Water Utilisation in Agriculture:

The use of Social Media among Smallholder Farmers for Sustainable Water Management Practices

Report to the
Water Research Commission

by

J Ndoro, A Jumman, N Jere, M van der Laan, S Walker

engaged Students

WNS Zondo, M Mabuza, N Shongwe, S Mamba, W Bhoroma

WRC Report No. 3076/1/23
ISBN 978-0-6392-0409-3

May 2023

Obtainable from

Water Research Commission
Bloukrans Building, 2nd Floor
Lynnwood Bridge Office Park
4 Daventry Road
Lynnwood Manor
PRETORIA

orders@wrc.org.za or download from www.wrc.org.za

This is the final report of WRC project no. C2020/2021-00222.

EXECUTIVE SUMMARY

This report is based on the WRC Project No. K4 (C2020/2021-00222): Water Utilisation in Agriculture, project title: The use of social media among smallholder farmers for sustainable water management practices. The project was for three-years, and it was based in Nkomazi Local Municipality, Mpumalanga Province, South Africa. The project set out to explore the use of social media among smallholder farmers for dissemination of sustainable agricultural practices. The rationale of the project was founded upon social media having a high potential for agricultural communication.

Social media are interactive technologies that enable the creation of profiles and making explicit as well as traverse relationships. It provides several prospects and incentives that lighten the provision of agricultural extension services, allows for wider farmer coverage, and eases real-time delivery of services of information and training. Social media has emerged as a technology that is easily accessible and adaptable to even those that lack fundamental ICT skills. Social media encompasses sites and applications that include micro-blogs, socially integrated messaging platforms, professional networking, and content communities (i.e. Facebook, Google+, Twitter, Instagram, WhatsApp, Facebook Messenger, LinkedIn, Academia.edu, YouTube). The use of social media provides beneficial ways of creating, interacting, and sharing information. It offers benefits of disseminating information and knowledge across geographical and temporal barriers. Regarding agricultural advisory services, clarifications, feedback, and after-care training can be provided within a reasonable time. Through social media smallholder farmers have the potential to access real-time data and information to improve their decision-making on innovative water management initiatives.

Numerous studies have focused mostly on the use of social media to attain knowledge on sustainable agriculture, training needs on the usage of social media, social media use to enhance the coverage and scope of traditional agricultural extension, analysis of attitudes and behaviours of farmers towards social media platforms, liability exposure and sharing of knowledge through social media. There is scanty knowledge on the utilisation of social media among smallholder farmers for the dissemination of agricultural information, especially for sustainable water management practices in water-scarce countries such as South Africa. Additionally, agricultural support services interventions provide minimum support to improve smallholder farmers' competency, specifically in agricultural water management practices. Moreover, a comprehensive view of architecture in the form of a framework considering all the core impacts and processes of social media adoption by smallholder farmers in relation to sustainable water

management practices has not been explored. Social media has the potential to enhance advisory service delivery to smallholder farmers thus allowing for more sustainable management of agricultural water and enhance farming practices.

Social media can improve information sharing on water accountability and water management practices for successful agricultural production, food security and sustainability. In South Africa it has been predicted that freshwater accessibility will be less than 1000 m^3 per capita by the year 2025. Smallholder farmers face new water quality and quantity challenges owing to rapid population growth, pollution, climate change and its impacts on water resources and increased competition between water sectors. Failing to mitigate these constraints may lead to physical water insufficiency in many economic sectors, including agriculture. Relevant and continuous dissemination of knowledge and information is essential for smallholder farmers to equip themselves with innovative practices to adapt to the changing environment. This project set out to explore the use of social media among smallholder farmers for sustainable water management practices, assess smallholder farmers' online access and interaction in a water management training programme and the development of a framework for the dissemination of sustainable water management practices. The main objectives of the project were:

- To review the literature on the use of social media for sustainable agricultural practices among smallholder farmers.
- To design and deliver a social media-based agricultural water management training programme.
- To identify the constraints and opportunities in using social media to promote sustainable water management practices among smallholder farmers.
- To develop a framework for the dissemination of sustainable agricultural water management practices through social media.

A mixed research approach was utilised to identify comprehensive methodologies of achieving the main objectives of the project. Both quantitative and qualitative approaches were used by employing positivist and empiricism paradigms. A convenience sampling method was employed in the Nkomazi Local Municipality, which is a Category B municipality and is the smallest of the four municipalities within the Ehlanzeni District. The main economic sectors in Nkomazi Local Municipality include agriculture, mining, and tourism mostly in the towns of, Komatipoort, Marloth, Kamhlushwa and Malalane (MSA 2020). Numerous communities were visited, including Jepees, Schoemansdal, Langloope, Mzinti, Mbuzini, Skhwahlane, Stenbork, Tonga, Hoyi Trust, Magogeni and Naas. Structured questionnaires were distributed using a house-to-house approach throughout the various communities. A sample population of 121 smallholder farmers participated in the study. Quantitative data were analysed using descriptive statistics in the Statistical Package for Social Sciences (SPSS).

A qualitative research approach was employed using Participatory Rural Appraisal (PRA) tools, with a sample size of 37 from the total of 121 smallholder farmers. Through transact walk and field observations, and semi-structured interviews, smallholder farmers within the municipality were identified as well as other relevant stakeholders such as agricultural extension officials and NGOs that work with smallholder farmers. Focused group discussions based on the social media training programme were held with the 37 smallholder farmers. A training programme was developed that involved the use of WhatsApp as a platform for users to be able to receive and share diverse information such as video, audio, and other types of visual formats. Thematic analysis was used to analyse the qualitative data. Additionally, a new agriculturally based social media platform was developed. Through this platform, smallholder farmers will be able to find agricultural information and share amongst themselves and with other varying stakeholders. The given name for the platform was the Abalimi Forum. The major findings of the study were as follows:

- ***The social media use survey revealed that 68% of the 121 smallholder farmers do not utilise social media.***
  This finding indicates that most smallholder farmers in the Nkomazi local municipality do not utilise social media.
- ***The training programme survey revealed that SiSwati (75.7%) was the highly preferred social media language by smallholder farmers.***
  This could be because Nkomazi local municipality is dominated by a Swati-speaking people.
- ***The training programme revealed that a total of 62.2% of smallholder farmers were motivated to use social media to gain information.***
  Social media can enable smallholder farmers to create and share content rather than just access and browse the content. Social networking also supports the sharing of educational knowledge between multiple smallholder farmers.
- ***Social media training was preferred to be through practical videos by 54.1% of the smallholder farmers (54.1%)***

Videos offer a better way to explain the subject matter. A video showing practical steps through images, voice prompts and designed according to smallholder farmers' preferred language makes it easy to understand the information being disseminated.

- ***A total of 62.2% of smallholder farmers preferred to receive training on agricultural water management practices through the WhatsApp social media platform.*** WhatsApp platform is used on a more personal level where private messages, videos, pictures, and audios are sent and received instantly. It consists of peer-formed groups that promote interaction among users. It also allows the users to make voice and video calls to communicate with each other at ease and at a lower cost.

The study shows that there is a need for more technological and simpler forms of information dissemination among smallholder farmers and other agricultural stakeholders. Social media has the potential to enable the sharing of agricultural information among smallholder farmers. Through social media various platforms are easily accessible at a cost-effective amount. An agricultural water management training programme was developed to allow smallholder farmers and other diverse stakeholders to interact and add perspectives on how to improve the methods of training smallholder farmers through social media. The findings support that a training programme through social media is feasible, though only in a situation where the necessary infrastructure, electronic devices, networks, and platforms are available to all smallholder farmers. The Abalimi Forum is an innovative agricultural platform that encompasses such aspects, though it requires further development and testing before widespread distribution.

The study, therefore, recommends that agricultural support services need to evolve to adapt to the changing environment which requires innovations such as the use of social media to disseminate innovative agricultural information among smallholder farmers. Additionally, it is recommended that policies be developed and adopted for training and educating smallholder farmers on ICT skills. Social media platforms that are better associated with agricultural practices and activities, which are open access and operate on full-time basis should also be developed by relevant stakeholders (i.e. government, agricultural extension officials, ICT technicians and NGOs). The Abalimi Forum is just such an example of the platform that can empower smallholder farmers and allow them to easily share information with each other and other stakeholders. This can improve the competencies of smallholder farmers and facilitate the immediate dissemination of innovative information to promote sustainable agriculture and sustainable water management practices.

ACKNOWLEDGEMENTS

The project team wishes to thank the following people for their contributions to the project.

Reference Group	**Affiliation**
Dr Luxon Nhamo	WRC - Project Manager
Prof Sylvester Mpandeli	WRC
Dr Samkelisiwe Hlophe-Ginindza	WRC
Dr Mokhele Moeletsi	ARC
Mpho Kapari	WRC
Prof. Joyce Chitja	University of KwaZulu-Natal
Nomvuso Mujadu	DALRRD
Edwin Mametja	DALRRD
Freddy Rabothata	DALRRD
Prof. Charles Mutengwa	University of Fort Hare
Dr Vimbai Chimonyo	CIMMYT

This page was intentionally left blank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS & ABBREVIATIONS

AEAS	Agricultural Extension and Advisory Services
AFRRI	Armed Forces Radiobiology Research Institute
AKIS	Agricultural Knowledge and Innovation
ANC	African National Congress
ARC	Agricultural Research Council
BMPs	Better Management Practices
CRDP	Comprehensive Rural Development Programme
CS	Community Survey
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DRDLF	Department of Rural Development and Land Reform
E-Books	Electronic Books
FAO	Food and Agricultural Organisation of the United Nations
GPRS	General Packet Radio Service
GRACE	Gravity Recovery and Climate Experiment satellites
GSM	Global System for Mobile communication
ICT	Information Communication Technology
IDP	Integrated development Plan
ILRI	International Livestock Research Institute
ITU	International Telecommunication Union
LED	Light-Emitting Diode
LIVES	Livestock and Irrigation Value Chains for Ethiopian Smallholders
MASDT	Mobile Agricultural Skills Development and Training
MSA	Municipalities South Africa
NAB	National Association of Broadcasters

NASA	National Aeronautics and Space Administration
NDP	National Development Plan
PLA	Participatory Learning and Action
PRC	Participatory Radio Campaign
SASA	South African Sugar Association
SASAE	South African Society for Agricultural Extension
SCADA	Supervisory Control and Data Acquisition
SMS	Short Messaging Service
SPSS	Statistical Package for Social Sciences
STATSSA	Statistics South Africa
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USG	User Generated Content
WI-FI	Wireless Fidelity

GLOSSARY

Application: is the software that is installed into a device or hardware in the form of a platform in which interactions between users can occur.

Facebook: is an online social networking platform that has different and similar groups and pages in which users share media, such as videos, pictures, direct messages, and links.

Icon: an individual or item regarded as an illustrative representation.

Media: refers to content that is accessed through digital technology, such as the internet, which allows for participation in sharing and feedback, such as videos and pictures.

Platform: is an application of social media in which a user can generate and share content and opinions, privately or to a larger more public audience.

Site: refers to a web page wherein a person can post or distribute their opinions for other users of the site to view and comment.

Social media: is a medium of communication and interactions which utilises Web 2.0, wherein the content is formed by varying users and shared among themselves or to the wider public within similar networks that include varying platforms, sites, or applications such as WhatsApp, YouTube, Twitter, and Facebook.

Twitter: is a microblogging and social networking service on which its employers post and interact through messages referred to as "tweets", wherein its users can post, retweet tweets, and like, yet unregistered individuals are only able to read them.

WhatsApp: is a mobile device social networking platform, which allows its users to dispense text as well as voice messages, make videos along with voice calls, share images, locations, and documents.

YouTube: is a video distribution platform and website in which individual utilisers can upload videos to share with the wider public audience.

1. INTRODUCTION

Social media has enhanced how people communicate and share information (Thakur, Chander, & Sinha, 2017; Mladenović & Krajina, 2019). Even though there is high social media potential in agricultural communication, there is low usage and a lack of awareness of social media in rural areas in developing countries (Kimani, Nyang'anga & Mburu, 2019). Social media provides several prospects and benefits that has potential to ease the provision of agricultural extension services, allow for wider access to smallholder farmer coverage and facilitate real-time delivery of services (Kimani *et al.,* 2019). There are several social media platforms that smallholder farmers can utilise for sharing information on sustainable agriculture, especially agricultural water management practices. Social media is emerging as a beneficial way of interacting and sharing information. Therefore, smallholder farmers adoption of social media networks and their platforms can allow for easier information sharing (Thakur *et al*., 2017).

Social media offers several benefits as a method of communication in agriculture and information dissemination. Social media has the advantage of disseminating information and knowledge beyond geographical boundaries and time (Thakur *et al*., 2017). This allows for any clarification and feedback within a reasonable time, especially for both smallholder farmers and the agricultural extension service providers. The availability and affordability of Information Communication Technology (ICT) can increase the ease of communication through social media and limit communication barriers among smallholder farmers, as well as with agricultural extension officials, especially about sustainable water management practices (Yadav, Sulaiman, Yaduraju, Balaji & Prabhakar, 2015).

Water is considered one of the extremely scarce resources in agriculture, particularly in developing countries (FAO, 2023). It is not only essential for agriculture, economic growth, and industry, but it also affects the conservation of natural resources thus making it a vital component of the environment (Chartzoulakisa & Bertaki, 2015). South Africa is a water-stressed country, and it is estimated that freshwater accessibility will be significantly reduced by the year 2025 leading to physical water insufficiency (Otieno & Ochieng, 2004). The majority of smallholder farmers seek and receive information about sustainable water management from agricultural extension officials, libraries and websites (Kuria, 2014). Most African countries have insufficient numbers of extension officers to assist the ever-increasing number of smallholder farmers, and South Africa is no exception (Amer, Odero & Kwake, 2018). South Africa has a low extension officer to smallholder farmers ratio, this is because of a lack of extension capacity (DAFF 2016). This challenge could be overcome by considering different modes of delivering extension services such as through social media (Mithum, Shaikh & Abdullah, 2021). Limited studies on social media in agriculture have focused on agricultural marketing (Balkrishna & Deshmukh, 2017; Lathiya, Rothod & Choudhary, 2015; White, Meyers, Doerfert & Irlbeck, 2014). A few studies have looked at social media and soil and water conservation (Anderson-Wilk, 2009; Werts, Mikhailova, Post & Sharp, 2012).

However, there is limited knowledge on the utilisation of social media for the dissemination of agricultural information, especially for sustainable water management practices among smallholder farmers in water-scarce regions of South Africa. This is despite the notable potential of social media to easily and quickly spread information across diverse smallholder farmers experiencing common freshwater scarcity constraints. The adoption of social media for sustainable water practices seeks to resolve important questions, such as: What are the determinants of social media adoption as a source of information among smallholder farmers? What are the constraints that hinder access to information on social media among smallholder farmers? What are the factors that support the use of social media among smallholder farmers? What are the benefits/utilities of social media for smallholder farmers accessing the information on sustainable agricultural water management practices?

Therefore, social media adoption for the dissemination of information on sustainable water practices needs to be measured and contextualised. Moreover, an encompassing consideration of architecture in the form of a framework of all core influences and the process of social media adoption by smallholder farmers anchored on sustainable water practice needs to be explored, especially towards ensuring access to real time data, information, knowledge, and experience, along with best practices and lessons learnt on sustainable water management practices. With the aim of promoting dissemination, transfer, development, and diffusion of sound sustainable water management practices in South Africa that are in line with the National Development Plan (NDP) 2030, Strategic Plan 2015/16 to 2019/20 and the United Nations 2030 Agenda for Sustainable Development.

The study will provide policymakers as well as extension officers with valuable information on the preference of smallholder farmers towards social media as a platform to share information on sustainable agricultural water management practices. The study seeks to gain insight into the factors that support the use of social media among smallholder farmers and develop an online platform.

The online platform will be used to establish a comprehensive mapping of, and serve as a gateway for, information on existing science, technology and innovation initiatives, mechanisms, and programmes within and beyond the study area. The online platform will facilitate access to information, knowledge, and experience, as well as best practices and lessons learnt, on science, technology and innovation facilitation initiatives and policies. The online platform will also facilitate the dissemination of relevant open-access scientific publications generated worldwide. The online platform will be developed based on an independent technical assessment which will consider best practices and lessons learnt from other initiatives, within and beyond the country. The best practices drawn from other initiatives will ensure that the study will complement, facilitate access to and provide adequate information on existing science, technology, and innovation platforms, thereby avoiding duplication and enhancing synergies.

2. LITERATURE REVIEW AND CONCEPTUAL ASPECTS

2.1. Introduction

The agricultural sector in many developing countries is becoming more complex and knowledge intensive (Babu *et al*., 2011). Agricultural information is a central component that interrelates with accompanying production factors (Vidanapathirana, 2012). Obtaining timely and frequent access to information and advice is one of the core resources for smallholder farmers to improve and uplift their living standards. Access to information brings about change and enhances development among smallholder farmers (Bell, 2014; Rehman *et al*., 2013). Agricultural information is a basic necessity that aids in decision making, especially among smallholder farmers (Odini, 2014). Accessibility to agricultural information plays an important role in increasing agricultural production as well as improving marketing and distribution opportunities for smallholder farmers' produce (Rehman *et al*., 2013). Participation by smallholder farmers in the global economy requires access to up-to-date information and innovations concerning new crops, seeds, pesticides, production techniques and cultivation methods (Singh *et al*., 2011; Pigford *et al*., 2018).

Smallholder farmers access information from varied sources that include foremost agricultural extension services as well as Information Communication Technologies (ICT) (Bhattacharjee & Raj, 2016). Although ICTs have been used for some time to facilitate communication among smallholder farmers and agricultural extension officers, social media is a more recent addition (Davis & Terblanché, 2016). Smallholder farmers depend on information for increasing their production and enhancing their livelihoods. An agricultural extension officer is the middleman for the two-way communication between researchers and smallholder farmers. According to Van der Ban and Hawkins (1996), the role of agricultural extension includes the transferring of knowledge from researchers to smallholder farmers, advising in their decision making and educating on how to make better decisions, enabling them to clarify their goals and possibilities and stimulating desirable agricultural developments. Moreover, agricultural extension services together with digital technologies such as social media have the potential of giving a special edge towards evoking innovation among smallholder farmers.

Social media has developed into an imperative component of people's existence in the world in general and specifically for the agricultural industry. It has enhanced how people can communicate with each other and how they share information (Thakur, Chander & Sinha, 2017). According to Kimani, Nyang'anga and Mburu (2019), social media provides several prospects and incentives that could ease agricultural information dissemination among stakeholders, in particular smallholder farmers and agricultural extension officials. It allows for wider smallholder farmer coverage and facilitates real-time delivery of vital information on sustainable practices such as water management practices.

The literature review and conceptual aspects outlines the potential application of social media in agriculture as well as constraints and opportunities. A valuable array of better management practices and associated problems and challenges among smallholder irrigation farmers is also presented. The first section includes an overview of social media platforms and networks with constraints and opportunities, as well as common social media tools used in agriculture. The second section is a brief discussion on agricultural extension services and roles as well as technologies for agricultural extension officers and technologies for water management practices. The third section presents better management practices, including associated problems and challenges for smallholder irrigation farmers. Lastly, a conclusion is drawn.

2.2. Overview of social media platforms and networks

The impending Fourth Industrial Revolution has caused reforms in every sphere of day-to-day life with the changes blurring the cyber-physical systems. Traditionally, networking existed in the physical space but of late, it has effectively penetrated the cyberspace. The growing need for convenience, increasing profit margins and the ease of doing business has forced markets to also gravitate towards the cyberspace (Balkrishna & Deshmukh, 2017). Within the cyberspace, social media has taken a centre stage in facilitating the penetration of traditionally physical markets into the virtual space (Shava & Chinyamurindi, 2018).

Definitions

Although there is a wide range of definitions for social media, this study will conceptually focus on the technocratic definition and a loose definition that applies to ordinary users without advanced computer expertise. A technocratic definition of social media was suggested by Kaplan and Haenlein (2010) and Kane *et al*. (2014) who defined it as a system encompassing a collection of connected Internet-based applications that roots in the conceptual and technical fundamentals of Web 2.0 and that permit the creation of individual profiles and sharing of User Generated Content (UGC). To an ordinary user, social media is a "platform to create profiles, make explicit and traverse relationships" (Boyd & Ellison, 2008).

Social media is a generic term referring to a system, a network and/or platform that is a mutual communication pathway that allows users to choose who they want to connect with and the content they want to share (Edosomwan *et al*., 2011). Although social media and social networks are technically different, most people use these terms interchangeably. Therefore, social media platforms and networks are online podia that can be used to create, disseminate and communicate between users.

Social media has created cyber communities of users with the same interests and who interact beyond physical, geographical, and biological boundaries. Miller *et al*. (2009) defined these on-line communities as users on a wide range of internet fora, including markets and auction sites, bulletin boards, social networking sites, blogs, gaming, and shared interest sites.

Background and benefits of social media

The use of smartphones has ushered in a revolution. Among the global population, 39% are social media users, and 36% of the world population access social media from mobile phones (Hootsuite, 2017). These numbers have certainly increased since then, particularly due to the 2020 COVID-19 pandemic. Social media has evolved from personal uses and has essentially infiltrated professionals resulting in the emergence and expansion of business networking. The penetration of social media into corporate organisations began when employees informally used social media platforms to communicate official organisational information (Balkrishna & Deshmukh, 2017). With time, organisations embraced social media as a way of ensuring timeous information dissemination and feedback from employees, customers, and other interested parties. It allows information to reach a wide audience in a very short time and, in most instances, in real time (Edosomwan *et al*., 2011).

Social media has come out as a platform that is easily adaptable even to those that do not have strong computer backgrounds due to ease of access. Furthermore, social media platforms have facilitated knowledge sharing in addition to being cost effective in comparison with direct telephone calls (Ng, 2016) or 'face-to-face communication' as it uses a 'one to many' system. In a study by Roux and Dalvit (2014) in rural communities of South Africa, it was revealed that over 70% of people who do not own smartphones still access social media by sharing gadgets with those who have them. This annuls the suggestion that access to social media is a challenge in rural communities. In terms of attitudes towards the use of social media platforms for knowledge dissemination, a study by Shava and Chinyamurindi (2018) showed that more than 30% of the youth in rural communities agreed that they used social media platforms for knowledge sharing. Social media platforms can be classified into social media sites (Facebook, Google+), micro-blogs (Twitter, Instagram), socially integrated messaging platforms

(WhatsApp, Facebook messenger), professional networking (LinkedIn, Academia.edu) and content community (YouTube), among others (Kaplan & Hainlein, 2010).

Social media use in South Africa

A total of 98% of South Africans live within cellular network coverage and two-thirds of smallholder farmers prefer using smartphones to access the internet, and this provides an opportunity for using ICT in improving productivity among smallholder farmers (Simpson & Calitz, 2014). A wide range of social media is currently being utilised to achieve different organisational or individual objectives, including blogs, podcasts, fora, and wikis (Andryani *et al*., 2019). Current figures show that the most popular social media platform in South Africa is Facebook which takes up almost half of the total social media users as shown on ***Figure 1*** (Statscounter, 2020). The distribution of the other platforms according to Statscounter (2020) are Pinterest (36.48%), Twitter (10.08%), YouTube (2.97%), Instagram (1.8%) and Tumblr (0.66%).

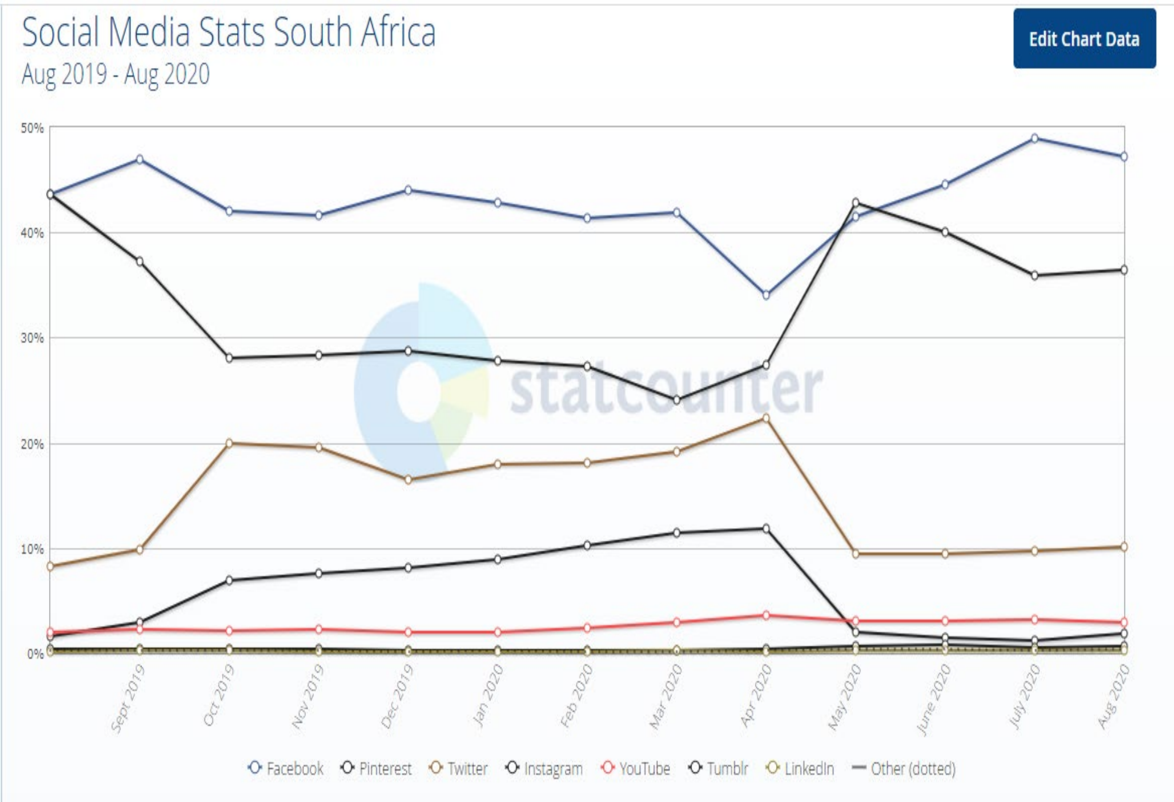

Figure 1: *Trends in social media usage between Aug 2019 and Aug 2020 in South Africa (Statcounter, 2020).*

2.3. Common social media tools in agriculture

Bhattacharjee and Raj (2016) provided a comprehensive overview of 27 examples of agricultural social media groups, communities, and pages. However, many of the links to these examples are now no longer functional as of October 2020. Although no data could be found on the turnover rates of social media profiles, the very nature of social media lends itself to rapid and continuous evolution. The success of using social media platforms for agriculture is dependent on the prevalence of the use of social media in Africa in general. The general use of social media networks offers a foundation on where agriculturally based initiatives can be built (Joshi *et al*., 2017). Against this background, social media has the potential to be used as an effective platform to grow the agricultural sector in rural communities.

Agriculture has utilised social media platforms as an arena to market products, train new skills, network, access weather forecasts and for expert advice (Joshi *et al*., 2017). The following social media sites represent some of the platforms that are being used for agricultural purposes:

Facebook allows farmers to have their individualised pages and groups which market their brands and products (Balkrishna & Deshmukh, 2017). Founded in February 2004, Facebook is the leading social media site with 1.415 billion active users (Bhattacharjee & Raj, 2016) and more than 16 million subscribers in South Africa only as of March 2019 (Edosomwan *et al*., 2011; NapoleanCat, 2019). Among agricultural stakeholders, Facebook is the most popular social media network with more than 60% of farmers preferring to use it as compared to other networks (Bhattacharjee & Raj, 2016). Although Facebook is currently being used as a business platform (e.g. Facebook Marketplace), it is commonly known as a social networking site (Mills *et al*., 2019).

In their survey of 229 agricultural extension stakeholders from 62 countries (8.5% of which were classified as belonging to developing countries), Bhattacharjee and Raj (2016) report a strong preference for the use of Facebook, with 64.7% of respondents listing the platform as their preferred social media platform. In the African context, few formal studies have quantified the size of the agricultural community on Facebook. Hay (under review) reports that during initial scoping studies, several Facebook groups for smallholder farmers were identified, ranging in size from less than a hundred members to over 500 000 members.

Smallholder farmers are already using social media platforms informally to actively seek information. Kuria (2014) reports that smallholder farmers in Kenya are using social media to source a wide range of agricultural information, such as training material, agrochemical guidelines and technological information for themselves. Facebook lends itself to sharing information as there are few limitations on the type of media that can be shared. This platform was found to be suitable for hosting virtual learning programmes. However, further work is needed to understand if such learning programmes lead to measurable increases in smallholder farmer knowledge or real-world action changes by smallholder farmers (Hay under review).

YouTube enables smallholder farmers to increase the visibility of what they can offer by uploading videos of their farming activities. In addition, YouTube facilitates knowledge dissemination by acting as a database for agricultural training videos (Balkrishna & Deshmukh, 2017). YouTube was launched in 2005 and is considered to have the biggest video online community (Edosomwan *et al*., 2011).

In the sugar cane industry, video webcasting has been proven to be a viable means of providing timely, high-impact and low-cost extension resources (Thomas, 2009) and shown to facilitate referencing of peers when combined with online discussion forums (Thomas, 2010). However, it must be noted that these studies were done in the context of Shed meeting, a social media platform created specifically for agricultural extension purposes. Thomas (2009) argues that public video-sharing platforms such as YouTube have created a misplaced perception that production quality is unimportant and that agricultural extension providers run the risk of devaluing this significant technology as an agricultural extension tool if they do not invest in the right equipment and techniques.

Twitter is a microblogging site that has a subscription of 330 million active subscribers worldwide (Mills *et al*., 2019). Twitter permits subscribers to broadcast messages or 'twits' of up to 140 characters at a time (Mills *et al*., 2019). Each subscriber is identified by a 'handle' which is placed after the @ sign. In addition, users can post videos, photos, or web links. One of the uses of Twitter is that it allows users to be actively involved in open discussions where the hashtag (#) sign is used to follow a discussion. In agriculture, Twitter allows farmers to follow the latest news and information as well as participate in discussions in agricultural circles. It allows farmers to contribute to discussions. In a study by Cline (2011), most farmers preferred using Twitter as a means of advocating for agriculture, a process that they termed 'advocacy'. One example of a popular agricultural-inclined account is @SoilCare_eu which boasts 2743 followers (as of 30 September 2020) from 18 countries as shown in ***Figure 2*** below.

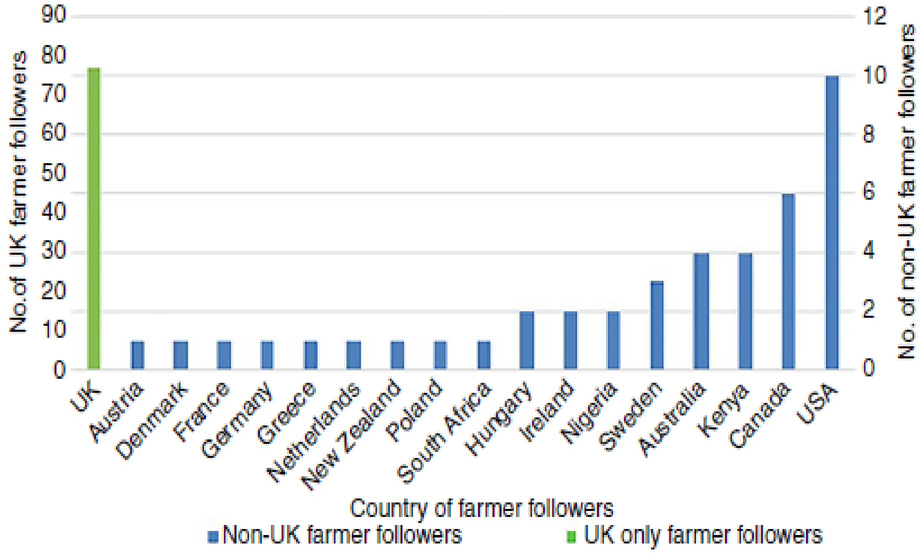

Figure 2: *Distribution of Twitter followers at @SoilCare_eu according to country of origin (Mills et al., 2019).*

WhatsApp is a platform that is used on a more personal level where private messages, videos, pictures, and audios are sent and received instantly. Additionally, it consists of peer-formed groups that promote interaction among users. It also allows the users to make voice and video calls to communicate with each other. Although WhatsApp is popular, the irony is that WhatsApp has fewer users compared to other social networking sites (Montag *et al*., 2015). WhatsApp has approximately 2 billion users with 1 billion daily active users (Andjelic, 2020). According to Naruka *et al*. (2017), WhatsApp allows smallholder farmers to share messages at reduced costs thus enabling them to interact with agricultural extension personnel to enquire about farm operations and diseases affecting their livestock and plants. Although WhatsApp is good for communication, it also has shortfalls that hinder the dissemination of information to smallholder farmers such as no immediate solutions to the problems and the absence of interaction between smallholder farmers, scientists and researchers. Smallholder farmers are often uninformed about the agricultural-related events and information. Zendera *et al*. (2019) discovered in a study in Zimbabwe that 54.1% of the smallholder farmers agreed that they are using WhatsApp to communicate with other smallholder farmers, seek help and get new information. WhatsApp is being used to access agricultural extension services and saves smallholder farmers transport costs and time which traditionally were expended in physically visiting agricultural extension institutions for assistance (Thakur & Chander, 2018a).

2.4. Constraints and opportunities of social media

Although social media presents itself as a novel form of agricultural extension, many of the existing challenges that smallholder farmers face while seeking agricultural information will not be overcome by merely switching to digital agricultural extension. As Chisita (2012) discusses, many smallholder farmers in developing countries remain isolated from the rapid advancement of digital technologies due to various socio-economic reasons. Some of the key challenges identified by Barau and Afrad (2017) include unreliable electricity supplies and poor internet connectivity infrastructure which disproportionately affect rural communities in developing countries. However, even those smallholder farmers with access to newer technologies are often inhibited by a lack of awareness, low literacy levels, and uncoordinated research and dissemination of information (Munene & Kasamani, 2018). Of particular concern are generally lower education and literacy skills by agricultural extension, digital literacy rates, which present a challenge for the introduction of digital agriculture applications that require more advanced digital skills (Barau & Afrad, 2017; Chisita, 2012).

The social media business model centres on increasing the number of users for social media corporations to sell more advertising space and so there is an economic incentive to ensure widespread accessibility of these platforms. One concern is the relative cost for access in the form of data as smallholder farmers in developing countries generally have little disposable income to incur data costs for accessing social media (Barau & Afrad, 2017). Despite this, Kuria (2014) reported a majority of smallholder farmers in the study had a positive attitude towards the use of social media and that it is perceived to be a cheap and convenient source of agricultural information. Kuria (2014) concludes that social media can play a role in building feedback mechanisms to monitor and evaluate the impact of agricultural projects, as well as provide agricultural extension services in areas where there are geographically dispersed groups.

The rapid dissemination of information across social media is a double-edged sword. While it is largely accepted that access to information is positive, Barau and Afrad (2017) discuss that the 'unregulated system of social media platforms can account for blowout of both false information and rumours'. This has the potential to 'detach a smallholder farmer, agricultural extension worker or any other professional in the line, rather than facilitate salient physical interactions which are indispensable for proper networking and ultimate development' (Barau & Afrad, 2017). Barau and Afrad (2017) suggest that in order for institutions providing agricultural extension services to maintain their reputation, it will require some level of online moderation and credibility by ensuring the information being shared is reliable.

2.5. Agricultural extension services and roles

The promotion of the adoption of farm technologies in agricultural extension services is an essential part of increasing farm productivity (Berhane, Ragasa, Abate & Assefa, 2018). Agricultural extension is a system that places its focus on training and empowerment of farmers by assisting smallholder farmers with capabilities that help them manage their farm businesses, solve problems on their own and make sound decisions (Vanclay & Leach, 2011). The activities involved in the agricultural extension services are to transfer innovations along with technologies to smallholder farmers and provide education on alternative practices, which causes a reduction in the irregularity of information that is at most times related to innovations and technologies (Ghimire & Huang, 2015). In most developing countries, agricultural extension seeks to solve problems that are related to management and production, though some smallholder farmers do not have access to agricultural extension services and information (Ghimire & Huang, 2015).

Agricultural extension is responsible for supplying need-based services that are to all groups of smallholder farmers, thereby enabling them to improve their use of capital, to encourage socio-economic development and sustainable agriculture (Hoque & Usami, 2007). Agricultural extension offers smallholder farmers the tools and knowledge that they need to adopt new sustainable methods of farming thereby increasing their yields, advancing their food security and standard of living (Baloch & Thapa, 2018).

Achieving the goal of increased crop yields through sustainable farming methods and practices necessitates agricultural extension services to share new knowledge and innovation with smallholder farmers and other stakeholders. Innovation in agricultural extension is coined under the concept of Agricultural Knowledge and Innovation (AKIS) (Abudu, 2015; Bhattacharjee & Raj, 2016; Zahran *et al*., 2020). According to Zahran *et al*. (2020), innovation is a key driver of productivity, self-sufficiency, profitability, competitiveness and means to secure environmental sustainability. The growth of the agricultural sector strategically depends on the formation of innovation niches and the implementation of innovations (Pigford *et al*., 2018; Zahran *et al*., 2020). Innovation niches include communication networks and connections of varied information sources to keep individuals informed (Bhattacharhjee & Raj, 2016). Agricultural extension services through the use of social media can aid in facilitation and coordination linkages between smallholder farmers and varying stakeholders together with innovation niches (Bhattacharge & Raj, 2016; Pigford,, 2018; Zahran *et al*., 2020). Davis and Terblanché (2016) added that agricultural extension services bring about innovative skills, information and technologies which may stimulate smallholder farmers to enhance their capacities to adopt new ways of elevating their farming practices.

The role played by agricultural extension services in many cases does not fulfil its intended purpose as factors that influence smallholder farmers in the adoption of practices and innovations to increase production or yield are limited to smallholder farmers' perceptions and attitudes. According to Baloch and Thapa (2018), poor service delivery in terms of agricultural extension services, a lack of equipment and low numbers in terms of extension service agents and workers result in the purpose of agricultural extension service provision not being successful or adequate.

Although the implementation of agricultural extension services may be inadequate in certain aspects, the concepts behind them hold significant value in improving smallholder farmers' lives and their production practices if they are properly implemented. According to Hagmann, Chuma, Murwira and Connolly (1999), approaches such as the participatory approach ensure the involvement of key stakeholders in problem solving along with the implementation process of agricultural extension services. In the approach, smallholder farmers have the opportunity to facilitate and participate in their knowledge and experience sharing. Agricultural extension agents facilitate the processes of experience and knowledge sharing; this is known as diffusion of innovation (Baloch & Thapa, 2018). The diffusion of the innovation process could be potentially enhanced by the adoption of social media communication platforms.

2.6. Technologies for agricultural extension officers

Social media

Agricultural extension services play a critical role in providing and transferring knowledge to smallholder farmers through facilitation, advisory and technology transfer. Agricultural extension service is significant in improving productivity such that three-quarters of South African farmers rely on agricultural extension services (Stone & Terblanché, 2012). Challenges that have been faced in agricultural extension services include reaction time constraints. This is especially when a smallholder farmer experiences an emergency that requires urgent expert advice. Additionally, the inability to physically cater for smallholder farmers due to the low extension officer-to-farmer ratio, the incapacity of agricultural extension officers to offer up-to-date expertise and connect smallholder farmers and markets and facilitate the networks of smallholder farmers with similar interests in different geographical regions (Davis & Terblanche, 2016). The above-mentioned challenges can be controlled by a system that can ensure an effective and timeous communication channel among smallholder farmers, agricultural extension officers and other stakeholders. Social media can potentially provide these agricultural extension solutions.

Social media is essential in providing timeous agricultural extension services and can be utilised, especially in areas where officials have difficulties accessing them physically. In a study conducted in India, four in every five farmers agreed that social media has assisted them with the provision of crop and livestock disease solutions (Thakur & Chander, 2018a). The use of social media has also been embraced by official agricultural extension organisations who are now using it as a platform to connect with their stakeholders. The South African Society for Agricultural Extension, for example, has an official interactive Facebook page (SASAE - South African Society for Agricultural Extension) where announcements, encouragements and other information are posted.

Mass media broadcast

Media broadcast is one technology that can be utilised by agricultural extension services to ensure that information reaches every smallholder farmer in a timeous and regular manner. Radio and television listenership and viewership are generally large with a combined audience of 74 million people in South Africa in 2018 (NAB, 2019). More than half of the households residing in rural areas of Lesotho own at least one radio (Akintunde & Oladele, 2019). Successful agricultural extension campaigns have been reported, one of them being a participatory radio campaign (PRC) by AFRRI-I in Malawi (Chapota *et al*., 2014). The project resulted in regular listenership by half of the smallholder farmers in broadcasted areas and inactive communities. One in every five smallholder farmers adopted a new skill that was taught via radio (Chapota *et al*., 2014). In Kenya, the Mali Shambani Show, an hour-long radio show, provides agricultural extension services, weather updates, agricultural news, and market trends among others (Kiambi, 2018).

Use of mobile phones

The penetration of mobile phones in developing countries has provided solutions even to communities that cannot afford expensive gadgets such as desktop and laptop computers. By 2016, Botswana had the largest penetration (70%) of mobile phones in Southern Africa while

Malawi had the lowest (40%) (ITU Statistics, 2016). A study conducted in Kenya revealed that 70% of smallholder farmers with mobile phones use them to access agricultural information (Gwademba *et al*., 2019). The growing prevalence of mobile phone ownership coupled with the high cellular network coverage provides agricultural extension officers with a gap that can be used in information dissemination.

Use of e-books

The introduction of mobile phones and portable computer gadgets has also provided agricultural extension officers with an opportunity to utilise e-books. A successful project, The Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project, was conducted courtesy of the International Livestock Research Institute (ILRI) where e-book readers were distributed to agricultural extension officers. The project reported that 80% of the officers successfully used their devices which improved their performance (Mekonnen *et al*., 2016). E-books are handy and provide agricultural extension officers with a wide variety of resources to use to enhance their workmanship.

Wireless technology

Agricultural extension officers can also embrace wireless communication technology such as Bluetooth and Wi-Fi. Wireless technology enhances the experience of the transfer of information from the officer to the smallholder farmer (Thakur & Chander, 2018a). For example, officers can share agricultural videos with smallholder farmers during training through Bluetooth or Wi-Fi, which then act as a visual aid. In addition, extension officers can receive real-time information on changes in weather and/or markets and subsequently, they can advise smallholder farmers accordingly. Wireless technologies have the potential to diversify the delivery of agricultural extension knowledge and information to meet the requirements of smallholder farmers (Ahuja & Shore, 2011). Using Wireless technologies to access new knowledge and information is vital for sustainable agriculture (Ahuja & Shore, 2011).

2.7. Sustainable agricultural management practices

Sustainability is highlighted as a system in which resources are kept balanced by the acts of recycling, conservation, and renewal such that it prevents environmental damage directly to the farm and surrounding areas (Pearson, 2003). Sustainable agriculture is a philosophy that depends on current humanity's goals and a clear understanding of the long-term impacts of their actions on the environment and ecosystem (Francis, 1990). Implementation of sustainable agriculture is important for the current generation of smallholder farmers to ensure that future generations get to enjoy the same benefits enough for a decent standard of living. Sustainable agriculture requires a shift to agricultural systems that conserve water, land, plant and animal genetic resources, non-environmental degradation, technologically appropriate, economic viability, and social acceptability (FAO, 1989). The realisation of sustainable agriculture will require appropriate agricultural production practices. This will again be achieved through the use of sustainable farming practices that enhance and protect soil fertility, control soil erosion, limit soil water waste, choose the correct cultivars and understand ecosystems of farming at large (Mollica, 2017).

Quantifying the sustainability of agricultural practices is a complex and multi-faceted problem, with the variability of future conditions thus making it inherently impossible to define at present what would be considered sustainable in the future (Uphoff, 2014). Uphoff (2014) proposes that it is more appropriate to judge an agricultural practice on the probability of it being unsustainable in the long-term than it is to judge an agricultural practice on what is currently perceived as sustainable. Sustainable intensification is widely viewed as the most appropriate means of sustainably uplifting smallholder farmers and is built on four premises (Garnett *et al*., 2013):

1. Increased production is a necessity
2. Increased production being achieved through higher yields, as opening new land for agriculture carries an environmental cost that renders any production system unsustainable
3. Food security requires both increased productivity and increased sustainability
4. Strategies being context-dependent to account for site-specific biophysical and social differences

These premises are built on the earlier work of Pretty *et al*. (2011), which proposed that a sustainable agricultural system would exhibit most, if not all, of the following general traits:

- The use of crop cultivars and livestock breeds which are the most productive, relative to the external and internal inputs
- The reduction, if not total elimination of unnecessary external inputs
- An increased use of ecosystem services and processes

- The reduction in the use of practices and/or technologies with known or potential adverse effects on human and ecosystem health
- A more productive use of human capital
- The quantification and minimisation of system impacts on the surrounding ecosystems and biosphere at large

By being context-dependent, a diverse range of sustainable agricultural practices exists across all aspects of the production system. Practices such as intercropping, relative to mono-cropped plots, have been shown to reduce insect abundance and disease incidence and increased radiation interception and lateral root density (Zhang *et al*., 2014a), increase nutrient scavenging (Postma & Lynch, 2012), increase plot revenue (Campbell *et al*., 2014) and greatly improve food security in vulnerable regions (Rusinamhodzi *et al*., 2012). Transgenic cultivars, such as Bt brinjal (Solanum melongena L.) and Golden Rice (Oryza spp. L.), have been shown potential in reducing smallholder farmers' reliance on pesticides (Padmanaban, 2009) and malnutrition and vitamin deficiencies in rural and impoverished communities (Potrykus, 2012) respectively. Mulching reduces unproductive soil-moisture losses while increasing infiltration through various mechanisms (Prosdocimi *et al*., 2016) and, depending on the materials used, can increase soil fertility, positive microbial activity, soil structure, organic matter content, seed germination and survival and crop development while reducing soil loss, soil temperature fluctuations and disease incidence (Chalker-Scott, 2007). Lastly, tools such as the Wetting Front Detector (Stirzaker, 2003) and Chameleon soil water sensor (Stirzaker *et al*., 2014) have enabled smallholder farmers across Africa to better manage their irrigation water resources.

Despite the wide range of practices available, the only truly sustainable practice is one that the smallholder farmer can successfully implement within their site-specific biophysical and socio-economic conditions. Pretty and Bharucha (2014) emphasise that more responsible farming communities can be created through the integration of traditional knowledge and modern practices. Though, sustainable agricultural practices are more likely to be adopted as packages rather than singular practices or technologies, thus further emphasising the need for holistic approaches.

2.7.1. Sustainable agricultural practices common to smallholder farmers Intercropping

Intercropping is defined by Seran and Brintha (2010) as the practice of cultivating two or more crops on the land or field and at the same time. This system was not only designed to improve food production and profits but to help keep the crops safe from complete yield failure as it can be when compared to a mono-cropping system because in case of pests or disease outbreaks, not all the plants are at the state of being wiped off or damaged but a portion of it. Hence, intercropping increases yield and also prevents complete crop failure (Nasar*,* Alam, Ashfaq, Khan & Zubair, 2019). The classic purpose of intercropping is to productively use the natural resources for plant growth by consuming water, soil nutrients and sunlight effectively such that it also limits the competition from unwanted weed or invader plants, as well as pests and diseases (Gawankar, Haldankar, Maheswarappa, Malshe, Haldavanekar & Salvi, 2019; Nasar *et al.*, 2019). Also, successful intercropping has prerequisite aspects that need to adhere to it as to have higher productivity which include compatible crops, plant density and time of planting.

According to Hamel (2017), plant density is referred to as the space left between the crops, and the relationship of plant spacing is directly proportional to plant population or total yield. Therefore, the lower the plant population, the lower the yield (Seran & Brintha, 2010). The variations in root length or depth, root spreading, and density are considerations that have to be well-thought-out when calculating the space between the plants and plant density. This is important to follow as it is the key to plants receiving sufficient water and nutrients well enough to sustain their growth until harvest. Compatible plants speak to choosing plants that are complementary such that they can be planted on the same field and/or plot at the same time. Plant spacing and resources (water, light and nutrients) reduces mono-cropping system yield. Therefore, to avoid plant competition in intercropping, the two selected plants must be compatible with one another's biological demands as well as their requirements (Seran & Brintha, 2010; Egbe, 2010). A study conducted in Mozambique concluded that there are high levels of productivity and economic benefits of this sustainable practice, and it enables smallholder farmers to overcome constraints of food insecurity, although this practice requires an additional 36% of labour when compared to mono-cropping (Rusinamhodzi *et al.*, 2012).

Seran and Brintha (2010) found that planting a maize crop together with cowpea gives better results in total yield. There are a lot of benefits that are embedded in the practice of intercropping such as resource and nutrient effective use, weed control, pest and disease control, erosion limiting and yield benefits, and the control of soil erosion. Intercropping controls the washing away of soil particles and nutrients by preventing rain waters from landing on bare soils and preventing water from entering the soil and increasing surface erosion, hence in the example of cowpea versus maize crops, cowpea is the best cover crop to prevent erosion (Huang *et al.*, 2015).

Mulching

As stated by Muttaleb (2018), mulch refers to any material that is spread over the soil surface as a covering. It can be either organic or inorganic. Organic mulch refers to a mulch material that readily decomposes over time, such as leaves, straw, hay, and shredded bark. Inorganic mulch is different from organic mulch because it is made up of inert materials that cannot decompose over time (Grassbaugh, Regnier & Bennett, 2002). Mulching is required to control weeds and restrict soil splash on flowers and foliage from irrigation and rain waters. Mulching helps by improving the physical properties of the quality of soil by preserving the nutrients, protecting them from environmental and external stress factors, and thus producing an overall healthier plant and resulting in more or higher yield in produce. Additionally, a study done by Maggard, Will, Hennessey, McKinley and Cole (2012) acknowledges that it also protects microbial animals. Furthermore, the application of a mulching system reduces the need for agrochemical applications such as fertilizer and pesticides, which in most cases are hazardous to the environment of the given ecosystem.

The choice of the perfect mulch for the environment, location and weather is highly important to consider as it affects the cost and accuracy of the practice (Muttaleb, 2018). Mulching is very vital when the objective is to maintain and sustain the agricultural soils. It is important because it stabilises the pH level of the soil's organic matter, as it is affected by the input through plant residues and other solids, whilst the output is by decomposition, leaching and erosion of the soil. Additionally, it is vital in yield production because of its impact on reducing fungal infections, and reduces chances of pest infestation and molding cases. Previous studies suggest that mulching practices improve soil physical properties in terms of allowing good drainage, increasing porosity between soil particles and soil moisture potential capacity to keep the soil hydrated and protected, favouring microbial life activities (Moore & Wszelaki, 2019). As highlighted, there are two types of mulches available: organic and inorganic mulch.

The inorganic mulch according to a study conducted by Balkic, Gubbuk, Tozlu and Altinkaya (2016) is mostly used to prevent the growth of common weeds and invader plants as they do not decompose quickly as compared to organic mulches. Mulch can trap or enhance the soil temperature by 1.5-2°C, and this is important because it reduces the evaporation of soil moisture and soil temperature, resulting in more life for microbes in the soil which causes soil fertility organically. Organic mulch is optimally much more important and preferred for the soil and the actual plant. Examples of this type of mulch include mowed grass, hay, animal manure and other plant residues. These mulches act as manure as they decompose at a later stage and increase the nutrient concentration amongst the soils and plants. This type of mulch is environmentally recommended because it has the potential to reduce by up to 13% the rate of weed germination by not making the conditions for weed growth possible (Kołota & Adamczewska-Sowińska, 2013; Balkic *et al.*, 2016).

Terracing

Terrace farming in agriculture is defined as a cultivation method that made farming in steep hilly areas possible and productive. It is a method of slowing down surface water run-off from the top of the mountain while preventing soil erosion and the leaching of nutrients (Omondi, 2017). The philosophy behind this farming practice was formed around the cases of intense storms where a large quantity of rainfall accesses the soil surface and infiltrates, but it depends on the soil type. Terraces are usually done as a measure to manage soils to protect the area from runoff by systematic land planning. Hence, the basic principle of terracing is to decrease the runoff and soil loss by creating steps or terraces that slow down the activity and result in increased soil moisture content through improved infiltration (Dorren & Rey, 2004). However, for this system to be more effective, it must be accompanied by other conservational practices that correspond to the land use planning such as contour plowing, strip cropping and cover crops (Liebman & Dyck, 1993; Dorren & Rey, 2004; Cui *et al.*, 2018).

Integrated Pest Management

Pest management has a very vital role to cover in processes of production. It is an environmentally friendly response for pest control by combining a variety of practices. Integrated pest management in a study by Dreistadt (2016) is explained as a combination of cultural, biological and mechanical practices used to control pests in agriculture, which uses information on the lifecycle of pests and their interactions with the environment or agroecosystem.

It is a modern approach to sustainability. It encourages the natural way of encouraging pests with the objectives of causing less disruption on agroecosystems and growing healthy crops that are environmentally and socially friendly (Liebman & Dyck, 1993; Allahyari, Damalas & Ebadattalab, 2017). Biological control can imply the phenomena of natural enemies where predators, parasites, competitors, and pathogens are used to control pest outbreaks and relatively their damage. Cultural control methods are practices that seek to limit the establishment of pests by making the condition not favourable for their reproduction and survival. Furthermore, cultural methods focus on making the crop healthy and compatible with pests and diseases by improving the soil conditions and good irrigation. Mostly, this is achieved by changing irrigation practices and crop rotation. Mechanical and/or physical control involves killing the identified pest directly or by blocking them out. The sole purpose is also to make known favourable conditions for the pests' survival. Examples of physical methods of integrated pest management include mulching and cover crops (Flint, 2012; Allahyari, Damalas & Ebadattalab, 2017).

Conservation Tillage

Tillage is referred to as a way of mechanical manipulation in preparing the soils for the production of crops by improving soil characteristics such as soil temperature, soil moisture, water infiltration and evaporations (Busari *et al.*, 2015). This suggests that tillage practices have an impact on the environment of production. According to Ehlers and Claupein (2017), conservation tillage practice is any system that touches and leaves approximately 30 percent of the soil covered with crop residue or any other mulch, after planting to reduce the vast levels of soil erosion. Therefore, this is an environmentally friendly approach to surface soil management and seedbed preparation. The advantages of this principle include improving the soil's physical properties by increasing soil organic matter, soil moisture conservation, limiting soil erosion and leaching, improving soil temperature (favouring microbial activity) and soil quality (Busari *et al.*, 2015; Nandan *et al.*, 2018).

The core principles of this practice are maintaining and enhancing the soil surface, as it is achievable by using crop residues, minimal tillage, and little mechanical soil disturbance. The importance of crop residues is to protect the soils from direct sunlight, reducing evaporation levels and thereby conserving soil moisture. It also protects the soil from direct raindrops which may cause erosions and lead to loss of nutrients (Busari *et al*., 2015). Busari *et al*. (2015) further highlighted the different types of conservation tillage practices ranging from zero tillage, reduced tillage, ridge tillage, contour tillage and mulch tillage. The zero-tillage practice defines land cultivation with little or no disturbance of the soil surface, and the only expected disturbance occurs during planting. Reduced tillage refers to minimising the levels of soil preparation and manipulation such as ploughing activities. In mulch tillage, the soil preparation is practised such that it leaves plant residues or other materials covering the surface at the highest extent. Planting on ridges involves propagating crops in rows along both sides on top of the ridges.

2.8. Technologies for water management practices

Water is one of the core inputs of sustainable agriculture (Skoulikaris *et al*., 2018). Climate change has brought about variable rainfall which has caused great unpredictability in the agriculture industry and hard-hit are the smallholder farmers who have no capital to adopt expensive high technological water interventions. Water management seeks to retain water in the system during periods when there is excess and use it during dry spells when there is a negative water balance (Dzikiti & Schachtschneider, 2015). As a result, water management is an ongoing process that requires attention all year round. This section seeks to outline an overview of existing technologies in water management, including social and physical sensors.

Social media

Water management technologies that can be adopted can assist to address the knowledge and information gap among smallholder farmers on techniques meant to better utilise the water resource (Parris, 2010). Implementation of sustainable water management programmes is, however, difficult in some instances due to the lack of participation by smallholder farmers. Unsuccessful irrigation schemes meant to rehabilitate smallholder farming have been reported in Zimbabwe (Mutambara *et al*., 2014), South Africa (Averbeke, 2013) and Ethiopia (Awulachew & Ayana, 2011) due to a lack of interest by smallholder farmers. This was attributed to oversight by NGOs and other stakeholders on the importance of social capital throughout the development process. Smallholder farmers decode this oversight as an 'imposed' and 'alien' idea making them not to have a sense of ownership of the projects. Social media can be used as a platform for researchers, development officials and smallholder farmers to have open conversations and build relationships before implementation (Mills *et al*., 2019). In Australia, Murray-Darling Basin Authority successfully implemented a social media-based project aimed at engaging all stakeholders in water management conversations (Johns, 2014).

Satellite remote sensing

Satellite remote sensing is a technology that has been utilised to monitor and visualise global hydrological processes from space. These processes include precipitation, snow cover and evapotranspiration. It can also be used to observe global water quality, specifically in oceanic ecosystems (Nezlin *et al*., 2010). Satellite imagery was initially launched in 2002 by NASA's Gravity Recovery and Climate Experiment satellites (GRACE) which showed the outlook on water storage worldwide (Skoulikaris *et al*., 2018). Localised satellite remote sensing has been used to manage irrigation systems by monitoring evapotranspiration, degree of irrigation and biomass assessments (Skoulikaris *et al*., 2018).

Real time remote sensing

A telemetric monitoring system is a real time remote system that has been used as an early warning system in many fields of water management, including river flows, water quality and reservoir level (Thomson *et al*., 2012). The system is made up of a field and base equipment. The base equipment consists of databases and relevant software while field equipment is made up of sensors, data logger systems and a modem (Skoulikaris *et al*., 2018). Telemetric monitoring equipment requires a source of power that can be provided by electricity or solar systems.

Technology for data transmission

Data transmission is one of the crucial components of the telemetric monitoring system. Ideally, the General Packet Radio Service (GPRS) protocol has been used, especially in rural areas where farms are located. Currently, rural communities have wide cellular network coverage (Skoulikaris *et al*., 2018), making this wireless technology practical even in smallholder farms. This packet data service can be used by 2G, 3G, 4G and 5G, Global System for Mobile communication (GSM) users. The GPRS protocol is being integrated into other technologies which need data transmission, including water consumption meters, leak sensors and Supervisory Control And Data Acquisition (SCADA).

Water consumption meters

Water consumption meters (flow meters) are computer technologies that can be adopted in both large-scale, commercial enterprises and smallholder farms. Flow meters are technologies that can be used to monitor water usage by measuring the speed of flow and quantity of water (Dzikiti & Schachtschneider, 2015). Flow meters can essentially monitor the water footprints of crops grown by smallholder farmers.

Leak sensors

Leak sensors can detect water leakages in water distribution systems. A low-cost leak sensor system was reported by Dvajasvie *et al*. (2018) which was able to detect leakages in a system with any type of pipe material, including plastic and metal, whether old or new. Wireless signals are sent to a computer that identifies where the leakage is taking place (Skoulikaris *et* *al*., 2018). This kind of system can potentially be installed in water distribution systems that are already in existence even in smallholder farms.

Supervisory Control And Data Acquisition (SCADA) system

Supervisory Control And Data Acquisition (SCADA) system is one innovation that can be used in the management of waste and irrigation. SCADA can be used to ensure that irrigation water is applied effectively by monitoring any source of water loss in a system. The main components of a system can be visualised from either a centralised computer or smartphone via wireless communication with a SCADA server (Ozdemir & Karacor, 2006). Although SCADA is mostly used by large farms, smallholder enterprises can incorporate it into their irrigation system when they combine resources. In South Africa, SCADA was used effectively in the South African sugar industry for wastewater management (Palazzo, 2004).

2.9. Technology implementation in agriculture

The implementation of technological projects in agriculture is becoming increasingly widespread in Africa due to the need for increased efficiency and poverty alleviation (Barakabitze *et al*., 2017). The use of traditional methods in agriculture, for instance, home visits in agricultural extension is becoming progressively counterproductive in terms of cost and time constraints. However, the success of a conceptualised project depends on the approach used in implementing it.

The directive approach or the top down is a strategy that encompasses the flow of instructions and influence from project leaders or experts to project participants. Traditionally, government experts or "policy elites" or researchers generate a conceptual project and 'impose' it on local stakeholders who have no say in the course of the project (Barakabitze *et al*., 2017). The project leaders or management determine the problem to be solved as well as the solution which is usually received as 'alien' by project management, resulting in failure of the intervention. The challenge is that local stakeholders may reject the project due to a lack of a sense of 'ownership' of the project (Joshi *et al*., 2017). The advantage of the approach is that it has a structure, and its progress can be monitored better.

The participative approach (bottom-up) involves collaborative efforts that are involved where all stakeholders are involved from planning to implementation. In this regard, external stakeholders are only there to guide and structure the project (Koontz & Newig, 2014). The role of the local area stakeholders is clearly denoted in defining and addressing the challenge in the area of interest (Koontz & Newig, 2014). Although the participatory approach is inclusive, it comes with its challenges, including a lack of clarity, accountability, and control.

Case Study 1: Implementation of information technology in vegetable smallholder farms, Tanzania

A study was conducted in Tanzania aimed at assessing the adoption of a web-based application among smallholder farmers involved in vegetable production. The platform provided an interactive podium for all stakeholders, including agricultural extension officers, weather forecasts, general information on the seven types of vegetables grown in the study area and pest and disease control. The technology was poorly adopted and the main factor affecting its implementation was low literacy levels (Maginga & Ally, 2019).

Case study 2: Implementation of a computer-based decision support system for smallholder sugarcane farmers, South Africa

A pilot study involved the use of the MyCanesim system, a technology that combined the competencies of 'internet, cellular communication, electronic monitoring of resources, and mathematical' comprising 'a sugarcane model, an on-line weather database and a communication network', (Singels, 2007). The system was implemented with smallholder sugarcane farmers in Pongola and Makhathini, KwaZulu-Natal, who used irrigation systems. Despite being a scientifically robust system and ahead of its time, the implementation yielded poor results, with farmers citing that they could not follow the recommendations of MyCanesim because of irrigation infrastructure issues such as the breakdown of pipes. In addition, there were occasions when there was a delay in the reception of recommendation messages from MyCanesim due to a system hardware breakdown. Furthermore, some smallholder farmers cited that the system was too 'complex' for them (Singels, 2007).

From the above case studies, it is clear that the implementation of technology involves an integration of several factors, including literacy levels (Maginga & Ally, 2019), the ability of farmers to understand the technology and infrastructure (Singels, 2007). Other factors contributing to failure in the adoption of implemented technology include an unfavourable policy environment (Kiambi, 2018) and inefficiencies in the agricultural support institutions (Ayima *et al*., 2020).

2.10. Smallholder irrigation: better management practices (BMPs) and associated problems and challenges

Sugarcane sustainability programmes, such as Bonsucro (2020), SmartCane BMP (2020) and SUSFARMS® (SASA, 2019), comprehensively document and promote irrigation better management practices (BMPs). Similarly, the Water Research Commission (WRC) in South Africa has supported numerous research projects and delivered several publications that detail recommended irrigation BMPs (Reinders *et al*., 2010; Stevens *et al.*, 2012; Van der Stoep, 2006). Notably, the Irrigation User Manual (ARC, 2020) consolidates past research and provides the most updated and comprehensive set of guidelines for irrigation managers in South Africa. In addition, research on smallholder irrigation and the associated BMPs, challenges and constraints in South Africa has been extensively captured in publications by Crosby *et al*. (2000), de Lange *et al*. (2000), Van Averbeke (2008), Fanadzo *et al*. (2010), Mnkeni *et al*. (2010), Van Averbeke *et al*. (2011), Gomo *et al*. (2014) and Fanadzo and Ncube (2018).

In this section, an overview of irrigation BMPs is presented. Irrigation management is required at the bulk water infrastructure scale, as well as in-field at the individual plot level (James & Woodhouse, 2015). Engineering consultants and contractors are typically responsible for the design and installation of bulk water infrastructure and infield irrigation systems. Designers are encouraged to work closely with smallholder farmers and groups in the design stage to ensure that the irrigation system is well-matched to the prevailing climate, soils, crop choices and end-user preferences (ARC, 2020). Once the irrigation system hardware has been installed and commissioned, the responsibility of management is handed over to the smallholder farmer and/or local governance organisation. In this section, BMPs relating to shared bulk water infrastructure are presented first, followed by infield irrigation BMPs. Infield irrigation BMPs have been subdivided into (1) routine operation of the system according to design specifications, (2) irrigation scheduling and (3) management of irrigation hardware to ensure that degradation and diminishing performance is detected and addressed (via monitoring, maintenance and evaluation). Importantly, the typical problems and challenges which inhibit smallholder farmers from implementing the BMPs are also discussed in each subsection. It must be noted at the outset that the information presented in this review is skewed towards pressurised overhead sprinkler irrigation systems, which is dominant amongst smallholder farmers (Van Averbeke *et al*., 2011), especially in the SA sugarcane industry (Crosby *et al*., 2000).

Management and maintenance of shared bulk water infrastructure

Most smallholder irrigation schemes make use of shared bulk water infrastructure to distribute water on a rotational basis to individual plots (Van Averbeke *et al*., 2008; Van Averbeke *et al*., 2011). Owners of the bulk water infrastructure are required to establish a local governance institution, which holds the responsibility to mobilise smallholder farmers towards making financial contributions and being actively involved in the routine operation and management of the shared infrastructure (Mutambara *et al*., 2016; Fanadzo & Ncube, 2018). This can include managing the process of collecting funds to service the water and electricity bills, conducting routine maintenance and emergency repairs, and managing water orders and releases to ensure fair and equitable distribution to all smallholder farmers' plots in the scheme (Van Averbeke *et al*., 2008; Van Averbeke *et al*., 2011; Gomo *et al*., 2014).

Most studies indicate that smallholder irrigation schemes perform at lower than desired levels (Van Averbeke *et al*., 2011; Fanadzo & Ncube, 2018). Weak institutional arrangements and poor scheme management are attributed as the most important area requiring improvement (Van Averbeke *et al*., 2008; Mnkeni *et al*., 2010; Van Averbeke *et al*., 2011; Fanadzo & Ncube, 2018). Past revitalisation efforts have failed because of a tendency to only focus on the engineering aspects of infrastructure refurbishment, neglecting the institutional, capacity building and socio-economic aspects (Fanadzo *et al*., 2010; Mnkeni *et al*., 2010; Van Averbeke *et al*., 2011; Fanadzo & Ncube, 2018). In the first instance, if farmers are uninvolved in the planning and development stages, there is no sense of ownership and a reduced willingness to participate and contribute to scheme governance and management (Mnkeni *et al*., 2010). As a result, the establishment of a management institution is poor, leading to poor scheme management, an unhealthy dependency on the government and low investment in the maintenance of the shared infrastructure (Mnkeni *et al*., 2010; Van Averbeke *et al*., 2011; Woodhouse, 2017), failure to service electricity and water bills (Van Averbeke *et al*., 2008; Woodhouse, 2017) and inequitable distribution of water due to excessive or illegal water abstraction and non-adherence to rotational cycles (Van Averbeke *et al*., 2011; Gomo *et al*., 2014). Participatory irrigation planning and development with smallholder farmers is, therefore, strongly encouraged (Crosby *et al*., 2002; de Lange *et al*., 2000; Fanadzo & Ncube, 2018).

Furthermore, rural smallholder irrigation schemes are often associated with poor financial reserves, either due to the tribal land tenure system which inhibits access to credit financing options (Van Averbeke *et al*., 2011; Fanadzo & Ncube, 2018) or the lower economies of scale associated with smallholder farming (James & Woodhouse, 2015; Metiso & Tsvakirai, 2019). Low capital reserves affect the capacity for routine maintenance or emergency repairs of shared infrastructure, resulting in a more rapid deterioration of the infrastructure and more frequent breakdowns, accompanied by loss of productivity and which feedback to deplete financial reserves even further (Van Averbeke *et al*., 2011; James & Woodhouse, 2015; Woodhouse, 2017). Repairing pump breakdowns, pipeline burst, breakages in canal walls and cleaning sediment out of canals are examples of ongoing maintenance activities (Fernadzo *et al*., 2010). In pressurised schemes, which are dependent on electricity, repeated and ongoing theft of cables, transformers, and irrigation equipment, along with flood damage to river pump stations and vandalism were also reported as major challenges (Mnkeni *et al*., 2010; James & Woodhouse, 2015; Woodhouse, 2017).

Routine in-field operation

All irrigation designers should equip smallholder farmers with a set of operating rules for the system (ARC, 2020). These rules are generally specific to the design and site. Operating rules and specifications could include:

- the maximum number of blocks or number of sprinklers or emitters which can be operated simultaneously for a given pump configuration,
- stand times (operating hours per shift) and number of shifts per day,
- cycle lengths (interval between successive irrigation applications),
- the minimum pressure or flow rate required at strategic points such as the pump station, block inlet or furthest and highest sprinkler or emitter.

These operating rules must be adhered to for uniform and correct application of water.

Smallholder farmers are known to have lower literacy levels and poor technical irrigation knowledge and are therefore often incapable of coping with sophisticated irrigation management (Van Verbeke *et al*., 2011). As a result, smallholder farmers do not always adhere to the operating rules. Additionally, they have been known to irrigate haphazardly, not moving sprinklers to the correct positions or at the right time and sometimes allowing sprinklers to stand in the same position for 24 hours (Crosby *et al*., 2000; Fanadzo *et al*., 2010). Due to a lack of knowledge, smallholder farmers have also tended to add an excess number of sprinklers to a field (Woodhouse, 2017) or expand the cultivated area beyond the irrigation design and pump capability (Bahnemann, 2014). Smallholder farmers also tend to not irrigate at night, either because of traditional or ancestral beliefs or because irrigation plots are distant from homesteads (Bahnemann, 2014). In instances when night irrigation is practised, moving sprinklers at night is impractical and farmers tended to irrigate disproportionately with an 8 hour stand time during the day and a 16 hour stand time at night (Crosby *et al*., 2000). Farmers also tend to cut out leaking portions of dragline hoses and join the pipe again for re-use, resulting in incorrect sprinkler spacing which causes poor overlap of wetting patterns and non-uniform irrigation (Bahnemann, 2014). ***Figure 3*** demonstrates the detrimental impact of non-uniform sprinkler irrigation, arising from various causes discussed above.

Figure 3: *Uneven height of sugarcane crop (wavy cane) due to non-uniform irrigation.*

Irrigation scheduling

Irrigation scheduling is the process of deciding when and how much water to apply (Pereira, 1999). Poor irrigation scheduling can result in either under-irrigation, leading to crop stress and reduced yields or over-irrigation which leads to misuse of water and electricity resources, leaching of expensive fertilisers, pollution of water, erosion of topsoil and potential yield reductions from anaerobic soil conditions (Pereira, 1999; Lecler, 2003; Stevens, 2005; Annandale *et al*., 2011).

A detailed account of available irrigation scheduling tools in South Africa is reported by Stevens *et al*. (2005) and Annandale *et al*. (2011). Examples of scheduling tools appropriate for smallholder sugarcane growers in South Africa include wetting front detectors (Stirzaker *et al*., 2010), irrigation calendars (Lecler, 2003), MyCanesim SMS service (Singels & Smith, 2006; Singels & Smith, 2009) and chameleon sensors (Stirzaker *et al*., 2017). Tools such as the wetting front detector are relatively inexpensive and do not require computers or automatic weather stations to function. It is a simple tool designed for smallholder farmers who have varying levels of literacy and limited access to computers and/or agronomic knowledge (Stirzaker *et al*., 2010). Similarly, farmers who subscribe to the MyCanesim irrigation scheduling service receive short messaging service (SMS) on their cell phones (Singels & Smith, 2006). The SMS informs them to, either start, stop, or continue irrigating (Singels &

Smith, 2006). The SMS is generated by the MyCanesim soil water balance and sugarcane crop growth model. These types of tools are attractive since the complicated scientific computer simulation model is hidden and smallholder farmers receive the information in a simple, digestible format for easy decision making (Singels & Smith, 2006). The chameleon sensors detect changes in the soil water status and report the result in a simple colour coded format, i.e. red, green or blue, thus LED light indicates dry, moist (optimal for crops) or wet soil, respectively (Stirzaker *et al*., 2017).

Considering the difficulty to adhere to basic operating rules and the ongoing financial struggles to secure agronomic inputs and combat the deterioration of irrigation hardware, accurate irrigation scheduling appears to still be beyond the reach of smallholder farmers currently. Case studies indicate that a large portion of smallholder farmers did not practise irrigation scheduling and appear to be ignorant of the detrimental impact of under and over-irrigation (Monde *et al*., 2005; Singels & Smith, 2006; Fanadzo *et al*., 2010; Mnkeni *et al*., 2010).

Monitoring, maintenance, and evaluation

Irrigation monitoring refers to the daily or weekly monitoring of the irrigation system (Reinders *et al*., 2010). At the start of every irrigation cycle, pressure and flow rates should be checked to ensure that the irrigation system is operating according to design. Measurement points may be at the pump station, the inlet of the irrigation block or at a discharge emitter, as shown in ***Figure 4*** (Reinders *et al*., 2010). Regular monitoring can serve as an early warning system to detect poor system performance.

Figure 4: *Pressure and flow rate measurement (adapted from Koegelenberg and Breedt, 2003)*

Poor irrigation performance is often linked to a lack of maintenance (Thoreson *et al.*, 1997). Irrigation hardware will inevitably degrade over time (Svendsen & Huppert, 2003). Reaching the end of the design life of components, damage from contaminants in the water, routine wear and tear or theft and vandalism are some of the reasons maintenance is necessary. Maintenance can be subdivided into either preventative or corrective action. Thoreson *et al*. (1997) defined corrective maintenance as action initiated only after damage or a breakdown has occurred, i.e. fix it when it breaks, whereas preventative maintenance is any action required to keep a system's performance at a desired level, i.e. fix it before it breaks. As can be expected, budgeting for corrective maintenance, which arises from unforeseen circumstances, can be difficult. Preventative maintenance, however, is a periodic and recurring activity, which can be pre-planned. Diligent preventative maintenance can substantially reduce the need for corrective maintenance (Murray-Rust *et al*., 2003).

Reinders *et al*. (2010) provide preventative maintenance schedules for the commonly used irrigation systems in South Africa. ***Table 1*** presents an example of the preventative maintenance schedule for sprinkler systems as published in the Irrigation User Manual (ARC, 2020).

Table 1: *Monitoring and maintenance programme for sprinkler systems (Adopted from ARC, 2020).*

Monitor	**Interval**	
	With each cycle	**Annually**
Inspect the system for leakages	X	
Check system pressure and system flow	X	
Service air valves and hydrants		X
Check sprinklers for wear and replace springs, washers, and nozzles where necessary		X
Flush mainlines		X
Replace rubbers at quick coupling pipes where necessary		X

Notes: After the irrigation season, before the pipes are stored, the following must be done:

- Mark all the holes in quick coupling pipes with paint so that they can be repaired.

- Remove all gaskets from pipes if they are stored in the sun.
- Replace all damaged and hardened gaskets.
- Replace all worn male and female pipe fittings.
- Replace all dragline pipes that have more than three joints.
- Check standpipes for corrosion and replace them if necessary.
- Ensure that all standpipes are of the same length and straight.

In addition, water quality and soil health must also be monitored seasonally (Reinders, 2010; ARC, 2020). Samples from the water source should be analysed for high and low rainfall periods. Poor water quality can harm the irrigation systems and crop and soil health (du Plessis *et al*., 2017). Therefore, soils should be tested for salinity and sodicity periodically (ARC, 2020). If the water quality is a problem, corrective actions include water treatment (e.g. sedimentation dams, filtering, and chemical injection) or adapted maintenance programmes for irrigation hardware (e.g. regular flushing) or soil treatment (e.g. installation of drainage systems, leaching of excessive salts and the use of soil ameliorants) (du Plessis *et al*., 2017; ARC, 2020).

Irrigation evaluations aim to measure or gauge how well the irrigation system or hardware is performing relative to the design specifications (Bos *et al*., 1993). It is different from monitoring since it is performed periodically (once in 3-5 years) rather than continuously. Irrigation evaluations typically involve field measurements of specific parameters which are used to calculate performance indicators, such as distribution uniformity and application efficiency, that are comparable to published norms and standards (Merriam & Keller, 1978; Hoffman *et al*., 2007). In South Africa, detailed field measurement and data processing procedures, as well as acceptable norms and standards, have been published in a manual by Koegelenberg and Breedt (2003).

For pressurised irrigation systems, evaluation involves capturing water as emitted by the irrigation system over a designated representative surface area and period, while monitoring the corresponding pressure. As depicted in ***Figure 5***, rain gauges can be laid out across a representative wetted area. The pressure measurements and rain gauge readings are processed to indicate whether the system is operating according to acceptable norms.

Figure 5: *Rain gauge set-up to measure the distribution of water under a dragline sprinkler (adapted from Koegelenberg and Breedt, 2003).*

Irrigation system evaluations can benchmark the performance of the irrigation system and, if necessary, serve to develop a post-evaluation plan for improving the performance (Merrey, 1995). The results from the exercise are also used to inform the maintenance plan and budgets for the upcoming seasons (Möller & Weatherhead, 2007). Interventions for improving performance can range from replacing or correcting hardware components, such as pipe leaks, worn nozzles and damaged emitters, to clearing blockages by flushing and applying chemicals or even adjusting irrigation schedules and operation routines.

The frequent occurrences of under-, over- and non-uniform irrigation, arising from the non-adherence to basic operating rules (Crosby *et al*., 2000), poor irrigation scheduling (Monde *et al*., 2005; Singels & Smith, 2006; Fanadzo *et al*., 2010) and a lack of maintenance of hardware (Van Averbeke *et al*., 2008; Mneni *et al*., 2010, Van Averbeke *et al*., 2011; Woodhouse, 2017), detrimentally impact crop yields and profit margins. Smallholder farmers do not appear to have the technical knowledge to appreciate the detrimental impacts or do not have the resources and skills to make the corrections (Mnkeni *et al*., 2010). Often, financial reserves are used for emergency repairs (Woodhouse, 2017) and other agronomic inputs such as fertilisers or labour for weeding and harvesting (Fanadzo *et al*., 2010; Mnkeni *et al*., 2010), leaving little resources for proactive preventative maintenance, monitoring or evaluation (Fanadzo *et al*., 2010).

As a result of poor technical knowledge, smallholder farmers also tend to conduct maintenance in improper ways. For example, infield hardware such as sprinklers and nozzles are often replaced with components that do not conform to design specifications. It is common to find many different sprinkler types and nozzle diameters in the same field or inconsistent lengths of dragline hoses, leaking pipes, malfunctioning valves and non-erect standpipes, all of which contribute to inefficient irrigation (Crosby *et al*., 2000; Mnkeni *et al*., 2010).

In the context of routine operation, irrigation scheduling, maintenance, monitoring and evaluation, active input from well-trained and knowledgeable agricultural extension advisory specialists are required to train and support smallholder farmers in irrigation management and to continually remind them of the detrimental impacts of poor management and neglect of irrigation infrastructure (Mnkeni *et al*., 2010, Van Averbeke *et al*., 2011; Fanadzo & Ncube, 2018).

The incentives for implementing the irrigation BMPs are transparent. BMPs aim to ensure that the crop receives adequate water for optimal growth while minimising water loss and irrigation costs and maximising the life span of irrigation systems. However, low financial reserves, the lack of technical knowledge and training, a poor sense of ownership and other socio-political and socio-economic factors which limit the willingness to contribute or participate in local management institutions collectively hinder the implementation of irrigation BMPs both at the bulk water supply and infield plot scales. The literature is skewed to reporting hardware deterioration and breakdowns as a major factor contributing to poor performance, ahead of non-adherence to operating rules of the irrigation system or poor irrigation scheduling.

3. MATERIAL AND METHODS

3.1. Study area

The province of Mpumalanga is the second smallest province in South Africa after the Gauteng province. It has a surface area of 76 495 km^2, which is 6.3% of the total area and has the fourth largest economy in the country. The province is bordered by Swaziland, along with Mozambique to the east and Gauteng to the west. It is situated generally on the high mesa grasslands in the Middleveld, which roll eastwards. In the northeast, it escalates towards mountain peaks and dismisses in an immense escarpment. In other places, the escarpment plunges hundreds of metres down to the low-lying area known as the Lowveld.

The province has a population of 4 038 939 with the dominant languages being siSwati (27.7%), isiZulu (24.1%) and Xitsonga (10.4%) (StatsSA 2017). The capital of the province is formally Nelspruit, now known as Mbombela City and is the business and administrative centre of the Lowveld (Department of Rural Development and Land Reform (DRDLF), 2015).
Mpumalanga is mainly within the grassland biome and the escarpment along with the Lowveld form a transitional zone between the savanna biome and the grassland area. The province constitutes three municipal districts, which are the Ehlanzeni District, Gert Sibande District, and the Nkangala District (DRDLF, 2015).

The Ehlanzeni District Municipality, which is one of the three district municipalities in the Mpumalanga province, constitutes five local municipalities which are the Mbombela, Bushbuckridge, Thaba Chweu, Umjindi and Nkomazi local municipalities (DRDLF, 2015). Mbombela is the most concentrated economic hub within the Mpumalanga province. The district is in the north-eastern part of the province, which is also known as the Lowveld. The main economic sectors in the district are community services (25%), manufacturing (22%), trade (20%), agriculture (9%), financial and real estate (9%), transport (7%), mining (3%), construction (3%) and electricity (2%) (DRDLF, 2015). The Nkomazi Local Municipality is in the eastern portion of the Ehlanzeni District Municipality of the Mpumalanga Province. The municipality forms a strategic boundary between the east of Mozambique and the North of Swaziland. The link between the study area and Mozambique is by the N4 main national road and by a railway line that forms the Maputo Corridor, and the link between the study area and Swaziland is by two provincial roads (Nkomazi Municipality, 2014). The municipality is also bounded by Mbombela Local Municipality from the northwest to the west, Umjindi Local Municipality to the west and Kruger National Park to the north. The Nkomazi Municipality makes up 23% of the Ehlanzeni District Municipality and 4.07% of the Mpumalanga Province. ***Figure 6*** represents the location of the Nkomazi Local Municipality.

Nkomazi municipality is a Category B municipality and is the smallest of the four municipalities within the district (MSA, 2020). The main economic sectors that are present in the area include agriculture, mining and tourism mostly originating from the towns of, Komatipoort, Marloth, Kamhlushwa and Malalane (MSA, 2020). The study focused on the communities of Phiva, Langloop, Mzinti, Buffelspruit and Driekoppies. The climatic conditions in the municipality are generally temperate and warm. Summers in the area have much more rain than winters, and the average annual temperature ranges at 21.7°C and has about 716mm of precipitation or rainfall on an annual base (Climate Data, 2020). According to the Department of Agriculture, Forestry and Fisheries (2012), there is a significant amount of smallholder farmers who have no water supply in the area. It is, furthermore, stipulated by DAFF (2012) that where irrigation systems were installed for water allocation, their systems are either not functional or pump engines were too weak to allocate water. Another area of significance is the seasonal swamping that covers most of the municipality mostly in the sugarcane growing regions.

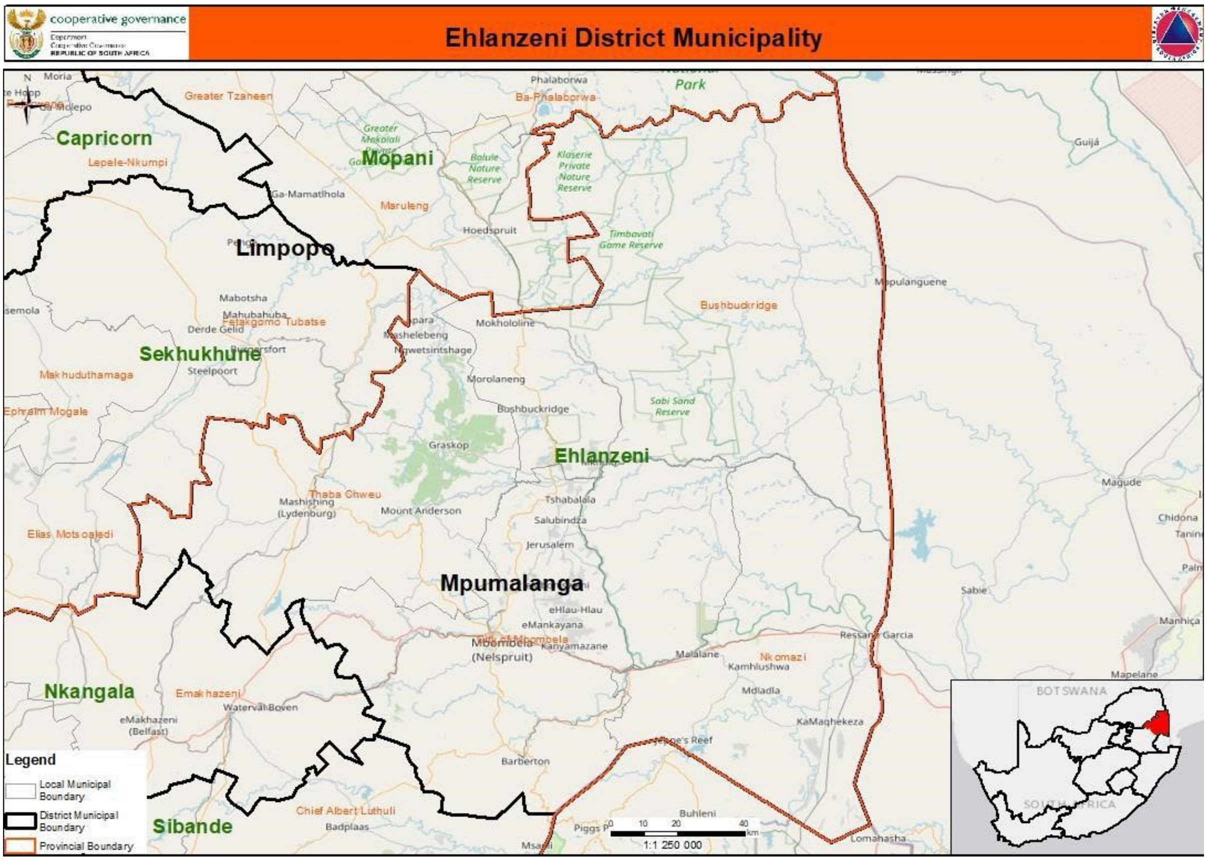

Figure 6*: Map of Ehlanzeni District (Cooperative Governance & Traditional Affairs, 2020).*

3.2. Biophysical aspects

The Nkomazi Local municipality is within a summer rainfall region with the season lasting from October to March. The average mean annual rainfall varies between 750mm and 860mm (Climate Data, 2020). Steep slopes and mountains are mainly found in the western part and along the eastern boundary of the municipality. The Kaalrug Mountain range is found to the west forming part of the Barberton Mountain lands, and the Lebombo Mountain range is located along the eastern boundary. The Lebombo Plains, located between the Komati River and the Lebombo Mountains to the east, are characterised by flat to undulating landscapes (MSA, 2018). The central part between the Komati River and the mountainous western areas is flat but steeper slopes occur to the south towards the Swaziland border. According to the Nkomazi Municipality IDP (2017), the mountainous areas and the river systems form the backbone of the natural environmental system, providing the major water source needed for development and the scenic environment essential for tourism. Areas of the pristine natural environment in the northern part of Nkomazi include the Kaalrug Mountain range to the west, the Lebombo Mountain range to the east and the whole length of the Crocodile River. These areas have excellent potential for eco-tourism uses and agriculture. The southern part contains large areas of a pristine natural environment with conservational value. Important to mention are the banks of the Mlumati River, naturally occurring cycads at Mbuzini, the Mananga Wetland, the areas surrounding Lake Matsamo and the Mananga Whaleback, which form part of the Lebombo Mountain range on the far eastern side.

3.3. Demographics and sociocultural aspects

3.3.1. Population and household dynamics

Members of a population are dependent on the same resources and rely on the availability of other members to persist throughout. Populations are also subject to similar environmental constraints. The population size is described by Lebreton, Burnham, Clobert and Anderson (1992) as the amount or number of individuals that can be found in a subjectively designated geographic variety. According to CS (2016), Ehlanzeni District has a population of 1 754 931 individuals:

- 626 535 (35.7%) of the population are between the ages of 0-14,
- 640 190 (36.5%) are between the ages of 15-34,
- 414 556 (23.6%) are between the ages of 35-64,
- 73 649 (4.2%) of the population within the district are 65 years of age and above.

The population size in the community of Nkomazi, according to MSA (2016), is 410 907 people. The number of individuals under the age of 15 makes up 38% of the population, and those that are 15 years of age to 64 years of age make up 58.3% of the population (CS, 2016). Those individuals that are over 65 make up 3.6% of the area's population. Males that are present in the population group per females is 91. Census (2011) reported that the population groups that are present in the area range between 21 525 black Africans, meaning 98.27%, 234 coloured which makes up 1.07%, and the other is 89, which contributes 0.41% to the total population. Indians or Asians are at 39, which contributes 0.18% to the total population, and whites are at 18, which contributes 0.08% to the entire population of the area (MSA, 2018). There are 103 965 households present in the municipality, which have an average household size of 4 (MSA 2018). According to StatsSA (2017), 28 004 of the households are agricultural households. The Municipalities of South Africa (2018) found that 45.4% of the households are female headed, 91.7% are formal dwellings, and 84% of those dwellings are owned by members of the community. Only 4% of the households in the community have flush toilets connected, 5.6% have piped water inside their households, and 95.1% of the households have electricity within their households (MSA, 2018).

3.3.2. Language

The existing advances in technology along with a rapid increase in the frequency of intercultural interactions allow people to become bicultural or multicultural (Sari, Chasiotis, Van de Vijver & Bender, 2020). The people are not only immigrants but also encompass people that are indigenous and people in interethnic relationships. The knowledge and use of common languages expedite communication with people from different groups (Sari *et al*., 2020). It is, therefore, easy to associate language with sociocultural adjustment (Selmer, 2006). The languages in the Nkomazi local municipality are SiSwati 17,418, which makes up 82.16% of the population, English is at 796, which makes up 3.75% of the population, Xitsonga is at 717, which takes up 3.38% of the population, IsiZulu is standing at 625, which makes up 2.95% of the population, and those that fall under other are 550 and make up 2.59% of the population (Census, 2011). Sesotho speaking people are 485 and make up 2.29% of the population, Sepedi speaking people are 177, and they contribute 0.83% of the total population, Tshivenda at 93 and contributes 0.44% of the entire population (MSA, 2018). People that have IsiNdebele as a first language are 87 and contribute 0.41%, IsiXhosa speaking people are 86 and make up 0.41%, Setswana speaking members of the community are 83 and make up 0.39% of the entire population, Afrikaans individuals are 72 making up 0.34% of the total population, people that use Sign language are 10 and contribute to 0.05% of the population those that are not applicable are 706 (Census, 2011). Most of the Nkomazi population is Black African ranging at 99%, the remaining 1% forms the Coloured, Asian, Indian and White ethnic Groups (CS, 2016).

3.3.3. Education

The South African government has tried to achieve the educational goals set by UNESCO, with an adult literacy of 89% (Donohue & Bornman, 2014). In the Ehlanzeni District Municipality, people that are 20 years and older who have no formal education are 17.7%, individuals that have matric within the region account for 29.6%, and those that have attained a higher education or qualification are 6.5% (MSA, 2018). According to CS (2016), the number of individuals aged between 5-24 years that attend an educational institution in the district is 565 440, which is 77% of individuals within the age bracket. The lack of education in the community is highly influenced by a lower standard of living and the legacy of the Apartheid government. According to the Nkomazi Municipality IDP (2017), the standard of education for most black people is of poor quality, and there is a lack of proper infrastructure to foster proper education along with adult learning in the area.

3.3.4. Historical background

Nkomazi Local Municipality in the eastern region of the Mpumalanga province makes a triangular wedge between the Kruger National Park in the north, Swaziland in the South and Mozambique in the east. The Kaalrug mountain range on the western border from the beginning of the Drakensburg Mountain range that runs down to the Cape (MSA, 2018). Some of the oldest rocks along with the oldest and largest meteorite impact deposit have been found in Kaalrug, along with some of the oldest fossils on earth (Thembalethu, 2021). In the area, there are also some of the oldest rock carvings that were painted by the San tribes, estimated to be approximately 3000 years ago. The art resembles the lives and beliefs of the people that lived in those times.

From as early as the 1980s, refugees from Mozambique migrated over the borders into the Nkomazi area, fleeing the political conflict and eventual war from their country (Thembalethu, 2021). The number of refugees reached the thousands by the mid-80s, and while many of them contributed significantly to the economic developments in the region, most of the refugees lacked legal documentation and, therefore, were unable to access the medical and social programmes offered by the South African government.

During the years of the Apartheid government, the Nkomazi area was designated as a homeland known as Kangwane. A large number of people were moved from the areas adjacent to the Crocodile River, which is along the border of the Kruger Park, to make way for the development of large commercial sugar and citrus farms owned by white smallholder farmers and to enable the establishment of TSB, which is a major private employer in the region (Thembalethu, 2021). People that were living in the villages were not permitted to move to other areas of the country without obtaining permission from the government. Travelling between the homeland and the rest of the Mpumalanga province was therefore severely restricted. The resettlement programmes disturbed, not only the roots of thousands of ethnic South Africans but also the natural evolution of Nkomazi communities. This led to substantial obstacles to sustainable development during the following decades. However, TSB has been the world leader in developing a smallholder farming programme benefitting hundreds of households in Nkomazi local municipality. The Nkomazi community today is a rich mix of cultures and traditions that has blended the 'old' ways with modern technology, systems and norms to create a pleasant lifestyle that boasts a country atmosphere with the hustle and bustle of a typically African hawker and market scene.

The influence of the Afrikaners is found on commercial farms and in Malelane, Hectorspruit and Komatiport. An Afrikaner is a South African person whose family was originally Dutch and whose first language is Afrikaans (Cambridge University Press, 2021). This has blended with the English lifestyles of farmers and businesspeople engaged in a thriving tourist industry into the Kruger National Park. The biggest portion of the land is populated by Mozambicans, who have brought the Shangaan influence and the Swazis from Swaziland. The two main languages spoken are SiSwati and Shangaan (StatsSA, 2017). However, in recent years, people from many other countries, including Pakistan, China, England, Ghana, Zimbabwe and Uganda, have settled in the Nkomazi area.

The two most significant effects on the community have been the drive by the government to supply electricity to the villages and the availability of credit for purchasing buildings and homes (Nkomazi Municipality IDP, 2017). Ultra-modern homes are now found dispersed throughout the villages. Three shopping 'Malls', in Schoemansdal, Tonga and Naas bring the all-latest consumer products closer to the people. Two hospitals, Shongwe and Tonga, along with many village clinics, offer modern medicine; however, attending a 'traditional healer' known as a 'sangoma' is frequently the preferred method of treatment. The facilities and level of education in the schools have improved over the years, and many youths are attending tertiary institutions (Thembalethu, 2021). Some important events and gatherings provide opportunities for garnering community togetherness, networking and relaxation. Most functions still support traditional entertainment and dances, and traditional attire is often favoured.

3.3.5. Technological aspects

Information Communication Technology (ICT) can either substitute or augment services within a community and may even foster different network connections (Larivière, Bowen, Andreassen, Kunz, Sirianni, Voss, Wünderlich & De Keyser, 2017). The advancement in technology globally aligned to the fourth industrial revolution supports varying developmental needs in the world. In developing countries such as South Africa, technological innovations can significantly benefit socio-economic problems such as unemployment and the development of skills (Van Rensburg, Telukdarie & Dhamija, 2019). African countries are lagging behind into technological advancements. Adeka, Anoh, Ngala, Shepherd, Ibrahim, Elfergani and Abd-Alhameed (2017) state that countries like the USA, China and Europe are at a faster rate of progressing technologically as compared to the African continent. Technological support is mostly received from other countries in Africa, especially China since it has a strong technological base (Adams & Opoku, 2017). Africa is therefore a consumer of technology from other countries, which does not give development on its own, leading to a lack of skills development in the technological sector (Van Rensburg *et al.*, 2019). In the Nkomazi municipality, technology use through internet access is limited to the types of devices owned and infrastructure present. A total of 47% of individuals in the area use cell phones to access the internet, 5% access the internet through places of education, 4% from places of work or employment and 5% of individuals access the internet from libraries, 15% of people in the area access the internet through other types of mobile devices. A further 14% access the internet in their dwelling, 14% access internet through internet cafés that are less than 2 km away from their places of residence and 9% from internet cafés further than 2 km from their place of residence (CS, 2016).

3.4. Socio-economic characteristics

3.4.1. Employment

The demographic and social profile of the Nkomazi local Municipality indicates that many youths are unemployed each year (Urban-Econ, 2015). It is further stated by the Urban-Econ (2015) that there is an urgent need for skills requirements and education within the population that is economically active, which will help increase household income and decrease unemployment within the area. The unemployment rate within the municipality is currently ranging at 32.4%, where youth unemployment is at 41.5% percent, thus showing the lack of skills, education and job opportunities that are available for the young population in the area (StatsSA, 2017). Census (2011) found that 34.3% of the population in the age range of 15 to 64 years are unemployed, 42.5% of which are women, and 41.5% are young people. The Nkomazi Municipality IDP (2017) states that the high rate of unemployment is linked to the municipality being rural and mainly focusing on agriculture for job creation. In essence, agriculture is the largest contributor to employment in the area, ranging from 11.5% in terms of livestock, 32.8% is poultry, 28.5% is vegetables, other crops such as fruits are at 16.5%, and the rest fall under 10.1% (Census, 2011).

According to the Nkomazi Municipality IDP (2017), the second largest contributor to employment is trading (19.7%), followed by community services (19.2%). Other major industries that contribute to employment include private households which contribute 9.6% of employment, finance and construction contribute 7.9% each, manufacturing contributes 6.4%, transport is at 4.3%, utilities only contribute 1.2%, and mining is at 1%. The Nkomazi Municipality IDP (2017) indicates that the community had an improved human development index in 2017 of 0.55 from 0.51 in 2014, and the share of the population is below the lower-bound poverty line.

3.4.2. Income

A significant decrease was documented in the number and percentage of households that do not have any income at all in the municipality from 2001, though, in 2011, it was still extremely high at 16.8% (Census, 2011). The percentage of household earnings from R1-R9600 per year decreased from 45.2% in 2001 to 19.7% in 2011. A total of 36% of the households in Nkomazi local municipality still earn less than R800 per month, which has serious implications for the impoverished policies of the municipality as well as their ability to generate income from rates and taxes. The number of households in Nkomazi local municipality increased by 7 763 from 96 202 in 2011 to 103 965 in 2016 (Nkomazi Municipality IDP, 2017). According to CS (2016) the household income percentages shows that 17% of the population earns nothing, 7% have an annual income of R4 800, 13% of the population has an annual income of R5 000-R10 000, 23% has an annual income of R10 000-R20 000, 29% receive an annual income of R20 000-

R75 000 and 11% of the population with the area receive an annual income of R75 000-R600 000.

3.4.3. Governance

The democratically elected structure in the area is the African National Congress (ANC), and there are about nine traditional authorities present in area. In terms of the office of the municipal manager, the Council of Ehlanzeni Municipality is required in the terms of Section 25 of the Local Government Municipal Systems Act (Act 32 of 2000) to adopt a single, inclusive and strategic plan for the development of the municipality. According to the Ehlanzeni District Municipality IDP (2019), in line with the National Development Plan, there is an emphasis placed on crafting strategies and addressing the triple challenge, which is poverty, inequality and unemployment.

3.4.4. Government

In Nkomazi local municipality, the Municipal Council is the supreme authority, and its basic role is to initiate, facilitate and oversee the rendering of quality, affordable and sustainable municipal services in accordance with its institutional mandate (City of Mbombela Local Municipality, 2016). The council is responsible for the delivery of municipal services in accordance with legislation such as the Constitution of the Republic of South Africa (Act 108 of 1996), The Local Government: Municipal Systems Act (Act 32 of 2000), The Local Government: Municipal Structures Act (Act 117 of 1998), The Local Government: Municipal Finance Management Act (Act 56 of 2003), The Local Government: Municipal Properties Rates Act and Regulations, (Act 6 of 2004) and The White Paper on Local Government (9 March 1998). Local government is a highly sophisticated environment that needs the best people to render quality, affordable and sustainable municipal services. One of the management tools that is utilised is a system of delegated powers in which all the role players are empowered to execute the duties and responsibilities that they have. The council holds both legislative and executive authority, it implies that the council can decide on the method of exercising both its legislative and executive authority. To exercise its powers, the council resolved to divide its legislative and executive authority into two separate divisions which are namely the Legislative Division and the Executive Division. The legislative division consists of Council (Including the Traditional Leaders), the Speaker, The Chief Whip, Section 79 Oversight Committees, Section 79 House and/or Standing Committees and Ward Committees. The executive division consists of the Executive Mayor (Head of the Executive), Members of the Mayoral Committee, Mayoral Committee, Section 80 Executive Committees, and Administration with the Municipal Manager as the Head and Accounting Officer of the municipality. Using this arrangement, the council strives to achieve the following objectives; to provide infrastructure and sustainable basic services, to provide sustainable social amenities to the community, to strengthen the delivery of sustainable integrated human settlement and environmental management, to initiate a strong and sustainable economic development, to build a strong good governance and institutional development, to ensure legally sound financial viability and management and to maintain and sustain the 2010 legacy projects.

3.4.5. Stakeholders in the community

The Nkomazi Local Municipality has the following stakeholder groups: The provincial government of Mpumalanga, The Department of Economic Development and Tourism; The Department of Human Settlement; The Department of Agriculture; The municipal government of Nkomazi, with specific reference to: The Municipal Council; The Department of Local Economic Development; The Department of Town Planning; The CSIR (in relation to the innovation programmes references herein); Several private sector investors forming part of the early investment pipeline; Sources of private equity and other forms of capital; Traditional leaders and organised agriculture.

The interaction of stakeholders with communities can lead to generating a meaningful understanding of the development process and inspire the community to achieve present challenges and needs and use available opportunities to improve their livelihood strategies. Stakeholder involvement or participation necessitates commitment, transparency in the process, acknowledgment of different views, ideas, time, and human resources (Herman, 2017). A stakeholder can be an individual and or institution with an interest in a policy or project. It includes non-government organisations, intermediary organisations, public interest groups, private sectors, and technical and professional bodies. The table below highlights actively involved stakeholders and their responsibilities in the district.

Table 2: *Stakeholders and their responsibilities.*

Stakeholders	**Responsibilities**
Community members/farmers (cooperative)	They are implementers, and they are the beneficiaries. They provide labour and have indigenous agricultural knowledge.
Extension officers.	Support smallholder farmers through advising, motivating, and working with them in advancing agricultural productivity and increasing food security to improve smallholder farmers' livelihoods.
Parastatal (ESKOM)	ESKOM is the provider of electricity. Irrigation pressure pumps used by smallholder farmers require electricity.
Local markets	They buy produce from smallholder farmers. They need bulk quantity and quality produce.
Department of Agriculture (Phezukomkhono Mlimi)	It encourages and supports smallholder farmers and rural households to utilise both existing and fallow fields for food production. Source of funds from planting until harvesting. Search markets for smallholder farmers.
The tribal authority (chief)	They offer unity in the community. They are responsible for land administration and tradition.
NGO Research planning agencies	Providing potential means of technology development, bringing what is new to the smallholder farmers (Provision of information for sustainable agriculture development). They are legal and political supporters for communities and assistance providers by providing community organisers, planting materials and support

Stakeholders	Responsibilities
	for the expansion of alternative livelihood enterprises.
Comprehensive Rural Development Program (CRDP)	Vibrant, equitable and sustainable rural communities with food security. No more silos.
Local (Municipal) government	Infrastructure development such as roads, provision of information and capital and community development. They facilitate the use of local information or knowledge to treat local problems and matters.
INKOMATI-USUTHU	Ensure efficient management of water resources through empowering and contributing towards transformation and promoting equal water access and protecting the environment. It further ensures collective and coordinated combined water resource management for wise socio-economic development and promotes knowledge generation and distribution.
Mobile Agricultural Skills Development and Training (MASDT)	It provides a comprehensive and integrated range of support services mainly in agriculture focusing on emerging smallholder farmers aiming to develop and incubate them for a maximum of three years. They train and offer support services to smallholder farmers.

3.4.6. Problems, issues, and opportunities

Issues and Problems

Across the Ehlanzeni District Municipality, individuals living in poverty are projected to be 1.26 million, and this is mainly perpetrated by the high rate of unemployment within the district which is nearly 43.41%. The city of Mbombela Local Municipality experiences high unemployment levels within the rural villages and townships, formally ranging from 25% to 41%, but is projected to far surpass this in deep rural areas (Adams & Moila, 2010). The urban cities experience relatively low levels of unemployment rates of less than 10% but increase due to high rural-urban migration. According to the Nkomazi Local Municipality Draft IDP (2020), low levels of skills advancement and literacy negatively hinder the economic development of the municipality. To sustainably develop, it is a need to facilitate the enhancement of literacy levels of the community dwellers, ensuring effective training and a satisfactory skills base to foster enterprise growth and job establishment. The Nkomazi local municipal unemployment rate is 32.3%, and the unemployed youth (age 15-34) is approximately 68.9% of the total unemployed. Also, the populace below the lower-bound poverty line is about 42.6%. The Nkomazi Local Municipality faces other challenges such as the high levels of poverty, low levels of skills development along with literacy, limited access to basic household services, high levels of crime and risk and unsustainable development practices (Nkomazi Municipality IDP, 2017).

The weather in the area which ranges from extreme heat in the summer, accompanied by fierce thunderstorms, to cold winters, presents major problems for people who live in shacks, particularly when there are heavy rains (Climate Data, 2020; Thembalethu, 2021). Nkomazi local municipality suffers from a controversial past in significant historical events and its remoteness from South Africa's capitals that are thriving has contributed to rampant poverty and innumerable challenges related to HIV and AIDS. Currently, the Nkomazi area depends largely on its agricultural productivity and diverse workforce for sustained income. Although the area is one of the largest sugarcane and citrus-producing region in South Africa, the commonly erratic weather patterns, and climate variability largely due to the area's unique terrain often led to irregular growing seasons, insufficient crop yields and drastic drops in employment (Thembalethu, 2021). This along with the ever-rising number of immigrant families arriving from Mozambique, Swaziland and beyond in search of employment and the infrastructure of the region becomes increasingly strained.

The crisis of old irrigation systems for smallholder farming for sugarcane or vegetable farming, has developed a major challenge resulting in falling levels of productivity and income, and the collapse of individual farms and whole irrigation projects (James & Woodhouse, 2015). Physical and climatic shocks have overlapped with an increasingly marginal economic environment and a need for significant reinvestment to replace irrigation infrastructure.

Lack of water remains a major challenge for most of the smallholder farmers in the area. According to Gininda *et al.* (2014), most smallholder farmers experience water shortages which severely affect their agricultural activities. The region has experienced severe drought (2003-2005), thus intensifying the challenges for smallholder farmers, and the effects of drought tend to be also carried to other seasons (James & Woodhouse, 2015). The sugarcane sector, with its high-water demand, has been affected negatively. Under constrained water supply to crops, there is a need for smallholder farmers to receive adequate guidance on the efficient use of water.

Moreover, the area face challenges with regards to a marketable and skilled workforce, which creates a productivity gap and results in a negative impact on the economic growth path of the area (Nkomazi Municipality IDP, 2017). More efforts in the encouragement of the development of a green economy and the development of infrastructure to support economic development will allow for opportunities to reduce the high levels of unemployment. The high level of unemployment and the high household dependency ratio leads to an increased number of people living in abject poverty. A strategic approach by the municipality can be encouraged to ensure that more job opportunities are made available, economic development programmes are enhanced and basic services are provided to uplift citizens out of poverty.

There is an urgent need to improve and transfer scarce skills to the people. The municipality has a responsibility to facilitate the improvement of literacy levels of the community and to ensure an adequate skills base to foster enterprise growth and job creation. This will assist the citizens to penetrate the competitive economic and manufacturing market.

3.5. Research Design

The study used mixed method research design that includes the collection and analysis of both qualitative and quantitative data. Qualitative methods included Participatory Learning and Action (PLA) methods and techniques. These are practical research strategies that allows diverse groups (researchers, smallholder farmers, extension agents and various stakeholders) to learn, work together in exploring issues through different worldviews and come up with joint solutions. Quantitative methods used structured questionnaires that were developed using emergent themes from qualitative data collected.

The quantitative method utilised the convenience sampling method which is a nonprobability sampling method. Convenience sampling allows participants from the target population that meet practical criteria such as availability, geographical proximity, and willingness to participate (Etikan *et al*., 2016). A total of 121 smallholder farmers participated in the study and were informed by similar studies (Kehinde & Ayobami, 2015).

The main instrument used was a structured questionnaire. The questionnaire consisted of Likert scale questions. The survey questionnaire was prepared, distributed, and administered. The house-to-house administration helped in the mitigation of smallholder farmers that found it hard to understand the questions in the questionnaire, and in ensuring that more smallholder farmers had the opportunity to take part in the study. A pre-test study of the questionnaire was done before it was administered to the respondents.

The qualitative research approach was employed using Participatory Rural Appraisal (PRA) tools. Through transact walking and observations, and semi-structured interviews, smallholder farmers within the municipality were identified as well as other relevant stakeholders such as agricultural extension officials and NGOs that work with smallholder farmers. Furthermore, this approach assisted in the identification of smallholder farmers' water management practices and social media use. The engagement in semi-structured interviews enabled smallholder farmers to be subjected to dialogue and share more of their opinions and attitudes towards social media use. Semi-structured questionnaires were used in the collection of qualitative data. After the easing of COVID-19 restrictions, several visits were made to the Nkomazi Local Municipality to identify smallholder farmers to participate in a training programme shared on social media. The purpose of the visits was to liaise and develop further trust with agricultural support services, smallholder farmers and other relevant stakeholders. A total sample population of 37 from the initial 121 smallholder farmers participated in the training programme. Focus group discussions based on the social media training programme were held a group of 37 smallholder farmers from the initial sample size.

Descriptive statistics were used for data analysis. Frequencies and percentages were used to analyse the data. The Statistical Package for Social Sciences (SPSS) version 26 was used for data entry, screening, and statistical analysis. Content analysis was used to analysis the qualitative data.

3.6. Informal meetings with stakeholders

Through field visits, informal interview with some of the development stakeholders were conducted. The stakeholders include TsGrow, LIMA and the Department of Agriculture and Komati-Usuthu.

TsGrow

This is a Non-Governmental Organisation that provides services and knowledge dissemination mainly to sugarcane smallholder farmers. TsGrow is responsible for a complex value chain that spans from farm production to consumption of yields and enriches communities in which they operate. In 2020, they were able to help support South Africans through the COVID-19 crisis, producing and distributing over 1 500 tonnes of sugar. TsGrow operates in seven tribal authorities, having 36 projects in Nkomazi Local Municipality. They support smallholder farmers plus land reform beneficiaries where they provide all agricultural inputs which include implements, seeds (cutting), fertilizers, herbicides and pesticides. Agricultural extension officers provide advice to smallholder farmers and identify training gaps, and training is done through workshops.

TsGrow-Uncovered issues

Commercial smallholder farmers only deliver 30% of sugarcane, and they gradually diversify out of sugarcane causing a shortage in the sugarcane processing mill. Smallholder farmers only produce 20% for the mill, which is approximately 850 thousand tonnes of sugarcane which is not enough. The smallholder farmers' irrigation infrastructure is old (funded and installed in 1994 by the government), and the rain factor is identified as a negative impact that mainly hinders smallholder farmers. The high cost of electricity for pumping irrigation water is also an expense. Smallholder farmers who are dominating are 60 years and above, and the main reason is that the old age is unwilling to transfer powers to their kin young and the lack of farming interests experienced by the young.

LIMA

This is a non-governmental rural development foundation that focuses on food security to support and increase food production in vulnerable households through the provision of education, basic agricultural training, infrastructure grants, economic development and employment opportunities. It aids sustainable and transformative community growth, providing support to smallholder farmers either in cooperatives or as individuals or youth. Currently, in Nkomazi Local Municipality, they work with 1000 smallholder farmers on livestock, vegetable, and sugarcane production. They strive hard to give smallholder farmers access to local markets and introduce them to the local gaps.

LIMA-Uncovered issues

Water rights are a foremost problem whereby smallholder farmers have to attain limited litres of water from the river. Whilst probing, some challenges were identified that included lack of funding, land access and shortage of skills. Also, the rate of dishonesty is high because some smallholder farmers are granted loans but never pay back. Youth (age 16-35) involvement in farming is minimal, and education level has the key impact that can ascertain sustainable smallholder rural farming.

The Department of Agriculture

The department has various programmes that support smallholder farmers. One of their main programmes is Phezukomkhono Mlimi (PKM), which provides the resources which include seeds, seedlings, and fertilizers. Smallholder farmers, also receive tractors, fuel, and tools. The tools include a spade, shovel, trowel, hoe, fork, rake, and wheelbarrow. The department has agricultural extension officers whose role is to work with the smallholder farmers, advising them to advise and doing demonstrations. They must collect smallholder farmers’ data by classifying them according to their scale of production needs and commodities. They ensure that all smallholder farmers are recorded in a database using a digital pen. The extension officers also identify smallholder farmers' training gaps and invite accredited stakeholders to train the smallholder farmers. Training is mainly done through Further Education and Training (FET). Several stakeholders which collaborate with the department include Grain SA, Cotton SA, TsGrow, OMNIA, AgroData and LIMA.

The Department of Agriculture-Uncovered issues

They mainly work with marginalised rural smallholder farmers, and therefore technology dissemination is a problem due to their age, skills, and educational level (age 46 and above). The youth is mainly interested in quick cash, so they are unlikely to join farming because it does not offer quick money.

Komati-Usuthu

Komati-usuthu mainly focuses on the management of water usage, working closely with the Department of Agriculture. They look at water volumes on dams and weather focus predictions. If rains would not be enough, decisions are then taken based on the available water. Lesser dam volumes and negative weather predictions necessitate water restrictions in terms of water allocation. Smallholder farmers’ access to water is determined by the quantity of water available, and lesser the quantity means high restrictions on water. The water is allocated per hectare according to crop water requirements. Smallholder farmers are billed for water extracted from either the river or dam in relation to water cubes per hectare. Changing sprinkler irrigation systems to drip lines system is one of the key strategies embarked on to save the available water.

They have empowerment programmes that support emerging smallholder farmers (who produce in -10 ha field) by providing smallholder farmers with JoJo tanks, irrigation pumps, and drill boreholes based on the cooperative structure and beneficiaries. With large-scale farming, when an agreement is reached, the Komati-Usuthu uses its material only to extract water from the river to the margin of the farm. Most smallholder farmers in Nkomazi participate in vegetable production. So far, the Komati-Usuthu has assisted +/-5 cooperatives along the Komati River catchment, and the number of individuals per cooperative varies from 35-50 members and are mainly subsistence smallholder farmers. Few smallholder farmers in Nkomazi are growing cotton, and it is an advantage as cotton does not require a lot of water.

Komati-Usuthu-Uncovered issues

The water level is decreasing dramatically daily. Most of Nkomazi Municipality is dominated by sugarcane farms whereas sugarcane needs high volumes of water daily. Most smallholder farmers are old. The high electricity costs for pumping irrigation water negatively impact smallholder farmers. It is smallholder farmers' most obstacle to sustain ESKOM bills due to their level of farming (mostly subsistence farming), therefore, some projects collapse. The means of channelling water from the river to smallholder farmers' plots is costly. Water awareness to smallholder farmers is not frequently done, and they have limited training in water management practices.

3.7. Mobilizing the growers' community

Visits were made to the following communities: Jeppe's reff, Schoemansdal, Langloop, Mzinti, Mbuzini, Skhwahlane, Tonga and Naas. The visits were aimed at identifying smallholder farmers with access to smartphones. The visits enabled a relationship of trust to be built with the smallholder farmers. During informal meetings with the different stakeholders, it was found that it would be difficult to work with some of the stakeholders. Some of the impediments

included time constraints and Covid-19 restrictions. Though as smallholder farmer identification continued, a gatekeeper was identified, that is, the chairperson of Ikwezi group.

The chairperson assisted the smallholder farmers by having a meeting through a focus group discussion and semi-structured questionnaire roll out. The focus of the meeting was to identify smallholder farmers' training needs concerning agricultural water management and the development of a training programme through social media.

Figure 7**:** *Meeting with the farmers.*

4. REPORT ON SOCIAL MEDIA USE BY SMALLHOLDER FARMERS

4.1. Social media use among smallholder farmers in the Nkomazi local municipality

4.1.1. Demographics and socio-economic characteristics

The results obtained from the survey on the socio-economic and demographic characteristics of smallholder farmers are presented in ***Table 3***.

Table 3: *Demographics and Socio-Economic Characteristic Summary (n=121).*

Variable	Description	Frequency	Percent (%)
Age	20-29	31	25.6
	30-39	19	15.7
	40-49	29	24.0
	50-59	18	14.9
	60+	24	19.8
Gender	Female	76	62.8
	Male	45	37.2
Education level	No school	14	11.6
	Primary	34	28.1
	Secondary	22	18.2
	Matriculated	28	23.1
	Tertiary	12	19
Source of income	Social grant/pension	13	10.7
	Farming	39	32.2
	Remittance	40	33.1
Co-operative membership	Yes	66	54.5
	No	55	45.5
Type of production/farming	Crop	103	85.1
	Livestock	18	14.9
Source of water	Dam	41	33.9
	River	63	52.1
	Borehole	13	10.7
	Water well	3	2.5
Methods of water allocation	Irrigation	48	39.7
	Rain-fed	11	9.1

Variable	Description	Frequency	Percent (%)
	Both irrigation & rain-fed	46	38.0
	Buckets	16	13.2
Electronic device	None	7	5.8
	Basic cell phone	55	45.5
	Smartphone	53	43.8
	Laptop	2	1.7
	Smartphone/laptop	4	3.3
Social media use	Yes	46	38.0
	No	75	62

Age

The results from ***Table 3*** show that 25.6% of the smallholder farmers are between the ages of 20-29, and 15.7% are in the age group of 30-39. The results also indicate that 24% of the smallholder farmers are between the ages of 40-49. It also revealed that 14 .9% of the smallholder farmers are in the age group of 50-59, and smallholder farmers in the age group of 60 and above were found to be 19.8%.

Level of education

The results in ***Table 3*** indicated that 11.6% of the smallholder farmers had no formal education. The respondents had limited formal education, with 28.1% having a primary level of education, and 18.2% of them had a secondary level of formal education. The study also showed that only 23.1% of the respondents matriculated, and 19% had a tertiary level of education.

Source of income

The study also shows that the majority (33.1%) of smallholder farmers receive their income from remittance as represented in ***Table 3***. Smallholder farmers whose source of income is farming, or farm activities were found to be 32.2%. The minority (10.7%) receive social grant pensions, and this composed mostly of smallholder farmers from the age group 60 and above. The results from the study also indicate that a majority (54.5%) of the smallholder farmers are part of co-operatives, and most (85.1%) of the smallholder farmers are in crop production.

Source of water

The findings from the study show that (52.1%) of smallholder farmers draw water from the river, and 33.9% get their water from a dam. Only 10.7% have a borehole as their source of water, and 2.5% have a water well as their water source, see ***Table 3***.

Electronic devices and social media use

The findings in ***Table 3*** also revealed that 45.5% of smallholder farmers have a basic cell phone, and those that have a smartphone were found to be 43.8%. It was also found that 38% of them made use of social media, and 62% were found not to be utilising social media.

4.1.2. Social media platforms used by smallholder farmers.

The results that were obtained from the survey in relation to social media platforms used by smallholder farmers to gather agricultural information are presented in ***Table 4***.

Table 4: *Social media platforms used by smallholder farmers.*

			Gathering agricultural information					
			None	WhatsApp	Facebook	Twitter	YouTube	Total
Gender	Female	Count	46	13	11	1	5	76
		Percentage (%)	60.5%	17.1%	14.5%	1.3%	6.6%	100.0%
	Male	Count	29	8	2	2	4	45
		Percentage (%)	64.4%	17.8%	4.4%	4.4%	8.9%	100.0%
Total		Count	75	21	13	3	9	121
		Percentage (%)	62.0%	17.4%	10.7%	2.5%	7.4%	100.0%

The results presented in ***Table 4*** show that WhatsApp is the most utilised platform in terms of gathering agricultural information, with 17.4% of smallholder farmers making use of the platform. Only 10, 7% use Facebook, and 7.4% use YouTube.

4.1.3. Gendered use of social media platforms by smallholder farmers

It is also depicted by the results in ***Table 4*** that there are 76 females of which 17.1% of them frequently make use of WhatsApp, and only 45 males which is 17.8% utilise the same platform frequently. Facebook is the second most utilised social media platform among females, with

14.5% of them utilising it, though among males, only 4.4% of them make use of the same platform. YouTube is the second most frequently used platform among males (8.9%), followed by Twitter and Facebook (4.4%), whereas females, 6.6% use YouTube among themselves, and only 1.3% use Twitter.

4.1.4. Differences between genders in the use of social media among smallholder farmers

Table 5: *Gender differences in the use of social media*

			Social media use		Total
			Yes	No	
Gender	Female	Count	30	46	76
		Percentage (%)	39.4%	60.5%	100.0%
	Male	Count	16	29	45
		Percentage (%)	35.6%	64.4%	100.0%
Total		Count	46	75	121
		Percentage (%)	38.0%	62.0%	100.0%

The results in ***Table 5*** represent the use of social media between different genders of smallholder farmers. From the results, it can be noted that 38% of smallholder farmers make use of social media. The results also reveal that of all the smallholder farmers, females use social media more than males. The results further show that 39.4% of women utilise social media, whereas 35.6% males use it as well.

4.1.5. Attitudes of smallholder farmers towards the use of social media for sustainable water management practices

The results obtained from the survey on the attitudes of smallholder farmers towards social media use for sustainable water management practices are presented in ***Table 6***.

Table 6: *Attitudes of smallholder farmers towards social media use in water management practices.*

		Mulching	Localized irrigation	Rainwater harvesting	Irrigation scheduling	Green manure
Social media helps me in learning about	Yes	21(17.4%)	33(27.3%)	8(6.6%)	18(14.9%)	22(18.2%)
	No	100(82.6%)	88(72.7%)	113(93.4%	103(85.1%)	99(81.8%)
I prefer farmer-to-farmer information sharing about	Yes	81(66.9%)	33(27.3%)	33(27.3%)	37(30.6%)	73(60.3%)
	No	40(33.1%)	17(14%)	88(72.7%)	84(69.4%)	48(39.7%)

The results in ***Table 6*** show that a majority (82.6%) of smallholder farmers have a negative attitude towards the utilisation of social media for gathering information about mulching. The results further show that 72.7% of smallholder farmers have a negative attitude towards the utilisation of social media to learn about localised irrigation as opposed to 27.3% which had a positive attitude. The results also show that most smallholder farmers have a negative attitude towards using social media to learn about irrigation scheduling as only 14.9% feel that social media helps them in learning about it (irrigation scheduling). The results further show that only 6.6% of smallholder farmers have a positive attitude towards using social media to learn about rainwater harvesting, and for green manure, only 18.2% of them had a positive attitude towards using social media.

A total of 66.9% of smallholder farmers as represented by ***Table 6*** had a favourable and positive attitude towards farmer-to-farmer information sharing about localised irrigation. In terms of irrigation scheduling, most smallholder farmers have a negative attitude towards farmer-to-farmer information sharing, as only 27.3% of smallholder farmers prefer farmer-to-farmer information sharing in that regard. The study further revealed that most (66.9%) of the smallholder farmers have a positive attitude towards farmer-to-farmer information sharing in terms of mulching. In terms of farmer-to-farmer information sharing about rainwater harvesting, the study revealed that only 27.3% of smallholder farmers have a positive attitude towards it. The results further show that 60.3% of smallholder farmers have a positive attitude towards farmer-to-farmer information sharing about green manure.

4.1.6. Attitudes of smallholder farmers towards social media use

Smallholder farmers were asked to respond to the statements listed in ***Table 7*** in order to assess their attitude towards the use of social media. A total of 55.4% of the smallholder farmers have a positive attitude towards receiving information from extension officers over social media. It can also be seen from the results that 61.2% have a positive attitude towards using radio and television over social media. The data also showed that 74.4% of the smallholder farmers have a positive attitude towards the younger generation being better suited for using social. The data from the study further revealed that 71.1% of smallholder farmers felt that it is essential to have ICT skills to utilise social media meaningfully.

Table 7: *Attitude of smallholder farmers towards social media.*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I prefer going to an extension officer to seeking information on social media	67(55.4%)	10(8.3%)	11(9.1%)	6(5%)	27(22.3%)
I prefer using radio and television as my source of information	74(61.2%)	9(7.4%)	14(11.6%)	7(5.8%)	17(14%)
I think the younger generation is better suited for social media	90(74.4%)	7(5.8%)	22(18.2%)	0(0%)	2(1.7%)
Using social media requires ICT skills that you must learn	86(71.1%)	6(5%)	26(21.5%)	2(1.7%)	1(.8%)

4.1.7. Constraints of smallholder farmers towards the use of social media

The results obtained from the survey on the constraints of smallholder farmers in the utilisation of social media are presented in ***Table 8***.

Table 8: *Constraints of smallholder farmers in the use of social media.*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Hard to understand the information received from social media	14(11.6%)	12(9.9%)	42(34.7%)	15(12.4%)	37(30.6%)
Information on social media is sometimes incorrect	33(27.3%)	13(10.7%)	74(61.2%)	0(0%)	1(.8%)
Social media discussions lose focus on the main topic	23(19%)	17(14%)	75(62%)	0(0%)	6(5%)
I do not know how to apply the information I get from social media to my farming practices	7(5.8%)	6(5%)	69(57%)	9(7.4%)	30(24.8%)
Data to access social media is too expensive	67(55.4%)	16(13.2%)	37(30.6%)	0(0%)	1(.8%)
You need to know to read to use social	107(88.4%)	8(6.6%)	6(5.0)	0(0%)	0(0%)

Smallholder farmers were asked to respond to the statements in ***Table 8*** in order to assess the constraints of smallholder farmers towards the use of social media. A total of 34.7% of smallholder farmers remained neutral to the statement on information from social media being hard to understand. It was also found that a large number of smallholder farmers responded positively to data for accessing social media being too expensive and is, therefore, a major constraint. Only 19% of smallholder farmers also responded positively to the main topics on social media losing focus and diverting to other topics. The study further shows that 27.7% of smallholder farmers agree that information that is attained through social media is at times incorrect. A total of 88.4% of smallholder farmers responded positively to the importance of reading (literacy) to be able to utilise the social media.

4.2. Discussion on social media usage

From the results, it was found that 25.6% of the respondents fall under the age group of 20-29. The results presented also show that most smallholder farmers within this age group (20-29) have a positive attitude towards the use of social media for sharing information. This is in agreement with the findings of Darshan *et al*. (2017) who state that most farmers that are young, especially smallholder farmers that are up to 35 years of age, are highly attracted to the use of the social media. The findings also coincide with the American Farm Bureau Federation (2013) that 82% of smallholders within the age group 18-29 utilise social media in some form or the other. The study further reveals that most of the smallholder farmers have not completed their formal education thus impacting negatively on their use of the social media. Kuria (2014) corroborates this statement by stating that the digital divide impacts the poorly educated and results in poor digital literacy. Darshan *et al*. (2017) also states that higher levels of education result in easier use and a better understanding of social media and a positive attitude towards it.

In terms of income, the study indicates that most smallholder farmers receive their income from the remittance. The results also indicate that most of the smallholder farmers are part of co-operatives, and most of them are in crop production. It can also be seen that most smallholder farmers attain draw from a river, and most of them have an irrigation system installed on their farms. The findings also reveal that in terms of electronic devices, most smallholder farmers have a basic cell phone. This is in agreement with the findings of Kuria (2014) that the digital divide that impacts the elderly and economically poor is a result of poor digital literacy and limited internet access. It was also found that of all the farmers, only 38% of them made use of social media, and 62% did not use the social media. These findings are in agreement with previous studies that indicate that most smallholder farmers do not utilise social media (Aldosari *et al*., 2019; American Farm Bureau Federation, 2013).

4.2.1. Social media platforms used by smallholder farmers

The results from the study further show that WhatsApp, Facebook and YouTube are the most commonly used social media platforms by smallholder farmers. The results are in agreement with Thakur and Chander (2018b) who found that social media platforms that are popular in farming practices and sharing of diverse farm information and knowledge are WhatsApp, Facebook and YouTube. The study further shows that WhatsApp is the most commonly utilised platform by smallholder farmers in terms of gathering agricultural data. Facebook is the second most utilised platform for gathering agricultural information. This is in agreement with Suchiradipta and Saravanan (2016) who found that social media usage in terms of Agricultural Extension and Advisory Services (AEAS) has two dominant platforms, which are Facebook with an average of 64.7% and WhatsApp with an average usage of 33.3%. YouTube is the third mostly utilised platform with a usage of 7.4% among smallholder farmers. It was also found that most smallholder farmers do not make use of any of the abovementioned social media platforms for gathering agricultural information, which agrees with other studies that found that most smallholder farmers do not make use of social media (Aldosari *et al.,* 2019; American Farm Bureau Federation, 2013; Darshan *et al.,* 2017; Kuria, 2014)

The findings also show that between both males and females, the most used platform is WhatsApp, followed by Facebook among other platforms such as Twitter, YouTube and Instagram. However, most smallholder farmers (62%) make use of none of the social media platforms. Kante *et al*. (2017) further concurs that 89.5% of smallholder farmers feel that ICT is suitable for gaining agricultural information. The results further reveal that more females frequently make use of WhatsApp than males as opposed to those that utilise Facebook and those that use none of the platforms at all. Facebook is also the least utilised social media platform for both genders. A total of 55.3% of females do not use any of the social media platforms, and 60% of males do not utilise the same. The difference between males and females who frequently use a particular platform can easily be noted, and it can therefore be said that females tend to use both WhatsApp and Facebook more than males. It can also be deduced that more males than females use social media less and utilise none of the presented social media platforms for varying reasons. This coincides with Idemudia *et al*. (2017), with 37% of males that found social media to be useful, compatible, easy to use and satisfactory to its intended use.

4.2.2. Attitudes of smallholder farmers towards the use of social media

In terms of the attitude of smallholder farmers towards the use of social media, most of the smallholder farmers have a positive attitude towards receiving information from extension officers over social media. This concurs with the findings of Kuria (2014), who found that more smallholder farmers seek information from agricultural extension services (16.9%) compared to social media (13%). The results further concur with findings by Kuria (2014), with 59.7% of smallholder farmers preferring other sources of information to social media. Most smallholder farmers have a positive attitude towards using radio and television over social media. This coincides with the findings by Kumar *et al*. (2017) and Aldosari *et al*. (2019) whose studies showed that smallholder farmers tend to make more use of information mostly from face-to-face agricultural extension services, television, print media and radio stations than social media.

4.2.3. Attitudes of smallholder farmers towards the use of social media for sustainable water management practices

The results show that most smallholder farmers have a negative attitude towards the utilisation of social media for gathering information about mulching. This coincides with the findings of Osundu and Ibezim (2015) that there is an association between the level of education of smallholder farmers and awareness as well as use of social media to gather information. The results further show that most smallholder farmers have a negative attitude towards the utilisation of social media to learn about sustainable water management practices such as localised irrigation, irrigation scheduling, rainwater harvesting and green manure. This concurs with Kuria (2014) who found that most smallholder farmers seek and receive information about sustainable water management from libraries, websites and agricultural extension officials.

A majority of smallholder farmers had a favourable and positive attitude towards farmer-to-farmer information sharing about mulching as opposed to (33.1%) those have a negative attitude. The study also shows that 60.3% of smallholder farmers prefer farmers-to-farmer information sharing about green manure. From the results, it was revealed that most smallholder farmers have a negative attitude towards farmer-to-farmer information sharing in terms of localised irrigation, rainwater harvesting and irrigation scheduling.

4.2.4. Constraints of smallholder farmers towards the use of social media

It was also found that many smallholder farmers responded positively to the cost of mobile data for accessing social media being too expensive and is, therefore, a major constraint. This concurs with Mohan (2016) who reported that internet data that is not affordable and is an indispensable requirement for smallholder farmers to have access to information that is vital. Barau and Afrad (2017) also agree with the statement as a significant number of smallholder farmers have little to pay for data costs to access social media and the high costs that are incurred make it difficult for them to utilise social media. Most smallholder farmers also responded positively to the main topics on social media losing focus and diverting to other topics. Thakur and Chander (2018a) concur with this statement, stating that smallholder farmers face constraints such as sharing or receiving irrelevant information, and some users are also overloaded with irrelevant posts which result in extra or unnecessary data costs. It was further revealed that smallholder farmers agree that information that is attained through social media is at times incorrect. This concurs with studies by Kuria (2014) and Fuess (2011) who found that some of the information that may be obtained from the internet cannot be completely reliable. The study further shows that smallholder farmers responded positively to the ability to read as important for the utilisation of social media. Barau and Afrad (2017) concur that to use social media, both technical and educational literacy are required and that this is a major constraint in social media utilisation. Often, smallholder farmers are uneducated, and this results in an absence of understanding of the utilisation of social media and technology (Barau & Afrad, 2017).

4.3. Concluding remarks on smallholder farmers' social media

Communication and information transfer play a vital role in the learning and training of smallholder farmers on sustainable agricultural practices. Lack of proper communication can lead to poor adoption rates of vital sustainable water management practices by smallholder farmers. Social media has high potential in the agricultural industry and can reshape and enhance the dissemination of information to smallholder farmers. The results revealed that most of the smallholder farmers had an unfavourable negative attitude towards the effectiveness of social media for sharing information. A positive attitude towards social media is important to promote the use of social media among smallholder farmers. Meetings with smallholder farmers to encourage awareness and benefits of social media in agriculture need to be set up in collaboration with other stakeholders.

Some of the constraints experienced were due to a lack of literacy in both the use of social media and the application of information attained from the varying platforms. The findings suggested that most of the smallholder farmers have not completed their formal education thus leading to such illiteracy. Most smallholder farmers in the area were found to be females, which represents the gender gap present in the South African agricultural sector. The gender gap demonstrates the high spread differences in terms of social media use and platform preference. The results also indicate that female smallholder farmers have more access to social media through smartphone devices, yet some of them do not utilise social media. This is mostly due to a lack of literacy and the expensive data costs. The findings of this study suggest that for smallholder farmers to access and disseminate vital information on sustainable water management practices, an appropriate social media platform that is easy to use should be introduced. Furthermore, the development of a social media platform that is solely agriculturally based and provides prompts that are easily understood by farmers, in terms of language and accessibility would prove to be beneficial in the promotion of social media as a means of information dissemination, learning and training, as well as farmers-to-farmer communication on sustainable water management practices. The results also reveal that smallholder farmers do not believe that the information from the internet is always correct, hence social media hosts need to ensure that the information posted is scientifically correct and relevant.

Training is a crucial aspect to encourage the utilisation of social media by smallholder farmers. A training programme is prosed for smallholder farmers. This will assist in allowing them to improve their level of literacy and increase their awareness along with access to social media. This will also create more effective ways to disseminate information between smallholder farmers themselves, agricultural extension officials and other agricultural stakeholders. The development of an agricultural social media platform, with the components of other platforms that smallholder farmers utilise such as WhatsApp, should also be considered, as it will allow for better communication and easier access to information. The platform should be easy to use and reliable for smallholder farmers, especially those with a lower level of literacy. Engagement of smallholders in innovations towards social media usage in the agricultural sector is very important, not forgetting that social media itself is anchored on engagement with stakeholders. Through engagement, constraints can be overcome thus bringing opportunities for social media realised by all stakeholders, especially the smallholder farmers. Smallholder farmers need to work together with other stakeholders to enhance the utilisation of social media in agriculture by encouraging and being ambassadors of social media to other stakeholders and their peer.

5. REPORT ON SOCIAL MEDIA TRAINING PROGRAMME

5.1. Introduction

The process of training involves the teaching and learning of individuals through the dissemination of information and skills for their development. The purpose of the social media training programme is to disseminate information and knowledge about agricultural water management practices to smallholder farmers. The training programme involves the use of the WhatsApp platform that allows its users to receive and share diverse information such as video, audio, and other types of visual formats.

Several visits were made to Nkomazi Local municipality to find out how smallholder farmers participate in the training programme shared on social media. The visits were beneficial and allowed a partnership to be established with smallholder farmers and the stakeholder assisting the smallholder farmers. Information was obtained using both formal and informal methods. The number of participants was reduced from 121 to 37 in the training programme to allow for more specific and generalisable results and due to the qualitative approach and Covid-19 restrictions.

5.2. Findings from 37 smallholder farmers in the training programme

5.2.1. Demographic and socio-economic characteristics of the 37 participants

Table 9: *Demographic and socio-economic characteristics of smallholder farmers*.

Variable	Description	Frequency	Percent (%)
Age	20-29	2	5.4
	30-39	5	13.5
	40-49	5	13.5
	50-59	10	27.0
	60+	15	40.5
Gender	Female	15	40.5
	Male	22	59.5
Household head	No	3	8.1
	Yes	34	91.9
Marital status	Single	9	24.3
	Divorced	1	2.7
	Engaged	1	2.7

Variable	Description	Frequency	Percent (%)
	Married	25	67.6
	Widowed	1	2.7
Education level	No school	4	10.8
	Primary	11	29.7
	Secondary	9	24.3
	Matriculated	7	18.9
	Agricultural certificate	1	2.7
	Diploma	1	2.7
	Degree	4	10.8
Source of income	Social grant	1	2.7
	Farming	29	78.4
	Pension	7	18.9
Annual income	R0-R54 344	31	89.2
	R54 345-R151 27	4	10.8
Type of production/farming	Crop	103	85.1
	Livestock	18	14.9
Farm size	<5 ha	20	54
	6-10 ha	11	29.7
	11-20 ha	2	5.4
	31-40 ha	1	2.7
	41 ha<	3	8.1
Land ownership	Government-owned	3	8.1
	Rain-fed	11	9.1
	Owned	27	73.0
	Renting/leased	2	5.4
Crops grown	Cabbages	17	45.9
	Green peppers	1	2.7
	Lettuce	1	2.7
	Maize	1	2.7
	N/A	2	5.4
	Spinach	1	2.7
	Tobacco	2	5.4

Variable	Description	Frequency	Percent (%)
	Tomatoes	2	5.4
	Variety of vegetables	10	27.0
Livestock owned	Cattle	6	16.2
	Fowl	2	5.4
	Goats	3	8.1
	N/A	26	70.3
Reason for farming	Cash	14	37.8
	Consumption and cash	23	62.2
Co-operative membership	No	9	24.3
	Yes	28	75.7
Irrigation scheme membership	No	24	64.9
	Yes	13	35.1
Water rights	No	19	51.4
	Yes	18	48.6
	Borehole	3	8.1
	Canal	1	2.7
	Dam	4	10.8
	None	1	2.7
	River	21	56.8
	Spring	5	13.5
	Water well	2	5.4
Irrigation method	Buckets	7	18.9
	Drip irrigation	20	54.1
	Drip & sprinkler irrigation	1	2.7
	Farrow	3	8.1
	Rain-fed	1	2.7
	Sprinkler irrigation	5	13.5

The results from the study indicate of 40.5% of the smallholder farmers are 60 and above in age, followed by smallholder farmers in the age group of 50-59, with 27%. The least number of smallholder farmers was found between 20-29 years, with 5.4% of smallholder farmers. In terms of gender, there were 59.5% males and 40.5% females. Smallholder farmers that were married were 67.6%, and those that were single were 24.3%. Most smallholder farmers were found to have little to no education level, with 29.7% of them having a primary level of education, 10.8% having no schooling and 24.3% of them having a secondary level of education. Smallholder farmers that matriculated were 18.9%, and those with an agricultural certificate as well as a diploma were 2.7% each respectively, whereas those with a degree amounted to 10.8%.

Considering the source of income of the participants, most of them received their income from farming (78.4%), followed by those that received pensions thus making up 18.9%, and those that relied on the social grant were at 2.7%. A total of 89.2% of smallholder farmers made R0-R54 344, and only 10.8% made an annual income of R54 345-R151 727. The results showed that most smallholder farmers have a landholding of less or equal to five hectares (54%), followed by those that have a landholding of 6-10 ha (29.7%). Those that have a landholding of 40 or more hectares make up 8.1%. A total of 73% of smallholder farmers own their land, 8.1% farm on government-owned land, and 5% are renting the land. The findings showed that 49.1% of the smallholder farmers grow cabbages, followed by those that grow a variety of different vegetables ranging from lettuce, green pepper, maize, and spinach thus accounting for 27% of smallholder farmers. Cattle are owned by 16.2% of smallholder farmers, 8.1% own goats, and those that produce fowls make up 5.4%. A total of 62.2% of smallholder farmers farm for household consumption and sell, while only 37.8% farm only for selling.

The results show that 75.7% of the smallholder farmers have cooperative membership, and only 35.1% belonged to an irrigation scheme. Smallholder farmers that had water rights were 48.6%, whereas those that did not have water rights were 51.4%. The results also revealed that 56.8 of smallholder farmers relied on river water, 13.5% relied on springs, 10.8% depended on a dam, 8.1% of them used boreholes, and 5.4% relied on well water. A total of 54.1% have a drip irrigation system, followed by 18.9% of them making use of buckets to water crops, and those that make use of sprinkler irrigation amounted to 13.5%. Those that made use of farrow irrigation were 8.1%, and those that had both drip and micro-sprinkler on the farmland were 2.7%, as well as those that relied on rain.

5.2.2. Social media use by smallholder farmers in the training programme

Table 10 represents the use of social media according to smallholders.

__Table 10:__ Social media use by smallholder farmers

Variable	Description	Frequency	Percent (%)
Social media use	No	19	51.4
	Yes	18	48.6
Language preferred on social media	English	7	18.9
	IsiZulu	2	5.4
	SiSwati	28	75.7
Difficulties in social media use	Cannot use social media	8	21.6
	Data cost	12	32.4
	Data shortages	2	5.4
	Do not own an electronic device	3	8.1
	Late responses	1	2.7
	Not applicable	8	21.6
	Network conditions	1	2.7
	No experience in using social media	1	2.7
	Time constraints	1	2.7
Motivation for using social media	Gaining accurate information	23	62.2
	Improving farming practices	3	8.1
	Not applicable	2	5.4
	Sufficient mobile data	7	18.9
	Agricultural training	2	5.4

A total of 51.4% of the smallholder farmers did not make use of social media, and those that did make use of social media were 48.6%. It was also found that the language that was highly preferred by smallholder farmers on social media was SiSwati (75.7%), and those that preferred English were 18.9%. Only 5.4% preferred IsiZulu. In terms of the difficulties faced in the use of social media, the smallholder farmers noted that data costs affected their use (32.4%), followed by those that could not typically use it who were 21.6%. Those that did not own an electronic device to access social media were 8.1% of smallholder farmers, while those that felt that social media takes up too much mobile data were 5.4%. Besides, those that felt that they do not have time, experience in social media use as well as network issues and late responses were 2.7% respectively. In terms of what would motivate smallholder farmers to use social media, 62.2% felt that gaining accurate information would be a motivating factor, followed by having sufficient mobile data to access social media at 18.9% of smallholder farmers. Those that felt that getting agricultural training on social media would be a motivating factor were 5.4%.

5.2.3. Smallholder farmers' perceptions of social media training

Table 11 represents the finding from the investigation in relation to the measures of training on social media according to smallholder farmers' perceptions and preferences.

Table 11: *Agricultural water management practices training programme.*

Variable	Description	Frequency	Percent (%)
Agricultural water management practices training	Drip irrigation	15	40.5
	Irrigation as a whole	10	27.0
	Pumping water	1	2.7
	Purification and filtration	1	2.7
	Rainwater harvesting	1	2.7
	Micro-sprinkler irrigation	1	2.7
	Sustainable water management	5	13.5
	System installation	1	2.7
	Water access	1	2.7
	Water storage	1	2.7
Social media platforms preferred for training	All	9	24.3
	Audio	3	8.1
	audio and stepped pictures	1	2.7
	Practical videos	20	54.1
	Reading documents	3	8.1
	Stepped pictures	1	2.7
	Not applicable	2	5.4

Variable	Description	Frequency	Percent (%)
	Sufficient mobile data	7	18.9
	Agricultural training	2	5.4
Limitations to using social media	Cannot read or write	6	16.2
	Data cost	26	70.3
	Language barriers	2	5.4
	Not applicable	3	8.1

The results show that 40.5% of the smallholder farmers wanted to be trained in drip irrigation systems, followed by 27% that would like to be trained in irrigation, 2.7% of smallholder farmers wanted to be trained in pumping water, and another 2.7% wanted to be trained in purification and filtration. Those that wanted to be trained in rainwater harvesting were 2.7%, as well as those who wanted to be trained in micro-sprinkler irrigation. Smallholder farmers that wanted to be trained in sustainable practices made were 13.5%, with 2.7% that wanted to be trained in water storage. Also, those that wanted training in water access were 2.7%. Other smallholder farmers who wanted to be trained in irrigation system installation were 2.7%. Smallholder farmers wanted to be trained in social media through practical videos (54.1%), followed by those that were comfortable with all methods of training through social media (24.3%). Those that wished to be trained through audios were 8.1%, 2.7% wished to be trained through audios and stepped pictures, those that preferred reading documents were 8.1%, and those preferring stepped pictures were 2.7%. The social media platform that was highly preferred by smallholder farmers for training in agricultural water management practices was WhatsApp (62.2%), and those that preferred Facebook were 5.4%, YouTube were 2.7%, those that preferred all the platforms, except Twitter at 5.4% and those that preferred any or all the social media platforms were 21.6%. The limitation that smallholder farmers felt was present in these social media platforms and the use of social media, in general, was the language barrier (5.4%). Moreover, 70.3% of them felt that data was expensive while 16.2% felt that they cannot read and write, which limited them from using social media.

5.3. Training programme: Video on the installation of a micro-sprinkler irrigation system

5.3.1. Aim of programme

The process of training involves the teaching and learning of individuals through the dissemination of information, knowledge, and skills for their development. The purpose of the social media training programme is to disseminate information and knowledge about agricultural water management practices to smallholder farmers. The training programme involves the use WhatsApp platform that allows users to receive and share diverse information such as videos, audios, and other types of visual formats. WhatsApp allows for clarification at any given time and with less effort and minimal costs.

In designing the training programme, four main areas were put into consideration. These included:

- What learning outcomes will meet the needs of the smallholder farmers?
- What aspects should be included in the creation of the training video?
- What resources are available as it is vital to consider the resources, especially the finances?
- What are some potential challenges of the training programme?

5.3.2. Learning paradigms considered in the training programme

The programme encompasses and promotes a reflector, pragmatist, and activist approach by smallholder farmers from the information they receive through social media. The reflector type of learning style takes into account learning by observing and thinking about what they saw and considering all the possible measures as well as implications before considering what can be done before it is done (Rosewell, 2005). The training programme encompassed this style through a video encompassing steps and pictures that allow smallholder farmers to view and reflect on the information provided to them. The pragmatist learning style looks into practically trying things out and searching for ideas that can be applied to the faced issue, and also takes into account techniques with clear practical implications and advantages (Kolb, 1984). In terms of the programme, the video provided examples that could be practically tested by the smallholder farmers.

5.3.3. Design and format considerations

The video encompassed several of the major social media interaction software. This includes visuals through step-by-step pictures on the installation of a micro-sprinkler irrigation system, text-based format within the video via a slide show and voice-over audio for the PowerPoint presentation and narrated on the step-by-step images that were provided. The language used was isiZulu, given its similarity to the SiSwati language and the language preferences of smallholder farmers on social media platforms. The entire narration of the video was in this particular language, other interactions through WhatsApp involved both English and isiZulu by using voice notes and text messages.

Steps to follow on the video.

The video consisted of 7 steps on how to install a micro-sprinkler irrigation system. The steps are discussed as follow:

Step 1: Firstly, draw the irrigation design to scale, showing where you plan to place the pipes. Drawing a map of the farm to be irrigated is essential for proper planning of the irrigation system. The plan will help guide the number of materials required. Materials can include pipes, threaded risers, micro sprinklers, valves, and joints. The map should be drawn to scale, such as drawing as accurately as possible on graph paper that 1-inch equals 10 feet.

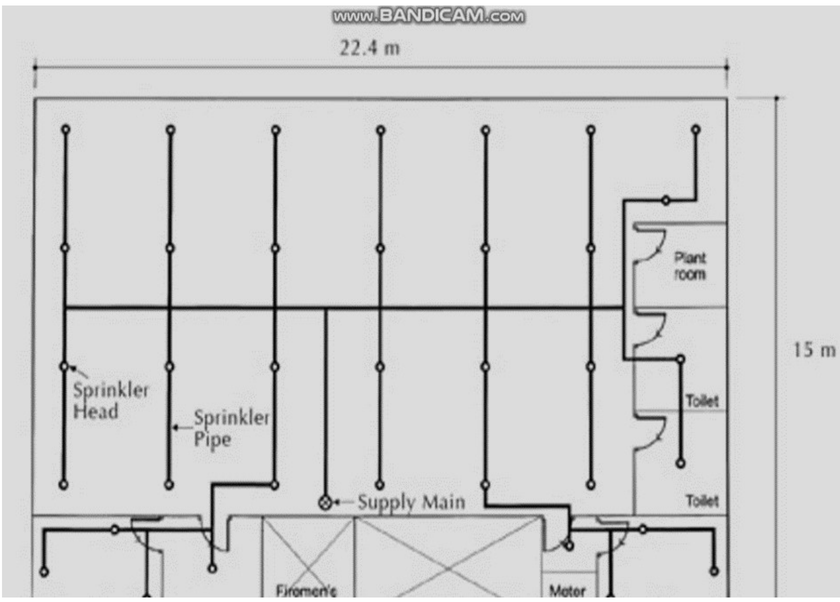

Figure 8: *Design (MPT 2014).*

Step 2: After the design is complete, mark the position of the nozzle with a flag on your farm. Connect each sprinkler with string wrapped around a flag to mark the location of the plumbing, including the water supply pipe, the location of the control valve and where you need to ditch the wiring between the timer and the valve.

Step 3: Water filtration is very important for almost all irrigation systems. The filter can be connected to the adjacent valve. Proper filtration helps extend the life of any irrigation system and improves its maintenance. For drip irrigation or micro-sprinklers, filtration is the basic requirement to avoid clogging. Sand, rust and other materials can clog micro and micro-sprinklers and sprinkler nozzles, which can cause plants to unexpectedly dehydrate. The antisiphon valve is essentially a one-way valve designed to prevent potentially contaminated water from flowing back into the water supply system. The anti-siphon device prevents low water pressure events in the water supply pipeline, thereby pumping contaminated water back into the water supply system.

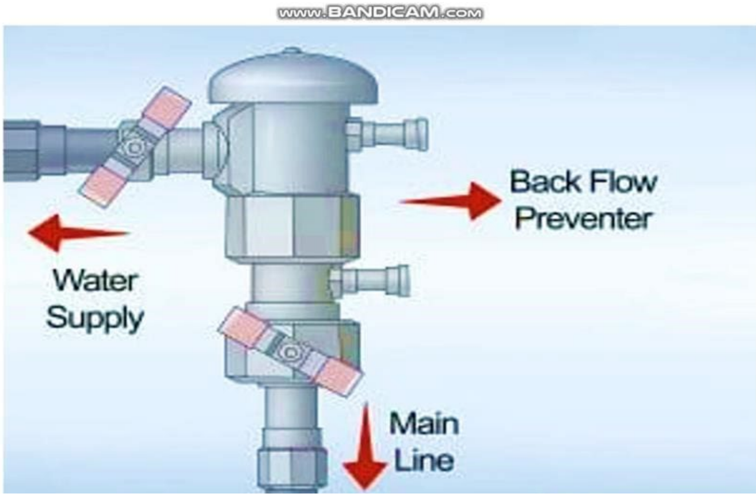

Figure 9: *Anti-siphon device (wikiHow 2021)*

Step 4: Use a hand hoe to open the soil and carefully. Use a hand hoe to dig a trench that is at least 15.2 cm and no more than 30.5 cm. The sub-surface installation of the pipeline avoids severe weather such as high temperatures. The location of the excavation can be marked with a rope. Flags must be put where sprinkler heads will be installed.

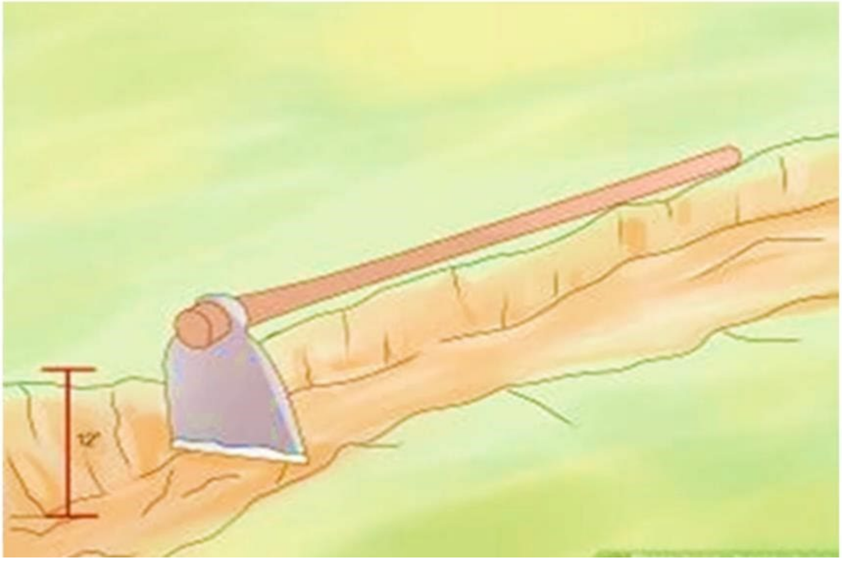

Figure 10: *Trench (wikiHow 2021)*

Step 5: Install the valve manifold. The irrigation manifold is a pipe branched into various openings, in this case, used to supply water to multiple irrigation valves or pipelines.

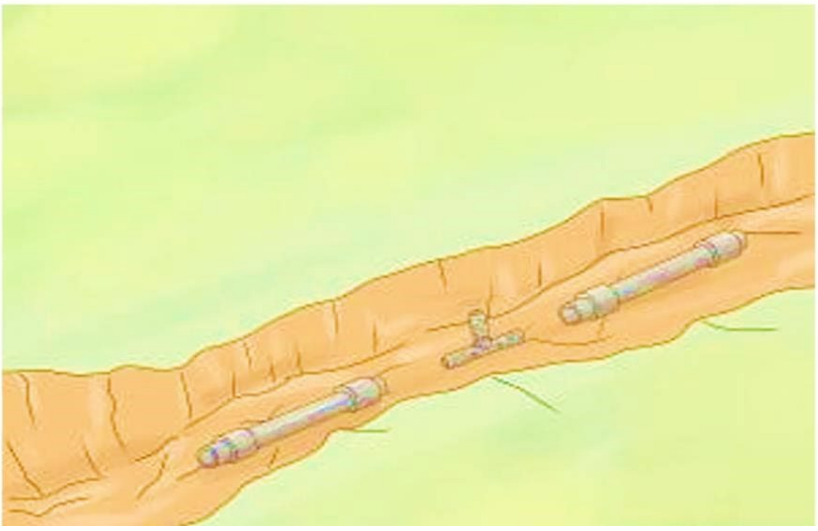

Figure 11: *Valve manifold (wikiHow 2021)*

Step 6: Install the sprinkler head. The selection of the head of the sprayer depends on the type of crop to be grown. Before installing the sprinkler head, it is important to pump water into the system to rinse all the fragments. Firstly, open the main valve and use the mini valve to control the water flow in the system.

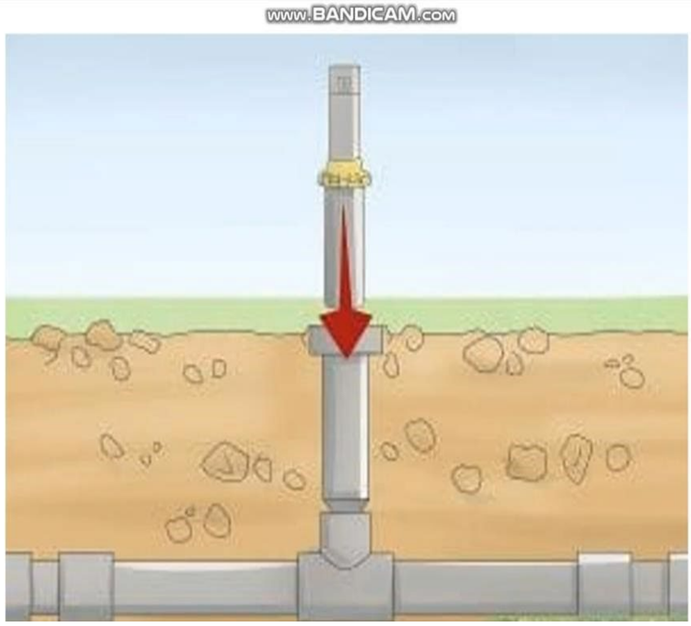

Figure 12: *Sprinkler head installation (wikiHow 2021)*

Smallholder farmers' responses

The video was sent to the WhatsApp group, and each farmer was granted 50 megabytes to download and view the video. The questions below were asked to the farmers:

Questions in English

1. Did you find the information on the video helpful?
2. What did you not like about the video?
3. Is WhatsApp a good platform to get information?
4. Will you be able to implement the practices you saw on the video?
5. What are your suggestions for other videos?

Imibuzo NgesiZulu

1. Ngabe uthole ulwazi olukule vidiyo lusizo?
2. Yini ongayithandanga ngevidiyo?
3. Ngabe iWhatsApp yinkundla enhle yokuthola ulwazi?
4. Uzokwazi ukusebenzisa imikhuba oyibonile kuvidiyo?

5. Ziyini iziphakamiso zakho ngamanye amavidiyo?

Interest and useful information on the video

Based on the shared video, smallholder farmers responded by stating that how the video was shared was very helpful. The smallholder farmers found that the steps taken on the video were clear and informative, as well as relevant to their on-farm needs. Although the video was useful, the farmers mentioned that it did not show people installing the system practically, which made it difficult for some of them to consider implementing the practice.

WhatsApp as a source of information

Smallholder farmers also added that WhatsApp was a good platform for sharing information with all the farmers. Many farmers were satisfied with the ease and effective way of sharing knowledge and information via WhatsApp.

Implementing the installation of a micro-sprinkler irrigation system

The farmers mentioned that it would be difficult for them to put the video into practice. The video did not show people installing the system practically, and this would make it difficult for some of them to consider implementing the practice.

Suggestions from the farmers

The farmers highlighted that the entire planning of an irrigation system is complicated and requires a proper budget and planning, which should have been included on the video, thus allowing everyone to be aware of the financial requirements.

Furthermore, the farmers suggested that other stakeholders in agriculture should be included in the WhatsApp group. This will enable diverse interactions between stakeholders and sharing of diverse agricultural information.

The learning outcome of the programme was to equip smallholder farmers with relevant knowledge on the installation of a micro-sprinkler irrigation system to sustainably conserve irrigation water. Limitations such as ownership of smart devices and data costs were identified. Interventions or programmes in increasing access to the internet and social media, as well as smart devices, should involve bringing these resources closer to smallholder farmers.

Future improvements and considerations

An awareness programme about the benefits of using the internet and social media in agriculture should be put in place:

There is a need for the government and NGOs to make smallholder farmers aware of the benefits of accessing the internet and social media. Furthermore, the project team members should have workshops to highlight the benefits of social media use in agriculture, especially for water management. Potential collaboration with other stakeholders such as extension officers to bring awareness on water management may be beneficial to the smallholder farmers. Extension officers should be the ones that encourage smallholder farmers to use social media. Also, gatekeepers are crucial and need to be identified so that they encourage their other farmers to adopt social media and access vital agricultural information.

An information portal is essential and can be developed together with other stakeholders. The portal will enable smallholder farmers and various stakeholders in the agricultural sector to access information related to water management practices as well as other important agricultural matters. It is necessary that zero-rated data is made available to enable smallholder farmers to access social media platforms and the portal.

Accessing social media platforms requires a language which smallholder farmers may understand. The smallholder farmers in Nkomazi Local municipality prefer the social media language to be siSwati. This implies that the practical videos that will be uploaded on the preferred platform, WhatsApp, must also be in siSwati.

5.4. Concluding remarks on the social media training programme

Social media has the potential of developing into an imperative part of training smallholder farmers. A training programme through social media is possible and feasible, though only in a situation where the necessary infrastructure, electronic devices, networks, and platforms are present. Smallholder farmers are willing to be trained on drip irrigation through the use of social media. The development of a social media platform with some of the aspects of WhatsApp that is free to use is important. Collaboration with other stakeholders who are willing to interact, share information and guide smallholder farmers in implementing agricultural practices is essential in developing a training programme through social media. The platform should encompass language choices that allow smallholder farmers to receive training in their preferred language and should have varying methods or techniques of training, including videos and audios.

The aim of the training programme was partially achieved despite many challenges brought about by the Covid-19 pandemic. A reflective process is now required in the training programme to identify what worked and what needs to be improved. This will require the use of the Participatory Learning and Action approaches to be used with the identified group of smallholder farmers. Together the project team members and the smallholder farmers still need to come up with a suitable training programme and social media platforms that will suit the needs of the farmers. It is also imperative to consider the demographic data and how it will influence the nature of the social media platform and the training programme. This will require that more workshops are held and that a training programme is developed which will take into consideration the inputs of the smallholder farmers.

6. PROPOSED FRAMEWORK FOR SMALLHOLDER FARMERS' SOCIAL MEDIA USE

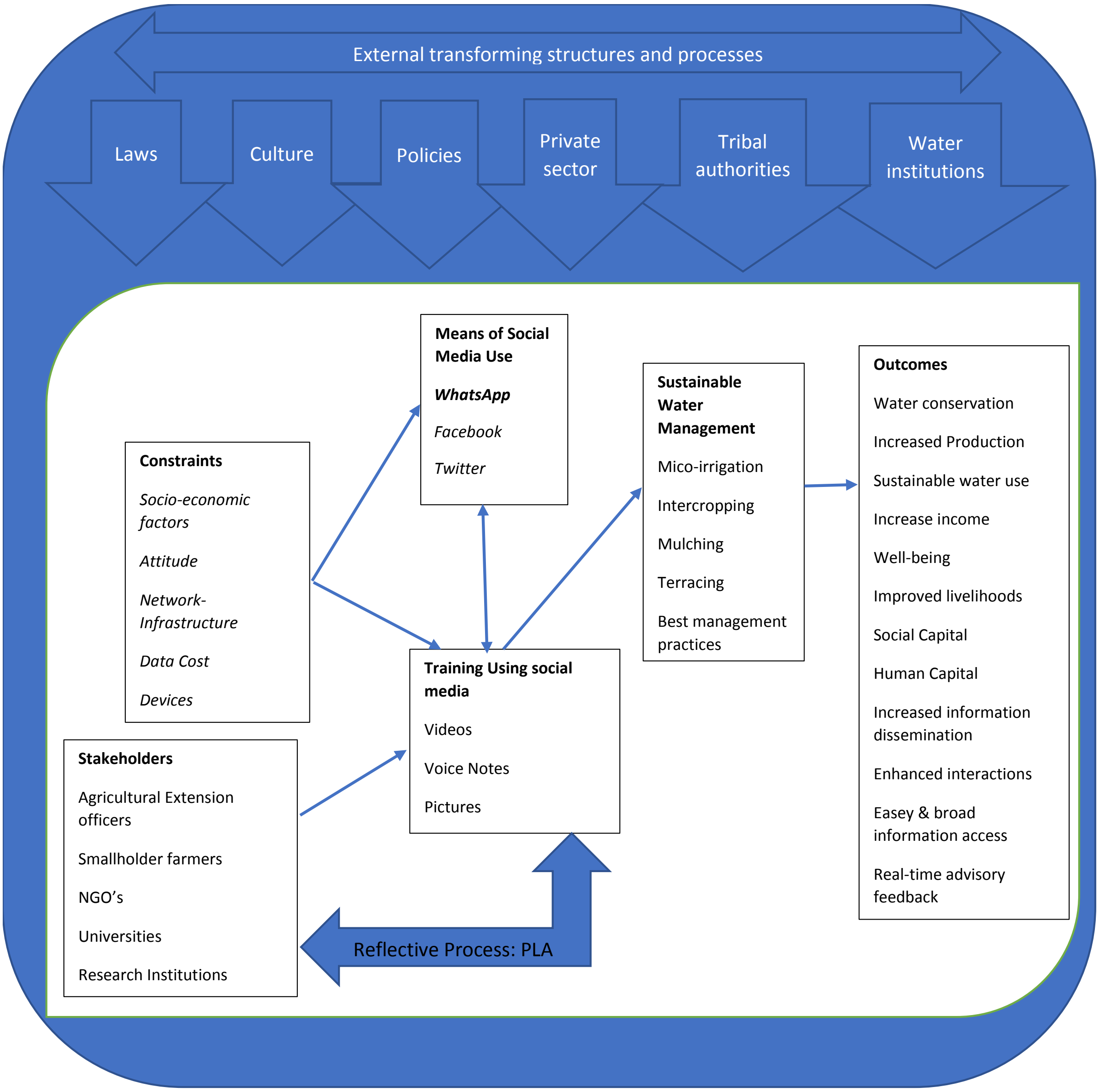

Figure 13: *Proposed framework for smallholder farmers' social media use.*

The social media use framework is an instrument that is designed to enhance people's understanding of the benefits of utilising the social media in a smallholder farming and rural context. It has been developed to outline the key factors that play a role in smallholder farmers' use of social media for information dissemination and sharing. The framework outlines the distinctive relationship between the internal and external factors that influence social media use by smallholder farmers. It can be applied in the development of new agricultural extension interventions and the assessment of information sharing and dissemination amongst smallholder farmers themselves and other varying stakeholders. It draws links between the issues of sustainable water management and varying other factors that contribute to or could be used to mitigate these issues in managing water resources in smallholder farming systems.

6.1. Innovative Solution

Through the developed framework, an innovative solution was identified as being a social media platform that encompasses all the factors identified throughout the study. The findings of the study suggested an easy, open-access and multi-lingual social media platform. Therefore, the Abalimi Forum was created and developed by members of the ICT department at the Walter Sisulu University. They created an agriculturally based platform using critical findings from the studies. The platform was titled *Abalimi Forum* to create a social online environment in which smallholder farmers and various stakeholders (i.e. extension services, NGOs, government, and private sector agricultural service providers) can interact and disseminate diverse agricultural information and knowledge. ***Figures 14-15*** below show some of the diversified features of the platform for illustration purposes.

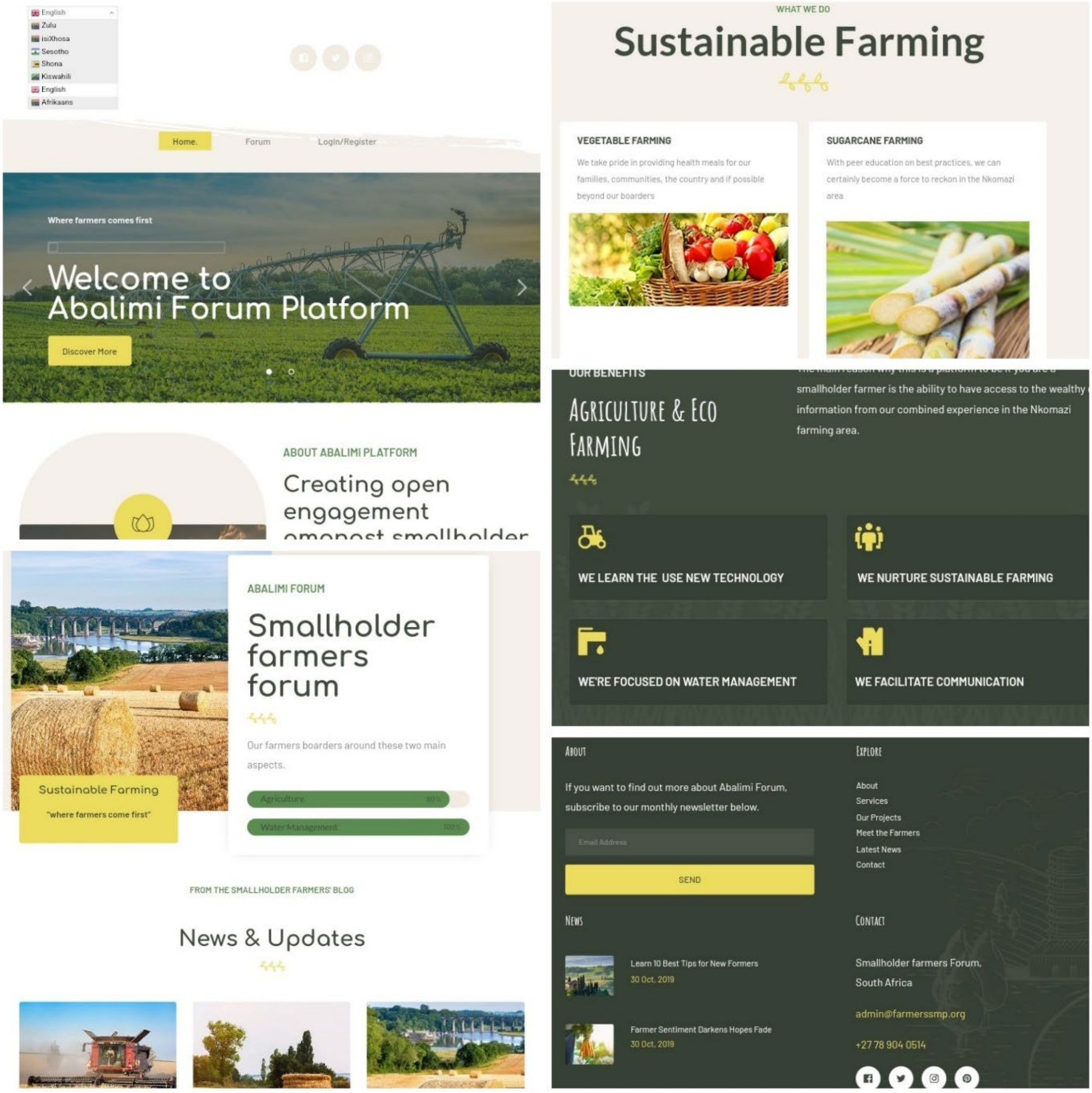

Figure 14: *Abalimi Forum social media platform home page illustration.*

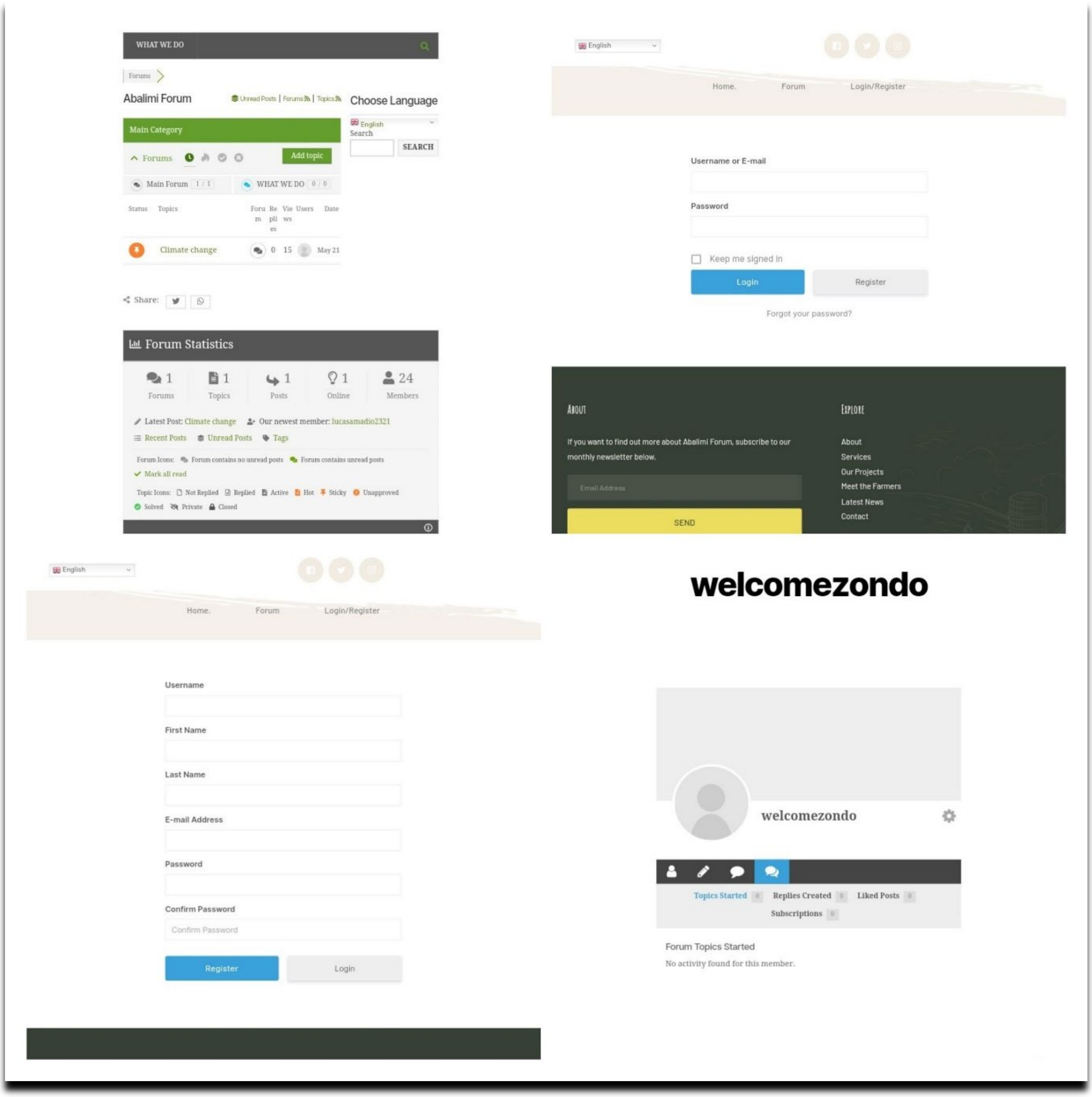

Figure 15: *Abalimi Forum registration and login pages.*

The platform includes a homepage that has a language selection feature with various limited official South African languages, a forum icon that allows an individual to go straight to the interactive page of the platform, as well as a login and register icon that allows individuals to either register using an email address or phone number or login if already registered. The homepage also encompasses an "about us" section to discover more options that can be presented in any of the chosen languages, and link icons for other varying social media platforms for further engagement such as WhatsApp, Facebook and Twitter. Additionally, it has a "What we do" section for categorising the various agricultural fields and information that can be attained through the platform.

CONCLUSION

Agricultural literature was reviewed about the use of social media by smallholder farmers, which outlined the need for more technological and simpler forms of information dissemination among smallholder farmers and other agricultural stakeholders. The industry 4.0 innovation has given birth to democratisation of knowledge and information through social media. A shift emerged in the way knowledge and information are now accessed and shared. Social media provides various platforms that are easily accessible and cost-effective among different sectors of the economy. An agricultural water management training programme was developed, which allowed smallholder farmers and other varying stakeholders to react, comment and add perspective on how to better the methods of training smallholder farmers through social media. The farmers engaged actively with the programme and declared interest in the programme on the WhatsApp platform and considered it an informative and convenient measure of receiving information. Smallholder farmers being a dominant sector in many developing countries stand to receive huge gains using social media, especially for marginalised small-scale farmers. Social media bears global reach through fast and cost-effective platforms. Arguably, research into how effective social media can be used to improve the efficiency of small-scale farmers' production practices is in its infancy, and literature on the topic is scarce.

Accessing agricultural knowledge, information, and innovations in real-time provide several prospects and incentives that could benefit small-scale farmers and agricultural extension service providers as well as other stakeholders. Crucial information and innovations on sustainable agricultural practices and water management practices are readily available on various social media platforms. Such information is crucial, especially for small-scale farms in water scare environments. Social media offers an approach that is quite flexible, as it can be utilised through many platforms, such as WhatsApp, Facebook, Twitter, and YouTube. Social media has the potential to improve the livelihoods of small-scale farmers by creating broad and accessible opportunities for them to engage with agricultural extension officers and other stakeholders. The proposed framework for social media use among smallholder farmers can stimulate agricultural information dissemination and improve information sharing among smallholder farmers themselves and other agriculturists.

REFERENCES

Abudu, S., 2015. Assessment of agricultural knowledge and information systems (AKIS) in extension information delivery in Nigeria. *International Journal of Materials, Methods and Technologies, 3*(1),1-10.

Adams, S. & Opoku, E.E.O., 2017. *BRIC versus OECD foreign direct investment impact on development in Africa, Foreign Capital Flows and Economic Development in Africa*. Palgrave Macmillan, New York, 147-161.

Adams, W. & Moila, B., 2010. *Nelspruit (Mbombela) Ten-year review*, Mbombela, South Africa.

Adeka, M.I., Anoh, K.O., Ngala, M., Shepherd, S.J., Ibrahim, E., Elfergani, I.T., Hussaini, A.S., Rodriguez, J. & Abd-Alhameed, R.A., 2017. Africa: cyber-security and its mutual impacts with computerisation, miniaturisation and location-based authentication. *EAI Endorsed Transactions on Mobile Communications and Applications*, *3*(11), 1-9.

Agricultural Research Council Agricultural Engineering (ARC-AE), 2020. Irrigation user manual. WRC report no. TT 819/2/20, viewed 10 November 2022, from https://www.agrilimpopo.co.za/wp-content/uploads/2020/07/TT-819-IRRIGATION-USER-MANUAL_final.pdf.

Ahuja, S.P. & Shore, R., 2011. Wireless transport layer congestion control evaluation. *International Journal of Wireless Networks and Broadband Technologies, 1*(3),71-81.

Akintunde, M.A.O. & Oladele, O.I., 2019. Use of information communication technologies among Agricultural Extension Officers in Lesotho. *Journal of Agricultural Extension, 23*(3), 50-65.

Aldosari, F., Al Shunaifi, M.S., Ullah, M.A., Muddassir, M. & Noor, M.A., 2019. Farmers' perceptions regarding the use of Information and Communication Technology (ICT) in Khyber Pakhtunkhwa, Northern Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, *18*(2), 211-217.

Allahyari, M.S., Damalas, C.A. & Ebadattalab, M., 2017. Farmers' technical knowledge about integrated pest management (IPM) in olive production. *Agriculture*, *7*(12), 1-9.

Amer, J.N., Odero, D. & Kwake, A., 2018. Towards improving agricultural marketing information systems for smallholder farmers: A Tharaka Nithi Case. *Journal of Agriculture & Sustainability,11*(2), 99-128.

American Farm Bureau Federation, 2013. *Adequate land ranks as the top concern of young farmers*, viewed 25 April 2020, from http://www.fb.org/index.php?action=newsroom.news&year=2013&file=nr0307.html.

Anderson-Wilk, M., 2009. Changing the engines of change: Natural resource conservation in the era of social media. *Journal of Soil Water Conservation, 64*, 129-131.

Andjelic, J., 2020. *WhatsApp Statistics: Revenue, Usage, and History*. Fortney.

Andryani, R., Negara, E.S. & Triadi, D., 2019. Social media analytics: Data utilization of social media for research. *Journal of Information Systems and Informatics, 1*(2),193-205.

Annandale, J.G, Stirzaker, R.J, Singels, A., Van der Laan, M. & Laker, M., 2011. Irrigation scheduling research: South African experiences and future prospects. *Water SA, 37*(5),751-763.

Averbeke, W.V., 2013. *Performance of Smallholder Irrigation Schemes in Vhembe District of South Africa Weak Land Tenure*. The Water Wheel, Pretoria.

Awulachew, S.B. & Ayana, M., 2011. Performance of irrigation: an assessment at different scales in Ethiopia. *Experimental Agriculture, 47,*57-69.

Ayim, C., Kassahun, A., Tekinerdogan, B. & Addison, C., 2020. Adoption of ICT innovations in the agriculture sector in Africa: A Systematic Literature Review. *arXiv preprint arXiv, 2006,* 13831.

Babu, S.C., Glendenning, C.J., Asenso-Okyere, K. & Govindarajan, S.K., 2011. *Farmer's information needs and search behaviours: Case study in Tamil Nadu.* India. IFPRI, Washington.

Bahnemann, M., 2014. *Personal Communication. TSGro. WRC NIRESA Workshop, Nkomazi, Mpumalanga, RSA*. 25-27 November, 2014.

Balkic, R.E., Gubbuk, H., Tozlu, İ.L. & Altinkaya, L.O.K., 2016. Effects of inorganic mulching on morphological features, quality and yield of banana. In *X International Symposium on Banana: ISHS-ProMusa Symposium on Agroecological Approaches to Promote Innovative Banana 1196*, 169-172.

Balkrishna, B.B. & Deshmukh, A.A., 2017. A study on role of social media in agriculture marketing and its scope. *Global Journal of Management and Business Research, 17*(1), 1-5.

Baloch, M.A. & Thapa, G.B., 2018. The effect of agricultural extension services: Date farmers' case in Balochistan, Pakistan. *Journal of the Saudi Society of Agricultural Sciences, 17*(3), 282-289.

Barakabitze, A.A., Fue, K.G. & Sanga, C.A., 2017. The use of participatory approaches in developing ICT-based systems for disseminating agricultural knowledge and information for farmers in developing countries: The case of Tanzania. *The Electronic Journal of Information Systems in Developing Countries, 78*(1),1-23.

Barau, A.A. & Afrad, S.I., 2017. An overview of social media use in agricultural extension service delivery. *Journal of Agricultural Informatics, Hungarian Association of Agricultural Informatics*, *8*(3), 50-61.

Bell, D., 2014. Communication technology: For better, for worse. *Harvard Business Review, 57(*95),4.

Berhane, G., Ragasa, C., Abate, G.T. & Assefa, T.W., 2018. *The state of agricultural extension services in Ethiopia and their contribution to agricultural productivity*. Intl Food Policy Res Inst.

Bhattacharjee, S. & Raj, S., 2016. *Social Media: Shaping the Future of Agricultural Extension and advisory Services.* GFRAS Interest Group on ICT4RAS discussion paper, GFRAS: Lindau, Switzerland.

Bonsucro, 2020. *About Bonsucro*, viewed 17 September 2020 from, http://bonsucro.com/site/.

Bos, M.G., Murray-Rust, D.H., Merrey, D.J., Johnson, H.G. & Snellen, W.B., 1993. Methodologies for assessing performance of irrigation and drainage management. *Irrigation and Drainage Systems, 7*(4), 231-261.

Boyd, D.M. & Ellison, N.B., 2008. Social Network Sites: Definition, History, and Scholarship. *Journal of Computer-Mediated Communication, 13*,210-230.

Busari, M.A., Kukal, S.S., Kaur, A., Bhatt, R. & Dulazi, A.A., 2015. Conservation tillage impacts on soil, crop and the environment. *International soil and water conservation research*, *3*(2), 119-129.

Cambridge University Press, 2021. *Apartheid, Meaning of apartheid in English,* viewed 24 March 2021, from https://dictionary.cambridge.org/us/dictionary/english/apartheid.

Campbell, B.M., Thornton, P., Zougmoré, R., Van Asten, P. & Lipper, L., 2014. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability*, *8*, 39-43.

Census, 2011. Mpumalanga, Ehlanzeni District, viewed 23 March 2021, from https://census2011.adrianfrith.com/place/87403.

Chalker-Scott, L., 2007. Impact of mulches on landscape plants and the environment—a review. *Journal of Environmental Horticulture, 25*, 239.

Chapota, R, Fatch, P. & Mthinda. C., 2014. The Role of Radio in Agricultural Extension and Advisory Services – Experiences and Lessons from Farm Radio Programming in Malawi. *MEAS Case Study 8,*1-11

Chartzoulakis, K. & Bertaki, M., 2015. Sustainable Water Management in Agriculture under Climate Change. *Agriculture and Agricultural Science Procedia, 4,* 88-98.

Chisita, C.T., 2012. Knotting and networking agricultural information services through Web 2.0 to create an informed farming community: a case of Zimbabwe. In *World Library and Information Congress: 78th IFLA General Conference and Assembly*, 11-17.

City of Mbombela Local Municipality, 2016. *Government Model and System for Delegations*. Mpumalanga, South Africa.

Climate Data, 2020. *Climate Malelane*, viewed 22 March 2020, from https://en.climatedata.org/africa/south-africa/mpumalanga/malelane-26824/.

Cline, M., 2011. Expansion of social media in agriculture: A user profile of Twitter's@ AgChat, @ FollowFarmer and@ TruffleMedia followers (Doctoral dissertation, Oklahoma State University).

Crosby, C.T., de Lange, M., Stimmie, C.M. & Van der Stoep, I., 2000. *A review of planning and design procedures applicable to small-scale farmer irrigation projects.* Report No. 578/2/00. Water Research Commission, Pretoria, RSA.

Cui, Z., Zhang, H., Chen, X., Zhang, C., Ma, W., Huang, C., Zhang, W., Mi, G., Miao, Y., Li, X. & Gao, Q., 2018. Pursuing sustainable productivity with millions of smallholder farmers. *Nature*, *555*(7696), 363-366.

Darshan, N.P., Meena, B.S. & Meena, H.R., 2017. *Influence of socio-economic characteristics of farmers on their use of social media in Haryana*, India, viewed on 13 March 2020, from https://doi.org/10.20546/ijcmas.610.002.

Davis, K.E. & Terblanche, S.E., 2016. Challenges facing the agricultural extension landscape in South Africa, Quo Vadis? *South African Journal of Agricultural Extension, 44*(2), 231-247.

de Lange, M., Adendorff, J. & Crosby, C.T., 2000. *Developing sustainable small-scale farmer irrigation in poor rural communities: guidelines and checklists for trainers and development facilitators.* Report No. 774/00. Water Research Commission, Pretoria, RSA.

Department of Agriculture, Forestry and Fisheries (DAFF), 2012. *Strategic plan for smallholder support,* viewed 18 September 2021, from https://www.nda.agric.za/doaDev/sideMenu/SmallHolder/docs/Strategic%20Plan%20for%2Smallholder%20Support.pdf.

Department of Agriculture, Forestry and Fisheries (DAFF), 2016. *National Policy on Extension and Advisory services.* Pretoria, South Africa.

Department of Rural Development and Land Reform (DRDLF), 2015. *One pager executive summaries: Agri-hubs*. Mpumalanga, South Africa.

Donohue, D. & Bornman, J., 2014. The challenges of realising inclusive education in South Africa. *South African journal of education*, *34*(2).

Dorren, L. & Rey, F., 2004. A review of the effect of terracing on erosion. In *Briefing papers of the 2nd SCAPE workshop,* Cinque Terre, Italy. Citeseer, 97-108.

Dreistadt, S.H., 2016. *Pests of landscape trees and shrubs: an integrated pest management guide*. UCANR Publications.

du Plessis, M., Annandale, J., Benarde, N., Van der Laan, M., Jooste, S., du Preez, C., Bernard J., Rodda, N., Dabrowski, J., Genthe, B. & Nell, P., 2017. *Risk based, site-specific, irrigation water quality guidelines. Volume 1 – Description of decision support system*. Report No. TT 727/17. Water Research Commission, Pretoria, RSA.

Dvajasvie, G., Farisha, B.P., Babu, S.N., Saheen, K.P. & Binoy, N.C., 2018. Leak detection in water-distribution pipe system. *In 2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS),* IEEE 1-4.

Dzikiti, S. & Schachtschneider, K., 2015. *Water stewardship for stone fruit farmers* (p. 4). WWF Technical Report. Available at www. wwf. org. za/freshwater.

Edosomwan, S., Prakasan, S.K., Kouame, D. Watson, J. & Seymour T., 2011. The History of Social Media and its Impact on Business. *The Journal of Applied Management and Entrepreneurship, 16*(3), 79-91.

Egbe, O.M., 2010. Effects of plant density of intercropped soybean with tall sorghum on competitive ability of soybean and economic yield at Otobi, Benue State, Nigeria. *Journal of Cereals and Oilseeds*, *1*(1), 1-10.

Ehlanzeni District Municipality IDP, 2019. Ehlanzeni district municipality's draft IDP and Budget review 2018/2019. Ehlanzeni District Municipality.

Ehlers, W. & Claupein, W., 2017. Approaches toward conservation tillage in Germany. In *Conservation tillage in temperate agroecosystems*. CRC Press, pp. 141-165

Etikan, I., Musa, S.A. & Alkassim, R.S., 2016. Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1),1-4.

Fanadzo, M. & Ncube, B., 2018. Challenges and opportunities for revitalising smallholder irrigation schemes in South Africa. *Water South Africa*, *44,* 436-447.

Fanadzo, M., Chiduza, C. & Mnkeni P.N.S., 2010. Overview of smallholder irrigation schemes in South Africa: Relationship between farmer crop management practices and performance. *African Journal of Agricultural Research*, *525,* 3514-3523.

Flint, M.L., 2012. *IPM in practice: principles and methods of integrated pest management*. University of California Agriculture and Natural Resources.

Food and Agriculture Organization of the United Nations (FAO), 1989. *The state of food and agriculture*. FAO, Rome.

Food and Agriculture Organization of the United Nations (FAO), 2023. Land & Water, Water scarcity, viewed 28 February 2023, from https://www.fao.org/land-water/water/water-scarcity/en/.

Francis, C.A., 1990. Sustainable Agriculture: Myths and realities. *Journal of Sustainable Agriculture, 1*(1), 97.

Fuess, L.C., 2011. An Analysis and Recommendations of the Use of Social Media within the Cooperative Extension System: Opportunities, Risks and Barriers, Honours Thesis. *College of Agriculture and Life Sciences, Social Sciences of Cornell University*, Ithaca, New York.

Garnett, T., Appleby, M., Balmford, A., Bateman, I., Benton, T., Bloomer, P, Burlingambe B., Dawkins, M., Dolan, L. & Fraser, D., 2013. Sustainable intensification in agriculture: premises and policies. *Science, 341*(6141), 33-34.

Gawankar, M.S., Haldankar, P.M., Maheswarappa, H.P., Malshe, K.V., Haldavanekar, P.C. & Salvi, B.R., 2019. Economics of mixed cropping in juvenile oil palm orchard. *IJCS*, *7*(1), 71-73.

Ghimire, R. & Huang, W.C., 2015. Household wealth and adoption of improved maize varieties in Nepal: a double-hurdle approach. *Food Security, 7*(6), 1321-1335.

Gininda, P.S., Antwi, M.A. & Oladele, O.I., 2014. Smallholder sugarcane farmers' perception of the effect of micro agricultural finance institution of South Africa on livelihood outcomes in Nkomazi local municipality, Mpumalanga Province. *Mediterranean Journal of Social Sciences*, *5*(27), 1032.

Gomo, T., Senzanje, A., Mudhara, M. & Dhavu, K., 2014. Assessing the performance of smallholder irrigation and deriving best management practices in South Africa. *Irrigation and Drainage, 63,*419-429.

Grassbaugh, E.M., Regnier, E.E. and Bennett, M.A., 2002. Comparison of organic and inorganic mulches for heirloom tomato production. In *XXVI International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century, 638*, 171-176.

Gwademba, G.K., Muthee, D.W. & Masinde, J.M., 2019. Application of ICTs in Transforming Agricultural Extension. *Regional Journal of Information and Knowledge Management, 4*(2), 12-21.

Hagmann, J., Chuma, E., Murwira, K. & Connolly, M., 1999. *Putting process into practice: operationalising participatory extension, Network paper No. 94.* Agricultural Research and Extension Research.

Hamel, C. & Plenchette, C., 2017. Implications of past, current, and future agricultural practices for mycorrhiza-mediated nutrient flux. *Mycorrhizal Mediation of Soil*, 175-186.

Hay, R., under review. *The City of Tshwane Agri-parks initiative as a case study for the sustainable intensification of smallholder agriculture in South Africa*. University of Pretoria.

Hermans, F., Sartas, M., Van Schagen, B. & Van Asten, P., 2017. Social network analysis of multi-stakeholder platforms in agricultural research for development: Opportunities and constraints for innovation and scaling. *PLoS One,*12(2)e0169634.

Hoffman, G.J., Evans, R.G., Jensen, M.E., Martin, D.L. & Elliott, R.L., 2007. *Design and operation of farm irrigation systems,* 2nd Ed., ASABE, St. Joseph, MI.

Hootsuite, 2017. Digital in 2017 *Global Overview Vancouver, Canada: Hootsuite Media Incorporated*, viewed 26 September 2020, from https://www.techinasia.com/talk/digital-snapshot-internet-social-media-2017.

Hoque, M. & Usami, K., 2007. Effectiveness of agricultural extension training courses for bloc supervisors at the Department of Agricultural Extension (DEA) in Bangladesh. *Journal of International Agriculture and Extension Education, 14,* 51-59.

Huang, C., Liu, Q., Heerink, N., Stomph, T., Li, B., Liu, R., Zhang, H., Wang, C., Li, X., Zhang, C. & Van der Werf, W., 2015. Economic performance and sustainability of a novel intercropping system on the North China Plain. *PloS one*, *10*(8), e0135518.

Idemudia, E.C., Raisinghani, M.S., Adeola, O. & Achebo, N., 2017. The Effects of Gender on The Adoption of Social Media: An Empirical Investigation, in *A Tradition of Innovation: 23rd Americas Conference on Information Systems,* Massachusetts, Boston, August 10-12.

ITU Statistics, 2016. *Measuring the Information Society Report, The 14th World Telecommunication/ICT Indicators Symposium (WTIS), Botswana, 21-23 November 2016,* ITU.

James, P. & Woodhouse, P., 2015. *Rural livelihoods and small-scale sugarcane farming in Nkomazi, Mpumalanga province, South Africa*. Working paper 2. The University of Manchester, Manchester, UK, viewed 07 August 2020, from http://hummedia.manchester.ac.uk/institutes/gdi/research/impact/farm-scale/farmscale-wp2.pdf.

Johns, R., 2014. Community change: Water management through the use of social media, the case of Australia's Murray-Darling Basin. *Public Relations Review, 40*(5), 865-867.

Joshi, P., Sharma, N., Raksha, G., Mahra S. & Mukherjee, A., 2017. Social media in Agriculture: A new paradigm for extension and advisory services. *Indian Farmers' Digest, 3*, 1-7.

Kane, G.C., Alavi, M., Labianca, G. & Borgatti, S. P., 2014. What's different about social media networks? A framework and research agenda. *MIS Quarterly, 38*(1), 275-304.

Kante, M., Oboko, R., Chepken, C. & Hamunyela, S., 2017. Farmers' perception of ICTs and is effects on access and use in agricultural input information on developing countries: Case of Sokasso, Mali. *Information Processing in Agriculture*, *6*(1), 26-46.

Kaplan, A.M. & Haenlein, M., 2010. Users of the world, unite! The challenges and opportunities of Social Media. *Business Horizons, 53*(1), 59-68.

Kiambi, D., 2018. The use of Information Communication and Technology in advancement of African agriculture. *African Journal of Agricultural Research, 13*(39), 2025-2036.

Kimani, A.W., Nyang'anga, H.T. & Mburu, J.I., 2019. Assessing the Status of Social Media Familiarity among Smallholder Farmers: A Case Study of Thika, Kiambu, Kenya. *International Journal of Agricultural Extension, 7*(1), 13-20.

Koegelenberg, F. & Breedt, H., 2003. *Manual for the evaluation of irrigation systems*. ARC – Institute for Agricultural Engineers, Silverton, Pretoria, RSA.

Kolb, D.A., 1984. *Experiential Learning: Experience as the source of learning and development*. Englewood Cliffs, Prentice-Hall.

Kołota, E. & Adamczewska-Sowińska, K., 2013. Living Mulches in vegetable crops production: perspectives and limitations (A review). *Acta Scientiarum Polonorum-Hortorum Cultus*. *Wydawnictwo Akademii Rolniczej w Lublinie, 12*(6), 127-142.

Koontz, T.M. & Newig, J., 2014. From planning to implementation: Top-down and bottom-up approaches for collaborative watershed management. *Policy Studies Journal, 42*(3), 416-442.

Kumar, R., Hudda, R.S., Chahal, P. & Yadav, K., 2017. Availability of information communication technologies (ICTs) tools usages by farmers in Haryana. *International Journal Pure Application and Bioscience*, *5*(3), 648-653.

Kuria, C.W., 2014. *Use of social media as a source of agricultural information by small holder farmers; a case study of lower Kabete, Kiambu county*. Doctoral dissertation, University of Nairobi.

Larivière, B., Bowen, D., Andreassen, T.W., Kunz, W., Sirianni, N.J., Voss, C., Wünderlich, N.V. & De Keyser, A., 2017. Service Encounter 2.0: An investigation into the roles of technology, employees and customers. *Journal of Business Research*, *79*, 238-246.

Lathiya, A., Rothod, A. & Choudhary, K., 2015. Role of social media in agriculture. *International Journal of Commerce & Business Management,8*(2),268-273.

Lebreton, J.D., Burnham, K.P., Clobert J. & Anderson D.R., 1992. Modelling survival and testing biological hypotheses using marked animals: A unified approach with case studies, *Ecological Monographs, 62*, 67-118.

Lecler, N.L., 2003. Charts and calendars for the irrigation scheduling of sugarcane in the Zimbabwe lowveld. *Proceedings of the South African Sugar Technologists Association 77,* 364-368.

Liebman, M. & Dyck, E., 1993. Crop rotation and intercropping strategies for weed management. *Ecological applications*, *3*(1), 92-122.

Maggard, A.O., Will, R.E., Hennessey, T.C., McKinley, C.R. & Cole, J.C., 2012. Tree-based mulches influence soil properties and plant growth. *HortTechnology*, *22*(3), 353-361.

Maginga, T. J. & Ally, M., 2019. Adoption of ICT enabled extension support system for vegetable crop production among small holder farmers: A Case of Tanzania. *International Journal of Advanced Technology and Engineering Exploration, 6*(56), 186-193.

Mekonnen, F., Hoekstra, D., Gebremedhin, B. & Bogale, A., 2016. E-book readers: Handy tools for agricultural extension workers in Ethiopia? *Rural, 21*, 41-43.

Merrey, D.J., 1995. Performance improvement capacity audit: A methodology for diagnosing capacity to improve irrigation performance. *International Journal of Water Resources Development, 11*(1), 11-24.

Merriam, J. & Keller, J., 1978. *Farm irrigation systems evaluation: A guide for management*. Logan Utah: Utah State University,

Metiso, H. & Tsvakirai, C.Z., 2019. Factors affecting small-scale sugarcane production in Nkomazi local municipality in Mpumalanga province, South Africa. *South African Journal of Agricultural Extension, 47*(4), 1-8.

Miller, K., Fabian, F. & Lin, S., 2009. Strategies for Online Communities. *Strategic Management Journal, 30,* 305-322.

Mills, J., Reed, M., Skaalsveen, K. & Ingram, J., 2019. The use of Twitter for knowledge exchange on sustainable soil management. *Soil use and management, 35*(1), 195-203.

Mithum, K.G., Shaikh, S.H. & Abudullah, A.N., 2021. Social media in agricultural extension services: Farmers and extension agents' perspectives. *European Journal of Humanities and Social Sciences,1*(5), 36-43.

Mladenović, D., & Krajina, A., 2019. Knowledge sharing on social media: state of the art in 2018. *Journal of Business Economics and Management, 21*(1), 44-63.

Mnkeni, P.N.S., Chiduza, C., Modi, A.T., Stevens, J.B., Monde, N., Van der Stoep, I. & Dladla, R., 2010. *Best management practices for smallholder farming on two irrigation schemes in the Eastern Cape and KwaZulu-Natal through participatory adaptive research*. Report No. TT 478/10. Water Research Commission, Pretoria, RSA.

Modern Pumping Today (MPT), 2014. Uniform Distribution in Headers and Distribution Systems, viewed 8 March 2021, from https://modernpumpingtoday.com/uniform-distribution-headers-distribution-systems/.

Mohan, V., 2016. Cheaper internet data may lead, India to digital farming, *Times of India*, viewed 10 March 2020, from https://timesofindia.indiatimes.com/india/cheaper-internet-datamay-lead-india-to-digital-farming/articleshow/54281510.cms.

Möller, M. & Weatherhead, E.K., 2007. Evaluating drip irrigation in commercial tea production in Tanzania. *Irrigation and Drainage Systems, 21*(1), 17-34.

Mollica, D., 2017. *Sustainability*. Routledge, Sussex, UK.

Monde, N., Mtshali, S., Mnkeni, P.N.S., Chiduza, C., Modi, A.T., Brutsch, M.O., Dladla, R. & Mthembu, B.E., 2005. *A situation analysis report on the Zanyokwe and Tugela Ferry irrigation schemes.* Water Research Commission Project K5/1477 Deliverable 2 report. Pretoria, South Africa.

Montag, C., Błaszkiewicz, K., Sariyska1, R., Lachmann, B., Trendafilov, B., Eibes, M. & Markowetz, A., 2015. Smartphone usage in the 21st century: who is active on WhatsApp? *BMC Research Notes, 8,* 331-337.

Moore, J.C. & Wszelaki, A.L., 2019. The use of biodegradable mulches in pepper production in the Southeastern United states. *HortScience*, 54(6)1031-1039.

Munene, N.K. & Kasamani, B.S., 2018. A Mobile-based Tea Farming Information System. *International Journal of Computer Applications, 975*, 8887.

Municipalities of South Africa (MSA), 2018. *Ehlanzeni District Municipality*, viewed on 24 March 2021, from https://municipalities.co.za/demographic/131/ehlanzeni-districtmunicipality.

Municipalities of South Africa (MSA), 2020. *Nkomazi Local Municipality (MP324): Geography, History & Economy*, viewed 22 March 2020, from https://municipalities.co.za/overview/1144/nkomazi-local-municipality.

Murray-Rust, D.H., Svendsen, M., Burton, M. & Molden, D., 2003. Irrigation and drainage systems maintenance: Needs for research and action. *Irrigation and Drainage Systems 17(1-2),* 129-140.

Mutambara, S., Darkoh, M.B.K. & Atlhopeng, J.R., 2016. A comparative review of water management sustainability challenges in smallholder irrigation schemes in Africa and Asia. *Agricultural Water Management, 177*, 63-72.

Mutambara, S., Mutambara, J. & Darkoh, M.B.K., 2014. Towards sustainable stakeholder engagement in smallholder irrigation schemes in Zimbabwe. *African Journal of Agricultural Research, 9*(50), 3587-3599.

Muttaleb, A.A., 2018. The Effect of Three Different Mulches on Weed Presence, Soil Characteristics, and Zinnia Growth, (Doctoral dissertation), Murray State University, USA.

Nandan, R., Singh, S.S., Kumar, V., Singh, V., Hazra, K.K., Nath, C.P., Malik, R.K., Poonia, S.P. & Solanki, C.H., 2018. Crop establishment with conservation tillage and crop residue retention in rice-based cropping systems of eastern India: yield advantage and economic benefit. *Paddy and Water Environment*, *16*(3), 477-492.

NapoleanCat, 2019. *Facebook users in South Africa, March 2019*, viewed 26 September 2020, from https://napoleoncat.com/stats/facebook-users-in-south_africa/2019/03.

Naruka, P.S., Verma, S, Sarangdevot, S.S., Pachauri, C.P., Kerketta, S. & Singh, J.P., 2017. A study on role of WhatsApp in agriculture value chains. *Asian Journal of Agricultural Extension, Economics and Sociology, 20*(1), 1-11.

Nasar, J., Alam, A., Nasar, A. & Khan, M.Z., 2019. Intercropping induce changes in above and below ground plant compartments in mixed cropping system. *Biomedical Journal of Scientific & Technical Research*, *17*(5),13043-13050.

National Association of Broadcasters (NAB), 2019. *State of the broadcasting industry report, Broadcasting Complaints Commission of South Africa*, 1-35.

Nezlin, N.P., Polikarpov, I.G., Al-Yamani, F.Y., Subba Rao, D.V. & Ignatov, A.M., 2010. Satellite monitoring of climatic factors regulating phytoplankton variability in the Arabian (Persian) Gulf. *Journal of Marine Systems, 82,*47-60.

Ng, J.C.Y., Shao, I.Y.T., Liu, Y., 2016. This is not what I wanted: The effect of avoidance coping strategy on non-work-related social media use at the workplace. *Employee Relations*, 38, 466-486.

Nkomazi Municipality IDP, 2017. *Nkomazi local municipality draft integrated development plan (2017-2021)*, viewed 24 March 2021, from https://www.cogta.gov.za/cgta_2016/wpcontent/uploads/2021/02/Nkomazi-Municipality.pdf

Nkomazi Municipality IDP, 2020. *Nkomazi local municipality final integrated development plan (2017-2021)*, Review 2020/2021, 4th Review, viewed 24 March 2021, from https://www.cogta.gov.za/cgta_2016/wp-content/uploads/2021/02/Nkomazi-Municipality.pdf.

Nkomazi Municipality, 2014. *Nkomazi Local Municipality*, viewed 22 March 2020, from https://www.nkomazi.gov.za/aboutus.html.

Odini, S., 2014, Access to and use of agricultural information by small scale women farmers in support of efforts to attain food security in Vihiga County, Kenya. *Journal of Emerging Trends in Economic Management Science, 5*(2), 100-107.

Omondi, H.M., 2017. Nutrient Management Options for Enhancing Productivity of Maize and Beans Under Conservation and Conventional Tillage Systems (Doctoral dissertation), University of Nairobi.

Osundu, C.K. & Ibezim, G.M.C., 2015. Awareness and perception of farmers to the use of Information and Communication Technologies (ICTs) in agricultural extension service delivery: A case study of Imo State. *International Journal of Agriculture Innovation and Research*, *4*(1), 2319-1473.

Otieno, F.A.O. & Ochieng, G.M.M., 2004. Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025. *Water Institute of South Africa, 30*(5), 120-124.

Ozdemir, E. & Karacor, M., 2006. Mobile phone-based SCADA for industrial automation. *ISA transactions, 45*(1), 67-75.

Padmanaban, G., 2009. Bt brinjal-ban or boon? *Current Science, 97(12),1715-1716*.

Palazzo, A., 2004. Mill-wide water management in the South African sugar industry. *Proceedings of South African Sugar Technology Association, 78,* 419-426.

Parris, K., 2010. *Sustainable management of water resources in agriculture*. OECD Publishing.

Pearson, C.J., 2003. Sustainability: Perceptions of problems and progress of the paradigm. *International Journal of Agricultural Sustainability*, *1*(1), 3-13.

Pereira, L.S., 1999. Higher performance through combined improvements in irrigation methods and scheduling: a discussion. *Agricultural Water Management, 40*(2-3), 153-169.

Pigford, A.E., Gordon, H.M. & Laurens, K., 2018. Beyond agricultural innovation systems? Explaining an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. *Agricultural Systems, 164*, 116-121.

Postma, J. & Lynch, J.P., 2012. Complementarity in root architecture for nutrient uptake in ancient maize/bean and maize/bean/squash polycultures. *Annals of Botany,110,*521-534

Potrykus, I., 2012. “Golden rice”, a GMO-product for public good, and the consequences of GE-regulation. *Journal of Plant Biochemical Biotechnology, 21,* 68-75.

Pretty, J., Toulimin, C. & Williams, S., 2011. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5-24.

Pretty., J. & Bharucha, Z.P., 2014. Sustainable intensification in agricultural systems. *Annals of Botany, 114*(8), 1571-1596.

Pretty., J. & Bharucha, Z.P., 2014. Sustainable intensification in agricultural systems. *Annals of Botany, 114*(8), 1571-1596.

Prosdocimi, M., Jordán, A., Tarolli, P., Keesstra, S., Novara, A. & Cerdà, A., 2016. The immediate effectiveness of barley straw mulch in reducing soil erodibility and surface runoff generation in Mediterranean vineyards. *Science Total Environment, 547,* 323-330.

Rehman, F., Muhammad, S., Ashraf, I., Chaudry, K.M., Ruby, T. & Bibi, I., 2013. Effect of Farmers' Socioeconomic Characteristics on Access to Agricultural Information: Empirical Evidence from Pakistan. *The Journal of Animal & Plant Sciences, 23*, 324-329.

Reinders, F., Van der Stoep, I. & Backeberg, G. R., 2010. *Improved efficiency of irrigation water use*: A South African framework, viewed 22 September 2021, from https://www.researchgate.net/publication/261546321

Reinders, F., Van der Stoep, I., Lecler, N., Greaves, K., Vahrmeijer, J., Benade, N., du Plessis, F., Van Heerden, P., Steyn, J., Grove, B., Jumman, A. & Ascough, G., 2010. *Standard and guidelines for improved efficiency of water use from dam wall release to root zone application*. Report No. TT 466/10. Water Research Commission, Pretoria, RSA.

Rosewell, J., 2005. *Learning styles*, The Open University, viewed 21 May 2021, from http://www.open.edu/openlearn/ocw/pluginfile.php/629607/mod_resource/content/1/t175_4_3.pdf.

Roux, K. & Dalvit, L., 2014. Mobile women: Investigating the digital gender divide in cell phone use in a South African rural area. In *Proceedings of the e-Skills for Knowledge Production and Innovation Conference 2014,* Cape Town, South Africa, November 17-21, Informing Science Institute, pp. 401-416.

Rusinamhodzi, L. Corbeels, M. & Nyamangara, J., 2012. Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Research, 136*, 12-22.

Sari, B.T., Chasiotis, A., Van de Vijver, F.J. & Bender, M., 2020. The importance of language vocabulary and language usage for sociocultural adjustment among Indonesian adolescents from three bilingual ethnic groups. *Journal of Multilingual and Multicultural Development*, *41*(6), 531-546.

SASA, 2019. *SUSFARMS, Sustainable Sugarcane Farm Management System, 4th edition, February 2019*. South African Sugarcane Research Institute, Mt Edgecombe, RSA, viewed 02 October 2020, from https://sasri.org.za/susfarms-new/.

Selmer, J., 2006. Language ability and adjustment: Western expatriates in China, *Thunderbird International Business Review, 48*(3), 347-368.

Seran, T. & Brintha, I., 2010. Review on Maize Based Intercropping. *Journal of Agronomy. ANSInet, Asian Network for Scientific Information, 9*(3), 135-145.

Shava, H. & Chinyamurindi, W.T., 2018. Determinants of social media usage among a sample of rural South African youth. *South African Journal of Information Management, 20*(1), 1-8.

Simpson, A.P. & Calitz, A.P., 2014. The use of mobile technologies amongst South African commercial farmers. *South African Journal of Agricultural Extension, 42*(1), 98-107.

Singels, A. & Smith, M.T., 2006. Provision of irrigation scheduling advice to small-scale sugarcane farmers using a web-based crop model and cellular technology: a South African case study. *Irrigation and Drainage, 55*(4), 363-372.

Singels, A. & Smith, M.T., 2009. *Real time irrigation advice for small-scale sugarcane production using a crop model.* Report No. K5/1576/4. Water Research Commission, Pretoria, RSA.

Singels, A., 2007. A new approach to implementing computer-based decision support for sugarcane farmers and extension staff. The Case of MyCanesim. In *Proceedings International Society of Sugar Cane Technology, 26,* 211-219.

Singh, J.S., Pandey, V.C. & Singh, D.P., 2011. Efficient soil microorganisms: a new dimension for sustainable agriculture and environmental development. *Agriculture, ecosystems & environment*, *140*(3-4), 339-353.

Skoulikaris, C., Filali-Meknassi, Y., Aureli, A., Amani, A. & Jiménez-Cisneros, B.E., 2018. Information-communication technologies as an Integrated Water Resources Management (IWRM) tool for sustainable development. *Achievements and Challenges of Integrated River Basin Management,* 179-181.

Smartcane BMP, 2020. *About Smartcane BMP*, viewed 17 September 2020, from https://smartcane.com.au/.

Statcounter, 2020. *Social media stats South Africa*, viewed 30 September 2020, from https://gs.statcounter.com/social-media-stats/all/south-africa.

Statistics South Africa (StatsSA), 2017. *Census of commercial agriculture, 2017 Mpumalanga: Financial, production and related statistics*.

Stevens, J.B., Duvel, G.H., Steyn, G.J. & Marobane, W., 2005. *The range, distribution and implementation of irrigation scheduling models and methods in South Africa.* Report No. 1137/1/05. Water Research Commission, Pretoria, RSA.

Stevens, J.B., Van Heerden, P.S., Buys, F. & Laker, M.C., 2012. *Training material for extension advisors in irrigation water management.* Water Research Commission Report No. TT 539/12, Water Research Commission, Pretoria, South Africa, 1-137.

Stirzaker, R., Car, R. & Christen, E., 2014. *A traffic light soil water sensor for resource poor farmers: proof of concept.* Final project report. Australian Centre for International Agricultural Research (ACIAR), Canberra.

Stirzaker, R., Mbakwe, I. & Mziray N.R., 2017. A soil water and solute learning system for small-scale irrigations in Africa. *International Journal of Water Resources Development, 33*(5), 788-803.

Stirzaker, R.J., 2003. When to turn the water off: Scheduling micro-irrigation with a wetting front detector. *Irrigation Science, 22,*17-185.

Stirzaker, R.J., Stevens, J.B., Annandale, J.G. & Steyn, J.M., 2010. Stages in the adoption of a wetting front detector. *Irrigation and Drainage, 59*(4), 367-376.

Stone, W.A. & Terblanché, S.E., 2012. The evaluation of the subtropical crops extension and advisory service (SUBTROP) as perceived by farmer members in the subtropical regions, South Africa. *South African Journal of Agricultural Extension, 40*(1), 58-67.

Suchiradipta, B. & Saravanan, R., 2016. Social Media: Shaping the Future of Agricultural Extension and Advisory Services, GFRAS Interest Group on ICT4RAS Discussion Paper, *Global Forum for Rural Advisory Services*, Lindau, Switzerland.

Svendsen, M. & Huppert, W., 2003. Optimal maintenance in irrigation. *Irrigation and Drainage Systems, 17*(1-2), 109-128.

Thakur, D. & Chander, M., 2018a. Social media in agricultural extension: Benefits and challenges under Indian Context. *Asian Journal of Agricultural Extension, Economics & Sociology*, *27*(2), 1-8.

Thakur, D. & Chander, M., 2018b. Use of social media in agricultural extension: Some evidence from India. *International Journal of Science, Environment and Technology*, *7*(4), 1334-1346.

Thakur, D., Chander, M. & Sinha, S.K., 2017. WhatsApp for farmers: Enhancing the scope and coverage for agricultural extension. *International Journal of Science, Environment and Technology, 6*(4), 2190-2201.

Thembalethu, 2021. *Nkomazi, History and culture*, viewed 24 March 2021, from http://thembalethu.biz/history/.

Thomas, W., 2009. Online shed meetings: experiences producing video webcasts that showcase sugar industry best practice. *Australian Society of Sugar Cane Technologists,* 240-249.

Thomas, W.H.P., 2010. Video mediated social networking: a case of how this occurred in the Australian sugar industry. In *Proceedings of the 2010 Conference of the Australian Society of Sugar Cane Technologists held at Bundaberg, Queensland, Australia, 11-14 May 2010*, 497-506, Australian Society of Sugar Cane Technologists.

Thomson, P., Hope, R. & Foster, T., 2012. GSM-enabled remote monitoring of rural handpumps: A proof-of-concept study. *Journal of Hydroinformatics, 14*(4), 829-839.

Thoreson, B.P., Slack, D.C., Satyal, R.P. & Neupane, R.S.S., 1997. Performance-based maintenance for irrigation systems. *Journal of Irrigation and Drainage Engineering, 123*(2), 100-105.

Uphoff, N., 2014. Systems thinking on intensification and sustainability: systems boundaries, processes and dimensions. *Current Opinion in Environmental Sustainability, 8,* 89-100.

Urban-Econ, 2015. *Mbombela Local Economic Development Strategy Review*. Mpumalanga, South Africa.

Van Averbeke, W., 2008. *Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research in Limpopo Province.* Report No. TT 344/08. Water Research Commission, Pretoria, RSA.

Van Averbeke, W., Denison, J. & Mnkeni, P.N.S., 2011. Smallholder irrigation schemes in South Africa: A review of knowledge generated by the Water Research Commission. *Water SA*, *37*(5), 797-808.

Van der Ban, A.W. & Hawkins, H.S., 1996. *Agricultural Extension.* Wiley, California.

Van der Stoep, I. & Stevens, J.B. 2006. *Best management practices for smallholder farming on two irrigation schemes and surrounding areas in Eastern Cape and KwaZulu-Natal through participatory adaptive research,* Report No. K5/1477//4. Water Research Commission, Gezina, Pretoria.

Van Rensburg, N.J., Telukdarie, A. & Dhamija, P., 2019. Society 4.0 applied in Africa: Advancing the social impact of technology, *Technology in Society*, *59*, 101-125.

Vanclay, F. & Leach, G., 2011. Enabling change in rural and regional Australia. in J Jennings, R Packham & D Woodside (eds), Shaping Change: Natural Resource Management, Agriculture and the Role of Extension. *Australasia Pacific Extension Network, Australia,* 6-11.

Vidanapathirana, N.P., 2012. Agricultural information systems and their applications for development of agriculture and rural community, a review study. *In The 35th Information Systems Research Seminar in Scandinavia-IRIS, 1,* 1-14.

Werts, J.D., Mikhailova, E.A., Post, C.J. & Sharp, J.L., 2012. An integrated WebGIS framework for volunteered geographical information and social media in soil and water conservation. *Environmental Management, 49*,816-832.

White, D., Meyers, C., Doerfert, D. & Irlbeck, E., 2014. Exploring agriculturalist use of social media for agricultural marketing. *Journal of Applied Communication, 98*(4), 1-14

wikiHow, 2021. *How to Install a Sprinkler System*, viewed 08 March 2021, from https://www.wikihow.com/Install-a-Sprinkler-System.

Woodhouse, P. & James, P., 2017. *A farm survey of small-scale sugarcane growers in Nkomazi, Mpumalanga province, South Africa*. GDI Working Paper 2017-018. Manchester: The University of Manchester.

Yadav, K., Sulaiman, R.V., Yaduraju, N.T., Balaji, V. & Prabhakar, T.V., 2015. ICTs in knowledge management: the case of the Agropedia platform for Indian agriculture. *Knowledge Management for Development Journal, 11*(2), 5-22.

Zahran, Y., Kassem, H.S., Naba, S.M. & Alotaibi, B.A., 2020. Shifting from fragmentation to integration: A proposed framework for strengthening Agricultural Knowledge and Innovation Systems in Egypt. *Sustainability, 12,* 5131-5154.

Zendera, W., Makedenge, A., Sithole, N., Mutetwa, M. & Kurehwatira, M., 2019. Adoption and use of information and communication technologies (ICTs) by agricultural research institutions in information dissemination: A case study of Zimbabwe. *International Journal of Development and Sustainability,* 692-712.

Zhang, Z., Hu, H., Tian, F., Yao, X. & Sivapalan, M., 2014. Groundwater dynamics under water-saving irrigation and implications for sustainable water management in an oasis: Tarim River basin of western China. *Hydrology and Earth System Sciences*, *18*(10), 3951-3967.