RB \Rightarrow A_B$	Perceived risks and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H1548	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1549	$TX \Rightarrow SN$	Trust factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1550	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1551	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1552	$TF \Rightarrow SN$	Technical factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1553	$IL \Rightarrow SN$	Institutional and legal factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1554	$RB_2 \Rightarrow SN$	Perceived risks from load-shedding and tariffs have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1555	$RB \Rightarrow SN$	Perceived risks and benefits have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1556	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1557	$TX \Rightarrow PBC$	Trust factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1558	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1559	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1560	$TF \Rightarrow PBC$	Technical factors have a significant influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1561	$IL \Rightarrow PBC$	Institutional and legal factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1562	$RB_2 \Rightarrow PBC$	Perceived risks from load-shedding and tariffs have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H1563	$RB \Rightarrow PBC$	Perceived risks and benefits have a substantial impact on perceived behavioural control regarding the intention to adapt to climate variability.
H1564	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1565	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H1566	$TX \Rightarrow INT$	Trust factors are a significant determinant of intentions to adapt to climate variability.
H1567	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H1568	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H1569	$TF \Rightarrow INT$	Technical factors are a significant determinant of intentions to adapt to climate variability.
H1570	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H1571	$IL \Rightarrow INT$	Institutional and legal factors are significant determinants of intentions to adapt to climate variability.
H1572	$RB_2 \Rightarrow INT$	Perceived risks from load-shedding and tariffs are a significant determinant of intentions to adapt to climate variability.
H1573	$RB \Rightarrow INT$	Perceived risks and benefits are a significant determinant of intentions to adapt to climate variability.
H1574	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H1575	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.

Note: The double arrow ($\Rightarrow$) signifies the total effect, indicating that both direct and indirect paths are included; Source: Project team compilation

Appendix C 2- Hypotheses- Small Holder Farmers

C 6.1: Hypotheses of Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme - Adoption of Water Saving Technologies

Table C.76: Adoption of Water-Saving Technologies of Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1576	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving technologies.
H1577	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H1578	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.77: Augmented TPB hypotheses for the direct predictors of intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1579	$AR \rightarrow A_B$	Access to resources is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1580	$AR2 \rightarrow A_B$	Access to resources for resilience is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1581	$IL \rightarrow A_B$	Institutional factors are a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1582	$SS \rightarrow A_B$	Perceived social support is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1583	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1584	$PFC2 \rightarrow A_B$	Perceived financial cost related to energy and debt is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1585	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1586	$RB \rightarrow A_B$	Perceived risks and benefits are a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1587	$RB2 \rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a direct predictor of attitudes regarding the adoption of water-saving technologies.
H1588	$AR \rightarrow SN$	Access to resources is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1589	$AR2 \rightarrow SN$	Access to resources for resilience is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1590	$IL \rightarrow SN$	Institutional factors are a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1591	$SS \rightarrow SN$	Perceived social support is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1592	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1593	$PFC2 \rightarrow SN$	Perceived financial cost related to energy and debt is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1594	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1595	$RB \rightarrow SN$	Perceived risks and benefits are a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1596	$RB2 \rightarrow SN$	Perceived risk related to tariffs and load-shedding is a direct predictor of subjective norms regarding the adoption of water-saving technologies.
H1597	$AR \rightarrow PBC$	Access to resources is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1598	$AR2 \rightarrow PBC$	Access to resources for resilience is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1599	$IL \rightarrow PBC$	Institutional factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1600	$SS \rightarrow PBC$	Perceived social support is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1601	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1602	$PFC2 \rightarrow PBC$	Perceived financial cost related to energy and debt is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1603	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1604	$RB \rightarrow PBC$	Perceived risks and benefits are a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1605	$RB2 \rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a direct predictor of perceived behavioural control regarding the adoption of water-saving technologies.
H1606	$A_B \rightarrow INT$	Attitude is a direct predictor of intentions to adopt water-saving technologies.
H1607	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving technologies.
H1608	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving technologies.
H1609	$AR \rightarrow INT$	Access to resources is a direct predictor of intentions to adopt water-saving technologies.
H1610	$AR2 \rightarrow INT$	Access to resources for resilience is a direct predictor of intentions to adopt water-saving technologies.
H1611	$IL \rightarrow INT$	Institutional factors are a direct predictor of intentions to adopt water-saving technologies.
H1612	$SS \rightarrow INT$	Perceived social support is a direct predictor of intentions to adopt water-saving technologies.
H1613	$PFC \rightarrow INT$	Perceived financial cost is a direct predictor of intentions to adopt water-saving technologies.
H1614	$PFC2 \rightarrow INT$	Perceived financial cost related to energy and debt is a direct predictor of intentions to adopt water-saving technologies.
H1615	$IF \rightarrow INT$	Information factors are a direct predictor of intentions to adopt water-saving technologies.
H1616	$RB \rightarrow INT$	Perceived risks and benefits are a direct predictor of intentions to adopt water-saving technologies.
H1617	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding is a direct predictor of intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.78: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1618	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H1619	$AR2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources for resilience and intentions to adopt water-saving technologies.
H1620	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional factors and intentions to adopt water-saving technologies.
H1621	$SS \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived social support and intentions to adopt water-saving technologies.
H1622	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1623	$PFC2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving technologies.
H1624	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving technologies.
H1625	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk and benefits and intentions to adopt water-saving technologies.
H1626	$RB2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving technologies.
H1627	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving technologies.
H1628	$AR2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources for resilience and intentions to adopt water-saving technologies.
H1629	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional factors and intentions to adopt water-saving technologies.
H1630	$SS \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived social support and intentions to adopt water-saving technologies.
H1631	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1632	$PFC2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving technologies.
H1633	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving technologies.
H1634	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk and benefits and intentions to adopt water-saving technologies.
H1635	$RB2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving technologies.
H1636	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving technologies.
H1637	$AR2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources for resilience and intentions to adopt water-saving technologies.
H1638	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional factors and intentions to adopt water-saving technologies.
H1639	$SS \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived social support and intentions to adopt water-saving technologies.
H1640	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving technologies.
H1641	$PFC2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving technologies.
H1642	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving technologies.
H1643	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk and benefits and intentions to adopt water-saving technologies.
H1644	$RB2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.79: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1645	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving technologies.
H1646	$AR2 \rightarrow INT$	Access to resources for resilience indirectly contributes to intentions to adopt water-saving technologies.
H1647	$IL \rightarrow INT$	Institutional factors indirectly contribute to intentions to adopt water-saving technologies.
H1648	$SS \rightarrow INT$	Perceived social support indirectly contributes to intentions to adopt water-saving technologies.
H1649	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving technologies.
H1650	$PFC2 \rightarrow INT$	Perceived financial costs related to energy and debt indirectly contribute to intentions to adopt water-saving technologies.
H1651	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving technologies.
H1652	$RB \rightarrow INT$	Perceived risk and benefits indirectly contribute to intentions to adopt water-saving technologies.
H1653	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding indirectly contributes to intentions to adopt water-saving technologies.

Source: Project team compilation

Table C.80: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Brief description
H1654	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1655	$AR2 \Rightarrow A_B$	Access to resources for resilience is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1656	$IL \Rightarrow A_B$	Institutional factors have an overall influence on attitudes regarding the adoption of water-saving technologies.
H1657	$SS \Rightarrow A_B$	Perceived social support is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1658	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1659	$PFC2 \Rightarrow A_B$	Perceived financial cost related to energy and debt is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1660	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving technologies.
H1661	$RB \Rightarrow A_B$	Perceived risk and benefits have an overall influence on attitudes regarding the adoption of water-saving technologies.
H1662	$RB2 \Rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a significant determinant of attitudes regarding the adoption of water-saving technologies.
H1663	$AR \Rightarrow SN$	Access to resources is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1664	$AR2 \Rightarrow SN$	Access to resources for resilience is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1665	$IL \Rightarrow SN$	Institutional factors have an overall influence on subjective norms regarding the adoption of water-saving technologies.
H1666	$SS \Rightarrow SN$	Perceived social support is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1667	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1668	$PFC2 \Rightarrow SN$	Perceived financial cost related to energy and debt is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1669	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving technologies.
H1670	$RB \Rightarrow SN$	Perceived risk and benefits have an overall influence on subjective norms regarding the adoption of water-saving technologies.
H1671	$RB2 \Rightarrow SN$	Perceived risk related to tariffs and load-shedding is a significant determinant of subjective norms regarding the adoption of water-saving technologies.
H1672	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1673	$AR2 \Rightarrow PBC$	Access to resources for resilience is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1674	$IL \Rightarrow PBC$	Institutional factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technologies.
H1675	$SS \Rightarrow PBC$	Perceived social support is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1676	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1677	$PFC2 \Rightarrow PBC$	Perceived financial cost related to energy and debt is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1678	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving technologies.
H1679	$RB \Rightarrow PBC$	Perceived risk and benefits have an overall influence on perceived behavioural control regarding the adoption of water-saving technologies.
H1680	$RB2 \Rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a significant determinant of perceived behavioural control regarding the adoption of water-saving technologies.
H1681	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving technologies.
H1682	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving technologies.
H1683	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving technologies.
H1684	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving technologies.
H1685	$AR2 \Rightarrow INT$	Access to resources for resilience is a significant determinant of intentions to adopt water-saving technologies.
H1686	$IL \Rightarrow INT$	Institutional factors are a significant determinant of intentions to adopt water-saving technologies.
H1687	$SS \Rightarrow INT$	Perceived social support is a significant determinant of intentions to adopt water-saving technologies.
H1688	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving technologies.
H1689	$PFC2 \Rightarrow INT$	Perceived financial costs related to energy and debt are significant determinants of intentions to adopt water-saving technologies.
H1690	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving technologies.
H1691	$RB \Rightarrow INT$	Perceived risk and benefits are significant determinants of intentions to adopt water-saving technologies.
H1692	$RB2 \Rightarrow INT$	Perceived risk related to tariffs and load-shedding is a significant determinant of intentions to adopt water-saving technologies.

Source: Project team compilation

C 6.2: Hypotheses of Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme - Adoption of Water Saving Policies

Table C.81: Standard TPB Hypotheses for Adoption of Water Saving Policies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1693	$A_B \rightarrow INT$	Attitudes are a direct predictor of intentions to adopt water-saving policies.
H1694	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H1695	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.82: Augmented TPB hypotheses for the direct predictors of intentions of small-scale maize irrigators to adopt water-saving policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1696	$AR \rightarrow A_B$	Access to resources is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1697	$AR2 \rightarrow A_B$	Access to resources for resilience is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1698	$IL \rightarrow A_B$	Institutional factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1699	$SS \rightarrow A_B$	Perceived social support is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1700	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1701	$PFC2 \rightarrow A_B$	Perceived financial cost related to energy and debt is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1702	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1703	$RB \rightarrow A_B$	Perceived risks and benefits are a direct predictor of attitudes regarding the adoption of water-saving policies.
H1704	$RB2 \rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a direct predictor of attitudes regarding the adoption of water-saving policies.
H1705	$AR \rightarrow SN$	Access to resources is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1706	$AR2 \rightarrow SN$	Access to resources for resilience is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1707	$IL \rightarrow SN$	Institutional factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1708	$SS \rightarrow SN$	Perceived social support is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1709	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1710	$PFC2 \rightarrow SN$	Perceived financial cost related to energy and debt is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1711	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1712	$RB \rightarrow SN$	Perceived risks and benefits are a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1713	$RB2 \rightarrow SN$	Perceived risk related to tariffs and load-shedding is a direct predictor of subjective norms regarding the adoption of water-saving policies.
H1714	$AR \rightarrow PBC$	Access to resources is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1715	$AR2 \rightarrow PBC$	Access to resources for resilience is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1716	$IL \rightarrow PBC$	Institutional factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1717	$SS \rightarrow PBC$	Perceived social support is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1718	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1719	$PFC2 \rightarrow PBC$	Perceived financial cost related to energy and debt is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1720	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1721	$RB \rightarrow PBC$	Perceived risks and benefits are a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1722	$RB2 \rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a direct predictor of perceived behavioural control regarding the adoption of water-saving policies.
H1723	$A_B \rightarrow INT$	Attitude is a direct predictor of intentions to adopt water-saving policies.
H1724	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adopt water-saving policies.
H1725	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adopt water-saving policies.
H1726	$AR \rightarrow INT$	Access to resources is a direct predictor of intentions to adopt water-saving policies.
H1727	$AR2 \rightarrow INT$	Access to resources for resilience is a direct predictor of intentions to adopt water-saving policies.
H1728	$IL \rightarrow INT$	Institutional factors are a direct predictor of intentions to adopt water-saving policies.
H1729	$SS \rightarrow INT$	Perceived social support is a direct predictor of intentions to adopt water-saving policies.
H1730	$PFC \rightarrow INT$	Perceived financial cost is a direct predictor of intentions to adopt water-saving policies.
H1731	$PFC2 \rightarrow INT$	Perceived financial cost related to energy and debt is a direct predictor of intentions to adopt water-saving policies.
H1732	$IF \rightarrow INT$	Information factors are a direct predictor of intentions to adopt water-saving policies.
H1733	$RB \rightarrow INT$	Perceived risks and benefits are a direct predictor of intentions to adopt water-saving policies.
H1734	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding is a direct predictor of intentions to adopt water-saving policies.

Source: Project team compilation

Table C.83: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1735	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1736	$AR2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources for resilience and intentions to adopt water-saving policies.
H1737	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional factors and intentions to adopt water-saving policies.
H1738	$SS \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived social support and intentions to adopt water-saving policies.
H1739	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1740	$PFC2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving policies.
H1741	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adopt water-saving policies.
H1742	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk and benefits and intentions to adopt water-saving policies.
H1743	$RB2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving policies.
H1744	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adopt water-saving policies.
H1745	$AR2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources for resilience and intentions to adopt water-saving policies.
H1746	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional factors and intentions to adopt water-saving policies.
H1747	$SS \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived social support and intentions to adopt water-saving policies.
H1748	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1749	$PFC2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving policies.
H1750	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adopt water-saving policies.
H1751	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk and benefits and intentions to adopt water-saving policies.
H1752	$RB2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving policies.
H1753	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adopt water-saving policies.
H1754	$AR2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources for resilience and intentions to adopt water-saving policies.
H1755	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional factors and intentions to adopt water-saving policies.
H1756	$SS \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived social support and intentions to adopt water-saving policies.
H1757	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adopt water-saving policies.
H1758	$PFC2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost related to energy and debt and intentions to adopt water-saving policies.
H1759	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adopt water-saving policies.
H1760	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk and benefits and intentions to adopt water-saving policies.
H1761	$RB2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk related to tariffs and load-shedding and intentions to adopt water-saving policies.

Source: Project team compilation

Table C.84: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1762	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adopt water-saving policies.
H1763	$AR2 \rightarrow INT$	Access to resources for resilience indirectly contributes to intentions to adopt water-saving policies.
H1764	$IL \rightarrow INT$	Institutional factors indirectly contribute to intentions to adopt water-saving policies.
H1765	$SS \rightarrow INT$	Perceived social support indirectly contributes to intentions to adopt water-saving policies.
H1766	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adopt water-saving policies.
H1767	$PFC2 \rightarrow INT$	Perceived financial costs related to energy and debt indirectly contribute to the intention to adopt water-saving policies.
H1768	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adopt water-saving policies.
H1769	$RB \rightarrow INT$	Perceived risks and benefits indirectly contribute to the intention to adopt water-saving policies.
H1770	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding indirectly contributes to intentions to adopt water-saving policies.

Source: Project team compilation

Table C.85: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of small-scale maize irrigators to adopt water-saving policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Brief description
H1771	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1772	$AR2 \Rightarrow A_B$	Access to resources for resilience is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1773	$IL \Rightarrow A_B$	Institutional factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1774	$SS \Rightarrow A_B$	Perceived social support is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1775	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1776	$PFC2 \Rightarrow A_B$	Perceived financial cost related to energy and debt is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1777	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes regarding the adoption of water-saving policies.
H1778	$RB \Rightarrow A_B$	Perceived risk and benefits have an overall influence on attitudes regarding the adoption of water-saving policies.
H1779	$RB2 \Rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a significant determinant of attitudes regarding the adoption of water-saving policies.
H1780	$AR \Rightarrow SN$	Access to resources is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1781	$AR2 \Rightarrow SN$	Access to resources for resilience is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1782	$IL \Rightarrow SN$	Institutional factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1783	$SS \Rightarrow SN$	Perceived social support is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1784	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1785	$PFC2 \Rightarrow SN$	Perceived financial cost related to energy and debt is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1786	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1787	$RB \Rightarrow SN$	Perceived risk and benefits have an overall influence on subjective norms regarding the adoption of water-saving policies.
H1788	$RB2 \Rightarrow SN$	Perceived risk related to tariffs and load-shedding is a significant determinant of subjective norms regarding the adoption of water-saving policies.
H1789	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1790	$AR2 \Rightarrow PBC$	Access to resources for resilience is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1791	$IL \Rightarrow PBC$	Institutional factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1792	$SS \Rightarrow PBC$	Perceived social support is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1793	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1794	$PFC2 \Rightarrow PBC$	Perceived financial cost related to energy and debt is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1795	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1796	$RB \Rightarrow PBC$	Perceived risk and benefits have an overall influence on perceived behavioural control regarding the adoption of water-saving policies.
H1797	$RB2 \Rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a significant determinant of perceived behavioural control regarding the adoption of water-saving policies.
H1798	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adopt water-saving policies.
H1799	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adopt water-saving policies.
H1800	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adopt water-saving policies.
H1801	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adopt water-saving policies.
H1802	$AR2 \Rightarrow INT$	Access to resources for resilience is a significant determinant of intentions to adopt water-saving policies.
H1803	$IL \Rightarrow INT$	Institutional factors are a significant determinant of intentions to adopt water-saving policies.
H1804	$SS \Rightarrow INT$	Perceived social support is a significant determinant of intentions to adopt water-saving policies.
H1805	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adopt water-saving policies.
H1806	$PFC2 \Rightarrow INT$	Perceived financial costs related to energy and debt are significant determinants of intentions to adopt water-saving policies.
H1807	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adopt water-saving policies.
H1808	$RB \Rightarrow INT$	Perceived risk and benefits are significant determinants of intentions to adopt water-saving policies.
H1809	$RB2 \Rightarrow INT$	Perceived risk related to tariffs and load-shedding is a significant determinant of intentions to adopt water-saving policies.

Source: Project team compilation

C 6.3: Hypotheses of Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme - Adoption of Climate Variability

Table C.86: Standard TPB Hypotheses for Adaptation to Climate Variability by Small-Scale Maize Irrigators in Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1810	$A_B \rightarrow \text{INT}$	Attitudes are a direct predictor of intentions to adapt to climate variability.
H1811	$SN \rightarrow \text{INT}$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H1812	$PBC \rightarrow \text{INT}$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.87: Augmented TPB hypotheses for the direct predictors of intentions of small-scale maize irrigators to adapt to climate variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1813	$AR \rightarrow A_B$	Access to resources is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1814	$AR2 \rightarrow A_B$	Access to resources for resilience is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1815	$IL \rightarrow A_B$	Institutional factors are a direct predictor of attitudes toward intentions to adapt to climate variability.
H1816	$SS \rightarrow A_B$	Perceived social support is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1817	$PFC \rightarrow A_B$	Perceived financial cost is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1818	$PFC2 \rightarrow A_B$	Perceived financial cost related to energy and debt is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1819	$IF \rightarrow A_B$	Information factors are a direct predictor of attitudes toward intentions to adapt to climate variability.
H1820	$RB \rightarrow A_B$	Perceived risks and benefits are a direct predictor of attitudes toward intentions to adapt to climate variability.
H1821	$RB2 \rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a direct predictor of attitudes toward intentions to adapt to climate variability.
H1822	$AR \rightarrow SN$	Access to resources is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1823	$AR2 \rightarrow SN$	Access to resources for resilience is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1824	$IL \rightarrow SN$	Institutional factors are a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1825	$SS \rightarrow SN$	Perceived social support is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1826	$PFC \rightarrow SN$	Perceived financial cost is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1827	$PFC2 \rightarrow SN$	Perceived financial cost related to energy and debt is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1828	$IF \rightarrow SN$	Information factors are a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1829	$RB \rightarrow SN$	Perceived risks and benefits are a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1830	$RB2 \rightarrow SN$	Perceived risk related to tariffs and load-shedding is a direct predictor of subjective norms toward intentions to adapt to climate variability.
H1831	$AR \rightarrow PBC$	Access to resources is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1832	$AR2 \rightarrow PBC$	Access to resources for resilience is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1833	$IL \rightarrow PBC$	Institutional factors are a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1834	$SS \rightarrow PBC$	Perceived social support is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1835	$PFC \rightarrow PBC$	Perceived financial cost is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1836	$PFC2 \rightarrow PBC$	Perceived financial cost related to energy and debt is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1837	$IF \rightarrow PBC$	Information factors are a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1838	$RB \rightarrow PBC$	Perceived risks and benefits are a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1839	$RB2 \rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a direct predictor of perceived behavioural control toward intentions to adapt to climate variability.
H1840	$A_B \rightarrow INT$	Attitude is a direct predictor of intentions to adapt to climate variability.
H1841	$SN \rightarrow INT$	Subjective norms are a direct predictor of intentions to adapt to climate variability.
H1842	$PBC \rightarrow INT$	Perceived behavioural control is a direct predictor of intentions to adapt to climate variability.
H1843	$AR \rightarrow INT$	Access to resources is a direct predictor of intentions to adapt to climate variability.
H1844	$AR2 \rightarrow INT$	Access to resources for resilience is a direct predictor of intentions to adapt to climate variability.
H1845	$IL \rightarrow INT$	Institutional factors are a direct predictor of intentions to adapt to climate variability.
H1846	$SS \rightarrow INT$	Perceived social support is a direct predictor of intentions to adapt to climate variability.
H1847	$PFC \rightarrow INT$	Perceived financial cost is a direct predictor of intentions to adapt to climate variability.
H1848	$PFC2 \rightarrow INT$	Perceived financial cost related to energy and debt is a direct predictor of intentions to adapt to climate variability.
H1849	$IF \rightarrow INT$	Information factors are a direct predictor of intentions to adapt to climate variability.
H1850	$RB \rightarrow INT$	Perceived risks and benefits are a direct predictor of intentions to adapt to climate variability.
H1851	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding is a direct predictor of intentions to adapt to climate variability.

Source: Project team compilation

Table C.88: Augmented TPB hypotheses for the specific indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adapt to climate variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1852	$AR \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between access to resources and intentions to adapt to climate variability.
H1853	$AR2 \rightarrow A \rightarrow INT$	Attitudes mediate the relationship between access to resources for resilience and intentions to adapt to climate variability.
H1854	$IL \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between institutional factors and intentions to adapt to climate variability.
H1855	$SS \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived social support and intentions to adapt to climate variability.
H1856	$PFC \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1857	$PFC2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived financial cost related to energy and debt and intentions to adapt to climate variability.
H1858	$IF \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between information factors and intentions to adapt to climate variability.
H1859	$RB \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk and benefits and intentions to adapt to climate variability.
H1860	$RB2 \rightarrow A_B \rightarrow INT$	Attitudes mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adapt to climate variability.
H1861	$AR \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources and intentions to adapt to climate variability.
H1862	$AR2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between access to resources for resilience and intentions to adapt to climate variability.
H1863	$IL \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between institutional factors and intentions to adapt to climate variability.
H1864	$SS \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived social support and intentions to adapt to climate variability.
H1865	$PFC \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost and intentions to adapt to climate variability.
H1866	$PFC2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived financial cost related to energy and debt and intentions to adapt to climate variability.
H1867	$IF \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between information factors and intentions to adapt to climate variability.
H1868	$RB \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk and benefits and intentions to adapt to climate variability.
H1869	$RB2 \rightarrow SN \rightarrow INT$	Subjective norms mediate the relationship between perceived risk related to tariffs and load-shedding and intentions to adapt to climate variability.
H1870	$AR \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources and intentions to adapt to climate variability.
H1871	$AR2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between access to resources for resilience and intentions to adapt to climate variability.
H1872	$IL \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between institutional factors and intentions to adapt to climate variability.
H1873	$SS \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived social support and intentions to adapt to climate variability.
H1874	$PFC \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost and intentions to adapt to climate variability.
H1875	$PFC2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived financial cost related to energy and debt and intentions to adapt to climate variability.
H1876	$IF \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between information factors and intentions to adapt to climate variability.
H1877	$RB \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk and benefits and intentions to adapt to climate variability.
H1878	$RB2 \rightarrow PBC \rightarrow INT$	Perceived behavioural control mediates the relationship between perceived risk related to tariffs and load-shedding and intentions to adapt to climate variability.

Source: Project team compilation

Table C.89: Augmented TPB hypotheses for the total indirect effects of additional and standard constructs on the intentions of small-scale maize irrigators to adapt to climate variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Hypothesised Relationship
H1879	$AR \rightarrow INT$	Access to resources indirectly contributes to intentions to adapt to climate variability.
H1880	$AR2 \rightarrow INT$	Access to resources for resilience indirectly contributes to intentions to adapt to climate variability.
H1881	$IL \rightarrow INT$	Institutional factors indirectly contribute to intentions to adapt to climate variability.
H1882	$SS \rightarrow INT$	Perceived social support indirectly contributes to intentions to adapt to climate variability.
H1883	$PFC \rightarrow INT$	Perceived financial cost indirectly contributes to intentions to adapt to climate variability.
H1884	$PFC2 \rightarrow INT$	Perceived financial costs related to energy and debt indirectly contribute to intentions to adapt to climate variability.
H1885	$IF \rightarrow INT$	Information factors indirectly contribute to intentions to adapt to climate variability.
H1886	$RB \rightarrow INT$	Perceived risk and benefits indirectly contribute to intentions to adapt to climate variability.
H1887	$RB2 \rightarrow INT$	Perceived risk related to tariffs and load-shedding indirectly contributes to intentions to adapt to climate variability.

Source: Project team compilation

Table C.90: Augmented TPB hypotheses for the total effects of additional and standard constructs on the intentions of small-scale maize irrigators to adapt to climate variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Brief description
H1888	$AR \Rightarrow A_B$	Access to resources is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1889	$AR2 \Rightarrow A_B$	Access to resources for resilience is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1890	$IL \Rightarrow A_B$	Institutional factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1891	$SS \Rightarrow A_B$	Perceived social support is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1892	$PFC \Rightarrow A_B$	Perceived financial cost is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1893	$PFC2 \Rightarrow A_B$	Perceived financial cost related to energy and debt is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1894	$IF \Rightarrow A_B$	Information factors have an overall influence on attitudes toward the intention to adapt to climate variability.
H1895	$RB \Rightarrow A_B$	Perceived risk and benefits have an overall influence on attitudes toward the intention to adapt to climate variability.
H1896	$RB2 \Rightarrow A_B$	Perceived risk related to tariffs and load-shedding is a significant determinant of attitudes toward the intention to adapt to climate variability.
H1897	$AR \Rightarrow SN$	Access to resources has a significant influence on subjective norms regarding the intention to adapt to climate variability.
H1898	$AR2 \Rightarrow SN$	Access to resources for resilience is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1899	$IL \Rightarrow SN$	Institutional factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1900	$SS \Rightarrow SN$	Perceived social support is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1901	$PFC \Rightarrow SN$	Perceived financial cost is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1902	$PFC2 \Rightarrow SN$	Perceived financial cost related to energy and debt is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1903	$IF \Rightarrow SN$	Information factors have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1904	$RB \Rightarrow SN$	Perceived risk and benefits have an overall influence on subjective norms regarding the intention to adapt to climate variability.
H1905	$RB2 \Rightarrow SN$	Perceived risk related to tariffs and load-shedding is a significant determinant of subjective norms regarding the intention to adapt to climate variability.
H1906	$AR \Rightarrow PBC$	Access to resources is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1907	$AR2 \Rightarrow PBC$	Access to resources for resilience is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1908	$IL \Rightarrow PBC$	Institutional factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1909	$SS \Rightarrow PBC$	Perceived social support is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1910	$PFC \Rightarrow PBC$	Perceived financial cost is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1911	$PFC2 \Rightarrow PBC$	Perceived financial cost related to energy and debt is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1912	$IF \Rightarrow PBC$	Information factors have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1913	$RB \Rightarrow PBC$	Perceived risk and benefits have an overall influence on perceived behavioural control regarding the intention to adapt to climate variability.
H1914	$RB2 \Rightarrow PBC$	Perceived risk related to tariffs and load-shedding is a significant determinant of perceived behavioural control regarding the intention to adapt to climate variability.
H1915	$A_B \Rightarrow INT$	Attitudes are a significant determinant of intentions to adapt to climate variability.
H1916	$SN \Rightarrow INT$	Subjective norms are a significant determinant of intentions to adapt to climate variability.
H1917	$PBC \Rightarrow INT$	Perceived behavioural control is a significant determinant of intentions to adapt to climate variability.
H1918	$AR \Rightarrow INT$	Access to resources is a significant determinant of intentions to adapt to climate variability.
H1919	$AR2 \Rightarrow INT$	Access to resources for resilience is a significant determinant of intentions to adapt to climate variability.
H1920	$IL \Rightarrow INT$	Institutional factors are a significant determinant of intentions to adapt to climate variability.
H1921	$SS \Rightarrow INT$	Perceived social support is a significant determinant of intentions to adapt to climate variability.
H1922	$PFC \Rightarrow INT$	Perceived financial cost is a significant determinant of intentions to adapt to climate variability.
H1923	$PFC2 \Rightarrow INT$	Perceived financial cost related to energy and debt is a significant determinant of intentions to adapt to climate variability.
H1924	$IF \Rightarrow INT$	Information factors are a significant determinant of intentions to adapt to climate variability.
H1925	$RB \Rightarrow INT$	Perceived risk and benefits are a significant determinant of intentions to adapt to climate variability.
H1926	$RB2 \Rightarrow INT$	Perceived risk related to tariffs and load-shedding is a significant determinant of intentions to adapt to climate variability.

Source: Project team compilation

Appendix D- Soil Classification of South Africa- Land Type Survey of South Africa (1:250 000 scale)

In the main body of this report, soil data obtained from the Harmonized World Soil Database (HWSD) were used to parameterise the AquaCrop simulations. However, in order to make the results more relatable to a South African audience, this appendix provides supporting soil information derived from the Land Type Survey of South Africa (1:250 000 scale)

For each irrigation scheme, the main irrigation zone was delineated in ArcGIS Pro and clipped from the Land Type Survey dataset. Within these zones, the land types present were identified, and for each land type, the dominant soil series was determined, defined as the soil series covering the most significant area within that land type. The University of the Free State's Department of Soil, Crop, and Climate Sciences assisted with the conversion of these dominant soil series to the corresponding South African soil forms based on the Soil Handbook for South Africa (ARC-ISCW, 2018).

D.1 The Orange-Riet irrigation scheme

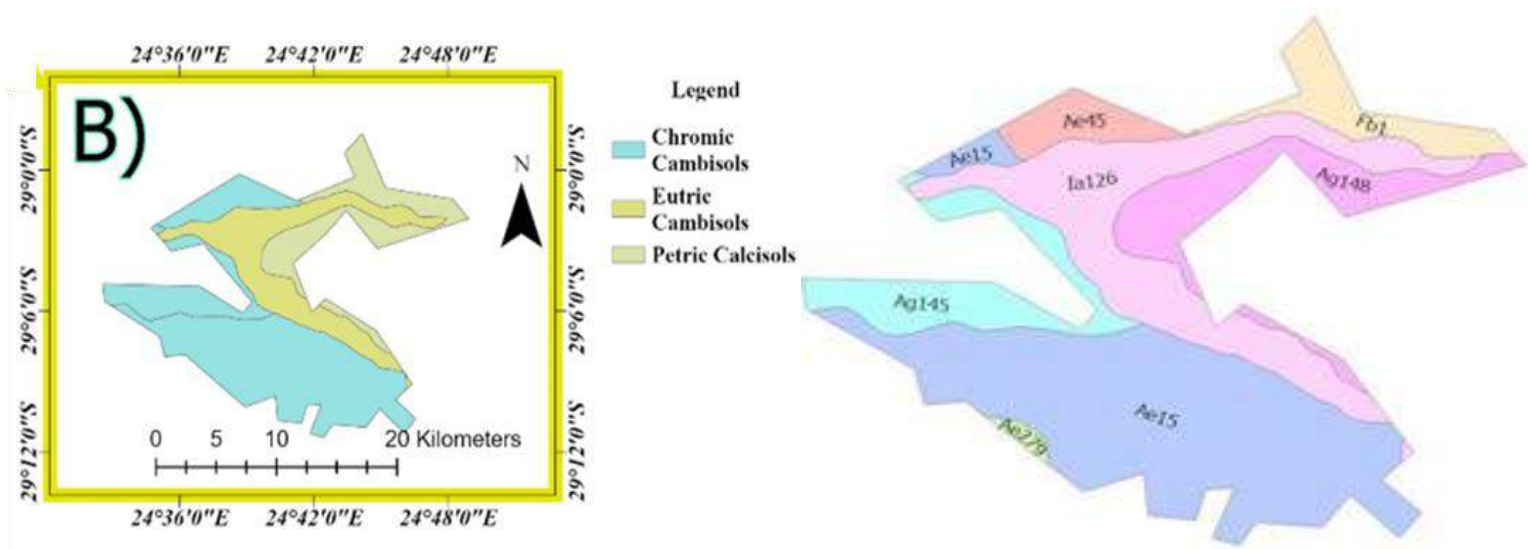


Figure D.1: Main irrigation zone of the Orange Reit irrigation scheme overlaid on the Land Type Survey (1:250 000 scale) land types

Table D.1: Conversion of dominant soil series to South African soil forms

Land Type	Dominant soil series total (%)
Ag145	Hu
Ae15	Hu
Ae45	Hu
Fb1	Ms
Ag148	Hu
Ae279	Hu

Source: Land Type Survey Staff (1972-2002)

Table D.2: Conversion of dominant soil series to South African soil forms

Dominant Soil Series (from Table D1)	South African Soil Form
Chromic Cambisols	Hutton
Eutric Cambisols	Hutton
Petric Calcisols	Plooysburg

Note: The soil series identified in Table D1 served as the starting point for this conversion.

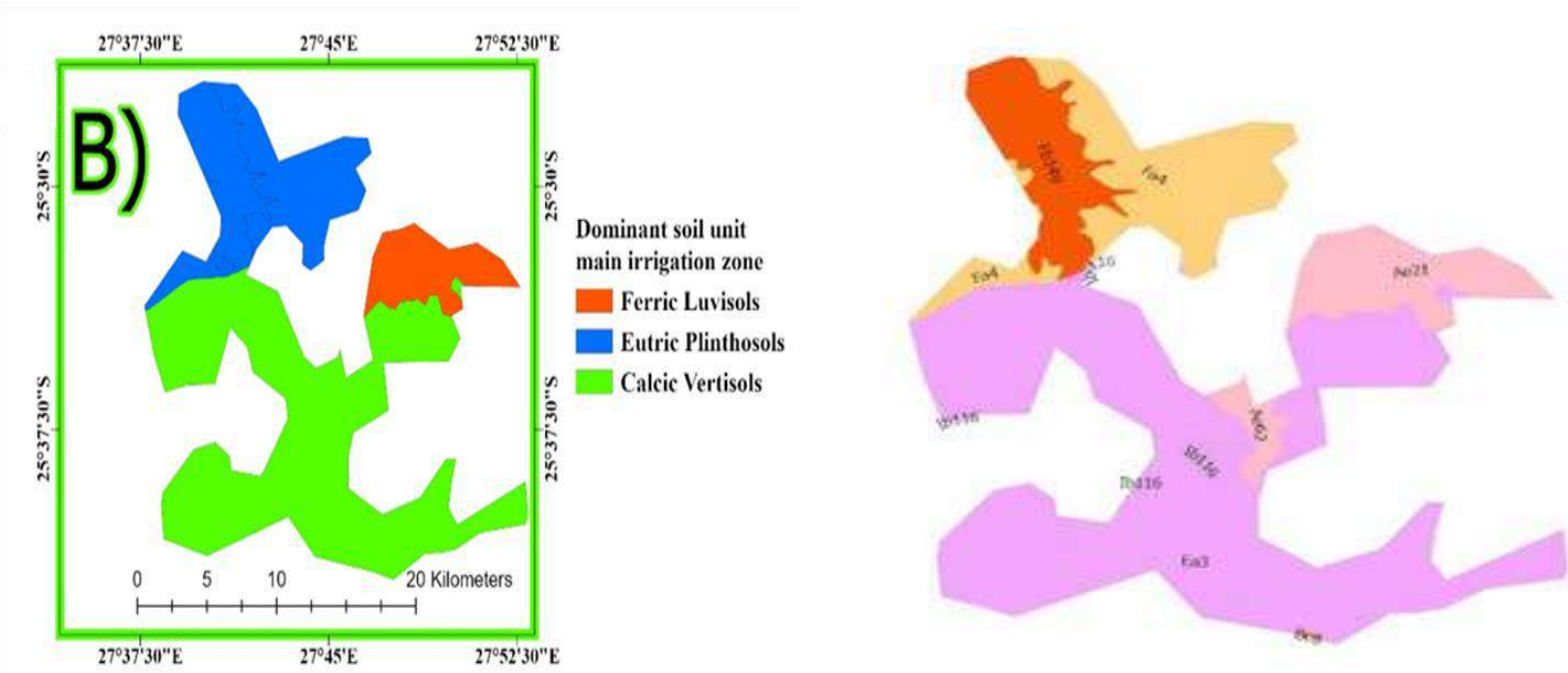
Source: ARC-ISCW (2018)

Table D.3: Key properties of dominant South African soils in the Orange-Riet irrigation scheme

South African Soil Form	Key Properties
Hutton	Well-drained, deep, red to reddish-brown, clay loam to clay, moderate to high fertility, suitable for crops requiring good water-holding capacity.
Plooysburg	Shallow to moderately deep, calcareous, sandy clay loam to clay, moderate fertility, may have calcrete layers limiting root penetration.

Source: ARC-ISCW (2018)

D.2 Hartbeespoort irrigation scheme



Note: Left shows the soil data in the main irrigation zone used for AquaCrop simulations, and right shows the land types in the main irrigation zone from the Land Type Survey 1 at 250 000 scale

Figure D.2: Main irrigation zone of the Hartbeespoort irrigation scheme overlaid on the Land Type Survey (1:250 000 scale) land types

Table D.4: Dominant soil series occurring in each land type within the Hartbeespoort irrigation zone

Land Type	Dominant soil series total (%)
Fb149	Gs
Fa4	Gs
Ib116	Ar (40%) and Rg (40%) are equally dominant
Ea3	Ar
Bc8	Hu
Ae21	Hu
Ae62	Hu
Ae21	Hu

Note: Soil series abbreviations: HU = Hutton, Gs = Glenrosa, Ar = Arcadia, Rg = Regosol

Source: Land Type Survey Staff (1972-2002)

Table D.5: Conversion of dominant soil series to South African soil forms

Dominant Soil Series (from Table F.1)	South African Soil Form
Ferric Luvisol	Hutton (clayey Hutton, increase in clay from topsoil to subsoil)
Eutric Plinthosol	Longlands
Calcic Vertisol	Arcadia

Source: ARC-ISCW (2018)

Table D.6: Key properties of dominant South African soils in the Hartbeespoort irrigation scheme

South African Soil Form	Key Properties
Hutton (Ferric Luvisol)	Well-drained, deep, clayey texture, red to reddish-brown, moderate to high fertility, clay increases from topsoil to subsoil, suitable for irrigation crops requiring water retention.
Longlands (Eutric Plinthosol)	Shallow to moderately deep, iron-rich plinthic horizons, sandy clay to clay, moderate fertility, prone to seasonal waterlogging if not drained.
Arcadia (Calcic Vertisol)	Deep, heavy clay, calcareous, high fertility, prone to swelling and cracking, may require careful irrigation management.

Source: ARC-ISCW (2018)

D.3 Impala irrigation scheme

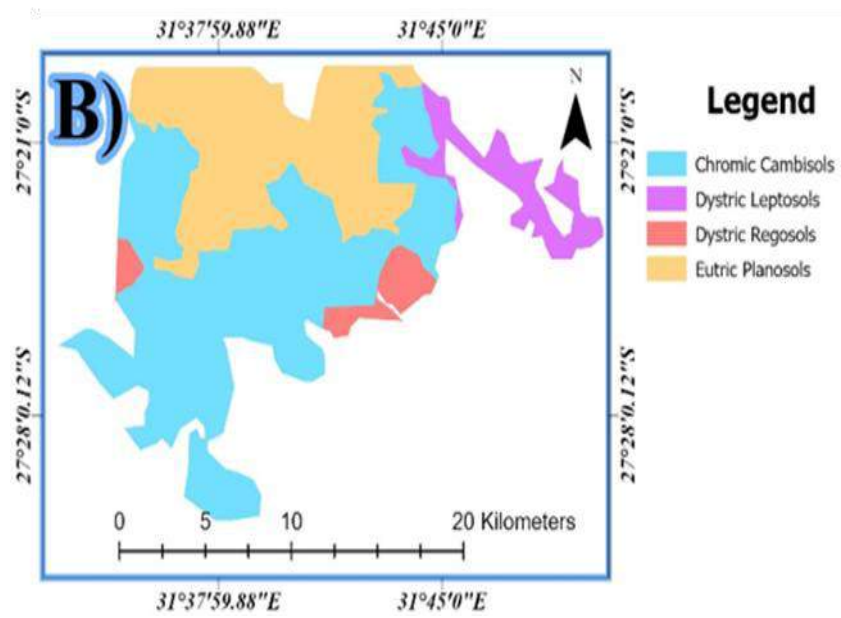


Figure D.3: Main irrigation zone of the Impala irrigation scheme overlaid on the Land Type Survey (1:250 000 scale) land types

Table D.7: Dominant soil series occurring in each land type within the Impala irrigation zone.

Land Type	Dominant soil series total (%)
Db144	Sw
Fb254	Gs
Fb256	Ms
Fb257	Ms
Fb255	Ms
Ae159	Hu
Fa380	Ms
Fb129	Gs

Note: Soil series abbreviations: HU = Hutton, SW = Swartland, MS = Mispah, GS = Glenrosa

Source: Land Type Survey Staff (1972-2002)

Table D.8: Conversion of dominant soil series to South African soil forms

Dominant Soil Series	South African Soil Form
Chromic Cambisols	Hutton
Dystric Leptosols	Mispah
Dystric Regosols	Regosol
Eutric Planosols	Estcourt

Note: The soil series identified in Table D1 served as the starting point for this conversion.

Table D.9: Key properties of dominant South African soils in the Impala irrigation scheme

South African Soil Form	Key Properties (from Soil Handbook, ARC-ISCW, 2018)
Hutton	Well-drained, deep, red to reddish-brown, clay loam to clay, moderate to high fertility, suitable for crops requiring good water-holding capacity.
Mispah	Shallow to moderately deep, reddish yellow to brown, sandy clay loam, moderate fertility, may require careful irrigation management.
Regosol	Very shallow, sandy to loamy sand, low fertility, prone to drought stress, limited rooting depth.
Estcourt	Moderately deep, poorly drained, clay-to-clay loam may have seasonal waterlogging and high fertility, but requires drainage management for optimal crop growth.

Source: ARC-ISCW (2018).

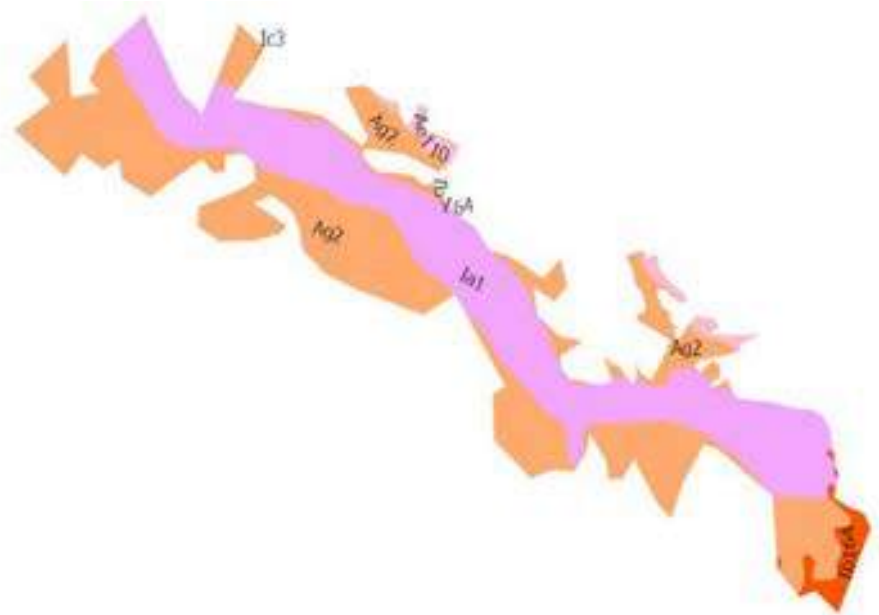


Figure D.4: Main irrigation zone of the Orange Riet irrigation scheme overlaid on the Land Type Survey (1:250 000 scale) land types

Table D.10: Dominant soil series occurring in each land type within the Kakamas irrigation zone

Land Type	Dominant soil series total (%)
Ic3	Hu
Ag2	Hu
Ae110	Hu
Ib164	Hu
Ia1	Du

Note: Soil series abbreviations: HU = Hutton, DU = Dundee

Source: Land Type Survey Staff (1972-2002).

Table D.11: Conversion of dominant soil series to South African soil forms

Dominant Soil Series (from Table D1)	South African Soil Form
Chromic Cambisols	Hutton
Eutric Fluvisol	Dundee
Ferralic Arenosol	Hutton (very sandy, like Kalahari dunes)

Note: The soil series identified in Table D1 served as the starting point for this conversion

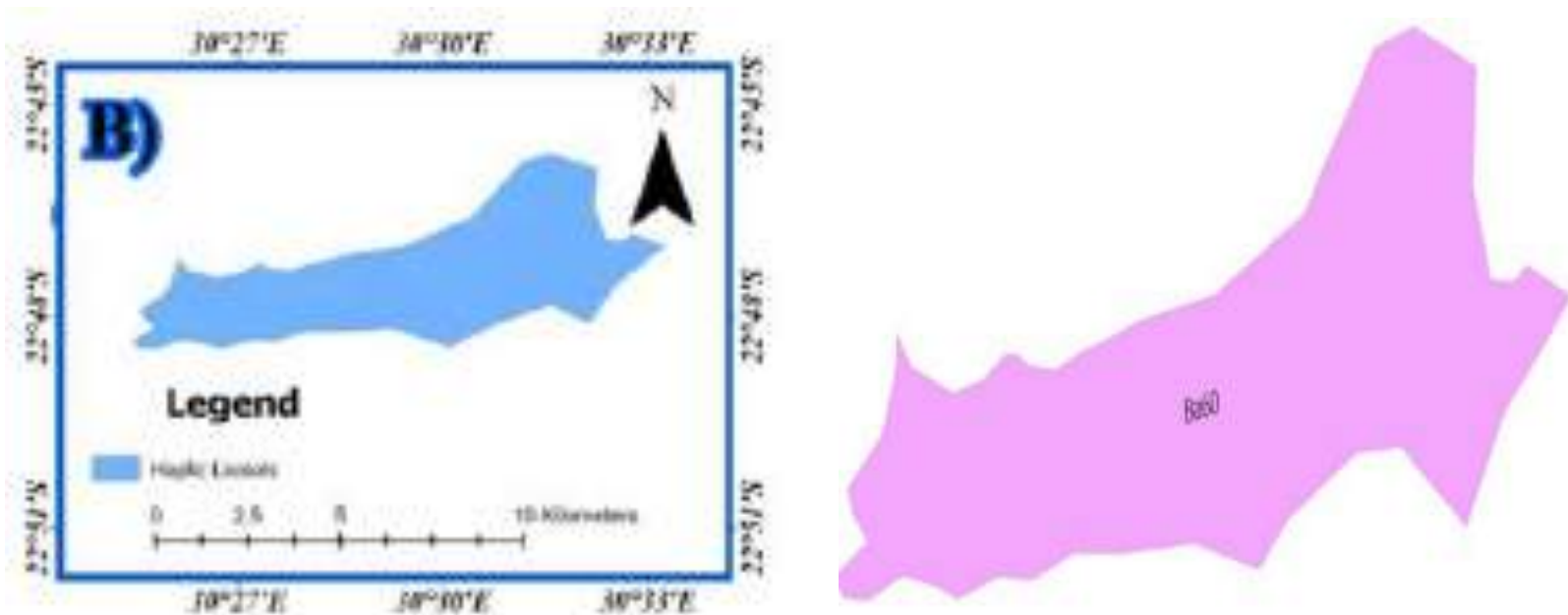
Source: ARC-ISCW (2018).

Table D.12: Key properties of dominant South African soils in the Kakamas irrigation scheme

South African Soil Form	Key Properties
Hutton (Chromic Cambisols / Ferralic Arenosol)	Well-drained, deep (or very sandy), red to reddish-brown, clay loam to sandy texture, moderate fertility, suitable for irrigation; Ferralic Arenosol is very sandy, with low water-holding capacity, drought-prone.
Dundee (Eutric Fluvisol)	Shallow to moderately deep, alluvial deposits, sandy to sandy loam, and fertile may be prone to seasonal flooding or saturation in low-lying areas.

Source: ARC-ISCW (2018)

D.5 Tshiombo Irrigation Scheme



Note: Left shows the soil data in the main irrigation zone used for AquaCrop simulations, and right shows the land types in the main irrigation zone from the Land Type Survey 1 at 250 000 scale

Figure D.5: Main irrigation zone of the Tsiombo irrigation scheme overlaid on the Land Type Survey (1:250 000 scale) land types

Table D.13: Dominant soil series occurring in each land type within the Tshiombo irrigation zone

Land Type	Dominant soil series total (%)
Ba60	Hu

Note: Soil series abbreviations: HU = Hutton

Source: Land Type Survey Staff (1972-2002)

Table D.14: Conversion of dominant soil series to South African soil forms

Dominant Soil Series (from Table F.1)	South African Soil Form
Haplic Lixisols	Clovelly

Source: ARC-ISCW (2018)

Table D.15: Key properties of the dominant South African soil in the Tshiombo irrigation scheme

South African Soil Form	Key Properties
Clovelly (Haplic Lixisols)	Well-drained, moderately deep to deep, red to reddish-brown, sandy clay loam to clay, moderate fertility, moderately acidic to neutral, suitable for crops under irrigation; may have moderate seasonal water-holding limitations.

Source: ARC-ISCW (2018)

Appendix E- Macro-SAM of South Africa

Table E.1: A 2020 Macro- SAM for South Africa (R million)

	Activities	Commodities	Labour	Capital	Land	Enterprise	Households	Governments	Activity taxes	Net dom prod taxes	Direct taxes	Change in inventory	Accumulation	Exports	Total
Activities		11 316 036													11316036
Commodities	6 333 555						4 027 882	485 044				-81859	951364	1484355	13200341
Labour	2 712 055														2712055
Capital	2 162 256														2162256
Land	5361														5361
Enterprise				990 701	3 488	201 303	403 395	398 694							1997581
Households			2696 276	978 652	1 873	896 342		372 053						21713	4968910
Government								176 099	102 809	526 700	678 707			1285	1485599
Net activity taxes	102 809														102809
Net dom prod taxes		526 700													526700
Direct taxes						212 907	465 800								678707
Change in inventory													-81859		-81859
Savings						661 505	62 222	2 019						143 759	869505
Imports		1 357 605	13 779	192 902		25 525	9 611	51 690							1651 112
Total	11 316 036	13 200 341	2712055	2162256	5361	1997581	4 968 910	1 485 599	102809	526700	678707	-818 59	869 505	1651112	

Sources: Project team, with the assistance of various stakeholders

Appendix F

Table F.1: Hypothesis Testing Results for the Structural Model of Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1576	$A_B \rightarrow INT$	0.736	0.732	0.029	25.634	0.000***	Accepted
H1577	$SN \rightarrow INT$	0.041	0.046	0.038	1.073	0.283	Reject
H1578	$PBC \rightarrow INT$	0.025	0.031	0.034	0.745	0.457	Reject

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.2: Specific Indirect Effects of Constructs on Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1631	$PFC \rightarrow SN \rightarrow INT$	-0.003	-0.003	0.006	0.487	0.626	Rejected
H1632	$PFC2 \rightarrow SN \rightarrow INT$	0.004	0.003	0.006	0.601	0.548	Rejected
H1634	$RB \rightarrow SN \rightarrow INT$	0.000	0.000	0.005	0.011	0.992	Rejected
H1635	$RB2 \rightarrow SN \rightarrow INT$	0.007	0.007	0.006	1.066	0.287	Rejected
H1630	$SS \rightarrow SN \rightarrow INT$	0.012	0.012	0.008	1.433	0.152	Rejected
H1636	$AR \rightarrow PBC \rightarrow INT$	0.000	0.000	0.004	0.052	0.958	Rejected
H1637	$AR2 \rightarrow PBC \rightarrow INT$	0.006	0.006	0.007	0.886	0.375	Rejected
H1642	$IF \rightarrow PBC \rightarrow INT$	-0.001	-0.001	0.004	0.347	0.729	Rejected
H1638	$IL \rightarrow PBC \rightarrow INT$	0.011	0.011	0.011	1.033	0.301	Rejected
H1618	$AR \rightarrow A_B \rightarrow INT$	-0.000	0.001	0.007	0.019	0.985	Rejected
H1640	$PFC \rightarrow PBC \rightarrow INT$	0.002	0.002	0.005	0.469	0.639	Rejected
H1619	$AR2 \rightarrow A_B \rightarrow INT$	-0.000	-0.000	0.002	0.004	0.997	Rejected
H1641	$PFC2 \rightarrow PBC \rightarrow INT$	0.003	0.003	0.005	0.629	0.529	Rejected
H1624	$IF \rightarrow A_B \rightarrow INT$	-0.000	0.000	0.003	0.003	0.998	Rejected
H1643	$RB \rightarrow PBC \rightarrow INT$	-0.001	-0.000	0.004	0.185	0.853	Rejected
H1620	$IL \rightarrow A_B \rightarrow INT$	0.000	-0.001	0.004	0.015	0.988	Rejected
H1644	$RB2 \rightarrow PBC \rightarrow INT$	0.004	0.004	0.005	0.854	0.393	Rejected
H1639	$SS \rightarrow PBC \rightarrow INT$	0.002	0.002	0.004	0.473	0.636	Rejected
H1622	$PFC \rightarrow A_B \rightarrow INT$	-0.000	0.000	0.003	0.004	0.997	Rejected
H1623	$PFC2 \rightarrow A_B \rightarrow INT$	0.000	0.000	0.005	0.018	0.986	Rejected
H1625	$RB \rightarrow A_B \rightarrow INT$	-0.000	-0.000	0.002	0.009	0.993	Rejected
H1626	$RB2 \rightarrow A_B \rightarrow INT$	0.000	-0.000	0.004	0.020	0.984	Rejected
H1621	$SS \rightarrow A_B \rightarrow INT$	0.000	0.000	0.006	0.021	0.983	Rejected
H1627	$AR \rightarrow SN \rightarrow INT$	0.000	0.001	0.006	0.017	0.986	Rejected
H1619	$AR2 \rightarrow A_B \rightarrow INT$	0.001	0.001	0.006	0.127	0.899	Rejected
H1633	$IF \rightarrow SN \rightarrow INT$	0.003	0.003	0.005	0.633	0.527	Rejected
H1629	$IL \rightarrow SN \rightarrow INT$	0.001	0.001	0.005	0.199	0.842	Rejected

Source: Project team compilation

Table F.3: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1645	$AR \rightarrow INT$	0.000	0.001	0.010	0.021	0.984	Rejected
H1646	$AR2 \rightarrow INT$	0.007	0.007	0.009	0.740	0.459	Rejected
H1651	$IF \rightarrow INT$	0.002	0.002	0.007	0.281	0.778	Rejected
H1647	$IL \rightarrow INT$	0.012	0.011	0.012	1.024	0.306	Rejected
H1649	$PFC \rightarrow INT$	-0.001	-0.001	0.008	0.101	0.919	Rejected
H1650	$PFC2 \rightarrow INT$	0.007	0.007	0.009	0.741	0.459	Rejected
H1652	$RB \rightarrow INT$	-0.001	-0.000	0.006	0.100	0.920	Rejected
H1653	$RB2 \rightarrow INT$	0.011	0.011	0.009	1.252	0.210	Rejected
H1648	$SS \rightarrow INT$	0.014	0.014	0.011	1.288	0.198	Rejected

Source: Project team compilation

Table F.4: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1606	$A_B \rightarrow INT$	0.001	-0.001	0.038	0.023	0.982	Rejected
H1579	$AR \rightarrow A_B$	-0.141	-0.142	0.084	1.675	0.094	Rejected
H1609	$AR \rightarrow INT$	0.057	0.053	0.043	1.316	0.188	Rejected
H1597	$AR \rightarrow PBC$	0.005	0.003	0.068	0.069	0.945	Rejected
H1588	$AR \rightarrow SN$	0.001	0.004	0.076	0.020	0.984	Rejected
H1580	$AR2 \rightarrow A_B$	-0.010	-0.007	0.064	0.157	0.875	Rejected
H1610	$AR2 \rightarrow INT$	-0.012	-0.010	0.046	0.262	0.794	Rejected
H1598	$AR2 \rightarrow PBC$	0.127	0.131	0.063	2.010	0.044**	Accepted
H1589	$AR2 \rightarrow SN$	0.011	0.013	0.075	0.146	0.884	Rejected
H1585	$IF \rightarrow A_B$	-0.009	-0.002	0.076	0.113	0.910	Rejected
H1615	$IF \rightarrow INT$	0.608	0.606	0.039	15.648	0.000	Accepted
H1603	$IF \rightarrow PBC$	-0.029	-0.030	0.060	0.476	0.634	Rejected
H1594	$IF \rightarrow SN$	0.047	0.049	0.062	0.764	0.445	Rejected
H1581	$IL \rightarrow A_B$	0.062	0.063	0.067	0.937	0.349	Rejected
H1611	$IL \rightarrow INT$	0.206	0.206	0.039	5.231	0.000***	Accepted
H1599	$IL \rightarrow PBC$	0.237	0.237	0.058	4.109	0.000***	Accepted
H1590	$IL \rightarrow SN$	0.015	0.015	0.063	0.231	0.818	Rejected
H1608	$PBC \rightarrow INT$	0.047	0.046	0.042	1.116	0.264	Rejected
H1583	$PFC \rightarrow A_B$	-0.013	-0.017	0.079	0.165	0.869	Rejected
H1613	$PFC \rightarrow INT$	0.068	0.072	0.046	1.482	0.138	Rejected
H1601	$PFC \rightarrow PBC$	0.046	0.047	0.063	0.725	0.468	Rejected
H1592	$PFC \rightarrow SN$	-0.043	-0.042	0.072	0.596	0.551	Rejected
H1584	$PFC2 \rightarrow A_B$	0.093	0.093	0.075	1.244	0.213	Rejected
H1614	$PFC2 \rightarrow INT$	-0.036	-0.034	0.047	0.778	0.437	Rejected
H1602	$PFC2 \rightarrow PBC$	0.061	0.064	0.063	0.965	0.335	Rejected
H1593	$PFC2 \rightarrow SN$	0.052	0.052	0.071	0.735	0.463	Rejected
H1586	$RB \rightarrow A_B$	-0.023	-0.017	0.057	0.408	0.683	Rejected
H1616	$RB \rightarrow INT$	-0.022	-0.019	0.040	0.546	0.585	Rejected
H1604	$RB \rightarrow PBC$	-0.014	-0.012	0.058	0.244	0.807	Rejected
H1595	$RB \rightarrow SN$	0.001	0.002	0.067	0.012	0.990	Rejected
H1587	$RB2 \rightarrow A_B$	0.098	0.096	0.053	1.870	0.062	Rejected
H1617	$RB2 \rightarrow INT$	0.044	0.044	0.051	0.864	0.388	Rejected
H1605	$RB2 \rightarrow PBC$	0.092	0.095	0.056	1.652	0.099	Rejected
H1596	$RB2 \rightarrow SN$	0.097	0.099	0.062	1.548	0.122	Rejected
H1607	$SN \rightarrow INT$	0.068	0.068	0.038	1.791	0.073	Rejected
H1582	$SS \rightarrow A_B$	0.152	0.152	0.074	2.045	0.041**	Accepted
H1612	$SS \rightarrow INT$	-0.017	-0.016	0.040	0.423	0.673	Rejected
H1600	$SS \rightarrow PBC$	0.044	0.041	0.062	0.699	0.485	Rejected
H1591	$SS \rightarrow SN$	0.171	0.172	0.063	2.717	0.007***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.5: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Technologies by Small-Scale Maize Irrigators in the Tshiombi Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1681	$A_B \Rightarrow INT$	0.001	-0.001	0.038	0.023	0.982	Rejected
H1654	$AR \Rightarrow A_B$	-0.141	-0.142	0.084	1.675	0.094	Rejected
H1684	$AR \Rightarrow INT$	0.057	0.055	0.043	1.335	0.182	Rejected
H1672	$AR \Rightarrow PBC$	0.005	0.003	0.068	0.069	0.945	Rejected
H1663	$AR \Rightarrow SN$	0.001	0.004	0.076	0.020	0.984	Rejected
H1655	$AR2 \Rightarrow A_B$	-0.010	-0.007	0.064	0.157	0.875	Rejected
H1685	$AR2 \Rightarrow INT$	-0.005	-0.003	0.045	0.117	0.907	Rejected
H1673	$AR2 \Rightarrow PBC$	0.127	0.131	0.063	2.010	0.044**	Accepted
H1664	$AR2 \Rightarrow SN$	0.011	0.013	0.075	0.146	0.884	Rejected
H1660	$IF \Rightarrow A_B$	-0.009	-0.002	0.076	0.113	0.910	Rejected
H1690	$IF \Rightarrow INT$	0.610	0.608	0.038	16.227	0.000***	Accepted
H1678	$IF \Rightarrow PBC$	-0.029	-0.030	0.060	0.476	0.634	Rejected
H1669	$IF \Rightarrow SN$	0.047	0.049	0.062	0.764	0.445	Rejected
H1656	$IL \Rightarrow A_B$	0.062	0.063	0.067	0.937	0.349	Rejected
H1686	$IL \Rightarrow INT$	0.218	0.217	0.039	5.536	0.000***	Accepted
H1674	$IL \Rightarrow PBC$	0.237	0.237	0.058	4.109	0.000***	Accepted
H1665	$IL \Rightarrow SN$	0.015	0.015	0.063	0.231	0.818	Rejected
H1683	$PBC \Rightarrow INT$	0.047	0.046	0.042	1.116	0.264	Rejected
H1658	$PFC \Rightarrow A_B$	-0.013	-0.017	0.079	0.165	0.869	Rejected
H1688	$PFC \Rightarrow INT$	0.067	0.071	0.045	1.475	0.140	Rejected
H1676	$PFC \Rightarrow PBC$	0.046	0.047	0.063	0.725	0.468	Rejected
H1667	$PFC \Rightarrow SN$	-0.043	-0.042	0.072	0.596	0.551	Rejected
H1659	$PFC2 \Rightarrow A_B$	0.093	0.093	0.075	1.244	0.213	Rejected
H1689	$PFC2 \Rightarrow INT$	-0.030	-0.028	0.046	0.640	0.522	Rejected
H1677	$PFC2 \Rightarrow PBC$	0.061	0.064	0.063	0.965	0.335	Rejected
H1668	$PFC2 \Rightarrow SN$	0.052	0.052	0.071	0.735	0.463	Rejected
H1661	$RB \Rightarrow A_B$	-0.023	-0.017	0.057	0.408	0.683	Rejected
H1691	$RB \Rightarrow INT$	-0.023	-0.019	0.040	0.571	0.568	Rejected
H1679	$RB \Rightarrow PBC$	-0.014	-0.012	0.058	0.244	0.807	Rejected
H1670	$RB \Rightarrow SN$	0.001	0.002	0.067	0.012	0.990	Rejected
H1662	$RB2 \Rightarrow A_B$	0.098	0.096	0.053	1.870	0.062	Rejected
H1692	$RB2 \Rightarrow INT$	0.055	0.054	0.049	1.121	0.262	Rejected
H1680	$RB2 \Rightarrow PBC$	0.092	0.095	0.056	1.652	0.099	Rejected
H1671	$RB2 \Rightarrow SN$	0.097	0.099	0.062	1.548	0.122	Rejected
H1682	$SN \Rightarrow INT$	0.068	0.068	0.038	1.791	0.073	Rejected
H1656	$SS \Rightarrow A_B$	0.152	0.152	0.074	2.045	0.041**	Accepted
H1687	$SS \Rightarrow INT$	-0.003	-0.002	0.039	0.078	0.938	Rejected
H1675	$SS \Rightarrow PBC$	0.044	0.041	0.062	0.699	0.485	Rejected
H1666	$SS \Rightarrow SN$	0.171	0.172	0.063	2.717	0.007***	Accepted

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table F.6: Hypothesis Testing Results for the Structural Model of Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1693	$A_B \rightarrow INT$	0.178	0.184	0.045	3.992	0.000***	Accepted
H1694	$SN \rightarrow INT$	0.296	0.298	0.045	6.539	0.000***	Accepted
H1695	$PBC \rightarrow INT$	0.222	0.225	0.052	4.270	0.000***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.7: Specific Indirect Effects of Constructs on Small-Scale Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1748	$PFC \rightarrow SN \rightarrow INT$	-0.010	-0.010	0.008	1.290	0.197	Rejected
H1749	$PFC2 \rightarrow SN \rightarrow INT$	0.001	0.001	0.004	0.198	0.843	Rejected
H1751	$RB \rightarrow SN \rightarrow INT$	-0.006	-0.005	0.005	1.125	0.261	Rejected
H1752	$RB2 \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.004	0.150	0.881	Rejected
H1747	$SS \rightarrow SN \rightarrow INT$	-0.009	-0.009	0.007	1.300	0.193	Rejected
H1753	$AR \rightarrow PBC \rightarrow INT$	0.002	0.003	0.006	0.403	0.687	Rejected
H1754	$AR2 \rightarrow PBC \rightarrow INT$	0.008	0.008	0.007	1.246	0.213	Rejected
H1759	$IF \rightarrow PBC \rightarrow INT$	0.008	0.008	0.007	1.277	0.201	Rejected
H1755	$IL \rightarrow PBC \rightarrow INT$	0.015	0.015	0.009	1.738	0.082	Rejected
H1735	$AR \rightarrow A_B \rightarrow INT$	-0.000	-0.000	0.003	0.112	0.911	Rejected
H1757	$PFC \rightarrow PBC \rightarrow INT$	0.009	0.009	0.007	1.242	0.214	Rejected
H1736	$AR2 \rightarrow A_B \rightarrow INT$	0.001	0.001	0.003	0.403	0.687	Rejected
H1758	$PFC2 \rightarrow PBC \rightarrow INT$	0.003	0.003	0.006	0.487	0.627	Rejected
H1741	$IF \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.004	0.530	0.596	Rejected
H1760	$RB \rightarrow PBC \rightarrow INT$	-0.000	0.000	0.005	0.014	0.989	Rejected
H1737	$IL \rightarrow A_B \rightarrow INT$	-0.006	-0.006	0.008	0.719	0.472	Rejected
H1761	$RB2 \rightarrow PBC \rightarrow INT$	0.009	0.009	0.007	1.315	0.189	Rejected
H1756	$SS \rightarrow PBC \rightarrow INT$	0.012	0.011	0.007	1.643	0.100	Rejected
H1739	$PFC \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.004	0.597	0.551	Rejected
H1740	$PFC2 \rightarrow A_B \rightarrow INT$	0.000	-0.000	0.002	0.007	0.994	Rejected
H1742	$RB \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.004	0.533	0.594	Rejected
H1743	$RB2 \rightarrow A_B \rightarrow INT$	-0.003	-0.002	0.004	0.632	0.528	Rejected
H1738	$SS \rightarrow A_B \rightarrow INT$	-0.004	-0.004	0.006	0.680	0.496	Rejected
H1744	$AR \rightarrow SN \rightarrow INT$	0.003	0.002	0.004	0.637	0.524	Rejected
H1745	$AR2 \rightarrow SN \rightarrow INT$	-0.007	-0.007	0.006	1.221	0.222	Rejected
H1750	$IF \rightarrow SN \rightarrow INT$	-0.006	-0.006	0.006	1.011	0.312	Rejected
H1746	$IL \rightarrow SN \rightarrow INT$	-0.011	-0.010	0.007	1.480	0.139	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.8: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for the Adoption of Water-Saving Policies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1762	$AR \rightarrow INT$	0.005	0.005	0.008	0.610	0.542	Rejected
H1763	$AR2 \rightarrow INT$	0.002	0.002	0.010	0.246	0.805	Rejected
H1768	$IF \rightarrow INT$	0.001	0.000	0.010	0.067	0.947	Rejected
H1764	$IL \rightarrow INT$	-0.001	-0.001	0.014	0.091	0.927	Rejected
H1766	$PFC \rightarrow INT$	-0.004	-0.004	0.011	0.320	0.749	Rejected
H1767	$PFC2 \rightarrow INT$	0.004	0.004	0.008	0.485	0.628	Rejected
H1769	$RB \rightarrow INT$	-0.008	-0.008	0.008	0.937	0.349	Rejected
H1770	$RB2 \rightarrow INT$	0.006	0.006	0.009	0.670	0.503	Rejected
H1765	$SS \rightarrow INT$	-0.002	-0.002	0.012	0.127	0.899	Rejected

Source: Project team compilation

Table F.9: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for the Adoption of Water-Saving Policies by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1723	$A_B \rightarrow INT$	-0.028	-0.029	0.037	0.773	0.440	Rejected
H1696	$AR \rightarrow A_B$	0.011	0.017	0.058	0.185	0.853	Rejected
H1726	$AR \rightarrow INT$	-0.021	-0.022	0.040	0.518	0.605	Rejected
H1714	$AR \rightarrow PBC$	0.027	0.031	0.061	0.450	0.653	Rejected
H1705	$AR \rightarrow SN$	-0.043	-0.039	0.055	0.782	0.434	Rejected
H1697	$AR2 \rightarrow A_B$	-0.045	-0.045	0.057	0.787	0.432	Rejected
H1727	$AR2 \rightarrow INT$	0.097	0.099	0.045	2.153	0.031**	Accepted
H1715	$AR2 \rightarrow PBC$	0.093	0.096	0.060	1.535	0.125	Rejected
H1706	$AR2 \rightarrow SN$	0.115	0.118	0.055	2.098	0.036**	Accepted
H1702	$IF \rightarrow A_B$	0.072	0.072	0.059	1.212	0.226	Rejected
H1732	$IF \rightarrow INT$	0.070	0.070	0.041	1.688	0.091	Rejected
H1720	$IF \rightarrow PBC$	0.093	0.091	0.056	1.675	0.094	Rejected
H1711	$IF \rightarrow SN$	0.091	0.089	0.056	1.623	0.105	Rejected
H1698	$IL \rightarrow A_B$	0.209	0.209	0.051	4.115	0.000***	Accepted
H1728	$IL \rightarrow INT$	0.733	0.733	0.031	23.430	0.000***	Accepted
H1716	$IL \rightarrow PBC$	0.170	0.170	0.063	2.724	0.006***	Accepted
H1707	$IL \rightarrow SN$	0.172	0.170	0.054	3.153	0.002***	Accepted
H1725	$PBC \rightarrow INT$	0.090	0.089	0.039	2.295	0.022**	Accepted
H1700	$PFC \rightarrow A_B$	0.082	0.082	0.053	1.550	0.121	Rejected
H1730	$PFC \rightarrow INT$	0.026	0.028	0.042	0.621	0.535	Rejected
H1718	$PFC \rightarrow PBC$	0.097	0.096	0.060	1.621	0.105	Rejected
H1709	$PFC \rightarrow SN$	0.160	0.161	0.060	2.668	0.008***	Accepted
H1701	$PFC2 \rightarrow A_B$	-0.001	0.002	0.051	0.013	0.990	Rejected
H1731	$PFC2 \rightarrow INT$	0.001	0.003	0.044	0.013	0.990	Rejected
H1719	$PFC2 \rightarrow PBC$	0.032	0.033	0.058	0.540	0.589	Rejected
H1710	$PFC2 \rightarrow SN$	-0.013	-0.012	0.057	0.230	0.818	Rejected
H1703	$RB \rightarrow A_B$	0.072	0.075	0.052	1.370	0.171	Rejected
H1733	$RB \rightarrow INT$	-0.035	-0.036	0.038	0.933	0.351	Rejected
H1721	$RB \rightarrow PBC$	-0.001	0.001	0.056	0.015	0.988	Rejected
H1712	$RB \rightarrow SN$	0.091	0.092	0.054	1.677	0.093	Rejected
H1704	$RB2 \rightarrow A_B$	0.089	0.089	0.054	1.671	0.095	Rejected
H1734	$RB2 \rightarrow INT$	0.021	0.022	0.039	0.541	0.589	Rejected
H1722	$RB2 \rightarrow PBC$	0.103	0.103	0.064	1.625	0.104	Rejected
H1713	$RB2 \rightarrow SN$	0.010	0.010	0.058	0.177	0.859	Rejected
H1724	$SN \rightarrow INT$	-0.063	-0.062	0.038	1.642	0.101	Rejected
H1699	$SS \rightarrow A_B$	0.140	0.138	0.055	2.530	0.011**	Accepted
H1729	$SS \rightarrow INT$	-0.068	-0.070	0.041	1.690	0.091	Rejected
H1717	$SS \rightarrow PBC$	0.131	0.129	0.053	2.464	0.014**	Accepted
H1708	$SS \rightarrow SN$	0.150	0.148	0.055	2.702	0.007***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.10: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Policies by Small-Scale Maize Irrigators in the Tshiombi Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1798	$A_B \Rightarrow INT$	-0.028	-0.029	0.037	0.773	0.440	Rejected
H1771	$AR \Rightarrow A_B$	0.011	0.017	0.058	0.185	0.853	Rejected
H1801	$AR \Rightarrow INT$	-0.016	-0.017	0.041	0.389	0.697	Rejected
H1789	$AR \Rightarrow PBC$	0.027	0.031	0.061	0.450	0.653	Rejected
H1780	$AR \Rightarrow SN$	-0.043	-0.039	0.055	0.782	0.434	Rejected
H1772	$AR2 \Rightarrow A_B$	-0.045	-0.045	0.057	0.787	0.432	Rejected
H1802	$AR2 \Rightarrow INT$	0.099	0.101	0.044	2.230	0.026**	Accepted
H1790	$AR2 \Rightarrow PBC$	0.093	0.096	0.060	1.535	0.125	Rejected
H1781	$AR2 \Rightarrow SN$	0.115	0.118	0.055	2.098	0.036**	Accepted
H1777	$IF \Rightarrow A_B$	0.072	0.072	0.059	1.212	0.226	Rejected
H1807	$IF \Rightarrow INT$	0.070	0.070	0.042	1.675	0.094	Rejected
H1795	$IF \Rightarrow PBC$	0.093	0.091	0.056	1.675	0.094	Rejected
H1786	$IF \Rightarrow SN$	0.091	0.089	0.056	1.623	0.105	Rejected
H1773	$IL \Rightarrow A_B$	0.209	0.209	0.051	4.115	0.000***	Accepted
H1803	$IL \Rightarrow INT$	0.732	0.731	0.028	25.752	0.000***	Accepted
H1791	$IL \Rightarrow PBC$	0.170	0.170	0.063	2.724	0.006***	Accepted
H1782	$IL \Rightarrow SN$	0.172	0.170	0.054	3.153	0.002***	Accepted
H1800	$PBC \Rightarrow INT$	0.090	0.089	0.039	2.295	0.022**	Accepted
H1775	$PFC \Rightarrow A_B$	0.082	0.082	0.053	1.550	0.121	Rejected
H1805	$PFC \Rightarrow INT$	0.022	0.024	0.041	0.539	0.590	Rejected
H1793	$PFC \Rightarrow PBC$	0.097	0.096	0.060	1.621	0.105	Rejected
H1784	$PFC \Rightarrow SN$	0.160	0.161	0.060	2.668	0.008***	Accepted
H1776	$PFC2 \Rightarrow A_B$	-0.001	0.002	0.051	0.013	0.990	Rejected
H1806	$PFC2 \Rightarrow INT$	0.004	0.006	0.044	0.095	0.924	Rejected
H1794	$PFC2 \Rightarrow PBC$	0.032	0.033	0.058	0.540	0.589	Rejected
H1785	$PFC2 \Rightarrow SN$	-0.013	-0.012	0.057	0.230	0.818	Rejected
H1778	$RB \Rightarrow A_B$	0.072	0.075	0.052	1.370	0.171	Rejected
H1808	$RB \Rightarrow INT$	-0.043	-0.044	0.038	1.143	0.253	Rejected
H1796	$RB \Rightarrow PBC$	-0.001	0.001	0.056	0.015	0.988	Rejected
H1787	$RB \Rightarrow SN$	0.091	0.092	0.054	1.677	0.093	Rejected
H1779	$RB2 \Rightarrow A_B$	0.089	0.089	0.054	1.671	0.095	Rejected
H1809	$RB2 \Rightarrow INT$	0.027	0.028	0.038	0.716	0.474	Rejected
H1797	$RB2 \Rightarrow PBC$	0.103	0.103	0.064	1.625	0.104	Rejected
H1788	$RB2 \Rightarrow SN$	0.010	0.010	0.058	0.177	0.859	Rejected
H1799	$SN \Rightarrow INT$	-0.063	-0.062	0.038	1.642	0.101	Rejected
H1774	$SS \Rightarrow A_B$	0.140	0.138	0.055	2.530	0.011**	Accepted
H1804	$SS \Rightarrow INT$	-0.070	-0.072	0.040	1.753	0.080	Rejected
H1792	$SS \Rightarrow PBC$	0.131	0.129	0.053	2.464	0.014**	Accepted
H1783	$SS \Rightarrow SN$	0.150	0.148	0.055	2.702	0.007***	Accepted

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table F.11: Hypothesis Testing Results for the Structural Model of Small-Scale Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1810	$A_B \rightarrow INT$	0.619	0.619	0.032	19.262	0.000	Accepted
H1811	$SN \rightarrow INT$	0.167	0.168	0.043	3.858	0.000	Accepted
H1812	$PBC \rightarrow INT$	0.103	0.105	0.040	2.598	0.009	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.12: Specific Indirect Effects of Constructs on Small-Scale Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1865	$PFC \rightarrow SN \rightarrow INT$	-0.000	-0.000	0.002	0.083	0.934	Rejected
H1866	$PFC2 \rightarrow SN \rightarrow INT$	0.001	0.001	0.002	0.526	0.599	Rejected
H1868	$RB \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.002	0.582	0.561	Rejected
H1869	$RB2 \rightarrow SN \rightarrow INT$	-0.002	-0.002	0.003	0.606	0.544	Rejected
H1864	$SS \rightarrow SN \rightarrow INT$	-0.004	-0.003	0.004	0.871	0.384	Rejected
H1870	$AR \rightarrow PBC \rightarrow INT$	0.001	0.001	0.002	0.419	0.675	Rejected
H1871	$AR2 \rightarrow PBC \rightarrow INT$	-0.001	-0.002	0.003	0.533	0.594	Rejected
H1876	$IF \rightarrow PBC \rightarrow INT$	-0.001	-0.001	0.002	0.526	0.599	Rejected
H1872	$IL \rightarrow PBC \rightarrow INT$	-0.004	-0.004	0.004	1.131	0.258	Rejected
H1852	$AR \rightarrow A_B \rightarrow INT$	0.011	0.011	0.044	0.263	0.793	Rejected
H1874	$PFC \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.003	0.971	0.332	Rejected
H1853	$AR2 \rightarrow A_B \rightarrow INT$	0.002	0.006	0.037	0.064	0.949	Rejected
H1875	$PFC2 \rightarrow PBC \rightarrow INT$	-0.004	-0.004	0.004	1.030	0.303	Rejected
H1858	$IF \rightarrow A_B \rightarrow INT$	0.030	0.031	0.038	0.788	0.431	Rejected
H1877	$RB \rightarrow PBC \rightarrow INT$	-0.004	-0.004	0.004	1.010	0.313	Rejected
H1854	$IL \rightarrow A_B \rightarrow INT$	0.062	0.059	0.038	1.620	0.105	Rejected
H1878	$RB2 \rightarrow PBC \rightarrow INT$	-0.000	-0.000	0.002	0.147	0.883	Rejected
H1873	$SS \rightarrow PBC \rightarrow INT$	-0.002	-0.002	0.002	0.793	0.428	Rejected
H1856	$PFC \rightarrow A_B \rightarrow INT$	0.055	0.054	0.037	1.467	0.142	Rejected
H1857	$PFC2 \rightarrow A_B \rightarrow INT$	0.018	0.020	0.037	0.493	0.622	Rejected
H1859	$RB \rightarrow A_B \rightarrow INT$	0.036	0.035	0.032	1.107	0.268	Rejected
H1860	$RB2 \rightarrow A_B \rightarrow INT$	0.029	0.028	0.045	0.638	0.523	Rejected
H1855	$SS \rightarrow A_B \rightarrow INT$	0.003	0.004	0.037	0.093	0.926	Rejected
H1861	$AR \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.002	0.436	0.663	Rejected
H1853	$AR2 \rightarrow A_B \rightarrow INT$	-0.002	-0.003	0.003	0.716	0.474	Rejected
H1867	$IF \rightarrow SN \rightarrow INT$	-0.001	-0.002	0.003	0.575	0.565	Rejected
H1863	$IL \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.002	0.435	0.663	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table F.13: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1879	$AR \rightarrow INT$	0.011	0.011	0.044	0.261	0.794	Rejected
H1880	$AR2 \rightarrow INT$	-0.002	0.002	0.038	0.040	0.968	Rejected
H1885	$IF \rightarrow INT$	0.027	0.028	0.038	0.716	0.474	Rejected
H1881	$IL \rightarrow INT$	0.057	0.054	0.039	1.480	0.139	Rejected
H1883	$PFC \rightarrow INT$	0.051	0.051	0.037	1.372	0.170	Rejected
H1884	$PFC2 \rightarrow INT$	0.016	0.018	0.038	0.416	0.677	Rejected
H1886	$RB \rightarrow INT$	0.031	0.030	0.032	0.955	0.339	Rejected
H1887	$RB2 \rightarrow INT$	0.027	0.025	0.046	0.586	0.558	Rejected
H1882	$SS \rightarrow INT$	-0.002	-0.002	0.038	0.055	0.956	Rejected

Source: Project team compilation

Table F.14: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Small-Scale Maize Irrigators in the Tshiombo Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1840	$A_B \rightarrow INT$	0.603	0.602	0.028	21.382	0.000***	Accepted
H1813	$AR \rightarrow A_B$	0.019	0.018	0.072	0.264	0.792	Rejected
H1843	$AR \rightarrow INT$	-0.004	-0.002	0.022	0.167	0.867	Rejected
H1831	$AR \rightarrow PBC$	-0.034	-0.032	0.059	0.575	0.565	Rejected
H1822	$AR \rightarrow SN$	0.046	0.049	0.062	0.742	0.458	Rejected
H1814	$AR2 \rightarrow A_B$	0.004	0.010	0.062	0.064	0.949	Rejected
H1844	$AR2 \rightarrow INT$	-0.011	-0.010	0.024	0.471	0.638	Rejected
H1831	$AR2 \rightarrow PBC$	0.051	0.056	0.068	0.755	0.450	Rejected
H1823	$AR2 \rightarrow SN$	0.119	0.121	0.065	1.843	0.065	Rejected
H1819	$IF \rightarrow A_B$	0.049	0.052	0.064	0.776	0.438	Rejected
H1849	$IF \rightarrow INT$	0.661	0.661	0.029	22.735	0.000***	Accepted
H1837	$IF \rightarrow PBC$	0.046	0.045	0.061	0.757	0.449	Rejected
H1828	$IF \rightarrow SN$	0.071	0.070	0.061	1.165	0.244	Rejected
H1815	$IL \rightarrow A_B$	0.103	0.098	0.062	1.653	0.098	Rejected
H1845	$IL \rightarrow INT$	0.002	0.002	0.022	0.077	0.939	Rejected
H1833	$IL \rightarrow PBC$	0.147	0.147	0.054	2.725	0.006***	Accepted
H1824	$IL \rightarrow SN$	0.046	0.047	0.060	0.758	0.449	Rejected
H1842	$PBC \rightarrow INT$	-0.028	-0.028	0.021	1.323	0.186	Rejected
H1817	$PFC \rightarrow A_B$	0.091	0.090	0.062	1.460	0.144	Rejected
H1847	$PFC \rightarrow INT$	0.013	0.011	0.024	0.524	0.600	Rejected
H1835	$PFC \rightarrow PBC$	0.116	0.115	0.065	1.785	0.074	Rejected
H1826	$PFC \rightarrow SN$	0.008	0.006	0.068	0.122	0.903	Rejected
H1818	$PFC2 \rightarrow A_B$	0.030	0.034	0.062	0.492	0.623	Rejected
H1848	$PFC2 \rightarrow INT$	-0.036	-0.035	0.024	1.500	0.134	Rejected
H1836	$PFC2 \rightarrow PBC$	0.139	0.140	0.064	2.179	0.029**	Accepted
H1827	$PFC2 \rightarrow SN$	-0.063	-0.063	0.062	1.006	0.315	Rejected
H1820	$RB \rightarrow A_B$	0.060	0.058	0.054	1.106	0.269	Rejected
H1850	$RB \rightarrow INT$	-0.005	-0.004	0.024	0.197	0.843	Rejected
H1838	$RB \rightarrow PBC$	0.132	0.131	0.059	2.251	0.024**	Accepted
H1829	$RB \rightarrow SN$	0.063	0.064	0.062	1.022	0.307	Rejected
H1821	$RB2 \rightarrow A_B$	0.048	0.045	0.075	0.643	0.520	Rejected
H1851	$RB2 \rightarrow INT$	-0.047	-0.046	0.023	2.044	0.041	Rejected
H1839	$RB2 \rightarrow PBC$	0.011	0.015	0.061	0.184	0.854	Rejected
H1830	$RB2 \rightarrow SN$	0.084	0.091	0.068	1.229	0.219	Rejected
H1841	$SN \rightarrow INT$	-0.021	-0.021	0.022	0.949	0.343	Rejected
H1816	$SS \rightarrow A_B$	0.006	0.006	0.061	0.092	0.926	Rejected
H1846	$SS \rightarrow INT$	0.027	0.026	0.023	1.159	0.247	Rejected
H1834	$SS \rightarrow PBC$	0.070	0.069	0.055	1.260	0.208	Rejected
H1825	$SS \rightarrow SN$	0.172	0.169	0.060	2.845	0.004***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table F.15: Total Effects (Sum of Direct and Indirect Effects) for Adaptation Towards Climate Variability by Small-Scale Maize Irrigators in the Tshiombi Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1915	$A_B \Rightarrow INT$	0.603	0.602	0.028	21.382	0.000***	Accepted
H1888	$AR \Rightarrow A_B$	0.019	0.018	0.072	0.264	0.792	Rejected
H1918	$AR \Rightarrow INT$	0.008	0.009	0.049	0.161	0.872	Rejected
H1906	$AR \Rightarrow PBC$	-0.034	-0.032	0.059	0.575	0.565	Rejected
H1897	$AR \Rightarrow SN$	0.046	0.049	0.062	0.742	0.458	Rejected
H1889	$AR2 \Rightarrow A_B$	0.004	0.010	0.062	0.064	0.949	Rejected
H1919	$AR2 \Rightarrow INT$	-0.013	-0.008	0.044	0.285	0.776	Rejected
H1907	$AR2 \Rightarrow PBC$	0.051	0.056	0.068	0.755	0.450	Rejected
H1898	$AR2 \Rightarrow SN$	0.119	0.121	0.065	1.843	0.065	Rejected
H1894	$IF \Rightarrow A_B$	0.049	0.052	0.064	0.776	0.438	Rejected
H1924	$IF \Rightarrow INT$	0.688	0.689	0.034	20.004	0.000***	Accepted
H1912	$IF \Rightarrow PBC$	0.046	0.045	0.061	0.757	0.449	Rejected
H1903	$IF \Rightarrow SN$	0.071	0.070	0.061	1.165	0.244	Rejected
H1890	$IL \Rightarrow A_B$	0.103	0.098	0.062	1.653	0.098	Rejected
H1920	$IL \Rightarrow INT$	0.059	0.056	0.043	1.375	0.169	Rejected
H1908	$IL \Rightarrow PBC$	0.147	0.147	0.054	2.725	0.006***	Accepted
H1899	$IL \Rightarrow SN$	0.046	0.047	0.060	0.758	0.449	Rejected
H1917	$PBC \Rightarrow INT$	-0.028	-0.028	0.021	1.323	0.186	Rejected
H1891	$PFC \Rightarrow A_B$	0.091	0.090	0.062	1.460	0.144	Rejected
H1922	$PFC \Rightarrow INT$	0.064	0.062	0.044	1.461	0.144	Rejected
H1910	$PFC \Rightarrow PBC$	0.116	0.115	0.065	1.785	0.074	Rejected
H1901	$PFC \Rightarrow SN$	0.008	0.006	0.068	0.122	0.903	Rejected
H1893	$PFC2 \Rightarrow A_B$	0.030	0.034	0.062	0.492	0.623	Rejected
H1923	$PFC2 \Rightarrow INT$	-0.021	-0.017	0.044	0.465	0.642	Rejected
H1911	$PFC2 \Rightarrow PBC$	0.139	0.140	0.064	2.179	0.029**	Accepted
H1902	$PFC2 \Rightarrow SN$	-0.063	-0.063	0.062	1.006	0.315	Rejected
H1895	$RB \Rightarrow A_B$	0.060	0.058	0.054	1.106	0.269	Rejected
H1925	$RB \Rightarrow INT$	0.026	0.026	0.042	0.626	0.531	Rejected
H1913	$RB \Rightarrow PBC$	0.132	0.131	0.059	2.251	0.024**	Accepted
H1904	$RB \Rightarrow SN$	0.063	0.064	0.062	1.022	0.307	Rejected
H1896	$RB2 \Rightarrow A_B$	0.048	0.045	0.075	0.643	0.520	Rejected
H1926	$RB2 \Rightarrow INT$	-0.020	-0.021	0.047	0.431	0.667	Rejected
H1914	$RB2 \Rightarrow PBC$	0.011	0.015	0.061	0.184	0.854	Rejected
H1905	$RB2 \Rightarrow SN$	0.084	0.091	0.068	1.229	0.219	Rejected
H1916	$SN \Rightarrow INT$	-0.021	-0.021	0.022	0.949	0.343	Rejected
H1891	$SS \Rightarrow A_B$	0.006	0.006	0.061	0.092	0.926	Rejected
H1921	$SS \Rightarrow INT$	0.025	0.024	0.044	0.566	0.571	Rejected
H1909	$SS \Rightarrow PBC$	0.070	0.069	0.055	1.260	0.208	Rejected
H1900	$SS \Rightarrow SN$	0.172	0.169	0.060	2.845	0.004***	Accepted

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Appendix G

Table G.1: Hypothesis Testing Results for the Structural Model of Wheat Irrigators' Intentions to Adopt Water-Saving Technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H316	$A_B \rightarrow INT$	0.211	0.213	0.074	2.854	0.004***	Accepted
H317	$SN \rightarrow INT$	0.12	0.122	0.152	0.803	0.422	Reject
H318	$PBC \rightarrow INT$	0.328	0.327	0.095	3.469	0.001***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.2: Specific Indirect Effects of Constructs on Wheat Irrigators' Intentions to Adopt Water-Saving Technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H374	$IL \rightarrow PBC \rightarrow INT$	0.000	-0.002	0.012	0.024	0.981	Rejected
H368	$RB \rightarrow SN \rightarrow INT$	0.004	0.007	0.018	0.228	0.819	Rejected
H367	$RB_2 \rightarrow SN \rightarrow INT$	-0.004	-0.007	0.019	0.194	0.846	Rejected
H355	$AR \rightarrow A_B \rightarrow INT$	0.001	0.000	0.005	0.121	0.904	Rejected
H372	$PFC \rightarrow PBC \rightarrow INT$	0.013	0.010	0.014	0.947	0.344	Rejected
H362	$TF \rightarrow SN \rightarrow INT$	-0.001	0.002	0.010	0.099	0.921	Rejected
H358	$IL \rightarrow A_B \rightarrow INT$	-0.002	0.000	0.007	0.237	0.812	Rejected
H376	$RB \rightarrow PBC \rightarrow INT$	0.016	0.021	0.023	0.696	0.486	Rejected
H362	$TX \rightarrow SN \rightarrow INT$	0.007	0.007	0.029	0.23	0.818	Rejected
H375	$RB_2 \rightarrow PBC \rightarrow INT$	0.008	0.009	0.011	0.721	0.471	Rejected
H356	$PFC \rightarrow AB \rightarrow INT$	0.005	0.001	0.015	0.301	0.764	Rejected
H373	$TF \rightarrow PBC \rightarrow INT$	0.015	0.013	0.013	1.141	0.254	Rejected
H360	$RB \rightarrow A_B \rightarrow INT$	0.005	0.005	0.015	0.327	0.744	Rejected
H370	$TX \rightarrow PBC \rightarrow INT$	-0.005	-0.004	0.014	0.338	0.735	Rejected
H359	$RB_2 \rightarrow A_B \rightarrow INT$	0.000	0.000	0.006	0.059	0.953	Rejected
H357	$TF \rightarrow A_B \rightarrow INT$	0.002	0.001	0.007	0.29	0.772	Rejected
H354	$TX \rightarrow A_B \rightarrow INT$	0.001	0.001	0.009	0.163	0.871	Rejected
H363	$AR \rightarrow SN \rightarrow INT$	0.005	0.008	0.023	0.208	0.835	Rejected
H366	$IL \rightarrow SN \rightarrow INT$	0.001	0.002	0.012	0.087	0.931	Rejected
H371	$AR \rightarrow PBC \rightarrow INT$	0.004	0.004	0.009	0.424	0.671	Rejected
H364	$PFC \rightarrow SN \rightarrow INT$	0.002	0.002	0.015	0.111	0.911	Rejected

Source: Project team compilation

Table G.3: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H379	$AR \rightarrow INT$	0.009	0.012	0.026	0.362	0.717	Rejected
H382	$IL \rightarrow INT$	-0.001	0	0.018	0.054	0.957	Rejected
H380	$PFC \rightarrow INT$	0.019	0.013	0.025	0.762	0.446	Rejected
H384	$RB \rightarrow INT$	0.025	0.033	0.028	0.899	0.368	Rejected
H383	$RB_2 \rightarrow INT$	0.004	0.002	0.022	0.19	0.85	Rejected
H381	$TF \rightarrow INT$	0.016	0.015	0.018	0.869	0.385	Rejected
H378	$TX \rightarrow INT$	0.003	0.004	0.033	0.104	0.917	Rejected

Source: Project team compilation

Table G.4: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H343	$A_B \rightarrow INT$	0.020	0.017	0.056	0.351	0.725	Rejected
H320	$AR \rightarrow A_B$	0.032	0.019	0.087	0.367	0.714	Rejected
H345	$AR \rightarrow INT$	0.020	0.019	0.055	0.37	0.712	Rejected
H336	$AR \rightarrow PBC$	0.047	0.042	0.081	0.577	0.564	Rejected
H328	$AR \rightarrow SN$	0.217	0.206	0.115	1.89	0.059	Rejected
H323	$IL \rightarrow A_B$	-0.088	-0.082	0.103	0.848	0.396	Rejected
H349	$IL \rightarrow INT$	-0.017	-0.019	0.068	0.248	0.804	Rejected
H339	$IL \rightarrow PBC$	-0.003	-0.001	0.108	0.031	0.975	Rejected
H331	$IL \rightarrow SN$	0.048	0.044	0.117	0.406	0.684	Rejected
H353	$PBC \rightarrow INT$	0.085	0.090	0.062	1.373	0.170	Rejected
H321	$PFC \rightarrow A_B$	0.228	0.220	0.141	1.62	0.105	Rejected
H346	$PFC \rightarrow INT$	0.002	0.014	0.088	0.021	0.983	Rejected
H337	$PFC \rightarrow PBC$	0.154	0.140	0.123	1.251	0.211	Rejected
H329	$PFC \rightarrow SN$	0.077	0.074	0.127	0.607	0.544	Rejected
H325	$RB \rightarrow A_B$	0.256	0.254	0.089	2.879	0.004	Accepted
H351	$RB \rightarrow INT$	0.529	0.511	0.069	7.699	0.000***	Accepted
H341	$RB \rightarrow PBC$	0.192	0.196	0.148	1.295	0.196	Rejected
H333	$RB \rightarrow SN$	0.179	0.158	0.082	2.176	0.030**	Accepted
H324	$RB_2 \rightarrow A_B$	-0.018	-0.013	0.096	0.184	0.854	Rejected
H350	$RB_2 \rightarrow INT$	0.118	0.118	0.066	1.778	0.075	Rejected
H340	$RB_2 \rightarrow PBC$	0.098	0.102	0.088	1.116	0.264	Rejected
H332	$RB_2 \rightarrow SN$	-0.165	-0.154	0.112	1.474	0.140	Rejected
H348	$SN \rightarrow INT$	0.022	0.039	0.095	0.235	0.814	Rejected
H322	$TF \rightarrow A_B$	0.110	0.100	0.094	1.169	0.242	Rejected
H347	$TF \rightarrow INT$	0.436	0.438	0.05	8.652	0.000***	Accepted
H338	$TF \rightarrow PBC$	0.175	0.166	0.100	1.746	0.081	Rejected
H330	$TF \rightarrow SN$	-0.045	-0.022	0.099	0.452	0.651	Rejected
H319	$TX \rightarrow A_B$	0.074	0.081	0.127	0.579	0.563	Rejected
H344	$TX \rightarrow INT$	0.025	0.035	0.081	0.311	0.755	Rejected
H335	$TX \rightarrow PBC$	-0.056	-0.065	0.127	0.442	0.659	Rejected
H327	$TX \rightarrow SN$	0.302	0.254	0.181	1.675	0.094	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table G.5: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Technologies by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H410	$A_B \Rightarrow INT$	0.020	0.017	0.056	0.351	0.725	Rejected
H387	$AR \Rightarrow A_B$	0.032	0.019	0.087	0.367	0.714	Rejected
H412	$AR \Rightarrow INT$	0.03	0.031	0.059	0.502	0.616	Rejected
H403	$AR \Rightarrow PBC$	0.047	0.042	0.081	0.577	0.564	Rejected
H395	$AR \Rightarrow SN$	0.217	0.206	0.115	1.890	0.059	Rejected
H390	$IL \Rightarrow A_B$	-0.088	-0.082	0.103	0.848	0.396	Rejected
H416	$IL \Rightarrow INT$	-0.018	-0.018	0.066	0.271	0.786	Rejected
H406	$IL \Rightarrow PBC$	-0.003	-0.001	0.108	0.031	0.975	Rejected
H398	$IL \Rightarrow SN$	0.048	0.044	0.117	0.406	0.684	Rejected
H420	$PBC \Rightarrow INT$	0.085	0.090	0.062	1.373	0.170	Rejected
H388	$PFC \Rightarrow A_B$	0.228	0.22	0.141	1.62	0.105	Rejected
H413	$PFC \Rightarrow INT$	0.021	0.027	0.086	0.246	0.805	Rejected
H404	$PFC \Rightarrow PBC$	0.154	0.14	0.123	1.251	0.211	Rejected
H396	$PFC \Rightarrow SN$	0.077	0.074	0.127	0.607	0.544	Rejected
H392	$RB \Rightarrow A_B$	0.256	0.254	0.089	2.879	0.004***	Accepted
H418	$RB \Rightarrow INT$	0.554	0.544	0.066	8.407	0.000***	Accepted
H408	$RB \Rightarrow PBC$	0.192	0.196	0.148	1.295	0.196	Rejected
H400	$RB \Rightarrow SN$	0.179	0.158	0.082	2.176	0.030**	Accepted
H391	$RB_2 \Rightarrow A_B$	-0.018	-0.013	0.096	0.184	0.854	Rejected
H417	$RB_2 \Rightarrow INT$	0.122	0.119	0.066	1.853	0.064	Rejected
H407	$RB_2 \Rightarrow PBC$	0.098	0.102	0.088	1.116	0.264	Rejected
H399	$RB_2 \Rightarrow SN$	-0.165	-0.154	0.112	1.474	0.140	Rejected
H415	$SN \Rightarrow INT$	0.022	0.039	0.095	0.235	0.814	Rejected
H389	$TF \Rightarrow A_B$	0.110	0.100	0.094	1.169	0.242	Rejected
H414	$TF \Rightarrow INT$	0.452	0.453	0.051	8.928	0.000***	Accepted
H405	$TF \Rightarrow PBC$	0.175	0.166	0.100	1.746	0.081	Rejected
H397	$TF \Rightarrow SN$	-0.045	-0.022	0.099	0.452	0.651	Rejected
H386	$TX \Rightarrow A_B$	0.074	0.081	0.127	0.579	0.563	Rejected
H411	$TX \Rightarrow INT$	0.029	0.039	0.078	0.368	0.713	Rejected
H402	$TX \Rightarrow PBC$	-0.056	-0.065	0.127	0.442	0.659	Rejected
H394	$TX \Rightarrow SN$	0.302	0.254	0.181	1.675	0.094	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table G.6: Hypothesis Testing Results for the Structural Model of Wheat Irrigators' Intentions to Adopt Water-Saving Policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H421	$A_B \rightarrow INT$	-0.229	-0.228	0.078	2.949	0.003***	Accepted
H422	$SN \rightarrow INT$	N/A	N/A	N/A	N/A	N/A	N/A
H423	$PBC \rightarrow INT$	0.027	0.032	0.104	0.255	0.799	Reject

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.7: Specific Indirect Effects of Constructs on Wheat Irrigators' Intentions to Adopt Water-Saving Policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H482	$IF \rightarrow PBC \rightarrow INT$	0.000	-0.001	0.004	0.001	0.500	Rejected
H469	$PFC \rightarrow SN \rightarrow INT$	-0.002	-0.001	0.008	0.282	0.389	Rejected
H479	$IL \rightarrow PBC \rightarrow INT$	-0.000	-0.001	0.006	0.035	0.486	Rejected
H473	$RB \rightarrow SN \rightarrow INT$	0.000	0.000	0.005	0.044	0.482	Rejected
H472	$RB_2 \rightarrow SN \rightarrow INT$	0.003	0.002	0.010	0.342	0.366	Rejected
H460	$AR \rightarrow A_B \rightarrow INT$	0.003	0.002	0.008	0.352	0.362	Rejected
H477	$PFC \rightarrow PBC \rightarrow INT$	-0.000	0.000	0.005	0.016	0.494	Rejected
H470	$TF \rightarrow SN \rightarrow INT$	0.001	0.001	0.005	0.287	0.387	Rejected
H466	$IF \rightarrow A_B \rightarrow INT$	-0.004	-0.002	0.012	0.369	0.356	Rejected
H481	$RB \rightarrow PBC \rightarrow INT$	-0.000	-0.000	0.006	0.017	0.493	Rejected
H467	$TX \rightarrow SN \rightarrow INT$	-0.003	-0.001	0.011	0.258	0.398	Rejected
H463	$IL \rightarrow A_B \rightarrow INT$	-0.002	-0.001	0.008	0.208	0.418	Rejected
H480	$RB_2 \rightarrow PBC \rightarrow INT$	0.000	-0.000	0.006	0.018	0.493	Rejected
H478	$TF \rightarrow PBC \rightarrow INT$	0.000	-0.000	0.003	0.001	0.500	Rejected
H461	$PFC \rightarrow AB \rightarrow INT$	0.001	0.001	0.005	0.201	0.420	Rejected
H475	$TX \rightarrow PBC \rightarrow INT$	0.000	0.000	0.005	0.023	0.491	Rejected
H465	$RB \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.007	0.310	0.378	Rejected
H464	$RB_2 \rightarrow A_B \rightarrow INT$	0.001	-0.000	0.005	0.233	0.408	Rejected
H462	$TF \rightarrow A_B \rightarrow INT$	0.001	0.002	0.008	0.138	0.445	Rejected
H459	$TX \rightarrow A_B \rightarrow INT$	0.002	0.002	0.006	0.281	0.389	Rejected
H468	$AR \rightarrow SN \rightarrow INT$	0.001	0.001	0.008	0.169	0.433	Rejected
H474	$IF \rightarrow SN \rightarrow INT$	-0.002	-0.001	0.007	0.268	0.394	Rejected
H471	$IL \rightarrow SN \rightarrow INT$	-0.003	-0.001	0.009	0.295	0.384	Rejected
H476	$AR \rightarrow PBC \rightarrow INT$	-0.000	0.000	0.005	0.018	0.493	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.8: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Policy Adoption by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H484	$AR \rightarrow INT$	0.004	0.004	0.012	0.339	0.367	Rejected
H490	$IF \rightarrow INT$	-0.006	-0.004	0.013	0.460	0.323	Rejected
H487	$IL \rightarrow INT$	-0.005	-0.003	0.013	0.346	0.365	Rejected
H485	$PFC \rightarrow INT$	-0.001	-0.000	0.010	0.123	0.451	Rejected
H489	$RB \rightarrow INT$	-0.002	-0.002	0.011	0.195	0.423	Rejected
H488	$RB_2 \rightarrow INT$	0.005	0.001	0.012	0.391	0.348	Rejected
H486	$TF \rightarrow INT$	0.002	0.003	0.009	0.255	0.399	Rejected
H483	$TX \rightarrow INT$	-0.001	0.001	0.013	0.084	0.467	Rejected

Source: Project team compilation

Table G.9: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Policy Adoption by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H448	$A_B \rightarrow INT$	0.017	0.012	0.043	0.402	0.344	Rejected
H425	$AR \rightarrow A_B$	0.167	0.159	0.113	1.479	0.070	Rejected
H450	$AR \rightarrow INT$	-0.093	-0.077	0.044	2.104	0.018**	Accepted
H441	$AR \rightarrow PBC$	0.079	0.071	0.140	0.563	0.287	Rejected
H433	$AR \rightarrow SN$	-0.097	-0.074	0.157	0.616	0.269	Rejected
H431	$IF \rightarrow A_B$	-0.245	-0.238	0.131	1.871	0.031**	Accepted
H457	$IF \rightarrow INT$	0.795	0.787	0.082	9.664	0.000***	Accepted
H447	$IF \rightarrow PBC$	-0.003	0.010	0.104	0.026	0.490	Rejected
H439	$IF \rightarrow SN$	0.133	0.127	0.098	1.356	0.088	Rejected
H428	$IL \rightarrow A_B$	-0.093	-0.098	0.160	0.581	0.281	Rejected
H454	$IL \rightarrow INT$	-0.002	-0.015	0.043	0.043	0.483	Rejected
H444	$IL \rightarrow PBC$	0.169	0.147	0.096	1.761	0.039**	Accepted
H436	$IL \rightarrow SN$	0.199	0.187	0.116	1.721	0.043**	Accepted
H458	$PBC \rightarrow INT$	-0.001	-0.000	0.035	0.036	0.486	Rejected
H426	$PFC \rightarrow A_B$	0.055	0.058	0.091	0.598	0.275	Rejected
H451	$PFC \rightarrow INT$	0.038	0.024	0.036	1.032	0.151	Rejected
H442	$PFC \rightarrow PBC$	0.065	0.045	0.134	0.489	0.312	Rejected
H434	$PFC \rightarrow SN$	0.157	0.119	0.127	1.236	0.108	Rejected
H430	$RB \rightarrow A_B$	-0.127	-0.120	0.107	1.183	0.118	Rejected
H456	$RB \rightarrow INT$	0.006	0.005	0.039	0.145	0.442	Rejected
H446	$RB \rightarrow PBC$	0.092	0.110	0.140	0.655	0.256	Rejected
H438	$RB \rightarrow SN$	-0.016	-0.002	0.117	0.137	0.445	Rejected
H429	$RB_2 \rightarrow A_B$	0.071	0.048	0.110	0.645	0.260	Rejected
H455	$RB_2 \rightarrow INT$	-0.063	-0.020	0.078	0.805	0.211	Rejected
H445	$RB_2 \rightarrow PBC$	-0.081	-0.005	0.158	0.514	0.304	Rejected
H437	$RB_2 \rightarrow SN$	-0.239	-0.153	0.148	1.617	0.053	Rejected
H453	$SN \rightarrow INT$	-0.014	-0.007	0.042	0.329	0.371	Rejected
H427	$TF \rightarrow A_B$	0.064	0.066	0.111	0.576	0.282	Rejected
H452	$TF \rightarrow INT$	0.637	0.606	0.111	5.742	0.000***	Accepted
H443	$TF \rightarrow PBC$	-0.002	0.006	0.079	0.025	0.490	Rejected
H435	$TF \rightarrow SN$	-0.095	-0.091	0.067	1.425	0.077	Rejected
H424	$TX \rightarrow A_B$	0.091	0.074	0.106	0.856	0.196	Rejected
H449	$TX \rightarrow INT$	0.027	0.019	0.041	0.654	0.257	Rejected
H440	$TX \rightarrow PBC$	-0.102	-0.102	0.118	0.859	0.195	Rejected
H432	$TX \rightarrow SN$	0.206	0.217	0.133	1.553	0.060	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$.

Source: Project team compilation

Table G.10: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Policies by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H515	$A_B \Rightarrow INT$	0.017	0.012	0.043	0.402	0.344	Rejected
H492	$AR \Rightarrow A_B$	0.167	0.159	0.113	1.479	0.070	Rejected
H517	$AR \Rightarrow INT$	-0.089	-0.073	0.043	2.076	0.019**	Accepted
H508	$AR \Rightarrow PBC$	0.079	0.071	0.140	0.563	0.287	Rejected
H500	$AR \Rightarrow SN$	-0.097	-0.074	0.157	0.616	0.269	Rejected
H498	$IF \Rightarrow A_B$	-0.245	-0.238	0.131	1.871	0.031**	Accepted
H524	$IF \Rightarrow INT$	0.789	0.783	0.083	9.548	0.000***	Accepted
H514	$IF \Rightarrow PBC$	-0.003	0.010	0.104	0.026	0.490	Rejected
H506	$IF \Rightarrow SN$	0.133	0.127	0.098	1.356	0.088	Rejected
H495	$IL \Rightarrow A_B$	-0.093	-0.098	0.160	0.581	0.281	Rejected
H521	$IL \Rightarrow INT$	-0.006	-0.018	0.040	0.160	0.436	Rejected
H511	$IL \Rightarrow PBC$	0.169	0.147	0.096	1.761	0.039**	Accepted
H503	$IL \Rightarrow SN$	0.199	0.187	0.116	1.721	0.043**	Accepted
H525	$PBC \Rightarrow INT$	-0.001	-0.000	0.035	0.036	0.486	Rejected
H493	$PFC \Rightarrow A_B$	0.055	0.058	0.091	0.598	0.275	Rejected
H518	$PFC \Rightarrow INT$	0.036	0.024	0.035	1.046	0.148	Rejected
H509	$PFC \Rightarrow PBC$	0.065	0.045	0.134	0.489	0.312	Rejected
H501	$PFC \Rightarrow SN$	0.157	0.119	0.127	1.236	0.108	Rejected
H497	$RB \Rightarrow A_B$	-0.127	-0.120	0.107	1.183	0.118	Rejected
H523	$RB \Rightarrow INT$	0.004	0.002	0.037	0.094	0.463	Rejected
H513	$RB \Rightarrow PBC$	0.092	0.110	0.140	0.655	0.256	Rejected
H505	$RB \Rightarrow SN$	-0.016	-0.002	0.117	0.137	0.445	Rejected
H496	$RB_2 \Rightarrow A_B$	0.071	0.048	0.110	0.645	0.260	Rejected
H522	$RB_2 \Rightarrow INT$	-0.058	-0.019	0.076	0.762	0.223	Rejected
H512	$RB_2 \Rightarrow PBC$	-0.081	-0.005	0.158	0.514	0.304	Rejected
H504	$RB_2 \Rightarrow SN$	-0.239	-0.153	0.148	1.617	0.053	Rejected
H520	$SN \Rightarrow INT$	-0.014	-0.007	0.042	0.329	0.371	Rejected
H494	$TF \Rightarrow A_B$	0.064	0.066	0.111	0.576	0.282	Rejected
H519	$TF \Rightarrow INT$	0.640	0.609	0.112	5.731	0.000***	Accepted
H510	$TF \Rightarrow PBC$	-0.002	0.006	0.079	0.025	0.490	Rejected
H502	$TF \Rightarrow SN$	-0.095	-0.091	0.067	1.425	0.077	Rejected
H491	$TX \Rightarrow A_B$	0.091	0.074	0.106	0.856	0.196	Rejected
H516	$TX \Rightarrow INT$	0.026	0.020	0.038	0.672	0.251	Rejected
H507	$TX \Rightarrow PBC$	-0.102	-0.102	0.118	0.859	0.195	Rejected
H499	$TX \Rightarrow SN$	0.206	0.217	0.133	1.553	0.060	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.11: Hypothesis Testing Results for the Structural Model of Wheat Irrigators' Intentions for Adaptation Towards Climate Variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H526	$A_B \rightarrow INT$	0.318	0.320	0.085	3.743	0.000***	Accepted
H527	$SN \rightarrow INT$	0.140	0.145	0.098	1.439	0.150	Reject
H528	$PBC \rightarrow INT$	0.058	0.074	0.105	0.548	0.584	Reject

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.12: Specific Indirect Effects of Constructs on Wheat Irrigators' Intentions for Adaptation Towards Climate Variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H584	$IL \rightarrow PBC \rightarrow INT$	0.001	-0.000	0.006	0.181	0.857	Rejected
H574	$PFC \rightarrow SN \rightarrow INT$	-0.001	-0.003	0.014	0.045	0.964	Rejected
H578	$RB \rightarrow SN \rightarrow INT$	-0.000	-0.000	0.008	0.026	0.979	Rejected
H565	$AR \rightarrow A_B \rightarrow INT$	0.012	0.013	0.019	0.615	0.539	Rejected
H582	$PFC \rightarrow PBC \rightarrow INT$	-0.001	0.000	0.006	0.133	0.894	Rejected
H572	$TF \rightarrow SN \rightarrow INT$	-0.000	-0.001	0.006	0.006	0.995	Rejected
H568	$IL \rightarrow A_B \rightarrow INT$	0.024	0.020	0.016	1.436	0.151	Rejected
H586	$RB \rightarrow PBC \rightarrow INT$	0.005	0.004	0.016	0.344	0.731	Rejected
H572	$TX \rightarrow SN \rightarrow INT$	-0.000	-0.001	0.009	0.034	0.973	Rejected
H580	$TF \rightarrow PBC \rightarrow INT$	0.000	0.001	0.006	0.066	0.947	Rejected
H566	$PFC \rightarrow A_B \rightarrow INT$	0.027	0.026	0.025	1.082	0.279	Rejected
H580	$TX \rightarrow PBC \rightarrow INT$	0.003	0.002	0.012	0.249	0.804	Rejected
H570	$RB \rightarrow A_B \rightarrow INT$	0.000	0.000	0.018	0.002	0.998	Rejected
H567	$TF \rightarrow A_B \rightarrow INT$	0.029	0.029	0.023	1.268	0.205	Rejected
H564	$TX \rightarrow A_B \rightarrow INT$	-0.006	0.008	0.022	0.250	0.803	Rejected
H573	$AR \rightarrow SN \rightarrow INT$	-0.000	-0.002	0.012	0.042	0.967	Rejected
H576	$IL \rightarrow SN \rightarrow INT$	-0.001	-0.005	0.018	0.046	0.963	Rejected
H581	$AR \rightarrow PBC \rightarrow INT$	0.004	0.004	0.014	0.257	0.797	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.13: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H589	$AR \rightarrow INT$	0.015	0.015	0.026	0.563	0.573	Rejected
H592	$IL \rightarrow INT$	0.024	0.015	0.024	0.985	0.324	Rejected
H590	$PFC \rightarrow INT$	0.026	0.023	0.029	0.903	0.366	Rejected
H594	$RB \rightarrow INT$	0.005	0.004	0.024	0.216	0.829	Rejected
H591	$TF \rightarrow INT$	0.029	0.030	0.024	1.218	0.223	Rejected
H588	$TX \rightarrow INT$	-0.003	0.009	0.026	0.114	0.909	Rejected

Source: Project team compilation

Table G.14: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H553	$A_B \rightarrow INT$	0.163	0.163	0.059	2.774	0.006***	Accepted
H530	$AR \rightarrow A_B$	0.072	0.077	0.106	0.679	0.497	Rejected
H555	$AR \rightarrow INT$	0.027	0.037	0.059	0.452	0.651	Rejected
H546	$AR \rightarrow PBC$	0.165	0.181	0.114	1.447	0.148	Rejected
H538	$AR \rightarrow SN$	0.154	0.150	0.113	1.370	0.171	Rejected
H533	$IL \rightarrow A_B$	0.145	0.129	0.095	1.533	0.125	Rejected
H559	$IL \rightarrow INT$	0.039	0.053	0.056	0.694	0.488	Rejected
H549	$IL \rightarrow PBC$	0.052	0.044	0.090	0.577	0.564	Rejected
H541	$IL \rightarrow SN$	0.255	0.253	0.104	2.450	0.014**	Accepted
H563	$PBC \rightarrow INT$	0.022	0.020	0.061	0.356	0.722	Rejected
H556	$PFC \rightarrow INT$	0.168	0.157	0.136	1.233	0.218	Rejected
H531	$PFC \rightarrow A_B$	0.007	0.031	0.092	0.074	0.941	Rejected
H547	$PFC \rightarrow PBC$	-0.034	0.002	0.091	0.380	0.704	Rejected
H539	$PFC \rightarrow SN$	0.190	0.182	0.110	1.724	0.085	Rejected
H535	$RB \rightarrow A_B$	0.000	0.001	0.105	0.003	0.998	Rejected
H561	$RB \rightarrow INT$	0.545	0.541	0.061	8.931	0.000***	Accepted
H551	$RB \rightarrow PBC$	0.247	0.223	0.115	2.151	0.031**	Accepted
H543	$RB \rightarrow SN$	0.062	0.058	0.102	0.612	0.540	Rejected
H558	$SN \rightarrow INT$	-0.003	-0.017	0.063	0.051	0.959	Rejected
H532	$TF \rightarrow A_B$	0.178	0.175	0.111	1.605	0.108	Rejected
H557	$TF \rightarrow INT$	0.397	0.392	0.061	6.484	0.000***	Accepted
H548	$TF \rightarrow PBC$	0.018	0.018	0.092	0.191	0.848	Rejected
H540	$TF \rightarrow SN$	0.011	0.006	0.096	0.119	0.905	Rejected
H529	$TX \rightarrow A_B$	-0.034	0.049	0.131	0.260	0.795	Rejected
H554	$TX \rightarrow INT$	-0.102	-0.025	0.115	0.886	0.376	Rejected
H545	$TX \rightarrow PBC$	0.135	0.074	0.164	0.824	0.410	Rejected
H537	$TX \rightarrow SN$	0.089	0.044	0.120	0.738	0.460	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table G.15: Total Effects (Sum of Direct and Indirect Effects) for Adaptation Towards Climate Variability by Wheat Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H620	$A_B \Rightarrow INT$	0.163	0.163	0.059	2.774	0.006***	Accepted
H597	$AR \Rightarrow A_B$	0.072	0.077	0.106	0.679	0.497	Rejected
H622	$AR \Rightarrow INT$	0.041	0.052	0.058	0.711	0.477	Rejected
H613	$AR \Rightarrow PBC$	0.165	0.181	0.114	1.447	0.148	Rejected
H605	$AR \Rightarrow SN$	0.154	0.150	0.113	1.370	0.171	Rejected
H600	$IL \Rightarrow A_B$	0.145	0.129	0.095	1.533	0.125	Rejected
H626	$IL \Rightarrow INT$	0.063	0.068	0.054	1.164	0.244	Rejected
H616	$IL \Rightarrow PBC$	0.052	0.044	0.090	0.577	0.564	Rejected
H608	$IL \Rightarrow SN$	0.255	0.253	0.104	2.450	0.014**	Accepted
H630	$PBC \Rightarrow INT$	0.022	0.020	0.061	0.356	0.722	Rejected
H623	$PFC \Rightarrow INT$	0.168	0.157	0.136	1.233	0.218	Rejected
H598	$PFC \Rightarrow A_B$	0.033	0.054	0.086	0.380	0.704	Rejected
H614	$PFC \Rightarrow PBC$	-0.034	0.002	0.091	0.380	0.704	Rejected
H606	$PFC \Rightarrow SN$	0.190	0.182	0.110	1.724	0.085	Rejected
H602	$RB \Rightarrow A_B$	0.000	0.001	0.105	0.003	0.998	Rejected
H628	$RB \Rightarrow INT$	0.551	0.545	0.061	9.090	0.000***	Accepted
H618	$RB \Rightarrow PBC$	0.247	0.223	0.115	2.151	0.031**	Accepted
H610	$RB \Rightarrow SN$	0.062	0.058	0.102	0.612	0.540	Rejected
H625	$SN \Rightarrow INT$	-0.003	-0.017	0.063	0.051	0.959	Rejected
H599	$TF \Rightarrow A_B$	0.178	0.175	0.111	1.605	0.108	Rejected
H624	$TF \Rightarrow INT$	0.426	0.421	0.057	7.455	0.000	Accepted
H615	$TF \Rightarrow PBC$	0.018	0.018	0.092	0.191	0.848	Rejected
H607	$TF \Rightarrow SN$	0.011	0.006	0.096	0.119	0.905	Rejected
H596	$TX \Rightarrow A_B$	-0.034	0.049	0.131	0.260	0.795	Rejected
H621	$TX \Rightarrow INT$	-0.105	-0.016	0.119	0.880	0.379	Rejected
H612	$TX \Rightarrow PBC$	0.135	0.074	0.164	0.824	0.410	Rejected
H612	$TX \Rightarrow SN$	0.089	0.044	0.120	0.738	0.460	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Appendix H

Table H.1: Hypothesis Testing Results for the Structural Model of Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1	$A_B \rightarrow INT$	0.306	0.307	0.102	2.982	0.003***	Accepted
H2	$SN \rightarrow INT$	0.111	0.134	0.119	0.926	0.354	Rejected
H3	$PBC \rightarrow INT$	0.245	0.242	0.103	2.376	0.018**	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.2: Specific Indirect Effects of Constructs on Maize Irrigators' Intentions to Adopt Water-Saving Technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H59	$IL \rightarrow PBC \rightarrow INT$	-0.001	0.000	0.009	0.073	0.942	Rejected
H53	$RB \rightarrow SN \rightarrow INT$	0.008	0.008	0.012	0.616	0.538	Rejected
H52	$RB_2 \rightarrow SN \rightarrow INT$	-0.002	-0.002	0.007	0.282	0.778	Rejected
H40	$AR \rightarrow A_B \rightarrow INT$	-0.01	-0.01	0.011	0.854	0.393	Rejected
H57	$PFC \rightarrow PBC \rightarrow INT$	-0.001	0.000	0.01	0.077	0.939	Rejected
H50	$TF \rightarrow SN \rightarrow INT$	0.001	0.006	0.012	0.125	0.900	Rejected
H43	$IL \rightarrow A_B \rightarrow INT$	-0.003	0.000	0.012	0.248	0.804	Rejected
H61	$RB \rightarrow PBC \rightarrow INT$	-0.001	0.001	0.01	0.082	0.934	Rejected
H47	$TX \rightarrow SN \rightarrow INT$	0.014	0.015	0.022	0.647	0.517	Rejected
H60	$RB_2 \rightarrow PBC \rightarrow INT$	0.000	0.000	0.003	0.023	0.982	Rejected
H41	$PFC \rightarrow AB \rightarrow INT$	0.008	0.007	0.015	0.542	0.588	Rejected
H58	$TF \rightarrow PBC \rightarrow INT$	-0.001	0.000	0.014	0.089	0.929	Rejected
H45	$RB \rightarrow A_B \rightarrow INT$	0.032	0.031	0.020	1.631	0.103	Rejected
H55	$TX \rightarrow PBC \rightarrow INT$	0.001	0.000	0.009	0.082	0.934	Rejected
H44	$RB_2 \rightarrow A_B \rightarrow INT$	0.022	0.022	0.021	1.044	0.297	Rejected
H42	$TF \rightarrow A_B \rightarrow INT$	0.004	0.001	0.011	0.377	0.706	Rejected
H39	$TX \rightarrow A_B \rightarrow INT$	0.022	0.023	0.020	1.064	0.287	Rejected
H48	$AR \rightarrow SN \rightarrow INT$	0.007	0.009	0.014	0.528	0.597	Rejected
H51	$IL \rightarrow SN \rightarrow INT$	0.001	0.002	0.01	0.132	0.895	Rejected
H56	$AR \rightarrow PBC \rightarrow INT$	0.001	0.000	0.009	0.081	0.935	Rejected
H49	$PFC \rightarrow SN \rightarrow INT$	0.001	0.002	0.012	0.083	0.934	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.3: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H64	$AR \rightarrow INT$	-0.002	0.000	0.023	0.069	0.945	Rejected
H67	$IL \rightarrow INT$	-0.002	0.002	0.018	0.120	0.904	Rejected
H65	$PFC \rightarrow INT$	0.008	0.009	0.024	0.346	0.729	Rejected
H69	$RB \rightarrow INT$	0.039	0.041	0.022	1.78	0.075	Rejected
H68	$RB_2 \rightarrow INT$	0.020	0.02	0.022	0.881	0.378	Rejected
H66	$TF \rightarrow INT$	0.004	0.007	0.021	0.219	0.827	Rejected
H63	$TX \rightarrow INT$	0.036	0.037	0.028	1.276	0.202	Rejected

Source: Project team compilation

Table H.4: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H28	$A_B \rightarrow INT$	0.111	0.109	0.061	1.822	0.068	Rejected
H5	$AR \rightarrow A_B$	-0.088	-0.083	0.075	1.169	0.242	Rejected
H30	$AR \rightarrow INT$	-0.027	-0.024	0.052	0.516	0.606	Rejected
H21	$AR \rightarrow PBC$	-0.160	-0.158	0.075	2.153	0.031**	Accepted
H13	$AR \rightarrow SN$	0.147	0.133	0.102	1.440	0.150	Rejected
H8	$IL \rightarrow A_B$	-0.026	-0.005	0.094	0.277	0.782	Rejected
H34	$IL \rightarrow INT$	0.012	0.010	0.060	0.191	0.848	Rejected
H24	$IL \rightarrow PBC$	0.134	0.133	0.100	1.343	0.179	Rejected
H16	$IL \rightarrow SN$	0.027	0.042	0.112	0.240	0.810	Rejected
H38	$PBC \rightarrow INT$	-0.005	0.000	0.052	0.092	0.927	Rejected
H6	$PFC \rightarrow A_B$	0.072	0.062	0.112	0.642	0.521	Rejected
H31	$PFC \rightarrow INT$	-0.043	-0.043	0.051	0.844	0.399	Rejected
H22	$PFC \rightarrow PBC$	0.167	0.160	0.103	1.616	0.106	Rejected
H14	$PFC \rightarrow SN$	0.019	0.003	0.132	0.146	0.884	Rejected
H10	$RB \rightarrow A_B$	0.288	0.280	0.064	4.482	0.000***	Accepted
H36	$RB \rightarrow INT$	0.522	0.514	0.054	9.631	0.000***	Accepted
H26	$RB \rightarrow PBC$	0.176	0.177	0.094	1.872	0.061	Rejected
H18	$RB \rightarrow SN$	0.147	0.138	0.082	1.802	0.072	Rejected
H9	$RB_2 \rightarrow A_B$	0.196	0.195	0.139	1.408	0.159	Rejected
H35	$RB_2 \rightarrow INT$	0.101	0.093	0.055	1.818	0.069	Rejected
H25	$RB_2 \rightarrow PBC$	-0.013	-0.002	0.052	0.252	0.801	Rejected
H17	$RB_2 \rightarrow SN$	-0.041	-0.024	0.080	0.509	0.611	Rejected
H33	$SN \rightarrow INT$	0.051	0.059	0.071	0.724	0.469	Rejected
H7	$TF \rightarrow A_B$	0.038	0.019	0.093	0.411	0.681	Rejected
H32	$TF \rightarrow INT$	0.538	0.533	0.052	10.399	0.000***	Accepted
H23	$TF \rightarrow PBC$	0.257	0.246	0.096	2.691	0.007***	Accepted
H15	$TF \rightarrow SN$	0.029	0.040	0.112	0.260	0.795	Rejected
H4	$TX \rightarrow A_B$	0.194	0.202	0.120	1.619	0.106	Rejected
H29	$TX \rightarrow INT$	-0.063	-0.052	0.071	0.893	0.372	Rejected
H20	$TX \rightarrow PBC$	-0.149	-0.138	0.097	1.545	0.122	Rejected
H12	$TX \rightarrow SN$	0.274	0.256	0.140	1.951	0.051	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.5: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Technologies by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H95	$A_B \Rightarrow INT$	0.111	0.109	0.061	1.822	0.068	Rejected
H72	$AR \Rightarrow A_B$	-0.088	-0.083	0.075	1.169	0.242	Rejected
H97	$AR \Rightarrow INT$	-0.028	-0.025	0.052	0.550	0.582	Rejected
H88	$AR \Rightarrow PBC$	-0.160	-0.158	0.075	2.153	0.031**	Accepted
H80	$AR \Rightarrow SN$	0.147	0.133	0.102	1.440	0.150	Rejected
H75	$IL \Rightarrow A_B$	-0.026	-0.005	0.094	0.277	0.782	Rejected
H101	$IL \Rightarrow INT$	0.009	0.012	0.058	0.163	0.871	Rejected
H91	$IL \Rightarrow PBC$	0.134	0.133	0.100	1.343	0.179	Rejected
H83	$IL \Rightarrow SN$	0.027	0.042	0.112	0.240	0.810	Rejected
H105	$PBC \Rightarrow INT$	-0.005	0.000	0.052	0.092	0.927	Rejected
H73	$PFC \Rightarrow A_B$	0.072	0.062	0.112	0.642	0.521	Rejected
H98	$PFC \Rightarrow INT$	-0.035	-0.034	0.050	0.706	0.480	Rejected
H89	$PFC \Rightarrow PBC$	0.167	0.160	0.103	1.616	0.106	Rejected
H81	$PFC \Rightarrow SN$	0.019	0.003	0.132	0.146	0.884	Rejected
H77	$RB \Rightarrow A_B$	0.288	0.28	0.064	4.482	0.000***	Accepted
H103	$RB \Rightarrow INT$	0.560	0.555	0.050	11.175	0.000***	Accepted
H93	$RB \Rightarrow PBC$	0.176	0.177	0.094	1.872	0.061	Rejected
H85	$RB \Rightarrow SN$	0.147	0.138	0.082	1.802	0.072	Rejected
H76	$RB_2 \Rightarrow A_B$	0.196	0.195	0.139	1.408	0.159	Rejected
H102	$RB_2 \Rightarrow INT$	0.121	0.113	0.064	1.873	0.061	Rejected
H92	$RB_2 \Rightarrow PBC$	-0.013	-0.002	0.052	0.252	0.801	Rejected
H84	$RB_2 \Rightarrow SN$	-0.041	-0.024	0.080	0.509	0.611	Rejected
H100	$SN \Rightarrow INT$	0.051	0.059	0.071	0.724	0.469	Rejected
H74	$TF \Rightarrow A_B$	0.038	0.019	0.093	0.411	0.681	Rejected
H99	$TF \Rightarrow INT$	0.542	0.540	0.054	10.087	0.000***	Accepted
H90	$TF \Rightarrow PBC$	0.257	0.246	0.096	2.691	0.007***	Accepted
H82	$TF \Rightarrow SN$	0.029	0.040	0.112	0.26	0.795	Rejected
H71	$TX \Rightarrow A_B$	0.194	0.202	0.120	1.619	0.106	Rejected
H96	$TX \Rightarrow INT$	-0.027	-0.014	0.067	0.403	0.687	Rejected
H87	$TX \Rightarrow PBC$	-0.149	-0.138	0.097	1.545	0.122	Rejected
H79	$TX \Rightarrow SN$	0.274	0.256	0.14	1.951	0.051	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table H.6: Hypothesis Testing Results for the Structural Model of Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H106	$A_R \rightarrow INT$	-0.279	-0.280	0.082	3.395	0.001***	Accepted
H107	$SN \rightarrow INT$	0.054	0.039	0.125	0.435	0.663**	Rejected
H108	$PBC \rightarrow INT$	0.007	0.010	0.101	0.065	0.948	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table H.7: Specific Indirect Effects of Constructs on Maize Irrigators' Intentions to Adopt Water-Saving Policies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H167	$IF \rightarrow PBC \rightarrow INT$	0.001	0.001	0.005	0.284	0.776	Rejected
H154	$PFC \rightarrow SN \rightarrow INT$	0.000	0.000	0.004	0.026	0.979	Rejected
H164	$IL \rightarrow PBC \rightarrow INT$	-0.017	-0.013	0.013	1.262	0.207	Rejected
H158	$RB \rightarrow SN \rightarrow INT$	0.001	0.000	0.007	0.091	0.928	Rejected
H157	$RB_2 \rightarrow SN \rightarrow INT$	0.000	0.000	0.006	0.06	0.952	Rejected
H145	$AR \rightarrow A_B \rightarrow INT$	-0.003	-0.002	0.005	0.563	0.574	Rejected
H162	$PFC \rightarrow PBC \rightarrow INT$	-0.002	-0.002	0.005	0.484	0.629	Rejected
H155	$TF \rightarrow SN \rightarrow INT$	0.000	0.000	0.003	0.043	0.965	Rejected
H151	$IF \rightarrow A_B \rightarrow INT$	-0.007	-0.007	0.010	0.701	0.483	Rejected
H166	$RB \rightarrow PBC \rightarrow INT$	-0.002	-0.003	0.006	0.394	0.693	Rejected
H152	$TX \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.010	0.077	0.939	Rejected
H148	$IL \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.004	0.431	0.666	Rejected
H165	$RB_2 \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.004	0.689	0.491	Rejected
H160	$TF \rightarrow PBC \rightarrow INT$	0.001	0.001	0.004	0.316	0.752	Rejected
H146	$PFC \rightarrow AB \rightarrow INT$	0.001	0.001	0.003	0.383	0.702	Rejected
H160	$TX \rightarrow PBC \rightarrow INT$	0.000	-0.001	0.005	0.099	0.921	Rejected
H150	$RB \rightarrow A_B \rightarrow INT$	-0.001	-0.002	0.004	0.341	0.733	Rejected
H149	$RB_2 \rightarrow A_B \rightarrow INT$	0.002	0.002	0.005	0.448	0.654	Rejected
H147	$TF \rightarrow A_B \rightarrow INT$	0.001	0.002	0.004	0.405	0.685	Rejected
H144	$TX \rightarrow A_B \rightarrow INT$	0.001	0.000	0.003	0.157	0.876	Rejected
H153	$AR \rightarrow SN \rightarrow INT$	0.000	0.000	0.003	0.001	0.999	Rejected
H159	$IF \rightarrow SN \rightarrow INT$	0.000	-0.001	0.006	0.074	0.941	Rejected
H156	$IL \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.013	0.088	0.930	Rejected
H161	$AR \rightarrow PBC \rightarrow INT$	0.007	0.006	0.007	0.981	0.326	Rejected

Source: Project team compilation

Table H.8: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Policy Adoption by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H169	$AR \rightarrow INT$	0.004	0.004	0.009	0.442	0.658	Rejected
H175	$IF \rightarrow INT$	-0.006	-0.006	0.012	0.511	0.609	Rejected
H172	$IL \rightarrow INT$	-0.019	-0.016	0.016	1.215	0.224	Rejected
H170	$PFC \rightarrow INT$	-0.001	-0.001	0.007	0.153	0.879	Rejected
H174	$RB \rightarrow INT$	-0.003	-0.004	0.01	0.317	0.751	Rejected
H173	$RB_2 \rightarrow INT$	-0.001	-0.001	0.01	0.111	0.911	Rejected
H171	$TF \rightarrow INT$	0.003	0.003	0.006	0.485	0.627	Rejected
H168	$TX \rightarrow INT$	-0.001	-0.001	0.012	0.059	0.953	Rejected

Source: Project team compilation

Table H.9: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Policy Adoption by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H133	$A_R \rightarrow INT$	0.019	0.019	0.027	0.726	0.468	Rejected
H110	$AR \rightarrow A_R$	-0.145	-0.136	0.109	1.324	0.185	Rejected
H135	$AR \rightarrow INT$	-0.077	-0.074	0.032	2.416	0.016**	Accepted
H126	$AR \rightarrow PBC$	-0.154	-0.165	0.086	1.793	0.073	Rejected
H118	$AR \rightarrow SN$	-0.001	-0.004	0.080	0.012	0.991	Rejected
H116	$IF \rightarrow A_R$	-0.357	-0.344	0.102	3.494	0.000***	Accepted
H142	$IF \rightarrow INT$	-0.011	-0.006	0.036	0.300	0.764	Rejected
H132	$IF \rightarrow PBC$	-0.032	-0.029	0.098	0.330	0.742	Rejected
H124	$IF \rightarrow SN$	0.144	0.154	0.085	1.695	0.090	Rejected
H113	$IL \rightarrow A_R$	-0.091	-0.091	0.093	0.977	0.329	Rejected
H139	$IL \rightarrow INT$	-0.002	-0.002	0.030	0.073	0.942	Rejected
H129	$IL \rightarrow PBC$	0.379	0.356	0.119	3.178	0.001***	Accepted
H121	$IL \rightarrow SN$	0.340	0.339	0.089	3.809	0.000	Accepted
H143	$PBC \rightarrow INT$	-0.044	-0.037	0.033	1.320	0.187	Rejected
H111	$PFC \rightarrow A_R$	0.066	0.076	0.081	0.808	0.419	Rejected
H136	$PFC \rightarrow INT$	0.712	0.715	0.067	10.584	0.000***	Accepted
H127	$PFC \rightarrow PBC$	0.050	0.046	0.084	0.594	0.553	Rejected
H119	$PFC \rightarrow SN$	0.030	0.039	0.093	0.318	0.751	Rejected
H115	$RB \rightarrow A_R$	-0.068	-0.069	0.094	0.723	0.47	Rejected
H141	$RB \rightarrow INT$	0.645	0.637	0.061	10.534	0.000***	Accepted
H131	$RB \rightarrow PBC$	0.057	0.059	0.116	0.489	0.625	Rejected
H123	$RB \rightarrow SN$	-0.189	-0.174	0.086	2.197	0.028**	Accepted
H114	$RB_2 \rightarrow A_R$	0.116	0.073	0.15	0.775	0.438	Rejected
H140	$RB_2 \rightarrow INT$	0.000	-0.004	0.028	0.017	0.986	Rejected
H130	$RB_2 \rightarrow PBC$	0.067	0.077	0.07	0.957	0.338	Rejected
H122	$RB_2 \rightarrow SN$	0.117	0.089	0.149	0.782	0.434	Rejected
H138	$SN \rightarrow INT$	-0.003	-0.004	0.036	0.091	0.928	Rejected
H112	$TF \rightarrow A_R$	0.074	0.069	0.09	0.828	0.407	Rejected
H137	$TF \rightarrow INT$	-0.011	-0.014	0.025	0.436	0.663	Rejected
H128	$TF \rightarrow PBC$	-0.027	-0.026	0.075	0.361	0.718	Rejected
H120	$TF \rightarrow SN$	-0.043	-0.056	0.069	0.626	0.532	Rejected
H109	$TX \rightarrow A_R$	0.028	0.006	0.101	0.272	0.785	Rejected
H134	$TX \rightarrow INT$	-0.006	-0.011	0.035	0.171	0.864	Rejected
H125	$TX \rightarrow PBC$	0.011	0.013	0.095	0.112	0.911	Rejected
H117	$TX \rightarrow SN$	0.231	0.237	0.119	1.937	0.053	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.10: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Policies by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H200	$A_R \rightarrow INT$	0.020	0.020	0.027	0.741	0.458	Rejected
H177	$AR \rightarrow A_R$	-0.151	-0.142	0.108	1.404	0.160	Rejected
H202	$AR \rightarrow INT$	-0.075	-0.071	0.031	2.410	0.016**	Accepted
H193	$AR \rightarrow PBC$	-0.128	-0.141	0.084	1.521	0.128	Rejected
H185	$AR \rightarrow SN$	0.020	0.014	0.083	0.247	0.805	Rejected
H183	$IF \rightarrow A_R$	-0.341	-0.329	0.100	3.417	0.001***	Accepted
H209	$IF \rightarrow INT$	-0.017	-0.013	0.035	0.485	0.628	Rejected
H199	$IF \rightarrow PBC$	-0.065	-0.059	0.101	0.644	0.520	Rejected
H191	$IF \rightarrow SN$	0.132	0.145	0.085	1.568	0.117	Rejected
H180	$IL \rightarrow A_R$	-0.130	-0.129	0.097	1.337	0.181	Rejected
H206	$IL \rightarrow INT$	-0.015	-0.012	0.027	0.539	0.590	Rejected
H196	$IL \rightarrow PBC$	0.409	0.386	0.129	3.169	0.002***	Accepted
H188	$IL \rightarrow SN$	0.296	0.299	0.095	3.119	0.002***	Accepted
H210	$PBC \rightarrow INT$	-0.048	-0.041	0.034	1.393	0.164	Rejected
H178	$PFC \rightarrow A_R$	0.064	0.075	0.081	0.790	0.429	Rejected
H203	$PFC \rightarrow INT$	0.711	0.714	0.067	10.554	0.000***	Accepted
H194	$PFC \rightarrow PBC$	0.051	0.047	0.085	0.601	0.548	Rejected
H186	$PFC \rightarrow SN$	0.028	0.036	0.094	0.294	0.769	Rejected
H182	$RB \rightarrow A_R$	-0.066	-0.066	0.092	0.714	0.475	Rejected
H208	$RB \rightarrow INT$	0.639	0.631	0.059	10.770	0.000***	Accepted
H198	$RB \rightarrow PBC$	0.066	0.068	0.115	0.578	0.564	Rejected
H190	$RB \rightarrow SN$	-0.168	-0.155	0.085	1.973	0.049**	Accepted
H181	$RB_2 \rightarrow A_R$	0.114	0.072	0.149	0.768	0.442	Rejected
H207	$RB_2 \rightarrow INT$	-0.001	-0.005	0.029	0.040	0.968	Rejected
H197	$RB_2 \rightarrow PBC$	0.069	0.078	0.070	0.978	0.328	Rejected
H189	$RB_2 \rightarrow SN$	0.114	0.088	0.147	0.780	0.435	Rejected
H205	$SN \rightarrow INT$	-0.006	-0.007	0.035	0.176	0.860	Rejected
H179	$TF \rightarrow A_R$	0.075	0.070	0.089	0.845	0.398	Rejected
H204	$TF \rightarrow INT$	-0.008	-0.011	0.024	0.333	0.739	Rejected
H195	$TF \rightarrow PBC$	-0.031	-0.030	0.074	0.418	0.676	Rejected
H187	$TF \rightarrow SN$	-0.046	-0.058	0.068	0.688	0.492	Rejected
H176	$TX \rightarrow A_R$	0.042	0.019	0.100	0.419	0.675	Rejected
H201	$TX \rightarrow INT$	-0.008	-0.014	0.034	0.226	0.821	Rejected
H192	$TX \rightarrow PBC$	-0.012	-0.007	0.097	0.123	0.902	Rejected
H184	$TX \rightarrow SN$	0.230	0.239	0.124	1.856	0.064	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.11: Hypothesis Testing Results for the Structural Model of Maize Irrigators' Intentions for Adaptation Towards Climate variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H211	$A_P \rightarrow INT$	0.303	0.303	0.089	3.421	0.001***	Accepted
H212	$SN \rightarrow INT$	0.096	0.108	0.087	1.099	0.084*	Accepted
H213	$PBC \rightarrow INT$	0.153	0.165	0.088	1.730	0.272	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table H.12: Specific Indirect Effects of Constructs on Maize Irrigators' Intentions for Adaptation Towards Climate Variability in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H269	$IL \rightarrow PBC \rightarrow INT$	0.000	-0.001	0.006	0.079	0.937	Rejected
H263	$RB \rightarrow SN \rightarrow INT$	0.004	0.004	0.009	0.411	0.681	Rejected
H262	$RB_2 \rightarrow SN \rightarrow INT$	0.003	0.003	0.006	0.525	0.599	Rejected
H250	$AR \rightarrow A_R \rightarrow INT$	0.008	0.009	0.020	0.378	0.706	Rejected
H267	$PFC \rightarrow PBC \rightarrow INT$	0.001	0.001	0.006	0.196	0.845	Rejected
H260	$TF \rightarrow SN \rightarrow INT$	0.008	0.008	0.011	0.72	0.471	Rejected
H253	$IL \rightarrow A_R \rightarrow INT$	0.030	0.027	0.019	1.606	0.108	Rejected
H271	$RB \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.012	0.253	0.800	Rejected
H257	$TX \rightarrow SN \rightarrow INT$	0.001	0.001	0.008	0.124	0.902	Rejected
H270	$RB_2 \rightarrow PBC \rightarrow INT$	0.000	0.000	0.004	0.107	0.915	Rejected
H251	$PFC \rightarrow A_R \rightarrow INT$	0.026	0.025	0.018	1.437	0.151	Rejected
H265	$TF \rightarrow PBC \rightarrow INT$	0.000	0.001	0.005	0.089	0.929	Rejected
H255	$RB \rightarrow A_R \rightarrow INT$	0.003	0.005	0.018	0.178	0.859	Rejected
H265	$TX \rightarrow PBC \rightarrow INT$	0.000	-0.001	0.006	0.041	0.967	Rejected
H254	$RB_2 \rightarrow A_R \rightarrow INT$	-0.03	-0.027	0.017	1.742	0.082	Rejected
H252	$TF \rightarrow A_R \rightarrow INT$	0.036	0.038	0.025	1.440	0.150	Rejected
H249	$TX \rightarrow A_R \rightarrow INT$	-0.006	-0.009	0.022	0.293	0.769	Rejected
H258	$AR \rightarrow SN \rightarrow INT$	0.004	0.005	0.010	0.424	0.671	Rejected
H261	$IL \rightarrow SN \rightarrow INT$	0.012	0.008	0.012	0.977	0.329	Rejected
H266	$AR \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.013	0.223	0.824	Rejected
H259	$PFC \rightarrow SN \rightarrow INT$	0.012	0.011	0.013	0.926	0.354	Rejected

Source: Project team compilation

Table H.13: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H274	$AR \rightarrow INT$	0.009	0.011	0.027	0.334	0.739	Rejected
H277	$IL \rightarrow INT$	0.041	0.035	0.023	1.796	0.073	Rejected
H275	$PFC \rightarrow INT$	0.039	0.037	0.025	1.608	0.108	Rejected
H279	$RB \rightarrow INT$	0.004	0.006	0.025	0.150	0.880	Rejected
H278	$RB_2 \rightarrow INT$	-0.026	-0.024	0.019	1.365	0.172	Rejected
H276	$TF \rightarrow INT$	0.045	0.047	0.029	1.534	0.125	Rejected
H273	$TX \rightarrow INT$	-0.006	-0.009	0.025	0.225	0.822	Rejected

Source: Project team compilation

Table H.14: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H238	$A_B \rightarrow INT$	0.168	0.165	0.06	2.814	0.005***	Accepted
H215	$AR \rightarrow A_B$	0.045	0.059	0.113	0.402	0.687	Rejected
H240	$AR \rightarrow INT$	0.047	0.045	0.052	0.907	0.365	Rejected
H231	$AR \rightarrow PBC$	0.178	0.192	0.118	1.500	0.134	Rejected
H223	$AR \rightarrow SN$	0.069	0.080	0.112	0.613	0.540	Rejected
H218	$IL \rightarrow A_B$	0.177	0.170	0.098	1.809	0.070	Rejected
H244	$IL \rightarrow INT$	0.002	0.005	0.051	0.044	0.965	Rejected
H234	$IL \rightarrow PBC$	0.030	0.025	0.104	0.291	0.771	Rejected
H226	$IL \rightarrow SN$	0.188	0.184	0.103	1.823	0.068	Rejected
H248	$PBC \rightarrow INT$	-0.016	-0.016	0.054	0.293	0.770	Rejected
H241	$PFC \rightarrow INT$	0.158	0.155	0.095	1.661	0.097	Rejected
H216	$PFC \rightarrow A_B$	-0.040	-0.039	0.049	0.825	0.409	Rejected
H232	$PFC \rightarrow PBC$	-0.071	-0.063	0.081	0.873	0.383	Rejected
H224	$PFC \rightarrow SN$	0.193	0.196	0.085	2.285	0.022**	Accepted
H220	$RB \rightarrow A_B$	0.019	0.024	0.104	0.187	0.852	Rejected
H246	$RB \rightarrow INT$	0.581	0.578	0.051	11.385	0.000***	Accepted
H236	$RB \rightarrow PBC$	0.193	0.183	0.116	1.662	0.097	Rejected
H228	$RB \rightarrow SN$	0.058	0.062	0.099	0.583	0.560	Rejected
H219	$RB_2 \rightarrow A_B$	-0.178	-0.162	0.087	2.056	0.040**	Accepted
H245	$RB_2 \rightarrow INT$	0.007	0.006	0.022	0.292	0.770	Rejected
H235	$RB_2 \rightarrow PBC$	-0.03	-0.032	0.075	0.404	0.686	Rejected
H227	$RB_2 \rightarrow SN$	0.053	0.045	0.071	0.745	0.456	Rejected
H243	$SN \rightarrow INT$	0.061	0.055	0.055	1.123	0.262	Rejected
H217	$TF \rightarrow A_B$	0.216	0.221	0.106	2.039	0.041**	Accepted
H242	$TF \rightarrow INT$	0.415	0.419	0.064	6.472	0.000***	Accepted
H233	$TF \rightarrow PBC$	-0.031	-0.019	0.096	0.32	0.749	Rejected
H225	$TF \rightarrow SN$	0.130	0.142	0.097	1.334	0.182	Rejected
H214	$TX \rightarrow A_B$	-0.038	-0.039	0.121	0.312	0.755	Rejected
H239	$TX \rightarrow INT$	0.082	0.085	0.061	1.334	0.182	Rejected
H230	$TX \rightarrow PBC$	0.015	0.018	0.103	0.150	0.881	Rejected
H222	$TX \rightarrow SN$	0.015	0.016	0.099	0.154	0.877	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table H.15: Total Effects (Sum of Direct and Indirect Effects) for Adaptation Towards Climate Variability by Maize Irrigators in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H305	$A_B \Rightarrow INT$	0.168	0.165	0.06	2.814	0.005***	Accepted
H282	$AR \Rightarrow A_B$	0.045	0.059	0.113	0.402	0.687	Rejected
H307	$AR \Rightarrow INT$	0.056	0.056	0.058	0.960	0.337	Rejected
H298	$AR \Rightarrow PBC$	0.178	0.192	0.118	1.500	0.134	Rejected
H290	$AR \Rightarrow SN$	0.069	0.080	0.112	0.613	0.540	Rejected
H285	$IL \Rightarrow A_B$	0.177	0.170	0.098	1.809	0.070	Rejected
H311	$IL \Rightarrow INT$	0.043	0.040	0.052	0.823	0.411	Rejected
H301	$IL \Rightarrow PBC$	0.030	0.025	0.104	0.291	0.771	Rejected
H293	$IL \Rightarrow SN$	0.188	0.184	0.103	1.823	0.068	Rejected
H315	$PBC \Rightarrow INT$	-0.016	-0.016	0.054	0.293	0.770	Rejected
H308	$PFC \Rightarrow INT$	0.158	0.155	0.095	1.661	0.097	Rejected
H283	$PFC \Rightarrow A_B$	-0.001	-0.002	0.043	0.019	0.985	Rejected
H299	$PFC \Rightarrow PBC$	-0.071	-0.063	0.081	0.873	0.383	Rejected
H291	$PFC \Rightarrow SN$	0.193	0.196	0.085	2.285	0.022**	Accepted
H287	$RB \Rightarrow A_B$	0.019	0.024	0.104	0.187	0.852	Rejected
H313	$RB \Rightarrow INT$	0.585	0.584	0.053	11.023	0.000***	Accepted
H303	$RB \Rightarrow PBC$	0.193	0.183	0.116	1.662	0.097	Rejected
H295	$RB \Rightarrow SN$	0.058	0.062	0.099	0.583	0.560	Rejected
H286	$RB_2 \Rightarrow A_B$	-0.178	-0.162	0.087	2.056	0.040**	Accepted
H312	$RB_2 \Rightarrow INT$	-0.020	-0.017	0.025	0.792	0.429	Rejected
H302	$RB_2 \Rightarrow PBC$	-0.030	-0.032	0.075	0.404	0.686	Rejected
H294	$RB_2 \Rightarrow SN$	0.053	0.045	0.071	0.745	0.456	Rejected
H310	$SN \Rightarrow INT$	0.061	0.055	0.055	1.123	0.262	Rejected
H284	$TF \Rightarrow A_B$	0.216	0.221	0.106	2.039	0.041**	Accepted
H309	$TF \Rightarrow INT$	0.460	0.466	0.061	7.515	0.000***	Accepted
H300	$TF \Rightarrow PBC$	-0.031	-0.019	0.096	0.320	0.749	Rejected
H284	$TF \Rightarrow SN$	0.130	0.142	0.097	1.334	0.182	Rejected
H281	$TX \Rightarrow A_B$	-0.038	-0.039	0.121	0.312	0.755	Rejected
H306	$TX \Rightarrow INT$	0.076	0.076	0.071	1.080	0.28	Rejected
H297	$TX \Rightarrow PBC$	0.015	0.018	0.103	0.150	0.881	Rejected
H289	$TX \Rightarrow SN$	0.015	0.016	0.099	0.154	0.877	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Appendix I

Table I.1: Hypothesis Testing Results for the Structural Model of Lucerne Irrigators' Intentions to Adopt Water-Saving Technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1261	$A_B \rightarrow INT$	0.332	0.339	0.069	4.792	0.000***	Accepted
H1262	$SN \rightarrow INT$	0.224	0.222	0.077	2.897	0.004***	Accepted
H1263	$PBC \rightarrow INT$	0.111	0.121	0.088	1.262	0.207	Reject

Note: $*\rho < 0.1$, $**\rho < 0.05$, $***\rho < 0.01$

Source: Project team compilation

Table I.2: Specific Indirect Effects of Constructs on Intentions to Adopt Water-Saving Technologies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1322	$IF \rightarrow PBC \rightarrow INT$	-0.002	-0.002	0.002	0.831	0.406	Rejected
H1309	$PFC \rightarrow SN \rightarrow INT$	-0.001	-0.001	0.003	0.221	0.825	Rejected
H1319	$IL \rightarrow PBC \rightarrow INT$	-0.000	-0.000	0.003	0.068	0.946	Rejected
H1313	$RB \rightarrow SN \rightarrow INT$	0.001	0.002	0.003	0.259	0.795	Rejected
H1312	$RB_2 \rightarrow SN \rightarrow INT$	0.000	-0.000	0.002	0.077	0.938	Rejected
H1300	$AR \rightarrow A_B \rightarrow INT$	-0.002	-0.001	0.003	0.530	0.596	Rejected
H1317	$PFC \rightarrow PBC \rightarrow INT$	-0.002	-0.002	0.003	0.719	0.472	Rejected
H1307	$TF \rightarrow SN \rightarrow INT$	0.000	0.000	0.002	0.146	0.884	Rejected
H1306	$IF \rightarrow A_B \rightarrow INT$	-0.003	-0.002	0.005	0.638	0.523	Rejected
H1321	$RB \rightarrow PBC \rightarrow INT$	-0.004	-0.004	0.004	0.999	0.318	Rejected
H1307	$TX \rightarrow SN \rightarrow INT$	0.003	0.003	0.005	0.544	0.586	Rejected
H1303	$IL \rightarrow A_B \rightarrow INT$	-0.000	-0.001	0.002	0.060	0.952	Rejected
H1320	$RB_2 \rightarrow PBC \rightarrow INT$	0.000	-0.000	0.002	0.007	0.995	Rejected
H1318	$TF \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.003	0.949	0.343	Rejected
H1301	$PFC \rightarrow AB \rightarrow INT$	0.000	-0.000	0.002	0.025	0.980	Rejected
H1315	$TX \rightarrow PBC \rightarrow INT$	-0.001	-0.001	0.002	0.579	0.562	Rejected
H1304	$RB \rightarrow A_B \rightarrow INT$	-0.002	-0.002	0.004	0.506	0.613	Rejected
H1304	$RB_2 \rightarrow A_B \rightarrow INT$	-0.001	-0.001	0.002	0.338	0.736	Rejected
H1302	$TF \rightarrow A_B \rightarrow INT$	-0.001	-0.001	0.002	0.310	0.757	Rejected
H1299	$TX \rightarrow A_B \rightarrow INT$	-0.000	-0.001	0.002	0.201	0.840	Rejected
H1308	$AR \rightarrow SN \rightarrow INT$	0.000	0.000	0.002	0.131	0.896	Rejected
H1314	$IF \rightarrow SN \rightarrow INT$	-0.001	-0.000	0.002	0.229	0.819	Rejected
H1311	$IL \rightarrow SN \rightarrow INT$	0.001	0.001	0.003	0.279	0.780	Rejected
H1316	$AR \rightarrow PBC \rightarrow INT$	0.002	0.002	0.003	0.806	0.420	Rejected

Source: Project team compilation

Table I.3: Summary of Total Indirect Effects in the Augmented TPB Model for Water-Saving Technology Adoption in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1324	$AR \rightarrow INT$	0.001	0.001	0.005	0.124	0.901	Rejected
H1330	$IF \rightarrow INT$	-0.006	-0.004	0.006	0.948	0.343	Rejected
H1327	$IL \rightarrow INT$	0.001	-0.000	0.005	0.117	0.907	Rejected
H1325	$PFC \rightarrow INT$	-0.003	-0.003	0.005	0.587	0.557	Rejected
H1329	$RB \rightarrow INT$	-0.006	-0.005	0.007	0.830	0.406	Rejected
H1328	$RB_2 \rightarrow INT$	-0.001	-0.001	0.003	0.160	0.873	Rejected
H1326	$TF \rightarrow INT$	-0.003	-0.003	0.004	0.754	0.451	Rejected
H1323	$TX \rightarrow INT$	0.001	0.001	0.006	0.155	0.877	Rejected

Source: Project team compilation

Table I.4: Summary of Direct Effects in the Augmented TPB Model for Water-Saving Technology Adoption in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1288	$A_B \rightarrow INT$	-0.013	-0.011	0.020	0.668	0.504	Rejected
H1265	$AR \rightarrow A_B$	0.134	0.125	0.098	1.371	0.171	Rejected
H1290	$AR \rightarrow INT$	-0.027	-0.022	0.020	1.365	0.172	Rejected
H1281	$AR \rightarrow PBC$	-0.097	-0.091	0.085	1.132	0.257	Rejected
H1273	$AR \rightarrow SN$	0.028	0.026	0.099	0.287	0.774	Rejected
H1271	$IF \rightarrow A_B$	0.242	0.238	0.095	2.552	0.011**	Accepted
H1297	$IF \rightarrow INT$	0.545	0.545	0.039	14.117	0.000***	Accepted
H1287	$IF \rightarrow PBC$	0.095	0.093	0.082	1.159	0.247	Rejected
H1279	$IF \rightarrow SN$	-0.050	-0.022	0.103	0.491	0.623	Rejected
H1268	$IL \rightarrow A_B$	0.011	0.015	0.100	0.108	0.914	Rejected
H1294	$IL \rightarrow INT$	0.018	0.021	0.020	0.891	0.373	Rejected
H1284	$IL \rightarrow PBC$	0.009	0.014	0.117	0.078	0.938	Rejected
H1276	$IL \rightarrow SN$	0.087	0.062	0.141	0.619	0.536	Rejected
H1298	$PBC \rightarrow INT$	-0.022	-0.021	0.014	1.502	0.133	Rejected
H1266	$PFC \rightarrow A_B$	-0.004	0.013	0.087	0.043	0.966	Rejected
H1291	$PFC \rightarrow INT$	-0.018	-0.015	0.022	0.834	0.404	Rejected
H1282	$PFC \rightarrow PBC$	0.101	0.110	0.099	1.018	0.308	Rejected
H1274	$PFC \rightarrow SN$	-0.058	-0.056	0.111	0.522	0.602	Rejected
H1270	$RB \rightarrow A_B$	0.158	0.161	0.102	1.553	0.120	Rejected
H1296	$RB \rightarrow INT$	0.646	0.641	0.034	18.845	0.000***	Accepted
H1286	$RB \rightarrow PBC$	0.198	0.201	0.114	1.741	0.082	Rejected
H1278	$RB \rightarrow SN$	0.079	0.097	0.106	0.745	0.457	Rejected
H1269	$RB_2 \rightarrow A_B$	0.057	0.050	0.094	0.606	0.545	Rejected
H1295	$RB_2 \rightarrow INT$	-0.009	-0.008	0.017	0.528	0.598	Rejected
H1285	$RB_2 \rightarrow PBC$	-0.001	-0.002	0.066	0.008	0.994	Rejected
H1277	$RB_2 \rightarrow SN$	0.018	0.004	0.104	0.171	0.864	Rejected
H1293	$SN \rightarrow INT$	0.011	0.013	0.018	0.580	0.562	Rejected
H1267	$TF \rightarrow A_B$	0.042	0.033	0.072	0.578	0.564	Rejected
H1292	$TF \rightarrow INT$	-0.001	0.000	0.019	0.052	0.959	Rejected
H1283	$TF \rightarrow PBC$	0.127	0.121	0.089	1.435	0.151	Rejected
H1275	$TF \rightarrow SN$	0.029	0.036	0.089	0.320	0.749	Rejected
H1264	$TX \rightarrow A_B$	0.036	0.054	0.095	0.378	0.705	Rejected
H1289	$TX \rightarrow INT$	-0.006	-0.008	0.020	0.313	0.754	Rejected
H1280	$TX \rightarrow PBC$	0.063	0.056	0.084	0.749	0.454	Rejected
H1272	$TX \rightarrow SN$	0.262	0.194	0.168	1.560	0.119	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.5: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1355	$A_B \Rightarrow INT$	-0.013	-0.011	0.020	0.668	0.504	Rejected
H1332	$AR \Rightarrow A_B$	0.134	0.125	0.098	1.371	0.171	Rejected
H1357	$AR \Rightarrow INT$	-0.026	-0.021	0.019	1.368	0.171	Rejected
H1348	$AR \Rightarrow PBC$	-0.097	-0.091	0.085	1.132	0.257	Rejected
H1340	$AR \Rightarrow SN$	0.028	0.026	0.099	0.287	0.774	Rejected
H1338	$IF \Rightarrow A_B$	0.242	0.238	0.095	2.552	0.011**	Accepted
H1364	$IF \Rightarrow INT$	0.539	0.541	0.039	13.980	0.000***	Accepted
H1354	$IF \Rightarrow PBC$	0.095	0.093	0.082	1.159	0.247	Rejected
H1346	$IF \Rightarrow SN$	-0.050	-0.022	0.103	0.491	0.623	Rejected
H1335	$IL \Rightarrow A_B$	0.011	0.015	0.100	0.108	0.914	Rejected
H1361	$IL \Rightarrow INT$	0.018	0.020	0.019	0.944	0.345	Rejected
H1351	$IL \Rightarrow PBC$	0.009	0.014	0.117	0.078	0.938	Rejected
H1343	$IL \Rightarrow SN$	0.087	0.062	0.141	0.619	0.536	Rejected
H1365	$PBC \Rightarrow INT$	-0.022	-0.021	0.014	1.502	0.133	Rejected
H1333	$PFC \Rightarrow A_B$	-0.004	0.013	0.087	0.043	0.966	Rejected
H1358	$PFC \Rightarrow INT$	-0.021	-0.018	0.022	0.962	0.336	Rejected
H1349	$PFC \Rightarrow PBC$	0.101	0.110	0.099	1.018	0.308	Rejected
H1341	$PFC \Rightarrow SN$	-0.058	-0.056	0.111	0.522	0.602	Rejected
H1337	$RB \Rightarrow A_B$	0.158	0.161	0.102	1.553	0.120	Rejected
H1363	$RB \Rightarrow INT$	0.640	0.636	0.033	19.195	0.000***	Accepted
H1353	$RB \Rightarrow PBC$	0.198	0.201	0.114	1.741	0.082	Rejected
H1345	$RB \Rightarrow SN$	0.079	0.097	0.106	0.745	0.457	Rejected
H1336	$RB_2 \Rightarrow A_B$	0.057	0.050	0.094	0.606	0.545	Rejected
H1362	$RB_2 \Rightarrow INT$	-0.010	-0.009	0.018	0.541	0.589	Rejected
H1352	$RB_2 \Rightarrow PBC$	-0.001	-0.002	0.066	0.008	0.994	Rejected
H1344	$RB_2 \Rightarrow SN$	0.018	0.004	0.104	0.171	0.864	Rejected
H1360	$SN \Rightarrow INT$	0.011	0.013	0.018	0.580	0.562	Rejected
H1334	$TF \Rightarrow A_B$	0.042	0.033	0.072	0.578	0.564	Rejected
H1359	$TF \Rightarrow INT$	-0.004	-0.003	0.019	0.207	0.836	Rejected
H1350	$TF \Rightarrow PBC$	0.127	0.121	0.089	1.435	0.151	Rejected
H1342	$TF \Rightarrow SN$	0.029	0.036	0.089	0.320	0.749	Rejected
H1331	$TX \Rightarrow A_B$	0.036	0.054	0.095	0.378	0.705	Rejected
H1356	$TX \Rightarrow INT$	-0.005	-0.007	0.020	0.271	0.786	Rejected
H1347	$TX \Rightarrow PBC$	0.063	0.056	0.084	0.749	0.454	Rejected
H1339	$TX \Rightarrow SN$	0.262	0.194	0.168	1.560	0.119	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.6: Hypothesis Testing Results for the Structural Model of Lucerne Irrigators' Intentions to Adopt Water-Saving Policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1366	$A_B \rightarrow INT$	-0.201	-0.212	0.081	2.488	0.013**	Accepted
H1367	$SN \rightarrow INT$	0.219	0.235	0.069	3.188	0.001***	Accepted
H1368	$PBC \rightarrow INT$	0.141	0.141	0.089	1.584	0.113	Reject

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.7: Specific Indirect Effects of Constructs on Intentions to Adopt Water-Saving Policies in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1427	$IF \rightarrow PBC \rightarrow INT$	0.008	0.004	0.017	0.460	0.645	Rejected
H1424	$IL \rightarrow PBC \rightarrow INT$	0.015	0.015	0.015	0.973	0.331	Rejected
H1417	$RB_2 \rightarrow SN \rightarrow INT$	0.002	0.002	0.010	0.229	0.819	Rejected
H1405	$AR \rightarrow A_B \rightarrow INT$	-0.015	-0.015	0.018	0.853	0.394	Rejected
H1425	$RB_2 \rightarrow PBC \rightarrow INT$	-0.003	-0.003	0.009	0.347	0.729	Rejected
H1415	$TF \rightarrow SN \rightarrow INT$	-0.002	-0.002	0.009	0.276	0.783	Rejected
H1411	$IF \rightarrow A_B \rightarrow INT$	0.020	0.018	0.022	0.908	0.364	Rejected
H1412	$TX \rightarrow SN \rightarrow INT$	0.021	0.022	0.025	0.831	0.406	Rejected
H1408	$IL \rightarrow A_B \rightarrow INT$	0.006	0.005	0.013	0.481	0.631	Rejected
H1420	$TF \rightarrow PBC \rightarrow INT$	0.004	0.004	0.009	0.412	0.680	Rejected
H1420	$TX \rightarrow PBC \rightarrow INT$	0.016	0.017	0.017	0.905	0.366	Rejected
H1409	$RB_2 \rightarrow A_B \rightarrow INT$	-0.003	-0.003	0.011	0.295	0.768	Rejected
H1423	$TF \rightarrow A_B \rightarrow INT$	0.002	0.001	0.007	0.235	0.814	Rejected
H1404	$TX \rightarrow A_B \rightarrow INT$	-0.002	-0.003	0.011	0.216	0.829	Rejected
H1413	$AR \rightarrow SN \rightarrow INT$	-0.000	0.002	0.012	0.012	0.991	Rejected
H1419	$IF \rightarrow SN \rightarrow INT$	0.008	0.007	0.011	0.683	0.495	Rejected
H1421	$AR \rightarrow PBC \rightarrow INT$	-0.009	-0.006	0.016	0.548	0.584	Rejected
H1416	$IL \rightarrow SN \rightarrow INT$	0.016	0.020	0.021	0.776	0.438	Rejected

Source: Project team compilation

Table I.8: Summary of Total Indirect Effects in the Augmented TPB Model for Water-Saving Policies Adoption in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1429	$AR \rightarrow INT$	-0.024	-0.019	0.030	0.812	0.417	Rejected
H1435	$IF \rightarrow INT$	0.035	0.030	0.030	1.192	0.233	Rejected
H1432	$IL \rightarrow INT$	0.037	0.039	0.029	1.270	0.204	Rejected
H1433	$RB_2 \rightarrow INT$	-0.004	-0.003	0.019	0.216	0.829	Rejected
H1431	$TF \rightarrow INT$	0.003	0.003	0.014	0.222	0.824	Rejected
H1428	$TX \rightarrow INT$	0.034	0.036	0.036	0.934	0.350	Rejected

Source: Project team compilation

Table I.9: Summary of Direct Effects in the Augmented TPB Model for Water-Saving Policies Adoption in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1393	$A_B \rightarrow INT$	-0.081	-0.075	0.079	1.027	0.305	Rejected
H1370	$AR \rightarrow A_B$	0.190	0.169	0.103	1.854	0.064	Rejected
H1395	$AR \rightarrow INT$	0.079	0.058	0.109	0.725	0.468	Rejected
H1386	$AR \rightarrow PBC$	-0.070	-0.051	0.112	0.626	0.531	Rejected
H1378	$AR \rightarrow SN$	-0.002	0.017	0.108	0.019	0.985	Rejected
H1376	$IF \rightarrow A_B$	-0.244	-0.238	0.103	2.360	0.018**	Accepted
H1402	$IF \rightarrow INT$	0.450	0.468	0.083	5.404	0.000***	Accepted
H1392	$IF \rightarrow PBC$	0.064	0.056	0.145	0.443	0.657	Rejected
H1384	$IF \rightarrow SN$	0.107	0.109	0.078	1.363	0.173	Rejected
H1373	$IL \rightarrow A_B$	-0.074	-0.071	0.111	0.670	0.503	Rejected
H1399	$IL \rightarrow INT$	-0.046	-0.052	0.080	0.579	0.562	Rejected
H1389	$IL \rightarrow PBC$	0.122	0.120	0.101	1.215	0.225	Rejected
H1381	$IL \rightarrow SN$	0.223	0.234	0.080	2.782	0.005***	Accepted
H1403	$PBC \rightarrow INT$	0.122	0.121	0.063	1.924	0.054	Rejected
H1374	$RB_2 \rightarrow A_B$	0.039	0.044	0.099	0.394	0.693	Rejected
H1400	$RB_2 \rightarrow INT$	0.019	0.014	0.091	0.210	0.834	Rejected
H1390	$RB_2 \rightarrow PBC$	-0.027	-0.023	0.071	0.380	0.704	Rejected
H1382	$RB_2 \rightarrow SN$	0.033	0.035	0.093	0.353	0.724	Rejected
H1398	$SN \rightarrow INT$	0.073	0.081	0.077	0.942	0.346	Rejected
H1372	$TF \rightarrow A_B$	-0.021	-0.019	0.067	0.311	0.756	Rejected
H1397	$TF \rightarrow INT$	0.497	0.486	0.117	4.259	0.000***	Accepted
H1388	$TF \rightarrow PBC$	0.031	0.035	0.069	0.450	0.653	Rejected
H1380	$TF \rightarrow SN$	-0.032	-0.033	0.073	0.448	0.654	Rejected
H1369	$TX \rightarrow A_B$	0.030	0.031	0.098	0.306	0.759	Rejected
H1394	$TX \rightarrow INT$	-0.076	-0.069	0.085	0.888	0.375	Rejected
H1385	$TX \rightarrow PBC$	0.129	0.130	0.115	1.125	0.261	Rejected
H1377	$TX \rightarrow SN$	0.283	0.283	0.103	2.750	0.006***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.10: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1460	$A_B \Rightarrow INT$	-0.081	-0.075	0.079	1.027	0.305	Rejected
H1437	$AR \Rightarrow A_B$	0.190	0.169	0.103	1.854	0.064	Rejected
H1462	$AR \Rightarrow INT$	0.055	0.040	0.099	0.553	0.468	Rejected
H1453	$AR \Rightarrow PBC$	-0.070	-0.051	0.112	0.626	0.531	Rejected
H1445	$AR \Rightarrow SN$	-0.002	0.017	0.108	0.019	0.985	Rejected
H1443	$IF \Rightarrow A_B$	-0.244	-0.238	0.103	2.360	0.018**	Accepted
H1469	$IF \Rightarrow INT$	0.485	0.498	0.079	6.160	0.000***	Accepted
H1459	$IF \Rightarrow PBC$	0.064	0.056	0.145	0.443	0.657	Rejected
H1451	$IF \Rightarrow SN$	0.107	0.109	0.078	1.363	0.173	Rejected
H1440	$IL \Rightarrow A_B$	-0.074	-0.071	0.111	0.670	0.503	Rejected
H1466	$IL \Rightarrow INT$	-0.009	-0.012	0.072	0.127	0.562	Rejected
H1456	$IL \Rightarrow PBC$	0.122	0.120	0.101	1.215	0.225	Rejected
H1448	$IL \Rightarrow SN$	0.223	0.234	0.080	2.782	0.005***	Accepted
H1470	$PBC \Rightarrow INT$	0.122	0.121	0.063	1.924	0.054	Rejected
H1441	$RB_2 \Rightarrow A_B$	0.039	0.044	0.099	0.394	0.693	Rejected
H1467	$RB_2 \Rightarrow INT$	0.015	0.011	0.097	0.156	0.834	Rejected
H1457	$RB_2 \Rightarrow PBC$	-0.027	-0.023	0.071	0.380	0.704	Rejected
H1449	$RB_2 \Rightarrow SN$	0.033	0.035	0.093	0.353	0.724	Rejected
H1465	$SN \Rightarrow INT$	0.073	0.081	0.077	0.942	0.346	Rejected
H1439	$TF \Rightarrow A_B$	-0.021	-0.019	0.067	0.311	0.756	Rejected
H1464	$TF \Rightarrow INT$	0.500	0.489	0.118	4.245	0.000***	Accepted
H1455	$TF \Rightarrow PBC$	0.031	0.035	0.069	0.450	0.653	Rejected
H1447	$TF \Rightarrow SN$	-0.032	-0.033	0.073	0.448	0.654	Rejected
H1436	$TX \Rightarrow A_B$	0.030	0.031	0.098	0.306	0.759	Rejected
H1461	$TX \Rightarrow INT$	-0.042	-0.033	0.076	0.550	0.375	Rejected
H1452	$TX \Rightarrow PBC$	0.129	0.130	0.115	1.125	0.261	Rejected
H1444	$TX \Rightarrow SN$	0.283	0.283	0.103	2.750	0.006***	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.11: Hypothesis Testing Results for the Structural Model of Lucerne Irrigators' Intentions for Adaptation Towards Climate Variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1471	$A_B \rightarrow INT$	0.324	0.327	0.073	4.446	0.000***	Accepted
H1472	$SN \rightarrow INT$	0.129	0.128	0.089	1.446	0.148	Reject
H1473	$PBC \rightarrow INT$	0.144	0.156	0.069	2.081	0.037**	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.12: Specific Indirect Effects of Constructs on Intentions to Adapt to Climate Variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1529	$IL \rightarrow PBC \rightarrow INT$	0.003	0.003	0.006	0.518	0.605	Rejected
H1523	$RB \rightarrow SN \rightarrow INT$	0.007	0.007	0.009	0.830	0.406	Rejected
H1522	$RB2 \rightarrow SN \rightarrow INT$	0.004	0.004	0.006	0.703	0.482	Rejected
H1510	$AR \rightarrow A_B \rightarrow INT$	0.011	0.013	0.014	0.783	0.434	Rejected
H1527	$PFC \rightarrow PBC \rightarrow INT$	-0.001	-0.000	0.004	0.219	0.827	Rejected
H1520	$TF \rightarrow SN \rightarrow INT$	0.009	0.009	0.009	0.954	0.340	Rejected
H1513	$IL \rightarrow A_B \rightarrow INT$	-0.008	-0.007	0.013	0.673	0.501	Rejected
H1531	$RB \rightarrow PBC \rightarrow INT$	0.005	0.005	0.007	0.786	0.432	Rejected
H1517	$TX \rightarrow SN \rightarrow INT$	0.021	0.021	0.014	1.468	0.142	Rejected
H1530	$RB2 \rightarrow PBC \rightarrow INT$	-0.000	-0.000	0.003	0.011	0.991	Rejected
H1511	$PFC \rightarrow A_B \rightarrow INT$	0.022	0.021	0.014	1.563	0.118	Rejected
H1528	$TF \rightarrow PBC \rightarrow INT$	0.001	0.001	0.005	0.214	0.831	Rejected
H1515	$RB \rightarrow A_B \rightarrow INT$	0.029	0.028	0.016	1.754	0.079	Rejected
H1525	$TX \rightarrow PBC \rightarrow INT$	0.001	0.003	0.008	0.172	0.864	Rejected
H1514	$RB2 \rightarrow A_B \rightarrow INT$	-0.005	-0.005	0.011	0.435	0.663	Rejected
H1512	$TF \rightarrow A_B \rightarrow INT$	0.033	0.032	0.017	1.910	0.056	Rejected
H1509	$TX \rightarrow A_B \rightarrow INT$	0.031	0.031	0.017	1.758	0.079	Rejected
H1518	$AR \rightarrow SN \rightarrow INT$	0.000	0.001	0.009	0.018	0.986	Rejected
H1521	$IL \rightarrow SN \rightarrow INT$	0.007	0.007	0.010	0.719	0.472	Rejected
H1526	$AR \rightarrow PBC \rightarrow INT$	0.000	0.001	0.008	0.038	0.969	Rejected
H1519	$PFC \rightarrow SN \rightarrow INT$	0.022	0.021	0.013	1.615	0.106	Rejected

Source: Project team compilation

Table I.13: Summary of Total Indirect Effects in the Augmented TPB Model for Intentions to Adapt to Climate Variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1534	$AR \rightarrow INT$	0.012	0.015	0.019	0.633	0.527	Rejected
H1537	$IL \rightarrow INT$	0.002	0.003	0.017	0.110	0.913	Rejected
H1535	$PFC \rightarrow INT$	0.043	0.042	0.021	2.010	0.044**	Accepted
H1539	$RB \rightarrow INT$	0.041	0.040	0.021	1.987	0.047**	Accepted
H1538	$RB2 \rightarrow INT$	-0.001	-0.001	0.014	0.052	0.959	Rejected
H1536	$TF \rightarrow INT$	0.043	0.041	0.023	1.888	0.059	Rejected
H1533	$TX \rightarrow INT$	0.053	0.055	0.026	2.070	0.038**	Accepted

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table I.14: Summary of Direct Effects in the Augmented TPB Model for Intentions to Adapt to Climate variability in the Kakamas Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1498	$A_B \rightarrow INT$	0.136	0.136	0.054	2.506	0.012**	Accepted
H1475	$AR \rightarrow A_B$	0.083	0.098	0.092	0.905	0.366	Rejected
H1500	$AR \rightarrow INT$	-0.011	-0.010	0.048	0.220	0.826	Rejected
H1491	$AR \rightarrow PBC$	0.006	0.018	0.121	0.053	0.957	Rejected
H1483	$AR \rightarrow SN$	0.002	0.007	0.090	0.020	0.984	Rejected
H1478	$IL \rightarrow A_B$	-0.062	-0.050	0.085	0.729	0.466	Rejected
H1504	$IL \rightarrow INT$	0.062	0.060	0.049	1.281	0.200	Rejected
H1494	$IL \rightarrow PBC$	0.072	0.071	0.098	0.731	0.465	Rejected
H1486	$IL \rightarrow SN$	0.084	0.094	0.096	0.879	0.379	Rejected
H1508	$PBC \rightarrow INT$	0.045	0.045	0.038	1.170	0.242	Rejected
H1501	$PFC \rightarrow INT$	0.163	0.157	0.085	1.915	0.056	Rejected
H1476	$PFC \rightarrow A_B$	-0.058	-0.058	0.039	1.503	0.133	Rejected
H1492	$PFC \rightarrow PBC$	-0.017	-0.017	0.060	0.291	0.771	Rejected
H1484	$PFC \rightarrow SN$	0.256	0.255	0.064	3.983	0.000***	Accepted
H1480	$RB \rightarrow A_B$	0.210	0.206	0.084	2.512	0.012**	Accepted
H1506	$RB \rightarrow INT$	0.196	0.196	0.051	3.860	0.000***	Accepted
H1496	$RB \rightarrow PBC$	0.115	0.106	0.083	1.386	0.166	Rejected
H1488	$RB \rightarrow SN$	0.086	0.088	0.083	1.037	0.300	Rejected
H1479	$RB2 \rightarrow A_B$	-0.037	-0.037	0.077	0.473	0.636	Rejected
H1505	$RB2 \rightarrow INT$	0.035	0.035	0.029	1.205	0.228	Rejected
H1495	$RB2 \rightarrow PBC$	-0.001	0.001	0.059	0.015	0.988	Rejected
H1487	$RB2 \rightarrow SN$	0.051	0.051	0.059	0.871	0.384	Rejected
H1503	$SN \rightarrow INT$	0.084	0.084	0.047	1.792	0.073	Rejected
H1477	$TF \rightarrow A_B$	0.244	0.232	0.083	2.926	0.003***	Accepted
H1502	$TF \rightarrow INT$	0.731	0.733	0.037	19.502	0.000***	Accepted
H1493	$TF \rightarrow PBC$	0.026	0.030	0.091	0.287	0.774	Rejected
H1485	$TF \rightarrow SN$	0.101	0.100	0.079	1.279	0.201	Rejected
H1474	$TX \rightarrow A_B$	0.225	0.231	0.091	2.476	0.013**	Accepted
H1499	$TX \rightarrow INT$	-0.061	-0.059	0.046	1.332	0.183	Rejected
H1490	$TX \rightarrow PBC$	0.031	0.048	0.127	0.244	0.807	Rejected
H1482	$TX \rightarrow SN$	0.249	0.246	0.083	2.992	0.003	Accepted

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table I.15: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1565	$A_B \Rightarrow INT$	0.136	0.136	0.054	2.506	0.012**	Accepted
H1542	$AR \Rightarrow A_B$	0.083	0.098	0.092	0.905	0.366	Rejected
H1567	$AR \Rightarrow INT$	0.001	0.005	0.047	0.026	0.979	Rejected
H1558	$AR \Rightarrow PBC$	0.006	0.018	0.121	0.053	0.957	Rejected
H1550	$AR \Rightarrow SN$	0.002	0.007	0.090	0.020	0.984	Rejected
H1545	$IL \Rightarrow A_B$	-0.062	-0.050	0.085	0.729	0.466	Rejected
H1571	$IL \Rightarrow INT$	0.064	0.063	0.047	1.354	0.176	Rejected
H1561	$IL \Rightarrow PBC$	0.072	0.071	0.098	0.731	0.465	Rejected
H1553	$IL \Rightarrow SN$	0.084	0.094	0.096	0.879	0.379	Rejected
H1575	$PBC \Rightarrow INT$	0.045	0.045	0.038	1.170	0.242	Rejected
H1568	$PFC \Rightarrow INT$	0.163	0.157	0.085	1.915	0.056	Rejected
H1543	$PFC \Rightarrow A_B$	-0.015	-0.017	0.032	0.463	0.644	Rejected
H1559	$PFC \Rightarrow PBC$	-0.017	-0.017	0.060	0.291	0.771	Rejected
H1551	$PFC \Rightarrow SN$	0.256	0.255	0.064	3.983	0.000***	Accepted
H1547	$RB \Rightarrow A_B$	0.210	0.206	0.084	2.512	0.012**	Accepted
H1573	$RB \Rightarrow INT$	0.237	0.236	0.050	4.698	0.000***	Accepted
H1563	$RB \Rightarrow PBC$	0.115	0.106	0.083	1.386	0.166	Rejected
H1555	$RB \Rightarrow SN$	0.086	0.088	0.083	1.037	0.300	Rejected
H1554	$RB2 \Rightarrow A_B$	-0.037	-0.037	0.077	0.473	0.636	Rejected
H1572	$RB2 \Rightarrow INT$	0.034	0.035	0.029	1.180	0.238	Rejected
H1562	$RB2 \Rightarrow PBC$	-0.001	0.001	0.059	0.015	0.988	Rejected
H1554	$RB2 \Rightarrow SN$	0.051	0.051	0.059	0.871	0.384	Rejected
H1570	$SN \Rightarrow INT$	0.084	0.084	0.047	1.792	0.073	Rejected
H1569	$TF \Rightarrow A_B$	0.244	0.232	0.083	2.926	0.003***	Accepted
H1569	$TF \Rightarrow INT$	0.774	0.774	0.032	24.263	0.000***	Accepted
H1560	$TF \Rightarrow PBC$	0.026	0.030	0.091	0.287	0.774	Rejected
H1552	$TF \Rightarrow SN$	0.101	0.100	0.079	1.279	0.201	Rejected
H1541	$TX \Rightarrow A_B$	0.225	0.231	0.091	2.476	0.013**	Accepted
H1566	$TX \Rightarrow INT$	-0.008	-0.005	0.046	0.172	0.864	Rejected
H1557	$TX \Rightarrow PBC$	0.031	0.048	0.127	0.244	0.807	Rejected
H1549	$TX \Rightarrow SN$	0.249	0.246	0.083	2.992	0.003***	Accepted

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Appendix J

Table J.1: Specific Indirect Effects of Constructs on Soybean Irrigators' Intentions to Adopt Water-Saving Technologies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H689	$IL \rightarrow PBC \rightarrow INT$	0.023	0.014	0.021	1.109	0.270	Rejected
H679	$PFC \rightarrow SN \rightarrow INT$	-0.017	-0.016	0.025	0.693	0.490	Rejected
H683	$RB \rightarrow SN \rightarrow INT$	-0.017	-0.009	0.027	0.652	0.516	Rejected
H670	$AR \rightarrow A_B \rightarrow INT$	0.010	0.009	0.021	0.503	0.616	Rejected
H687	$PFC \rightarrow PBC \rightarrow INT$	-0.020	-0.014	0.016	1.237	0.219	Rejected
H677	$TF \rightarrow SN \rightarrow INT$	-0.008	-0.004	0.018	0.444	0.658	Rejected
H673	$IL \rightarrow A_B \rightarrow INT$	-0.005	-0.005	0.015	0.340	0.734	Rejected
H691	$RB \rightarrow PBC \rightarrow INT$	0.035	0.029	0.030	1.191	0.236	Rejected
H677	$TX \rightarrow SN \rightarrow INT$	-0.049	-0.025	0.048	1.008	0.316	Rejected
H685	$TF \rightarrow PBC \rightarrow INT$	-0.005	-0.002	0.017	0.282	0.778	Rejected
H671	$PFC \rightarrow AB \rightarrow INT$	0.024	0.015	0.031	0.766	0.445	Rejected
H685	$TX \rightarrow PBC \rightarrow INT$	0.013	0.010	0.025	0.521	0.603	Rejected
H675	$RB \rightarrow A_B \rightarrow INT$	0.034	0.024	0.028	1.200	0.233	Rejected
H672	$TF \rightarrow A_B \rightarrow INT$	0.006	0.007	0.014	0.446	0.657	Rejected
H669	$TX \rightarrow A_B \rightarrow INT$	0.029	0.022	0.027	1.056	0.294	Rejected
H678	$AR \rightarrow SN \rightarrow INT$	0.014	0.001	0.018	0.777	0.439	Rejected
H681	$IL \rightarrow SN \rightarrow INT$	0.041	0.028	0.037	1.122	0.265	Rejected
H686	$AR \rightarrow PBC \rightarrow INT$	0.031	0.030	0.032	0.982	0.328	Rejected

Source: Project team compilation

Table J.2: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H694	$AR \rightarrow INT$	0.056	0.040	0.040	1.407	0.162	Rejected
H697	$IL \rightarrow INT$	0.059	0.038	0.047	1.238	0.219	Rejected
H695	$PFC \rightarrow INT$	-0.013	-0.015	0.045	0.295	0.769	Rejected
H699	$RB \rightarrow INT$	0.052	0.044	0.037	1.400	0.165	Rejected
H696	$TF \rightarrow INT$	-0.006	0.001	0.029	0.217	0.828	Rejected
H693	$TX \rightarrow INT$	-0.007	0.007	0.054	0.128	0.899	Rejected

Source: Project team compilation

Table J.3: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Water-Saving Technology Adoption by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H658	$A_B \rightarrow INT$	0.122	0.094	0.091	1.343	0.182	Rejected
H635	$AR \rightarrow A_B$	0.086	0.112	0.137	0.626	0.533	Rejected
H660	$AR \rightarrow INT$	0.038	0.058	0.093	0.404	0.687	Rejected
H651	$AR \rightarrow PBC$	0.209	0.246	0.142	1.476	0.143	Rejected
H643	$AR \rightarrow SN$	-0.096	-0.052	0.123	0.780	0.437	Rejected
H638	$IL \rightarrow A_B$	-0.043	-0.041	0.117	0.363	0.717	Rejected
H664	$IL \rightarrow INT$	0.191	0.176	0.110	1.734	0.086	Rejected
H654	$IL \rightarrow PBC$	0.152	0.153	0.153	0.996	0.321	Rejected
H646	$IL \rightarrow SN$	-0.285	-0.292	0.124	2.286	0.024**	Accepted
H668	$PBC \rightarrow INT$	0.150	0.120	0.083	1.812	0.073	Rejected
H636	$PFC \rightarrow A_B$	0.197	0.198	0.218	0.904	0.368	Rejected
H661	$PFC \rightarrow INT$	-0.021	-0.001	0.106	0.200	0.842	Rejected
H652	$PFC \rightarrow PBC$	-0.134	-0.101	0.096	1.400	0.165	Rejected
H644	$PFC \rightarrow SN$	0.118	0.134	0.157	0.754	0.452	Rejected
H640	$RB \rightarrow A_B$	0.278	0.267	0.120	2.317	0.023**	Accepted
H666	$RB \rightarrow INT$	0.539	0.452	0.227	2.379	0.019**	Accepted
H656	$RB \rightarrow PBC$	0.236	0.224	0.135	1.745	0.084	Rejected
H648	$RB \rightarrow SN$	0.121	0.127	0.139	0.871	0.386	Rejected
H663	$SN \rightarrow INT$	-0.144	-0.088	0.118	1.216	0.227	Rejected
H637	$TF \rightarrow A_B$	0.053	0.086	0.117	0.452	0.652	Rejected
H662	$TF \rightarrow INT$	0.560	0.554	0.185	3.021	0.003***	Accepted
H653	$TF \rightarrow PBC$	-0.031	-0.001	0.120	0.262	0.794	Rejected
H645	$TF \rightarrow SN$	0.056	0.063	0.130	0.429	0.669	Rejected
H634	$TX \rightarrow A_B$	0.238	0.206	0.156	1.529	0.129	Rejected
H659	$TX \rightarrow INT$	0.055	0.041	0.148	0.370	0.712	Rejected
H650	$TX \rightarrow PBC$	0.086	0.079	0.163	0.529	0.598	Rejected
H642	$TX \rightarrow SN$	0.339	0.272	0.228	1.485	0.141	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table J.4: Total Effects (Sum of Direct and Indirect Effects) for the Adoption of Water-Saving Technologies by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H725	$A_B \rightarrow INT$	0.122	0.094	0.091	1.343	0.182	Rejected
H702	$AR \rightarrow A_B$	0.086	0.112	0.137	0.626	0.533	Rejected
H727	$AR \rightarrow INT$	0.093	0.097	0.083	1.128	0.262	Rejected
H718	$AR \rightarrow PBC$	0.209	0.246	0.142	1.476	0.143	Rejected
H710	$AR \rightarrow SN$	-0.096	-0.052	0.123	0.780	0.437	Rejected
H705	$IL \rightarrow A_B$	-0.043	-0.041	0.117	0.363	0.717	Rejected
H731	$IL \rightarrow INT$	0.249	0.214	0.122	2.051	0.063	Rejected
H721	$IL \rightarrow PBC$	0.152	0.153	0.153	0.996	0.321	Rejected
H713	$IL \rightarrow SN$	-0.285	-0.292	0.124	2.286	0.024**	Accepted
H735	$PBC \rightarrow INT$	0.150	0.120	0.083	1.812	0.073	Rejected
H703	$PFC \rightarrow A_B$	0.197	0.198	0.218	0.904	0.368	Rejected
H728	$PFC \rightarrow INT$	-0.034	-0.016	0.105	0.328	0.744	Rejected
H719	$PFC \rightarrow PBC$	-0.134	-0.101	0.096	1.400	0.165	Rejected
H711	$PFC \rightarrow SN$	0.118	0.134	0.157	0.754	0.452	Rejected
H707	$RB \rightarrow A_B$	0.278	0.267	0.120	2.317	0.023**	Accepted
H733	$RB \rightarrow INT$	0.591	0.496	0.236	2.504	0.014**	Accepted
H723	$RB \rightarrow PBC$	0.236	0.224	0.135	1.745	0.084	Rejected
H715	$RB \rightarrow SN$	0.121	0.127	0.139	0.871	0.386	Rejected
H730	$SN \rightarrow INT$	-0.144	-0.088	0.118	1.216	0.227	Rejected
H704	$TF \rightarrow A_B$	0.053	0.086	0.117	0.452	0.652	Rejected
H729	$TF \rightarrow INT$	0.553	0.556	0.192	2.887	0.005***	Accepted
H720	$TF \rightarrow PBC$	-0.031	-0.001	0.120	0.262	0.794	Rejected
H712	$TF \rightarrow SN$	0.056	0.063	0.130	0.429	0.669	Rejected
H701	$TX \rightarrow A_B$	0.238	0.206	0.156	1.529	0.129	Rejected
H726	$TX \rightarrow INT$	0.048	0.048	0.144	0.335	0.739	Rejected
H717	$TX \rightarrow PBC$	0.086	0.079	0.163	0.529	0.598	Rejected
H709	$TX \rightarrow SN$	0.339	0.272	0.228	1.485	0.141	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table J.5: Hypothesis Testing Results for the Structural Model of Soybean Irrigators' Intentions to Adopt Water-Saving Policies in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H736	$A_B \rightarrow INT$	-0.157	-0.154	0.109	1.439	0.153	Reject
H737	$SN \rightarrow INT$	0.123	0.124	0.103	1.194	0.235	Reject
H738	$PBC \rightarrow INT$	0.022	0.022	0.044	0.125	0.174	Reject

Source: Project team compilation

Table J.6: Hypothesis Testing Results for the Structural Model of Soybean Irrigators' Intentions for Adaptation Towards Climate variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H841	$A_B \rightarrow INT$	0.228	0.265	0.188	1.213	0.225	Reject
H842	$SN \rightarrow INT$	0.035	0.075	0.210	0.164	0.870	Reject
H843	$PBC \rightarrow INT$	0.135	0.096	0.227	0.593	0.553	Reject

Source: Project team compilation

Table J.7: Specific Indirect Effects of Constructs on Soybean Irrigators' Intentions for Adaptation Towards Climate Variability in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H899	$IL \rightarrow PBC \rightarrow INT$	-0.001	0.002	0.015	0.042	0.967	Rejected
H889	$PFC \rightarrow SN \rightarrow INT$	-0.002	-0.005	0.020	0.115	0.908	Rejected
H893	$RB \rightarrow SN \rightarrow INT$	-0.000	-0.000	0.015	0.026	0.979	Rejected
H880	$AR \rightarrow A_B \rightarrow INT$	0.048	0.043	0.048	1.000	0.317	Rejected
H897	$PFC \rightarrow PBC \rightarrow INT$	-0.001	0.003	0.017	0.043	0.965	Rejected
H890	$TF \rightarrow SN \rightarrow INT$	0.001	0.004	0.018	0.080	0.936	Rejected
H883	$IL \rightarrow A_B \rightarrow INT$	-0.050	-0.039	0.049	1.029	0.304	Rejected
H901	$RB \rightarrow PBC \rightarrow INT$	0.001	-0.001	0.028	0.045	0.964	Rejected
H887	$TX \rightarrow SN \rightarrow INT$	-0.002	-0.000	0.024	0.090	0.928	Rejected
H898	$TF \rightarrow PBC \rightarrow INT$	-0.001	0.004	0.018	0.051	0.959	Rejected
H881	$PFC \rightarrow A_B \rightarrow INT$	0.005	0.001	0.022	0.244	0.807	Rejected
H895	$TX \rightarrow PBC \rightarrow INT$	0.001	-0.005	0.038	0.028	0.977	Rejected
H885	$RB \rightarrow A_B \rightarrow INT$	-0.008	0.000	0.033	0.244	0.807	Rejected
H882	$TF \rightarrow A_B \rightarrow INT$	0.000	0.009	0.031	0.006	0.995	Rejected
H879	$TX \rightarrow A_B \rightarrow INT$	-0.023	-0.013	0.038	0.595	0.552	Rejected
H888	$AR \rightarrow SN \rightarrow INT$	0.000	-0.002	0.017	0.010	0.992	Rejected
H891	$IL \rightarrow SN \rightarrow INT$	0.008	0.010	0.059	0.143	0.886	Rejected
H896	$AR \rightarrow PBC \rightarrow INT$	0.001	0.000	0.019	0.044	0.965	Rejected

Source: Project team compilation

Table J.8: Summary of Total Indirect Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H904	$AR \rightarrow INT$	0.049	0.041	0.051	0.961	0.336	Rejected
H907	$IL \rightarrow INT$	-0.043	-0.027	0.075	0.569	0.569	Rejected
H905	$PFC \rightarrow INT$	0.002	-0.001	0.035	0.067	0.946	Rejected
H909	$RB \rightarrow INT$	-0.007	-0.001	0.044	0.164	0.869	Rejected
H906	$TF \rightarrow INT$	0.001	0.016	0.038	0.019	0.985	Rejected
H903	$TX \rightarrow INT$	-0.024	-0.018	0.053	0.445	0.656	Rejected

Source: Project team compilation

Table J.9: Summary of Direct Effects in the Augmented Theory of Planned Behaviour Model for Adaptation Towards Climate Variability by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H868	$A_B \rightarrow INT$	0.158	0.153	0.126	1.256	0.209	Rejected
H845	$AR \rightarrow A_B$	0.301	0.277	0.161	1.865	0.062	Rejected
H870	$AR \rightarrow INT$	-0.083	-0.060	0.113	0.731	0.465	Rejected
H861	$AR \rightarrow PBC$	0.144	0.098	0.152	0.944	0.345	Rejected
H853	$AR \rightarrow SN$	-0.010	-0.019	0.139	0.073	0.942	Rejected
H848	$IL \rightarrow A_B$	-0.318	-0.293	0.183	1.740	0.082	Rejected
H874	$IL \rightarrow INT$	-0.109	-0.130	0.112	0.970	0.332	Rejected
H864	$IL \rightarrow PBC$	-0.115	-0.081	0.116	0.988	0.323	Rejected
H856	$IL \rightarrow SN$	-0.490	-0.476	0.120	4.095	0.000***	Accepted
H878	$PBC \rightarrow INT$	0.006	-0.012	0.101	0.056	0.956	Rejected
H871	$PFC \rightarrow INT$	0.034	0.023	0.109	0.313	0.754	Rejected
H846	$PFC \rightarrow A_B$	0.047	0.043	0.087	0.539	0.590	Rejected
H862	$PFC \rightarrow PBC$	-0.132	-0.126	0.103	1.281	0.200	Rejected
H854	$PFC \rightarrow SN$	0.134	0.140	0.085	1.588	0.112	Rejected
H850	$RB \rightarrow A_B$	-0.051	-0.043	0.172	0.294	0.769	Rejected
H876	$RB \rightarrow INT$	0.559	0.535	0.105	5.341	0.000***	Accepted
H866	$RB \rightarrow PBC$	0.227	0.250	0.166	1.365	0.172	Rejected
H858	$RB \rightarrow SN$	0.024	0.038	0.124	0.190	0.849	Rejected
H873	$SN \rightarrow INT$	-0.017	-0.017	0.118	0.146	0.884	Rejected
H847	$TF \rightarrow A_B$	0.001	0.020	0.152	0.008	0.994	Rejected
H872	$TF \rightarrow INT$	0.438	0.430	0.106	4.145	0.000***	Accepted
H863	$TF \rightarrow PBC$	-0.163	-0.118	0.127	1.285	0.199	Rejected
H855	$TF \rightarrow SN$	-0.085	-0.068	0.133	0.641	0.521	Rejected
H844	$TX \rightarrow A_B$	-0.143	-0.090	0.174	0.824	0.410	Rejected
H869	$TX \rightarrow INT$	-0.023	-0.037	0.098	0.240	0.811	Rejected
H860	$TX \rightarrow PBC$	0.192	0.198	0.266	0.724	0.469	Rejected
H852	$TX \rightarrow SN$	0.125	0.154	0.125	0.999	0.318	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table J.10: Total Effects (Sum of Direct and Indirect Effects) for Adaptation Towards Climate Variability by Soybean Irrigators in the Hartbeespoort Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H935	$A_B \rightarrow INT$	0.158	0.153	0.126	1.256	0.209	Rejected
H912	$AR \rightarrow A_B$	0.301	0.277	0.161	1.865	0.062	Rejected
H937	$AR \rightarrow INT$	-0.034	-0.019	0.106	0.324	0.746	Rejected
H928	$AR \rightarrow PBC$	0.144	0.098	0.152	0.944	0.345	Rejected
H920	$AR \rightarrow SN$	-0.010	-0.019	0.139	0.073	0.942	Rejected
H915	$IL \rightarrow A_B$	-0.318	-0.293	0.183	1.740	0.082	Rejected
H941	$IL \rightarrow INT$	-0.151	-0.157	0.102	1.482	0.138	Rejected
H931	$IL \rightarrow PBC$	-0.115	-0.081	0.116	0.988	0.323	Rejected
H923	$IL \rightarrow SN$	-0.490	-0.476	0.120	4.095	0.000***	Accepted
H945	$PBC \rightarrow INT$	0.006	-0.012	0.101	0.056	0.956	Rejected
H938	$PFC \rightarrow INT$	0.034	0.023	0.109	0.313	0.754	Rejected
H913	$PFC \rightarrow A_B$	0.049	0.042	0.082	0.600	0.549	Rejected
H929	$PFC \rightarrow PBC$	-0.132	-0.126	0.103	1.281	0.200	Rejected
H921	$PFC \rightarrow SN$	0.134	0.140	0.085	1.588	0.112	Rejected
H917	$RB \rightarrow A_B$	-0.051	-0.043	0.172	0.294	0.769	Rejected
H943	$RB \rightarrow INT$	0.552	0.534	0.103	5.344	0.000***	Accepted
H933	$RB \rightarrow PBC$	0.227	0.250	0.166	1.365	0.172	Rejected
H925	$RB \rightarrow SN$	0.024	0.038	0.124	0.190	0.849	Rejected
H940	$SN \rightarrow INT$	-0.017	-0.017	0.118	0.146	0.884	Rejected
H914	$TF \rightarrow A_B$	0.001	0.020	0.152	0.008	0.994	Rejected
H939	$TF \rightarrow INT$	0.439	0.446	0.098	4.478	0.000***	Accepted
H930	$TF \rightarrow PBC$	-0.163	-0.118	0.127	1.285	0.199	Rejected
H922	$TF \rightarrow SN$	-0.085	-0.068	0.133	0.641	0.521	Rejected
H911	$TX \rightarrow A_B$	-0.143	-0.090	0.174	0.824	0.410	Rejected
H936	$TX \rightarrow INT$	-0.047	-0.055	0.084	0.563	0.573	Rejected
H927	$TX \rightarrow PBC$	0.192	0.198	0.266	0.724	0.469	Rejected
H919	$TX \rightarrow SN$	0.125	0.154	0.125	0.999	0.318	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Appendix K

Table K.1: Hypothesis Testing Results for the Structural Model of Sugarcane Irrigators' Intentions to Adopt Water-Saving Technologies in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H946	$A_B \rightarrow INT$	0.088	0.106	0.164	0.540	0.589	Reject
H947	$SN \rightarrow INT$	0.338	0.314	0.140	2.419	0.016**	Accepted
H948	$PBC \rightarrow INT$	0.314	0.333	0.192	1.638	0.102	Reject

Note: ** $\rho < 0.05$

Source: Project team compilation

Table K.2: Specific Indirect Effects of Constructs on Intentions to Adopt Water-Saving Technologies in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1004	$IL \rightarrow PBC \rightarrow INT$	0.014	0.015	0.041	0.340	0.734	Rejected
H994	$PFC \rightarrow SN \rightarrow INT$	0.055	0.045	0.069	0.794	0.429	Rejected
H997	$RB_2 \rightarrow SN \rightarrow INT$	-0.009	-0.011	0.024	0.384	0.702	Rejected
H985	$AR \rightarrow A_B \rightarrow INT$	-0.046	-0.047	0.056	0.814	0.418	Rejected
H1002	$PFC \rightarrow PBC \rightarrow INT$	-0.005	0.003	0.028	0.177	0.860	Rejected
H992	$TF \rightarrow SN \rightarrow INT$	0.000	0.007	0.033	0.011	0.991	Rejected
H988	$IL \rightarrow A_B \rightarrow INT$	0.073	0.068	0.071	1.023	0.309	Rejected
H1005	$RB_2 \rightarrow PBC \rightarrow INT$	0.004	0.011	0.027	0.167	0.868	Rejected
H992	$TX \rightarrow SN \rightarrow INT$	0.002	0.009	0.031	0.080	0.936	Rejected
H1003	$TF \rightarrow PBC \rightarrow INT$	-0.001	-0.001	0.028	0.035	0.972	Rejected
H986	$PFC \rightarrow AB \rightarrow INT$	-0.087	-0.065	0.064	1.363	0.176	Rejected
H1000	$TX \rightarrow PBC \rightarrow INT$	0.014	0.009	0.050	0.281	0.780	Rejected
H989	$RB_2 \rightarrow A_B \rightarrow INT$	0.021	0.013	0.032	0.652	0.516	Rejected
H987	$TF \rightarrow A_B \rightarrow INT$	-0.024	-0.019	0.041	0.586	0.559	Rejected
H984	$TX \rightarrow A_B \rightarrow INT$	0.037	0.036	0.055	0.669	0.505	Rejected
H993	$AR \rightarrow SN \rightarrow INT$	0.055	0.047	0.048	1.127	0.263	Rejected
H996	$IL \rightarrow SN \rightarrow INT$	0.058	0.045	0.050	1.169	0.245	Rejected
H1001	$AR \rightarrow PBC \rightarrow INT$	0.009	0.014	0.037	0.246	0.806	Rejected

Source: Project team compilation

Table K.3: Summary of Total Indirect Effects in the Augmented TPB Model for Water-Saving Technology Adoption in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1009	$AR \rightarrow INT$	0.018	0.014	0.067	0.266	0.791	Rejected
H1012	$IL \rightarrow INT$	0.145	0.127	0.094	1.540	0.127	Rejected
H1010	$PFC \rightarrow INT$	-0.036	-0.017	0.079	0.462	0.645	Rejected
H1013	$RB_2 \rightarrow INT$	0.016	0.012	0.052	0.305	0.761	Rejected
H1011	$TF \rightarrow INT$	-0.025	-0.013	0.060	0.412	0.681	Rejected
H1008	$TX \rightarrow INT$	0.054	0.055	0.078	0.686	0.494	Rejected

Source: Project team compilation

Table K.4: Summary of Direct Effects in the Augmented TPB Model for Water-Saving Technology Adoption in the Orange-Riet Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H973	$A_B \rightarrow INT$	0.260	0.228	0.171	1.515	0.133	Rejected
H950	$AR \rightarrow A_B$	-0.176	-0.193	0.202	0.872	0.385	Rejected
H975	$AR \rightarrow INT$	-0.073	-0.065	0.121	0.601	0.549	Rejected
H966	$AR \rightarrow PBC$	0.171	0.180	0.119	1.431	0.156	Rejected
H958	$AR \rightarrow SN$	0.251	0.278	0.135	1.861	0.066	Rejected
H953	$IL \rightarrow A_B$	0.280	0.284	0.188	1.494	0.138	Rejected
H979	$IL \rightarrow INT$	-0.087	-0.089	0.162	0.538	0.592	Rejected
H969	$IL \rightarrow PBC$	0.258	0.235	0.190	1.359	0.177	Rejected
H961	$IL \rightarrow SN$	0.268	0.209	0.145	1.848	0.068	Rejected
H983	$PBC \rightarrow INT$	0.054	0.067	0.144	0.374	0.709	Rejected
H951	$PFC \rightarrow A_B$	-0.334	-0.296	0.142	2.349	0.021**	Accepted
H976	$PFC \rightarrow INT$	0.182	0.164	0.125	1.456	0.149	Rejected
H967	$PFC \rightarrow PBC$	-0.091	-0.036	0.159	0.574	0.567	Rejected
H959	$PFC \rightarrow SN$	0.253	0.237	0.264	0.957	0.341	Rejected
H954	$RB_2 \rightarrow A_B$	0.079	0.070	0.121	0.657	0.513	Rejected
H980	$RB_2 \rightarrow INT$	0.206	0.161	0.159	1.293	0.199	Rejected
H970	$RB_2 \rightarrow PBC$	0.083	0.068	0.152	0.545	0.587	Rejected
H962	$RB_2 \rightarrow SN$	-0.042	-0.052	0.095	0.445	0.657	Rejected
H978	$SN \rightarrow INT$	0.218	0.178	0.146	1.492	0.139	Rejected
H952	$TF \rightarrow A_B$	-0.092	-0.096	0.140	0.660	0.511	Rejected
H977	$TF \rightarrow INT$	0.411	0.414	0.138	2.976	0.004***	Accepted
H968	$TF \rightarrow PBC$	-0.018	0.015	0.186	0.098	0.922	Rejected
H960	$TF \rightarrow SN$	0.002	0.037	0.134	0.012	0.990	Rejected
H949	$TX \rightarrow A_B$	0.143	0.138	0.167	0.854	0.395	Rejected
H974	$TX \rightarrow INT$	0.235	0.278	0.137	1.725	0.088	Rejected
H965	$TX \rightarrow PBC$	0.263	0.275	0.201	1.308	0.194	Rejected
H957	$TX \rightarrow SN$	0.011	0.054	0.151	0.076	0.940	Rejected

Note: ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table K.5: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1040	$A_B \Rightarrow INT$	0.260	0.228	0.171	1.515	0.133	Rejected
H1017	$AR \Rightarrow A_B$	-0.176	-0.193	0.202	0.872	0.385	Rejected
H1042	$AR \Rightarrow INT$	-0.055	-0.051	0.112	0.489	0.626	Rejected
H1033	$AR \Rightarrow PBC$	0.171	0.180	0.119	1.431	0.156	Rejected
H1025	$AR \Rightarrow SN$	0.251	0.278	0.135	1.861	0.066	Rejected
H1020	$IL \Rightarrow A_B$	0.280	0.284	0.188	1.494	0.138	Rejected
H1046	$IL \Rightarrow INT$	0.058	0.038	0.162	0.358	0.721	Rejected
H1036	$IL \Rightarrow PBC$	0.258	0.235	0.190	1.359	0.177	Rejected
H1028	$IL \Rightarrow SN$	0.268	0.209	0.145	1.848	0.068	Rejected
H1050	$PBC \Rightarrow INT$	0.054	0.067	0.144	0.374	0.709	Rejected
H1018	$PFC \Rightarrow A_B$	-0.334	-0.296	0.142	2.349	0.021**	Accepted
H1043	$PFC \Rightarrow INT$	0.146	0.146	0.139	1.051	0.296	Rejected
H1034	$PFC \Rightarrow PBC$	-0.091	-0.036	0.159	0.574	0.567	Rejected
H1026	$PFC \Rightarrow SN$	0.253	0.237	0.264	0.957	0.341	Rejected
H1021	$RB_2 \Rightarrow A_B$	0.079	0.070	0.121	0.657	0.513	Rejected
H1047	$RB_2 \Rightarrow INT$	0.222	0.174	0.172	1.293	0.199	Rejected
H1037	$RB_2 \Rightarrow PBC$	0.083	0.068	0.152	0.545	0.587	Rejected
H1029	$RB_2 \Rightarrow SN$	-0.042	-0.052	0.095	0.445	0.657	Rejected
H1045	$SN \Rightarrow INT$	0.218	0.178	0.146	1.492	0.139	Rejected
H1019	$TF \Rightarrow A_B$	-0.092	-0.096	0.140	0.660	0.511	Rejected
H1044	$TF \Rightarrow INT$	0.387	0.400	0.130	2.983	0.004***	Accepted
H1035	$TF \Rightarrow PBC$	-0.018	0.015	0.186	0.098	0.922	Rejected
H1027	$TF \Rightarrow SN$	0.002	0.037	0.134	0.012	0.990	Rejected
H1016	$TX \Rightarrow A_B$	0.143	0.138	0.167	0.854	0.395	Rejected
H1041	$TX \Rightarrow INT$	0.289	0.333	0.129	2.237	0.068	Rejected
H1032	$TX \Rightarrow PBC$	0.263	0.275	0.201	1.308	0.194	Rejected
H1024	$TX \Rightarrow SN$	0.011	0.054	0.151	0.076	0.940	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table K.6: Hypothesis Testing Results for the Structural Model of Sugarcane Irrigators' Intentions to Adopt Water-Saving Policies in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1051	$A_B \rightarrow INT$	-0.286	-0.251	0.275	1.038	0.302	Reject
H1052	$SN \rightarrow INT$	-0.060	-0.029	0.138	0.437	0.663	Reject
H1053	$PBC \rightarrow INT$	0.184	0.220	0.123	1.498	0.137	Reject

Source: Project team compilation

Table K.7: Specific Indirect Effects of Constructs on Intentions to Adopt Water-Saving Policies in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1112	$IF \rightarrow PBC \rightarrow INT$	0.006	-0.008	0.028	0.200	0.841	Rejected
H1109	$IL \rightarrow PBC \rightarrow INT$	0.010	0.005	0.037	0.274	0.784	Rejected
H1099	$PFC \rightarrow SN \rightarrow INT$	0.010	0.009	0.022	0.469	0.639	Rejected
H1102	$RB_2 \rightarrow SN \rightarrow INT$	-0.009	-0.007	0.025	0.377	0.706	Rejected
H1090	$AR \rightarrow A_B \rightarrow INT$	0.024	0.036	0.062	0.392	0.695	Rejected
H1107	$PFC \rightarrow PBC \rightarrow INT$	0.007	-0.000	0.022	0.310	0.757	Rejected
H1100	$TF \rightarrow SN \rightarrow INT$	-0.003	-0.002	0.017	0.176	0.860	Rejected
H1096	$IF \rightarrow A_B \rightarrow INT$	0.007	0.018	0.042	0.167	0.867	Rejected
H1110	$RB_2 \rightarrow PBC \rightarrow INT$	0.000	0.002	0.023	0.020	0.984	Rejected
H1097	$TX \rightarrow SN \rightarrow INT$	0.001	-0.003	0.014	0.094	0.925	Rejected
H1093	$IL \rightarrow A_B \rightarrow INT$	0.013	-0.001	0.040	0.323	0.747	Rejected
H1108	$TF \rightarrow PBC \rightarrow INT$	-0.001	0.002	0.016	0.092	0.927	Rejected
H1105	$TX \rightarrow PBC \rightarrow INT$	-0.004	-0.002	0.020	0.177	0.859	Rejected
H1091	$PFC \rightarrow AB \rightarrow INT$	0.008	0.017	0.033	0.226	0.821	Rejected
H1094	$RB_2 \rightarrow A_B \rightarrow INT$	-0.011	-0.012	0.040	0.277	0.782	Rejected
H1092	$TF \rightarrow A_B \rightarrow INT$	-0.004	-0.009	0.027	0.138	0.890	Rejected
H1089	$TX \rightarrow A_B \rightarrow INT$	-0.004	-0.003	0.023	0.178	0.859	Rejected
H1098	$AR \rightarrow SN \rightarrow INT$	-0.002	-0.002	0.018	0.134	0.893	Rejected
H1104	$IF \rightarrow SN \rightarrow INT$	-0.017	-0.019	0.033	0.498	0.619	Rejected
H1101	$IL \rightarrow SN \rightarrow INT$	-0.023	-0.019	0.042	0.538	0.591	Rejected
H1106	$AR \rightarrow PBC \rightarrow INT$	0.007	-0.000	0.025	0.289	0.773	Rejected

Source: Project team compilation

Table K.8: Summary of Total Indirect Effects in the Augmented TPB Model for Water-Saving Policies Adoption in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1118	$AR \rightarrow INT$	0.029	0.033	0.069	0.423	0.673	Rejected
H1120	$IF \rightarrow INT$	-0.004	-0.009	0.058	0.068	0.946	Rejected
H1117	$IL \rightarrow INT$	0.000	-0.015	0.064	0.006	0.995	Rejected
H1115	$PFC \rightarrow INT$	0.025	0.026	0.045	0.550	0.582	Rejected
H1118	$RB_2 \rightarrow INT$	-0.020	-0.016	0.051	0.390	0.697	Rejected
H1116	$TF \rightarrow INT$	-0.008	-0.008	0.035	0.232	0.817	Rejected
H1113	$TX \rightarrow INT$	-0.006	-0.008	0.033	0.196	0.845	Rejected

Source: Project team compilation

Table K.9: Summary of Direct Effects in the Augmented TPB Model for Water-Saving Policies Adoption in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1078	$A_B \rightarrow INT$	-0.055	-0.078	0.136	0.402	0.687	Rejected
H1055	$AR \rightarrow A_B$	-0.444	-0.427	0.122	3.627	0.000***	Accepted
H1080	$AR \rightarrow INT$	0.010	0.001	0.115	0.085	0.932	Rejected
H1071	$AR \rightarrow PBC$	0.185	0.183	0.150	1.235	0.217	Rejected
H1063	$AR \rightarrow SN$	0.037	0.022	0.154	0.244	0.807	Rejected
H1061	$IF \rightarrow A_B$	-0.128	-0.163	0.185	0.692	0.489	Rejected
H1087	$IF \rightarrow INT$	0.183	0.200	0.124	1.477	0.140	Rejected
H1077	$IF \rightarrow PBC$	0.146	0.173	0.193	0.754	0.451	Rejected
H1069	$IF \rightarrow SN$	0.261	0.237	0.143	1.824	0.068	Rejected
H1058	$IL \rightarrow A_B$	-0.236	-0.189	0.262	0.903	0.367	Rejected
H1084	$IL \rightarrow INT$	0.034	0.073	0.124	0.277	0.782	Rejected
H1074	$IL \rightarrow PBC$	0.261	0.241	0.228	1.145	0.252	Rejected
H1066	$IL \rightarrow SN$	0.357	0.343	0.185	1.925	0.054	Rejected
H1088	$PBC \rightarrow INT$	0.039	-0.002	0.106	0.364	0.716	Rejected
H1056	$PFC \rightarrow A_B$	-0.137	-0.142	0.148	0.924	0.355	Rejected
H1081	$PFC \rightarrow INT$	0.708	0.687	0.087	8.157	0.000***	Accepted
H1072	$PFC \rightarrow PBC$	0.181	0.167	0.129	1.400	0.161	Rejected
H1064	$PFC \rightarrow SN$	-0.161	-0.155	0.139	1.156	0.248	Rejected
H1059	$RB_2 \rightarrow A_B$	0.202	0.222	0.174	1.157	0.247	Rejected
H1085	$RB_2 \rightarrow INT$	-0.058	-0.047	0.134	0.434	0.664	Rejected
H1075	$RB_2 \rightarrow PBC$	0.012	0.030	0.202	0.060	0.952	Rejected
H1067	$RB_2 \rightarrow SN$	0.146	0.157	0.144	1.010	0.312	Rejected
H1083	$SN \rightarrow INT$	-0.064	-0.060	0.102	0.623	0.534	Rejected
H1057	$TF \rightarrow A_B$	0.067	0.080	0.152	0.439	0.660	Rejected
H1082	$TF \rightarrow INT$	-0.062	-0.056	0.093	0.664	0.507	Rejected
H1073	$TF \rightarrow PBC$	-0.038	-0.067	0.132	0.287	0.774	Rejected
H1065	$TF \rightarrow SN$	0.047	0.019	0.140	0.336	0.737	Rejected
H1054	$TX \rightarrow A_B$	0.075	0.056	0.141	0.532	0.595	Rejected
H1079	$TX \rightarrow INT$	0.283	0.275	0.139	2.030	0.042**	Accepted
H1070	$TX \rightarrow PBC$	-0.094	-0.052	0.181	0.520	0.603	Rejected
H1062	$TX \rightarrow SN$	-0.021	0.002	0.115	0.179	0.858	Rejected

Note: ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table K.10: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1145	$A_B \Rightarrow INT$	-0.055	-0.078	0.136	0.402	0.687	Rejected
H1122	$AR \Rightarrow A_B$	-0.444	-0.427	0.122	3.627	0.000***	Accepted
H1147	$AR \Rightarrow INT$	0.039	0.034	0.098	0.399	0.690	Rejected
H1138	$AR \Rightarrow PBC$	0.185	0.183	0.150	1.235	0.217	Rejected
H1130	$AR \Rightarrow SN$	0.037	0.022	0.154	0.244	0.807	Rejected
H1128	$IF \Rightarrow A_B$	-0.128	-0.163	0.185	0.692	0.489	Rejected
H1154	$IF \Rightarrow INT$	0.179	0.191	0.104	1.720	0.085	Rejected
H1144	$IF \Rightarrow PBC$	0.146	0.173	0.193	0.754	0.451	Rejected
H1136	$IF \Rightarrow SN$	0.261	0.237	0.143	1.824	0.068	Rejected
H1125	$IL \Rightarrow A_B$	-0.236	-0.189	0.262	0.903	0.367	Rejected
H1151	$IL \Rightarrow INT$	0.035	0.059	0.096	0.361	0.718	Rejected
H1141	$IL \Rightarrow PBC$	0.261	0.241	0.228	1.145	0.252	Rejected
H1133	$IL \Rightarrow SN$	0.357	0.343	0.185	1.925	0.054	Rejected
H1155	$PBC \Rightarrow INT$	0.039	-0.002	0.106	0.364	0.716	Rejected
H1123	$PFC \Rightarrow A_B$	-0.137	-0.142	0.148	0.924	0.355	Rejected
H1148	$PFC \Rightarrow INT$	0.733	0.713	0.081	9.080	0.000***	Accepted
H1139	$PFC \Rightarrow PBC$	0.181	0.167	0.129	1.400	0.161	Rejected
H1131	$PFC \Rightarrow SN$	-0.161	-0.155	0.139	1.156	0.248	Rejected
H1126	$RB_2 \Rightarrow A_B$	0.202	0.222	0.174	1.157	0.247	Rejected
H1152	$RB_2 \Rightarrow INT$	-0.078	-0.063	0.125	0.623	0.533	Rejected
H1142	$RB_2 \Rightarrow PBC$	0.012	0.030	0.202	0.060	0.952	Rejected
H1134	$RB_2 \Rightarrow SN$	0.146	0.157	0.144	1.010	0.312	Rejected
H1150	$SN \Rightarrow INT$	-0.064	-0.060	0.102	0.623	0.534	Rejected
H1124	$TF \Rightarrow A_B$	0.067	0.080	0.152	0.439	0.660	Rejected
H1149	$TF \Rightarrow INT$	-0.070	-0.064	0.082	0.853	0.394	Rejected
H1140	$TF \Rightarrow PBC$	-0.038	-0.067	0.132	0.287	0.774	Rejected
H1132	$TF \Rightarrow SN$	0.047	0.019	0.140	0.336	0.737	Rejected
H1121	$TX \Rightarrow A_B$	0.075	0.056	0.141	0.532	0.595	Rejected
H1146	$TX \Rightarrow INT$	0.276	0.267	0.138	1.995	0.046**	Accepted
H1137	$TX \Rightarrow PBC$	-0.094	-0.052	0.181	0.520	0.603	Rejected
H1129	$TX \Rightarrow SN$	-0.021	0.002	0.115	0.179	0.858	Rejected

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Project team compilation

Table K.11: Hypothesis Testing Results for the Structural Model of Sugarcane Irrigators' Intentions for Adaptation Towards Climate Variability in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1156	$A_B \rightarrow INT$	0.294	0.285	0.203	1.447	0.148	Reject
H1157	$SN \rightarrow INT$	0.336	0.332	0.133	2.530	0.011**	Accepted
H1158	$PBC \rightarrow INT$	0.099	0.138	0.197	0.503	0.615	Reject

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table K.12: Specific Indirect Effects of Constructs on Intentions to Adapt to Climate Variability in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1217	$IF \rightarrow PBC \rightarrow INT$	0.000	0.012	0.040	0.001	0.999	Rejected
H1204	$PFC \rightarrow SN \rightarrow INT$	0.003	0.004	0.016	0.204	0.839	Rejected
H1214	$IL \rightarrow PBC \rightarrow INT$	0.000	-0.007	0.052	0.006	0.995	Rejected
H1208	$RB \rightarrow SN \rightarrow INT$	-0.010	-0.008	0.026	0.374	0.708	Rejected
H1207	$RB2 \rightarrow SN \rightarrow INT$	0.002	0.002	0.023	0.077	0.939	Rejected
H1195	$AR \rightarrow A_B \rightarrow INT$	-0.000	-0.003	0.024	0.017	0.986	Rejected
H1212	$PFC \rightarrow PBC \rightarrow INT$	0.014	0.006	0.079	0.172	0.863	Rejected
H1205	$TF \rightarrow SN \rightarrow INT$	0.032	0.026	0.048	0.663	0.507	Rejected
H1201	$IF \rightarrow A_B \rightarrow INT$	-0.001	-0.003	0.031	0.043	0.966	Rejected
H1216	$RB \rightarrow PBC \rightarrow INT$	-0.015	-0.033	0.103	0.145	0.884	Rejected
H1202	$TX \rightarrow SN \rightarrow INT$	-0.002	-0.003	0.020	0.088	0.930	Rejected
H1198	$IL \rightarrow A_B \rightarrow INT$	-0.003	0.002	0.041	0.078	0.938	Rejected
H1216	$RB2 \rightarrow PBC \rightarrow INT$	-0.013	-0.010	0.100	0.134	0.893	Rejected
H1217	$TF \rightarrow PBC \rightarrow INT$	0.003	-0.013	0.044	0.070	0.944	Rejected
H1196	$PFC \rightarrow A_B \rightarrow INT$	0.001	0.001	0.016	0.064	0.949	Rejected
H1210	$TX \rightarrow PBC \rightarrow INT$	-0.001	0.022	0.050	0.029	0.977	Rejected
H1200	$RB \rightarrow A_B \rightarrow INT$	-0.003	0.010	0.044	0.059	0.953	Rejected
H1199	$RB2 \rightarrow A_B \rightarrow INT$	-0.002	0.001	0.027	0.059	0.953	Rejected
H1197	$TF \rightarrow A_B \rightarrow INT$	0.001	0.002	0.017	0.035	0.972	Rejected
H1194	$TX \rightarrow A_B \rightarrow INT$	-0.005	0.006	0.058	0.079	0.937	Rejected
H1203	$AR \rightarrow SN \rightarrow INT$	0.012	0.011	0.024	0.496	0.620	Rejected
H1209	$IF \rightarrow SN \rightarrow INT$	-0.009	-0.005	0.019	0.488	0.625	Rejected
H1206	$IL \rightarrow SN \rightarrow INT$	0.040	0.030	0.058	0.687	0.492	Rejected
H1211	$AR \rightarrow PBC \rightarrow INT$	-0.008	0.024	0.064	0.119	0.905	Rejected

Source: Project team compilation

Table K.13: Summary of Total Indirect Effects in the Augmented TPB Model for Intentions to Adapt to Climate Variability in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1219	$AR \rightarrow INT$	0.004	0.033	0.076	0.048	0.962	Rejected
H1225	$IF \rightarrow INT$	-0.010	0.004	0.050	0.209	0.834	Rejected
H1222	$IL \rightarrow INT$	0.037	0.025	0.078	0.477	0.633	Rejected
H1220	$PFC \rightarrow INT$	0.018	0.011	0.078	0.232	0.817	Rejected
H1224	$RB \rightarrow INT$	-0.027	-0.032	0.098	0.280	0.780	Rejected
H1223	$RB2 \rightarrow INT$	-0.013	-0.007	0.103	0.129	0.898	Rejected
H1221	$TF \rightarrow INT$	0.036	0.015	0.060	0.592	0.554	Rejected
H1218	$TX \rightarrow INT$	-0.008	0.025	0.075	0.103	0.918	Rejected

Source: Project team compilation

Table K.14: Summary of Direct Effects in the Augmented TPB Model for Intentions to Adapt to Climate Variability in the Impala Irrigation Scheme

Hypothesis	Relation	Original Sample	Sample mean	Standard deviation	T statistic	P Values	Decision
H1183	$A_B \rightarrow INT$	-0.013	0.015	0.145	0.088	0.930	Rejected
H1160	$AR \rightarrow A_B$	0.032	0.005	0.170	0.189	0.850	Rejected
H1185	$AR \rightarrow INT$	0.192	0.144	0.174	1.107	0.268	Rejected
H1176	$AR \rightarrow PBC$	0.188	0.205	0.172	1.094	0.274	Rejected
H1168	$AR \rightarrow SN$	0.154	0.140	0.126	1.220	0.222	Rejected
H1166	$IF \rightarrow A_B$	0.103	0.076	0.200	0.517	0.605	Rejected
H1192	$IF \rightarrow INT$	0.096	0.092	0.106	0.907	0.365	Rejected
H1182	$IF \rightarrow PBC$	-0.001	0.044	0.148	0.008	0.993	Rejected
H1174	$IF \rightarrow SN$	-0.121	-0.108	0.116	1.046	0.296	Rejected
H1163	$IL \rightarrow A_B$	0.254	0.253	0.160	1.589	0.112	Rejected
H1189	$IL \rightarrow INT$	0.170	0.162	0.159	1.067	0.286	Rejected
H1179	$IL \rightarrow PBC$	-0.008	-0.085	0.190	0.042	0.967	Rejected
H1171	$IL \rightarrow SN$	0.526	0.462	0.163	3.222	0.001***	Accepted
H1193	$PBC \rightarrow INT$	-0.041	-0.016	0.239	0.170	0.865	Rejected
H1186	$PFC \rightarrow INT$	-0.082	-0.068	0.097	0.846	0.397	Rejected
H1161	$PFC \rightarrow A_B$	0.032	0.035	0.106	0.301	0.763	Rejected
H1177	$PFC \rightarrow PBC$	-0.336	-0.316	0.130	2.574	0.010**	Accepted
H1169	$PFC \rightarrow SN$	0.044	0.020	0.118	0.368	0.713	Rejected
H1165	$RB \rightarrow A_B$	0.205	0.186	0.175	1.169	0.243	Rejected
H1191	$RB \rightarrow INT$	0.284	0.315	0.152	1.864	0.062	Rejected
H1181	$RB \rightarrow PBC$	0.370	0.395	0.202	1.834	0.067	Rejected
H1173	$RB \rightarrow SN$	-0.129	-0.080	0.178	0.724	0.469	Rejected
H1164	$RB2 \rightarrow A_B$	0.125	0.114	0.144	0.868	0.386	Rejected
H1190	$RB2 \rightarrow INT$	0.175	0.145	0.150	1.169	0.242	Rejected
H1180	$RB2 \rightarrow PBC$	0.332	0.333	0.235	1.415	0.157	Rejected
H1172	$RB2 \rightarrow SN$	0.023	0.048	0.176	0.131	0.895	Rejected
H1188	$SN \rightarrow INT$	0.076	0.065	0.112	0.679	0.497	Rejected
H1162	$TF \rightarrow A_B$	-0.047	-0.040	0.118	0.400	0.689	Rejected
H1187	$TF \rightarrow INT$	0.356	0.361	0.108	3.286	0.001***	Accepted
H1178	$TF \rightarrow PBC$	-0.075	-0.107	0.135	0.559	0.576	Rejected
H1170	$TF \rightarrow SN$	0.423	0.389	0.134	3.151	0.002	Accepted
H1159	$TX \rightarrow A_B$	0.356	0.377	0.179	1.989	0.047**	Accepted
H1184	$TX \rightarrow INT$	0.180	0.143	0.140	1.287	0.198	Rejected
H1175	$TX \rightarrow PBC$	0.036	0.059	0.189	0.193	0.847	Rejected
H1167	$TX \rightarrow SN$	-0.023	-0.037	0.143	0.158	0.874	Rejected

Note: * $\rho < 0.1$, ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation

Table K.15: Total effects (Sum of direct and indirect effects)

Hypothesis	Relation	Original Sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistic	P Values	Decision
H1250	$A_B \Rightarrow INT$	-0.013	0.015	0.145	0.088	0.930	Rejected
H1227	$AR \Rightarrow A_B$	0.032	0.005	0.170	0.189	0.850	Rejected
H1252	$AR \Rightarrow INT$	0.196	0.177	0.140	1.400	0.162	Rejected
H1243	$AR \Rightarrow PBC$	0.188	0.205	0.172	1.094	0.274	Rejected
H1235	$AR \Rightarrow SN$	0.154	0.140	0.126	1.220	0.222	Rejected
H1233	$IF \Rightarrow A_B$	0.103	0.076	0.200	0.517	0.605	Rejected
H1259	$IF \Rightarrow INT$	0.085	0.096	0.095	0.901	0.368	Rejected
H1249	$IF \Rightarrow PBC$	-0.001	0.044	0.148	0.008	0.993	Rejected
H1241	$IF \Rightarrow SN$	-0.121	-0.108	0.116	1.046	0.296	Rejected
H1230	$IL \Rightarrow A_B$	0.254	0.253	0.160	1.589	0.112	Rejected
H1256	$IL \Rightarrow INT$	0.207	0.188	0.142	1.457	0.145	Rejected
H1246	$IL \Rightarrow PBC$	-0.008	-0.085	0.190	0.042	0.967	Rejected
H1238	$IL \Rightarrow SN$	0.526	0.462	0.163	3.222	0.001***	Accepted
H1260	$PBC \Rightarrow INT$	-0.041	-0.016	0.239	0.170	0.865	Rejected
H1253	$PFC \Rightarrow INT$	-0.082	-0.068	0.097	0.846	0.397	Rejected
H1228	$PFC \Rightarrow A_B$	0.050	0.046	0.092	0.539	0.590	Rejected
H1244	$PFC \Rightarrow PBC$	-0.336	-0.316	0.130	2.574	0.010**	Accepted
H1236	$PFC \Rightarrow SN$	0.044	0.020	0.118	0.368	0.713	Rejected
H1232	$RB \Rightarrow A_B$	0.205	0.186	0.175	1.169	0.243	Rejected
H1258	$RB \Rightarrow INT$	0.257	0.283	0.159	1.613	0.107	Rejected
H1248	$RB \Rightarrow PBC$	0.370	0.395	0.202	1.834	0.067	Rejected
H1240	$RB \Rightarrow SN$	-0.129	-0.080	0.178	0.724	0.469	Rejected
H1231	$RB2 \Rightarrow A_B$	0.125	0.114	0.144	0.868	0.386	Rejected
H1257	$RB2 \Rightarrow INT$	0.162	0.138	0.133	1.214	0.225	Rejected
H1247	$RB2 \Rightarrow PBC$	0.332	0.333	0.235	1.415	0.157	Rejected
H1239	$RB2 \Rightarrow SN$	0.023	0.048	0.176	0.131	0.895	Rejected
H1255	$SN \Rightarrow INT$	0.076	0.065	0.112	0.679	0.497	Rejected
H1229	$TF \Rightarrow A_B$	-0.047	-0.040	0.118	0.400	0.689	Rejected
H1254	$TF \Rightarrow INT$	0.392	0.376	0.093	4.222	0.000***	Accepted
H1245	$TF \Rightarrow PBC$	-0.075	-0.107	0.135	0.559	0.576	Rejected
H1237	$TF \Rightarrow SN$	0.423	0.389	0.134	3.151	0.002	Accepted
H1226	$TX \Rightarrow A_B$	0.356	0.377	0.179	1.989	0.047**	Accepted
H1251	$TX \Rightarrow INT$	0.172	0.168	0.112	1.535	0.125	Rejected
H1242	$TX \Rightarrow PBC$	0.036	0.059	0.189	0.193	0.847	Rejected
H1234	$TX \Rightarrow SN$	-0.023	-0.037	0.143	0.158	0.874	Rejected

Note: ** $\rho < 0.05$, *** $\rho < 0.01$

Source: Project team compilation