AN EVALUATION OF TIMBER-BASED MIXED FARMING AND AGROFORESTRY IN LIMPOPO PROVINCE

Report to the
Water Research Commission

by

Phokele Maponya[1], Edward Nesamvuni[2], Vuwaani Manthakha[3], Thabo Nkuna[1], Meshack Makhwedzhana[1]

[1] Agricultural Research Council – Vegetables, Ornamentals and Plants
[2] University of the Free State
[3] Department of Environment, Forestry and Fisheries

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Water Research Commission
Private Bag X03
Gezina,
Pretoria, 0031

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

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EXECUTIVE SUMMARY

AN EVALUATION OF TIMBER-BASED MIXED FARMING AND AGROFORESTRY IN LIMPOPO PROVINCE

Agroforestry is considered a sustainable land use system that includes the use of woody perennial, agricultural crops and livestock in combination to achieve beneficial ecological and economical interactions. In some agroforestry systems, the woody component comprises commercial timber species such as Eucalyptus trees. The alternative to closely integrated agroforestry systems (where different enterprises take place within the same unit), is mixed farming where a farmer has multiple enterprises within the land he is using, but they may not be as closely integrated. Where such farms include some commercial timber production, such farming systems can be termed ‘timber-based mixed farming’ or ‘farm forestry’, which is a term commonly used in Australia. The TBMF systems encountered in South Africa in areas where smallholder farmers have established woodlots or small plantations, many of which are grazed by livestock or used for apiculture, can be termed potential agroforestry, as these systems provide opportunities for intensifying the integration of the different enterprises (be they crop or livestock production). Such integration is likely to involve modification of the current timber production practices to support the other enterprises, such as widening tree row spacing to allow for greater light penetration.

Recognising the opportunities that agroforestry offers, the Water Research Commission has funded a number of agroforestry research projects to date, but these have generally not been systems-based on commercial timber species. There is a national interest in finding sustainable ways of integrating timber production with other enterprises, especially for the emerging sector.

South Africa is considered a semi-arid country, vulnerable to water stress, particularly drought, and it falls amongst the 30 driest countries in the world. The Limpopo Province’s average annual rainfall is 600 mm and the threshold for rainfed agriculture is averaged at 250 mm annually. In terms of forestry, the forest plantations in South Africa use just 3% of the country's total water resources and rainfall needs to be higher than 750 mm per annum to sustain commercial forestry. There are parts of Limpopo that are well-suited to forestry production, but smallholder farmers engage in multiple activities including livestock and crop production and hence there is benefit in finding ways to integrate these different enterprises. One of the advantages of this is that it provides shorter-term income for farmers that are engaging in timber production. However, limited understanding, incorrect information, insufficient awareness and a negative mindset could hinder the benefits of this practice. Various authors also further acknowledged that most research on agroforestry has been conducted from the biophysical perspective, but socio-economic aspects in relation to perception of farmers should be given much attention.

Research was conducted in Limpopo Province by the Agricultural Research Council (ARC) and was fully funded by the Water Research Commission (WRC). The aim of the survey that was conducted was to identify agroforestry/TBMF systems in Limpopo Province and evaluate their current status. The following objectives were followed and fully achieved: (1) to identify and describe the characteristics of selected TBMF/agroforestry farms in Limpopo Province; (2) to determine the potential constraint of rainfall on the establishment and expansion of timber-based mixed farming/agroforestry farms in Limpopo Province; and (3) to determine factors that enhance farmers' participation in the TBMF/agroforestry sector in Limpopo Province.

A total of 65 potential agroforestry farmers participated in the study and were spread in districts as follows: Vhembe (40), Capricorn (21) and Mopani (4). These farmers were selected through a purposive sampling technique from the list of farmers provided by the Department of Agriculture, Forestry and Fisheries (DALRRD) and Forestry South Africa Limpopo. They were predominantly smallholder farmers but included three commercial farms that had introduced agroforestry practices. Quantitative and qualitative designs were adopted with the use of a questionnaire, stakeholder discussions, field observations and some demonstration trials. Data was coded, captured and analysed using Software Package for Social Science (SPSS).

The study confirmed that rainfall was not a constraint for the establishment and expansion of Eucalyptus-based agroforestry and mixed farming systems in the parts of Vhembe, Mopani and Capricorn Districts where the farmers were already engaged in growing trees. The results indicated that the majority of farmers (71%) had no access to research information and the important perceived constraints identified by farmers were: cost of production (53%); labour (53%); distance to the market (40%); cost to the market (46%); financial institutions (49%); suppliers (34%); land reform policy (49%); labour policy (52%); culture (49%); adaptability (45%); market power of buyers (46%); threats of substitutes (46%); fire (52%) and political stability (49%).The results also indicated that some of the agroforestry/TBMF farmers in Limpopo Province were generating income through renting of farms for grazing and selling trees to the communities to build shelter, kraals, medicinal purposes, fuelwood, etc. (as well as selling timber to formal markets). Those farmers with access to water were able to grow crops and sell their produce at local communities, local municipality and international market. The majority of farmers also indicated that they were also benefiting from having multiple enterprises (agroforestry/TBMF) through increased crop production, economic gain, soil conservation and improved soil quality, nitrogen fixation and sequestration of atmospheric carbon. The identified farmers' benefits were in line with some of the researchers' field observations.

The research study concluded that the promotion of agroforestry and TBMF is important because it offers the prospect of increasing production and hence raising farmer income. Recognising and tackling the main economic and sociological factors that determine the participation of farmers in agroforestry/TBMF practices is essential for ensuring the adoption of these practices.

The following recommendations have emerged from the study and should guide policy as well as implementation of projects:

1. The foremost recommendation is to clarify amongst all stakeholders the differences between true agroforestry systems, which may or may not include commercial timber species, and timber-based mixed farming systems. While both provide opportunities for improving the livelihoods of rural communities, they have different management requirements.
2. For areas where commercial forestry and/or woodlots are practiced, there is a need to promote the intentional integration of other enterprises (including livestock, cropping and apiculture).
3. For areas that are not suitable for growing commercial timber species, especially semi-arid parts of the province, there is a need to consider other agroforestry systems that make use of other woody species such as pigeon pea, which is a drought-tolerant, nitrogen fixing shrub.
4. There is a need to support effective farmer participation in TBMF and agroforestry through provision of technical training, assistance with fire management, access to inputs (especially planting material for new crops), and training in marketing and business skills.
5. In areas where there is extension support in place for the timber production, consider providing support to the non-timber components (livestock, cropping and/or apiculture), including value addition around products such as honey.
6. Support processes that allow farmer-to-farmer sharing, thereby drawing on those farmers with experience in these approaches.
7. Be very site-specific when designing programmes so that the systems are well-suited to prevailing physical and socio-economic circumstances.

The study has also identified a number of areas where more research is required. Some of these relate to the TBMF / agroforestry systems encountered through this study, while others relate to alternative AFS that could be appropriate for drier parts of Limpopo Province.

1. Investigate ways to improve TBMF systems that increase forage production and livestock production. This could include changing the current timber planting practices to increase fodder production (such as widening row spacing) and actively establishing shade-tolerant fodder species.
2. Quantify carbon sequestration by woodlots to determine whether there could be any opportunities for smallholder farmers to participate in the carbon economy.
3. Explore indigenous AFS in Limpopo Province where indigenous or other woody species are retained or tree species are being introduced.
4. Review other agroforestry systems and species that are suitable for the drier parts of the province.
5. Undertake an economic analysis to determine (1) the benefit of integrating other enterprises into plantations (for example by changing planting practice to accommodate commercial livestock production), and (2) to determine the potential benefits from the different components of TBMF systems.

This study has clearly indicated that the requirements of a particular agroforestry or TBMF system or practice are case-specific and depend on the physical conditions of the implementation area, scale or area, production level (commercial or subsistence) and management objectives. These aspects are important and should be carefully considered and continually researched in order to ensure success of the recommended farming system.

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Dr L Nhamo	Water Research Commission
Prof P Mafongoya	University of KwaZulu-Natal
Prof P Chirwa	University of Pretoria
Prof C Everson	University of KwaZulu-Natal
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LIST OF ABBREVIATIONS

AF	Agroforestry
AFS	Agroforestry Systems
ARC	Agricultural Research Council
ARC-ISCW	Agricultural Research Council – Institute of Soil, Climate and Water
ARC-PHP	Agricultural Research Council – Plant Health and Protection
ARC-SCW	Agricultural Research Council – Soil, Climate and Water
ARC-VOP	Agricultural Research Council – Vegetable and Ornamental Plants
CAS	Conventional Agriculture Systems
CPA	Communal Property Association
CS	Carbon Sequestration
CSC	Climate-Smart Cocoa
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEFF	Department of Environment, Forestry and Fisheries
DM	District Municipality
LM	Local Municipality
MTO	Mountain to Ocean
NGO	Non-Government Organisation
PTO	Permission to Occupy
REDD	Reducing Emissions from Deforestation and Degradation
SA	South Africa
SADC	Southern African Development Community
SAFCOL	South African Forestry Company Limited
SALM	Sustainable Agricultural Land Management
SAWS	South African Weather Services
SOC	Soil Organic Carbon
SPS	Silvopastoral Systems
SPSS	Statistical Package for Social Sciences
SWOT	Strength, Weaknesses, Opportunities and Threats
TBMF	Timber-based mixed farming
TCO_2 /ha	Tons of Carbon Dioxide per Hectare
US	United States
USDA	United States Department of Agriculture
WRC	Water Research Commission

1 INTRODUCTION

This chapter of the report provides a background about the importance of agroforestry and TBMF, the motivation for the study, its aims and objectives, the scope of the study and the structure of the report.

1.1 Background

The importance of agriculture and forestry to the country economy is well noted and it is seen as having potential to contribute to poverty alleviation and economic growth. According to Kotze and Rose (2015), commercial farmers account for 95% of the country's locally produced food, while the remaining 5% of food is produced by the 220 000 emerging farmers and the 2 million subsistence farmers in South Africa. It must be emphasised that while the country is food-secure and produces enough food to feed its population, more than half of the population live in such precarious circumstances that they are at risk of going hungry (Kotze and Rose, 2015; Maponya and Moja, 2012).

According to DAFF (2016), the forestry sector is a major contributor to the South African economy through its well-developed and diversified forest products industry. It supports manufacturing subsectors such as sawmilling, paper and pulp production, as well as mining and construction. In addition to its upstream and downstream impact, the sector has a strong potential for job and small business creation. According to DAFF (2017), in 2017, the sector provided 157 500 jobs across its entire value chain. Furthermore, the forest products industry ranks amongst the top exporting industries in the country, maintaining a positive trade balance, with a total value of R10.5 billion for exported forestry products (Farmers Weekly, 2019).

Agroforestry, which in this case is seen as the integration of agricultural practices and forestry production, is recognised as having opportunities to improve agricultural production, generate food, fibre, fuel and income, reduce pressure on natural forests and address the impacts of climate change on the agriculture and forestry sectors. It is also able to address the issue of competing land uses, such as is the case in many communal areas where conflicts arise between livestock owners and tree growers. Furthermore, this offers opportunities on farms that have been returned to land reform beneficiaries, where timber is being felled to make way for grazing lands.

An alternative to agroforestry is that of mixed farming systems that include commercial forestry species. In Australia this is referred to as Farm Forestry, and is said to include a range of practices such as the inclusion of timber belts, alleys and plantations. The timber component, which is generally on a smaller scale than industrial production, provides an alternative source of income while also having environmental and other benefits (Australian government, 2005). In the current context these systems are referred to as timber-based mixed farming systems as all farms included in the study had some scale of timber production. A study conducted by Carsan (2007) in Kenya revealed the role that such systems can play in strengthening the livelihoods of rural households.

The importance of a well-functioning extension service yields good information as it will offer good linkages between research, extension process and the end user. Without good research, extension will be affected adversely and extension without good research will be ideological and not based on facts. More research is still needed in the compatibility of certain systems of agroforestry and on-farm / field trials of agroforestry systems so that farmers and growers are given up-to-date information and advice on best practice methods.

Sustainable water resource management is an important requirement for agroforestry, especially in developing countries like South Africa. This requires the approach of a range of water resources from an integrated perspective, which is ecologically sound, economically feasible and socially acceptable. In order to achieve sustainable water resource management in agroforestry, it is key to identify the principles and constraints on water resource management in agroforestry, especially in the Limpopo Province. It is against this rationale that the research should demonstrate how better management of forest and water would help the various communities' food security, agricultural production and livelihoods. This rationale is also in line with Rethman et al. (2007) who found that water resource remains a serious key problem in the establishment of agroforestry in some parts of the Limpopo Province. The researchers found that in Sekhakhane village, almost 97% of rural communities recognized water resource as a key problem, while in Chuene Maja village, 71% of rural communities recognized water resource as a key problem. The participatory action approach of the research project will also help to identify the potential constraints of water resource in agroforestry in the Limpopo Province.

1.2 Motivation

Agroforestry is a land use system that includes the use of woody perennial and agricultural crops and animals in combination to achieve beneficial ecological and economical interactions for food, fibre and livestock production. It is further emphasised that properly managed agroforestry systems provide multiple benefits and contribute to improved livelihoods and income generation (DAFF, 2017). Mercer and Miller (1998) further acknowledged that most research on agroforestry has been conducted from the biophysical perspective, but socio-economic aspects in relation to perception of farmers should be given much attention. Agroforestry systems are also area- and climate-specific, hence, it is key to develop agroforestry systems that are locally relevant, and to consider the biophysical and socio-economic context on a case-by-case basis. Timber-based mixed farming systems (TBMF) or farm forestry, although they are potentially less integrated than agroforestry systems, also provide multiple benefits to rural households.

South Africa is considered a semi-arid country vulnerable to water stress, particularly drought. Much of Limpopo Province has an average annual rainfall of less than 600 mm, with some areas in the northern parts receiving less than 400 mm (Mpandeli et al., 2015), which is insufficient for timber production and risky for crop production. The parts of Limpopo where plantations and woodlots have been established historically, have rainfall that well above the annual average for the province, as well as agricultural production thresholds. Thus, the area has seen the integration of crops including maize, sweet potatoes, groundnuts and bambara nuts into stands of eucalyptus trees (Maponya et al., 2020).

It is against the above background that a comprehensive survey was conducted in the Limpopo Province to identify the following factors related to agroforestry and TBMF: (a) Social factors (potential benefits, perceptions, knowledge and skills in agroforestry and TBMF management practices); (b) Land related factors (shortage of land, operations within communal areas, security on land tenure); (c) Technical factors (management and integrating crops into forest systems, the ecology of the system, the need for common understanding of agroforestry, quality materials availability); (d) Economic factors (return on investments, labour requirements, etc.); and (e) Policy related factors (agriculture and forestry production systems, coordination between sectors and regulation of forestry aspects. It is envisaged that the outcomes of the research will be used to inform best operating practices, norms and standards and in the design of systems that will suit the various agro ecological zones).

1.3 Aim and Objectives

The general aim of the study was to evaluate the current status of timber-based mixed farming (TBMF)/agroforestry systems in the Limpopo Province, South Africa. The following specific objectives were established:

(1) To identify and describe the characteristics of selected TBMF and agroforestry farms in the Limpopo Province.

(2) To determine the potential constraint of rainfall on the establishment and expansion of TBMF and agroforestry farms in the Limpopo Province.

(3) To determine factors that enhance farmers' participation in the TBMF/agroforestry sector in the Limpopo Province.

Given that agroforestry and TBMF systems are not well understood in Limpopo Province, and yet they offer a range of potential benefits for rural communities, this topic was identified as an important research need to be pursued by the ARC with funding provided by the Water Research Commission (WRC).

1.4 Scope of the study

Given that the overall aim of the study, its scope involved providing an overview of the Limpopo Province districts in terms of selected climate and soil attributes. This information formed the basis for describing TBMF and agroforestry systems and determining the potential constraints related to rainfall for these systems. A questionnaire that included factors that best describe the status of farms with TBMF/agroforestry practices, identification of potential constraints of rainwater for promoting TBMF/agroforestry systems, and factors contributing to the success of these farming systems was designed and used. Data were collected and analysed to describe the status of TBMF and agroforestry in the Limpopo Province.

1.5 Contribution of individual chapters to the objectives of the project

Project chapters are arranged as follows: Chapter 2 (Literature Review); Chapter 3 (Methodology); Chapter 4 (Results and Discussion); Chapter 5 (General Discussions); Chapter 6 (Conclusions and Recommendations).

2 LITERATURE REVIEW

This chapter provides an understanding of agroforestry and TBMF systems that informs the remainder of the report. The focus of the study was initially on agroforestry systems that included commercial timber species, but later it emerged that many of the farms did not have sufficiently integrated systems to be termed agroforestry and were thus termed TBMF. Thus the literature review focuses on agroforestry, but also includes a review of literature related to TBMF.

The literature review starts by defining agroforestry, outlining various benefits of agroforestry systems, as well its contribution to climate resilience, drawing on African and global experiences. It looks at factors that might affect the adoption of agroforestry such as age, gender, education, land tenure, as well as support that has been provided through research and extension. The literature review then goes on to explore and define TBMF systems since the study found that many systems did not show sufficient interconnectedness to be termed agroforestry.

2.1 Defining agroforestry

Several studies have indicated that agroforestry practices are perceived in different ways. According to Lundgren and Raintree (1982), agroforestry is viewed as the set of land-use practices which involves the combination of trees, agricultural crops and/or animals on the same land management unit. Nair (1993) emphasized that although cultivating trees in combination with crops and livestock is considered an ancient practice, factors such as the deteriorating economic situation in many parts of the developing world, increased tropical deforestation, incorrect agricultural practices, degradation and scarcity of land because of population pressures, and growing interest in farming systems, intercropping and the environment have contributed to a rising interest in agroforestry since the 1970s. Based on the above mentioned factors Mercer and Miller (1998) further acknowledged that most research on agroforestry has been conducted from the biophysical perspective, but socio-economic aspects in relation to perception of farmers should be given much attention. Combe (1982) classified agroforestry systems into three broad groups, namely, agrosilvicultural (mixing trees and crops), silvopastoralism (mixing trees, pastures and animals) and agrosilvopastoralism (mixing trees with crops and animals). According to Rethman et al. (2007) these groups can further be subdivided as either simultaneous (where trees and crops are grown simultaneously), or sequential (where trees and crops are grown separately, temporally, over a number of seasons, as with improved fallows).

According to Zeruhun et al. (2014) agroforestry practices are not well established in South Africa. Zeruhun et al. (2014) further emphasized that Southern African countries such as Malawi, Namibia, Tanzania, Zambia, and Zimbabwe have benefited from the Southern African Development Community (SADC)-International Center for Research in Agroforestry (ICRAF) Zambezi Basin AF Project since the mid-1990s. South Africa has not been collaborating in such institutional partnerships and national efforts toward promoting agroforestry in smallholder farming systems. However, in the tree-rich savannah lands of South Africa, such as parts of the Eastern Cape, Northern Natal, the *Lowveld* and *Bushveld* in the Northern Province, and the Kalahari where livestock farming is practiced, trees are protected for the production of additional fodder for the drought the season, as a source of fencing material and firewood, for stabilising soil, for providing shade, and for general environmental conservation purposes (FAO, 2002).

According to Nair (1985), several criteria can be used to classify and group agroforestry systems (and practices). The following are the most commonly used criteria: the system's structure (composition and arrangement of components), its function, its socio-economic scale and level of management, and its ecological spread. According to Nair (1985) structurally, the system can be grouped as agrisilviculture (crops – including tree/shrub crops – and trees), silvopastoral (pasture/animals + trees), and agrosilvopastoral (crops + pasture/animals + trees). The researcher further indicated that other specialised agroforestry systems such as apiculture with trees, aquaculture in mangrove areas, multipurpose tree lots, and so on, can also be specified. According to Nair (1985), arrangement of components can be in time (temporal) or space (spatial) and several terms are used to denote the various arrangements. Functional basis refers to the main output and role of components, especially the woody ones. These can be productive functions (production of ‘basic needs’ such as food, fodder, fuelwood, other products, etc.) and protective roles (soil conservation, soil fertility improvement, protection offered by windbreaks and shelterbelts, and so on). On an ecological basis, systems can be grouped for any defined agro-ecological zone such as lowland humid tropics, arid and semi-arid tropics and tropical highlands. The socio-economic scale of production and level of management of the system can be used as the criteria to designate systems as commercial, ‘intermediate’, or subsistence. Each of these criteria has merits and applicability in specific situations, but they have limitations too so that no single classification scheme can be accepted as universally applicable. Classification will depend upon the purpose for which it is intended (Nair, 1985).

According to Paul et al. (2017), agroforestry – with a focus on timber-based agroforestry systems – can financially outcompete monocultures of trees and crops. This finding supports earlier empiric studies in tropical Taungya (Kalame et al., 2011; Gómez, 1995; Khasanah et al., 2015) and alley planting systems in both the tropics (Bertomeu, 2006; Current et al., 1995) and temperate regions (Palma et al., 2007; Graves et al., 2007; Cubbage et al., 2012).

2.2 Agroforestry benefits

As indicated in Figure 2, agroforestry contributes to food security by providing multiple products and benefits to farmers. These benefits include food, fodder and shade for livestock, timber and renewable wood energy. It improves agricultural production by improving soil conservation, soil water holding capacity, soil organic matter, soil fertility, and other ecosystem services. This land use practice has high potential to mitigate climate change through carbon sequestration.

According to Maponya et al. (2020c) agroforestry systems play a major role throughout human history in supporting livelihoods, assisting various communities generate income, create job opportunities, as well as meeting food security and nutritional needs in Limpopo Province. The researchers further indicated an evidence of the importance of agroforestry systems (and TBMF systems) especially silvipasture and agrosilvipasture for supporting food production and income generation in Limpopo Province. Some farmers in Limpopo Province highlighted that they are generating income through renting of farms for grazing, selling trees to the communities to build shelter, kraals, medicinal purposes, fuelwood, etc.

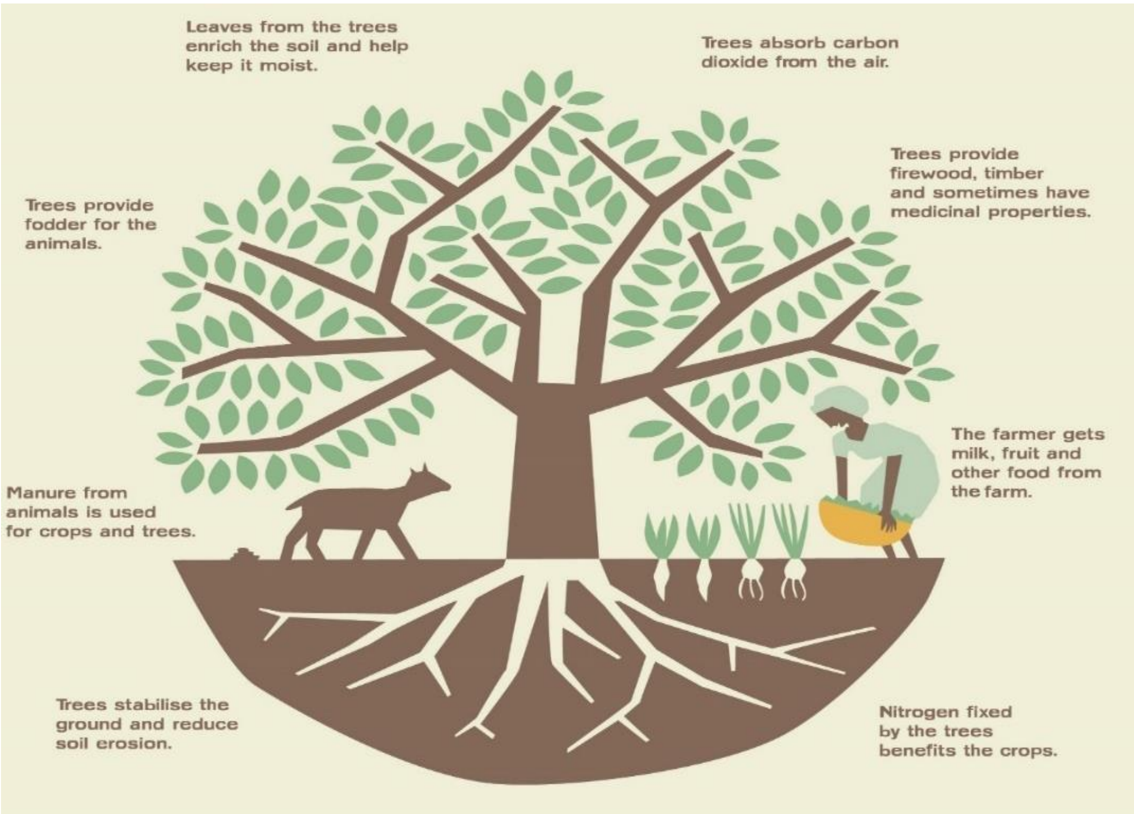

Figure 2 Some of the agroforestry benefits that are relevant to the Limpopo context (Forestrypedia, 2020)

2.2.1 Climate resilience: mitigation and adaptation

Agroforestry systems provide opportunities to both mitigate climate change as well as to adapt to the impacts thereof. For example, these systems can sequester carbon – as has been found with Eucalyptus woodlots in Zimbabwe (Choruma et al., 2019), while also enhancing local climatic conditions (Mbow et al., 2014; Ajayi et al., 2018). For example, in Ghana, shade trees are often used to protect crops from excess heat and light in the tropics, where agroforestry is clearly seen as a way to adapt to climate change (Borden et al., 2019). At the same time, the study conducted in Ethiopia indicated that agroforestry systems for coffee production have a higher level of resilience when facing future climate change and reinforce the idea of using this type of management to mitigate negative impacts of climate change on coffee production (Bezabeth et al., 2019).

The introduction of AFS in Southern Africa can also improve the resilience of ecosystems by promoting biodiversity, providing an alternative source of firewood and conserving soil and water (Ajayi et al. 2018, Musokwa et al., 2018), Kiyane et al. (2017) also found this to be the case in Rwanda, while agroforestry systems that incorporate woody legumes into maize fields were found to improve rain use efficiency in Zambia and Nigeria (Sileshi et al., 2011).

The importance of AFS in adapting to the impacts of climate change has also been explored in other parts of the world. According to Bentrup et al. (2019) a scientific assessment was conducted on the role of agroforestry in helping with the adaptation of agricultural lands to threats from climate change in the United States. This recently released report entitled *Agroforestry: Enhancing Resiliency in U.S. Agricultural Landscapes under Changing Conditions* was led by United States Department of Agriculture (USDA) Forest Service scientists and included participation from more than 50 scientific experts from the Forest Service, other federal agencies, research institutes, tribal lands, and universities across the United States (U.S) as well as inputs by scientists from Canada and Mexico (Bentrup et al., 2019). Based on expert input and information gleaned from over 1000 citations, this document represents a comprehensive synthesis on agroforestry as a mechanism to meet integrated climate change adaptation and mitigation objectives in the United States. The report also evaluated the social, cultural, and economic aspects of agroforestry and the capacity of agroforestry systems to provide multipurpose solutions. For instance, indigenous agroforestry systems of the United States and U.S.-affiliated islands offer time-tested models that can inform current agroforestry systems. In addition, the report presents U.S. regional overviews, as well as international overviews from Canada and Mexico to provide a North American perspective and understanding of agroforestry’s strengths and limitations.

In Portugal, various agroforestry studies were conducted, i.e. in semi-arid areas the recommendation was made for the implementation of the montado agroforestry system as a land use to mitigate the effect of the climate change, allowing agricultural production (Ferreiro et al., 2019). According to Navarrete et al. (2019) in Colombia, there is a high emphasis of the importance of agroforestry systems in restoring soil organic carbon (SOC) stocks and soil physical properties, highlighting their contribution with the 4 per 1000 soil for food security and climate initiative. The study by Andrade et al. (2019) further indicated that timber production and carbon sequestration of timber trees in agroforestry systems (AFS) are key for their productivity and climate change mitigation in Colombia.

In Brazil, silvopastoral systems are practiced on about 2 million hectares with Eucalyptus hybrids as the main tree species, and the area is increasing because of governmental incentives (Celentano et al., 2019). Multistrata agroforestry systems are known to provide goods, protect biodiversity and store carbon.

2.2.2 Agricultural, livelihood and food security benefits

According to Cordova et al. (2019) an estimated 570 million farms throughout the world are considered to be small or family operated, responsible for most of the world's agricultural production and probably the most vulnerable sector to the impact of climate change and variability, especially in mountain regions of developing countries. The researchers further emphasised that considering that smallholder farmers have a significant influence on the land use/cover change process and agrobiodiversity conservation, the maintenance of sustainable and resilient smallholder farming systems represents a key condition for sustainable land management and to safeguard the livelihoods of millions of rural households.

Agroforestry systems are seen as a mechanism for sustainable land management that also has direct benefits for smallholder farmers. Some AFS make use of nitrogen fixing woody plants and these have been found to add nitrogen through N fixation as well as through breakdown of biomass, which reduces the need for synthetic fertiliser, and also have a positive effect on crop yields, and are economically sound compared to farmers' traditional maize production practices, thus having the potential to improve the livelihoods of smallholders in southern Africa (Akinnifesi et al., 2011). Farmers in the Chongwe district of Zambia that perceived their soils to be sandy or sandy loam found the practice to increase maize productivity and were found to more actively adopt the use of 'fertiliser trees' (Kantashula et al., 2018). Case studies documented in Malawi and Zambia by Ajayi and Catacutan (2012) considered the contribution that fertiliser tree systems can make to food security (through increased maize production), while also potentially providing for carbon sequestration and mitigation of climate change. Work in Malawi showed that agroforestry systems allow the trees to bring nutrients to the surface where they are available to the understorey crop, reducing the reliance on external inputs (Makumba et al. 2006). A study in Zambia and Nigeria found that where legume trees were integrated into maize cropping systems, more stable maize yields were found when it was grown under rainfed conditions (Sileshi et al., 2011).

Besides contributing directly to household food security, AFS that include fodder crops have also proved to be effective in improving livestock production, for example the study of Mabeza et al. (2018) in Zimbabwe looked at the use of woody fodder legume species for improving growth rates of goats.

Fodder trees that can be integrated into cropping systems offer opportunities to address feed shortages during events such as droughts in the highlands of Eastern Africa (Franzel et al., 2014). They are also seen as an effective mechanism to address the reduced availability of grazing land in sub-Saharan Africa as it is seen to have the potential to improve human and animal health and increase the resilience of ecosystems (Toth et al., 2017).

Many households require firewood for domestic use and AFS can meet this need (Musokwa et al., 2018). For example, improved tree fallows are multi-output systems that can contribute to food security (through enhanced food production) and provision of firewood (Ajayi et al., 2018). Furthermore, there is a great demand in Sub-Saharan Africa for wood to produce charcoal, and agroforestry systems provide opportunities for a sustainable supply, but would need to be implemented at a landscape level (Liyama et al., 2014).

In the Mt Elgon region in Kenya, deforestation, inefficient agricultural practices, uncontrolled grazing and soil erosion have a direct impact on biodiversity, soil fertility and a farmer's capacity to adapt to climate change (Mutua and Nelima, 2019). Crop yields and milk production are low and smallholders do not have a guaranteed sustainable connection to markets for their produce. As emphasised by Mutua and Nelima (2019) the Livelihoods Mt Elgon project is improving the livelihoods of 30,000 smallholder farmers by empowering farmers to increase adoption of Sustainable Agricultural Land Management (SALM) practices with a strong focus on agroforestry, and establishing connections to dairy markets through 15 cooperatives.

According to Camara et al. (2019) in the Sahel, declining crop yields are a major obstacle to food security. This is mainly due to climate variability and land degradation due to unsustainable management practices. This is the case of the agro-ecological zone of the groundnut basin in Senegal where most of the soils are degraded by the effects of continuous cultivation with a peanut-millet rotation. The researchers further indicated that this agroforestry technological package helps to reduce the negative impacts of climate variability and thus improves the food security and the resilience of small Sahelian farmers (Camara et al., 2019).

A previous study conducted by the ARC in the Limpopo and Mpumalanga Provinces, South Africa by Maponya et al. (2020b) investigated the effect of integrating crop production into timber-based smallholder farming systems on food security. The food security indices that the study considered were (1) Availability (Sufficient) (2) Accessibility (Physical, Social & Economic Access) (3) Utilisation (Dietary Needs, Safe & Nutritious) (4) Stability (Short Term) (5) Sustainability (Environmental, Social & Economic) (6) Agency (People & Food Preferences). The study used standard questions to ask participants to address food security status (percentage food secure/insecure) and levels (Severe, Mild & Moderate. The study determined the food security status of the respondents before SAFCOL, Department of Environment, Forestry and Fisheries (DEFF) and MTO allocated land, provided production inputs and paid stipends and found that the food insecurity percentage was at +65%. The food security status was assessed after the intervention (after growers had harvested groundnuts, bambara nuts, maize, vegetables (Integrated with Moringa in Vhembe District, Limpopo). It was found that most growers used the harvest for household consumption while some managed to sell in the informal markets. The inclusion of crop production was found to have contributed to the flattening of the food insecurity curve and improved the communities' livelihoods as the final food insecurity percentage stood at 20% and most community growers fell in the mild and moderate categories (Maponya et al., 2020b).

In terms of the effects of AFS documented in other parts of the world, a study in Ecuador compared AFS with conventional agriculture systems and found that AFS contain greater agrobiodiversity; more diversified livelihoods; better land tenure security and household income; more diversified irrigation sources and less dependency on rainfall (Cordova et al., 2019). In addition, the study found that AFS are less vulnerable to climate change and variability, showing less exposition and sensitivity to climate and non-climate stressors, and having better adaptive capacity conditions than conventional systems. These findings highlight the role of AFS in supporting sustainable livelihoods and reducing the socioeconomic and environmental vulnerability of smallholder farmers.

Another study in Bangladesh found that agroforestry is a sustainable land use system that ensures food security through climate resilient agricultural promotion and increasing homestead yield by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land (Rahaman and Bijoy, 2019). The researchers indicated that the coastal belt of Bangladesh is vulnerable due to different climate induced slow onset and sudden disasters, and these catastrophic events significantly hinder the agriculture production systems, economic and social development of the community, who are mostly poor and disadvantaged groups and also depend on agricultural production for their livelihoods. Hence the adoption of agroforestry was an effective climate change adaptation practice in the climate vulnerable coastal areas of Bangladesh (Rahaman and Bijoy, 2019).

From the discussion above, it is clear that AFS have the potential to improve food security and livelihoods of smallholder farmers in South Africa, and in Limpopo Province in particular.

2.2.3 Economic benefits of agroforestry

This section explores some of the economic benefits of different AFS and that have been reported in Africa and from other parts of the world. Economic benefits are often the factors that motivate farmers to adopt agroforestry practices, which are then accompanied by other benefits (Mbow et al., 2014a). In some cases, farmers are unwilling to wait for benefits such as improved soil fertility in alley cropping systems to occur, highlighting the need for ensuring that the systems also provide economic benefits (Glover et al., 2013).

In Zimbabwe, the inclusion of eucalyptus woodlots in farmlands has been found to provide income, timber and fuel wood to the household, while also reducing land degradation (Choruma et al., 2019).

Ajayi and Akinnifesi (2007) compared the profitability of different cropping systems in Zambia and found that improved fallows followed by maize production, despite their labour requirements, were more profitable than traditional systems of continuous maize production without the addition of mineral fertiliser. A study of the benefits obtained from agroforestry in Busia county in Kenya showed that there are a range of AFS (most commonly boundary planting, use of multipurpose trees and live fences). The farmers mentioned a range of timber products (poles, timber, firewood, home implements) and non-timber products (including livestock, milk, fruit and poultry). Besides home use of products, farmers also reported marketing of products – especially poles and building materials, clearly indicating that these systems have economic benefits (Mugure and Oino, 2013). A review of relevant literature related to agroforestry (specifically fertiliser tree systems) in Malawi revealed that these systems can increase crop yields, either as a substitute or complementing the use of inorganic fertiliser. It was also concluded that AFS that yield an additional product that can be marketed are more likely to be adopted (Kaczan et al., 2013).

In terms of some local findings, the previous ARC study conducted in Limpopo and Mpumalanga Provinces further indicated that the agrosilviculture practices has economic benefits as the community managed to harvest groundnuts, Bambara nuts, sweet potatoes and maize (Maponya et al., 2020a), with some agrosilviculture community members selling their harvest at the informal markets, i.e. tollgates, pension pay points, outside towns, and within their villages (Maponya et al., 2020b).

Looking further afield, studies in other countries have also shown economic benefits from AFS. According to Asare and Mason (2019), smallholder farmers in Ghana grow almost one quarter of the world's cocoa and as cocoa's natural habitat is in rainforests' lower storey, shade is essential for cocoa's continued supply to the global chocolate industry. The study concluded that pollination-enhancing techniques like agroforestry could boost cocoa yields and thus incomes.

In Hungary, for example, a study concluded that farmers should invest in agroforestry and agricultural diversification because it is a mechanism to secure the income generation and to improve resilience (Bareith et al., 2019). While in rural Thailand, trees on farm have played a critical role in supporting local livelihoods where the majority of villagers are traditional farmers and have been practicing rice paddy production for domestic consumption (Onprom and Kladwang, 2019). According to Onprom and Kladwang (2019), farmers generated income from cash cropping, livestock and forest products. The researchers concluded that like other forest communities in northern Thailand, farmers of the Mae Tha community in Chiang Mai Province have been traditionally depending on tree and forest resources from natural forests for household consumption and income generation. The agroforestry practices were introduced three decades ago by a local non-government organisation (NGO).

A study in China examined whether intercropping a rain-fed jujube orchard in the Loess Plateau, with either *Brassica napus* (JB) or *Hemerocallis fulva* (JH) is a viable agroforestry system (Ling et al., 2019). The results indicated that agoforestry is a climate-smart agricultural system and can increase the resilience of semi-arid jujube plantations to extreme real-world drought and that agroforestry systems provide an economically feasible way to protect trees during both drought and normal years, and should be seriously considered by farmers who face water limitations and want to increase their income levels. Lastly, in Brazil, agroforestry planning and design is said to be fundamental for investment safety, especially for neo-rural entrepreneurs (Costa et al., 2019). The researchers designed an ecologic and economically sustainable regenerative agroforestry system in March-April, 2018. The results concluded that an integrated system is more ecologically and economically resilient, presenting revenue diversification while maximising cash flow, and scaling up adoption will depend on proper designed agroforestry systems.

Besides the economic benefits of improved yields and diversified production mentioned above, a balance analysis conducted by Neya et al. (2019) revealed that a carbon payment system promoted by reducing emissions from deforestation and degradation (REDD+) initiative will be profitable and compensable to smallholder farmers' efforts to keep trees when the tCO_2/ha price is approximately 4 US$. Carbon marketing appears to be the most relevant incentive method to enhance carbon stock in agroforestry parkland in order to meet the Paris agreement (Neya et al., 2019).

2.3 Socio-economic characteristics of agroforestry

A review of literature was undertaken to understand the socio-economic factors that are likely to encourage the adoption of AFS, as well as the characteristics of farmers that are practicing agroforestry. This considered age and gender of farmers as level of education and experience in agroforestry and/or agriculture. This section also considers the effect of land tenure on adoption of agroforestry, as well as the effects of access to agroforestry research, extension services and training.

2.3.1 Age and gender

Age and gender are two factors that affect the involvement of smallholders in agroforestry practices, especially where we have the introduction of new practices to an area. In a study conducted by Mwase et al. (2015), it was found that younger households in Southern Africa are more likely to take risk and engage in agroforestry than older households, which was also due to the labour requirements associated with agroforestry practices. Issues of labour requirements also have implications for both men and women as the introduction of systems may provide more tasks for both men and/or women.

In a study of multispecies agroforestry in northern Ethiopia, farm size and age of the household head were positively correlated with on-farm species diversity and density and therefore it is crucial to identify socio economic constraints on the households prior to introducing tree and shrub species (Taltamo et al., 2019). Another study in Ethiopia showed that climate change affects both male-headed and female-headed households, but poses more threat to female-headed households (Asheber et al., 2019). The study further indicated that the choice of adaptation strategies was also different between female and male-headed households. As compared to female-headed households, male-headed households adopted multiple adaptation strategies and those strategies include planting trees that are droughts resistant like acacia and cactus, crop diversification, and use of drought resistant and short growing crop varieties, and adjusting and shifting of planting dates. In addition, the study showed that age, sex, education, family size, access to extension service, participation in a social organization, participation in off-farm activity, livestock holding, farming experience and distance to the nearest market are major determinant factors that significantly affect a farmer's choice of adaptation of different strategies to climate change (Asheber et al., 2019).

Gachuiri et al. (2019) conducted a study that sought to understand gendered and age-related knowledge on food trees use in Uganda and Kenya. The purpose was to identify context-specific food tree portfolios that can sustainably address food and nutrition gaps while responding to the needs and strategic interests of different gender and age groups. According to Gachuiri et al. (2019) in Uganda, knowledge on food tree species differed between genders, with older women listing the greatest number of priority species (22), followed by younger women (19) and older and young men (15). In Kenya, older women and men identified 38 and 36 species, respectively, whereas younger women identified 26 species and younger men 23 species. The researchers further emphasised that both men and women especially valued food trees that contribute to improved health, nutrition and income, those whose products have a good taste, and with medicinal properties. For old and young women, the main reasons for selecting food trees species was their availability and role as children's food.

The research in Burkina Faso found that the most important factors associated with variation in levels of motivation to conserve trees on farms included household wealth, gender, age, education level, marital status, residence status, farmland size, household size and technical support (Sanou et al., 2019). The study concluded that an agroforestry project will be more successful if the diversity of smallholder socio-economic characteristics and their perceptions are considered in its design (Sanou et al., 2019). These results are in line with the study conducted by Zerihun et al. (2014); Maponya et al. (2018) and Maponya et al. (2019) in South Africa.

According to Smith et al. (2019) the gender dimension of tree-resources dependency has been well documented in the West African agroforestry parklands where women are the main beneficiaries of non-timber forest products. The gender action learning systems was developed to understand gender dimensions better. The participatory tools were applied in three communities in northern Ghana and four communities in southern Burkina Faso and interviews were conducted with male family heads and one adult female in each of 84 households. According to Smith et al. (2019) the analysis showed the contribution of income from trees, particularly shea (*Vitellaria paradoxa*) and household cash income was very significant in both countries, especially in poor households. This income was almost exclusively sourced by women, who often have neither control over how it is spent nor a voice in decision-making for land restoration (e.g. tree planting and/or management, as well as soil and water conservation improvements). Furthermore, activities typically done by women, both in respect to farming and tree-product harvesting and to their reproductive role, are significantly less valued than are men's (Smith et al., 2019).

Globally the importance of gender issues in agroforestry has been broadly recognized and demonstrated. In India there are still a number of issues that require special attention, especially the collection of fuel wood from agroforestry lands for household consumption (Prasad et al., 2019). Gender plays an important role in cow and buffalo dung cake making for household fuel consumption in India and the proportion of cow and buffalo dung cake replaced by fuel wood collected from agroforestry land is also a very important aspect in intra-household decision-making and power dynamics as they relate to agroforestry (Prasad et al., 2019). The study concluded that there is relevance of gender issues in agroforestry adoption in general and in fuel and energy consumption in particular. In such situations, agroforestry management through watershed interventions with due emphasis on gender concern appear to be an effective tool to make the gender dynamics in agroforestry systems (Prasad et al., 2019).

If we look at the local context, then we see that the previous ARC study conducted in Limpopo and Mpumalanga Provinces further indicated that most of the 182 community members involved in agrosilviculture were female (161) as compared to only 21 males (Maponya et al., 2020ab). Most of the women were doing soil preparation, weeding, harvesting and packaging. The researchers further indicated that in terms of age, 56% of the 182 community members were in the age group of >60. Youth involvement was very low (14.3%), 36-45 (11.5%) while 46-59 had 18.1%. This situation is worrisome and indicates the urgent need to attract younger people into agroforestry as an important priority.

2.3.2 Level of education

Education levels refers to school level education as well as skills that are developed through capacity building processes. Education levels of smallholder farmers has been found to affect the adoption of certain AFS. For example, Nkamleu and Manyong (2005) found that in Cameroon, apiculture was one type of AFS that was generally adopted by more educated farmers. This did not hold for the other forms of agroforestry encountered. A study in Ethiopia showed that the level of education is one of the major determinant factors that significantly affect farmers' choice of adaptation of different strategies to climate change, including agroforestry (Asheber et al., 2019). At the same time, research in Burkina Faso found that the most important factors associated with variation in levels of motivation to conserve trees on farms included household wealth, gender, age, education level, marital status, residence status, farmland size, household size and technical support (Sanou et al., 2019).

Mujuru et al. (2019), from their experiences in Zimbabwe, recognise the need for more education and awareness to increase knowledge on the importance of trees in urban agriculture to facilitate ecosystem restoration while achieving economic gains. These results are in line with the study conducted by

Zerihun et al. (2014) in the Eastern Cape and Maponya et al. (2020ab) in the Limpopo and Mpumalanga Provinces, South Africa.

Looking at experiences from elsewhere also yields interesting results. The Pacific Alliance – which represents Chile, Colombia, Mexico and Peru, and is a mechanism of political, economic, cooperation and integration has policies related to the promotion of education, and particularly on agroforestry, as strategic elements for sustainability (Lizarraga et al., 2019). In Nepal, science-technologies, level of education and local knowledge are seen to offer potential solutions to addressing the increasing vulnerability of mountain ecosystems and communities and building their resilience to natural hazards (Liu, 2019).

2.3.3 Agroforestry experience

A study conducted in Kenya emphasised the importance of agroforestry experience. According to Asayehegn et al. (2019) there is a strong correlation among agroforestry experience, farm performance and socio-institutional variables and the stakeholder interaction suggests the need for the establishment and strengthening of local institutions that have capacity to break the farmers' capital constraint to invest in climate smart agriculture which is beneficial to sustain systems (Asayehegn et al., 2019).

In most developing countries, there has been a long-standing conflict of interest between using land for agriculture and the conservation of biodiversity (Sanou et al., 2019). For example, the study conducted in Burkina Faso reports on factors influencing farmers' decisions to incorporate trees into their agricultural practice. The data was collected from personal interviews conducted with farmers in the Centre-West region of Burkina Faso and analysed using principal component analysis, multiple linear regression and binary logistic regression. The results showed that farmers' decisions to incorporate trees into their farmland were mainly influenced by silvicultural experience, knowledge and skills, participation in farmers' groups or other social organizations with an interest in tree conservation, the social value of biodiversity in the rural landscape and the perceived economic benefits of trees on farmland. The most important factors associated with variation in levels of motivation to conserve trees on farms included household wealth, gender, age, education level, marital status, residence status, farmland size, household size and technical support. The study concluded that an agroforestry project will be more successful if the diversity of smallholder socio-economic characteristics and their perceptions are considered in its design (Sanou et al., 2019).

According to Maponya et al., (2020ab) an assessment done in Limpopo and Mpumalanga Provinces indicated that community growers received no training on agroforestry as they mostly relied on their indigenous knowledge system (IKS). The agrosilviculture community growers further emphasised that they have experience and have been practicing agroforestry for decades in the study area.

2.3.4 Land tenure

Security of land tenure is an important factor influencing the adoption of agroforestry practices, and influencing the choice of system, especially improved fallow systems (Nkamleu and Manyong, 2005). Farmers will only invest in timber species if they have security of tenure and are assured that they will be able to harvest them. The social and institutional systems related to land that are found in a particular context will also affect the systems adopted. For example, in some places tree planting is seen as a mechanism to establish ownership of land (Glover et al., 2013). Similarly, people in Cameroon were found to invest in live fencing as it made their land rights more secure (Nkamleu and Manyong, 2005).

Adoption of agroforestry is not only influenced by land tenure but also the availability of land. Some agroforestry practices such as improved fallows are only appropriate for farms where size is not limiting and farmers can take some land out of production for a number of years (Glover et al., 2013). Limited land availability was identified in Southern Malawi as a factor that affected the adoption of agroforestry practices (Mwase et al., 2015). The same trend is observed in Zimbabwe, where the main challenge affecting adoption of agroforestry in urban areas was the small plot sizes and land tenure (Mujuru et al., 2019).

The situation in Ethiopia indicated that richer farmers with larger farm size and better income may not be constrained by food shortages for households and can allocate a significant part of the land for tree plantation (Taltamo et al., 2019). According to Taltamo et al. (2019) it is important to identify the socio-economic constraints on the households, particularly resource endowment status prior to the introduction of tree and shrub species in the farms for the adoption of the agroforestry system in the Kabe watershed and in areas with similar biophysical, socio-cultural settings (Taltamo et al., 2019)

In Senegal, a study was conducted on the socio-economic determinants of garden plank technologies and horticultural grafting adoption of *Adansonia digitata* L. (baobab) in the Kolda and Sedhiou regions (Mbaye et al., 2019). The study indicated that for the majority of the sample (74%), adoption is determined by water availability, access to seeds and land, and the possibility of selling or buying baobab products in markets. The results also showed that the land tenure mode and the household size significantly determine the adoption of horticultural vegetable and horticultural grafting technologies of *A. digitata* by local populations (Mbaye et al., 2019). Land acquisition and ownership is therefore a factor that promotes adoption, as well as a household size. The study concluded that improved access to land and increased household size facilitate the level of adoption of agroforestry technologies in the Kolda et Sedhiou areas (Mbaye et al., 2019).

In Cameroon, especially in the Melap Forest Reserve, the main constraints to the introduction of trees in farms are land tenure and the lack of arable lands (Temgoua et al., 2019). In the oil palm agroforestry system on the Adja Plateau (Yemadje et al., 2019), land titling plays an important role and landowners argue that oil palm fallow (*dekan*) restores soil fertility, but in the long-term it is also an instrument in the struggle for control over land (Yemadje et al., 2019).The researchers concluded that sustainable agricultural intensification in agroforestry systems requires institutional changes, based on a mixture of customary and formal rules, in both landownership and rental agreements to access land (Yemadje et al., 2019).

2.3.5 Research, extension services and training

Adoption of agroforestry has been negatively impacted by a lack of skills, especially those of a technical nature (Kiyane et al., 2017). A number of efforts have been made to develop agroforestry skills through training. Such training was perceived to be critical in various European countries, which led to the Agrof MM training project (Papadopoulos et al., 2019). The Agrof MM project (Agroforesterie – Formation-Mediterannee et Montagne), was a 3-year educational project that aimed to: i. Train between 130 and 150 agricultural professionals in Europe, ii. Improve and develop the education tools to enable agroforestry training to be sustainable, and, iii. Develop a unique agroforestry qualification program in each European country. It was coordinated by AgroSup Dijon, France. The training consisted of lectures, examples and a field trip. Interestingly, the priorities of the participants differed depending on their educational level and their age. European stakeholders were satisfied by the training format and stressed the need and willingness for interaction with other farmers and experts (Papadopoulos et al., 2019).

In Vietnam, agroforestry technology adoption required the understanding of cultural character, farming behaviour, challenge and interest of local people (La et al., 2019). Therefore, it is not a one-size-fit-all process. The researchers emphasised that agroforestry adoption requires to develop a strategy on research and to ensure the research results are mainstreamed on the development policy in order to build resilient livelihoods and ensure future environment benefits (La et al., 2019). According to Kerr et al. (2019), there is also more research needed on farmers' experiences and perceptions so that California's Central Valley becomes renowned not only for its agricultural output, but also for its diverse and sustainable perennial cropping systems.

In the Democratic Republic of Congo, an improved fallow agroforestry practice that involves planting *Acacia auriculiformis* trees to accelerate soil fertility recovery was taught to 306 farmers on the Batéké Plateau from 1995 to 2001 (Kachaka et al., 2019). This was a result of insufficient knowledge of the improved fallow practices and was identified as the greatest potential barrier to spreading this practice to non-adopters (Kachaka et al., 2019). According to (Temgoua et al., 2019), in Cameroon for a better contribution of agroforestry systems to firewood supply, farmers must be trained in nursery and tree management techniques, while in Kenya training and support for beekeeping and agroforestry were part of the 4 year Mau Mara Serengeti Sustainable Water initiative (MaMaSe), aiming to improve water safety and security, support structural poverty reduction, sustainable economic growth and conservation of the Mara River Basin's ecosystems (Ingram et al., 2019). The situation in Ghana also provided evidence on the importance of agroforestry research and according to Asare and Mason

(2019) research has played a crucial part in the development of climate-smart cocoa (CSC) production in Ghana, and in supporting the design and implementation of reduce emissions from deforestation and degradation (REDD+). The study tells the story of how research has played a major role in shaping CSC in Ghana and the pathway that was followed to where it is firmly embedded in policy, in private sector investment, and in practice (Asare and Mason, 2019)

In South Africa, according to Department of Agriculture, Forestry and Fisheries (DAFF) (2017), centres of excellence should be identified and established as lead research agents in agroforestry systems. These may include universities, agricultural colleges, forestry colleges, research stations and state research agencies (e.g. Agricultural Research Council). DAFF further suggested that a number of centres be established and be provided with funding for agroforestry research. The geographic location of these centres should reflect the different agro-ecological zones that occur in South Africa and the research focus should be on systems best suited in which the centre is located. The state should provide seed funding for research and assist the centres with securing funding from other sources (e.g. Water Research Commission, SADC funding mechanisms, etc.). The centres of excellence should conduct technical, social, environmental and economic elements of agroforestry, with a particular focus on shared learning and participatory action research (DAFF, 2017).

2.4 Defining timber-based mix farming systems

A variant of conventional, spatially integrated agroforestry is that of mixed farming systems that include commercial forestry species. These are referred to as timber-based mixed farming (TBMF) systems in this study. The principles of these two diversification strategies are presented in Figure 2. While agroforestry is defined as the direct mixing of trees and crops on the same piece of land in a spatial or temporal sequence, known as agroforestry (Nair, 1985), the alternative is “coarse-level mixing” of trees and crops on separated parcels (Price, 1995) or “compartments” (Odum, 1969) within a farm, which is referred as “farm mosaic” or mixed farming. Such systems could also be seen as farm forestry (Australian Government, 2005). An advantage of a farm mosaic system / mixed farming is the reduced management complexity and ease of mechanized agricultural management compared to agroforestry, while adverse effects of large-scale monocultures, such as soil erosion, may still be moderated (Odum, 1969; Knoke et al., 2012). Farm mosaic/mixed farming systems have the further advantage that they can avoid competition between species for light, water and soil resources, which may otherwise reduce productivity of individual components (Rao et al., 1997). Furthermore, a farm mosaic / mixed farming diversification approach, in which a farmer carefully allocates land to separate plots of trees and crop, can have economic and productive advantages.

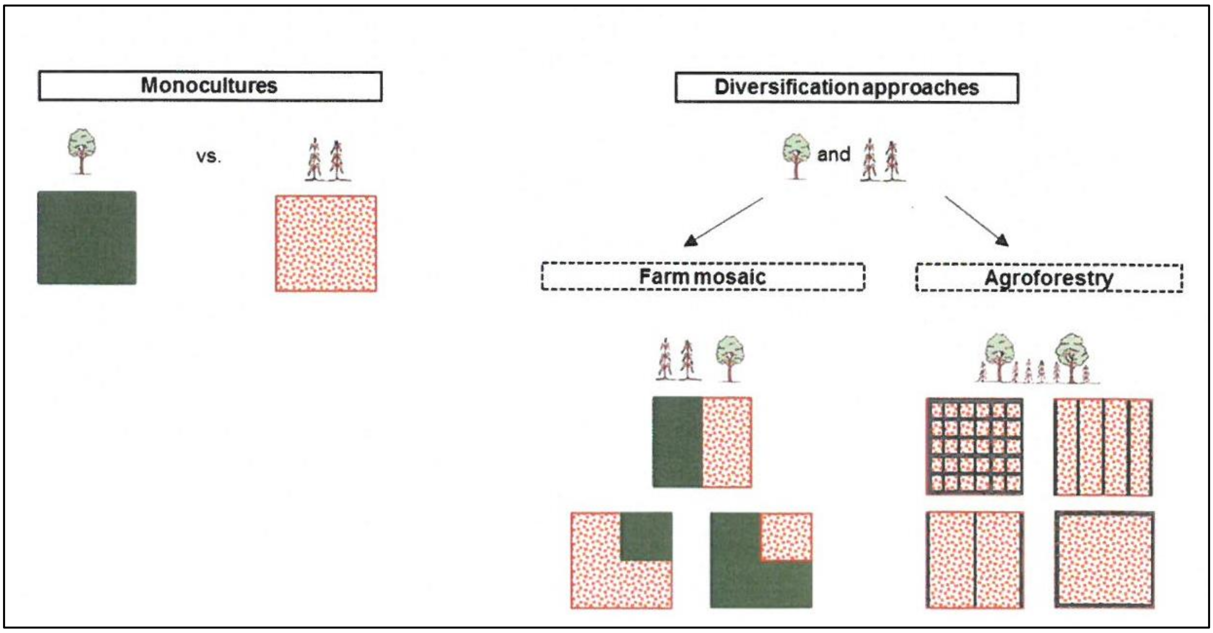

Figure 3 Farm mosaic/timber-based mixed farming vs agroforestry (Green parcels represent areas planted with trees. Crops (or pasture) covers orange areas (Paul et al., 2017).

What is clear from the current literature is that there is fairly limited work that has been done in Southern Africa on agroforestry systems where the main component is commercial timber production. The potential benefits that can accrue to rural households, through access to food crops and income in the shorter term, as well as benefits to the timber processors by keeping land currently under timber in production, make both TBMF and timber-based agroforestry important production system to explore further.

This research provides information that can inform the programmes of government extension departments as well as commercial timber companies that engage with small growers. It highlights that opportunities exist for integrating crops and livestock into timber production so that the diverse nature of smallholder production systems can be effectively maintained.

3 METHODOLOGY

3.1 Study area

The 35 sites that were included in the study covered portions of Vhembe District Municipality (DM), Capricorn DM and Mopani DM, as shown in Figure 4. Of the 65 farms documented during the study, three were commercial farms that had introduced agroforestry practices, namely Ratombo, Safcol and Merensky. The other sites were categorised as smallholder farms that were engaged in some scale of timber production (Eucalyptus). More detail pertaining to the sites is presented in Annexure 1.

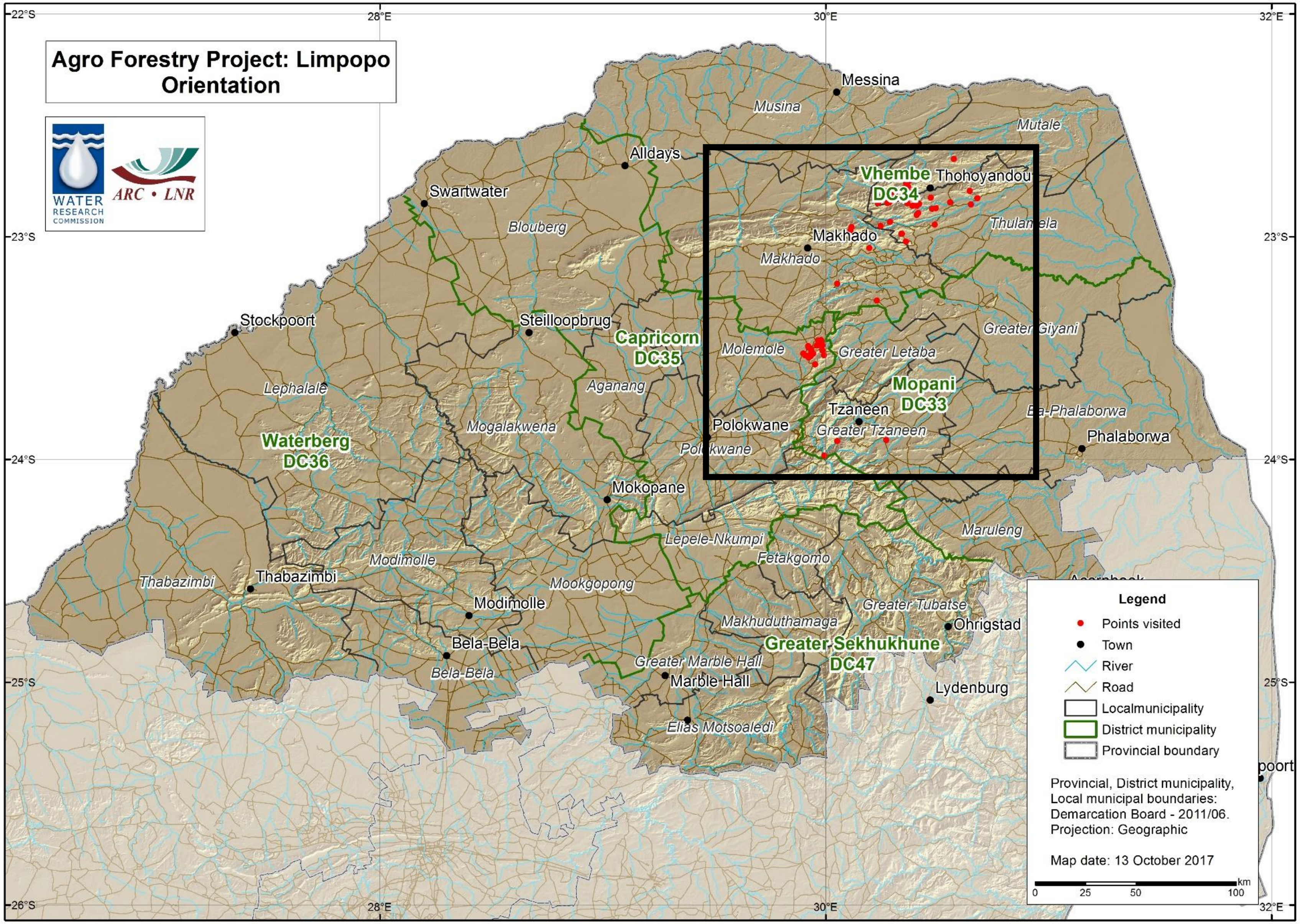

Figure 4: Timber-based mixed farming and agroforestry systems locations in the Limpopo Province (ARC-SCW, 2017).

3.2 Research methods

The research used quantitative and qualitative methods. A detailed questionnaire written in English was developed as a quantitative data collection method and data was collected from 04th to 15th September 2017 in the Vhembe, Capricorn and Mopani Districts. The questionnaire used both open and closed ended questions (See Appendix 5 for a copy of the document). The qualitative data collection method included focus group discussions and field observations. The two methods were also used to identify the smallholder farmers and potential agroforestry systems in the Limpopo Province and a purposive sampling technique was used to select 65 timber-based mixed farms and agroforestry systems from the list provided by the Department of Agriculture, Forestry and Fisheries and Forestry South Africa Limpopo.

According to Backeberg and Sanewe (2010), participatory action research is a most appropriate research method since people, especially farmers, benefit while the research is ongoing. Participatory action approach was also recommended by various researchers who emphasised that this approach is a good alternative to the traditional “transfer of technology" or “top-down approach" to agricultural research and extension. It is against this background that decision was taken to include some on-farm trials with farmers as part of the project. The demonstrations allowed for the involvement of researchers, collaborators, extension staff and farmers.

3.3 Sampling method

The farmers interviewed were identified from a database maintained by officials from DAFF (now Department of Environment, Forestry and Fisheries – DEFF). The study focused on farmers that were actively engaged in multiple enterprises. A total of 65 farmers were identified, which included a number of commercial enterprises that had initiated agroforestry techniques (specifically the integration of cropping practices or grazing of livestock within their plantations.

3.4 Data Analysis

Data collected was analysed quantitatively using the Statistical Package for Social Sciences (IBM SPSS Statistics) Windows version.

4 RESULTS AND DISCUSSION

This chapter of the report documents the results of the study and discusses the findings. It covers the types of farming systems included in the study (both large-scale commercial and smallscale production) – specifically their different components, areas of production, the physical conditions of the study area, incidence of drought and flood, demographic information about the farmers, income and marketing aspects and farmers’ perceptions about the competitiveness of their systems. Since the timber component was common for all farmers interviewed, this forms the basis for much of the discussion in this chapter of the report. An analysis of the strengths, weaknesses, opportunities and threats (SWOT) of these systems is also included and the rainfall-related constraints for timber-based systems are discussed. The outcomes of a number of demonstration trials conducted with farmers are also included, as well as a summary of the agroforestry-related research conducted by the ARC in parallel with the current study.

4.1 Types of farming systems

4.2 Describing the farming systems at the study sites

The types of systems encountered on the 65 farms included in the study are summarised in Table 1. The most commonly encountered systems comprised a combination timber and livestock production (silvipasture), followed by systems that included crop production, livestock production and timber (agrosilvipasture). A total of 7 respondents kept bees, which made use of the Eucalyptus plantations/ woodlots. More detail about the systems is presented in Appendix 1. The most popular systems identified were silvipasture (32) and agrosilvipasture (23). The systems were popular because farmers were generating good income by allowing the community's livestock to graze in their forests throughout the year at a cost.

The farms visited (shown in Figure 4) have been termed as potential agroforestry systems because they have unrealised ability to be a fully integrated system. More detail about the farms included in the study can be found in Appendix 1. The visited farms have all the ingredients/qualities/abilities for instance enough land, trees, crops, livestock that may be developed and lead to a fully integrated agroforestry system. Hence, most of the farms visited in the Limpopo Province were classified as timber-based mixed farming/farm mosaic, and only a few were classified as agroforestry systems.

The study also found that most smallholder farmers were classified as timber-based mixed farmers and commercial farmers were classified under agroforestry systems because there was a clear indication of integration between the different components being trees, crops, livestock and/or bees. These findings are also in line with the study conducted in the Eastern Panama on agroforestry versus farm mosaic systems (Paul et al., 2017). The question is still debated among various stakeholders on exactly how such an integration of trees to diversify farm portfolios should be designed. Hence according to Odum (1969), Nair (1985), Price (1995), Nair and Garrity (2012) and Maponya et al. (2018) two major strategies are of importance: 1) the direct mixing of trees and crops on the same piece of land in a spatial or temporal sequence, known as agroforestry, and 2) a "coarse-level mixing" of trees and crops on separated parcels or "compartments" within a farm, which is referred to as farm mosaic or in some instances timber-based mixed farming.

Photograph 1 Introduction of groundnuts into plantations – examples of agroforestry practices introduced into the MTO Plantations at White River.

Photograph 2 Example of a woodlot of a small grower woodlot (Source: BA Letty)

Table 1 Summary of agroforestry/TBMF systems included in the study

Agroforestry/TBMF system	No. of respondents	Percentage
Agrosilvipasture	23	35,38
Apiculture	1	1,54
Agrosilvipasture & Apiculture	6	9,23
Silvipasture	32	49,23
Agrosilviculture	3	4,62
Total	**65**	**100**

4.3 Land use for different components of farming systems.

As indicated in Figure 5 and Figure 6, the majority of respondents were identified within Vhembe District Municipality. The same trend is observed at a local municipality level where Thulamela local municipality in the Vhembe district had the most respondents followed by the Molemole local municipality in the Capricorn district.

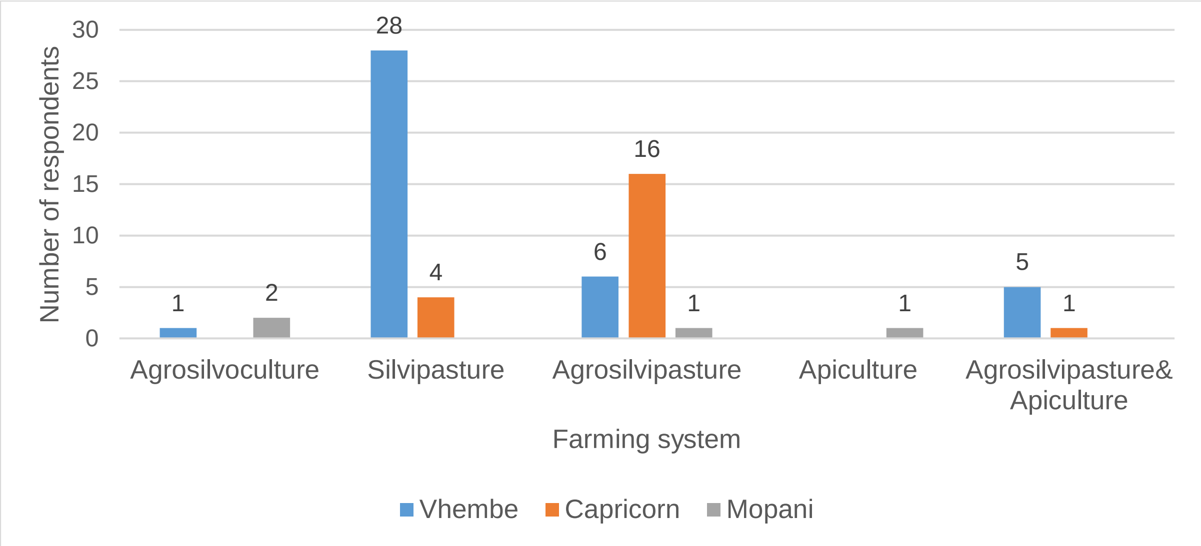

Figure 5 Number of respondents (categorised by farming system) identified per district municipality within Limpopo Province

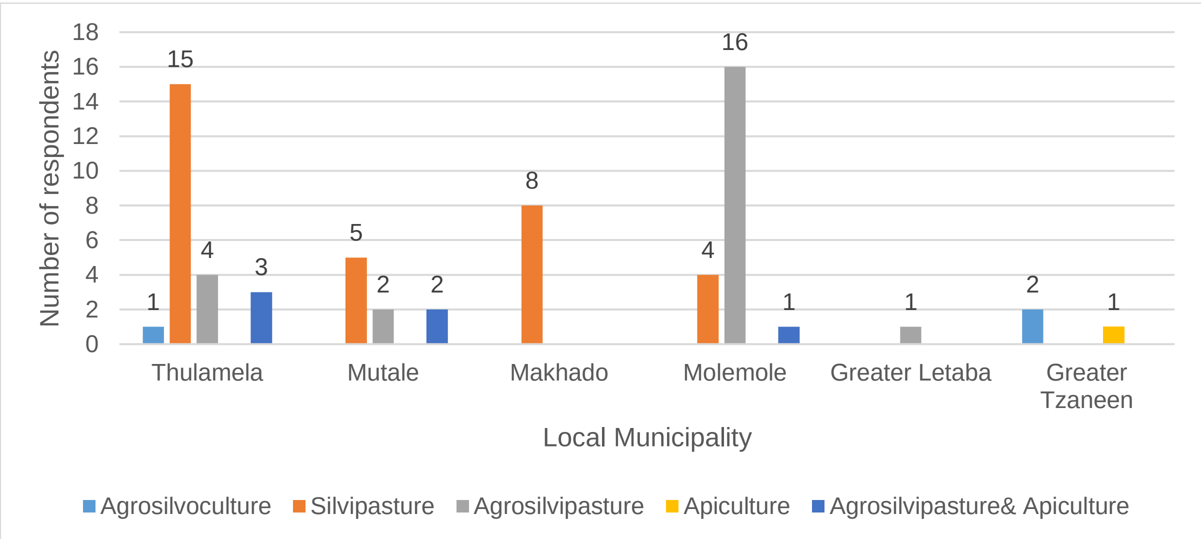

Figure 6 Number of respondents (categorised by farming system) identified per local municipality within Limpopo Province

The information pertaining to the 65 farms included in the study is summarised in Table 2. It should be noted that generally the area planted to timber is the same area used for grazing livestock or apiculture. The situation is different for crop production because in a minority of cases the crop production is integrated within the timber production area (true agroforestry) while in other cases it is adjacent to the timber and these systems are thus referred to as timber-based mixed farming systems.

Table 2 Summary of land areas (hectares) used for various enterprises within agroforestry/TBMF systems

Variable	Trees	Crops	Livestock	Apiculture
No. of respondents	65	32	61	7
Mean area used per farm (ha)	146,29	15,06	154,15	37,86
Total area	**9509**	**482**	**9403**	**265**
Minimum area (ha)	3	0,5		
Maximum area (ha)	1500	195		
Respondents per size category				
10 ha or less	22	23		
11-50 ha	18	8		
51-150 ha	12			
151-400 ha	7	1		
401-1000 ha	4			
>1000 ha	2			
Total	**65**	**32**		

The areas of land used for trees, crops, livestock and apiculture are summarised per farming system in Table 3. All of the households recorded having trees because they were all identified through a database of small timber growers. It is interesting to note that most of the households (61) also owned some form of livestock. There were only 7 respondents that were keeping bees (apiculture), which reflects that it is an activity that requires specific skills and investment in equipment. Again, it should be noted that the reason for similar areas for trees and for livestock is that the livestock are being grazed within the plantations.

Table 3 Land usage per enterprise for the different agroforestry/TBMF systems

Farming system	Trees (ha)	Crops (ha)	Livestock (ha)	Bees (ha)
Agrosilvipasture	5552	225	5703	0
Agrosilvipasture + Apiculture	128	45	165	165
Agrosilvoculture	230	212	0	0
Apiculture	80	210	0	100
Silvipasture	3518,9	0	3534,9	0
Total	9508,9	692	9402,9	265

4.4 Biophysical characteristics of Agroforestry/TBMF Systems in Limpopo Province

4.4.1 Soil conditions

According to ARC (2017), fairly large tracts of moderately deep to deep, well drained loam or clay loam soils are found in the Tzaneen area, the alluvial valleys of the major rivers, a belt between Tzaneen and Phalaborwa, and in areas between Phalaborwa and the Kruger National Park. Although the bulk of the lowveld area is dominated by shallow soils, sporadic occurrences of deeper soils occur. There is thus an overabundance of good soils in the Mopani District. As indicated in Figure 7 and Figure 8 (focusing specifically on the area enclosed in the black rectangle where the study sites were located), the potential agroforestry systems visited in the Mopani District falls in well-drained soil with soil depths of 901-1200 mm. Moderately deep to deep (901-1200 mm), well-drained loamy or clay loam soils occur commonly in the escarpment and Soutpansberg areas, as well as sporadically across the Vhembe District. Good soils are thus in overabundance. Moderately deep to deep (901-1200 mm), well-drained, sandy or loamy soils are fairly widespread to the west and south of the Polokwane plateau, although good soils are rare on the Polokwane plateau itself. Similarly, timber-based agroforestry systems visited in some parts of Capricorn were found in well drained soils with soil depths of 601-900 mm.

4.4.2 Temperature

Temperature is one of the climate variables that affect all organisms involved in an agroforestry system, possibly in very different ways (Luedeling, 2013).The temperatures in the study site are mild to moderate, with lowest temperatures being experienced in July (mean minimum temperature >6^{o}C) and highest in January (mean maximum temperature <28^{o}C) as shown in Table 4. It is clear from the information provided that this area generally does not receive frost. This temperature range offered good conditions for integration of most crops in the potential AFS. Additional information related to temperatures across the province and within the study sites are presented in Appendix 3

Table 4 Summary of monthly temperature for the study sites (Schulze 2007)

Month	Min	Max	Ave
January	17,22	28,06	22,91
February	17,93	27,78	22,82
March	16,48	26,95	21,69
April	13,75	25,67	19,69
May	9,9	23,74	16,79
June	6,89	21,55	14,19
July	6,7	21,36	14
August	8,4	23,2	15,78
September	11,81	26	18,88
October	14,37	26,91	20,62
November	16,14	27,51	21,8
December	17,22	27,99	22,58

More detail pertaining to the methods used for generating information used in this study is contained in Appendix 2.

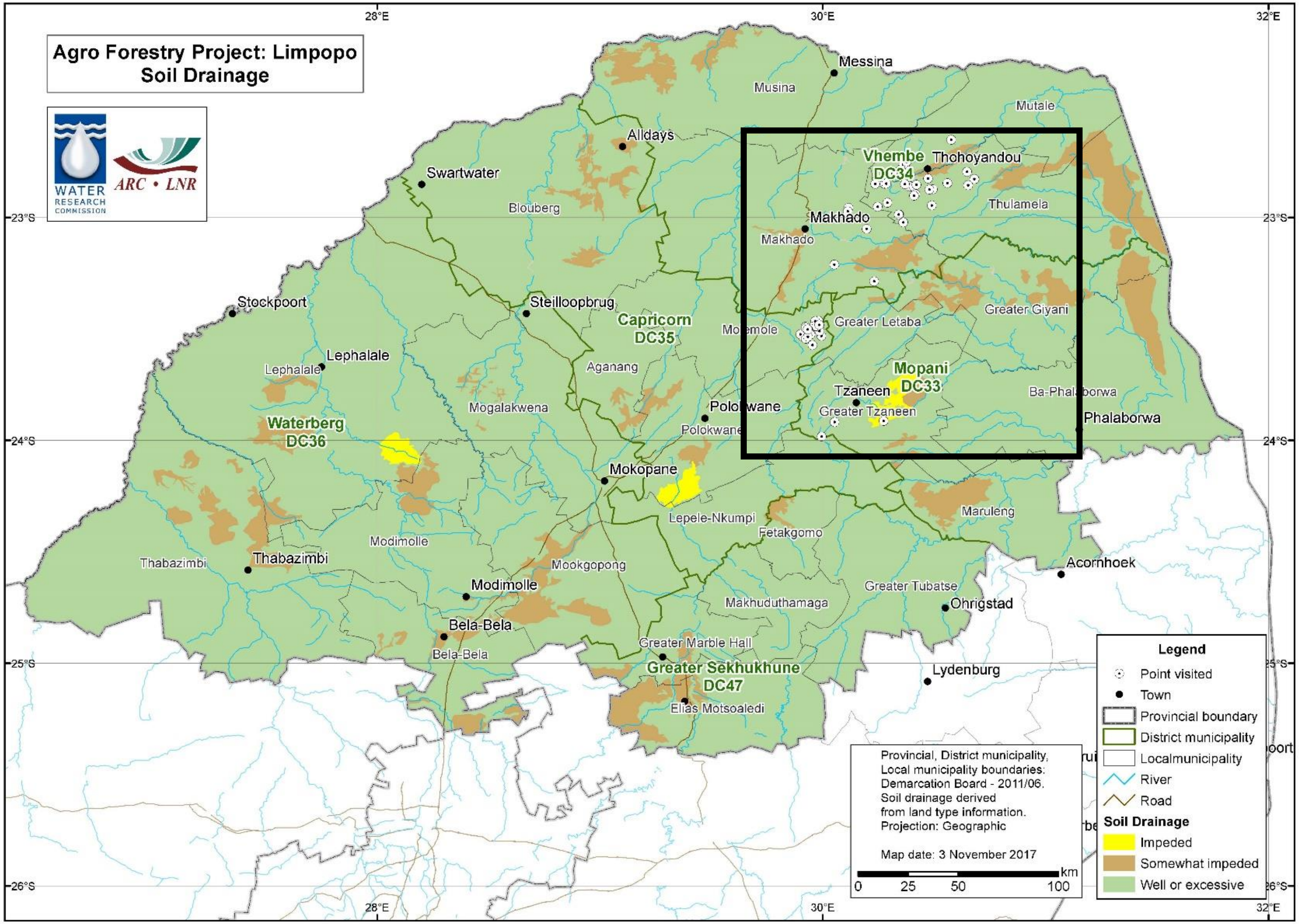

Figure 7 Limpopo Province soil drainage showing the position of the study sites (ARC-SCW, 2017).

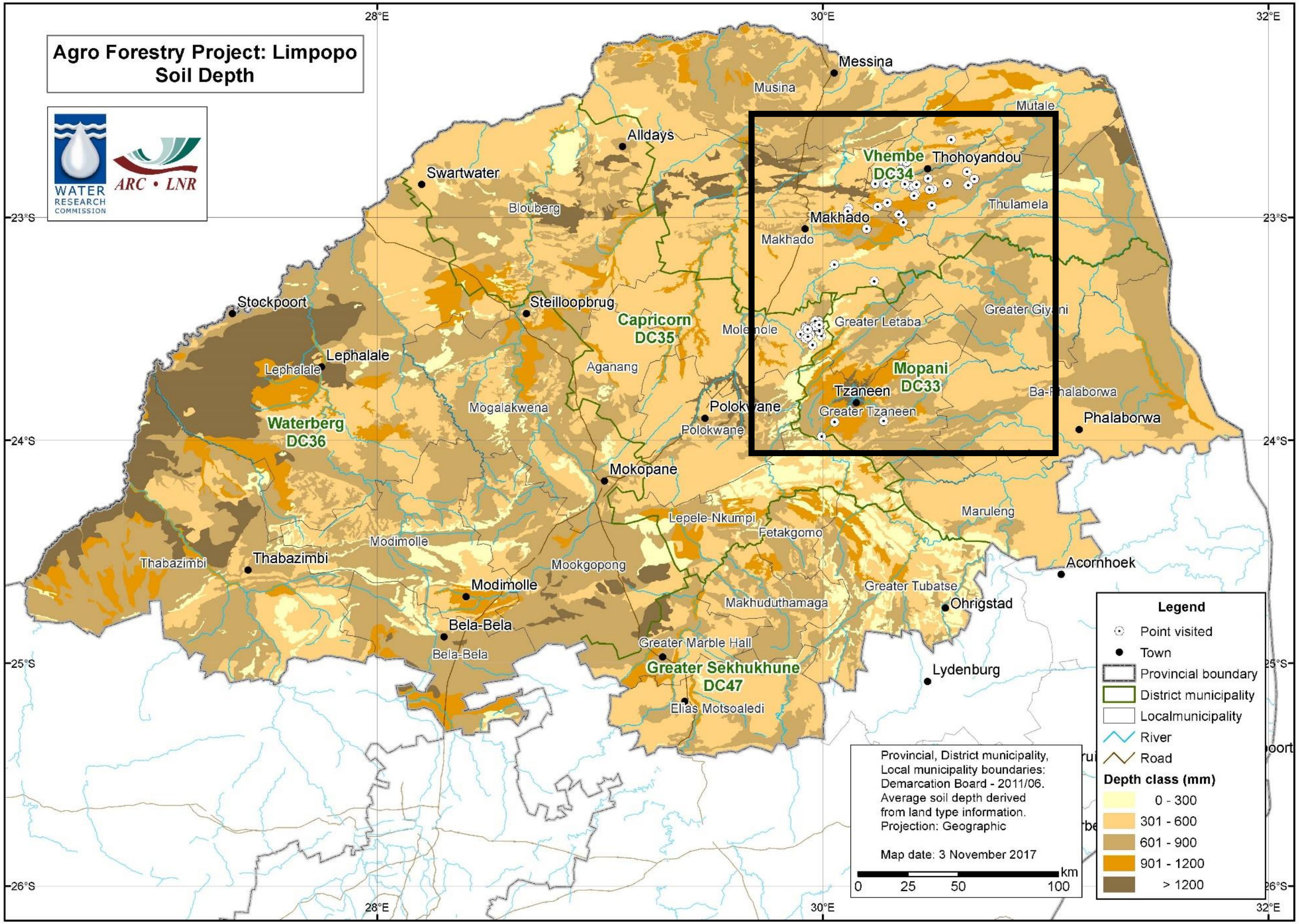

Figure 8 Limpopo Province soil depth showing the position of the study sites (ARC-SCW, 2017)

4.4.3 Climatic extremes

The incidence of climatic extremes was investigated as they have an adverse effect on the different components of agroforestry / TBMF systems. Respondents were whether they had been affected by drought and fire. The majority of respondents (56) in the identified areas indicated that they are affected by drought and fire, as shown in Figure 9. A total of 31 respondents (47.69%) recalled incidences of fire affecting their farms. These results are in line with the study conducted by Arca et al. (2019) in the Mediterranean basin, who indicated that wildfires represent one of the most extensive disturbances of the agroforestry systems, as for other land use systems.

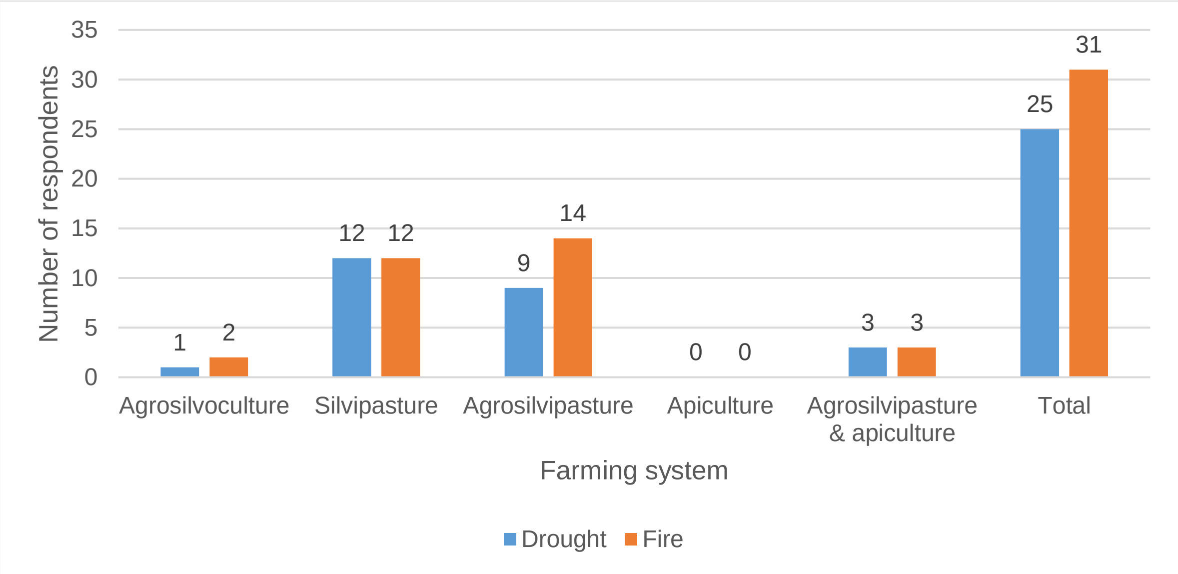

Figure 9 Number of respondents indicating that they are affected by climatic extremes (specifically fire and drought).

Fire is one of the disasters that has affected the farming systems of the respondents. Most respondents recall fires occurring in 2015 as shown in Figure 10. Farmers explained that the fire burned trees, crops, destroyed infrastructure, livestock and the damage ranked in millions of Rands. It must also be emphasised that support was received from the Limpopo Province N1 firefighters in putting out the fires. It was also note that no preparedness plan or fire breaks were available to the affected farmers as mandated by the National Disaster Management Act 57 of 2002. It is clear that efforts need to made to assist TBMF / agroforestry farmers with fire management if these are farming systems are to be promoted by government as fires can destroy the timber component.

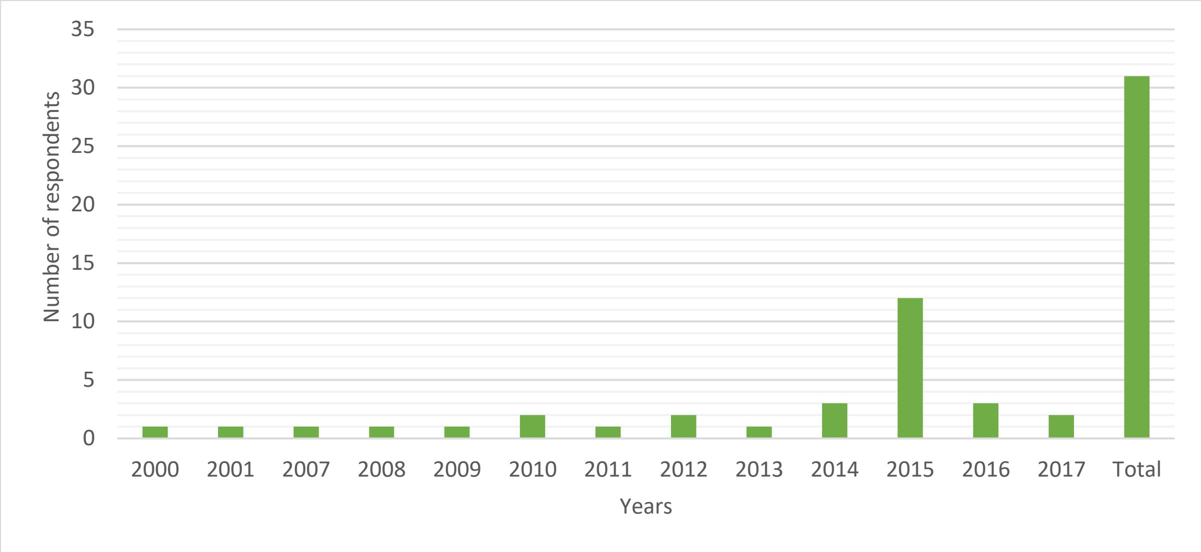

Figure 10 Recollection of the incidence of fire occurrence for the period 2000 to 2017.

Drought is another climate extreme that has implications for crops, timber and livestock. While the surveyed households were generally within relatively high rainfall areas, more than one third of respondents reported being affected by droughts. As indicated in Figure 11, drought had affected most of the respondents in 2016. This situation affected grazing, destroyed crops and plantations and resulted in low production in the affected areas. The farmers indicated that no/little support was received from government and they do not have any preparedness plan for future droughts. According to SAWS (2016), the 2015/2016 drought was one of the worst in the history of Southern Africa, with the country receiving the lowest rainfall since 1904. Eight South African provinces have been, or had some of their areas declared as disaster areas, except for the Gauteng Province. The situation threw the country into a panic mode as the water scarcity debate took centre stage with every sector looking for ways of conserving water.

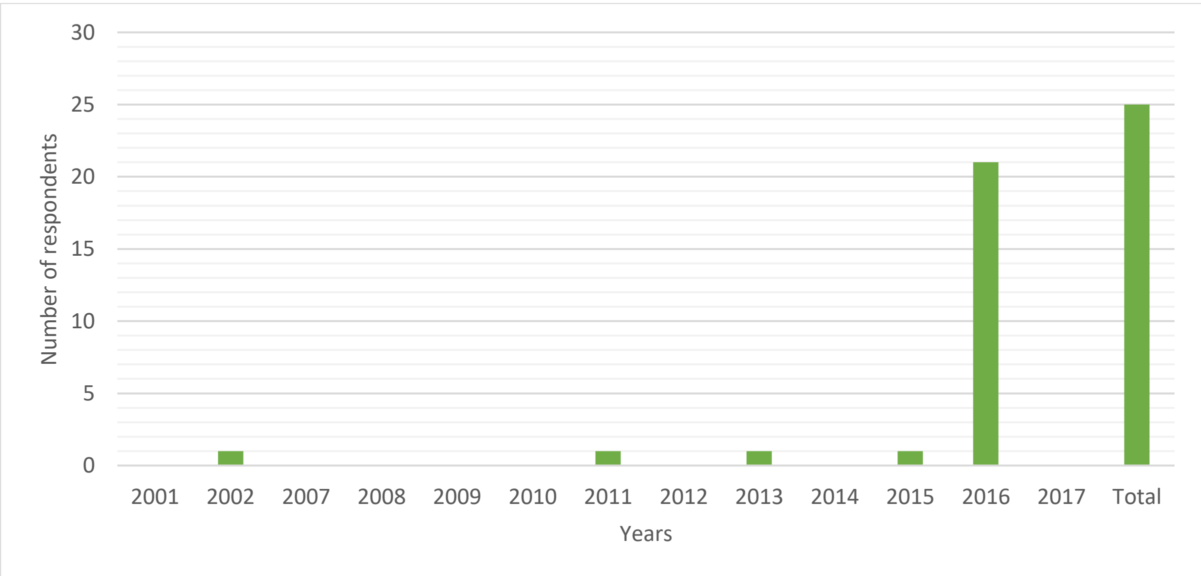

Figure 11 Respondents recollection of years when drought was experienced.

4.5 Socio economic characteristics of farmers

4.5.1 Socio-economic characteristics of farmers interviewed

This section of the report covers the socio-economic characteristics of the farmers that were gathered during the interviews. It covers demographics (gender, age, education, experience, land acquisition land tenure), access to extension support and research, financial support, sources of agricultural income, marketing of produce, and farmers' perceptions about the sector.

4.5.1.1 Demographic information

The majority of farmers interviewed were men, and these men are involved in agroforestry activities. According to Table 5, fifty-one men were interviewed as compared to fourteen females. This implies that any developmental strategy for the farmers in the areas will benefit more males than females. The interview procedure aimed at interviewing farmers affiliated to Forestry SA small growers, who happened to be dominated by men. Any future programmes would need to consider the roles that women play in these systems as they are very likely to be involved in household crop production. All farmers interviewed were black South African citizens. In terms of educational attainment (Table 5), 9 farmers had no education, 20 of the farmers completed primary education, 27 secondary education and 9 tertiary education. The educational levels of the farmers were generally good. Almost all farmers attended the secondary and tertiary education level. These results indicated that educational level of the selected farmers is generally adequate to enable interpretation and understanding of basic farming activities. It is expected of farmers with tertiary education to at least interpret and understand different farming principles to make informed decisions on general farming operations and to be able to negotiate contracts better than beneficiaries with lower education levels. The research done previously shows that farmers who have basic education are far better compared to farmers that do not have an education at all. The farmers are likely to be able to make strategic or informed decisions based on their understanding of agroforestry setups, and also the situations that they find themselves in (Maponya and Mpandeli, 2013).

According to Maponya et al. (2016), training and education plays an important role in smallholder farmer development. Failure to address some of the training needs has led to constrained agricultural growth in some districts in South Africa (Maponya et al., 2014 and Maponya et al., 2015). As indicated in Table 5, only 24 farmers received training, whereas the majority of farmers had not received any training. The results showed variation amongst farmers in terms of agroforestry experience acquired over time (Table 5). The majority of farmers (30) had more than ten years of experience, while 21 and 14 farmers had less than five years and six to ten years of experience, respectively.

As highlighted in the literature review, land tenure is often seen as a key factor impacting on the success of forestry and farming systems that incorporate timber because of the time required for the trees to reach maturity. Results in Table 5 indicate that the majority of farmers are making use of land that they acquired through Permissions to Occupy (PTOs) (25), while others received land through the following: bought (9), government (14), leased (11), renting (6), and inheritance (2). The role of traditional leaders must be recognised as the majority of farmers had PTOs.

Table 5 Demographics of the 65 respondents interviewed in Limpopo Province

Variables	Respondents	% of Respondents
Gender		
Female	14	21.5
Male	51	78.5
Level of Education		
No Education	9	13.8
Primary Education	20	30.8
Secondary Education	27	41.5
Tertiary Education	9	13.8
Training Skills Acquired		
Yes	24	40
No	41	60
Agroforestry Experience		
Less than Five Years	21	32
Six to Ten Years	14	22
More than Ten Years	30	46
Land tenure/ Acquisition		
Bought	9	14
Leased	11	17
Inherited	2	3
Government	14	22
Permission to Occupy	23	35
Renting	6	9

4.5.1.2 Research, extension services and training of farmers

As mentioned earlier in the report, the national agroforestry strategy (DAFF, 2017) states that centres of excellence should be identified and established as lead research agents in agroforestry systems, conducting research on technical, social, environmental and economic elements of agroforestry, with a particular focus on shared learning and participatory action research. Given that most farmers interviewed (70.8%) indicated that they had no access to research, such interventions are of importance and it is against this backdrop that the current research was initiated.

In terms of access to extension services, 36 of the respondents (55.4%) indicated that they did not receive support. Most of the farmers that were receiving extension services, did so through formal extension services, i.e. National, Provincial and Municipal Departments of Agriculture. This situation needs improvement, especially for those who are not accessing extension services, and needs to be encouraged as Mmbengwa (2009) and Maponya and Mpandeli (2013) emphasised that extension services have an important role in assisting farmers to acquire new technology, skills, innovation and production advice. It was also established by Maponya et al. (2018) that farmers need more information and training on agroforestry relative to other agricultural activities, which limits the spread of some practices. The majority of farmers visited in the Limpopo Province often lack skills to establish tree and shrub nurseries, pre-treat the seeds, carry out tree pruning activities and the integration of trees/crops/livestock/bees (Maponya et al., 2018). However, extension strategies, including field schools, exchange visits and farmer training, are effective ways of disseminating needed information. The demonstration training trials described below were an active effort on the part of the project team to address the need for information and skills development.

4.5.1.3 Financial support for agriculture

All farmers indicated that they had not received any financial support (loan, grant and subsidy) either from commercial banks, government and agricultural cooperatives. It must also be emphasised that some farmers were reluctant to disclose their financial support as some thought it will jeopardise their chances of receiving additional support from government and any other financial institutions.

4.5.1.4 Prices obtained for timber

As indicated in Table 6, respondents obtained different prices per ton for their timber. The prices obtained were dependent on factors such as the distance to the mill. The sale of timber indicates that trees are serving as an important source of income. In addition to sale of the wood to mills, communities were using some of the trees to build shelters and kraals, for medicinal purposes, for fuelwood, etc. It must also be emphasised that some farmers were reluctant to disclose their farm income as though it might jeopardise their chances of receiving support from government and thus prices were only obtained from 54 respondents.

Table 6 Price per ton obtained by 54 respondents for timber sold

Price obtained (Rands per ton)	Number of respondents
300	1
400	3
500	9
600	4
700	6
750	1
800	12
850	1
900	17

4.5.1.5 Income from grazing rentals

As indicated in Table 7, some farmers (86% of the respondents that answered this question) were generating income from rentals paid by people grazing cattle within their timber. These monthly rentals ranged from R1000 to R9000. This is likely to be one of the reasons why silvipasture and agrosilvipasture remain the most popular systems in the identified areas (Table 1). It must also be emphasised that some farmers were reluctant to disclose their farm income for the reasons mentioned above.

Table 7 Monthly grazing rentals obtained by 56 respondents

Monthly income (Rands)	No. of respondents
0	8
1000	3
1500	8
1700	1
2000	18
3000	13
4000	3
4500	1
9000	1

4.5.1.6 Marketing of farm produce

Besides timber, the farmers that participated in the study were also producing a range of other products including livestock, crops and honey. They used different marketing channels to market their produce for various reasons, for example, many opted for informal markets for reasons such as inability to satisfy the quality standards in the formal markets, meanwhile most commercial farmers prefer formal markets for reasons such as a secured market with better returns. Figure 12 indicates that almost all farmers were selling their produce within local communities, while one indicated that their market included the local municipality and one mentioned international markets, being a commercial farmer. Due to poor record keeping of farmers, it was difficult to quantify their market information.

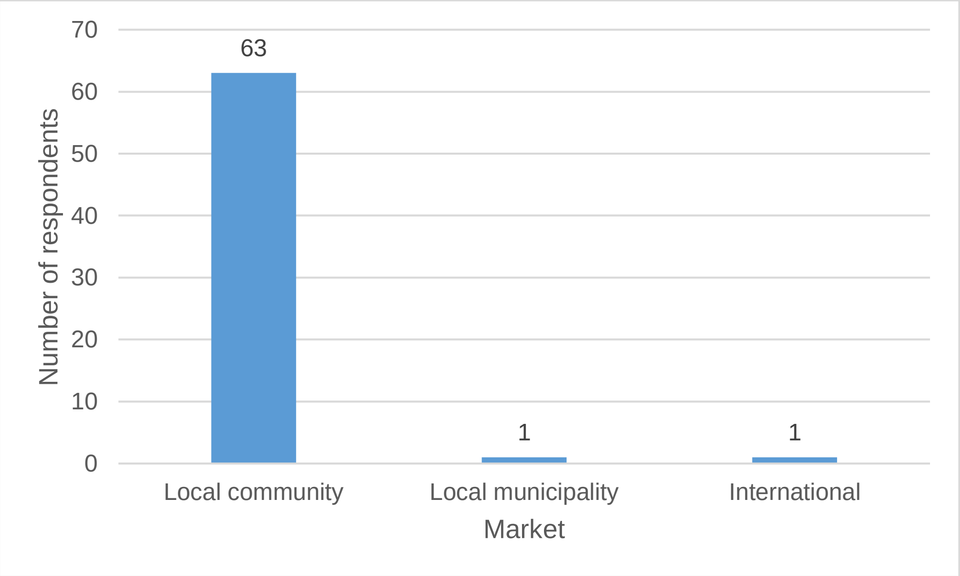

Figure 12 Markets for non-timber products from agroforestry/TBMF systems.

4.5.2 Perceptions on constraints to agroforestry/TBMF competitiveness

It is suggested that agroforestry projects can only be successful if the diversity of socio-economic characteristics of smallholders as well as their perceptions are considered when they are designed (Sanou et al. 2019). The interview process was designed to draw out respondents' perceptions about different factors that affected the competitiveness of their farming enterprises, specifically production factors, demand conditions, related and supporting industries, government support, characteristics of the firm (farm), market factors and chance events.

As indicated in Table 8, production factors were generally perceived to be causing a decrease in agroforestry competitiveness as majority of farmers either strongly agreed (total rating at 271) or agreed (total rating at 96) with the list of factors presented. There was a wide diversity in responses obtained, with a large number of farmers indicating that they were 'not sure'. The factors that were most frequently perceived to impact on competitiveness (i.e. 'strongly agree') were cost of production and labour – and specifically the availability of skilled labour.

Table 8 Production factors causing a decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing a decrease in competitiveness of agroforestry / TBMF systems	**Responses**				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Cost of production	11	10	10	7	27
Labour	7	14	10	7	27
Cost of unskilled labour	13	9	15	6	22
Quality of unskilled labour	6	19	14	7	19
Availability of unskilled labour	4	15	20	9	17
Cost of skilled labour	6	13	13	9	24
Availability of skilled labour	3	20	9	7	26
Administration cost associated with labour	7	16	15	5	22
Insufficient source of water	7	19	15	6	18
Infrastructure	13	15	12	5	20
Lack of knowledge	4	19	15	10	17
Lack of Technology	7	17	20	6	15
Capital / Finance	9	13	14	12	17
Total Responses	**97**	**199**	**182**	**96**	**271**

As indicated in Table 9, a range of demand conditions was perceived to be causing a decrease in competitiveness as the majority of farmers strongly agreed (total rating at 94) and agreed (total rating at 35). Among these conditions, distance to the market (strongly agreed by 23 farmers) and cost to market (strongly agreed by 23 farmers) were perceived as the factors mostly causing a decrease in competitiveness. However, quite a number of farmers perceived demand conditions as not causing any decrease in competitiveness or were 'not sure'.

Table 9 Demand conditions causing a decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing a decrease in competitiveness of Agroforestry/TBMF	Responses				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Distance to market	8	16	15	3	23
Market information	14	11	15	6	19
Cost to the market	5	13	17	7	23
Quality of products	6	14	18	10	17
Market for agroforestry	8	16	16	9	12
Total Responses	**41**	**70**	**81**	**35**	**94**

As indicated in Table 10, the results suggest that the respondents largely perceived that related and supporting industries were causing a decrease in competitiveness of their enterprises. The values obtained for financial institutions and suppliers, suggest that these are supporting industries that farmers are most familiar with – or whose services they best understand.

Table 10 Related and supporting industries causing a decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing the decrease in competitiveness of agroforestry/TBMF	Responses				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Financial institutions	6	16	11	9	23
Research institutions	11	10	12	15	17
Suppliers	8	14	15	6	22
Electricity suppliers	11	15	15	6	18
Total Responses	**36**	**55**	**53**	**36**	**80**

As indicated in Table 11, government support was perceived to cause a decrease in competitiveness as the majority of farmers strongly agreed (total rating at 122) and agreed (total rating at 57). Among the government support, indirect support and trade policy were perceived as the factors mostly causing a decrease in competitiveness. However, quite a number of farmers perceived government support as not causing any decrease in competitiveness. The high number indicating 'not sure' suggest that these were forms of government support that they had not encountered and which they did not understand

Table 11 Government support causing a decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing the decrease in competitiveness of agroforestry/TBMF	**Responses**				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Poor interaction & support between Government	11	16	11	6	21
Indirect support	15	9	11	7	23
Trade policy	6	17	12	8	22
Land reform policy	6	18	9	13	19
Labour policy	6	14	11	14	20
Fiscal policy	1	18	20	9	17
Total Responses	**45**	**92**	**74**	**57**	**122**

As indicated in Table 12, firm strategy, structure and rivalry – which refers to the strengths of the enterprise – were perceived to be causing a decrease in competitiveness as the majority of farmers strongly agreed (Total rating at 88) and agreed (Total rating at 47). Among the firm strategy, structure and rivalry, culture (strongly agreed by 20 farmers) and pricing strategy (strongly agreed by 19 farmers) were perceived as the factors mostly causing decrease in competitiveness. However, quite a number of farmers perceived firm strategy, structure and rivalry as not causing any decrease in competitiveness (strongly disagree by a total rating of 33 and disagree by a total rating of 82). A total of 75 of the total rating fell in the 'not sure' response. The spread of responses across the categories and the high highlights that the respondents were very unfamiliar with the terms and concepts presented to them. It suggests that farmers have not engaged in any processes that allow them to reflect on their own farming enterprises.

Table 12 Firm strategy, structure and rivalry causing a decrease in agroforestry/TBMF competitiveness

Views	**Responses**				
The following production factors are causing the decrease in competitiveness of agroforestry/TBMF	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Adaptability	10	16	10	11	18
Culture	6	15	12	12	20
Structure	6	14	19	11	15
Flexibility	4	19	18	8	16
Pricing strategy	7	18	16	5	19
Total Responses	**33**	**82**	**75**	**47**	**88**

As indicated in Table 13, market factors were perceived to be causing a decrease in competitiveness as majority of farmers strongly agreed (total rating at 83) and agreed (total rating at 32). Among market factors, market power of buyers (strongly agreed by 22 farmers) and threat of substitutes (strongly agreed by 22 farmers) were perceived as the factors mostly causing a decrease in competitiveness. Since many of the respondents were referring to marketing of timber, it is understandable that they would find market power of buyers (being the commercial mills) as impacting on their competitiveness because they are not able to negotiate around prices. However, quite a number of farmers perceived market as not causing any decrease in competitiveness (strongly disagree by a total rating of 22 and disagree by a total rating of 60). A total of 57 of total rating fell in the 'not sure' response. As with the factors in Table 12, this suggests that many of the respondents did not have sufficient understanding of these terms to be able to respond.

As indicated in Table 14, chance events were perceived to be causing a decrease in competitiveness as the majority of farmers strongly agreed (total rating at 183) and agreed (total rating at 79). Among chance events, fire (strongly agreed by 27 farmers) and aids, political stability and price stability (strongly agreed by 21 farmers) were perceived as the most factors causing a decrease in competitiveness. However, quite a number of farmers perceived chance events as not causing any decrease in competitiveness (strongly disagree by total rating of 56 and disagree by a total rating of 123). A large number of respondents (a total of 145) indicated that they were not sure whether the chance events listed would increase the competitiveness of their enterprises. While respondents may not have understood how factors such as political, economic and price stability can affect the competitiveness of an enterprise.

Table 13 Market factors causing a decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing the decrease in competitiveness of agroforestry/TBMF	**Responses**				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Market power of suppliers	9	19	10	6	21
Market power of buyers	8	12	15	8	22
Threat of substitutes	7	14	14	8	22
Threat of new substitutes	4	15	18	10	18
Total Responses	**28**	**60**	**57**	**32**	**83**

Table 14 Chance events causing decrease in agroforestry/TBMF competitiveness

Views The following production factors are causing the decrease in competitiveness of agroforestry/TBMF	Responses				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Economic stability	4	18	16	10	17
Aids	4	19	17	4	21
Political stability	4	18	11	11	21
Price stability	9	13	14	8	21
Crime	8	12	16	10	19
Drought	8	12	16	9	20
Floods	6	10	19	12	18
Fires	6	10	15	7	27
Frost	7	11	21	8	19
Total Responses	**56**	**123**	**145**	**79**	**183**

4.5.3 Agroforestry/TBMF systems SWOT analysis

A strength, weaknesses, opportunities and threats (SWOT) analysis was conducted to provide an accurate and relevant overview of what should be considered in taking agroforestry/TBMF systems forward in the identified areas. Some of the outcomes of the SWOT analysis are in line with the SWOT analysis conducted by Guiney (2016) for DAFF.

Table 15 A strength, weaknesses, opportunities and threats analysis of agroforestry/TBMF systems in Limpopo Province

Strengths	Weaknesses
• Increased agriculture / forestry production • Availability of land • Diversification of income and risk reduction • Climate change adaptation and mitigation benefits • Monetary benefits – increased income from agroforestry adoption (and in the shorter-term compared with timber)	• Management of projects is remote – many people on the ground needed, and increased management costs • Lack of national coordination of agroforestry interventions • Delayed benefits from agroforestry activities (Long term investment of 5-7 years) especially trees • Lack of focussed and documented research • Limited practical knowledge and applied research to address issues that affect agroforestry • Lack of on the ground technical skills • Skills shortage – management and administration of on the ground operations • Lack of monitoring and evaluation of agroforestry efforts
Opportunities	**Threats**
• Global carbon market (and other environmental service markets) • Increased land value – preservation of land productivity and restoration of degraded land • Potential linkages with conservation and climate smart agriculture • Co-benefits (socio-economic) such as honey production, and tourism, increased wildlife viewing • Markets for diverse goods	• No formal government agroforestry programme to support agroforestry • Climate change and climate variability • Lack of markets or incentives for ecosystem services or non-carbon benefits • Potential risks of fire and drought

The SWOT analysis provides a useful summary that justifies the promotion of TBMF/AF by government and other parties. It shows clear benefits for smallholder farmers of integrating other agricultural enterprises with their timber production – especially income generation while they wait for their timber to be old enough to harvest. The SWOT highlights that there is a need to upskill farmers as well support agents, while coordination of efforts of different stakeholders and effective monitoring of interventions. Finally, there is a need for government programmes that can promote the implementation of agroforestry practices while also taking advantages of opportunities that present themselves.

4.6 Potential constraints of rainfall for agroforestry/TBMF systems in the Limpopo Province

Timber-based mixed farming and agroforestry systems that have commercial timber species such as Eucalyptus as the woody component, are only suited to areas that receive sufficient rainfall to support production of the trees. In such areas, it is likely that there will be sufficient rainfall to support the other components of the system. This section of the report investigates long-term annual rainfall values as well as water surpluses / deficits within the study area.

4.6.1 Long term annual rainfall values

Long term rainfall values for the areas where the respondents were farming are presented in Table 16, while long term monthly averages for September to December are shown in Figure 13 to Figure 16. It is clear from Table 16 that most rainfall falls between the months of November to March, with the driest period being from June to August. While some rain is received in September, it is only in October that meaningful amounts are recorded. The long-term average for annual rainfall calculated for these areas from the models of Schulz (2007) is 551 mm.

Table 16 Summary of long-term monthly rainfall for the study sites (Schulze 2007)

Month	Min	Max	Ave
January	43	249	115,9
February	36	237	108,1
March	21	159	71,47
April	6	61	26,55
May	1	28	9,95
June	0	10	2,55
July	0	11	2,51
August	0	18	2,68
September	1	27	8,11
October	11	65	33,24
November	26	145	73,4
December	34	195	97,08

As indicated in Figure 13, the average rainfall for September is low (0-25 mm) for most parts of the Limpopo Province but for some parts of the Vhembe, Capricorn and Mopani Districts the average rainfall for September is a bit higher (20-50 mm and 51-75 mm). Most of the farms visited fell within those areas. As seen in Figure 14, the situation improves during October with an increase in rainfall (75-100 mm; 101-125 mm and 126-145 mm) in the study areas (Vhembe, Mopani and some of Capricorn). The study areas were experiencing 126-150 mm and 151-175 mm in November; 176-200 mm and 201-220 mm in December, respectively. This situation is not surprising as Forestry South Africa and DAFF have identified those districts as good for the establishment and expansion of agroforestry.

This trend offers a good platform for the establishment and expansion of agroforestry as rainwater is not a constraint as compared to other districts in the Limpopo Province (Waterberg, Sekhukhune and some parts of Capricorn). For example, Rethman et al. (2007) found that water resources remain a serious key problem in the establishment of agroforestry in some parts of the Limpopo Province. They documented that almost 97% of respondents in the Sekhakhane village, recognised water resource as a key problem, as did 71% of respondents in Chuene Maja village.

While current annual rainfall is sufficient to support timber and crop production, there is value in looking at likelihood of below average annual rainfall being experienced as this may limit opportunities for timber-based systems. The last three rainfall maps (Figure 17 to Figure 19) show the 33rd percentile, median (50th percentile) and 67th percentile. To explain what these maps depict, one can consider the 33rd percentile. *If there were 100 years of recorded data arranged in sequence from dry to wet, then the 33rd percentile would be the value of the 33rd year. In other words, the chances are good to exceed this rainfall, or the chances are small that you will have less rain*. The model estimated annual rainfalls for the broad study area at 601-700 mm for the 33rd percentile to 1001-2216 mm at the 66th percentile. Even at the 33rd percentile, these areas will allow for timber production and will thus support agroforestry / TBMF systems.

4.6.2 Water surplus/deficits

The Vhembe District Municipality covers part of the Limpopo, as well as parts of the Levuvhu and Letaba water management areas. With respect to Luvuvhu and Letaba, it occupies the Luvuvhu/Mutale sub-area and parts of the Shingwedzi and Klein Letaba sub-areas. In the Limpopo water management area, it occupies the Nwanedi and Nzhelele sub-areas apart from the Luvuvhu/Mutale area, where the new Nandoni Dam resulted in a temporary water surplus. As indicated in Figure 20 and Figure 21 the visited agroforestry and TBMF systems fall near the water bodies and this offers a good opportunity for establishment and expansion of different agroforestry systems. The same trend is seen in the Mopani District where the agroforestry systems fall within the Luvuvhu and Letaba water management areas. Luvuvhu/Mutale and Groot Letaba constitute important irrigation areas with high value crops.

Apart from water from the new Nandoni Dam, the surface water resources are over-extended and water for irrigation is being augmented by groundwater. As indicated in Figure 20 and Figure 21, the rivers and water bodies with their surpluses and deficits can be summarised as follows:

- ***Luvuvhu/Mutale****:* 12400 ha irrigated; yield of Alabasini Dam insufficient; high, but unmonitored groundwater use; short term surplus available following the completion of the Nandoni Dam; allocations being made for domestic water use and to revitalise irrigation schemes which have fallen into disuse.
- ***Klein Letaba:*** Surface water over-extended; 5100 ha irrigated; irrigation downstream of the Middle Letaba Dam in disuse due to decreasing assurance of water supply; targeted for revitalisation, despite insufficient water supply.

- ***Nzhelele**:* Surface water overexploited; water use dominated by irrigation; supplied by the Mutshedzi Dam, farm dams, run-of-river in the upper reaches of the catchment, and the Nzhelele Dam in the lower reaches; much of the irrigation managed by smallholder farmers.
- ***Nwaned**i:* Surface water overexploited; without major dams in the catchment area surface water resources are limited; ample groundwater resources, although use of it is limited; substantial irrigation, much of it managed by smallholder farmers.
- ***Groot Letaba:*** Surface water overextended; 19100 ha irrigated; groundwater supplementing irrigation supplies; irrigators upstream from the Tzaneen Dam experience relatively high level of assurance; users downstream experience shortages; irrigation highly efficient and well managed; scope for further improvements limited.

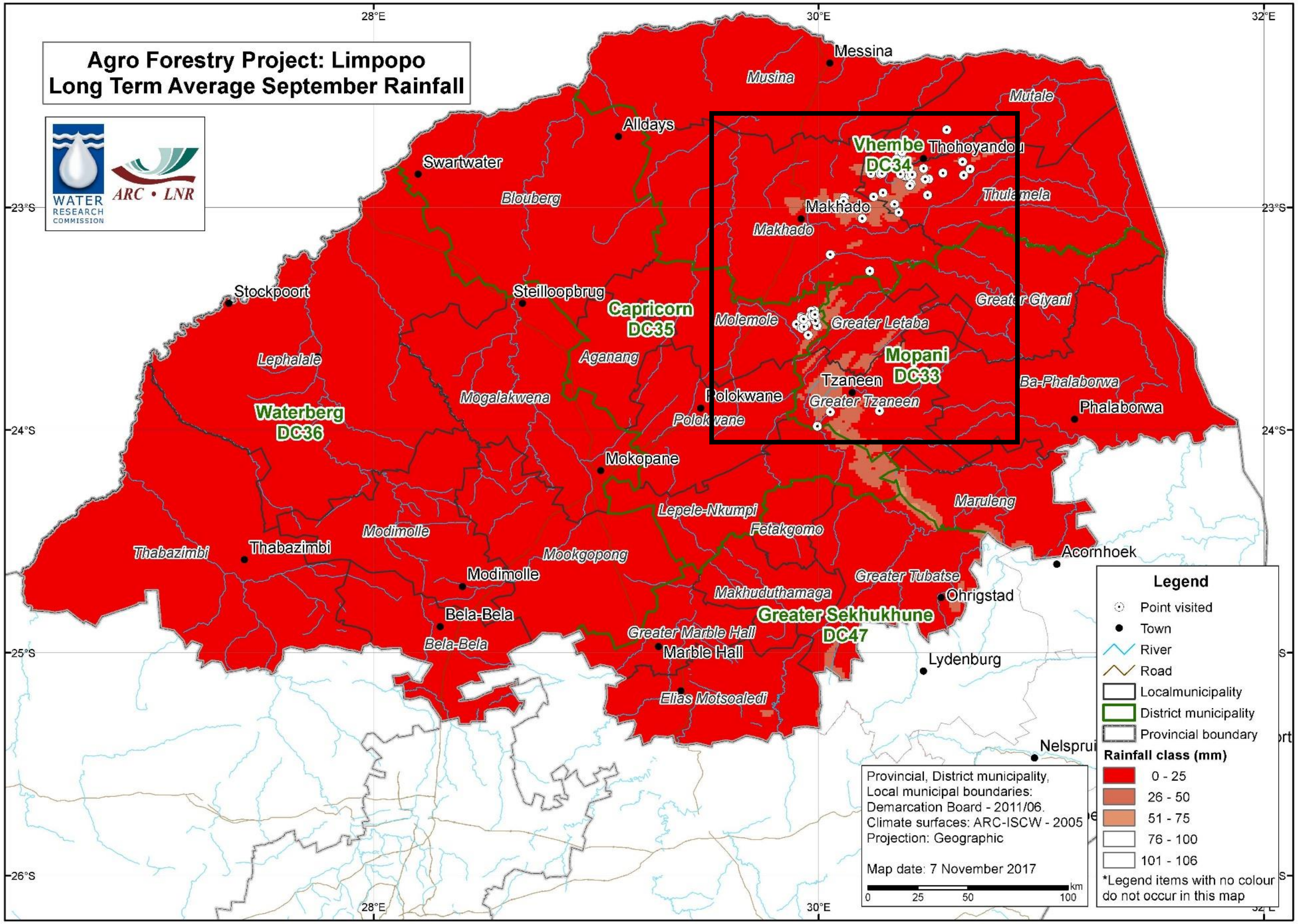

Figure 13 Limpopo Province long term average September rainfall (ARC-SCW, 2017)

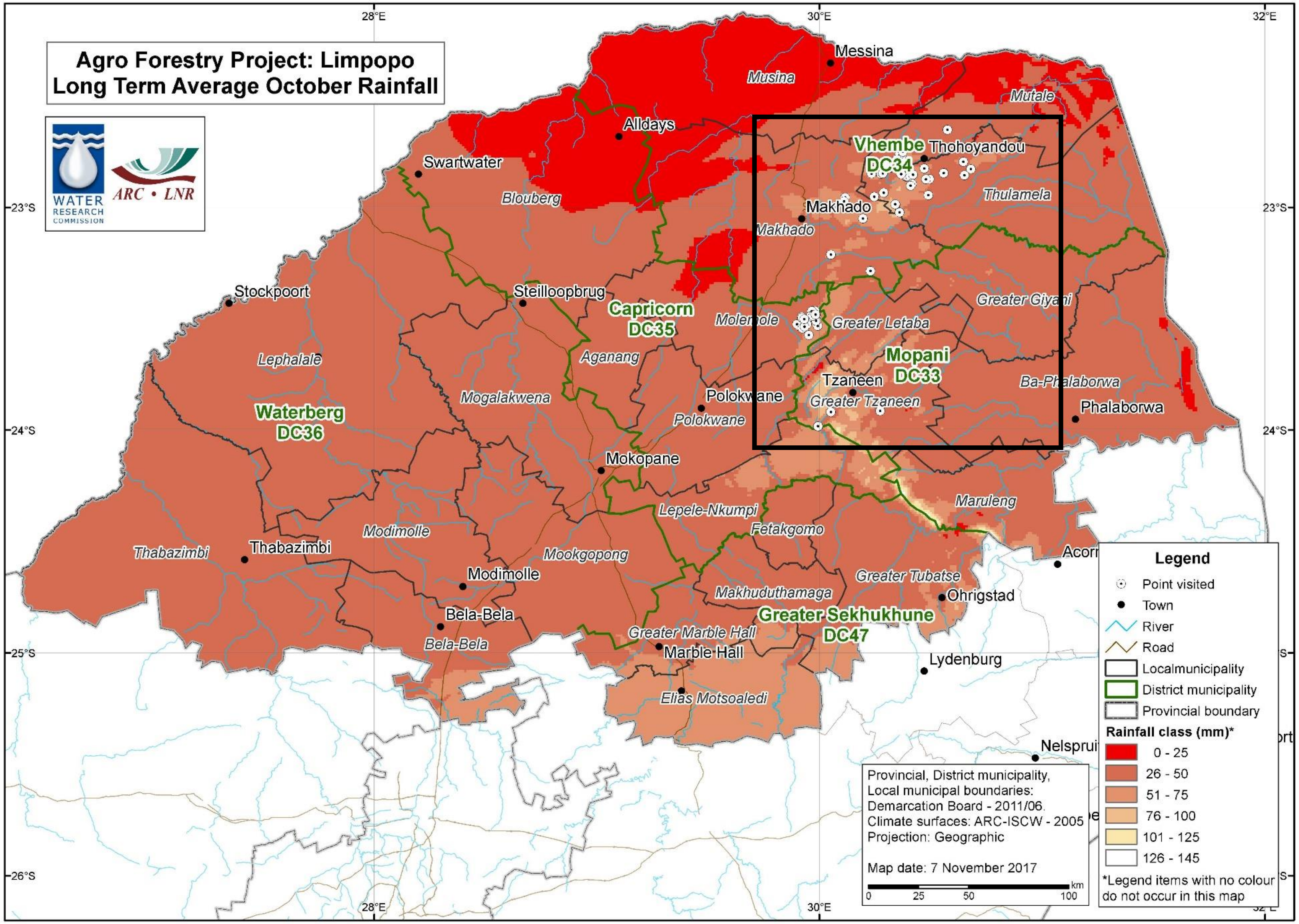

Figure 14 Limpopo Province long term average October rainfall (ARC-SCW, 2017).

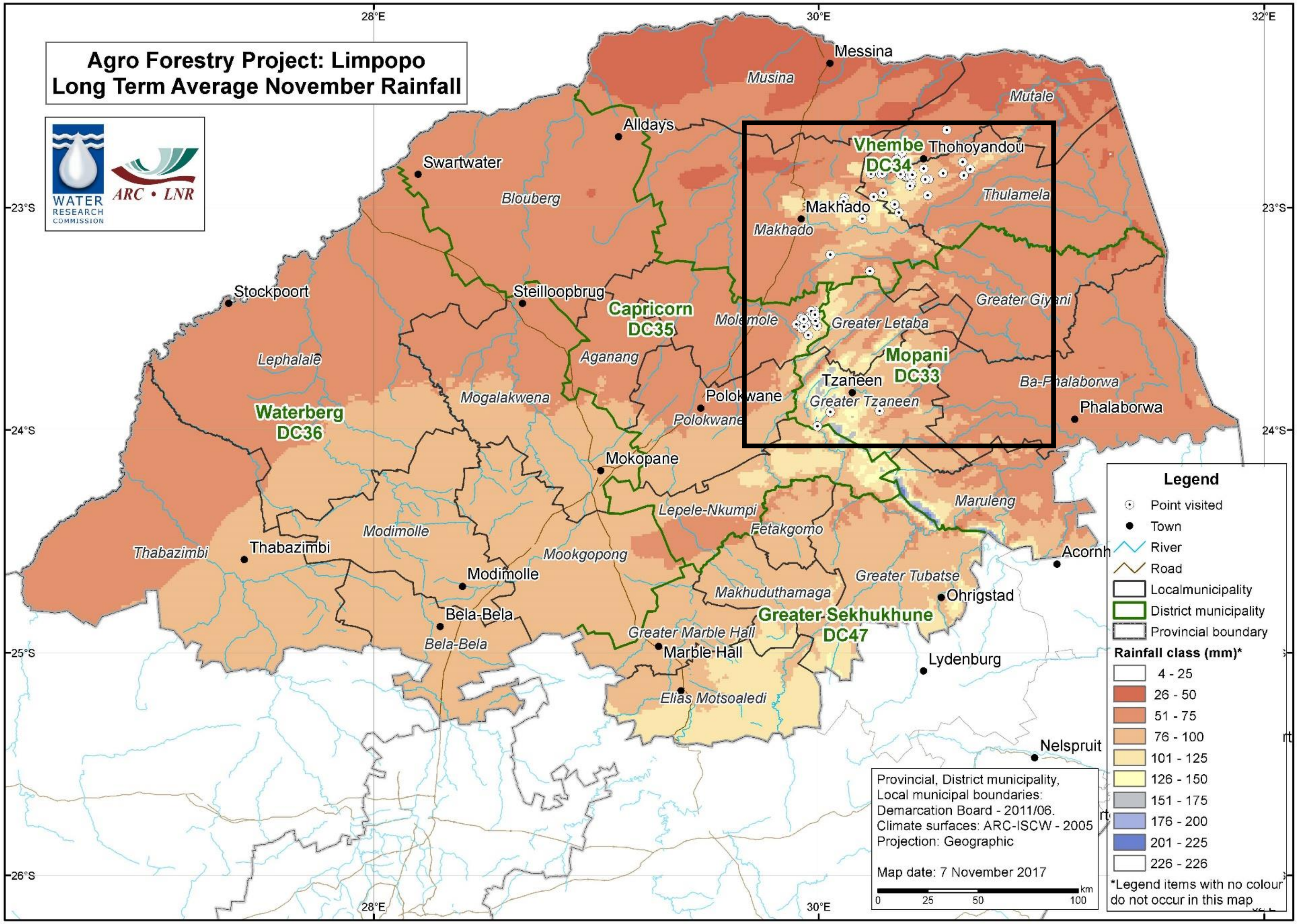

Figure 15 Limpopo Province long-term average November rainfall (ARC-SCW, 2017).

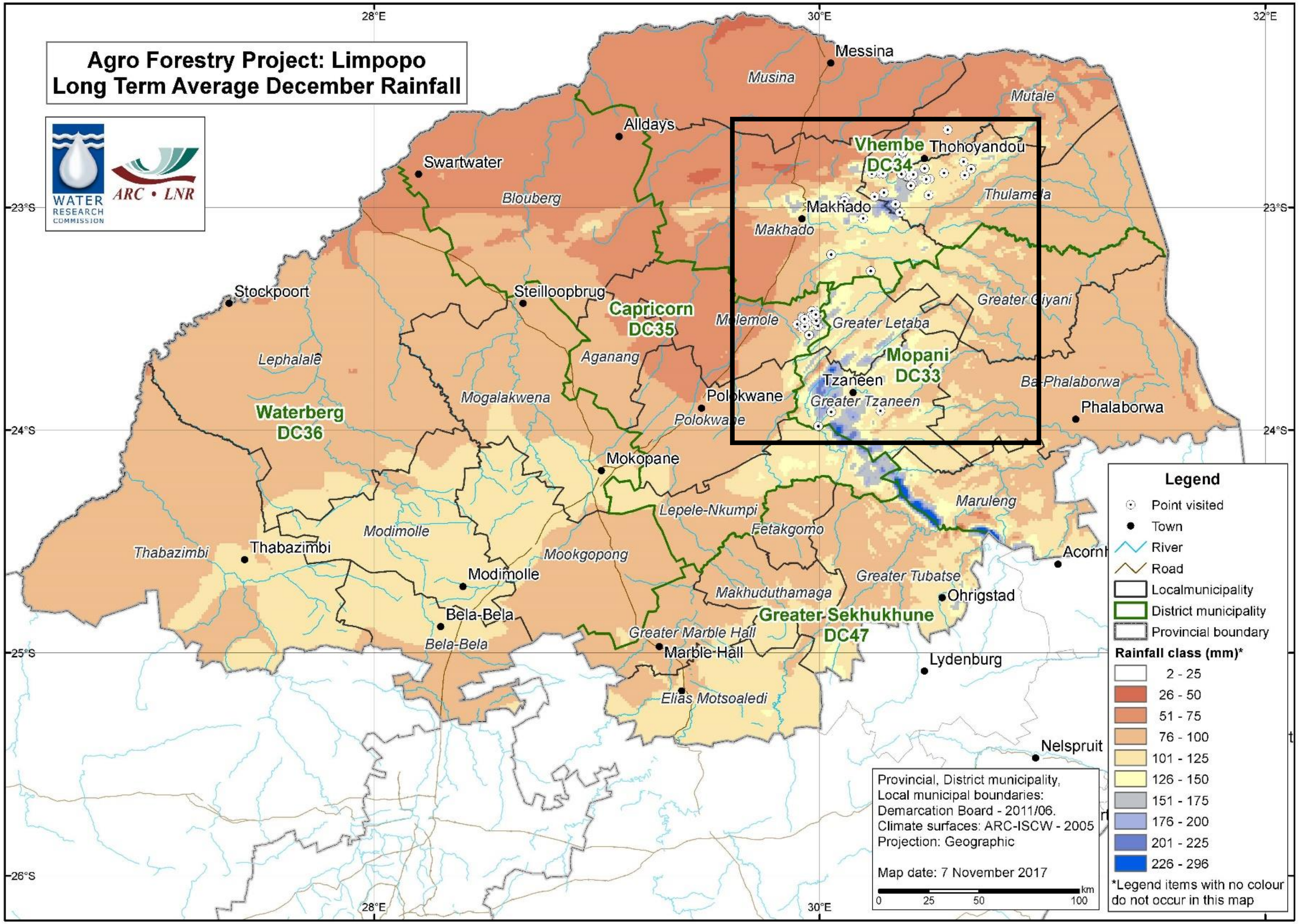

Figure 16 Limpopo Province long-term average December rainfall (ARC-SCW, 2017)

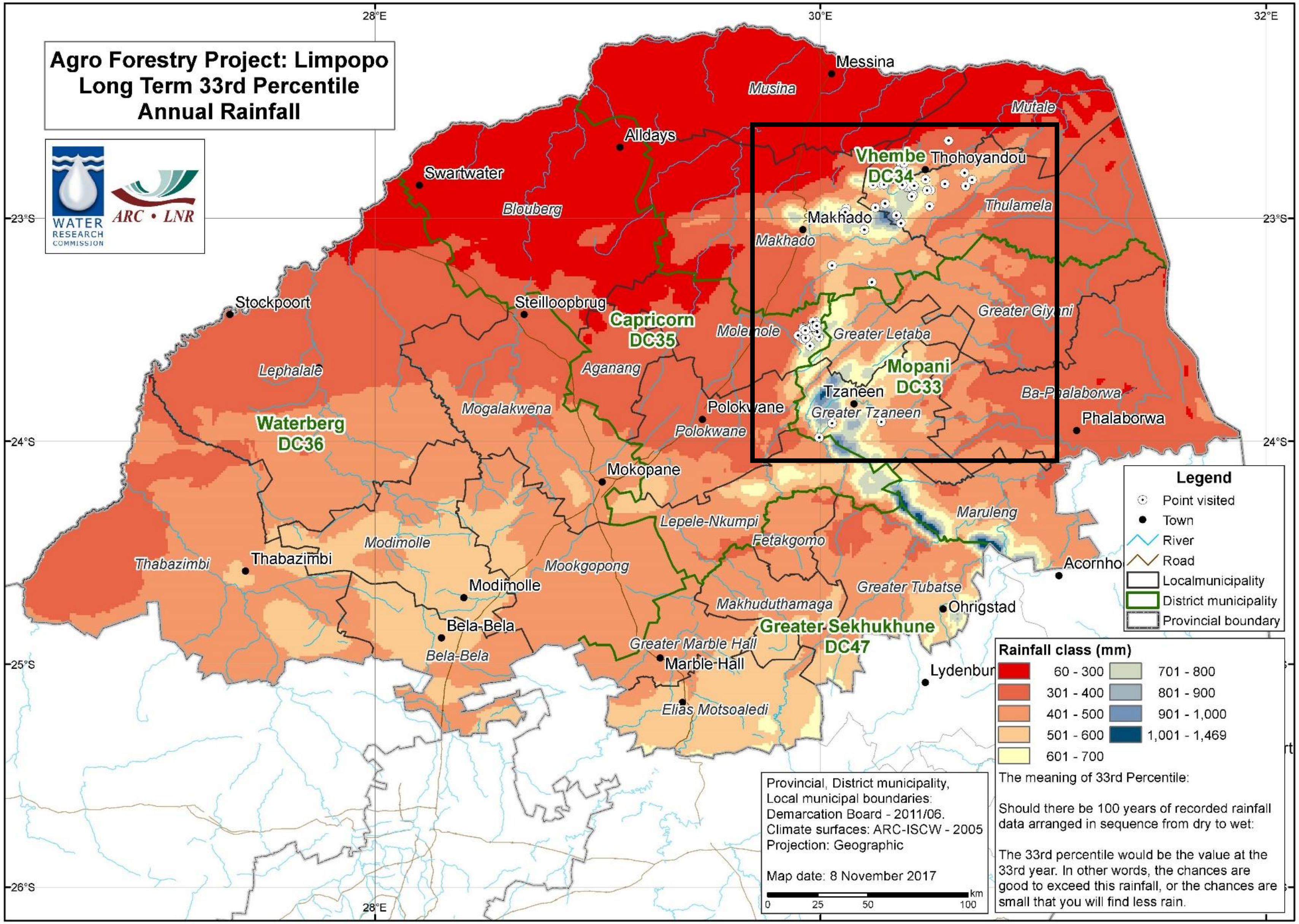

Figure 17 Limpopo Province long-term 33rd percentile annual rainfall (ARC-SCW, 2017)

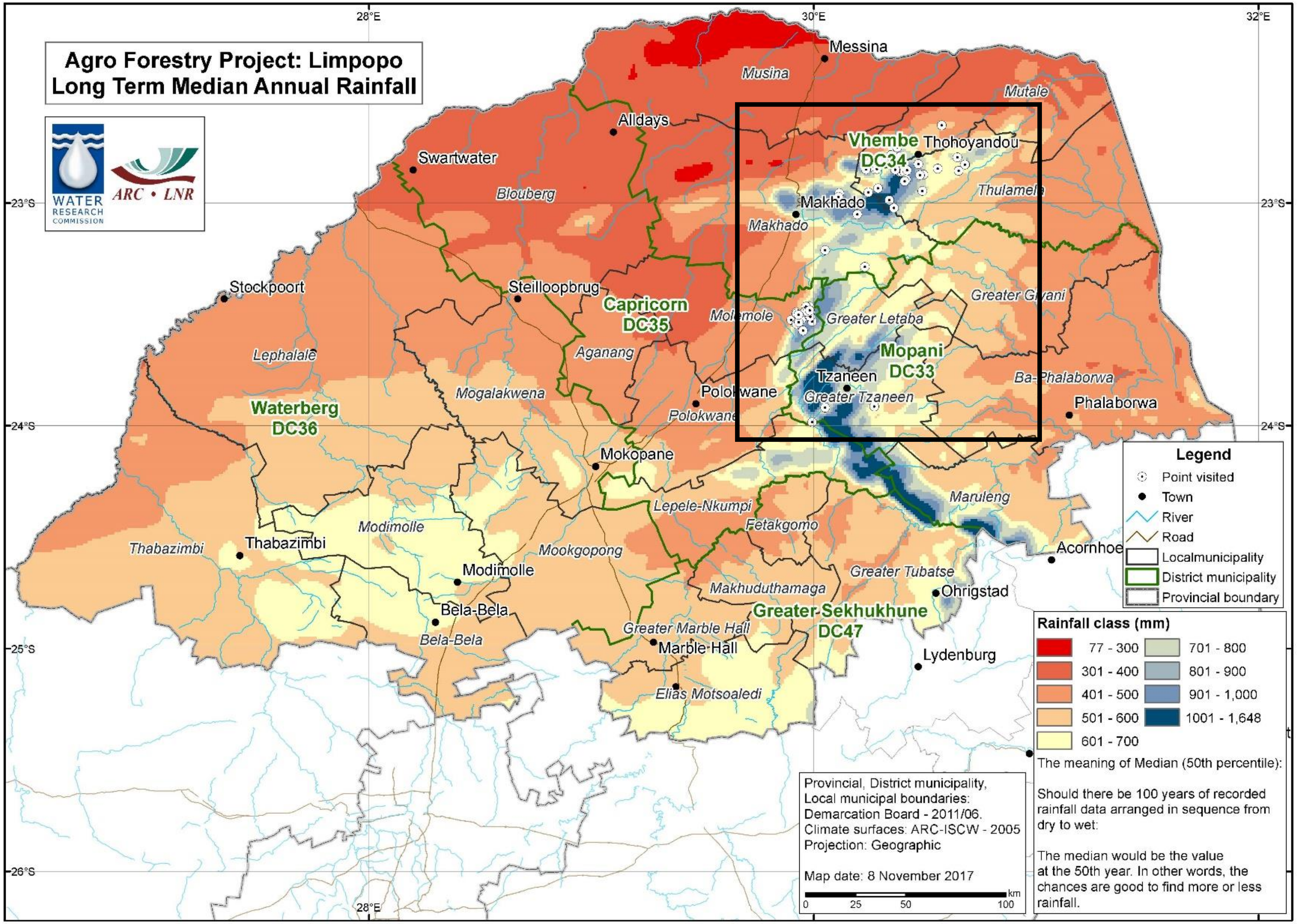

Figure 18 Limpopo Province long-term median percentile annual rainfall (ARC-SCW, 2017)

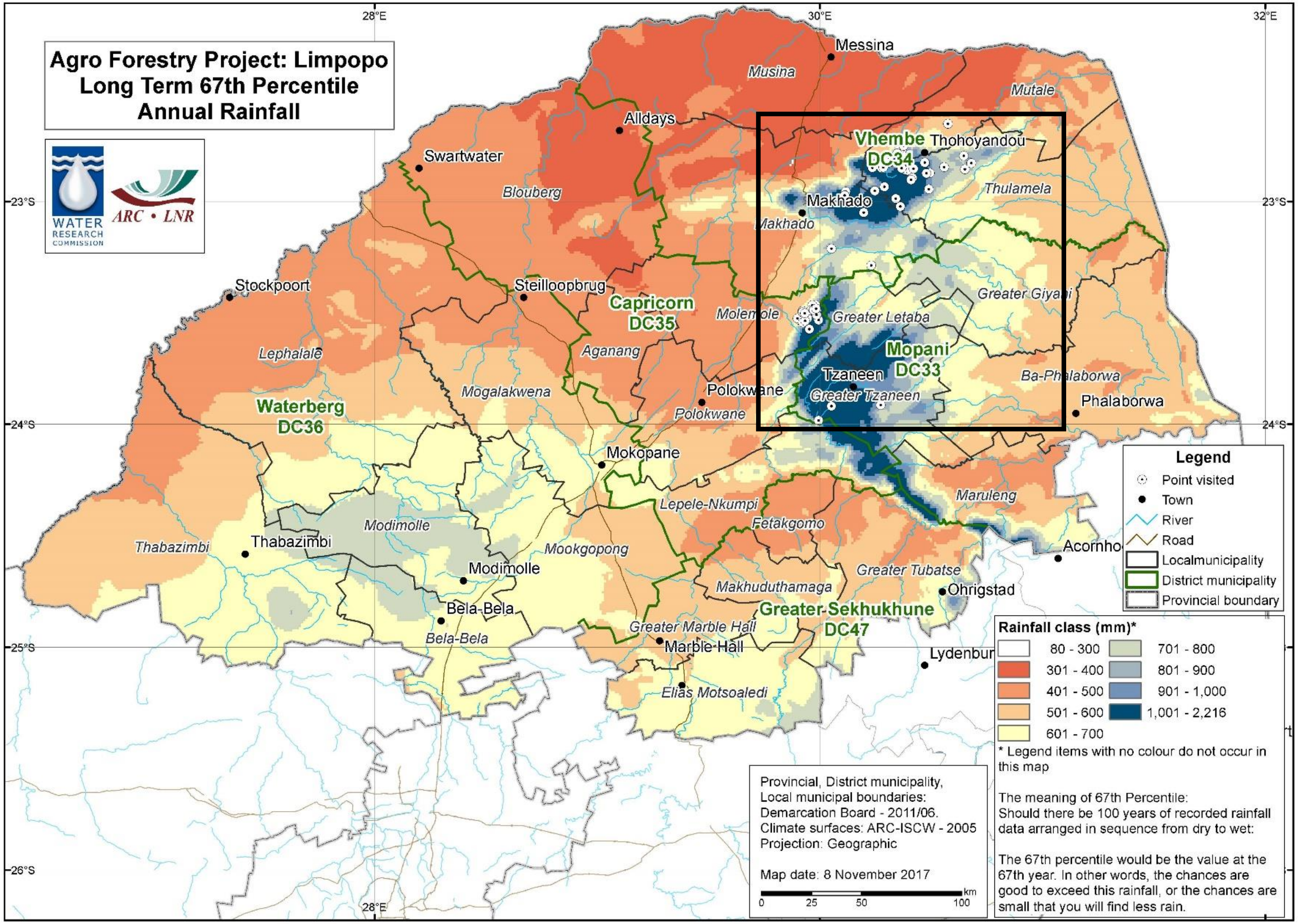

Figure 19 Limpopo Province long term 67th percentile annual rainfall (ARC-SCW, 2017).

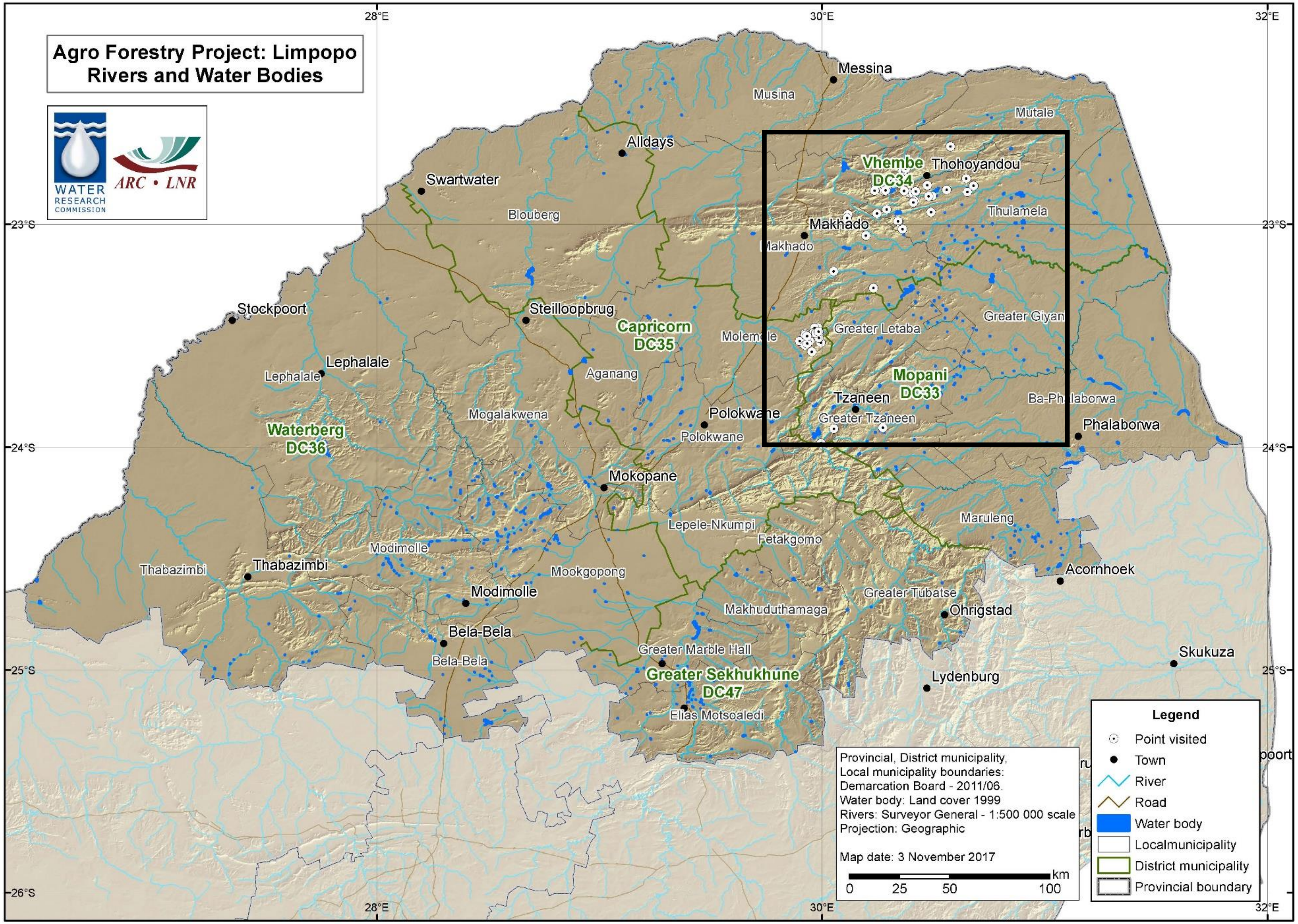

Figure 20 Limpopo Province rivers and water bodies (ARC-SCW, 2017)

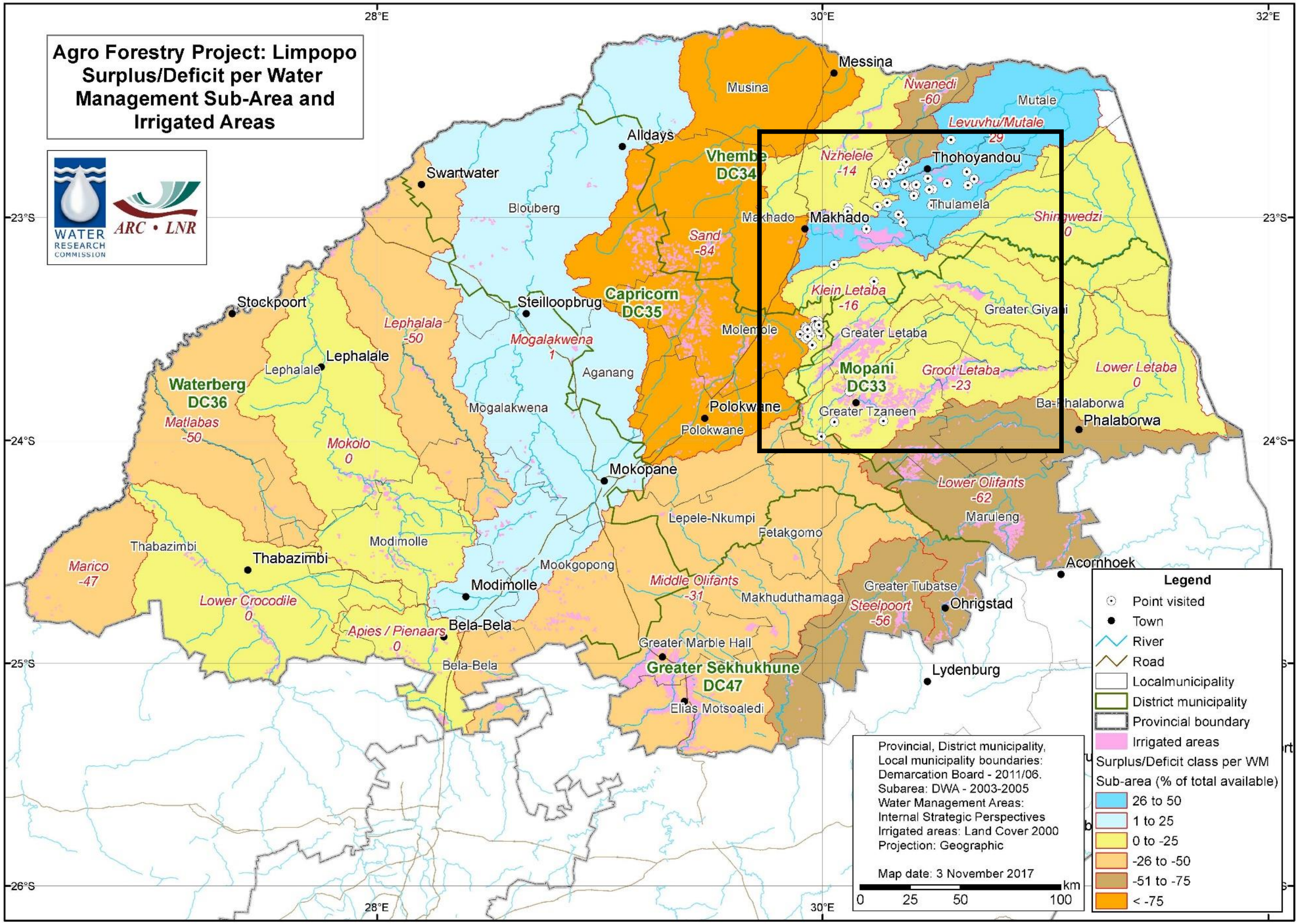

Figure 21 Limpopo Province water surplus/deficit (ARC-SCW, 2017)

4.7 Demonstration training trials

Demonstration training trials were established with the aim of capacitating farmers, extension officers, local communities and non-government organisations/ practitioners in agriculture and forestry on the concept and practice of agroforestry. The training also offered the opportunity to present and discuss the Limpopo Province assessment.

The trials were conducted in the Capricorn, Mopani and Vhembe Districts (See Photograph 3 to Photograph 5). The areas for demonstrations were selected carefully based on the situational analysis findings, especially in terms of water, soil and climate conditions. Crops were integrated in the following potential agroforestry systems: agrosilviculture (trees and crops) and agrosilvopasture (trees, crops and livestock).

Photograph 3 Agrosilviculture demonstration plot in Capricorn District, September 2018.

Photograph 4 Establishment of Agrosilvipastoral demonstration plots in Vhembe District Municipality, September 2018.

Photograph 5 Monitoring of spinach planted at agrosilviculture demonstration plots at Vhembe District Municipality, November 2018.

The training was well received and the different systems identified and classified were discussed. The stakeholders agreed that the majority of systems visited can be classified as TBMF and some as agroforestry systems. Maponya et al. (2018) explained that one needs to satisfy the following three I's to confirm an agroforestry system: intentional, intensive and interconnected. Maponya et al. (2018) gave examples of silvipasture systems in the Limpopo Province that meet the criteria of (i) intentional, (ii) intensive and (iii) interconnected as follows:

(1) Intentional: The individuals within the communities lease plantations for livestock grazing throughout the year and mostly sell them during Easter and festive seasons. The owner of the plantations also allows leasing to receive income, thus indicating that there is an intentional integration of livestock and timber;

(2) Intensive: The integration of livestock and timber happens annually and can thus be described as intensive.

(3) Interconnected: The cattle make use of grass within and between the woodlots/plantations and the households benefit from multiple sources of income, which is particularly important due to the long timeframes associated with timber production.

The stakeholders, including farmers, agreed with the training outcomes and went further to indicate that the multifunctional landscape systems can also fall into agroforestry systems as long as it meets the three I's (intentional, intensive and interconnected). The demonstration training trials have identified challenges for agroforestry integration and food security, i.e. lack of commitment from some farmers, choosing of the right compartment for integration, water challenges, fencing, and the uncontrolled roaming of game animals, to name just a few. The demonstration trials will serve as a tool to educate beneficiaries in different agroforestry systems in order to improve sustainability and ensure job creation, food security and income generation.

4.8 Additional agroforestry research being conducted

The following research involving the ARC (summarised in Table 17) is currently being conducted in Limpopo and Mpumalanga Provinces. Some of this also involves private companies such as the research undertaken with MTO, which is shown Table 17.

Table 17 Summary of other agroforestry research in Limpopo and Mpumalanga Provinces.

Deliverable	Activity	Timeframe (s)	Responsibility	Status
Nematode Analysis	Collection of Soil Samples.	July 2019	ARC Plant Health and Protection (PHP)	Completed
Soil Farmer Package Analysis	Collection of Soil Samples.	August 2019	ARC Institute of Soil, Climate and Water (ISCW)	Completed
Microbial Analysis	Collection of Soil Samples.	October 2019	Agritechnovation	Completed
Situational Analysis	Collection of Coordinates	July 2019	ARC ISCW	Completed
Socio Economic Data Collection	Face to Face Interviews & Observations	November 2019	ARC Vegetables and Ornamental Plants (VOP) Mountain to Ocean (MTO) Forest	Completed
Socio Economic Data Collection	Face to Face Interviews & Observations	December 2019	ARC VOP Ratombo Community Property Association (CPA)	Completed
Socio Economic Data Collection	Face to Face Interviews & Observations	2019	ARC VOP South African Forestry Company Limited (SAFCOL)	Completed
Socio Economic Data Collection	Face to Face Interviews & Observations	December 2019	ARC VOP Dimani	Completed
Planting 1	Maize + Eucalyptus Integration	December 2019	ARC VOP SAFCOL DEFF University of Pretoria; KZN & Mpumalanga	Completed
Planting 2	Sweet Potatoes + Eucalyptus Integration	December 2019	ARC VOP SAFCOL DEFF Universities of Pretoria; KZN & Mpumalanga	Completed
Planting 3	Groundnuts + Eucalyptus Integration (See Photograph 6)	December 2019	ARC VOP SAFCOL DEFF Universities of Pretoria; KZN & Mpumalanga	Completed

Deliverable	Activity	Timeframe (s)	Responsibility	Status
Monitoring & Evaluation	Trial Sites Visits	Ongoing	ARC VOP SAFCOL DEFF Universities of Pretoria; KZN & Mpumalanga;	Ongoing
Student Supervision	Supervisors visits & advises	Ongoing	Universities of Pretoria; KZN and Mpumalanga; ARC VOP	Ongoing

Photograph 6 Agrosilviculture (Eucalyptus trees and groundnuts) practice in the site of MTO White River, Ehlanzeni District, Mpumalanga Province, South Africa, March 2019.

5 GENERAL DISCUSSION

The research findings and reviewed literature highlighted that agroforestry and TBMF systems can bridge the gap that often separates agriculture and forestry by building integrated systems that address both environmental and socio-economic objectives. Reviewed literature suggested that integrating trees on farms can prevent environmental degradation, improve agricultural productivity, increase carbon sequestration, generate cleaner water, and support healthy soil and healthy ecosystems while providing stable incomes and other benefits to human welfare. While some of these benefits are more characteristics of multi-purpose woody legumes, the Eucalyptus trees in a TBMF or in an agroforestry system will definitely provide some benefits. For farmers already having Eucalyptus plantations or woodlots, the integration of other agricultural enterprises will also broaden the benefits.

According to Kelso and Jacobson (2011) and Zerihun et al. (2014), agroforestry is severely under developed and researched in South Africa. The researchers emphasised that there is limited country-specific data and information available on the status and the barriers affecting the development and implementation of agroforestry. According to Kelso and Jacobson (2011), the focus should be on the major agroforestry systems and practices implemented; description of the main barriers constraining agroforestry adoption and success; and categorising the key organisations developing and implementing agroforestry. But according to Zerihun et al. (2014), the efforts to promote agroforestry technologies in South Africa remains a challenge, though there is some prevalence of silvopastoral and agrisilviculture agroforestry systems in South Africa (Everson et al., 2011). Various authors have emphasised that the agroforestry systems in South Africa are not a one size fits all, but should be developed, implemented and adapted on a case-by-case basis and to suit predominant socio-economic conditions of the area or region (Mwase et al., 2015; Everson et al., 2011; Newaj et al., 2016).

While there has been little attention to agroforestry in South Africa, there has been even less attention given to systems termed TBMF in this study – and known elsewhere as *Farm Forestry*, where farms include a timber component that provides an alternative source of income. This study has brought attention to the opportunities that exist to increase the integration of different enterprises in areas where farmers are growing timber at some scale. Given that true AFS can be difficult to manage, meeting the needs of the different components within a single land unit, TBMF systems may be somewhat simpler. The current findings also echoed the findings of Everson et al. (2011) mentioned above as it found that silvopastoral systems are more popular in the Limpopo Province. The majority of farmers introduced livestock in their plantations to graze and then sell them during Easter and Christmas holidays.

The current research findings examined the main physical and socio-economic factors that affect a farmer's decision to adopt agroforestry/TBMF practices. Firstly, the climatic conditions are critical for the trees to grow, especially when these are commercial timber species. Secondly, the soil types, especially deep ones, offer great potential for tree growing. While the above environmental preconditions determine the promotion of timber-based agroforestry and mixed farming systems, the findings also indicated that it is important to understand the main socio-economic factors that determine the actual occurrence of TBMF/agroforestry.

For the majority of farmers assessed in the Limpopo Province, security of land tenure was found to be important for the adoption of agroforestry, i.e. access to land on which the farmer has the right to plant trees; rights over trees must be sufficient to justify the effort of planting them, while the right to harvest and utilise trees must be exclusive enough to give a return on investment. If farmers do not have the security that the land will be theirs for a sufficient length of time, then they will not be interested in practices such as timber-based agroforestry and mixed farming.

The other interesting finding is the areas of land utilised for timber and other practices by farmers. The findings established that farmers should maximise their land usage as much as possible and to grow as much food as possible for their household and for sale at the market. The use of land for multiple purposes (such as timber and livestock grazing) is an effective way of achieving this. It was observed in the Limpopo Province that when the farm sizes are relatively large and labour availability is low, farmers are willing to allocate part of the land to timber production (i.e. woodlots), but when farm sizes decrease, farmers are more interested in higher yielding but more labour-intensive systems such as alley cropping or highly productive home gardens. Hence, the current research did some demonstration trials in the farmers' home gardens and community gardens to introduce farmers to integrated agroforestry practices that would allow for multiple enterprises within a given piece of land. The demonstration trials were also coupled with agricultural practical training to raise awareness of farmers and extension officers about agroforestry and TBMF.

Lack of farming and agroforestry experience among young farmers remains a challenge in the Limpopo Province, hence the findings indicated that there are very few young farmers involved in agroforestry. The current study distributed seedlings to selected farmers in the Limpopo Province and most of them are currently continuing and expanding their cropping enterprises. The findings suggest that production inputs and short rotation tree/crop seedlings should be distributed to interested farmers, where possible, as a mechanism to encourage mixed farming – and specifically agroforestry practices.

These findings provided ample quantitative and qualitative evidence supported by reviewed literature that there is potential room for agroforestry establishment in the areas visited in the Limpopo Province. The findings also established that research about the socio-economic aspects of TBMF/agroforestry remains a field in its infancy in the Limpopo Province and there is a need to increase such research. This will help various stakeholders to (1) understand the agroforestry adoption decision-making process, (2) understand and improve the economic analyses of agroforestry systems, and (3) analyse the impacts of alternative policies (at local, regional and national levels) on the potential of agroforestry-based rural development initiatives.

6 CONCLUSIONS AND RECOMMENDATIONS

This section provides a summary of the key conclusions from the study as well as recommendations for policy and implementation.

6.1 Conclusions

The Sustainable Development Goals, agreed in to 2015, encourage all countries to address 17 social, environmental and economic goals that promote prosperity while protecting the planet. Agroforestry can support the attainment of these goals. The study highlighted that the promotion of agroforestry is important because it offers the prospect of increasing production and hence raising farmer income. Recognising and tackling the main factors, both socio-economic and biophysical consideration, that determine participation of farmers in agroforestry are essential for the adoption of agroforestry. The study also established that there is limited socio-economic agroforestry research in South Africa.

This study was conducted to provide more information and data on the socio-economic status of farmers from Limpopo Province that are engaging in agroforestry or TBMF. The study demonstrates that the potential for agroforestry implementation is possible in the Limpopo Province. The study results and literature reviewed indicate that the multiple goods and services (economic, environmental, social, land use and cultural) derived from agroforestry implementation confirm it as a sustainable production system. However, the requirements of the particular agroforestry system or practice are case-specific and depend on the implementation area, climatic conditions, scale or size, level (commercial or subsistence) and management objectives. These aspects are important and should be carefully considered and continually researched in order to ensure success of an agroforestry system.

The project was able to achieve the objectives that were established upfront. In terms of identifying and describing the characteristics of selected TBMF and agroforestry farms in the Limpopo Province, the study has provided a better understanding of the different agricultural enterprises that these systems comprise. The study was able to determine the potential constraint of rainfall on the establishment and expansion of these agricultural systems within Limpopo Province, specifically focusing on the water requirements of the commercial timber component of the systems. Lastly, through the survey that was conducted, a better understanding of factors that enhance farmers' participation in these systems.

The eight project deliverables were submitted within the required timeframes. Besides meeting the broad project objectives, the overview of the districts in terms of location of agroforestry/TBMF sites, water availability, selected climate and soil attributes will form the basis for promoting timber farming and agroforestry such systems.

The technicians from the ARC and students from University of Venda with knowledge on agricultural and environmental science skills were recruited and trained on conducting research in communities. Different stakeholders across the Limpopo Province engaged about the project and have benefited from the research findings, which have also been more widely shared through poster presentations (3); full conference papers and oral presentations (3) at local and international events (including a best paper award at an international conference); and a book chapter (See more detail in Appendix 4). In terms of capacity development that was achieved through the project, three students (1 Masters and 2 PhD) participated in the research.

What is clear from the study is that the successful development and implementation of an agroforestry system that suites a particular local area will require, most importantly, an enabling environment (through a support policy and strategy), further research and development, and coordination and collaboration.

6.2 Recommendations and future research needs

The following recommendations have emerged from the study and should guide policy as well as implementation of projects:

1. The foremost recommendation is to clarify amongst all stakeholders the differences between true agroforestry systems, which may or may not include commercial timber species, and

timber-based mixed farming systems. While both provide opportunities for improving the livelihoods of rural communities, they have different management requirements.

2. For areas where commercial forestry and/or woodlots are practiced, there is a need to promote the intentional integration of other enterprises (including livestock, cropping and apiculture).
3. For areas that are not suitable for growing commercial timber species, especially semi-arid parts of the province, there is a need to consider other agroforestry systems that make use of other woody species such as pigeon pea, which is a drought-tolerant, nitrogen fixing shrub.
4. There is a need to support effective farmer participation in TBMF and agroforestry through provision of technical training, assistance with fire management, access to inputs (especially planting material for new crops), and training in marketing and business skills.
5. In areas where there is extension support in place for the timber production, consider providing support to the non-timber components (livestock, cropping and/or apiculture), including value addition around products such as honey.
6. Support processes that allow farmer-to-farmer sharing, thereby drawing on those farmers with experience in these approaches.
7. Be very site-specific when designing programmes so that the systems are well-suited to prevailing physical and socio-economic circumstances.00

The study has also identified a number of areas where more research is required. Some of these relate to the TBMF / agroforestry systems encountered through this study, while others relate to alternative AFS that could be appropriate for drier parts of Limpopo Province. These areas for future research include:

1. Investigate ways to improve TBMF systems that increase forage production and livestock production. This could include changing the current timber planting practices to increase fodder production (such as widening row spacing) and actively establishing shade-tolerant fodder species.
2. Quantify carbon sequestration by woodlots to determine whether there could be any opportunities for smallholder farmers to participate in the carbon economy.
3. Explore indigenous AFS in Limpopo Province where indigenous or other woody species are retained or tree species are being introduced.
4. Review other agroforestry systems and species that are suitable for the drier parts of the province.
5. Undertake an economic analysis to determine (1) the benefit of integrating other enterprises into plantations (for example by changing planting practice to accommodate commercial livestock production) and (2) to determine the potential benefits from the different components of TBMF systems.

This study has clearly indicated that the requirements of a particular agroforestry or TBMF system or practice are case-specific and depend on the physical conditions of the implementation area, scale or area, production level (commercial or subsistence) and management objectives. These aspects are important and should be carefully considered and continually researched in order to ensure success of the recommended farming system.

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Appendix 1: Summaries of study site information

Limpopo Province potential agroforestry systems per village/area

Village/Area	System	Respondent	Percentage
Belemu	Silvipasture	2	3.1%
Gogogo	Silvipasture/Agrosilvipasture&Apiculture	2	3.1%
Gundani	Agrosilvipasture&Apiculture	1	1.5%
Ha Khakhu	Agrosilvipasture	1	1.5%
Ha Luvhimbi	Silvipasture	1	1.5%
Ha Manyiwa	Silvipasture	1	1.5%
Khalavha	Agrosilvipasture&Apiculture	1	1.5%
Khubvi	Silvipasture	1	1.5%
Khunda	Silvipasture	1	1.5%
Levubu	Silvipasture/Agrosilvipasture	2	3.1%
Luheni	Agrosilvipasture&Apiculture	1	1.5%
Lwamondo	Silvipasture	1	1.5%
Magangeni	Silvipasture	1	1.5%
Makwarani	Silvipasture	2	3.1%
Masakona	Silvipasture	1	1.5%
Matshavhe	Agrosilvipasture	1	1.5%
Mavhode	Agrosilvoculture/Agrosilvipasture	3	4.6%
Mukumbani	Silvipasture	1	1.5%
Sheshe	Agrosilvipasture&Apiculture	1	1.5%
Tshenzheni	Silvipasture	1	1.5%
Thononda	Silvipasture	1	1.5%
Tshiavha	Silvipasture	2	3.1%
Tshidzini	Silvipasture	2	3.1%
Tshidzivhe	Silvipasture/Agrosilvipasture	4	6.1%
Tshikambe	Silvipasture	1	1.5%
Tshilungwi	Silvipasture	1	1.5%
Tshixwadza	Silvipasture	1	1.5%
Vhufuli	Silvipasture	1	1.5%
Morebene	Silvipasture/Agrosilvipasture& Apiculture	16	24.6%
Munnik	Agrosilvipasture	2	3.1%
Driefontein	Agrosilvipasture	3	4.6%
Nthabiseng	Silvipasture	1	1.5%
Dan	Agrosilvoculture	1	1.5%
George’s Valley	Agrosilvipasture/Apiculture	2	3.1%
Modjadjiskloof	Agrosilvoculture	1	1.5%
Population		65	100%
Calculation % = respondent per village/total number of all respondent X 100			
System used Per Area			
Silvipasture			48%
Agrosilvipasture			36%
Agrosilvipasture & apiculture			9%
Agrosilvoculture			5%
Apiculture			2%
Calculation % = respondent per system used/total number of all respondent X 100			

Limpopo Province Potential Agroforestry Systems per Farm; *Smallholder Farm and **Commercial Farm

Farm	System	Respondent	Percentage (%)
Thiathu*	Agrosilvipasture & Apiculture	1	1.56
Thusanani*	Silvipasture	1	1.56
Thusanang*	Agrosilvipasture	1	1.56
Tshidzati coop*	Agrosilvipasture & Apiculture	1	1.56
Tshikambu*	Silvipasture	1	1.56
Tshinaiwa*	Silvipasture	1	1.56
Tshitongwe*	Silvipasture	1	1.56
Tshivhase Tribal*	Silvipasture	1	1.56
Art Farm*	Silvipasture	1	1.56
Avalands*	Agrosilvipasture	1	1.56
Chief*	Silvipasture	1	1.56
Diitele Project*	Silvipasture	1	1.56
Fourieskoik*	Agrosilvipasture	1	1.56
G Portion*	Silvipasture	1	1.56
Gugutwe*	Silvipasture	1	1.56
Hollywood T*	Silvipasture	1	1.56
Ikageng*	Agrosilvipasture	1	1.56
Jealous Down*	Agrosilvipasture & Apiculture	1	1.56
Khakhu Farm*	Agrosilvipasture	1	1.56
Khunda*	Silvipasture	1	1.56
Lerumo*	Agrosilvipasture & Apiculture	1	1.56
Luvhugenville*	Agrosilvipasture	1	1.56
Lwamondo C*	Silvipasture	1	1.56
Maberebere*	Agrosilvipasture	1	1.56
Maholoni*	Silvipasture	1	1.56
Makatu*	Silvipasture	1	1.56
Makgoto*	Silvipasture	1	1.56
Makhamotse*	Agrosilvipasture	1	1.56
Manaledzi*	Silvipasture	1	1.56
Maphutha*	Agrosilvipasture	1	1.56
Maranda*	Agrosilvipasture & Apiculture	1	1.56
Matilda*	Agrosilvipasture	1	1.56
Matombotsuka*	Silvipasture	1	1.56
Matome*	Agrosilvipasture	1	1.56
Mazwimba*	Silvipasture	1	1.56
Middagson*	Silvipasture	1	1.56
Mmatshehle*	Agrosilvipasture	1	1.56
Modiba*	Apiculture	1	1.56
Moletjie*	Silvipasture	1	1.56
Morabane*	Agrosilvipasture	1	1.56
Morebene*	Agrosilvipasture	1	1.56
Mulanduli*	Silvipasture	1	1.56
Mulilo*	Silvipasture	1	1.56
Musola*	Silvipasture	1	1.56
Muthala A*	Agrosilvipasture	1	1.56
Muthala*	Agrosilvipasture	1	1.56
Randima*	Silvipasture	1	1.56
Neluvhola*	Silvipasture	1	1.56
Nembulu*	Silvipasture	1	1.56
Nephiphide*	Silvipasture	1	1.56
Netsianda*	Silvipasture	1	1.56
Portion 44*	Agrosilvipasture	1	1.56
Portion 60*	Agrosilvipasture & Apiculture	1	1.56
Portion 38*	Agrosilvipasture	1	1.56
Portion 69*	Silvipasture	1	1.56
Raphalalani*	Agrosilviculture	1	1.56
Ratombo**	Agrosilvipasture	1	1.56
Ronderbelt*	Silvipasture	1	1.56
Safcol**	Agrosilviculture / Silvipasture	2	3.12
Merensky**	Agrosilviculture	1	1.56
Serala*	Agrosilvipasture	1	1.56
Sigama*	Agrosilvipasture	1	1.56
Soek Farm 62*	Agrosilvipasture	1	1.56
Sokaleholo*	Agrosilvipasture	1	1.56
Population		65	100%
	Silvipasture		49.44%
	Agrosilvipasture		36.52%
	Agrosilvipasture & Apiculture		9.36%
	Apiculture		1.56%
	Agrosilviculture		7.12%

Appendix 2: Detail pertaining to methods of obtaining study site information

The following approach was used to determine average monthly rainfall (Malherbe and Tackrah, 2003).

Decadal (ten day period) 1km x1km surfaces were created from rainfall data (1920-1999) downloaded from the AgroMet databank at the Agricultural Research Council – Soil, Climate and Water (ARC-SCW) (South African Weather Service and SCW weather stations) from stations with a recording period of 10 years or more. Regression analysis and spatial modelling were utilized taking into account topographic indices such as altitude, aspect, slope and distance to the sea during the development of the surface.

The following approach was used to determine soil types (ARC-SCW 2017)

Digital land type information – soil depth and the spatial component were used. Soil depth is recorded as a range for each soil entry. A weighted average was calculated for each land type unit. Land Type Survey Staff. 1972-2006. Land Types of South Africa: Digital map (1:250 000 scale).

The following model was used to determine average monthly temperature (Malherbe and Tackrah, 2003).

Decadal (ten-day period) 1km x1km surfaces were created from temperature data (1920-1999) downloaded from the AgroMet databank at the ARC-SCW (South African Weather Service and SCW weather stations) from stations with a recording period of 5 years or more. Regression analysis and spatial modelling were utilized taking into account topographic indices such as altitude, aspect, slope and distance to the sea during the development of the surface.

The following model was used to determine soil drainage (ARC-SCW 2017).

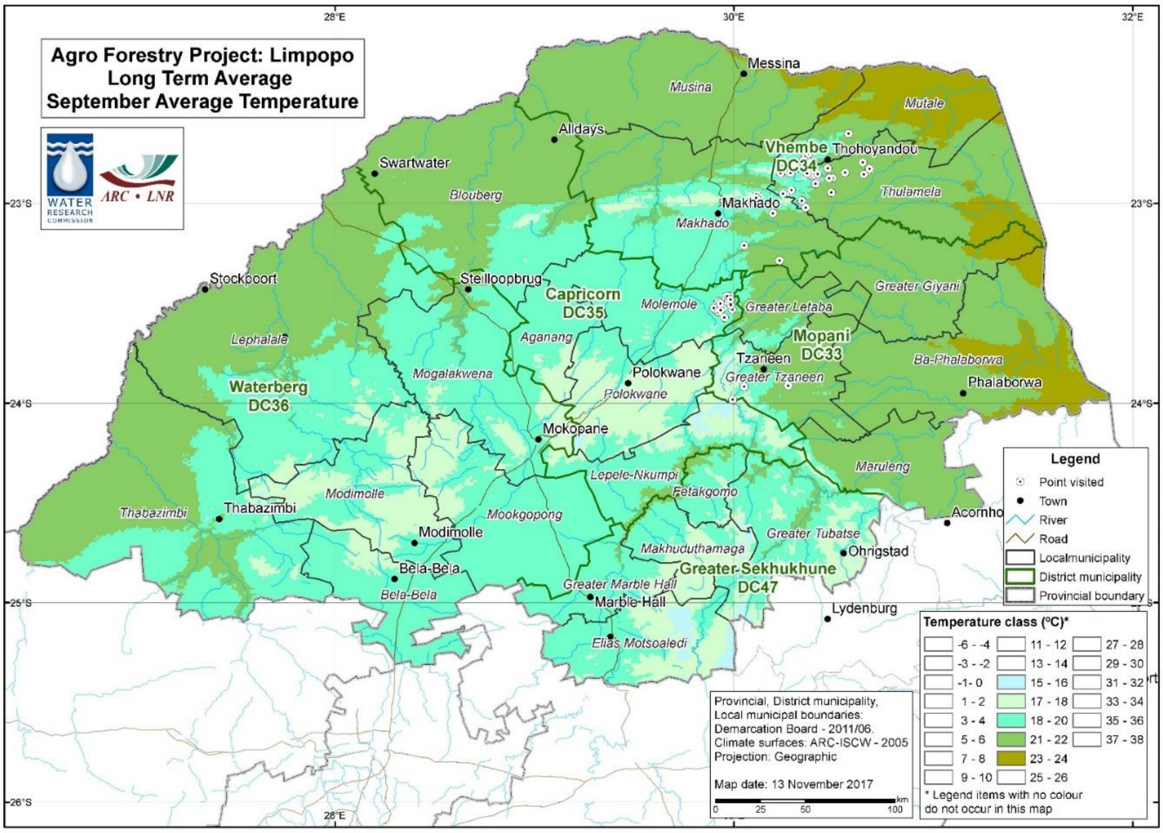
Digital land type information – soil type and the spatial component

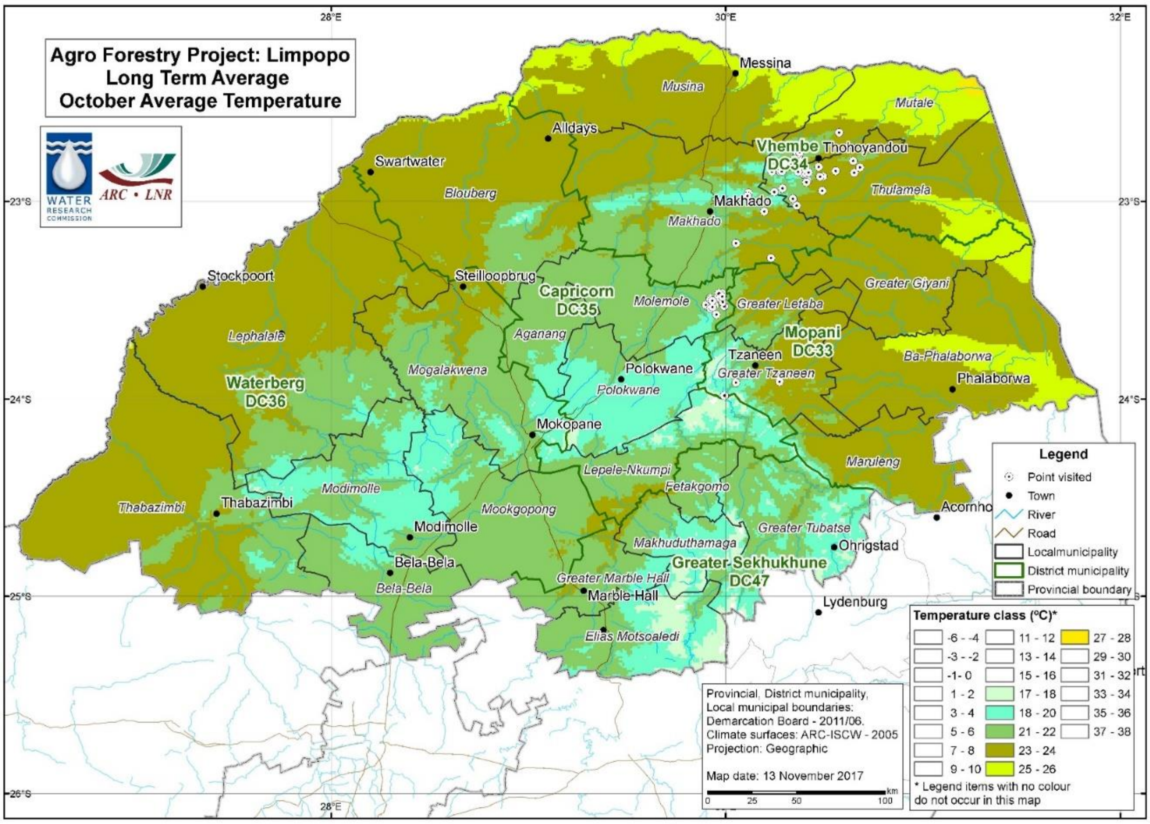
Class	Soil drainage	Qualifying soil forms	Percentage qualifying soil in land type
1	Poor	Ch, Rg, Wo, Ka, Kd , Es	>40
2	Impeded	Ch, Rg, Wo, Ka, Kd , Es, Lo, Wa, Cf, La	>40
3	Somewhat impeded	Ch, Rg, Wo, Ka, Kd , Es, Lo, Wa, Cf, La, Bo, Fw, Vf, We, Av, Gc, Pn, Bv, Ss, Va, Sw	>40
4	Other		

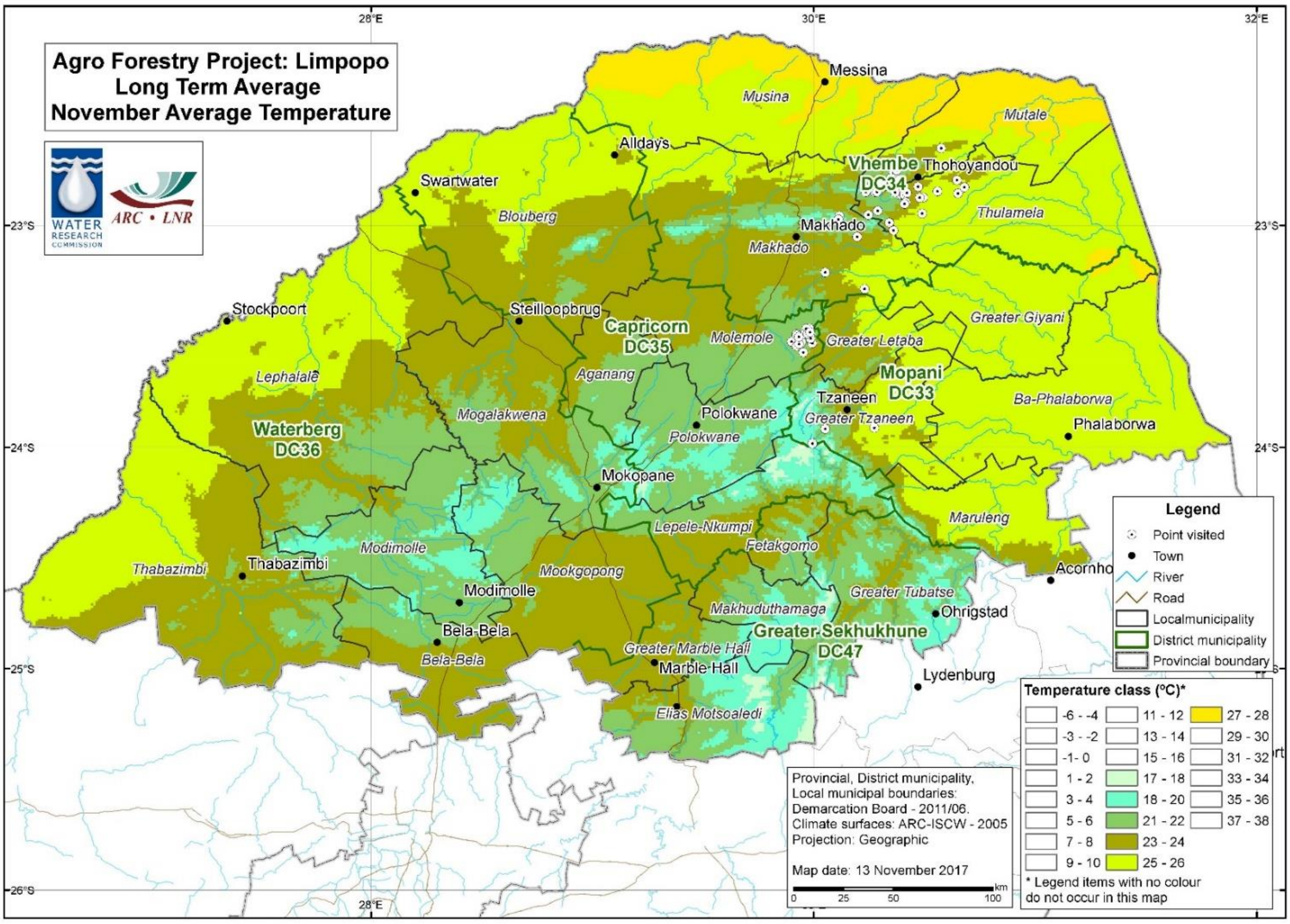
Climate data for the broad study site

The climate data was extracted from Schulze, R.E. 2007. South African Atlas of Climatology and Agrohydrology: Terminology. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report 1489/1/06. Median monthly, max, min and average rainfall and temperate was clipped using a shapefile that was generated based on the cluster of monitoring points found within the plantation region.

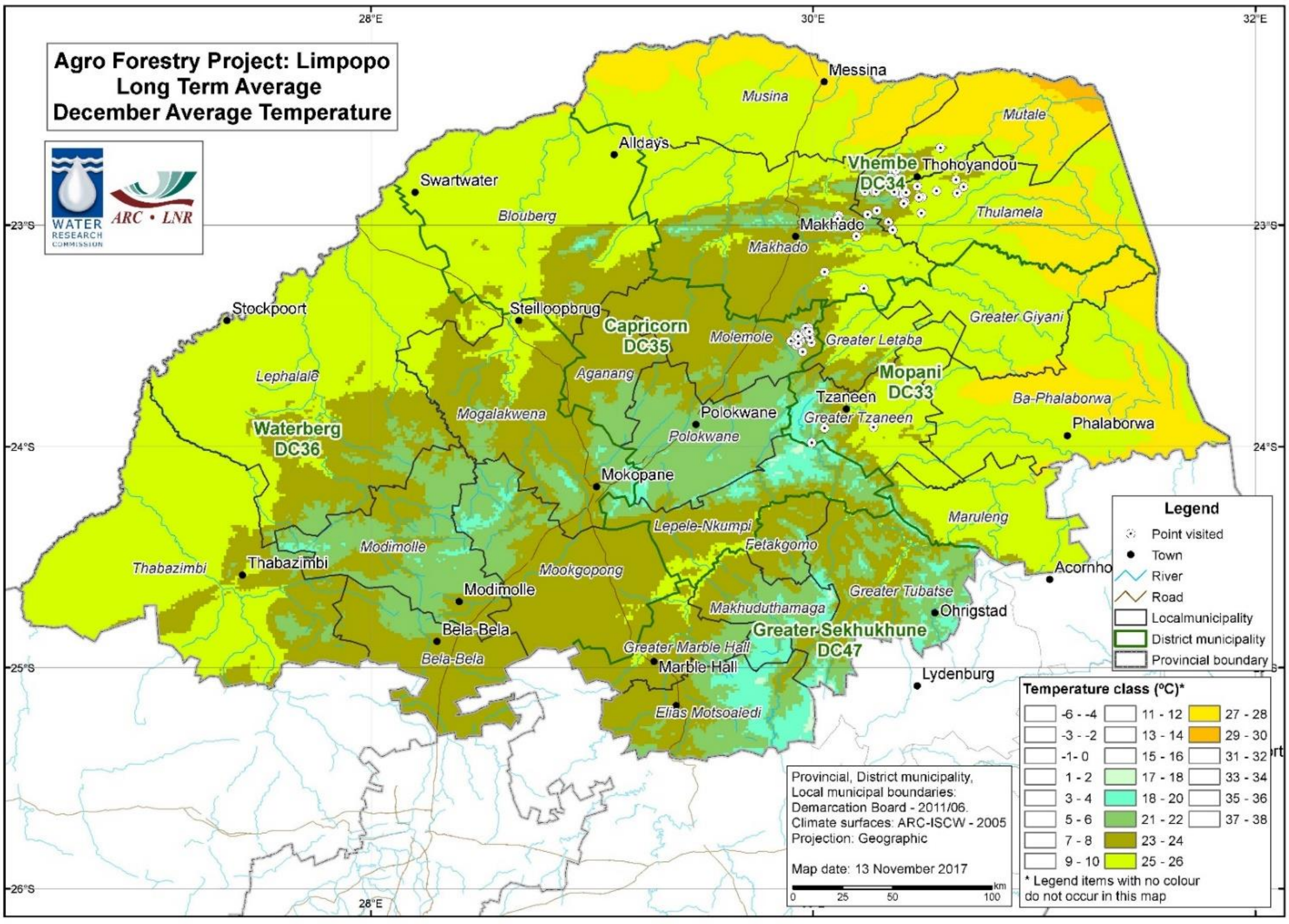
Appendix 3: Long term monthly average temperature for the period September to December for Limpopo Province (ARC, 2017)







Agro Forestry Project: Limpopo
Long Term Average
November Average Temperature
WATER RESEARCH COMMISSION
ARC • LNR
Messina
Musina
Mutale
Alldays
Swartwater
Vhembe DC34
Thohoyandou
Blouberg
Makhado
Thulamela
Stockpoort
Steilloopbrug
Capricorn DC35
Molemole
Greater Letaba
Greater Giyani
Lephalale
Aganang
Mopani DC33
Tzaneen
Greater Tzaneen
Ba-Phalaborwa
Phalaborwa
Waterberg DC36
Mogalakwena
Polokwane
Mokopane
Lepele-Nkumpi
Maruleng
Fetakgomo
Modimolle
Thabazimbi
Mookgopong
Acornhoek
Greater Tubatse
Makhuduthamaga
Ohrigstad
Bela-Bela
Greater Sekhukhune DC47
Greater Marble Hall
Marble Hall
Lydenburg
Elias Motsoaledi
Legend
Point visited
Town
River
Road
Localmunicipality
District municipality
Provincial boundary
Temperature class (ºC)*
-6 - -4
-3 - -2
-1- 0
1 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 14
15 - 16
17 - 18
18 - 20
21 - 22
23 - 24
25 - 26
27 - 28
29 - 30
31 - 32
33 - 34
35 - 36
37 - 38
* Legend items with no colour do not occur in this map
Provincial, District municipality, Local municipal boundaries: Demarcation Board - 2011/06.
Climate surfaces: ARC-ISCW - 2005
Projection: Geographic
Map date: 13 November 2017
0 25 50 100 km
28°E
30°E
32°E
23°S
24°S
25°S
26°S



Agro Forestry Project: Limpopo
Long Term Average
December Average Temperature
WATER RESEARCH COMMISSION
ARC • LNR
Messina
Musina
Mutale
Alldays
Swartwater
Vhembe DC34
Thohoyandou
Blouberg
Makhado
Thulamela
Stockpoort
Steilloopbrug
Capricorn DC35
Molemole
Greater Letaba
Greater Giyani
Lephalale
Aganang
Mopani DC33
Tzaneen
Greater Tzaneen
Ba-Phalaborwa
Phalaborwa
Waterberg DC36
Mogalakwena
Polokwane
Mokopane
Lepele-Nkumpi
Maruleng
Fetakgomo
Modimolle
Thabazimbi
Mookgopong
Acornhoek
Greater Tubatse
Makhuduthamaga
Ohrigstad
Bela-Bela
Greater Sekhukhune DC47
Greater Marble Hall
Marble Hall
Lydenburg
Elias Motsoaledi
Legend
Point visited
Town
River
Road
Localmunicipality
District municipality
Provincial boundary
Temperature class (ºC)*
-6 - -4
-3 - -2
-1- 0
1 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 14
15 - 16
17 - 18
18 - 20
21 - 22
23 - 24
25 - 26
27 - 28
29 - 30
31 - 32
33 - 34
35 - 36
37 - 38
* Legend items with no colour do not occur in this map
Provincial, District municipality, Local municipal boundaries: Demarcation Board - 2011/06.
Climate surfaces: ARC-ISCW - 2005
Projection: Geographic
Map date: 13 November 2017
0 25 50 100 km
28°E
30°E
32°E
23°S
24°S
25°S
26°S

Appendix 4: Technology Transfer

a) Conferences, Symposium and Poster presentations

1. **Maponya P,** (2020). Environmental and Socio Economic Assessments of Timber-Based Mixed Farming and Agroforestry Systems in Limpopo Province, South Africa, Poster Presentation, 22nd Session of African Forestry and Wildlife Commission (AFWC) and the 6th African Forestry and Wildlife Week (AFWW) in partnership with Food and Agriculture Organization (FAO), Agroforestry Side Event, Skukuza, Mpumalanga Province, South Africa, 09-13 March 2020.

2. **Maponya P,** (2020). Environmental and Socio Economic Assessments of Timber-Based Mixed Farming and Agroforestry Systems in Limpopo Province, South Africa, Oral Presentation, 22nd Session of African Forestry and Wildlife Commission (AFWC) and the 6th African Forestry and Wildlife Week (AFWW) in partnership with Food and Agriculture Organization (FAO), Agroforestry Side Event, Skukuza, Mpumalanga Province, South Africa, 09-13 March 2020.

3. Nkuna T**, Maponya P**, Madakadze C and Dube Z, (2020). Evaluating the potential constraints of climate and soil: A case study of agroforestry sites in Limpopo and Mpumalanga Provinces, South Africa, Poster Presentation, Combined Congress, 20-23 January 2020, University of the Free State, Bloemfontein, South Africa.
4. Makhwedzana M, **Maponya P**, Mbili N and Dube Z, (2020). Analysis of soil enzymes and microbial diversity for effective crop production under agroforestry environment in Limpopo and Mpumalanga Provinces, South Africa, Oral Presentation, Combined Congress, 20-23 January 2020, University of the Free State, Bloemfontein, South Africa.
5. Nkuna T, **Maponya P**, Madakadze C and Dube Z, (2019). Evaluating potential constraints hindering maize production under agroforestry environment in South Africa, Cereal Science and Technology Southern Africa (CST-SA), 11 September 2019, Pretoria.

6. Nkuna T, **Maponya P**, Madakadze C and Dube Z, (2019). Evaluating The Potential Constraints of Climate and Soil: A Case Study of Agroforestry Sites in Limpopo and Mpumalanga Provinces, South Africa, **<u>3rd Prize: BEST PhD SCIENTIFIC POSTER PRESENTATION</u>**, 6th Agricultural Research Council (ARC) Postgraduate Annual Conference, 07-09 October 2019.
7. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2019). Oral Presentation & Full Paper Publication, **<u>BEST PAPER AWARDED</u>**, Research, Extension Services and Training as key drivers to agroforestry adoption in Limpopo Province, South Africa, 3rd World Irrigation Forum, International Commission on Irrigation and Drainage (ICID), 01-09 September 2019, Bali, Indonesia.
8. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2019). Poster Presentation & Full Paper Publication, Evaluation of the timber-based mixed farming/agroforestry systems: A case of farmers in Limpopo Province, South Africa, **<u>GRANT AWARDED</u>**, 4th Word Congress on Agroforestry, 20-22 May 2019, Montpellier, France.

9. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2018). Oral Presentation & Full Paper Publication, Perceptions on the Constraints to Agroforestry Competitiveness: A Case of Smallholder Farmers in Limpopo Province, 9th International Scientific Agriculture Symposium, 04-07 October 2018, Bosnia – Herzegovonia.

10. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2018). Oral Presentation, Potential Constraint of Rainwater Availability on the Establishment and Expansion of Agroforestry in Limpopo Province, South Africa, International Commission on Irrigation (ICID), 12-17 August 2018, Saskatoon, Canada.

11. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2017). Oral Presentation, An Evaluation of Agroforestry Farms in Limpopo Province, 7th Forest Science Symposium, Institute for Commercial Forest Research, 18-20 July 2017, KwaZulu-Natal.

12. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2017). Poster Presentation, An Evaluation of Agroforestry Farms in Limpopo Province, South Africa, 7th Forest Science Symposium, Institute for Commercial Forest Research, 18-20 July 2017, KwaZulu-Natal.

b) **Book Chapter**

1. **Maponya P**, Venter SL, Du Plooy CP, Backeberg GR, Mpandeli SN and Nesamvuni E, (2020). Timber-Based Mixed Farming/Agroforestry Benefits: A Case Study of Smallholder Farmers in Limpopo Province, South Africa, In book: Global Climate Change and Environmental Policy: Agriculture Perspectives", In: Venkatramanan V., Shah S., Prasad R. (eds) Global Climate Change and Environmental Policy. Pages 275-302, Springer.

Appendix 5: Student abstracts

Analysis of soil enzymes and microbial diversity for effective crop production under agroforestry environment in Limpopo and Mpumalanga Province

Mmboniseni Makhwedzhana[1,2#], Phokele Maponya[2], Nokwazi Mbili[1] and Zakheleni Dube[3]

[1]University of KwaZulu-Natal, College of Agriculture, Engineering and Science, School of Agricultural, Earth and Environmental Sciences, Department of Plant Pathology, Private Bag X01, Scottsville, 3209, South Africa
[2]Agricultural Research Council – Vegetable and Ornamental Plants, Private Bag X293, Pretoria 0001
[3]University of Mpumalanga, Faculty of Agriculture and Natural Science, Department of Agriculture, Private Bag X11283, Mbombela 1200
Corresponding author: E-mail: makhwedzanam@arc.agric.za

ABSTRACT

Diversification and intensification through inclusion of vegetable crops in agroforestry-based cropping systems represents a key technology in the drive towards the sustainable intensification of agriculture in South Africa. Functional diversity can be measured to determine the biological status of soil microbial populations, since it relates to the actual or potential activities of organisms that contribute to ecosystem dynamics (Habig, 2019). The objective of this study was to determine the soil microbial community possible effects impeding agroforestry in South Africa. Soil samples were randomly collected from six trial sites in Limpopo and Mpumalanga, namely: Ratombo-Levubu, Safcol Graskop, Safcol Block J4, Safcol Block J25, Serala Georges Valley and MTO plantations at depth of 20 cm. Soil samples were diluted in sterile distilled water and inoculated into Biolog EcoPlatesTM containing 31 carbon sources and a control well, in triplicate. The plates were incubated at 28 °C. Respiration of carbon sources was measured twice daily over a period of 5-10 days at 590 nm. The functional diversity of the soil microbial populations was determined using the amount and equitability of carbon substrates metabolized as indicators of richness and evenness, respectively. The data were statistically analysed by cluster analyses. Biodiversity was determined using the Shannon-Weaver diversity index and Evenness Index, indicating species richness and abundance, respectively.After data collection and analysis, the results indicated from the Principal Component Analysis (PCA), that microbial communities in the Safcol Graskop site clustered separately from all the other sampling sites, while no clear clustering could be distinguished between the remaining sites. These results depict the carbon source utilization (CSU) of the soil microbial populations present, clearly indicating differences in carbon source utilisation profile (CSUP) between the different sampling sites, also implying differences in microbial functioning between the different sampling sites. The biological soil health seems to be more favourable at the Georges Valley and Ratombo sites due to the high microbial diversity and activity, compared to the soil health status of all other sites. Consequently, the latter sites might hinder crop production directly through lower mineralisation rates, or indirectly through the presence of a low microbial diversity. In conclusion, it is recommended that trends in CSUP and enzymatic activity be monitored over an extended period of time in order to attain a more complete reflection on the impact of different crops practices on microbial diversity and activity as an indicator of soil fertility and health.

Key words: Conservation agriculture, crop rotation, microorganisms, soilborne diseases

The contribution of gum trees *(Eucalyptus*) woodlots initiative to livelihoods of small-scale timber growers in Limpopo with special reference to Vhembe district

Vuwani Louis Manthakha

A dissertation submitted to the Institute for Rural Development (IRD), School of Agriculture, University of Venda, in fulfilment of the requirements for the Master in Rural Development degree

ABSTRACT

The *Eucalyptus* woodlots provide material benefits that could support the livelihoods of the communities. These trees are very important to the rural households; they provide an array of products, particularly timber and fuelwood. However, there is lack of information on contribution of *Eucalyptus* woodlots on the livelihoods of rural small-scale timber growers in Vhembe district, Limpopo. Establishment of *Eucalyptus* woodlots can be used as a poverty fighting tool in rural areas such as Vhembe district, the question that arises is; to what extent does these *Eucalyptus* woodlots contribute to the livelihoods of these small-scale timber growers? Therefore, the main objective of the study was to assess the contribution of *Eucalyptus* woodlots initiative to the livelihoods of small-scale timber growers. The specific objectives of the study were to evaluate economic benefits made from the *Eucalyptus* woodlots initiative by small-scale timber growers, to determine the factors affecting the contribution of woodlots to livelihoods and developing solutions to improve the contribution of Eucalyptus woodlots to livelihood of small-scale timber growers in Vhembe district. The focus of the study was on woodlots established by small-scale timber growers as individuals and those established under the government programmes before 1994 and after 1994 in the new democratic government.
A mixed methods approach was adopted due to the fact that all methods (quantitative and qualitative) had limitations, thus this research intended to reduce the bias inherent in individual methods. The methods were based either on constructivism or positivism. A semi-structured interview guide was used for qualitative data collection. The qualitative data was analysed using the thematic analysis approach, through Atlas ti Version 8 software. Data collection for the quantitative phase was done through administering a questionnaire with close and open-ended questions. Collected data was analysed using IBM-SPSS version 25. Principal Component analysis and descriptive statistics tests were performed and ranking of components.

Major socio-economic benefits of the *Eucalyptus* woodlots were timber production, employment and different Non-Timber Forest Products. The factors affecting the contribution of Eucalyptus woodlots growers' livelihood and solutions thereof were resources required for production such as skills, costs, funding and support by government and other institutions. It was observed that *Eucalyptu*s woodlots initiative had job creation potential. More than a quarter (37%), of the respondents survives through *Eucalyptus* woodlots production since they are unemployed. There are significant socio-economic benefits from *Eucalyptus* woodlots and the most common benefits are timber production, Non-Timber Forest Products and employment opportunities among the participants. Therefore, attention should be given to manage the identified socio-economic benefits and factors in order to change small-scale timber growers' attitude towards *Eucalyptus* woodlot initiative.

Key words: *Eucalyptus*, Livelihoods, Previously Disadvantaged Persons, small scale timber growers, woodlots,

Water utilisation of maize cultivars on seeds germination under agroforestry environment

T.S Nkuna#, P. Maponya, Z.P. Dube & C.I. Madakadze

[1]University of Pretoria, Faculty of Agriculture and Natural Science, Department of Plant and Soil Science, Private Bag X20, Hartfield 0028
#corresponding author: **2nd PhD Agronomy**

Introduction: Maize (*Zea mays* L.) is the principal food in Southern Africa (Mugo *et al*., 2002). Resource-poor farmers in South Africa still promote maize landraces; these are known for their adaptability to harsh environmental conditions and still produce reasonable yields (Zeven, 1998). This indicates their importance (Mabhaudhi, 2009), particularly in rural communities, and their potential ability to contribute to food security. However, the maize landraces that resource-poor farmers are familiar with tend to produce relatively low yields despite their adaptability to low-input farming systems (Mabhaudhi and Modi, 2013). Low yield could be the result of poor water availability or tree-maize competition under agroforestry from farmers' prior harvests (Manzanilla *et al*., 2011). This, coupled with the occurrence of drought, particularly in Sub-Saharan Africa, is a major concern. There is a need for strategies that will encourage efficient water utilisation and identify possible crops for future integration with crop improvement.

Objective: Determine attention gravitating towards studying traditional and underutilized crops to reduce water loss under agroforestry areas.

Aim: Study aimed at promoting utilisation of the underutilised moisture to enhance suitable maize production under agroforestry environment.

Materials and methods: Seeds of maize landraces Capstone “Okavango”, “PAN 1101”, “PAN 4110” and “PAD 000491” were sourced from local farmers in the Limpopo Province, South Africa. Field trials were conducted at SAFCOL plantation, Tzaneen, Limpopo Province (23º 53'10" S, 29º 44'15" E). Plots of *Eucalyptus Grandis* alone were used as control to compare with other plots of various maize landraces integrated with *E. Grandis*. Rainfed field trials were planted on a total land area of 360 m^2, each plot was 3 × 3 m, respectively. Inter-row spacing of 75cm and intra-row spacing of 25 cm according to maize recommended spacing. Treatments plots were arranged in a randomised complete block design (RCBD), replicated ten times. Data collected was analysed using SAS software at the probability level of 5%.

Results and Discussions: The findings of this study exhibited that “Okavango” landraces took at least 7 weeks to emerge. “PAD 000491”, “PAN 1101”, landraces were better than the “PAN 4110” landrace. It should be noted that “PAN 4110” is a wild landrace naturally adapted to wetlands; hence this may have affected its performance. Slow emergence of “PAN 1101”, landraces would imply that a lot of water is lost to soil evaporation during the establishment stage. Time taken to emerge may be reflective of different propagules used for each of the three landraces. Nonetheless, the study managed to index drought strategies in “Okavango” landraces. Drought avoidance was achieved through stomatal regulation. These responses had the net effect of reducing crop water losses to transpiration. The “Okavango” landrace showed greater adaptability to water stress under rainfed conditions.

Conclusions and recommendations: Future studies, which may include breeders, should evaluate whether there are any useful traits in the “Okavango” landrace that could be useful to future crop improvement. As such, the “Okavango” landrace may be suited for rainfed production given that management practices that favour biomass accumulation are practised.

Appendix 6: Capacity building report

1. Introduction

This section of the report covers the involvement of postgraduate students in the research, as well as organisational strengthening and community-level development.

2. Student information

Three students worked on the project. Their' research contributed to the project objectives as follows:

Project objectives	T Nkuna	M Makhwedzhana	V Manthakha
To identify and describe the characteristics of selected timber-based mixed farming and agroforestry farms.	X	X	X
To determine the potential constraint of rainfall on the establishment and expansion of timber-based mixed farming and agroforestry farms.	X	X	X
To determine factors that enhance farmer's participation in the timber-based mixed farming and agroforestry sector.	X	X	X

2.1 PhD Agronomy student: Thabo Nkuna

Thabo Nkuna, a male South African national, registered at University of Pretoria for PhD Agronomy. His supervisors are Dr Casper Madakadze (University of Pretoria), Dr Phokele Maponya (Agricultural Research Council) and Dr Zakheleni Dube (University of Mpumalanga).

<u>Status</u>: To Graduate in November 2021 or April 2022.

<u>Dissertation title:</u> Water utilisation of maize cultivars on seeds germination under agroforestry environment.

2.2 PhD student: Meshack Makhwedzhana

Meshack Makhwedzhana, a male South African national, registered at University of KwaZulu-Natal for PhD Plant Pathology. His supervisor are Dr Nokwazi Mbili (University of KwaZulu-Natal), Dr Phokele Maponya (Agricultural Research Council) and Dr Zakheleni Dube (University of Mpumalanga).

<u>Status:</u> To Graduate in November 2021 or April 2022.

Dissertation title: Analysis of soil enzymes and microbial diversity for effective crop production under agroforestry environment in Limpopo and Mpumalanga Province

2.3 Masters student: Vuwani Manthakha

Vuwani Manthakha, a male South African national, registered at University of Venda for Masters Rural Development. His supervisors are Dr M Manjoro (University of Venda), Dr BM Kilonzo (University of Venda) and Mr P Munyanduki (University of Venda).

Status: To Graduate in April/September 2021.

Title: The contribution of gum trees (Eucalyptus) woodlots initiative to livelihoods of small-scale timber growers in Limpopo with special reference to Vhembe district.

3. Organisational development

Staff members from the ARC have developed skills in a number of areas through this project. Firstly, a number of staff members attended a training on GIS training, which was provided by Dr Gary Paterson and Eric Economon (ARC ISCW). Another training that was attended by ARC staff, University of Venda postgraduate students, Department of Environment, Forestry and Fisheries, Local municipality office, Local agriculture office and local community members and organisation was questionnaire design and data collection, provided by Prof Edward Nesamvuni and Dr Phokele Maponya. Quite a number of presentations occurred with local agroforestry stakeholders and Dr Phokele Maponya presented the project to different stakeholders.

4. Community development activities

Capacity development activities has been through three key sets of activities, namely Involvement of community members, timber small growers, learners and teachers, nurses and security guards.

4.1 Involvement of local community members and timber small growers

Capacity development of timber small growers affiliated with Forestry SA and other local community members has been through different agroforestry demonstration trials. Different seedlings including moringa, groundnuts, spinach, carrots, beetroots, kale, onion, tomatoes and cabbages were sourced from ARC (VIMP) in Roodeplaat and distributed in the Vhembe and Capricorn Districts. Demonstration trials occurred from initial soil preparation phase until harvesting phase. ARC technicians and assistants and DEFF extension officers conducted monitoring and evaluation until harvesting time where the produce was given to community members. Some small growers indicated that they sold harvest surplus to other community members while others even donated to nearby orphanages and crèches.

4.2 Involvement of learners and teachers at a local primary school

School children and teachers participated in the practical demonstration trials from soil preparation until harvesting. Different seedlings including spinach, carrots, beetroots, kale, onion, tomatoes and cabbages were sourced from ARC (VIMP) in Roodeplaat and distributed in the Vhembe District identified primary school. The harvested produce augmented vegetables in the school feeding scheme programme.

4.4 Involvement of nurses and security guards at a local clinic

Nurses and security guards participated in the practical demonstration trials from soil preparation until harvesting. Different seedlings including spinach, carrots, beetroots, kale, onion, tomatoes and cabbages were sourced from ARC (VIMP) in Roodeplaat and distributed in the Vhembe District identified local clinic. The harvested produce was allocated to the clinic staff and security guards.

Appendix 7: Data Collection Tool

An Evaluation of Agroforestry Farms in Limpopo Province, South Africa

Enumerator ………………………………………………………………………………………......

Tel (work):……………………………………………………………………………………………………...

Mobile: ……………………………………………………………………………………………………

E-mail: …………………………………………………………………………………………………….

Questionnaire:

INFORMATION LEAFLET:

The evaluation of agroforestry farms in Limpopo province is being implemented by the Agricultural Research Council, Water Research Commission and University of Venda with the aim of evaluating the current status of farms with agroforestry practices in Limpopo Province, South Africa.

The objectives of the survey:

(a) To identify and describe the characteristics of selected Agroforestry farms in Limpopo province

(b) To determine the potential constraint of rainwater on the establishment and expansion of Agroforestry

(c) To determine factors that enhance farmer's participation in the Agroforestry sector in Limpopo province.

INSTRUCTIONS:

Please note, information provided will be treated with the highest degree of confidentiality.

INTERVIEWER DECLARATION:

I, ………………………………………………………………………………………., declare that I have asked this questionnaire as it has been laid out. I declare that all responses which have been recorded are the true responses of the respondent and that I have fully checked the questionnaire.

Signature: ……………………………………………………………………….

Date: ……………………………………………………………………………….

PARTICIPANT CONSENT:

I, ………………………………………………………………………………………… ID number: ………………………………………………………………….agree to take part in the aforementioned survey. I understand that my responses to this survey will be treated with the strictest confidence. I further understand that I will not receive any compensation for taking part in this study.

Signature: ………………………………………………………………………..

Date: ……………………………………………………………………………………………………..

Number of Beneficiaries:……………………………………………………………………………..……..

Agroforestry Description: ……………………………………………………………………………………..

1. GENERAL INFORMATION

Contact Information of the Farmer:

1.1. Name of the interviewer: ____

1.2. Name of farm: ____

1.3. a. Landline: ______________________ b. Mobile: _________________________

c. Facsimile address: __________________________

d. E-mail address: __________________________

Geographic information

(Location of Farm)

1.4. a. Local Municipality: ____

b. Village if the same as the location: ____________________________________

c. District's name: ____

1.4.1. GIS co-ordinate:

a. Latitude	b. Longitude

2. DEMOGRAPHIC INFORMATION OF FARMERS

2.1. Gender of the farmer head	Female
	Male

2.2. Age of the farmer head in years		**Years**

2.3. What is your Marital Status?			
Single	**Married**	**Divorced**	**Separated**

2.4. What is your farm size? (ha)	

2.5. Level of education	Less Grade 7(Primary)	1
	Matric	2
	Post Matric	3
	Other	4

2.6. Have you received any formal or informal training (skills)	**Yes**	**No**
a. **If yes, please specify the form or type of training** ……………………………………………………… ……………………………………………………………………………………………………..		
b. **And where or who offered the training** …………………………………………… …… ………………………………………………………………………………………...		

2.6. What is your occupation (apart from farming)?	

2.7. Language

Language	Farmer/Owner	Farm Manager
Venda	1	1
Shangaan	2	2
Sotho	3	3
Zulu	4	4
Afrikaans	5	5
Pedi	6	6
Tswana	7	7
Xhosa	8	8
Ndebele	9	9
Swazi	10	10
English	11	11
Sign	12	12

3. LAND AND AGRICULTURE

3.1. Type of farming	Agroforestry – Irrigation	1
	Agroforestry – Dryland	2
	Other:	3
Types of Agroforestry that are produced	Specify:	1

3.2. How did you acquire the land?

Bought (Title deed)		1
Leased		2
Inherited		3
Given by Government		4
Allocated by the Headman		5
Renting and /or share		6
0ther, specify		7

3.3. May you please complete the table below? (If practising other enterprise)

Field 1 put under production	**Area (ha)**	**Code**
Field 1		1
Field 2		2
Field 3		3
Field 4		4
Field 5		5
Other		6

3.4. Are you satisfied with the size of the land that you have?	1	Yes
	2	No
Why?.. **...**		

……..…………… **………………………………………………………………………………………..**

3.5. Do you really feel secure with land that you have in terms of ownership? Please indicate by a tick.	1	Yes
	2	No
And why?		

4 HUMAN CAPITAL ENDOWMENTS

4.1. Knowledge – farming experience in years

4.1.1. How long have you been farming?		Years
4.1.2. How long have you been farming on your current farm?		Years
4.1.3. How long have you been farming with the current enterprises?		Years

4.2. Are you involved in any other farm activities, apart from growing Agroforestry (e.g. value addition)? Please indicate by a tick.	1	Yes
	2	No
Specify (If yes)……………………………………………………………………………………..		

5. PRODUCTION RELATED BACKGROUND INFORMATION

5.1. Agroforestry	Stage of production	Years	
- Pine			tons
- Blue gum			tons
- Other, Specify			tons

5.2 Area of production/Size of the land

Total size of the land in hectare (ha)	
Size of the land under forestry (ha)	

5.3 Farming Systems

List other commodities the grower is producing:	Size (ha)

5.4 The use of natural forests in the area.

Which of the following are the uses of or the benefits you get from the natural forest?	**Tick**	**Code**
Timber for housing		1
Timber for kraals		2
Timber for fencing		3
Medicinal products		4
Honey production		5
Harvesting of insects		6
Others:		7

5.5 Marketing

How do you market your products?	Who buys?	
	Where do you market?	
	How much do you sell per annum (tons)?	

	How often per year do you sell?	

5.6 How long have you been involved in the production of Agroforestry?

Less than 5 years	**1**
6-10 years	**2**
More than 10 years	**3**

5.7. What has been your production on average for the period you have been in the business (harvesting year)? Indicate in terms of tons.

Year 1	
Year 2	
Year 3	
Year 4	
Year 5	
Other year(s)	

5.8. How much was your total expenditure of Agroforestry?

Year 1	
Year 2	
Year 3	
Year 4	
Year 5	
Other year(s)	

5.9. How much was your total income of Agroforestry?

Year 1	
Year 2	
Year 3	
Year 4	
Year 5	
Other year(s)	

5.10 May you please indicate any type of production loss when practising Agroforestry production

Theft	1
Disaster	2

6. Labour usage

6.1. Questions of skilled labours.				
6.1.1. Do you employ permanent skilled labour on your farm? Please indicate by a tick.	1	Yes	2	No
6.1.2. Please provide the list of skilled labour, their qualifications, roles and working days on the farm				
Name	Qualification	Role	Working days/year	Salary

6.2. Questions of unskilled / family labours.				
6.2.1. Do you employ permanent unskilled labour on your farm? Please indicate by a tick.	1	Yes	2	No
6.2.2. Please provide the list of unskilled labour with qualification, and functions on the farm				
Name	Qualification	Role	Working days/year	Salary

7. Assets

7.1 Do you have an asset (infrastructure, equipment, biological, etc.) register?	**Yes**	**No**

	7.2 Fixed Infrastructure usage				
	May you please indicate any five (5) most important infrastructures that you use for farm production?				
Type of infrastructure	Condition (e.g. poor, good, etc.)	Quantity	Age (years)	Estimated value (R)	Do you own or are you renting?

7.3 Biological assets

Biological assets	Condition (e.g. poor, good, etc.)	Quantity	Age (years)	Estimated value (R)	Do you own or are you renting?

7.4 Do you rent your farm for grazing? yes/no	**Yes**	**No**
7.5 If yes, for how much?		

3. Technology/equipment usage

8.1. May you please indicate any five (5) most important technologies/equipments that you use for farm productions?

Type of technology/equipment	Quantity	Estimated cost	Age (Years)	Operational cost/months	Do you own or are you renting?
Cell phone					
Computer					
Others:					

8.2. Please indicate the variable inputs e.g. fertilizers for the farm production

1
2
3
4
5
6
7
8

8.3 Farming practices

Do you perform the following practices?	**Tick**	**Code**
Planting		**1**
Fertilizing		**2**
Maintenance		**3**
Pruning		**4**
Thinning		**5**
Insects/pests control		**6**
Disease control		**7**
Harvesting		**8**

Processing		**9**
Other		**10**

How do you harvest? Manually or Mechanically?	Manually	1
	Mechanically	2
	Others:	3
Production capacity (m3 per annum)		
Where do you get the planting materials?		
What are the types of pests troubling you?		
What are the types of diseases troubling you?		

9. Disaster and Water Resources

9.1 Do the following climatic extremes affect you?

Select the appropriate answer	Yes	No
9.1.1 Drought?		
9.1.2 Floods?		
9.1.3 fire?		

9.1.4 Forest Fire/ Veld fire

9.1.4.1 Does the incidence of unplanned fire occur sometimes?	Yes			
	No			
9.1.4.2 When was the last fire you remember?	Year:			
9.1.4.3 Did the fire affect your agroforestry?	Yes			
	No			
What were the major Impacts:				
9.1.4.4 The estimated total damage in rinds?	R.			
9.1.4.6 Who (institutions) assisted you?				
9.1.4.7 How were you assisted?				
9.1.4.8 Have you recovered from the impacts of the fire?	Yes		No	
9.1.4.9 Do you have fire preparedness plan	Yes		No	
9.1.4.10 If yes, how are you preparing?				
9.1.4.11 If you do not have preparedness plan, Why don’t you have one?				

9.1.4.12 Do you get assistance on your combat against drought?	

9.2. If the drought affects you,

9.2.1. When was the last prominent drought you remember?	Year:			
9.2.2. Did the drought affect your agroforestry?				
9.2.3. What were the major Impacts:				
9.2.4. The estimated total damage in rinds?	R.			
9.2.5. Who (institutions) assisted you?				
9.2.6 How were you assisted?				
9.2.7. Have you recovered from the drought impacts?	Yes:		No:	
9.2.8. Do you have drought preparedness plan	Yes:		No:	
9.2.9. If yes, How are you preparing?				
9.2.10. If you do not have preparedness plan, why don't you have one?				
9.2.11. Do you get assistance on your combat against drought?				

9.3. Floods

9.3.1. When were the last prominent floods?	Year:			
9.3.2 Did the floods affect your agroforestry?				
9.3.3 What were the impacts of the floods:				
9.3.4 The damage in rand	R.			
9.3.5 Who (institutions) assisted you and How were you assisted?				
9.3.6 Have you recovered from the impacts of the floods?	Yes		No	
9.3.7 Do you have floods preparedness plan?	Yes		No	
9.3.8 If yes, how are you prepared for the future floods?				
9.3.9 If no, why don't you prepare yourself for floods?				
9.3.10 Do you get assistance on your combat against floods?				

9.4. Water Resources

9.4.1 What are your water sources?	Select the relevant water Sources that applies to you (Tick)
9.4.2 Rainwater	1
9.4.3 Municipal Water	2
9.4.4 Natural Water (Streams/rivers)	3
9.4.5 Groundwater	4
9.4.6 Other sources, indicate	5

9.5 Rainwater

9.5.1 Do you rely on rain-fed only?	Yes	No
9.5.2 Does the rain provide enough water?	Yes	No
9.5.3 If no, select the relevant alternative below	Yes	No

9.6 Municipal Water

9.6.1 Do you Get Enough water from the Municipality?	Yes	No
9.6.2 How often do you get water from this source?	Yes	No
9.6.3 Would you wish to have your supply increased from this source? And why?	Yes	No
9.6.4 If yes, Why?		
9.6.5 And by how much?		
9.6.6 How much water do you get from the municipality monthly, in litters?	………………….Litters/month/week/year	
9.6.7 How much do you pay for the water, monthly?	R…………………………………….. Litters/ month/ week/ year	
9.6.8 Do you think you are paying a lot of money?	Yes	No

9.7 Natural Water System (Rivers/streams)

9.7.1 Do you Get Enough water from this source?	Yes	No

9.7.2 How often do you get water from this source?	Always:	Seasonal	Other, Specify
9.7.3 Conveyance Technology	Gravity	Powered Engine:	Other:
9.7.4 Would you wish to have your supply increased from this source? And why?	Yes	No	
9.7.5 Do you have water license for this source?	Yes	No	
9.7.6 How much water do you get from this source?	………………...litters/…………/year/month/week		
9.7.7 How much do you pay for the water?	R………………………….…. year/month/week		
9.7.8 Do you think you are paying a lot of money?	Yes:	No:	
9.7.9 Water availability from this source?	Always:	Seasonally:	Other, Specify:
9.7.10 Operating Costs	R…………………………	Week/Month/Year	
9.7.11 Do you face water competition from other sectors?	Yes:	No:	
9.7.12 What type of the competition?	……………………………………………………… ……………………………………………………… ………………………………………………………		
9.7.12 How is it resolved?	……………………………………………………… ……………………………………………………… ………………………………………………………		
9.7.13 Challenges associated with this source?			
9.7.14 Advantages of this source?			

9.8 Groundwater

<table>
<tr><td>9.8.1 How often do you get water from this source (monthly)?</td><td colspan="8">……………….………………………/month</td></tr>
<tr><td>9.8.2 Who is the owner of the boreholes?</td><td colspan="3">Privately owned</td><td colspan="3">Communal</td><td colspan="2">Government</td></tr>
<tr><td>9.8.3 Who installed the infrastructure?</td><td colspan="3">Private individual</td><td colspan="3">Communal Contribution</td><td colspan="2">Government</td></tr>
<tr><td>9.8.4 In case of communal or government owned boreholes, are the boreholes located within your land?</td><td colspan="3">Yes</td><td colspan="5">No</td></tr>
<tr><td>9.8.5 If they are outside your land, how far?</td><td><200 m</td><td>1</td><td>200-500 m</td><td>2</td><td>500-2000 m</td><td>3</td><td>>2000 m</td><td>4</td></tr>
<tr><td rowspan="2">9.8.6 In case of shared boreholes, are there conflicts with other water users?

9.8.7 If yes, How are the conflicts resolved</td><td colspan="4">Yes</td><td colspan="4">No</td></tr>
<tr><td colspan="8">……………………………………….....................

…………………………………………………</td></tr>
<tr><td>9.8.8 How many boreholes are available?</td><td colspan="8">No:……………….………………boreholes</td></tr>
<tr><td>9.8.9 If you know, how much did it cost?</td><td colspan="8">R…………………………………boreholes</td></tr>
<tr><td>9.8.10 When was the boreholes drilled?</td><td colspan="8">Year:…………………………………………..</td></tr>
<tr><td>9.8.11 What is the power source for the boreholes?</td><td colspan="8"></td></tr>
<tr><td>9.8.12 Are your boreholes always having water?</td><td colspan="3">Yes</td><td colspan="5">No</td></tr>
<tr><td>9.8.13 Do you face water quality issues with your borehole?</td><td colspan="3">Yes</td><td colspan="5">No</td></tr>
<tr><td>9.8.14 How often is the borehole maintenance carried-out?</td><td colspan="3">Seasonal</td><td colspan="3">Yearly</td><td colspan="2">Other Specify</td></tr>
</table>

9.8.15 Was the borehole/s subjected to pumping test?	Yes	No
9.8.16 If yes? what is the recommended pumping rate:………………l/s (litres/seconds) Recommended pumping time?......................................………………hours/day What was the water level?...…………………m		
9.8.17 Was the water quality tested?	Yes	No
9.8.18 If yes, please provide the water quality summary:		
9.8.19 Is the boreholes still releasing same water as it was installed?	Yes	No
9.8.20 Would you wish to have your supply increased from this source? And why?	Yes	No
	Why	
9.8.21 Do you have water license for this source?	Yes	No
9.8.22 How much water do you get from this source?	Volume in litters:…………………………./month :…………………………/week :…………………………/year	
9.8.23 Do you pay for this water?	Yes	No
9.8.24 If yes, Who do you pay	:……………………...	
9.8.25 And how much?	R…………………………………………./year	
9.8.26 Do you think you are paying a lot of money?	Yes	No
9.8.27 Water availability from this source?	Always	Sometimes

9.8.28 Seasonal Availability, throughout the year		
9.8.29 Advantages of using boreholes?		
9.8.30 Disadvantages of the boreholes as a water source?		

9 Electricity source

10.1 Do you have electricity? Please indicate by a tick.	Yes	No
	1	2
10.2 Type of electricity		
10.3 Estimated amount per month (rand)		

10 Financial support

11.1 Indicate by a tick the type of financial support farmer received		Loan	Grant	Subsidy	Other (Specify)
Commercial banks	1				
Government	2				
Agricultural cooperatives	3				
Other (Specify)	4				

11 Demand conditions

12.1. Internationalisation of local buyers

12.1.1 Do you sell your product to international buyers? Please indicate by a tick.	Yes	1
	No	2

12.2. May you please indicate by a tick where do you sell your Agroforestry?

Bakkie informal	1
Informal market	2
Formal retails shop	3
Agric processing	4
Shops	5
Other	6

12.3. Good Agricultural Practice

Do you have the following Good Agricultural Practices in your farm? Please indicate by a tick.	Yes	No
Fertilizer storage		
Toilets		
Showers		
Washing basin		
Other		

12.4. Importance of ethics and production methods for local buyers

Is there a demand of your types of Agroforestry that is produced in a particular production method?	Yes	1
	No	2

12.5. Importance of environmentally friendly products for local consumers

Do you use fertilizers? Please indicate by a tick.	Yes	1	No	2
12.5.1 Option	Organic	Inorganic	Both	
12.5.2 Types used				
12.5.3 How much of fertilizer in kg or number of bags (kg) do you use?				

12.6 Pesticides

12.6.1 Do you use pesticides	Yes	No
12.6.2. How much pesticides do use?		

12.7. Product loss

Please indicate by a tick	Yes	1	No	2
Post-harvest				
Theft				
Disaster				
Disease				
Other				

The factors investigated, based on the determinants of competitive advantage as describe by Porter as (1990, 1998), can be classified as follows:

13 PERCEPTION ON CONSTRAINTS TO COMPETIVENESS TO AGROFORESTRY

To what extent do you agree with the following comments of competiveness to Agroforestry? Please tick (□) in the relevant box that best describes your view(s).

(NB*: the table below will be used to score the average factor condition)*

Views The following production factors are causing the decrease in competiveness of Agroforestry	**Responses**				
	1	**2**	**3**	**4**	**5**
	Strongly disagree	Disagree	Not sure	Strongly agree	Agree
Production conditions					
13.1Cost of production					
13.2 Labour					
13.3 Cost of unskilled labour					
13.4 Quality of unskilled labour					
13.5 Availability of unskilled labour					
13.6 Cost of skilled labour					
13.7 Availability of skilled labour					
13.8 Administration cost associated with labour matters					
13.9 Insufficient source of water					
13.10 Infrastructure					
13.11 Lack of Quality					
13.12 Lack of Availability					
14.1 Capital / Finance					

14.2 Costly					
14.3 Lack of availability					
15 Lack of knowledge of Agroforestry production					
16 Lack of technology					
Views The following production factors are causing the decrease in competiveness of Agroforestry	**Responses**				
	1.	**2.**	**3.**	**4.**	**5.**
	Strongly disagree	Disagree	Not sure	Strongly agree	Agree
Demand conditions					
16.1 Distance to market					
16.2 Market information					
16.3 Lack of quality					
16.4 Lack of availability					
16.5 Cost					
16.6 Quality of products					
16.7 Is there a market for Agroforestry?					
Views The following production factors are causing the decrease in competiveness of Agroforestry	**Responses**				
	1.	2.	3.	4.	5.
	Strongly disagree	Disagree	Not sure	Strongly agree	Agree
16.8 Related and supporting industries					
16.8.1 Financial institutions					
16.8.2 Research institutions					
16.8.3 Suppliers					
16.8.4 Electricity suppliers					
Views The following production factors are causing the decrease in competiveness of Agroforestry fruits	**Responses**				
	1.	2.	3.	4.	5.
	Strongly disagree	Disagree	Not sure	Strongly agree	Agree
18.9 Government support					

18.9.1 Poor interaction and support between Government					
18.9.2 Indirect support					
18.9.3 Trade policy					
18.9.4 Land reform policy					
18.9.5 Labour policy					
18.9.6 Fiscal policy					
Views	**Responses**				
The following production factors are causing the decrease in competiveness of Agroforestry	1. Strongly disagree	2. Disagree	3. Not sure	4. Strongly agree	5. Agree
Firm strategy, structure and rivalry					
1. Adaptability					
2. Culture					
3. Structure					
4. Flexibility					
5. Pricing strategy					
Views	**Responses**				
The following production factors are causing the decrease in competiveness of Agroforestry					
	1. Strongly disagree	2. Disagree	3. Not sure	4. Strongly agree	5. Agree
Market					
1 Market power of suppliers					
2 Market power of buyers					
3 Threat of substitutes					
4 Threat of new substitutes					
Views	**Responses**				
The following production factors are causing the decrease in competiveness of Agroforestry	1. Strongly disagree	2. Disagree	3. Not sure	4. Strongly agree	5. Agree
Chance					
1. Economic stability					

2. Aids					
3. Political stability					
4. Price stability					
5. Crime					
6. Drought					
7. Floods					
8. Fires					
9. Frost					

17 Description of agroforestry

What are the uses of agroforestry?

18 Agroforestry products

What are the agroforestry by-products you produce?

19 Value chain

How much value is added during the various stages in the processing of agroforestry in your company/plantation?	

20 Non-wood products

What are the different non-wood products that are available in your plantation and that people have access to?	

21 SWOT Analysis [To identify the perceptions of agroforestry growers regarding the industry's Strength, Weaknesses, the Opportunities and the Threats to its continued survival and relevance in the challenging operational environment]

21.1 Strength	
21.2 Weaknesses	
21.3 Opportunities	

21.4 Threats	

22 Potential area of production

General comment on the potential of the area for Agroforestry production	

23 Driving forces impacts

What are the driving forces which can impact production of Agroforestry?	

24 Extension, Research, Training and empowerment

Research and Extension

	Yes	**No**
24.1 Do you have access to research?		
24.2 Do you have access to extension?		

24.3 If yes, which research station helps you ?---

24.4 If yes, which organization provides extension? --

25.Training

	Yes	No
25.1 Do you have access to training?		
25.2 Do your staff have access to training?		

25.3 If yes, who trains you?---

25.4 How often? --

25.5 If yes, who trains your staff?--

25.6 How often?---

26. Empowerment

26.1 Who are the stakeholders of company/business enterprise?	
26.2 Do you provide capacity building and business support for emerging black entrepreneurs? Comment	
26.3 Is there any socio-economic development initiative that your company is providing that benefits the local communities? Comment	

27 Status of the forest

27.1 Comment on the status of the natural/woodland forest in your area	

28 Challenges/Problems

Indicate the challenges faced in the natural/woodlands in your area	

29 Observations

………
………
………
………
………
………
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………
………
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