Farming systems in South Africa beyond 2020: a scenario-based study, using systems analysis, of the connectivity between farming systems in the Vhembe district, Limpopo, South Africa.

by

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DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree in any other University.

____________________________________ (Signature of candidate)

___24th_____________day of_ January _____________2023

ABSTRACT

Agriculture is a significant contributor to the South African economy and overall development as it contributes to poverty reduction and food security. It is against this backdrop that agricultural development becomes a focus area for decision making amongst stakeholders, as it is directly linked to food systems. The traditional approach to agricultural production in the country has been one that views farming as mainly based on land ownership and yield in isolation from the broader context of the four drivers of production namely land, labour, capital and enterprise. The concept of farming systems provides a broader perspective on farming and encompasses the entire value chain for a commodity which includes production, management practices, marketing, value addition, financial resources, and policies.

The South African agrarian structure is characterised by a dualism in which large-scale commercial farmers co-exist alongside small-scale farmers. This is a legacy of the apartheid system of governance. Large-scale commercial farmers, who are mostly capital intensive, have historically been regarded as the main drivers of national food security while small-scale farmers on the other hand are viewed as significant contributors to food security at a household level. Both farmers are therefore important contributors to the national agricultural economy. Research on the two types of farmers in the South African context is usually focused on the respective farmers' approaches to production individually and does not consider them as joint ventures. This study was aimed at providing an alternative approach to viewing South Africa's farming systems by evaluating current farming systems in the Vhembe district of Limpopo, South Africa, using systems analysis as a tool to highlight the connectivity of the interactions within and between them. The study also aimed to conceptualize scenarios for sustainable future farming systems in South Africa.

The Vhembe district in the Limpopo province was chosen for the study because both large-scale commercial and small-scale farmers occur and due to the favourable sub-tropical climate, the area has become a hub for the farming of numerous high value crops that contribute positively to the country's agricultural economy. The study made use of a mixed methods approach that combined the analysis of primary data obtained from in-depth interviews and secondary data obtained from an agricultural database to identify and characterize large-scale commercial and small-scale farming systems in the Vhembe district. The study examined the drivers of production for three different commodities, macadamia nuts, mangos and avocado pears, the two types of farming systems and their connectivity. The study was grounded on the conceptual framework of systems thinking and used a systems analysis tool i.e., causal loop diagrams to analyse the connectivity between the two farming systems. Lastly, the study developed conceptual scenarios using a deductive scenario method to conceptualise scenarios for the future of the two farming systems and the different commodities.

Key findings of the study showed that farming systems need to be understood through the lens of the four drivers of production. Land as a driver of production interacts with multiple other factors in shaping the management of a sustainable farming system. Examples of these factors include the link between land availability, ownership and farm size, decision-making and resource allocation tied to land management practices, and socio-economic considerations including the diversification of livelihoods by incorporating non-farm income and the farmers' adaptability to uncertainties such as climate change. The findings also revealed that there are interconnections between the two types of farming systems presenting potential for enhanced production and commercial opportunities. The conceptual scenarios developed in the study and the systems thinking tool of causal loop diagrams proved to be valuable tools to inform decision making and policy development.

The study's main conclusion points to the potential of large-scale commercial and small-scale farming systems in South Africa operating as joint ventures in the future and enhancing the sustainability of agricultural production and livelihoods. It also recommends the use of systems thinking that includes social, financial and environmental values and impacts in decision making for agricultural development.

Key words: Farming systems, systems analysis, agricultural development, drivers of production, scenarios, sustainability, connectivity.

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DEDICATION

To my nieces, Zoé Soraya and Imara Ellen. You are my why. I did it so that you will believe it is possible.

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ABBREVIATIONS

ARC Agricultural Research Council

BFAP Berau for Food and Agricultural Policy

CLD/s Casual Loop Diagram/s

FAO Food and Agricultural Organization

FSR Farming systems research

GDP Gross Domestic Product

HVCs High Value Crops

IPM Integrated pest management

ISCW Institute for Soil, Climate and Water

LSF Large-scale farmer

SAAGA South African Avocado Growers Association

SAMAC Macadamias South Africa

SSA Sub-Saharan Africa

SSF Small-scale farmer

WHO World Health Organization

CHAPTER 1 - INTRODUCTION

1.1 **The significance of farming systems in South Africa**

Agricultural production has become an issue of increasing global importance as there is need to meet the demands of a rapidly growing population. A 60% increase in global agricultural production by 2050 is required compared to what it was in 2017 (Parihar et al., 2022). When compared with the rest of the world, the economies of most countries in Africa have a high reliance on agriculture for both jobs and output. According to Suri and Udry (2022) agriculture makes up almost 20% Africa's GDP compared with a world average of about 5%. In Sub-Saharan Africa (SSA) agriculture accounts for 20% of the region's GDP, employs 67% of the total labour force and is the main source of livelihood for poor people (FAO, 2019). In South Africa the agricultural sector is one of the most important economic sectors for the country's development as it is directly linked to food security and poverty reduction. In 2020 agriculture contributed around 2.5% to the country's GDP (Statista, 2022).

One commonly used definition of a farming system is that of Dixon et al. (2001): *"…a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households."* Literature reveals that farming systems are classified differently based on various criteria and these are applied to different geographical locations (Biggs, 1995; Dixon et al., 2001; Darnhofer, et al., 2012). According to the Food and Agricultural Organization (FAO, 2019), the classification of farming systems in developing regions is based on: the available natural resource base, landscape, dominant patterns of farming activities and household livelihoods, and processing and off-farm activities. Based on the significance of agriculture in the region of SSA indicated above, the FAO has acknowledged that there are numerous classifications of farming systems that exist with many variations across the countries that comprise the region. South Africa serves as an example of a country with its own variation of farming systems.

South African agricultural farming systems are characterised by a dualism in which there exist large-scale commercial farmers and small-scale farmers Kutya (2012). Despite the historical background of large-scale commercial farmers being capital intensive (Kutya, 2012) and also being regarded as the main drivers of national food security (PLAAS, 2019), Kirsten and Van

Zyl (1998) argue that small-scale farming in South Africa is as viable, profitable and efficient as large-scale farming. This argument is supported by the notion proposed by Uys (2016) that small-scale farmers are significant drivers of household food security. Baiphethi and Jacobs (2009) suggest that there is a significant need to increase the productivity of small-scale farmers in order to ensure long-term food security as small-scale production increases the food supply within households. Due to the uniqueness of the two farming systems and the variables that characterise them, there is a need to use a systems approach to address the complexity that is contained in the co-existence of these farming systems in South Africa. A systems approach aids in evaluating the systems appropriately as it accounts for the multivariable, non-linear attributes of the processes and interactions that characterise each of the systems and their relatedness to each other Mensah et al., (2018). In understanding large-scale commercial and small-scale farming systems in South Africa, decision makers are able to come up with suitable solutions for how to address the challenges associated with significantly contributing to the country's agricultural economy. One useful tool that can be used to actualize this understanding is through the use of scenarios which are utilized and presented in the current study.

1.2 **Rationale for the study**

The two main farming systems that currently exist in South Africa can be found across the country. According to Altman et al. (2010), both farming systems extend across the Northern part of the country where the Limpopo Province is located. The two farming systems are impacted by the same drivers of production namely land, labour, capital and enterprise (Dariusz, 2015), however respond to these drivers differently. The manner in which the two farming systems respond to the drivers of production may reveal the connectivity between the systems. A systems approach is best suited to illustrate the connectivity between the farming systems and is thus used in the study. The farming systems in South Africa operate against the backdrop of constantly changing environmental, political and socio-economic conditions. This is the context in which the current research is positioned. Although farming systems research and farming systems analysis are well established research fields (Bawden, 1991), little attention has been paid to how farming systems will respond to change in the future with respect to drivers. The study provides an outlook on future farming systems in the country that takes into account the reality of ongoing change. By using scenarios as a tool, the study identifies conceptual scenarios for production in farming systems in South Africa based on the Vhembe district in the province of Limpopo as a frame of context.

1.3 **Aim and objectives**

The study was guided by the aim to evaluate current farming systems in the Vhembe district of Limpopo, South Africa using systems analysis as a tool in order to highlight the connectivity of the interactions within and between them and to conceptualize scenarios for future farming systems in South Africa. In order to achieve this aim, the study was guided by the following primary objectives:

1. To identify locations within the Vhembe district in the Limpopo province where large-scale commercial and small-scale farming systems exist and to establish their characteristics.
2. To determine what are the drivers of production for large-scale commercial and small-scale farming systems in the Vhembe district in the Limpopo province.
3. To analyse the interactions within and between large-scale commercial and small-scale farming systems in the Vhembe district in the Limpopo province focusing solely on land as a driver of production.
4. To develop conceptual scenarios for sustainable farming systems in the Vhembe district in the Limpopo province that can be used to inform decision making for agricultural development in the country at large.

1.4 **Structure of the dissertation**

This dissertation is structured into seven chapters. Chapter 1 is the overall introduction to the study which describes the relevance of agriculture internationally and narrows down to a South African context. The chapter then presents the understanding of farming systems that grounds the current study and the aim and objectives of the research. Chapter 2 presents the key literature and existing knowledge on the main issues that inform the research i.e., farming systems research as a research field, farming systems in the South African context, acknowledging the complexity in understanding the term small-scale farmer within a South African context, the state of large-scale commercial farming in the country, the drivers of agricultural production with specific emphasis on land, systems analysis for addressing complex problems, which is the theoretical basis for the research, and scenarios as a research tool. Subsequently chapter 2 presents the conceptual framework of the study using an article that was published in the Conversation on 20 April 2022. Chapter 3 describes the detailed methodology used to identify and characterize large and small-scale farming systems, to determine the drivers of production, to analyse the interactions within and between the systems using systems analysis and to develop the conceptual scenarios that provide the novel contribution of the research. Chapter 4 is presented as a review article published in 2022 in the journal Frontiers in Sustainable Food Systems under the section Land, Livelihoods and Food Security. The chapter is outlined with a preface that explains the main objective of the paper and how it aligns with objective 2 of the study followed by the article and a postscript. Chapter 5 addresses objective 3 of the research and is outlined as a research article published in 2021 in the journal Agricultural Sciences. The chapter is presented in a similar format to the preceding chapter where a preface is provided followed by the article and a postscript. Chapter 6 is intended to test the conceptual framework of the study and is presented as a research article submitted for publication in 2022 in a special issue of the journal Agriculture titled Sustainable Agriculture: Theories, Methods, Practices, and Policies under the section Agricultural Systems and Management. The same format for all articles presented in the dissertation is used. Chapter 7 provides a general discussion that outlines the key aspects of the research, presents the research's novel contribution, and provides recommendations for the application of the research to inform decision making as well as suggestions for future research. Lastly, a consolidated alphabetical reference list is provided presenting all references used in all articles in the dissertation and all other references used in the dissertation. The next chapter provides an overview of the key literature that informs the study.

CHAPTER 2 – LITERATURE REVIEW

2.1 Farming systems research

The term farming systems research (FSR) is used to describe an approach to agricultural research and development that is premised on the understanding that a farm cannot be studied in isolation but needs to be understood as being part of a region with its own specific agroecological setting, economic opportunities and cultural values (Darnhofer et al., 2012). According to Collinson (2000), the term FSR emerged to address a new set of questions that leading approaches to agricultural research were poorly equipped to address. Collinson (2000) further explains that these approaches were dominantly based on a productivist view toward agriculture which was mainly aimed at productivity gains and optimization. Packham (2011) argues that one of the shortcomings of these kinds of approaches is that they were only successful in specific contexts which were characterized by homogeneous production environments, large commercial farm units, stable economic conditions, and biological interactions. In cases of environments that are slightly more complex due to their heterogeneity, these kinds of approaches would fall short. Darnhofer et al. (2012) explain that initially FSR viewed the farm as a starting point for an analysis of a broad range of issues linked to agricultural production. It was later recognised that to understand farming, the scale of analysis needed to be broadened in order to capture the interactions between farms and their natural, social and economic context. It is based on this understanding that FSR began to draw from different disciplines and to focus on specific aspects in order to customize to different contexts.

The core understanding of FSR is that farming and its related activities are understood as systems (Bawden, 1991). According to Darnhofer et al. (2012), systems are about drawing attention to the relationship between elements rather than focussing on their specific elements and studying them in isolation. In the context of FSR, the objective is to understand the interactions between factors and how they influence one another (Röling and Wagemakers, 2000). Bawden (1996) proposes that one of the ways in which farming systems are characterized as systems is by virtue of them being comprised of inputs, processes and outputs. This characteristic provides a link to the factors of production. In economics, factors of production refer to all the resources required to produce goods and services (Beattie et al., 2009). These factors of production, referred to from here on as drivers of production in the current study are traditionally divided into four categories namely land (including all natural resources), labour (including all human resources), capital (including all man-made resources) and enterprise (which brings all the previous resources together for production) (Kusz, 2015). In order to understand the link between farming systems and the drivers of production it is useful to consider Bawden's (1996) characterization of farming systems as being purposeful. The same author explains that this means that a farming system can produce the same outcome in different ways, and can change its goals under constant conditions. The four drivers of production can therefore be applied as drivers under which any farming system can be analysed and are thus be applied in this study.

2.2 Farming systems: The South African Context

According to Kirsten and van Zyl (1998), South African agriculture has historically been comprised of mainly two categories of farmers, namely subsistence farmers most of whom reside in the former homeland areas, predominantly black people, and large-scale commercial farmers who occupy large portions of arable land. The term subsistence famer as stated above is denoted for the purpose of this discussion as a farmer who produces crops on a small piece of land mainly for household consumption (Morton, 2007).

According to the FAO Food System Profile for South Africa (2022) the country is characterized by a food system that is paradoxical in nature. The profile presents increasing food and nutrition insecurity in the face of sufficient food availability and a positive food balance despite unsustainable agricultural production systems. This has been attributed to apartheid policies that resultantly create the inequities that currently exist in the food system. There is an agreed need to transition towards a more sustainable food system by addressing the identified core challenges associated with the system namely: improved nutrition, levelling the playing field for stakeholders, improved food system governance and sustainable agricultural production systems.

2.2.1 Defining "Small-scale" in South Africa

The term small-scale farmer is commonly used in literature about agriculture in South Africa. A review of existing literature on smallholder farmers reveals that there is a degree of ambiguity that exits in the general understanding of the term. Often the term small-scale farmer is used interchangeably with terms such as smallholder farmers, resource poor farmers, emerging farmers, subsistence farmers and low-income farmers. Given this ambiguity, it is evident that there is no single definition of a small-scale farmer and therefore the context in which the term is used should always be taken into account. According to Fanadza and Dube (2018) in the South African context, smallholder farmers form a highly diverse group such that the term ‘small-scale’ resists a universal or even national definition. Literature also shows that size is not solely used to define small-scale farmers in South Africa as is commonly the case in other countries (Chisasa and Makina, 2012). Uys (2016) argues that despite the source of debate that the definition of size creates, farming on family pieces of land, on traditional lands and smallholdings and on the periphery of urban areas may fall in this category. Though the interpretation of small-scale farming may vary significantly within the discourse about agriculture in South Africa, there are certain distinguishing characteristics that aid in understanding. Kutya (2012) explains that this type of farming is usually characterised by intensive labour and in most cases, animal traction, limited use of agrochemicals and supply to the local or surrounding markets. Kutya (2012) also highlights that unlike large-scale commercial agriculture, small-scale farming plays a dual role of being a source of household food security as well as income from sale of surplus. From these characteristics it is evident that the main objective of small-scale farming systems in South Africa is not solely subsistence. The highly dualistic nature of agriculture in South Africa is such that it allows a developed commercial sector to co-exist with large numbers of small-scale farms (Chisasa and Makina, 2012). By 2016 it was estimated that there were 35 000 remaining commercial farmers in South Africa, which shows a significant decline from the estimated 120 000 in 1994 (Uys, 2016). On the other hand, there are an estimated 100 000 to 150 000 small-scale farmers across the country to date (StatsSA, 2019). Kirsten and van Zyl (1998) draw attention to the fact that the South African situation is in contrast with that in many other countries in the world where one would find a whole range of farming systems that vary in size, ranging from the very small (often subsistence) farmer to the very large farmer/agribusiness types.

In the case of South Africa, large-scale commercial agriculture is regarded as the main driver of national food security (PLAAS, 2019). In contrast to this Uys (2016) elucidates that economically, small-scale agriculture in South Africa enhances local economic development as it is a source of employment and keeps most of the income local as the market is predominantly localised. Hendriks (2013) expresses a similar viewpoint and suggests that small-scale agriculture contributes to food security at a household level as socially, especially on traditional lands, the produce is first meant to feed the household. According to Kutya (2012), large-scale commercial farms in South Africa are distinguished as being capital intensive and operate within systems dominated by multinational corporations with influence across the entire food supply chain. Kutya (2012) also suggests that small-scale farms are distinguished by production that is not capital intensive; it involves the production of crops and/or livestock on a small piece of land without using advanced and expensive technologies and influence is limited to only parts of the food supply chain.

Despite significant changes over time that have been documented, such as South African small-scale farmers intensifying their production with new crops such as maize in the early decades of the twentieth century (Beinart and Delius, 2018), the reality of the dual farm system context remains as it has been for a long time. This context is best described by Sandrey and Vink (2009) who explain that South African commercial farmers have historically been relatively well-advanced in terms of technology; whether through imported machinery and/or agrochemicals while small-scale farmers have been less endowed in terms of technology and other factors of production. This circles back to the proposition that the four factors of production can be viewed as conditions within which farming systems may be analysed. It serves as an example of how different systems can produce the same outcome in different ways depending on how the systems respond to conditions. The result of the disparity between the two farming systems has been a situation where small-scale farmers have generally been viewed as not economically viable because they contribute very little to the country's economy (Baipheti and Jacobs, 2009). Kirsten and van Zyl (1998) however argue that the view that large, capital-intensive farms are more economically efficient than small farms is based on beliefs about economies of scale in farming. The same authors further argue that the concept of small-scale farmer in South Africa is value laden and therefore cannot be presumed to directly entail non-productive and non-commercial entities. Chisasa and Makina (2012) have further suggested that despite numerous challenges that threaten the sustainability of small-scale farmers, their significance cannot be overlooked. This view is supported by Baiphethi and Jacobs (2009) who propose that small-scale farmers are strategically important to the overall economic growth and development of the country because they contribute to the reduction of unemployment, hunger and food insecurity. Small-scale farmers are also said to be key role players in the reduction of household food insecurity (Poulton et al., 2005).

There is therefore a need to understand the circumstances in which these small-scale farms operate beyond merely their economic viability. Despite these arguments in favour of the value of South African small-scale farmers, it is widely accepted in literature that the small-scale farming sector is greatly challenged by several constraints that jeopardise its long-term success (Kirsten and van Zyl, 1998; PLAAS, 2009; Biénabe and Vermeulen, 2011; Chisasa and Makina, 2012; Mpandeli and Maponya, 2014; Olofsson, 2018). Jari and Fraser (2009) list some of these challenges that impact small-scale farmers as difficulty to integrate into agricultural markets, being located in remote areas, poor infrastructure and communications, limited skills and resources, reliance on 'middle men' and incurring high transaction costs. These challenges that affect small-scale farming and the farmers who practice it, illustrate the uniqueness of the sector as a whole. In contrast to this, large-scale commercial farmers experience their own specific challenges that differ vastly from those encountered by small-scale farmers. Wilk et al. (2012) list some of these challenges as lack of clear directives from the government e.g., with regard to land reform and issuing of water licenses which creates uncertainty; and competing with global markets against the backdrop of a volatile global economic and political climate. Despite the fact that there are unique challenges that affect the two farming systems, there are also challenges that are common to both, such as the impacts of climate change (PLAAS, 2009). This once more demonstrates the characteristic of farming systems being able to produce the same outcome in different ways provided, they are exposed to the same conditions. The variation of challenges encountered by the two types of farmers illustrates the dichotomy between the systems that characterise the two farm types. It can be inferred that the variables and processes that comprise these systems will be different based on the scale at which they operate and will therefore necessitate management practices that are specific to the farming systems.

However, despite the duality of the farming systems, that may exist in the same geographical location and may be exposed to the same vagaries such as climate change in South Africa, this does not entirely rule out the possibility of overlap in the processes between the two systems. Biénabe and Vermeulen 2011 provide a useful illustration of overlap in processes by highlighting the case of the maize industry in South Africa. Maize is the most important grain crop in South Africa (National Development Agency, 2009). Given this importance, it is a crop that is farmed at both commercial and smallholder level. There is a well-established commercial sector mainly based on centralised procurement systems developed at national level and a small informal subsistence-oriented sector where local small millers operate at a very local level (Biénabe and Vermeulen, 2011). In as much as the crop and the pathway of agricultural enterprise may be the same, the ecological and socio-economic processes associated with management of the farming of the crop at different scales may differ. The farming systems will operate very differently in relation to the factors of production. Management of these differing farming systems needs to account for both the uniqueness of the systems as well as the instances where the systems interact in any way.

This presents the management of large-scale commercial farming systems and small-scale farming systems as a complex problem due to the multi-variable nature of the processes within them that characterise them as systems, as well as the non-linear interconnections that exist between them. In viewing the dual farming systems and their functionality in their entirety and regarding their connectedness, one is presented with what can be deemed ‘a complex problem’. Complex problems are typically defined as those that include the ability to approach them from multiple, sometimes competing, perspectives and which may have multiple possible solutions (Dörner and Funke (2017). The interrelatedness of the systems can be applied for the benefit of reaching the unified goal of achieving and maintaining a strong and sustainable agricultural economy in South Africa.

2.2.2 Large-scale commercial farming in South Africa

The literature on commercial farming in South Africa predominantly refers to a well-established, internationally competitive sector that is characterized by mass production. Hall and Cousins (2015) draw our attention to the historical context of apartheid which involved state regulation and subsidy that enabled the success of a capitalist white farming class. According to the same authors, there was a notable decline in commercial farming units from approximately 60, 000 in 1996 to 35, 000 in 2014. Despite this drop in number, the number of large-scale commercial farmers in South Africa is still significantly less that small-scale farmers. The 2017 Agricultural census recorded 40, 122 large-scale commercial farms in that year compared to over 300,000 small-scale farm units across the country (StatsSA, 2020). Lienbenberg (2013) states that commercial farms produce 95% of the market agricultural output on farms in South Africa. The average farm size of large-scale commercial farms in South Africa is 2,113 ha (Mathinya et al., 200).

One of the main challenges to large-scale commercial farmers identified by the Berau for Food and Agricultural Policy (BFAP, 2020) has been rising labour costs which have resulted in declines in employment. The same authors report that employment has gradually shifted from permanent to temporary and irregular due to increased mechanization on large-scale farms. Other challenges that large-scale commercial farmers face include, the slowness of government bureaucracy such as experiencing delays in processing water licences; and theft of the crop at a regional scale (Wilk et al., 2013). Constraints are exacerbated by the impacts of climate change which are seen through the recurrence of droughts and more frequent extreme climatic events such as floods and fires (Mathinya et al., 2000). Wilk et al. (2013) suggest that large-sale farmers also struggle with uncertainties around land reform programmes and to what extent these will affect them and the future sustainability of their production. According to Genis (2015), large-scale capitalist farmers remain involved in the land reform process through their union Agri SA to this end. Moswetsi et al. (2017) propose that management practices are responsible for the large yield gap between large-scale commercial and small-scale farmers in South Africa despite both farmers being exposed to the same biophysical constraints at field scale. The ability to for large-scale farmers to apply good management practices has given them a long-term advantage over small-scale farmers which is seen in the stark difference in productivity. Large-scale commercial farmers are generally able to cope better with threats and production constraints than their small-scale farmer counterparts.

2.3 Systems thinking for complex problems

In order to address the understanding of complex problems such as that which characterises South African farming systems, there is need to adopt relevant analysis tools. Systems analysis has been widely accepted across various disciplines as a viable problem-solving tool for addressing complex problems (Zadeh, 1973; Hornberger and Spear, 1981; Fiksel, 2006; Meadows, 2012). Systems analysis is based on the theoretical framework of systems thinking. The term was first coined by Barry Richmond in 1987 who defined systems thinking as *"the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure*" (Richmond, 1994). Although this definition has undergone much revision over the years and there are diverse views on the definition of systems thinking there is seemingly an absence of a universal definition used amongst scholars across different disciplines. There are however common themes that appear in many of the literature sources on the subject. These themes have been summarized in the subsequent section.

Systems thinking is defined by Arnold and Wade (2015) as *"a system of thinking about systems"*. According to the same authors systems thinking must have three components in order to be defined namely elements i.e., characteristics, interconnections i.e., the way these interactions feed back into each other or relate, and a function or purpose. Monat and Gannon (2015) explain that systems thinking requires us to think about systems holistically regarding both spatial and temporal elements; it acknowledges that systems are dynamic. Systems thinking does not replace reductionist or statistical thinking, rather it complements it (Haines, 2000). There are numerous systems thinking tools that are integral to the practice of systems thinking. Examples of these include: system archetypes, behaviour over time graphs, causal loop diagrams (CLDs) with feedbacks and delays, stock and flow diagrams, systemigrams, root cause analysis, systems dynamics/computer modelling and interpretive structural modelling (ISM). In this study, the researcher uses systems analysis applied through the use of causal loop diagrams as a systems thinking tool to achieve the aim of the research.

Systems analysis is defined by Mensah et al. (2018) as a process of controlling and interpreting facts, identifying the problems and, decomposing a system into its components. The purpose of systems analysis proposed by Mensah et al. (2018) is to study a system or its parts in order to identify its objectives to improve the system and ensure that all the components of the system work efficiently according to their purpose. In summary it can be said that systems analysis specifies what the system should do. According to Fiksel (2006), systems analysis was first developed in the 1960s and has since evolved into widespread approaches for modelling dynamic, non-linear systems.

According to Kim (1999), one of the first steps in attempting to understand system behaviour is to construct a CLD. The existence of balancing and reinforcing loops typically determine system behaviour. By drawing CLDs it becomes easier to see the interrelationships between system components. Meadows (2012) states that CLDs can become fairly complicated as cause-and-effect-relationships, many of which are usually hidden, are identified.

In order to better understand and subsequently manage the two farming systems in South Africa a systems analysis approach can be employed to this end in order to obtain clearer and more detailed insight. Such insight can aid in enhancing the synergy between the two systems and improving the efficiency of the individual systems. By achieving these goals, through evaluating the processes and interactions within and between large-scale commercial and small-scale farming systems, stakeholders could be better equipped to facilitate long-term sustainable functioning of farming systems in South Africa. In the context of this study systems analysis is applied to aid in examining the connectivity between farming systems.

2.4 Scenarios as a research tool for addressing complex problems

Another approach that has been used by researchers to develop workable solutions to complex problems has been to develop scenarios (Lindgren and Bandhold, 2010). Although different definitions for the word scenario exist across different disciplines, a common thread of understanding that unifies these differences is that scenarios are not predictions of the future; rather they are pictures of possible futures (Schweizer and Kriegler, 2012).The scenario approach is widely used in many disciplines (physical, economic and social) in varied circumstances and for different purposes (Abuildtrup et al., 2006). Carter et al. (2001) explain that scenarios can be used as tools in analyses which are characterised by the assessment of future developments in complex systems that are often inherently unpredictable, are insufficiently understood and have high scientific uncertainties such as climate change analyses. One other use for scenarios is that proposed by Ramirez et al. (2015) who suggest that scenarios can be used as a scholarly research methodology to produce interesting research. In the context of this proposition, interesting research is defined by the authors as research that is innovative and develops theory while being both useable and rigorous. Based on the above examples of the usefulness of scenarios, scenario development can rightly be adopted as a meaningful tool for the production of interesting research drawn from analyses of complex systems. In the context of this research, conceptual scenarios are developed and used to help imagine plausible futures for South African farming systems that can inform agricultural planning and policy development.

2.5 Land as a resource in South Africa

The land issue is highly contentious in South Africa due to its historical and political complexity. Land access, rights and ownership form central points in conversations around land reform which is necessitated to redress skewed land ownership patterns of the past. Ramutsindela (2007) explains this historical disparity as "*a white minority owning large tracts of arable land, while confining the black majority to a small percentage of land*". Walker and Dubb (2013) quantify this as 87% of the land in the country being white-owned and 13% owned by black people in 1994. Stats SA (2010) reported less than 40,000 white owned farming units in the country accounted for 67% of the total land area. The Department of Agriculture, Forestry and Fisheries DAFF (2012) reported communal areas, namely former homelands, cover some 17, 2 million hectares of which 14,5 million was classified as "agricultural" in 1991. This land distribution of black communal areas has been quantified by Walker and Dubb (2013) as being 15% of the country's arable land.

Van Averbeke et al. (2011) propose that secure land tenure is a necessary pre-condition for the adoption of long-term sustainability of farming practices. The different forms of land tenure systems and land ownership in the country are: tribal, state ownership, trust land, quitrent and freeholds (Beinart and Delius, 2018). According to Mpandeli and Maponya (2014) the land tenure system in the former Venda homeland, where the current study is situated, is primarily dominated by communal land. Community members use most of the land in the tribal communities in accordance with the recognized traditional communal system of land tenure. The same authors point out that farmers who farm on communal areas in the Limpopo Province are constrained by a variety of challenges which include shortage of equipment, lack of capital and land to grow enough crops. In the case of communal land in the Vhembe district, land is allocated to farmers by the local chief (Nefale, 2016). Concerns of favoritism and nepotism often cause discomfort amongst farmers over this matter. The farms located on these communal land holdings are dominantly small-scale ranging between 2- 5 ha (Beinart and Delius, 2018).

2.6 The significance of large-scale commercial and small-scale farmers to South Africa's food systems

It has been alluded to earlier that the extent to which large-scale commercial and small-scale farmers contribute to food security in the country varies substantially. Elleboudt (2012) explains that small-scale farmers primarily aim to augment household food security through agriculture on farms that range in size between 1 and 5ha. Large-scale commercial farmers on the other hand contribute 80% of the country's total food production (Van der Merwe, 2011). This contribution is mainly through the large-scale cultivation of maize and wheat which are the main cereals consumed in South African households (Hendriks, 2014). This presents a situation where the country is said to be food secure at national level and food insecure at a household level (StatsSA, 2017). Mathinya et al. (2022) suggest that the knowledge of this disparity is influenced by the easily accessible productivity records for large-scale farmers, usually deduced from deliveries to silos, while data on small-scale farmers' production is obtained from memory recall of farming households that poses a challenge to data collection and analysis. This gap in data for research on small-scale farmers is not an anomaly and is commonly seen in other African countries where small-scale farming is prevalent (Palm et al., 2010).

According to the Food and Agriculture Organization of the United Nations (FAO, 2009) food security exists when people at all times have access to sufficient, safe and nutritious food and water to meet their dietary needs to attain an active and healthy life. This definition of food security is founded on the three dimensions of food availability, accessibility, and utilization. Food accessibility in this context refers to having enough resources to obtain food for a nourishing diet (WHO, 2016). High value crops (HVCs) are known to return a significant price premium per hectare or per unit compared to traditional staple food crops because they do not often form part of the customary diet of the local population and are largely grown for their cash values in domestic and export markets (Temu and Temu, 2005). The cultivation of HVCs by Small-scale farmers presents an opportunity to gain higher incomes from farming if they diversify their farming activities by incorporating HVCs as opposed to solely relying on staple crops which produce low earnings. There is evidence in literature of farmers in the Vhembe district of Limpopo opting to incorporate HVCs in their farming activities alongside other staple crops and vegetables. This approach serves as a means of improving their ability to access staple foods, mainly through purchasing from retail outlets, through income obtained from the sale of a variety of high value subtropical crops that benefit from the favourable subtropical climate in the region (Ncube et al., 2016; Olofsson, 2018; Olofsson, 2021). This agroforestry approach presents great potential for improving the food security status of small-scale farming households in rural areas.

2.7 Conceptual framework of the study

The conceptual thinking that guides the study is best presented through the following opinion article that was published in the online newsletter the Conversation on the 20th of April 2022. The Conversation is an independent source of news and views from the academic and research community, delivered direct to the public. The article presents a concise overview of the study and its key findings. It also highlights the usefulness of systems thinking as a tool to understand how the two main farming systems in South Africa interact. It proposes systems thinking as an approach to inform decision making and policy development in future attempts to sustain agricultural development in the country. The article is quoted below and is available online at: http://theconversation.com/there-a-place-for-big-and-small-farms-in-securing-south-africas-food-supply-180826

THE CONVERSATION

Academic rigour, journalistic flair

There's a place for big and small farms in securing South Africa's food supply

Published: April 20, 2022 4.05pm SAST

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The farming sector is arguably the most important economic sector for South Africa's development as it is directly linked to food security and poverty reduction. In 2019, 5.3% of employees in South Africa were in the agricultural sector and in 2020, agriculture contributed around 2.5% to the country's GDP. The constitutional right to food puts food systems and agricultural development firmly on the national development agenda. South Africa's history shaped farming into a two-part system: large-scale commercial farmers and small-scale farmers. Both types are important in the agricultural economy. Large-scale commercial farmers are typically viewed as the main drivers of national food security, producing about 80% of the country's food. The small-scale farmers have been promoted by government as significant drivers of household food security. In 2017 almost 20% of South African households had insufficient food. The existence of these two systems remains a sign of injustice and inequity. South Africa's efforts to reform land distribution have tended to focus on this duality. There's a problem with this approach: land isn't the only determinant of success in farming. The other three main drivers of production in agriculture are labour, capital and enterprise. If land was the only factor that counted, there'd be no need to consider market access or trade between the formal and informal sectors. Farming isn't isolated from the broader economy. There's a need for a more holistic approach to farming systems in South Africa – a systems approach. This was the way we approached a study of a farming area in South Africa. The study took place in the Vhembe district of the Limpopo province, where both commercial and small-scale farming occurs. We looked at factors like farm size, land ownership, topography, soil description, rainfall and threats like theft and disease, to see how these related to yield and income from three crops. The macadamia nuts, mangoes and avocado pears grown in the area are all high value commodities. We also considered how production under the two types of farming could sustain long-term food security at national and household level. Among our findings was that yield depended on an array of land management aspects, not just on farm size. Sustainability didn't depend on security of land tenure. Findings like this can help target investments more fruitfully and feed into the ongoing land reform debate. Since both types of farming are important, any efforts to address the country's long term food security should consider the complex connections between them and how this connectedness brings about food production. The research Agriculture is the key contributor to employment and livelihoods in the Vhembe district where we did the research in late 2020. The area is semi-arid and frequently affected by dry spells. Most commercial farmers rely on irrigation systems while the small-scale farmers depend on seasonal rainfall. We interviewed 19 local farmers in depth – men and women. A majority (70%) of the participants were small-scale farmers with communal land tenure; 30% were involved in large-scale commercial farming. We also collected official data on climate, land type and soils, and consulted academic sources. The analysis aimed to highlight the connectivity of interactions between the farming systems in terms of the four drivers of production: land, labour, capital and enterprise. Most farmers in the district (79%) were men and 90% were above the age of 51. Communal land ownership was the dominant (74%) form of land ownership among participants. Access to water for irrigation was a big constraint for small-scale farmers. We found that crop theft was the biggest threat, particularly on small farms, mainly due to inadequate fencing. Crop yield wasn't solely dependent on farm size. For macadamia farmers, the link between farm size and yield was positive but weak. For mango and avocado farmers, bigger farms yielded less than smaller ones. For income, however, there was a strong correlation with farm size. The study showed that changes in land management and access to additional income from off-farm activities can support the sustainability of farms. It has been argued elsewhere that secure land tenure is a necessary pre-condition for sustainable farming practices. Our study results don't support this theory. The majority of our respondents farmed on communal land yet they were sustainable (through incorporating off-farm activities). Changes to land tenure policy in the Vhembe district could have a negative impact on the sustainability of both farming systems – commercial and small-scale – if it didn't consider overlapping land use rights for people living on communal land, among other things. For example, even if a small-scale farmer were to be given ownership of a portion of communal land, they might plant crops on the land only to have someone else's cattle graze there after harvest. In relation to the capital and enterprise drivers of farming, we found that the two systems don't respond in the same way. A large-scale commercial avocado farmer, for example, will be able to transport produce quickly from farm to pack house, where it's prepared for market. A small-scale avocado farmer from the same location may not have transport and will have to sell the produce at local markets. Our study shows that there are significant points of connectivity between the two types of farmers. These include the supply of plants and produce between the two types of farms and the exchange of farming information. This shows that there's potential for the two types to work together to achieve food security. A systems approach Our study highlights the need to shift from a mindset of hierarchies to networks when solving the challenges of farming systems in South Africa. Existing policy frameworks are generally designed with a linear approach. Suggested solutions to specific problems don't consider the many instances where there's connectivity between the two farming systems. Neglecting this fact makes solutions less effective. Decision making also depends on collecting essential data against the backdrop of constantly changing environmental, political and socio-economic conditions.

2.8 Conclusion

The literature review presents a summary of key literature on the main subject matter of the research intended to provide a foundation of the knowledge on the issue of farming systems in South Africa. Through the review it is possible to understand the context of the dual nature of the country’s farming systems and how land is viewed in this context, the uniqueness of the understanding of the term “small-scale” farmer in the South African context, and the value of systems thinking and its application to address complex problems such as the one presented by the dichotomy of South African farming systems. The review has also highlighted the significance of scenarios as a tool for complex problem solving. The literature has shown that the two kinds of farmers respond differently to uncertainties and constraints based on the management practices that they employ and this has direct implications on their respective yields; this is shown in a wide yield gap. It is also clear that the sizes of the two types of farmers in South Africa vary substantially. The conceptual framework is also presented to aid in the overall understanding of the research work and to enable the reader to determine the research’s relevance. The subsequent chapter presents the details of the methodology that was used to achieve the aim of the study.

CHAPTER 3- METHODOLOGY

3.1 Description of the study area

The study took place in the Vhembe district which is the northern most district municipality of the Limpopo Province in South Africa (Figure 1. a). It shares borders with Zimbabwe and Botswana in the north-east and Mozambique in the south-east through the Kruger National Park. The Vhembe district is one of five district municipalities in the Limpopo Province. The district has an area of 25 596 km^2 and is comprised of four local municipalities: Thulamela, Mutale (renamed Collins Chabane), Musina and Makhado (Figure 1. b). The main towns within the district are Thohoyandou, Malamulele, Musina and Makhado respectively for the four municipalities. The South African governance structure regards the composition of local municipalities as towns and their surrounding rural areas (Independent Electoral Commission (IEC) of South Africa, 2016).

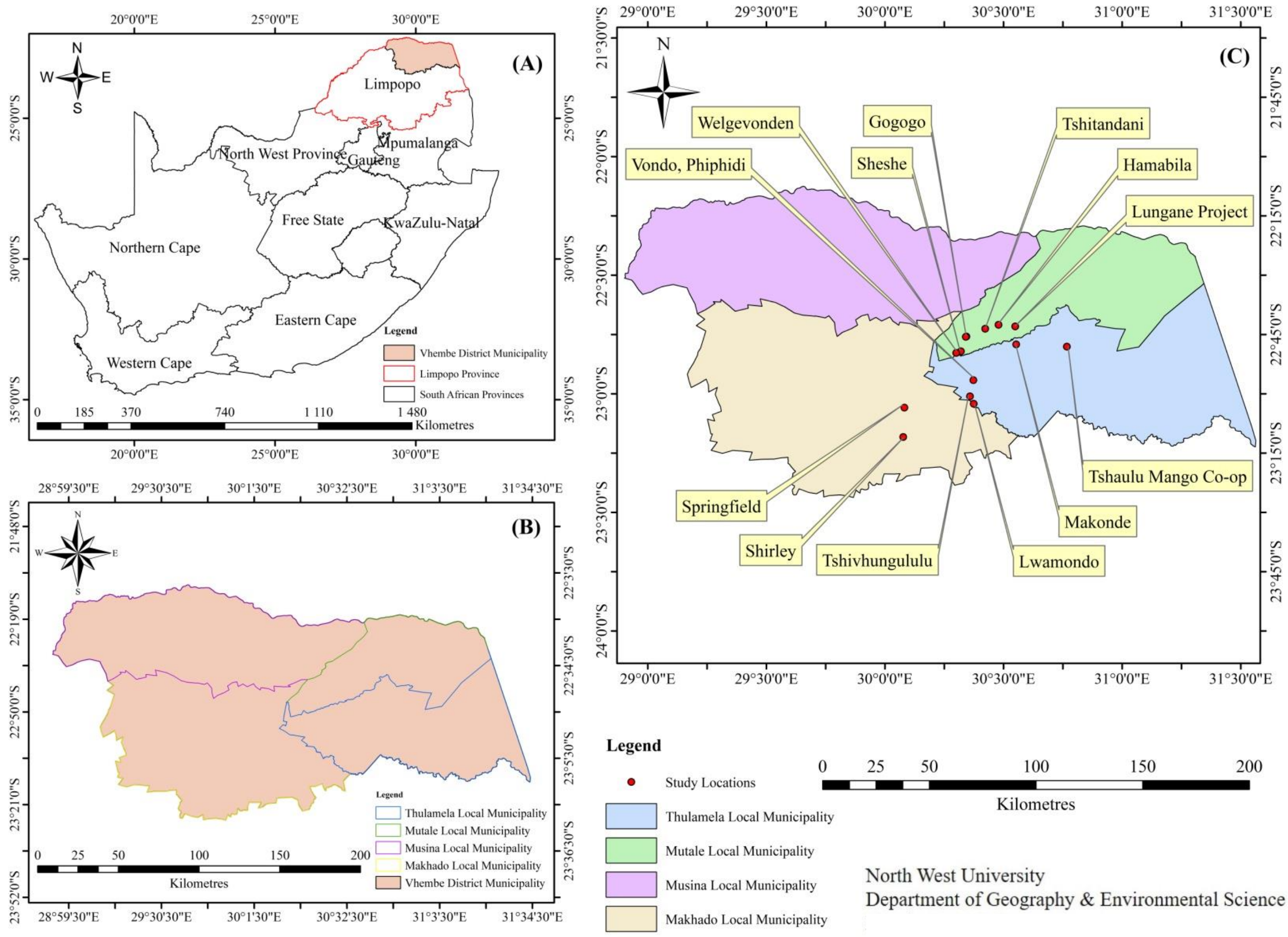

Figure 1. Map showing the location of (A) The Republic of South Africa' Provinces and provincial boundaries, highlighting the location of the Limpopo Province and the Vhembe district within the Limpopo Province of South Africa (B) shows the location of the four local municipalities within the Vhembe district and (C) shows the locations and names of the farm sites within the Vhembe district that were sampled in the study.

The district covers a geographical location that is predominantly rural (Rusere et. al., 2019). According to Mpandeli and Maponya (2014) agriculture is the main contributor to employment and livelihoods in the district. Odhiambo and Magandini (2008) state that 70% of the farming activities in the district can be accounted to smallholder agriculture and the remaining 30% is commercial agriculture. According to the Vhembe District Municipality's Local Economic Development Strategy (2020) the district produces no less than 4,4 % of South Africa's total agricultural output, 8,4 % of the country's sub-tropical fruits and 6,3 % of its citrus. The district is situated in a semi-arid area, is frequently affected by dry spells that often develop into severe drought and experiences severe water shortages from May to August (Rusere et al., 2019). The same authors document that most commercial farmers in the district rely on irrigation systems for farming whilst the smallholder farmers generally depend on seasonal rainfall which typically falls from November to March.

The average rainfall for the Vhembe district ranges from 246mm to 681mm per annum (Rusere et al., 2019). Soils in the district are variable and tend to be sandy in the west, but with a higher loam and clay content towards the east (Odiambo and Magandini ,2008; Rusere et al., 2019). The soils are mainly developed on basalt, sandstone and biotite gneiss and mostly have a low inherent soil fertility (Rusere et al., 2019).

Maize is the predominant cereal grain grown in the district among small holder farmers (Odiambo and Magandini, 2008). Leguminous crops like groundnuts, bambara nuts and cowpeas are also grown by smallholder farmers as well as vegetable crops which include spinach, cabbage, tomatoes and onions (Mpandeli, 2014) These are grown for the farmers' own consumption with any surplus sold to neighbors or relatives. Rainfed crop yields are generally poor due to low and erratic rainfall coupled with poor fertility.

According to Kom et al. (2020) the well-established white commercial horticulture farming is generally found in the south eastern side of the district (Makhado Levubu area). It is mainly made up of stakeholders in the subtropical industry which includes commodities such as mangos, litchis, bananas, avocados, citrus, pecan and macadamia nuts.

3.2 Justification for the study area

The Limpopo province covers an area of 124 600km2 which accounts for 10.2 % of the total land area of the country (De Cock et al., 2013). The province is endowed with abundant agricultural resources and is one of the country's prime agricultural regions noted for the production of livestock, fruits and vegetables, cereals and tea (Mpandeli and Maponya, 2014). The province has four distinct climatic regions namely: the Lowveld (arid and semi-arid) regions, the Middle veld, Highveld (semi-arid region) and the Escarpment region which is characterised by a sub-humid climate with rainfall in excess of 700mm per annum (Mafunzwaini and Hugo, 2005). Due to these varied climates, the province is able to produce a variety of agricultural produce ranging from tropical fruits such as bananas and mangos to cereals such as maize, wheat and vegetables such as tomatoes, onions and potatoes.

The Limpopo province was deemed best suited for the study on the basis of the following factors established from a preliminary literature review and desktop study: 1) both large-scale commercial and small-sale farming systems exist within the province 2) there is extensive agricultural activity that takes place in the province 3) production from the farming enterprises contribute significantly to the South African agricultural economy 4) accessibility, by road, of the province to the researcher. The Limpopo province borders with the Gauteng province to the south where the researcher is based 5) evidence that suggests due to the favourable and varied climatic, soil and topographic conditions in the province, the trajectory for the future leans towards this region becoming a greater contributor to the country’s agricultural economy over time (Petja et al., 2009; Omotayo, 2018; Ndwambi et al., 2020).

3.3 Methods and analysis

Methods employed in the study are detailed below for each of the study’s objectives:

Objective 1: To identify locations within the Vhembe district in Limpopo where large-scale commercial and small-scale farming systems exist and to establish their characteristics.

3.3.1 Sampling method for location identification and farming systems characterization

The study made use of primary and secondary data. Secondary data were collected from various sources including: the official subtropical crop database obtained from the local Department of Agriculture located in the town of Thohoyandou, climate data from the Institute for Soil, Climate and Water (ISCW), land type and soils data from the Agricultural Research Council

(ARC), peer reviewed research papers and related books. The target population was a combination of large-scale commercial and small-scale farmers within the district.

Based on the FAO definition of farming systems which informs the study, three different enterprises based on commodities grown at farm sites emerged in the initial characterisation which from hereon will be identified as systems namely: 1) macadamia nut farming systems 2) mango farming systems and 3) avocado farming systems. These farming systems were initially broadly characterised based on available information extracted from the local Department of Agriculture database. The database was comprised of data on the farm location (village or location and local municipality), farm size (ha), gender of farmer, farmer name and telephone number.

This information was available for six subtropical commodities, namely bananas (23), litchis (92), avocados (204), mangos (528), macadamia nuts (184) and citrus fruits (90). According to the database there were a total of 1, 121 documented subtropical crop farmers in the Vhembe district. There were four criteria for site selection extracted from the database that were used in the study namely commodity, size of the farm, location of the farm and gender of the farmer.

A purposive sampling method (Ames et al., 2019) was employed in choosing the above criteria in order to determine the sample size detailed as follows: with regards to commodity, the following commodities were selected: mangos, avocados and macadamias. Mangos were selected because they formed the largest number of farms documented in the database. Avocados were selected based on the willingness of the farmers to participate in the study determined by preliminary interaction with the farmers at a local study group meeting that the researcher attended at early stages of the research. Lastly, macadamias were selected based on their significance to the South African agricultural economy as high value export crops. The next selection criterion was size. Farms were selected using a systematic random sampling procedure to ensure that there was equal representation of farms within the size categories that existed in the database, these namely small (1-5 ha), medium (6-13 ha) and large (14-20 ha and above). The researcher later narrowed these to two categories namely small-scale (1-10ha) and large-scale (11 ha and above) as these provided a continuum that was context specific to the study.

The next selection criterion was location. Farms were selected to ensure that there was equal representation of all 4 local municipalities that comprise the Vhembe district municipality namely Mutale, Makhado, Thulamela and Musina to provide a comprehensive overview of the district. Lastly, the farmers' gender was also used as a farm selection criterion. A random number generation method was used to ensure that there was equal representation of both genders across the farms. The process of random number sampling involved allocating a number to the farmers selected from the database based on the above criteria, writing down the numbers and placing them in a container. Numbers were then randomly picked out of the container to make up a total of 12 farms. These 12 farms were comprised of 4 samples for each of the 3 commodities spread across the 4 local municipalities with 2 small-scale and 2 large-scale farms as well as an even mixture of male and female farmers.

Once this initial site selection was made, a more detailed characterization of the sites was done based on the significance of the 4 drivers of production (land, labour, capital and enterprise) with specific focus on land as a driver of production due to the availability of secondary data. In considering land as a driver, characteristics such as elevation, climate, vegetation, dominant soil and soil pattern and dominant geological formations were considered. (Table 1.) The detailed characterisation of the farming systems identified based on land as a driver did not take into account the significance of the other drivers, namely labour, capital and enterprise. This necessitated the collection of primary data.

Table 1. Summary of detailed farm site characterization for initial 12 selected farm sites based on secondary data

Name of Farm site	Local Municipality	GPS Coordinates	Elevation (m)	Nearest weather station (as the crow flies) (km)	Commodity	Size of farm (ha)	Climate (according to Koppen Climate Classification)	Land Type	Description of Broad Soil Pattern	Vegetation (Summary Description according to Koppen Climate Classification)	Dominant Geological groups/formations	Dominant Soil Description
1.Fefe	Mutale	-22.735509; 30.334941	8.795	Mutale (19.2)	Macadamia	1	Warm, Semi-arid with summer rainfall	Ab181	Red, freely drained soils with low to intermediate base status	Sour Lowveld Bushveld	Quartzite, sandstone and conglomerate of the WylliesPoort Formation, Soutpansberg Group	**Hutton (56.8%)** Red-brown to brown topsoil overlying freely drained, red apedal soil material
2.Gogogo	Mutale	-22.780263; 30.330578	4.659	Mutale (20.3)	Macadamia	1	Warm, Semi-arid with summer rainfall	Ib442	Rock areas (> 60% rock) with miscellaneous, usually shallow soils	Sour Lowveld Bushveld	Quartzite, sandstone and conglomerate of the WylilesPoort Formation with, in the south, sandstone, conglomerate, shale and basalt of the Fundudzi formation, Soutpansberg Group. Diabase dykes and sills are common	**Rock (63.8%)** Mispah**(12.7%)** Grey to dark brown topsoil over hard rock
3.SirelyHlangana ni	Makhado	-23.174257; 30.077557		Makwarela (49.1)	Macadamia	37	Warm, Semi-arid with summer rainfall	Fa308	Commonly shallow soils on hard rock, fractured rock or weathering rock materials. Other soils may occur. Lime is rare of absent in the landscape.	Mixed Bushveld	Grey biotite gneiss and migmatiteof the Goudplaats Gneiss; metapelite of the Bandelierkop Complex	**Glenrosa (18.5%)** Grey to dark brown topsoil over soil materials mixed with partly weathered rock-derived materials to hard rock fragments and stones

4.Khalavha	Thulamala	-22.925139; 30.274282	1.577	Makwarela (22.0)	Macadamia	10	Warm, Semi-arid with summer rainfall	Ab 176	Red, freely drained soils with low to intermediate base status	Sour Lowveld Bushveld	Quartzite, sandstone, conglomerate and shale of the Soutpansberg Group. Also diabase.	**Hutton (26.0%)** Red-brown to brown topsoil overlying freely drained, red apedal soil material
5.Tshimbupfe	Makhado	-23.177246; 30.485534		Makwarela (25.6)	Mango	10	Warm, Semi-arid with summer rainfall	Fa 754	Commonly shallow soils on hard rock, fractured rock or weathering rock materials. Other soils may occur. Lime is rare of absent in the landscape	Sour Lowveld Bushveld	Syenite and hornblende granite of the Schiel Complex	**Glenrosa (27.0%)** Grey to dark brown topsoil over soil materials mixed with partly weathered rock-derived materials to hard rock fragments and stones
6.Shirley	Makhado	-23.174257; 30.077557	1.539	Makwarela (49.1)	Mango	10	Warm, Semi-arid with summer rainfall	Fa308	Commonly shallow soils on hard rock, fractured rock or weathering rock materials. Other soils may occur. Lime is rare of absent in the landscape	Mixed Bushveld	Grey biotite gneiss and migmatiteoof the Goudplaats Gneiss; metapelite of the Bandelierkop Complex	**Glenrosa (18.5%)** Grey to dark brown topsoil over soil materials mixed with partly weathered rock-derived materials to hard rock fragments and stones
7.Tshifudi	Thulamela	-22.823756; 30.703304	4.171	Malamulele (14.6)	Mango	1	Warm, Semi-arid with summer rainfall	Ea205	Black, structured, swelling and non-swelling clay soils and red	Sour Lowveld Bushveld	Basalt, tuff, sandstone, quartzite and shale of the Sibasa formations as well as sandstone, conglomerate and shale of the	**Shortlands (55%)** Dark red-brown, finely structured topsoil overlying freely drained, fine to medium structured red subsoil materials.

									structured clay soils		Fundudzi Formation, Soutpansberg Group; Quaternary sand in the north; occasional diabase sills	Subsoil shows little change in colour, structure and texture from topsoil and commonly overlies
8.Tshaulu	Thulamela	-22.807549; 30.754951	2.026	Malamulele (9.0)	Mango	1	Warm, Semi-arid with summer rainfall	Ea205	Black, structured, swelling and non-swelling clay soils and red structured clay soils	Sour Lowveld Bushveld	Basalt, tuff, sandstone, quartzite and shale of the Sibasa formations as well as sandstone, conglomerate and shale of the Fundudzi Formation, Soutpansberg Group; Quaternary sand in the north; occasional diabase sills	**Shortlands (55%)** Dark red-brown, finely structured topsoil overlying freely drained, fine to medium structured red subsoil materials. Subsoil shows little change in colour, structure and texture from topsoil and commonly overlies
9.Mahlahl uvani	Makhado	-22.925139; 30.274282			Avocado	2	Warm, Semi-arid with summer rainfall	Fa308	Commonly shallow soils on hard rock, fractured rock or weathering rock materials. Other soils may occur. Lime is rare of absent in the	Mixed Bushveld	Grey biotite gneiss and migmatiteoof the Goudplaats Gneiss; metapelite of the Bandelierkop Complex	**Glenrosa (18.5%)** Grey to dark brown topsoil over soil materials mixed with partly weathered rock-derived materials to hard rock fragments and stones
10.Shirely	Makhado	-23.174257; 30.077557	1.539	Makwarela (49.1)	Avocado	1	Warm, Semi-arid with summer rainfall	Fa308	Commonly shallow soils on hard rock, fractured rock or weathering rock materials.	Mixed Bushveld	Grey biotite gneiss and migmatiteoof the Goudplaats Gneiss; metapelite of the Bandelierkop Complex	**Glenrosa (18.5%)** Grey to dark brown topsoil over soil materials mixed with partly weathered rock-derived materials to hard rock

									Other soils may occur. Lime is rare of absent in the landscape			fragments and stones
11.Phiphidi	Thulamela	-22.946326; 30.395496	8.360	Makwarela (9.5)	Avocado	5	Warm, humid subtropical with summer rainfall	Ab 179	Red, freely drained soils with low to intermediate base status	Sour Lowveld Bushveld	Basalt, sandstone and quartzite of the Sibasa formation, Soutpansberg Group. Diabase in the north.	**Hutton (34%)** Red-brown to brown topsoil overlying freely drained, red apedal soil material
12.Lwamondo	Thulamela	-23.010775; 30.358454	4.314	Makwarela (15.0)	Avocado	5	Warm, humid subtropical with summer rainfall	Ab 173	Red, freely drained soils with low to intermediate base status	Sour Lowveld Bushveld	Leucocratic biotite gneiss, granite and pegmatite of the SwazianErathem. Diabase dykes are common	**Hutton (47%)** Red-brown to brown topsoil overlying freely drained, red apedal soil material

Primary data were obtained from in-depth interviews that were conducted with farmers in selected farm locations within the Vhembe district. A sample of 12 farms was used to begin with. However, upon initial attempts by the researcher to contact the farmers it was discovered that the database used in preliminary sample selection proved to be out of date as the contact details of many farmers on the database were non-existent. A snowball sampling technique (Etikan *et al.*, 2016) was used in response to this with the aim of maintaining the same sample size initially selected. Results of the snowball sampling produced samples that differed vastly in number to those from the initial sample selection: macadamia nuts (7), mangos (4) and avocados (8). A total of 19 farmers were selected to participate in interviews based on their availability and willingness to participate. The final sample used in the study was comprised of 6 more farmers than he initially proposed sample size of 12. Mango farmers were the most underrepresented amongst the three commodities and large-scale farmers were underrepresented between the two farm sizes. The latter could potentially affect the outcomes of the study negatively as results could be skewed towards small-scale farmers without taking into account the realities of large-scale farmers.

Objective 2: To determine the drivers of production for large-scale commercial and small-scale farming systems in the Vhembe district in Limpopo.

3.3.2 Primary data collection for determining the drivers of production for large-scale commercial and small-scale farmers in the Vhembe district

Interviews were conducted over two visits to the Vhembe district in October and November 2020. Suitable interview dates and times were arranged with farmers telephonically. Permission and ethical clearance were obtained from the local Department of Agriculture (Appendix 1) and the University of the Witwatersrand Human Research Ethics Committee (number: H19/09/26) (Appendix 2). The researcher, together with a field assistant from the Mutale local municipality conducted the interviews. The field assistant was employed in order to aid in translation from the local language i.e., Tshivenda in instances where there was a language barrier to enable effective communication.

Interviews were conducted face-to face with farmers on-site at the actual farm locations. All covid-19 protective measures were adhered to by way of wearing face masks, practicing social distancing and making use of sanitizers to sanitize hands and surfaces where necessary. The interviewers explained to participants the purpose of the study and obtained either signed or verbal consent before proceeding with interviews (see Appendix 3 for sample of consent form). Interviews were recorded using a voice recorder with the consent of the respondents. Interview responses were therefore recorded by hand by the researcher and by voice recording. On-site observations were documented in a field journal and photographs were taken during guided walks on the farms. GPS co-ordinates were recorded using a hand-held GPS device in order to produce a location map.

3.3.2.1 Pilot study

A pilot study was conducted to test the reliability of research instruments and its level of difficulty to comprehend. Interviews were conducted by the researcher with cattle farmers in the town of Mahikeng in the North West Province of South Africa. Completion of the pilot study resulted in minor revisions being made to the instrument upon analysis of the recorded responses. The validated tools were interpreted into the local language of TshiVhenda.

3.3.2.2 In-depth interviews

A questionnaire was the main instrument of data collection (see Appendix 4) comprised of a combination of close and open-ended questions in order to access a wide array of data i.e., both quantitative and qualitative from participants. Wheeldon and Faubert (2009) explain that qualitative data can be used to confirm or verify results found during the collection of quantitative information. These data are useful because they are able to shed light on individual and/or community beliefs, values and perceptions. Close-ended questions were used to elicit background information and for statistical information regarding the four drivers of production in the context of the selected farm sites. Open-ended questions were used to enable respondents to provide longer answers. An interview guide was also designed by the researcher (see Appendix 5) to provide quick access to associated probing questions that the researcher used to facilitate conversation and obtain more detailed responses from participants.

The questionnaire was 9 pages long, divided into 4 sections: 1) land as a driver of production 2) labour as a driver of production 3) capital as a driver of production 4) enterprise as a capital of production. The sections were further sub-divided into sections that were more specifically related to aspects of the particular driver. A representative sample of 19 farmers were interviewed using a self-administered questionnaire (interview instrument). All questionnaires were completed therefore presenting a response rate of 100%.

Key informant interviews were conducted with managers from processing plants for macadamia nuts and avocados. Mango processing plant personnel could not be reached. Study group meetings for the respective commodities were attended by the researcher as part of field work. These were information sharing sessions with various stakeholders (farmers, equipment suppliers, extension officers, researchers, grower association representatives, and government officials from the local Department of Agriculture) that allowed for interaction with the researcher.

3.3.2.3 Data analysis

Descriptive statistics (Sarka, 2021) were the main analytical technique used to analyse the responses to close-ended questions by calculating averages, percentages, and standard errors. Student t-tests and Chi squared tests (Shen et al., 2021) were used to compare the means across the two categories of farm size and between the different commodities. From these data a combination of tables and bar graphs were constructed.

Qualitative data were analysed through the use of thematic analysis (Grodal et al., 2021) of participant responses to open-ended questions related to the drivers of production across the different commodities and between the two farm sizes. Responses from these questions were categorised into dominant themes and sub-themes. Emerging themes were triangulated with quantitative data in order to explain phenomenon.

Objective 3: To analyse the interactions within and between large-scale commercial and small-scale farming systems in the Vhembe district in Limpopo focusing solely on land as a driver of production.

3.3.3 Causal Loop Diagram construction for the analysis of interactions within and between large-scale commercial and small-scale farming systems in the Vhembe district

The Causal Loop Diagram (CLD) analytical tool used to represent the relationship between system variables and their dynamic feedback structures was constructed using Vensim modelling software (Ventana Systems Inc. 60 Jacob Gates Road Harvard, MA, 01451, USA, http://www.ventanasystems.com/). The overall structure of the CLD represents the links between large-scale and small-scale farmers of the three commodities and the broader farming system. The CLDs hypothesize system behaviour and identify balancing and reinforcing feedbacks; they provide a visual representation of these feedbacks which allows for an improved understanding of the factors that impact production.

In these CLDs, elements of the system are connected by arrows that link cause and effect variables together to form causal chains (Inam et al., 2015). A positive link represents parallel behaviour of variables whereby an increase in the causative variable will result in an increase in the effect variable, while a decrease in the causative variable implies a decrease in the affected variable. On the other hand, a negative link indicates an inverse linkage between the variables. Closed circles or loops are central to understanding CLDs. As indicated above, they may be either reinforcing or balancing loops. According to Binder et al. (2004), a reinforcing loop is described as a cycle in which the effect of a variation in any variable propagates through the loop and returns to the variable reinforcing the initial deviation. Alternatively, a balancing loop is the cycle in which the effect of a variation in any variable propagates through the loop and returns to the variable a deviation opposite to the initial one.

3.3.3.1 Problem definition

It is widely accepted in systems literature, that a clear articulation of the problem is useful in defining the purpose of the model and determining the system boundaries (Binder et al., 2004; Inam et al., 2015; Coletta et al., 2021). Through initial discussions with local stakeholders regarding potential problems and responses to open ended questions derived from participant responses combined with secondary data obtained from extensive literature review, the process of problem definition entailed identifying the problem central theme and associated key variables for each of the farming systems. Three CDLs for each farming system were resultantly constructed.

Objective 4: To develop conceptual scenarios for sustainable farming systems in the Vhembe district in Limpopo that can be used to inform decision making for agricultural development in the country at large.

3.3.4 Development and analysis of scenarios for future sustainable farming systems in the Vhembe district, Limpopo

Scenarios were constructed using a scenario method known as ‘deductive’ (van der Heijden, 2012). The deductive process uses multiple iterations of scenario drafts that are typically developed through stakeholder engagement facilitated through workshops (van der Heijden, 2012). Workshops allow for scenario deconstruction and revision which provide an opportunity to validate the plausibility of the scenarios. In the current study scenarios were created drawing from three iterations of scenario drafts based on 1) predominant themes on production issues arising within the farming systems of the selected commodities based on farmer interviews and secondary data, 2) key informant interviews and 3) interactive study group meetings. Each narrative provided as much detail as possible with the aim of developing equally plausible futures based on a chosen time frame of 10 years (2022- 2032). The 10-year time frame was preferred over a longer projected time as it provides a more realistic time-frame to imagine plausible futures based on current trends.

The process of creating scenarios involved three steps. In the first step key drivers and uncertainties surrounding production that emerged from interview responses were noted. Secondly, notes from conversations with key informants who were interviewed during field visits were used to give further detail to what these key drivers are which produced an outline of the narrative for each scenario. Key informants included technical managers for processing plants of macadamia nuts (Green Farms Nut Company and The Royal Macadamia) and representatives from the respective growers’ associations (Macadamias South Africa i.e., SAMAC and the South African Avocado Growers Association i.e., SAAGA. Lastly, primary information was obtained from multistakeholder participation at local information sharing sessions termed ‘study group’ meetings. These were used to further corroborate what the key drivers and uncertainties are and to produce the final two storylines outlining plausible scenarios for farming systems of the respective commodities in the Vhembe district by the year 2032.

This iterative process is illustrated in Figure 2. The key driving forces of production were continuously narrowed with each iteration based on the most common themes recurring from feedback of the different participants. Themes were used as direction for what the key issues that the scenario would address. A 2x2 quadrant of four key drivers based on a scale of uncertainty vs impact ranging from low to high (Figure 2.) was used to establish what the main subject of the scenarios would be. Issues for which farmers’ responses reflected a high level of uncertainty were typically used as conversation points during information sharing sessions to probe what kind of solutions could be explored to address the challenge. These aided the writing of the scenario narratives. The interactions between farmers highlighted in the CLDs were used to evaluate the scenarios.

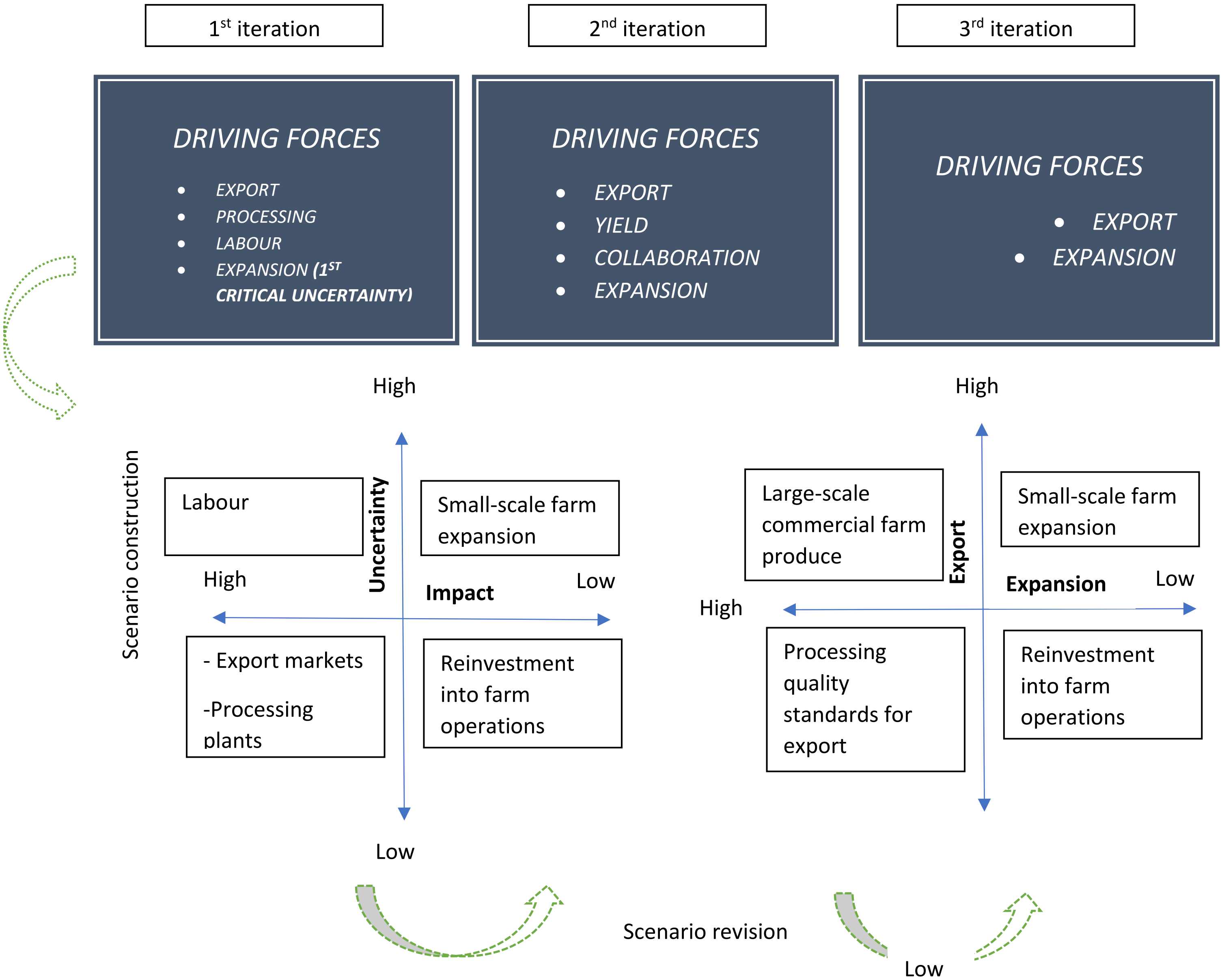

Figure 2. An example of the three iterations of the scenario development using the 2x2 quadrant of uncertainty vs impact used for scenario construction for macadamia nuts based on the key drivers and uncertainties identified from interviews. Adapted from Rameriz et al., (2015).

3.5 Concluding remark

The chapter has provided a detailed description of the main methodological tools used in the study namely the application of systems analysis through the use of CLDs and the development of conceptual scenarios. The methodology of this study is premised on the idea of coherence between methods of data collection and analysis. The following chapter will address how the study's second objective, i.e., determining the drivers of production in the Vhembe district, was approached.

CHAPTER 4 – THE DRIVERS OF PRODUCTION IN SOUTH AFRICAN FARMING SYSTEMS

4.1 Preface

To effectively evaluate the existing farming systems in South Africa there is a need to first establish what the drivers of production are. In determining the drivers of production and evaluating the extent to which they impact the respective farmers a better understanding of how the two farming systems interact with one another is achievable. This review paper uses the Vhembe district in Limpopo as a case study to illustrate these drivers of production that are typically unique to the context of South Africa's dual farming systems. The paper takes a broad look at the four factors of production i.e., land, labour, capital and enterprise and summarises the key issues of interest that are related to them at a national level. This review was done to provide context before focusing on the main drivers in the Vhembe district. The publication is available online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.722344/full

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REVIEW
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Understanding the Drivers of Production in South African Farming Systems: A Case Study of the Vhembe District, Limpopo South Africa

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Farming systems in South Africa operate against the backdrop of constantly changing environmental, political, and socio-economic conditions. Farming systems are commonly defined by the Food and Agriculture Organization (FAO) as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Historically farming systems in South Africa have been characterised by dualism in which large-scale commercial farmers co-exist with small-scale farmers. Although the two farming systems are impacted by the same drivers of production (land, labour, capital, and enterprise), however, they respond to these drivers differently and the nature of the responses reveal their connectivity and possible approaches to sustaining them. A systems thinking approach is best suited to draw possible scenarios of how farming systems in the Vhembe district located in the Limpopo Province of South Africa will respond to changes with respect to the four drivers. In this area, large-scale commercial farming forms a significant component of the production of a number of subtropical crops that contribute to the country's agricultural economy particularly through exports. Simultaneously 90% of rural communities in the district depend mainly on small-scale agriculture to sustain their livelihoods and generate income. The paper provides an overview of the drivers of production for the two farming systems in the Vhembe district and explores how the government can successfully promote development through agriculture by building capacity for the joint success of the two farming systems.

Keywords: farming systems, agriculture, agricultural production, food security, systems thinking

INTRODUCTION

Large-scale commercial farming alongside smallholder farming is a dichotomy that characterises South African farming systems and is a legacy of the Apartheid system. The two farming systems can be compared using a framework for production of which there are four drivers namely land, labour, capital, and enterprise (Dariusz, 2015). There has been some valuable research conducted on farming systems in the Vhembe district over the past 20 years as agriculture contributes significantly to the economy of the Limpopo Province and the country as well as to the provincial food security. Studies have shown that there is a production gap between commercial and small-scale producers in South Africa (Altman et al., 2010; Labadarios et al., 2011; Hendriks, 2014). Commercial agricultural production has been the primary driver of national food security predating democracy in 1994 (Hendriks, 2014). Baiphethi and Jacobs (2009) argue that even though small- scale production is important for household food security, the productivity of the sub-sector in South Africa is quite low. The South African government therefore places particular importance on small-scale agriculture in its efforts to fight food insecurity and poverty. According to Hendriks (2014), while the focus of agricultural production and marketing programmes in South Africa has shifted to small-scale production, legislative, and policy measures for creating an enabling environment for smallholders to establish sustainable and competitive production and marketing systems have not been provided. Hendriks (2014) further suggests that many of the elements that helped establish commercial farmers and ensure national food security such as input subsidies, infrastructure, security of tenure, market protection, credit etc. are either no longer available or non- functioning to both commercial and small-scale sectors. More recently Nwafor and van der Westhuizen (2020) proposed that smallholder farmers could improve their competitiveness through participating profitably and sustainably in agricultural supply chains. This has become the focus of a growing body of research (Giller et al., 2021; Marinus et al., 2022).

Statistics South Africa (StatsSA) (2017) revealed that the Limpopo Province has the highest number of households involved in agriculture in the country with 41% involved in agricultural production of some kind (De Cock et al., 2013). Despite this statistic the same source highlights that 91.5% of these households practice farming at a subsistence level as an additional food source and only 4.4% is engaged in agriculture as an additional source of income. Olofsson (2018) draws our attention to the fact that up to 41% of small-scale tree crop farmers in the Vhembe district depend primarily on welfare in the form of state pensions, available from the age of 60 years onwards, as their main livelihood source. These were used to purchase food from markets to supplement food obtained from home gardens.

Although the government desires to improve the quality of life of its citizens through farming and building capacity to farm high value crops (HVCs) that can contribute to food accessibility through profits made from sales and participating in export markets, the context of the dualism of the farming systems and their response to the drivers of production presents itself as a complex problem. Numerous debates have emerged within different spheres of government and amongst scholarly researchers surrounding the question of how the co-existence of South Africa's two main farming systems can be sustained. An understanding of the dynamics of how the factors of production affect South African farming systems and as a result contribute toward the transformation of agriculture in the country is paramount. There is need for an adequate evaluation of the farming systems in order to explore how they can continue to co-exist. The objective of the study is to understand the factors of production under the two farming systems in South Africa in order to explore the plausibility of various approaches that can be applied to support the development of these farming systems for purposes of long-term sustainability of agriculture in the country. Though the four drivers of production affect both farming systems significantly and intersect at various levels, for the purpose of this paper's discussion all four drivers are addressed generally however greater emphasis will be on land due to its contentious reputation and its significance in a politically- sensitive part of the country as the one chosen for the study.

CONTEXTUALISING THE DRIVERS OF PRODUCTION IN SOUTH AFRICAN FARMING SYSTEMS

The context of the dichotomous nature of South African farming systems is unique to South Africa and differs vastly from farming systems in other African countries given the historical background of apartheid and its aftermath (Garrity et al., 2012). The dual nature of the farming systems significantly affects productivity across all four drivers of production as can be seen in the following sections.

Land

Land is arguably the most critical driver of production in both large-scale commercial and small-scale farming systems in South Africa. There is a plethora of issues that pertain to land as a driver of production of which land access, availability, tenure, quality, and management of the land can be identified as major issues. Land management differs between the farming systems and becomes a key concern because it will determine the sustainability of the land. Land management is influenced by availability of land and tenure security amongst other factors. With regard to availability of land to the two farming systems, historically small-scale farmers, demographically classified as black, who made up the majority of the population were allocated limited proportions of land in the former homelands areas known as Bantustans (Van den Berg, 2013). This land was mostly of poor quality in comparison to the arable land allocated to their white South African counterparts who formed the minority (McCusker, 2004). This disparity in land availability is seen in the Limpopo province. There was reportedly a total of 5,000 commercial farming units in the Limpopo Province in 2002 (Whitbread et al., 2011). This number steadily decreased to 3054 in 2017 (8% of the national total) (Statistics South Africa (StatsSA), 2017) which corroborates the assertion made by Walker and Dubb (2013) that commercial farming units in South Africa have been rapidly decreasing since the 1990s. Although the exact number of commercial farming units in the Vhembe district is not specified, according to Oni et al. (2012) 174830 ha of arable land (70% of the total for the district) is owned by white commercial farmers while small-scale farmers own 74927 ha (30% of the district total). Olofsson (2018) describes the present state of small-scale farmers in the Vhembe district where farmers continue to be confined to overpopulated areas where land access is severely limited and land is governed by traditional authorities under a communal land tenure system. This communal land tenure system limits the production capacity of small-scale farmers as the combination of a lack of tenure rights and overlapping land uses restricts their ability to sustain production in the long term (Burger, 2021). Large-scale commercial farmers in the Vhembe district typically own the land they farm on (Olofsson, 2021) and this places them at an advantage as they are able to make more long-term production decisions. In terms of land quality as it pertains to fertility, irrigation plays a crucial role for the two farming systems. Irrigation promotes crop production throughout the year and crop diversification because of the availability of water. Irrigation is commonly practised by large-scale commercial farmers in the Vhembe district (Tapela, 2008). Most small-scale farmers in the district on the other hand depend on rainfed agriculture. According to Mpandeli (2014) rainfed crop yields amongst small-scale farmers are generally poor due to low and erratic rainfall coupled with already poor soil fertility.

Labour

Labour is also a key driver of production in South African farming systems. Some of the main issues of concern surrounding labour include the type of labour, i.e., permanent or seasonal, labour availability, quality, and management of labour with respect to decision making. There is heavy reliance family labour amongst small-scale farmers in South Africa and the Vhembe district in the Limpopo province is no exception. Labour is hired seasonally and to a limited extent mostly during the harvest season. Olofsson (2018) mentions the unique situation of smallholder tree crop farmers in the Vhembe district who rely primarily on their own labour, with some additional help coming from seasonal labour and family members and operate at a relatively small scale of production. This is in sharp contrast to their large-scale commercial farmer counterparts who according to Hall et al. (2013) have historically depended on hired seasonal and permanent labour to support large-scale production. The availability of seasonal labour is essential to the management of high value horticultural crops such as those typically found in the Vhembe district. The limited extent of hired family labour can be attributed to the size and demography of rural families which are impacted by urban migration patterns. According to Nhemachena and Hassan (2007) in most rural smallholder communities in Limpopo males are more often based in town as they seek for employment there, leaving much of the agricultural work to women. Mugovhani and Tshishonge (2012) highlight that the frequent absence from home of adult males involved in migrant labour in the Vhembe district resultantly increased social responsibility for women and boys. Hall et al. (2013) indicate that migration ushers in new patterns of displacement that bring migrants and refugees from the neighbouring country of Zimbabwe to Limpopo's farms and this has implications on the source of labour for small-scale farmers. Labour for large- scale commercial farmers on the other hand is generally hinged on costs.

In attempts to maximise profit, large-scale commercial farmers opt for mechanisation as an alternative to hired labour which can potentially reduce labour costs. Hall et al. (2013) suggest that this shift to a less labour-intensive production and increased mechanisation is a major driver of change in commercial agriculture in South Africa that is shaping the lives of workers on farms in the Limpopo Province. An unintended consequence of this shift in reliance on hired labour amongst large-scale farmers is a negative impact on labour relations between farmers and laborer's where members of the local communities feel excluded from participation in farming activities for production. The issue of what will promote the sustainability of production in terms of labour for South African farming systems remains unresolved.

There is ongoing research into what approach will result in success whether mechanisation is the best solution for both farming systems or a combination of mechanisation and hired labour. Due to the numerous constraints encountered by small-scale farmers across the country it is challenging to determine whether they have the capacity to replace the existing family labour structure with the adoption of new technologies and mechanisation.

Capital

Capital to support farming systems is yet another important driver of agricultural production. If neither of the two farming systems have access to sufficient capital, then the farming systems cannot be sustained. Most large-scale commercial farmers have access to capital from large commercial institutions. Greenberg (2013) points out that production finance in South Africa was historically provided for by state and statutory institutions such as the Land Bank and the Agricultural Credit Board. The Land Bank is said to have continued to play a valuable role in agricultural financing of commercial farmers in the province mostly excluding black producers (Cousins, 2016). Small-scale farmers on the other hand have limited access to capital which directly impacts the scale at which they can operate. Limited access to capital presents itself as a constraint to the farming of HVCs amongst small-scale farmers as the input costs for these crops are high. The lack of tenure rights for small-scale farmers alluded to earlier means farmers are unable to pledge land or income from harvests as surety for loans to improve their land (Burger, 2021). As a result of limited access small-scale farmers have to explore multiple avenues of generating capital such as diversifying farming systems to include livestock (Whitbread et al., 2011). Sale of some of the livestock serves as an alternative capital source. Other sources of capital amongst small-scale farmers include savings, money borrowed from family members and even money inherited from deceased family members. In order for small-scale farmers to transition into farming at a commercial level they need reliable sources of capital.

Enterprise

The issues of enterprise selection and combination are crucial to production in South African farming systems. Selection of the enterprise for small-scale farming systems is not based solely on profit. There are other considerations that must be factored into decision making such as the lack of land tenure security, the quality of the land and access to capital referred to in preceding sections. When small-scale farmers are unable to access capital from large financial institutions, they still need cashflow in order to cover running costs of farm operation and production for profit. It is common to find mixed enterprises amongst small- scale land holdings in South Africa. Small-scale farmers tend to mix the farming enterprise for example incorporating livestock alongside HVC farming. Beside the fact that livestock have social and cultural significance and are often used for cultural ceremonies, livestock can also be sold for additional income to reinvest in agriculture. Home gardens which include vegetables and nuts alongside the farming of HVCs are another example of mixed enterprises. Maize is the predominant cereal grain grown in the district among small-scale farmers (Odhiambo and Mag, 2008). Leguminous crops like groundnuts, bambara nuts and cowpeas are also grown by small-scale farmers as well as vegetable crops which include spinach, cabbage, tomatoes and onions (Obadire, 2010). These are grown for the farmers' own consumption with any surplus sold to neighbours or relatives. Sales from home garden produce are used to support the farming operations and resultantly sustain small-scale farming systems.

Theoretical Framework

South African farming systems operate against the backdrop of constantly changing environmental, political, and socio- economic conditions. It is within this context that agricultural production needs to be understood as it forms and important component of the water, energy, and food security nexus in a changing climate. A systemic approach to addressing agricultural development is necessitated by the reality of heterogenous approaches to production by way of the response to the drivers of production by the two dominant farming systems. Systems analysis is a valuable tool for the evaluation of complex problems such as that presented by the duality of farming systems in South Africa. Arnold and Wade (2015:7) define systems analysis as *"a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours and devising modifications to them in order to produce desired effects."* The application of systems analysis is rooted in the theoretical understanding of systems thinking which the same authors define simplistically as *"a system of thinking about systems."* (Arnold and Wade, 2015: 670). Systems thinking is based on the understanding that with globalisation comes increased interconnectedness and interdependence on systems that govern human existence (Meadows, 2008). The overlap in the various components of these global systems presents a complexity that necessitates a diversity of interventions and a systems dynamics (SD) approach to addressing complex problems. Simonovic (2012) describes systems dynamics as the understanding of the relationship between integrated systems elements and how they impact each other's behaviour.

METHODOLOGY

Study Site

The Vhembe district is a district municipality in the Limpopo Province of South Africa that is farthest north (**Figure 1**); sharing a border with Botswana and Zimbabwe in the north-east and Mozambique in the south-east through parts of the Kruger National Park (Maponya, 2021). The district is one of the five district municipalities that constitute the Limpopo Province. Out of an area of 2,140,708 ha, 247,757 ha of the land in the Vhembe district is arable (Setshego et al., 2020). Four local municipalities are found within the Vhembe district: Mutale (renamed Collins Chabane), Thulamela, Makhado and Musina. The South African governance structure regards the composition of local municipalities as towns and their surrounding rural areas (Independent Electoral Commission (IEC) of South Africa, 2016). The main towns within the district are, Malamulele, Thohoyandou, Makhado, and Musina, respectively, for the four local municipalities.

The Soutpansberg mountain range divides the Vhembe district into two agro-ecological systems. The northern side is largely semi-arid, with livestock farming and game ranching being the main activities and some limited horticulture where water is available; this is comprised of the local municipalities of Musina and Mutale. The southern side, comprised of the local municipalities of Thulamela and Makhado, is a subtropical regional hub with high rainfall, in excess of 700 mm per annum, making it suitable for the cultivation of subtropical fruits, cereals, vegetables, and nuts (Oni et al., 2011). The Vhembe district forms a significant component of the production of a number of subtropical crops that contribute to the country's agricultural economy particularly through exports. According to Kom et al. (2020) the well-established white commercial horticulture farming is generally found on the southern side of the district (local municipalities of Makhado and Thulamela). It is mainly made up of stakeholders in the subtropical industry which includes commodities such as litchis, bananas, mangos, avocados, citrus, and pecan nuts. Another subtropical crop found dominantly in the southern side of the Vhembe district is macadamia nuts.

Geographically, the Vhembe district covers a location that is predominantly rural (Rusere et al., 2019), which is characteristic of the Limpopo province. According to DAFF (2013) 89% of the population is classified as rural, therefore agriculture plays a prominent role in the economic development of rural areas in the province. The Vhembe District Municipality (VDM) (2014) reports that 90% of rural communities found in the Vhembe district depend mainly on agriculture to sustain their livelihoods and generate income. Maponya (2021) indicates that agriculture in the Vhembe district is one of the economic drivers that contribute to the Limpopo Province and nation at large. The Vhembe district produces 4.4% of South Africa's total agricultural output, 8.4% of the country's sub-tropical fruits and 6.3% of its citrus according to the Vhembe District Municipality's Local Economic Development Strategy (2020). A large proportion (70%) of the farming activities in the Vhembe district can be accounted for by small-scale agriculture and the remaining 30% is commercial agriculture (Odhiambo and Mag, 2008; Oni et al., 2012; Olofsson, 2018).

In terms of viability for agriculture, the district is located in a semi-arid area, is frequently affected by dry spells that often develop into severe drought and experiences severe water shortages from May to August (Rusere et al., 2019). The same authors document that most commercial farmers in the district

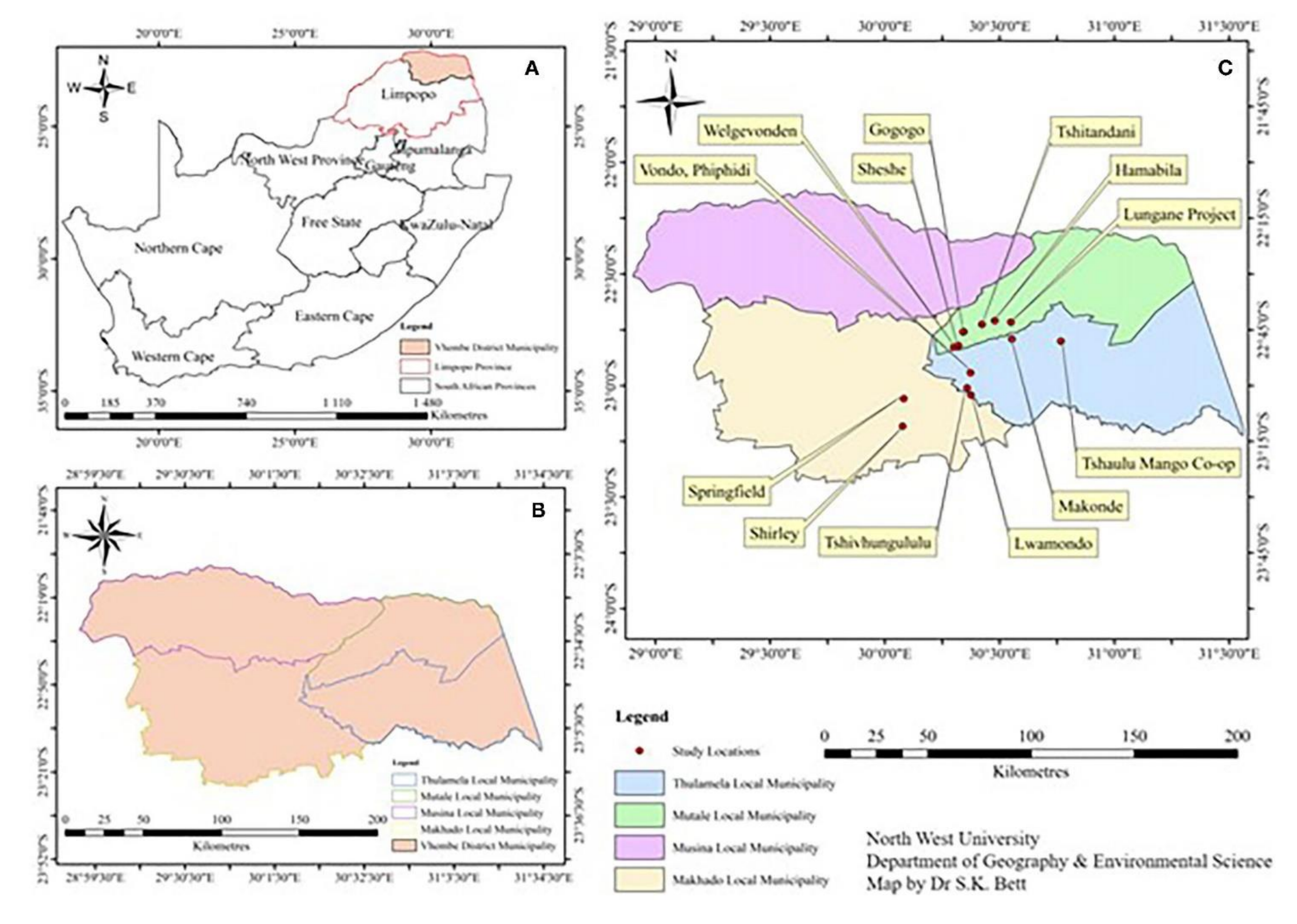

FIGURE 1 | Map showing the location of (A) The Republic of South Africa's Provinces and provincial boundaries, highlighting the location of the Limpopo Province and the Vhembe district within the Limpopo Province of South Africa (B) shows the location of the four local municipalities within the Vhembe district and (C) shows the locations and names of the farm sites within the Vhembe district that were sampled in the study.

depend on irrigation systems for farming whereas the small-scale farmers mostly rely on seasonal rainfall which typically falls from November to March. According to Moeletsi et al. (2013) seasonal rainfall (October-April) in the southern side of the district, identified earlier as including Makhado and Thulamela local municipalities and a horticulture hub, ranges from 400 to 600 mm. The average rainfall for the southern side ranges from 246 to 681 mm per annum (Rusere et al., 2019). Soils in the Vhembe district are variable and tend to have a higher loam and clay content toward the east but are sandy in the west (Odhiambo and Mag, 2008; Rusere et al., 2019). Moeletsi et al. (2013) state that soils in the southern region of the Vhembe district vary significantly from one place to another with most parts having Glenrosa and Hutton soils according to the South African soil classification (SA Soil Classification, 1991).

According to the census of commercial agriculture in 2017, the biggest crop output in the Vhembe district was fruit, mainly subtropical and citrus (Statistics South Africa (StatsSA), 2017). The district ranked third as the largest driver of agricultural production amongst the five districts in the province generating R5.4bn. The census also ranked the Vhembe district as the third biggest agricultural employer in the province employing 17,714 employees in large-scale commercial operations (Statistics South Africa (StatsSA), 2017).

Study Design

The study was conducted by analysing primary and secondary data to identify and characterise small and larger-scale farming systems of three tree crops in the Vhembe district namely macadamia nuts, avocados, and mangos. The aim of the analysis was to highlight the connectivity of interactions within and between the two farming systems in relation to the four drivers of production, i.e., land, labour, capital, and enterprise. Secondary data were collected from numerous sources: peer reviewed research articles, books, the official database of subtropical crops from the local Department of Agriculture, climate data from the Institute of Soil, Climate and Water (ISCW), and data of soils and land type from the Agricultural Research Council (ARC). The target population consisted of a combination of small-scale and large-scale commercial farmers of the three commodities within the district. Farming systems were first broadly categorised based on information extracted from the subtropical crop database which contained data on farm location (detailing the village or town and local municipality), gender of the farmer, farm size (ha) and the farmers personal contact details. A purposive sampling method (Ames et al., 2019) was used to select criteria for site selection. The four chosen criteria were farm size, commodity, farm location, and gender of the farmer. The database contained this information for six subtropical crops namely, litchis (92), avocados (204), bananas (23), macadamia nuts (184), citrus (90), and mangos (528). In total the database documents a total of 1,121 subtropical crop farmers in the Vhembe district. Based on the database information the three commodities selected for the study are the most commonly farmed commodities in the Vhembe district. This influenced the choice of commodities. Furthermore, macadamia nuts were selected based on their known export value as high HVCs and their significance to the country's agricultural economy while avocados were selected based on farmers' expressed willingness to participate in the study derived from preliminary interaction with farmers at a local study group information sharing meeting. Mangos were selected on the basis of having the largest number of documented farms on the database suggesting their popularity as a farming crop. With regard to farm size, farms were chosen using a systemic random sampling procedure to ensure equal representation within the various categories of size that are found in the database, namely small-scale (1–10 ha) and large-scale (11 ha and above) as the study required farmers with both smallholding and larger holdings. For the criterion of location farms were selected that reflected equal representation of all four local municipalities the characterise the Vhembe district namely Thulamela, Musina, Makhado, and Mutale. The last criterion for farm selection was famers' gender. A random number generation method was employed to ensure there was equal representation of both genders across the farms. The process of random number sampling was carried out by allocating a number to the selected farmers using the previously stated criteria, writing down the numbers and placing the m in a container. The researcher than randomly picked out numbers from the container to make up a total of 12 farms. The 12 farms were comprised of four samples for each of the three commodities spread across the four municipalities with two small-scale and 2 large-scale farms and an even combination of male and females. A detailed characterisation of the three farming systems based on the four drivers of production followed after the initial site selection. In- depth, on-site interviews with farmers provided primary data. Snowball sampling (Etikan et al., 2016) was used to conduct the interviews with farmers in selected farm locations with the objective of maintaining the same initially selected sample size. The outcome of the snowball sampling technique produced the following number of samples: mangos (4), macadamia nuts (7), and avocados (8). In total 19 farmers were selected to participate in in-depth interviews based on their availability and willingness to participate. Due to the extremely rural location of farm sites and challenges in accessing farms and farmers, data were collected at only one point in time. This explains the exceptionally small sample size which is acknowledged.

Data Collection

Face-to face interviews with farmers on-site at the farm locations were conducted over two visits to the Vhembe district in October and November 2020. Ethical clearance (number H19/09/26) was obtained from the University of the Witwatersrand ethics committee, as well as from the Local Department of Agriculture by way of an official letter of approval. Due to language barriers the researcher conducted the interviews alongside a local field assistant who served as an interpreter. Interviews were conducted in the local Vhenda language.

In-depth Interviews

The main instrument of data collection was a questionnaire made up of a combination of open and close-ended questions aimed at collecting both quantitative and qualitative data. Close-ended questions were used to obtain statistical information regarding the four drivers of production while open-ended questions were used to enable participants to provide more detailed answers. The questionnaire was divided into four sections: land, labour, capital, and enterprise.

Data Analysis

Qualitative data were analysed using descriptive statistics (Sarka, 2021) by calculating averages, percentages, and standard errors. Student *t*-tests and Chi squared tests (Shen et al., 2021) were used to compare the means across the two categories of farm size and between the different commodities. Qualitative data were analysed through the use of thematic analysis (Grodal et al., 2021) of participant responses to open-ended questions related to the drivers of production across the different commodities and between the two farm sizes. Responses from these questions were categorised into dominant themes and sub-themes. Emerging themes were triangulated with quantitative data in order to explain phenomenon.

RESULTS AND DISCUSSION

Results have been selected that speak to key issues raised under the sub-theme: Contextualising the drivers of production in South African farming systems. In line with the authors' decision to focus specifically on land as a driver of production, results reflect issues highlighted to this end.

Land Ownership

The predominant land ownership amongst participants in the study was communal (74%) compared to 26% who owned the land that they farmed on. Only a few macadamia (16%) and mango (5%) farmers owned the land compared to avocado farmers (26%). Results of the Chi-Square test revealed that the differences in land ownership between the three commodities are insignificant, $\chi^2(2, N = 19) = 3, 8, p > 0.05$. Results revealed higher proportions of small-scale farmers who farmed on communal land across all three commodities compared to those who owned the land (**Figure 2**). There was an insignificant difference between farm size and land ownership [$\chi^2(2, N = 19) = 0, p > 0.05$] amongst participants. This disparity in ownership reflects the common reality of tenure rights amongst farmers

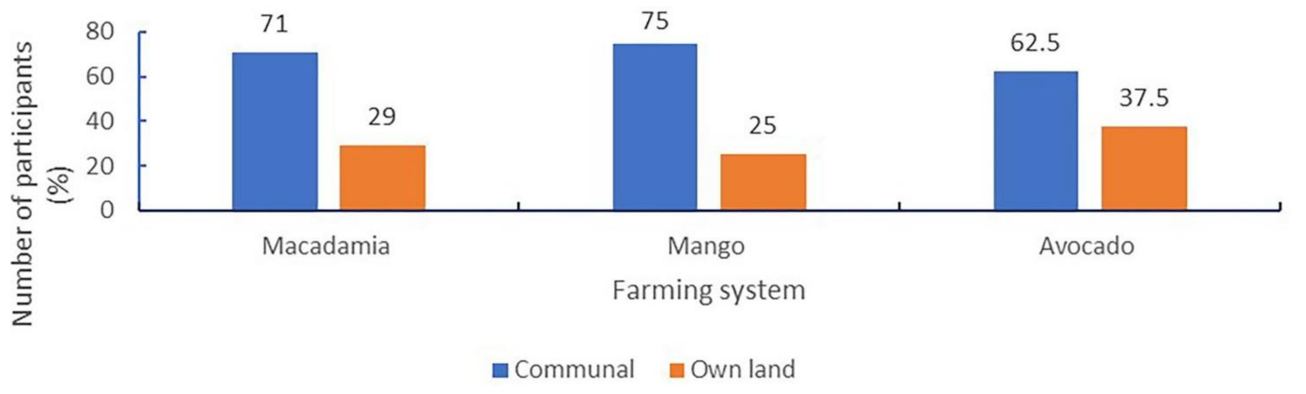

FIGURE 2 | Distribution of land ownership (%) of participants across three commodities in the study.

located in the former homelands of South Africa as indicated by Hall (2004).

Water Sources and Irrigation

The main source of water on farms was rivers (40%), dams (21%), boreholes (21%), and tanks (13%), The use of pipes was the most common form of irrigation identified amongst all participants in the study followed by rain-fed and jet irrigation (**Figure 3A**). All mango farmers reported relying on rain-fed agriculture as orchards were mature. Pipes for water reticulation were commonly used by small-scale macadamia and avocado farmers compared to jet irrigation, e.g., micro-jet and jet spray irrigation systems were commonly used by a few large-scale macadamia and avocado farmers (**Figure 3B**).

Farmers in the Vhembe district who irrigate get higher incomes from on-farm activities as opposed to dry-land farmers due to higher yields (Olofsson, 2021). Access to water for irrigation is considered a macro constraint for smallholder farmers in the Vhembe district according to Mpandeli and Maponya (2014). These farmers are often victims of water shortages and irrigation politics.

GENERAL DISCUSSION

The Significance of Small-Scale Farmers

The land issue is one of ongoing contention due the country's historic context of land distribution inequalities. Statistics show that small-holder farmers form a large percentage of farmers in South Africa at large. Aliber and Hall (2012) indicate that in 2012 there are ∼2.5 million smallholder farming households in South Africa and 35,000 commercial farming units. Though there are no accurate recent statistics on the current number of smallholder farming households as this appears to be a difficult demographic to document, results of the census on commercial agriculture report in 2017 showed that commercial farming units had increased to 40,122 (Statistics South Africa (StatsSA), 2017). Due to this higher percentage of small-scale farmers any intentions of government to improve on agricultural development interventions must prioritise the need to build capacity amongst small-scale farmers.

Globally small-scale farmers generally tend to be constrained by similar problems. There are some reports from 2013 to 2020 that small-scale farmers in the Limpopo Province are faced with a plethora of challenges that compromise their capacity to be significant contributors to the provincial and national agricultural economy (Greenberg, 2013; Hall et al., 2013; Mpandeli and Maponya, 2014; Olofsson, 2018; Setshego et al., 2020; Maponya, 2021). Some of these challenges include: the inability to purchase agricultural inputs (Oni et al., 2010), transport limitations which consequently hinder market access (Mpandeli and Maponya, 2014), lack of tenure security (McCusker, 2004; Beinart and Delius, 2018), limited access to labour (Hall et al., 2013), fragmented (or no) sources of technical and financial advice (Ortmann and King, 2007) and limited access to water for irrigation (Maponya, 2021) amongst others. Government is greatly invested in the promotion of small- scale farmers to a level that allows then to compete with their commercial counterparts. This is expressed in the resolution on rural development, land reform and agrarian change (2007) where the government is quoted as saying: *"the development of the smallholder sector is thus premised on creating an enabling environment for farmers to progress in a linear trajectory toward becoming increasingly commercially oriented and finally operating as fully fledged commercial farmers thus building "a modern and competitive smallholder sector"* (ANC., 2007:22).

There have been numerous interventions by government to address the challenges of small-scale farmers in order to improve on national agricultural development some of these are outlined below with reference to the Vhembe district. This is in line with a systems analysis approach which suggests that due to the complex, multi-variable nature of a problem there cannot be only one way approach to addressing problems but a diversity of interventions (Meadows, 2008; Arnold and Wade, 2015).

Land Tenure Reform

In attempts to address the inequalities presented by a historical land distribution framework that placed small-scale farmers in

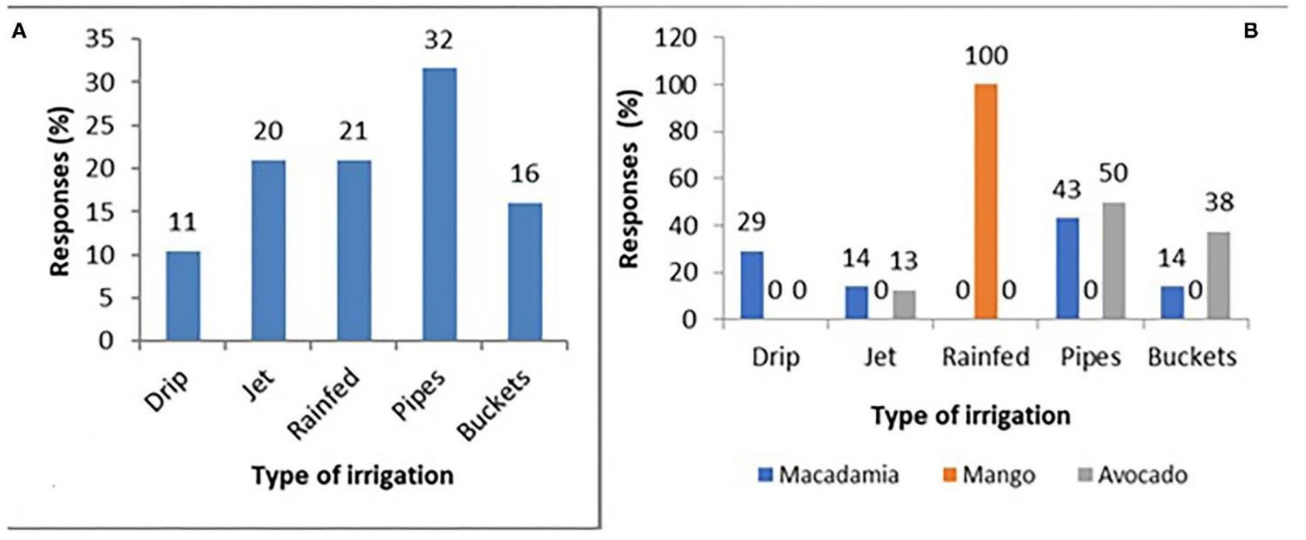

FIGURE 3 | (A) Main type of irrigation practiced on farms in the study. (B) Main type of irrigation practiced on farms in the study across commodities (n = 19).

a highly disadvantaged position compared to their commercial farmer counterparts, government has launched multiple policy interventions targeting land reform. Hall (2004) explains that the key focus of government's land reform has been the redistribution of land through a market-led "willing buyer, willing seller" land redistribution programme. The programme has received much criticism and current parliamentary debates around the success of this programme have been heated because it does not tie the acquisition of land to farmer support and resources to enable farmers to generate an appealing livelihood.

The lack of tenure rights for small-scale farmers in the Vhembe district much like the case of other small-scale farmers located in the former homelands is further compounded by overlapping use rights on communal land. Small-scale farmers are not able to fully participate in commercial activities because they do not own land. An example of this challenge is illustrated by Burger (2021) where a farmer may plant maize on a piece of land only to have someone else's cattle possibly graze there after the harvest and individuals from other families collecting water, food, and firewood from the same land. The same author (2021) suggests that in order to reform the current land tenure context on the communal level, the law must democratise control over communal land. This can be achieved by shifting power from the traditional leaders and placing it in the hands of community members. The challenge of land reform and the absence of tenure security is not unique to South Africa. Peters (2009) draws our attention to the fact that communal tenure is *"the joint creation of colonial officials and African leaders"* and therefore a complex problem that impact numerous African countries.

Using the example of Kenya, the post-colonial government's approach has been the creation of settlement schemes. According to Rutten et al. (1997) Kenyan land use policy was primarily targeted at adjudication and replacing customary land rights with individual tenure agreements. This approach was aimed at facilitating collateral for loans and enabling long-term investments. Unfortunately, one of the many negative consequences of this attempt at land reform has been the creation of a category of landless people as land has become increasingly concentrated in the hands of a privileged few. This sheds some light on the complex challenge that land reform presents for many governments in other African countries. It also presents an opportunity for the adoption of a systems analysis approach to address these complex problems.

The Commodity-Focused Approach

There has been a growing trend in agricultural policy toward a commodity-focused approach to agricultural development (Chawiche, 2015; Jaskiewicz, 2015; de Satgé and Phuhlisani, 2020). Olofsson (2018) draws our attention to how a commodity focus can be seen amongst small-scale farmers in the Vhembe district. Olofsson (2018) maintains that it is particularly visible amongst macadamia and avocado farmers where the focus has shifted entirely toward integrating small-scale farmers into national and international markets. This commodity-focused approach is also exemplified in agricultural extension in the district. Extension officers are aligned to a specific commodity specialisation and provide support and training to farmers who are grouped according to their production focus (Aliber et al., 2010; Genis, 2012). Olofsson (2018) dates the rapid growth in orchards for avocado, mango and macadamia nuts in the Vhembe district to the first decade after the transition to democracy in 1994. Another result of this commodity-focused approach has been the expanding role for commodity organisations in supporting small-scale farmers (Aliber and Hall, 2012). This has been especially evident in the activity of the South African Subtropical Growers Association (Subtrop) and the South African Macadamia Growers Association (SAMAC). Both organisations, which historically represented white commercial farmers in the region, have taken an active role in supporting small-scale farmers who produce avocados and macadamia nuts in recent years (Maponya, 2021). According to DAFF (2014) a statutory levy was implemented in 2014, of which 20% of the revenues were earmarked for small-scale "transformation" amounting to approximately R2 million in the first 4-year period. Most of this money was spent on enterprise development of small-scale macadamia farmers.

Access to Capital for Small-Scale Farmers

There are a few approaches that the government has used to finance the buying of land for emerging black farmers that have included access to both loans and grant funding. One such approach was the Land Grant which was put into operation in 1995 in the earliest years of South Africa's democracy. The Land Grant operated through the Settlement Land Acquisition Grant (SLAG). Through this grant the government provided a grant of R15 000 per beneficiary household to buy land that would be registered as a property, with up to 500 families registered as beneficiaries (Aliber and Hall, 2012). Hall et al. (2013) argues that while it stands to reason that concentrating resources on smaller numbers of beneficiaries and projects is a means of improving the "quality" of those particular projects, it is obviously at the expense of reaching larger numbers of farmers thus highlighting a shortfall of the scheme.

Greenberg (2013) indicates that the Land Bank's lending activities are split between business and corporate banking, retail commercial and retail emerging market. The retail emerging market is said to be for small-scale farmers "without a good credit profile." In 2011 the CEO of Land Bank, Phakamani Hadebe indicated that up to R1 bn would go to emerging farmers over 2 years under the Retail Emerging Market unit (Vollgraaff, 2011). More recently the Land Bank 2019 annual report indicates that the absolute value of "transformational loans" targeted at small- scale farmers has increased to R7.9 billion representing 17% of the loan book, up from 12% in 2018.

A Shift From "Small-Scale" to "Commercial"

Literature identifies a small cluster of small-scale farmers who are characterised by their larger scale of production, high reliance on hired labour and higher level of mechanisation in comparison to other small-scale farmers (Hall et al., 2013; Olofsson, 2018). These have been coined differently by various authors as *"small- scale capitalists"* (Olofsson, 2018), *"emerging commercial farmers"* (Whitbread et al., 2011), or *"emerging farmers"* (Senyolo et al., 2009). This small cluster of farmers has higher land access compared to other small-scale farmers with a median of 40 ha, ranging from 22 to 54 ha, as compared to other small-scale farmers who averaged between 5 and 7 ha according to a study by Olofsson (2018). It is commonplace in South African policy and planning documents to use the term smallholder and "emerging" farmer synonymously (DAFF, 2012, 2013, 2014) suggesting they are not a category of farmers in their own right but in a process of becoming a category. Non-farm employment plays an essential role in sustaining and developing the farm in the years leading up to full production for farmers who form part of this small cluster.

Non-farm Income

Marinus et al. (2022) highlight the value of diversification of livelihoods to improve the living income of small-scale farmers in Africa. Non-farm income, livestock and vegetable farming rank high amongst examples of additional income sources that have proven successful for smallholder farmers in Sub- Saharan Africa. Olofsson (2018) identified the most common form of non-farm employment amongst small-scale farmers in the Vhembe district as teaching, at primary and secondary school levels. According to Genis (2012) dependency on non-farm employment allows farmers to reinvest profits. In as much as non-farm income may serve as beneficial for small-scale farmers as it facilitates capitalization, it can also result in these farmers being marginalised and excluded from accessing information, training and other state or private sector opportunities premised on the expectation that one is a full-time farmer and therefore available during working hours (Aliber and Hall, 2012). This has created an opportunity for white commercial farmers to emerge as *"knowledge brokers"* (Olofsson, 2018:52) providing access to alternative resources and facilitating social relations across racial and class barriers and fostering interaction between large and small-scale farmers.

According to Aliber and Hall (2012), small-scale farmers in Limpopo have resorted to employing innovative strategies to optimise their potential to participate in the market value chain in a manner similar to large-scale commercial farmers. Some of these strategies include the use of intercropping systems. Using the example of tree-crop small-scale farmers in the Vhembe district, Olofsson (2018) illustrates how annual tree-crop income constitutes the main agricultural income. A very small share of this agricultural income is obtained from a variety of crops such as sweet potatoes, spinach, carrots, tomatoes, peppers, ground nuts and cabbage amongst others. These are mostly for home consumption and only surplus is sold to local markets generating small amounts of money. Non-tree crops are perceived to be a short-term strategy for income generation while tree crops reach maturity which can take between 2 and 4 years.

CONCLUSION AND RECOMMENDATIONS

In order for the South African government to successfully achieve the agenda of agricultural development, taking into account the dual nature of the country's farming systems and the varied ways in which they respond to the drivers of production there is need for multiple points of intervention. There is an urgent need to focus attention on capacitating small-scale farmers to be able to compete on similar terms as large-scale commercial farmers while sustaining a decent standard of living. Research and policy development priorities need to adopt a systems thinking approach which highlights the complexity of the interrelatedness of the factors that impact the drivers of production and the practicality of therefore applying interventions concurrently. There is potential for systems approach to be applied to a broader context beyond South Africa and in other sectors. Issues surrounding farming systems are closely tied to the sustainable development goals (SDG) 1 (no poverty) and 2 (zero hunger) but a systems analysis approach can be applied to tackle other issues encapsulated in the remaining SDGs that intersect across different spheres.

AUTHOR CONTRIBUTIONS

FM and MS contributed to conception and design of the study on which the manuscript is based. FM wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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4.2 Postscript

The paper provides an overview of the current state of understating on the drivers of production in South Africa within the research area of farming systems research. It highlights the importance of understanding farming systems as encompassing the entire production of commodities including land, growth, financial resources, policies etc. The paper further reveals the need to consider the challenges faced by the small-scale farmer and how the numerous constraints that they encounter result in them experiencing very different outcomes to the drivers of production as compared to their large-scale commercial counterparts. The paper places emphasis on land as a key driver of production and shows how land ownership can be seen as a major limitation to the sustainability of farmers, particularly small-scale farmers located in the former homelands, thus necessitating land tenure reform. The paper also presents some government approaches to building the capacity of small-scale farmers such as providing capital to finance the buying of land and a drive to help them transition to commercial status. Lastly the review highlights the importance of non-farm income as a means of improving the small-scale farmers' living income as a recommendation for future decision making. FM and MS conceptualized the study. FM collected the data and conducted the initial analysis. FM and MS conducted further analyses and prepared drafts of the paper for submission to the journal. FM worked on revisions of the paper after peer review. The subsequent chapter addresses the study's objective to identify and characterise the farming systems that exist in the Vhembe district of Limpopo.

CHAPTER 5 – CHARACTERIZATION OF LARGE-SCALE COMMERCIAL AND SMALL-SCALE FARMING SYSTEMS IN THE VHEMBE DISTRICT, LIMPOPO SOUTH AFRICA

5.1 Preface

In the preceding chapter, it was established that land, though not the only driver, is pivotal to driving agricultural production in farming systems in South Africa. It is for this reason that a further emphasis on land has been made in the current chapter. The third objective of the study is to analyse the interactions within and between large-scale and commercial and small-scale farming systems in the Vhembe district focusing solely on land as a driver of production. The paper presented in this chapter addresses this objective. The publication explores various components of the land resource as they pertain to the respective farming systems for the three main commodities in the study found in the Vhembe district. In addition to this, income from farming for both large and small-scale farmers is analysed as a factor that impacts on the sustainability of the two kinds of farming systems. The paper also directly addresses the first objective of the study which is to identify locations within the Vhembe district in Limpopo where large-scale commercial and small-scale farming systems exist and to establish their characteristics. Understanding how the two farming systems will interact with one another is not possible if they are not first characterized. This paper therefore serves as a means of providing that characterization as a basis for further analysis of the interactions addressed in proceeding chapters. The publication is available at: https://www.scirp.org/journal/paperinformation.aspx?paperid=113591

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Characterization of Farming Systems Using Land as a Driver of Production and Sustainability in the Vhembe District, Limpopo, South Africa

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Abstract

South African agricultural farming systems are characterised by a duality in which there exists large-scale commercial farmers and small-scale farmers. Large-scale commercial farmers, historically identified as capital intensive and characterized by the size of the landholdings, are considered as the main drivers of national food security. Small-scale farmers on the other hand are viewed as important drivers of food security at the household level. These two main farming systems can be found within the Vhembe district municipality of the Limpopo Province and are characterised differently according to land descriptors. The study used an analysis of primary data obtained from in-depth interviews and secondary data obtained from an agricultural data- base to identify and characterize large- and small-scale farming systems within the Vhembe district. The study examined the land resource namely farm size and land ownership, topography and soil description, rainfall and its variability and threats and hazards used under three different high value crop (HVC) commodities, macadamia nuts, mangos and avocado pears. The study further examined yield and income from farming as drivers of produc- tion that would ensure the sustainability of long-term food security at both national and household level. The study revealed that gender of farmers within the farming systems was predominantly (79%) male across all com- modities. Age distribution results showed an aging population of farmers mostly (90%) above the age of 51. Communal land ownership was the domi- nant (74%) land ownership amongst participants. Yield is not solely depend- ent on farm size and requires consideration of a broader array of land man- agement aspects. There was a strong, significant correlation between income and farm size. These factors have implications for sustainability of the two

farming systems and illustrate how certain aspects of land as a driver of pro- duction such as land ownership, rainfall variability, yield and income from farming can impact sustainability.

Keywords

High-Value Horticulture Crop Systems, Production, Farm-Size, Land, Sustainability, Food Security

1. Introduction

Farming systems have been commonly defined by Dixon *et al.* (2001) as "*… a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households*" [1]. A general approach to farming systems research and development is to select relatively uniform sets of conditions for conducting re- search [2]. Various criteria can be used to classify farming systems based on the farms and these may vary in different geographical locations [3]. Some of the major characteristics by which farms can be categorised are suggested by Shaner (2019) [2]; these include permanent cultivation of rain-fed land or irrigated farming, agro-climatic zone, soils and terrain. It is however widely accepted amongst farming systems researchers that farms are classified according to the area, the needs of the study and the available information.

In South Africa, agricultural farming systems are characterised by a duality in which there exist large-scale commercial farmers and small-scale farmers [4]. Historically large-scale commercial farmers were identified as capital intensive [5] and over time have been regarded as the main drivers of national food security [6]. Large-scale commercial farms were characterised by the size of the landholdings which according to [7] was on average about 1640 hectares in 2000 and continued to grow to 2113 hectares per farm in 2007. Despite this widely accepted view, [4] argues that small-scale farming in South Africa is as viable, profitable and efficient as large-scale farming. This argument is supported by evidence from the food security report for South Africa [8]. Various studies support the idea that emphasis needs to be placed on small-scale farmers in or- der to ensure long term food security at the national and household scales [4] [6] [9] [10] [11]. The two main farming systems can be found within the Vhembe district of the Limpopo Province and are impacted by the same core drivers of production *i.e.*, land, labour, capital and enterprise [12], however, they respond to these drivers differently.

According to [13] staple crops have commonly been the most important for cultivation by small-scale farmers in developing countries because they provide carbohydrates and calories that meet essential energy requirements. High-value crops (HVCs) also known as horticultural crops or non-traditional crops [14] are grown for food, nutrition, human health and wellbeing and include fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops. These crops are known to return a significant price premium per hectare or per unit compared to traditional staple food crops because they do not often form part of the customary diet of the local population and are largely grown for their cash values in domestic and export markets [13]. This characteristic makes the cultivation of HVCs an optimal choice to improve the financial position of small-scale farmers in developing countries.

Small-scale farmers stand to gain higher incomes from farming if they diversify their activities and venture into the cultivation of HVCs as opposed to solely relying on staple crops which produce low earnings [14]. HVCs can also improve the ability of small-scale farmers to meet their household food security needs through incomes obtained from participation in local and export markets to purchase food for household consumption. Farmers' potential to access lucrative markets is hinged on their ability to successfully produce quality products [15].

The Vhembe district has highly favourable agro-ecological conditions for the production of sub-tropical fruits and nuts [16]. Large-scale commercial farmers who are predominantly white have mainly controlled these sectors in the region; however there has been a more recent drive by government towards the commercialisation of these commodities amongst small-scale farmers as a means of addressing rural poverty and unemployment [16]. The local Department of Agriculture recorded 1113 commercially oriented small-scale farmers growing sub-tropical fruit and nuts in the Vhembe district in 2018 cultivating a total land area of 4713 hectares [17]. These farmers are strongly supported by the private sector, specifically commodity associations, that aim to assist small-scale farmers to increase their yields and expand the land area under cultivation. The government's prioritization of the sub-tropical fruit and nut sectors and the promotion of small-scale farmer integration in HVC markets raise concerns for sustainability and require investigation into whether farmers can sustain these HVC systems over time. There is a need for farmers to invest in various land use and management aspects that will affect the long-term sustainability of the farming systems.

The study examines the land resource used under different commodities *i.e.*, HVCs in the Vhembe district of Limpopo and how the land characteristics are driving the sustainable production of these commodities under different land ownership and management systems. In order to achieve the overarching goal of sustainability that will ensure long term food security in the country there is need to explore what land characteristics will support production.

2. Conceptual Framework

The two farming systems in the study *i.e.*, small-scale and large-scale are recognised as systems due to the multi-variable nature of the processes within the farms and the non-linear interconnectedness that exists between them. The commodities grown in these farming systems are recognized as HVC based on the definition provided by [14]. The four drivers of production *i.e.*, land, labour, capital and enterprise drive the two farming systems and the pathway of agri- cultural enterprise *i.e.*, production, management, marketing and value adding for each of the systems which have the potential to produce the same outcome in different ways. Future scenarios for sustainable agriculture within the different commodities must consider how production can be sustained under the two main farming systems.

The land resource and its use are arguably one of the most important drivers of sustainable agriculture as they highlight numerous environmental interactions that can either be detrimental or beneficial to the sustainability of farming systems. Land is a highly politicized issue in the South African context due to historical allocation of land based on race by the previous government prior to democracy in 1994. There is a need for an emphasis on scale in the analysis of these two main South African farming systems in order to accurately investigate what land variables will drive sustainable agriculture in the country. Land characteristics namely, farm size and ownership, topography, soil type and fertility, threats and hazards, water sources and irrigation, and the impact of climatic and its variability on the farming systems have been selected and are analysed between the two farm sizes and within three different commodities. These land characteristics are further analysed alongside two production characteristics, *i.e.*, income and yield in order to determine to what extent they can drive sustainability.

3. Methodology

3.1. Research Study Area

The study took place in the Vhembe district which is the northern most district municipality of the Limpopo Province in South Africa (**Figure 1**). It shares borders with Zimbabwe and Botswana in the north-east and Mozambique in the south-east through the Kruger National Park [18]. The Vhembe district is one of five district municipalities in the Limpopo Province. It has an area of 2,140,708 hectares of which 247,757 hectares is arable land [19]. The Vhembe district is comprised of four local municipalities: Thulamela, Mutale (renamed Collins Chabane), Musina and Makhado. The South African governance structure regards the composition of local municipalities as towns and their surrounding rural areas [20]. The main towns within the district are Thohoyandou, Mala- mulele, Musina and Makhado respectively for the four municipalities Thulamela, Mutale (currently Collins Chabane), Musina and Makhado.

The district covers a geographical location that is largely rural [21]. According to [22] agriculture is the key contributor to employment and livelihoods in the district. Seventy percent of the farming activities in the district are attributed to smallholder agriculture and the remaining 30% is commercial agriculture [17]

[23] [24]. According to the Vhembe District Municipality's Local Economic Development Strategy in 2019 [25] the district produces 4.4% of South Africa's total agricultural output, 8.4% of the country's sub-tropical fruits and 6.3% of its citrus. The district is situated in a semi-arid area, is frequently affected by dry spells that often develop into drought with severe water shortages from May to August [21]. Most commercial farmers in the district rely on irrigation systems for farming whilst the smallholder farmers generally depend on seasonal rainfall which typically falls from November to March. [21]. The average rainfall ranges from 246 mm to 681 mm per annum [26]. Soils in the district are variable and tend to be sandy in the west, but with a higher loam and clay content towards the east [21] [23]. (Refer to Table 1, Chapter 2).The soils developed on basalt, sandstone and biotite gneiss and some have low inherent soil fertility [27]. Maize is the predominant cereal grain grown in the district among smallholder farmers [23]. Leguminous crops like groundnuts, Bambara nuts and cowpeas are also grown by smallholder farmers as well as vegetable crops which include spinach, cabbage, tomatoes and onions [15]. These are grown for the farmers' own consumption with any surplus

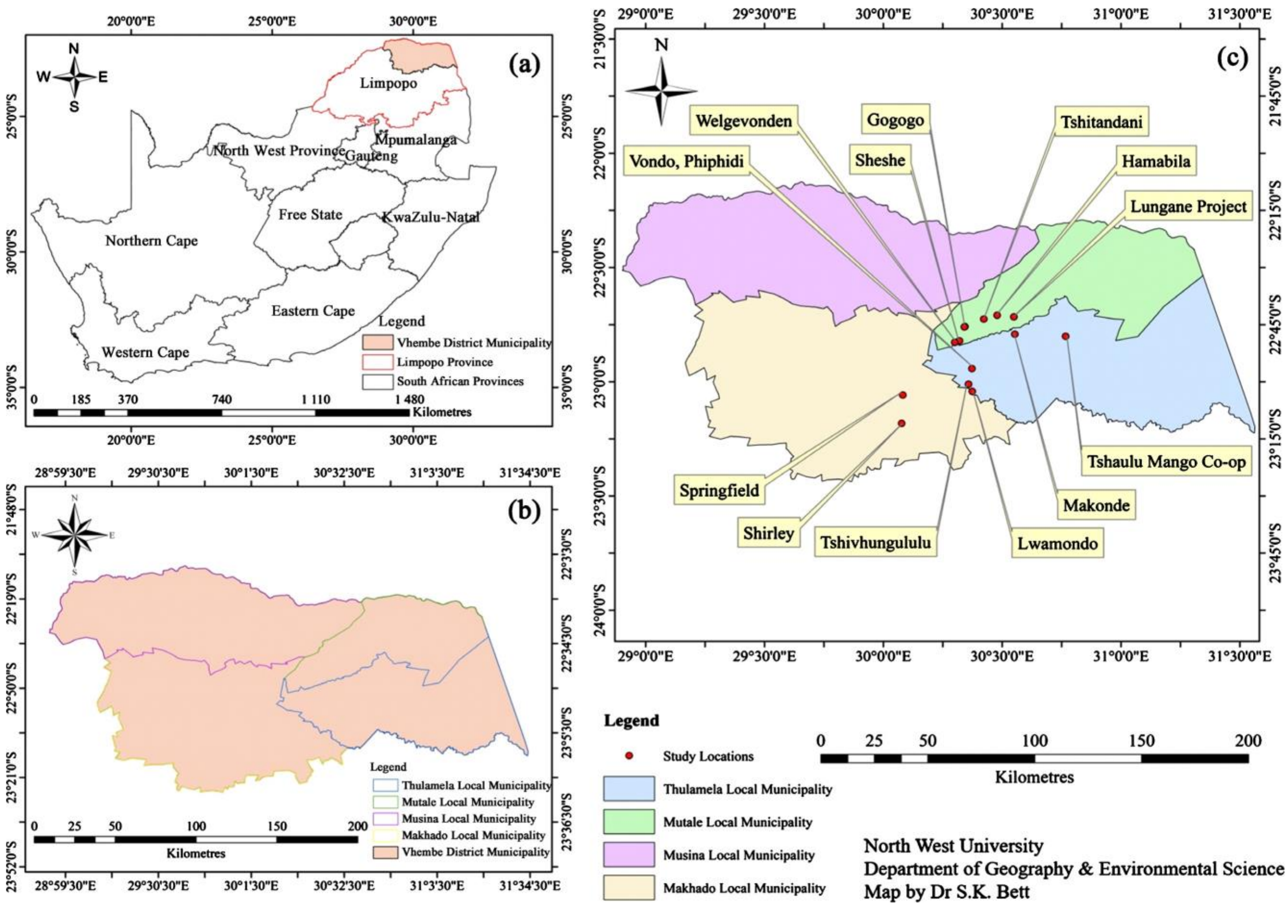


Figure 1. Map showing the location of (a) The Republic of South Africa' Provinces and provincial boundaries, highlighting the location of the Limpopo Province and the Vhembe district within the Limpopo Province of South Africa (b) shows the location of the four local municipalities within the Vhembe district and (c) shows the locations and names of the farm sites within the Vhembe district that were sampled in the study.

sold to neighbours or relatives. Rain-fed crop yields are generally poor due to low and erratic rainfall coupled with poor fertility [28] [29]. Commercial horticulture farming is well established in the south eastern side of the district (the Makhado Levubu area) and includes stakeholders which grow mangos, litchis, bananas, avocados, citrus, pecan and macadamia nuts [28].

3.2 Study Design

A study was conducted using an analysis of primary and secondary data to identify and characterize large and small-scale farming systems of three tree crops, in the Vhembe district. The analysis was aimed at highlighting the connectivity of interactions between the farming systems in terms of the four drivers of production. The focus of the paper is on land as a driver of production. Secondary data were collected from: the official subtropical crop database obtained from the local Department of Agriculture located in the town of Thohoyandou, climate data from the Institute for Soil, Climate and Water (ISCW), land type and soils data from the Agricultural Research Council (ARC), peer reviewed research papers and related books. The target population was a combination of large-scale commercial and small-scale farmers within the district. Based on the FAO definition of farming systems which informs the study, three different enterprises based on commodities grown at farm sites were chosen: 1) macadamia nut farming systems 2) mango farming systems and 3) avocado farming systems. Farming systems where initially broadly characterised based on available information extracted from the local Department of Agriculture database. The database is comprised of data on the farm location (village or township and local municipality), farm size (ha), gender of farmer, farmer name and telephone number.

A purposive sampling method [30] was employed in choosing four criteria for site selection, these were used in the study namely commodity, size of the farm, location of the farm and gender of the farmer. This information was available for six subtropical commodities, namely bananas (23), litchis (92), avocados (204), mangos (528), macadamia nuts (184) and citrus (90). According to the database there are a total of 1121 documented subtropical crop farmers in the Vhembe district. According to the database the three commodities selected in the study were the most commonly grown commodities in the district. Mangos were selected because they formed the largest number of farms documented in the database. Avocados were selected based on the willingness of the farmers to participate in the study based on a preliminary interaction with the farmers at a local study group meeting. Macadamias were selected based on their significance to the South African agricultural economy as high value export crops. The next selection criterion was size. Farms were selected using a systemic random sampling procedure to ensure that there was equal representation of farms within the size categories that exist in the database, these were namely small-scale (1 - 10 hectares and large-scale (11 hectares and above) as the study required both farmers with smallholdings and larger holdings.

The next selection criterion was location. Farms were selected to ensure that there was equal representation of all 4 local municipalities that comprise the Vhembe district municipality namely Mutale, Makhado, Thulamela and Musina. Lastly, the farmers' gender was also used as a farm selection criterion. A random number generation method was used to ensure that there was equal representation of both genders across the farms. The process of random number sampling involved allocating a number to the farmers selected from the database based on the above criteria, writing down the numbers and placing them in a container. Numbers were then randomly picked out of the container to make up a total of 12 farms. These 12 farms were comprised of 4 samples for each of the 3 commodities spread across the 4 local municipalities with 2 small-scale and 2 large-scale farms as well as an even mixture of male and female farmers.

Once this initial site selection was made, a more detailed characterization of the three farming systems was done based on the significance of the 4 drivers of production *i.e.*, land, labour, capital and enterprise. Primary data were obtained from in-depth interviews that were conducted with farmers in selected farm lo- cations within the Vhembe district. A snowball sampling technique [31] was used in response to this with the aim of maintaining the same sample size initially selected. The results of the snowball sampling produced samples that differed vastly in number to those from the initial sample selection: macadamia nuts (7), mangos (4) and avocados (8). A total of 19 farmers were selected to participate in interviews based on their availability and willingness to participate.

3.3 Primary Data Collection

Interviews were conducted over two visits to the Vhembe district in October and November 2020. Ethical clearance was obtained from the local Department of Agriculture and the University of the Witwatersrand, protocol number: H19/09/26. The researcher, together with a field assistant, who acted as an interpreter from the Mutale local municipality conducted the interviews. Interviews were conducted in the Vhenda language. Interviews were conducted face-to face with farmers on-site at the farm locations and recorded.

3.4 In-Depth Interviews

A questionnaire was the main instrument of data collection made up of closed and open-ended questions to collect quantitative and qualitative data. Close-ended questions were used to elicit background information and for statistical information regarding the four drivers of production in the context of the selected farm sites. Open-ended questions were used to enable respondents to provide longer answers. The questionnaire was divided into 4 sections: 1) land 2) labour 3) capital and 4) enterprise as drivers of production.

3.5 Data Analysis

Descriptive statistics were used to analyse quantitative data [32]. This was done by calculating averages, percentages and standard errors. Chi squared [33] and student t-tests were used to compare the means of different farming systems and between the two farm sizes. Pearson Correlation coefficients were used to establish the relationships between selected land and production variables within the two farm sizes and across the three different commodities which were then used to highlight possible relationships. Qualitative data were analysed using thematic analysis [34] using information from participant responses to open ended questions addressing issues relating to land variables between the two farm sizes and across the different commodities. The responses were categorized into pre- dominant themes and percentages calculated. The resulting themes were triangulated with the quantitative data to explain the phenomenon.

4. Results and Discussion

Due to the extremely rural location of the site, challenges in accessing farms and farmers as well as language barriers data were collected at only one point in time. This accounts for the exceptionally small sample size which is acknowledged. Considering these limitations, the authors believe that the data make a valuable contribution to the understanding of farming systems in a rapid changing rural and politically-sensitive part of South Africa.

4.1 Farm Size and Commodity

Data from the 19 participants were collated. Of the 19 participants there were 7 (37%) macadamia nut farmers, 4 (21%) mango farmers and 8 (42%) avocado farmers. Of the 7 macadamia nut farmers, 3 (16%) were classified as large-scale and 4 (21%) as small-scale. The average farm size amongst large-scale macadamia farmers was 576 hectares compared to 5 hectares amongst small-scale farmers. Of the 4 mango farmers only 1 (5%) was classified as a large-scale farmer on a 15 hectare farm and 3 (16%) as small-scale farmers. The average farm size amongst small-scale mango farmers was 4.7 hectares. The 8 avocado farmers were comprised of 2 (11%) large-scale farmers and 6 (32%) small-scale farmers. The average farm size amongst large-scale avocado farmers was 806 hectares compared to 4.9 hectares amongst small-scale farmers.

The average tonnage for large-scale macadamia nut farmers was 290 tons compared to 2.7 tons amongst small-scale macadamia farmers while the average yield was 0.5 tons per hectare for both large and small-scale macadamia farmers. The only large-scale mango farmer interviewed had a tonnage of 4.5 tons with a yield of 0.3 tons per hectare compared to an average tonnage of 3.3 tons amongst small-scale farmers and average yield of 1.1 tons per hectare. The average tonnage amongst large-scale avocado farmers was 408 tons compared to 4.9 tons per hectare amongst small-scale farmers. Large-scale avocado farmers had an average yield of 0.7 tons per hectare while small-scale farmers had an average yield of 1.1 tons per hectare. Correlations between farm size and yield will be addressed later in the discussion of results under the heading crop yields.

4.2 Gender and Age Profiles

Results revealed that 79% of participants were male while 21% were female. The overall gender profile of participants skewed towards male participants in both farm sizes and across the three commodities with only 25% and 38% female participants from mango and avocado farming systems respectively and no female macadamia farmers (**Figure 2**). Results indicated that a higher proportion (90%) of all participants were from the age group 51 years and above. This profile was skewed towards small-scale farmers with only 21% of large-scale farmers in this dominant age group and 5.2% who were between 36 - 50 years old.

Male farmers represent a larger percentage in this study compared to their female counterparts which is in line with the gender findings of other studies conducted in the Vhembe district and is attributed to cultural norms and values of the Vhenda people from the area [18] [35] [36] [37]. Age distribution results suggest an aging population of farmers within the two main farming systems in the Vhembe district possibly explained by youth having less interest in agricultural activities as they see it as older people's occupation [17] resultantly creating a disparity of farming knowledge and interest between youth and the elderly.

4.3 Land Characteristics for Sustainability

4.3.1. Farm Size and Land Ownership

The dominant land ownership amongst participants in the study was communal (74%) compared to 26% who owned the land that they farmed on. Only a few macadamia (16%) and mango (5%) farmers owned the land compared to avocado farmers (26%). Results of the Chi-Square test revealed that the differences in land ownership between the three commodities are insignificant, χ^2 (2, N = 19) = 3, 8, p > 0.05. Results revealed higher proportions of small-scale farmers who farmed on communal land across all three commodities com- pared to those who owned the land (**Figure 3**). There was an insignificant difference between farm size and land ownership (χ^2 (2, N = 19) = 0, p > 0.05) amongst participants.

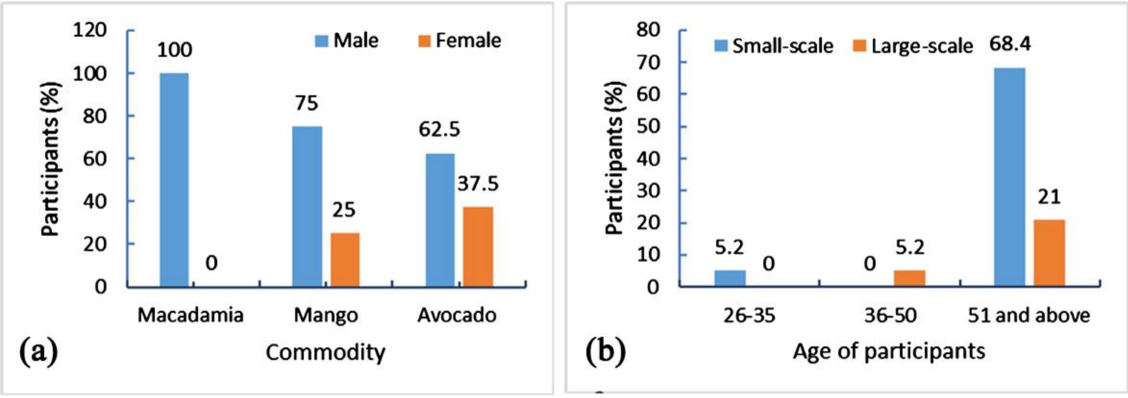


Figure 2. (a) Distribution of gender of participants (%) in the study across three commodities. (b) Distribution of age of participants (%) in the study within the two farm sizes. (n = 19).

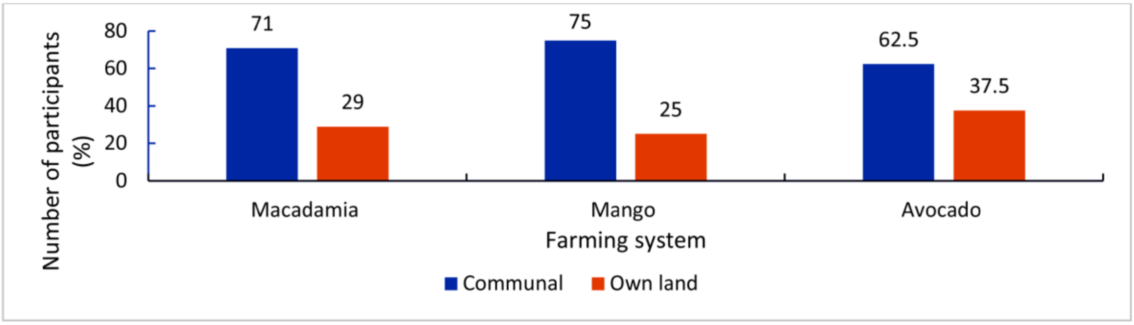


Figure 3. Distribution of land ownership (%) of participants across three commodities in the study.

4.3.2. Topography and Soil Description

Over half (52%) of participants in the study described the topographic location of the farm as mountainous compared to 47% who said the land was flat. A small proportion (11%) identified the land as being located in a valley. Macadamia farms were commonly located on mountainous locations while mango farms were located in either flat or partly flat locations or avocado farms in either partly flat or mountainous locations. More small-scale farmers (42%) described the topography of the farm as mountainous compared to 15% of large-scale farmers across all commodities. Based on the results of a two sample, equal variance t-test using a 2-tail distribution, there is no significant effect of topographic location of a farm and farm size, t (0.05) = 0.001, p = 3.09.

A higher proportion (42%) of all participants described the soil as either sandy or loam, 11% described it as clay and a small proportion (5%) used other descriptions such as the soil classification name e.g., Hutton or "*slippery*". With regard to soil colour, the most common colours identified were red and dark brown (both 37%), participants also referred to greyish-white (21%) and other (5%). Loamy, red soil was the dominant description amongst macadamia farmers. Mango farmers mostly described the soil as sandy and either red or dark-brown. Avocado farmers described the soil as sandy and red in colour. Responses revealed that large and small-scale farmers made used of various ser- vices e.g., specialist soil analysis facilities, the local Department of Agriculture and the local agriculture college to periodically conduct detailed soil analyses. Results of the Chi-Square test revealed that the differences in soil type and soil colour between the three commodities are insignificant (χ^2 (2, N = 19) = 0, p > 0.05). There was no correlation between soil type and average gross annual in- come (AGAI) (r = 0.000, p < 0.01) and a positive but non-significant correlation between AGAI and soil colour (r = 0.274, p < 0.01).

According to [18] farming on steep slopes is a cause for concern because of the threat of gradual erosion and leaching of nutrients which will enhance land degradation therefore compromising the sustainability of the farming systems. The Vhembe district is made up of complex topography driven by its geomorphology, it is characterized by the Soutpansberg "*Salt Pan Mountain*" *[27]*, which is predominantly quarzitic [38]. Small-scale farmers who occupy mountainous areas in the Vhembe district are allocated this land by the local chief generally as a result of insufficient land in the valleys [18]. The chiefs use their own discretion which is at times influenced by favouritism ("better" land allocations are prioritized to members of the chief's family). Despite farming on steep slopes some of the farmers on this kind of land claim they are able to produce good quality produce [18] which can be attributed to other land characteristics and management practices. Soil colour and soil type can indicate soil fertility [39]. Soil fertility within a farm size can be used to measure production levels and therefore sustainability because it is a limiting factor of production.

According to the land type surveys for the Vhembe district issued to the re- searcher by the ISCW for the period 1973-2004 (Ab, Ib, Fa, Ea), the broad de- scription of the soil pattern found in the area is red, freely drained soils with low to intermediate base status. The dominant soil is Hutton (*Doveton Makatini*) which is characterized as deep. The soil form description for Hutton according to the ISCW is red-brown to brown topsoil overlying freely drained, red apedal soil material. The soil series description is described as medium base status, clay loam to clay textured subsoil; high base status (lacking free lime), clay loam to clay. Other soils that characterize the area in which the study falls (in order of dominance) are: Streambeds, Valsrivier, Shortlands, Katspruit, Glenrosa.

In terms of the commodities, all soils in the district are suitable for production of these crops. Macadamia nuts prefer well drained soils [40]; as a result, most soil types can be regarded as suitable for macadamia production provided, they are well drained without restrictive layers in the top 1 m of the soil. According to

[41] Hutton soils are described as an optimal soil type suitable for mango cultivation both under irrigation and dry land cultivation. Avocados prefer deep soil which is well drained as a requirement [42] [43]. With regard to colour, [42] indicate that only reddish-brown, red and dark-brown soils, particularly in the subsoil, are suitable for avocado growth. All of the above requirements match the characteristics of Hutton soil.

4.3.3. The Impact of Rainfall and Its Variability

Three weather stations within the Vhembe district around which the farm sites for the study are located were selected namely Makwarela, Mutale and Malamulele. The data sets were for a 10-year period (2009-2019). The mean annual rainfall from the 3 stations ranges from 642 mm at Malamulele to 1037 mm at Makwarela (**Table 1**).

Table 1. Summary of annual rainfall (mm) statistics at weather stations in Vhembe District, Limpopo between 2009 and 2019 (n = 11).

Location	MAP ± SD (n = 11)	CV (%)
Makwarela	1 037 ± 201.7	19
Mutale	674 ± 309.6	45
Malamulele	643 ± 322.3	50

Based on the coefficient of variation at the 3 weather stations over the 10 years (**Table 1**) there was a distinct difference in the CV across the stations with Makwarela having the lowest CV (19%) and a sharp increase to 45% and 50% at Mutale and Malamulele respectively. This showed that there is extremely high variability within the months between the years at Mutale and Malamulele while the rainfall at Makwarela was relatively more reliable. High variability in rainfall amount between years can limit growth.
The total monthly rainfall distribution at all 3 (**Figures 4-6**) indicates that

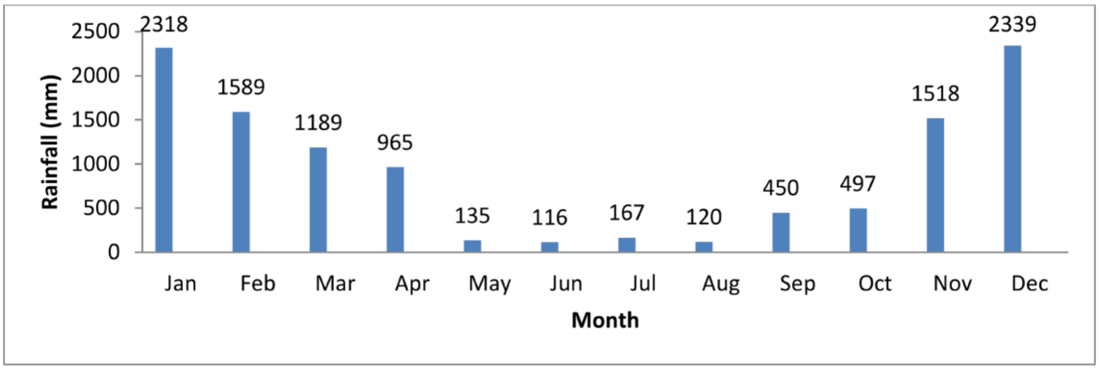


Figure 4. Total Monthly Rainfall (mm) at Makwarela between 2009 and 2019.

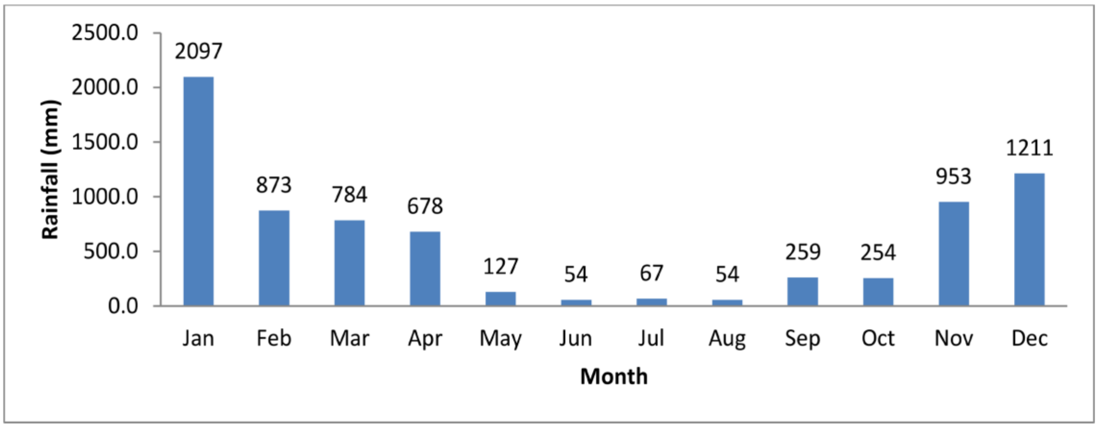


Figure 5. Total Monthly Rainfall (mm) at Mutale between 2009 and 2019.

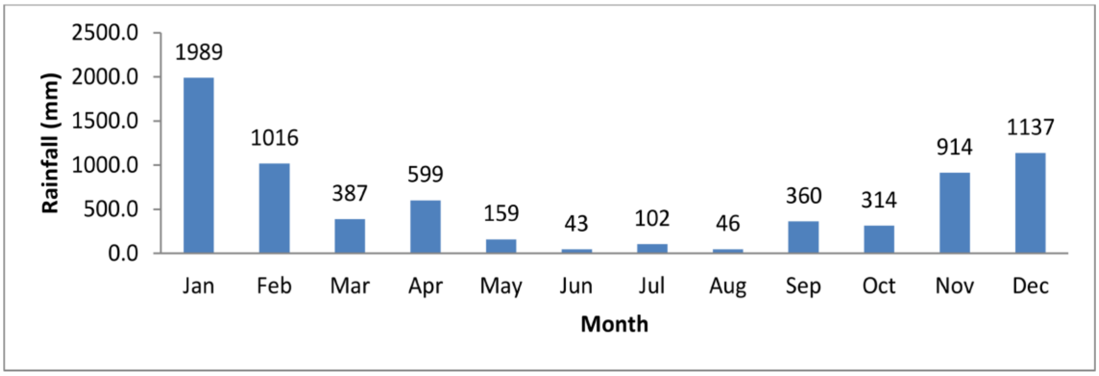


Figure 6. Total Monthly Rainfall (mm) at Malamulele between 2009 and 2019.

most of the annual rainfall comes during the months of September to March. This can be generalized as the wet summer season. The peak rainfall is from December to January/February with rainfall declining significantly after April. Very little rainfall, if none at all, is received between May and August. This can be generalised as the dry, winter season.

4.3.4. Water Sources and Irrigation

The main source of water on farms was rivers (40%), dams (21%), boreholes (21%) and tanks (13%), The use of pipes was the most common form of irrigation identified amongst all participants in the study followed by rain-fed and jet irrigation (**Figure 7(a)**). All mango farmers reported relying on rain-fed agri- culture as orchards were mature. Pipes for water reticulation were commonly used by small-scale macadamia and avocado farmers compared to jet irrigation e.g., micro-jet and jet spray irrigation systems were commonly used by a few large-scale macadamia and avocado farmers (**Figure 7(b)**).

Farmers in the Vhembe district who irrigate get higher incomes from on-farm activities as opposed to dry-land farmers due to higher yields [17]. Access to water for irrigation is considered a macro constraint for smallholder farmers in the Vhembe district according to [15]. These farmers are often victims of water shortages and irrigation politics.

4.3.5 Threats and Hazards

Theft, of the crop, is the biggest threat, particularly for mango and avocado farmers (75% for mango, 38% for avocado). This is exacerbated in small-scale farms (84%) due to the lack of fencing. The second most common threat across both small and large-scale farms is diseases (68%) and pests (63%) (**Table 2**). Farmers referred to integrated pest management (IPM) which they understand as a combination of multiple techniques to prevent pests or their damage as an approach to pest control.

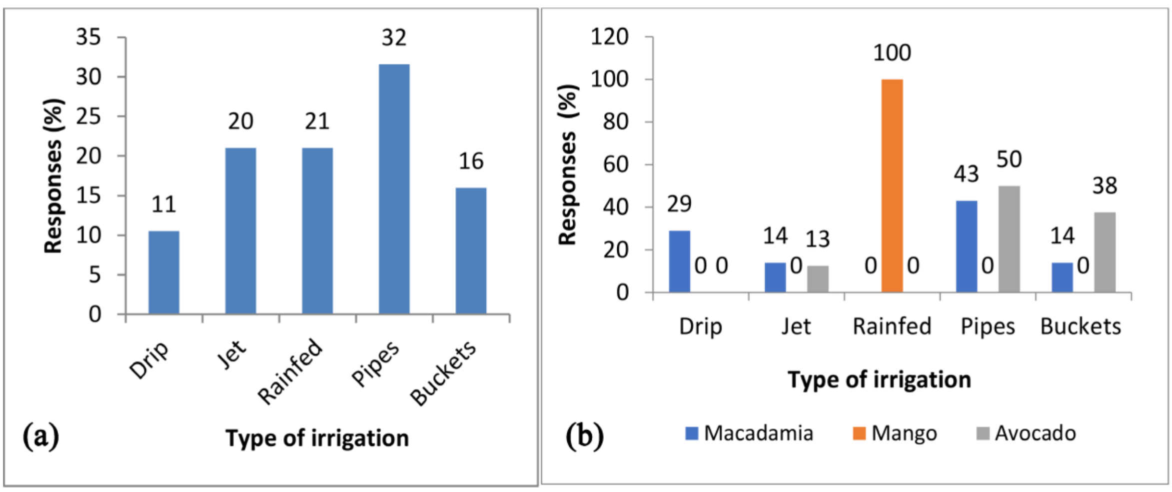
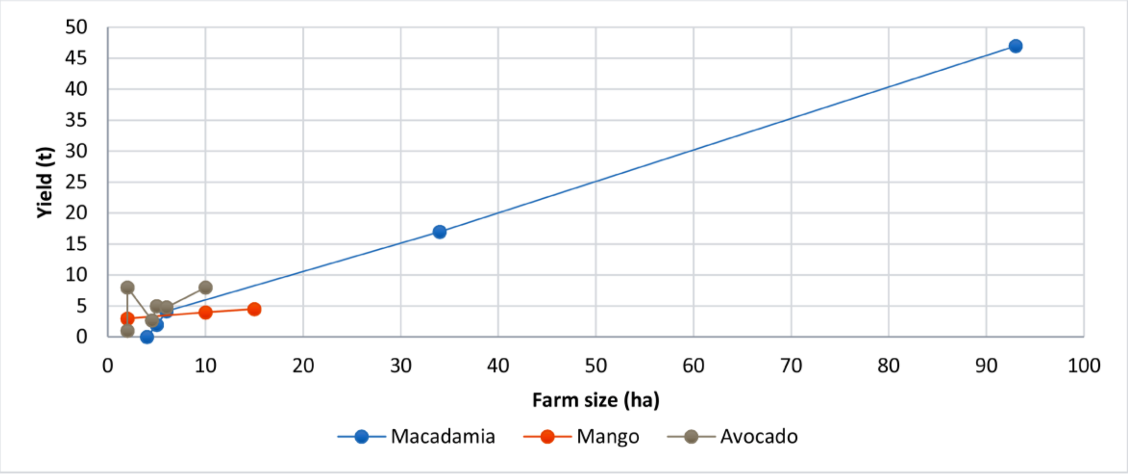


Figure 7. (a) Main type of irrigation practiced on farms in the study. (b) Main type of irrigation practiced on farms in the study across commodities. (n = 19).

4.3.6 Crop Yields

The data used to plot **Figures 8-11** are presented in **Table 3**. Results of the Pearson Correlation analysis showed there was a weak positive and statistically significant correlation ($r = 0.161$, $p < 0.01$) between farm size and yield (t/ha) amongst macadamia farmers, a strong negative correlation ($r = -0.965$, $p < 0.01$) amongst mango farmers and strong negative correlation ($r = -0.419$, $p < 0.01$) amongst avocado farmers.

Yield results with respect to commodity and farm size reveal that farm size does not always correlate to high yields as can be seen amongst some large-scale mango and avocado farms. This suggests that farm size alone cannot guarantee a high yield and there is need to consider a broader range of aspects. Increases in yield per unit area will require more investment into issues of soil fertility management, soil and water conservation, pest and disease control and technology usage amongst others.



*Values for a large-scale commercial farm of 1600 ha farming both macadamia nuts and avocados with an annual yield of 806 t have been excluded from the figure as the scales vary vastly. See **Table 3**.

Figure 8. Annual tonnage (t) compared to farm size (ha) across different commodities in the study (n = 19).

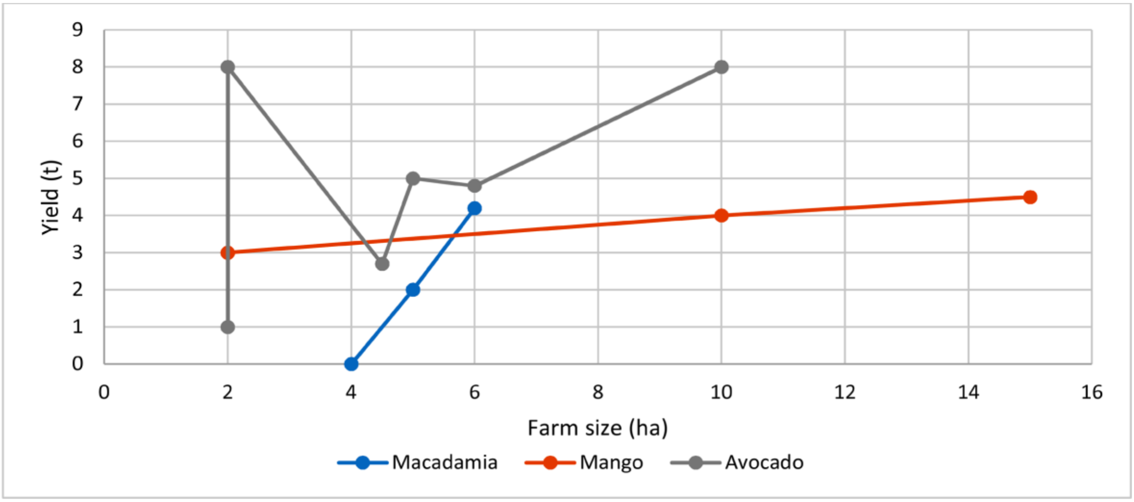


Figure 9. Annual tonnage (t) compared to farm size (ha) for farms less than 20 hectares across different commodities in the study (n = 19).

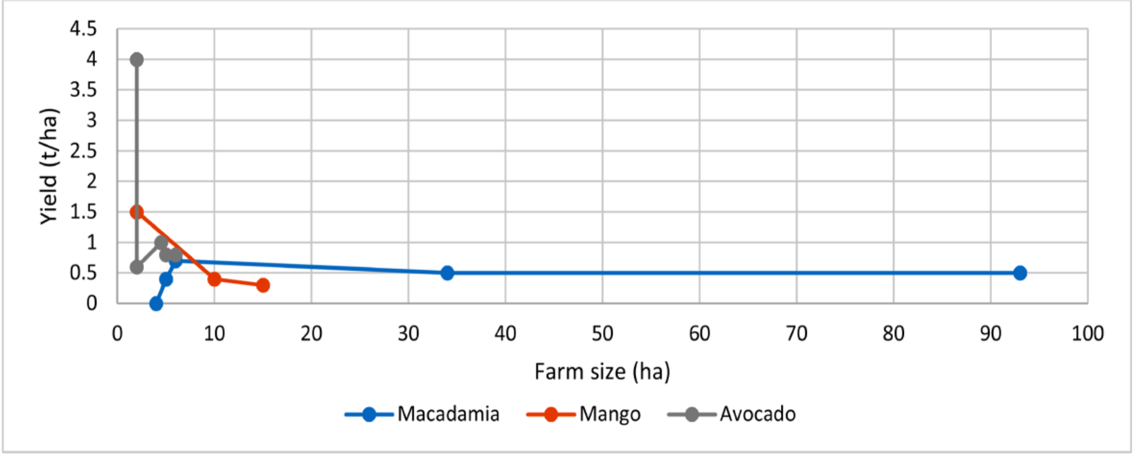


Figure 10. Annual yield (t/ha) compared to farm size (ha) across different commodities in the study (n = 19).

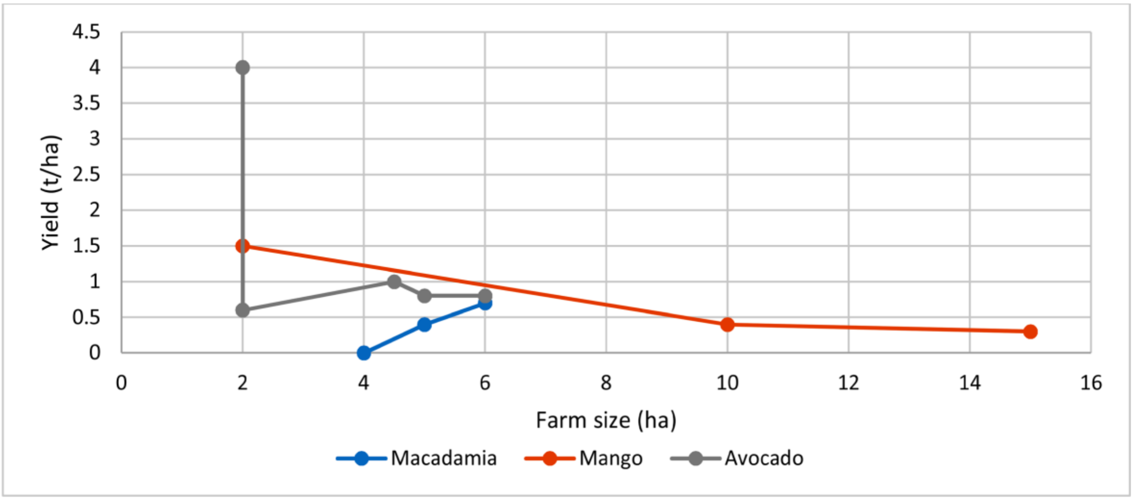


Figure 11. Annual yield (t/ha) compared to farm size (ha) for farms less than 20 hectares across different commodities in the study (n = 19).

Table 2. Distribution of threats and hazards to farming across commodities and within two farm sizes.

Threat	Commodity			Farm size	
	Macadamia	**Mango**	**Avocado**	**Small-scale**	**Large-scale**
Pests	26	25	38	63	37
Diseases	26	25	38	68	32
Droughts	11	25	0	5	0
Flooding	0	0	13	5	0
Theft	0	75	38	84	16

*Values are percentages within each commodity and farm size (n = 19).

4.3.7. Income from Farming

The data used to plot **Figure 12** are presented in **Table 3**. The average gross annual income (AGAI) from farming amongst participants ranged between R5000 and R40 million across the three commodities. Results revealed that macadamia farmers obtained the highest farming incomes, in both large-scale farms, average of R25,100,000, and small-scale, average of R120,000 compared to avocado, average of R20,075,000 amongst large-scale farmers and R22,500 amongst

Table 3. Characterization of farm size, farm type, tonnage, yield and income by commodity for one year (2019).

Commodity	Farm size (ha)	Farm type		Tonnage (t)	Yield (t/ha)	Gross annual income (ZAR)
		Small-scale	Large-scale			
Macadamia	4	→√		0	0	0
Macadamia	5	√		2	0.4	10,000
Macadamia	5	√		2	0.4	150,000
Macadamia	6	√		4.2	0.7	200,000
Mean ± SD	5 ± 0.8			2.7 ± 1.3	0.5 ± 0.2	120,000
Macadamia	34		√	17	0.5	300,000
Macadamia	93		√	47	0.5	35,000,000
Macadamia	1600		√	806	0.5	40,000,000
Mean ± SD	575.7 ± 887.6			290 ± 447.1	0.5 ± 0	25,100,000
Mango	2	√		3	1.5	12,000
Mango	2	√		3	1.5	10,000
Mango	10	√		4	0.4	150,000
Mean ± SD	4.7 ± 4.6			3.3 ± 0.6	1.1 ± 0.6	57,333
Mango	15		√	4.5	0.3	20,000
Avocado	2	√		1	0.5	5000
Avocado	2	√		8	4	30,000
Avocado	4.5	√		2.7	0.6	30,000
Avocado	5	√		5	1	20,000
Avocado	6	√		4.8	0.8	30,000
Avocado	10	√		8	0.8	20,000
Mean ± SD	4.9 ± 3			4.9 ± 2.8	1.1 ± 1.3	22,500
Avocado	12		√	10	0.8	150,000
Avocado	1600		√	806	0.5	40,000,000
Mean ± SD	806 ± 1122.9			408 ± 562.9	0.7 ± 0.2	20,075,000

*The first farmer appearing on the table was a first-time farmer who had planted trees 2 months prior to the interview and therefore did not have any yield to record.

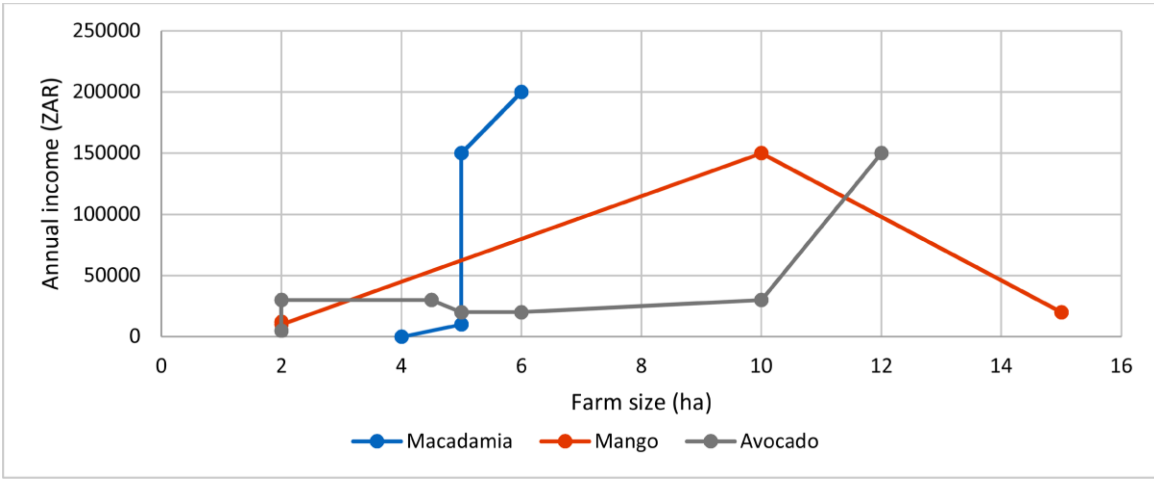


Figure 12. Average gross annual income from farming (ZAR) compared to farm size (ha) of less than 20 hectares across different commodities in the study.

small-scale farmers, and mango, R20,000 for the large-scale farmer and an average of R57,333 amongst small-scale farmers, farmers. (**Figure 12**) Results of the Pearson Correlations analysis show that there is a positive statistically significant correlation between AGAI and farm size amongst macadamia farmers ($r = 0.763$, $p < 0.01$), a positive significant correlation between AGAI and farm size amongst mango farmers ($r = 0.346$, $p < 0.01$) and a strong positive significant correlation between AGAI and farm size amongst avocado farmers.

5. General Discussion

This discussion will relate the various results to each other and to the overall understanding of these results on the sustainability of the systems. The results showed that males were mostly responsible for the farming activities and this may have a negative impact on sustainability of the farming systems in the future because demographic statistics show that female numbers are growing more quickly than male numbers [44]. The age of active farmers was mostly above 51. According to [45] in most rural smallholder communities in the Limpopo Province, the youth often leave the farm lands in the rural areas to seek employment in the towns; this may pose a threat to sustainability as there will not be enough farmers with suitable agricultural experience to continue the cultivation of HVCs in future. It is proposed by [46] that secure land tenure is a necessary pre-condition for the adoption of long-term sustainability of farming practices which characterizes sustainable farming systems. Results of the study do not support this theory as the majority of the farmers farm on communal land. If there were significant changes in land tenure policy in the Vhembe district, this would make the area vulnerable in terms of sustainability of the farming systems for both farm sizes. This is highly plausible, in the future, as land reform remains a pressing and controversial issue in the South African political context. The agronomic conditions for crop cultivation are mostly suitable with respect to the inherent soil fertility, however, fertilizer inputs are low due to high prices. The three areas studied receive differing amounts of rainfall, two areas are in the 650 mm range and the other area receives about 1020 mm. However, the CV of annual amount is much larger in the areas with the lower amounts of rainfall making these areas more vulnerable which may result in non-sustainable pro- duction conditions. According to [47] the adverse effects of climate change on agricultural productivity in South Africa are on the increase. These include rain- fall decreases amongst others. Future decreases in rainfall will make farms that are completely dependent on rain-fed agriculture, such as the mango farmers in the study, vulnerable in terms of sustainability. The challenges of theft, pests and diseases pose a threat to production and sustainability of the farming systems as lower incomes from farming can be expected as a result of low yields. This will negatively impact on farmers' ability to finance farm operations. Land is a finite resource that cannot be increased indefinitely [48]. Efforts to increase yields therefore need to target changes in land management, which should incorporate a range of considerations such as training, the incorporation of organic farming practices such as those suggested by Dassou *et al.* (2021) [49], access to finance, the use of higher inputs and changed technologies.

According to [18] annual tree-crop income amongst smallholder farmers in the Vhembe district, although still very limited, constitutes the main agricultural income. In the few cases that there is additional income from non-tree crops, it is generated from a wide range of vegetable crops and contributes a very small share of agricultural income. The same author asserts that non-tree crops, mostly vegetables, are primarily responsible for the agricultural income and are perceived to be a short-term strategy for income generation whilst waiting for tree-crops to reach maturity. This serves as a sustainable farming practice that can facilitate sustainable farming systems for small-scale farmers.

Macadamia nuts is the fastest growing tree crop industry in the country and their production is lucrative [40] [50] [51]. South Africa is currently the largest producer and exporter of macadamia nuts in the world and the Limpopo Province is the third largest producer amongst the country's nine Provinces. This explains the overall higher agricultural annual income amongst both small-scale and large-scale macadamia nut farmers recorded in the study.

Results from the study reveal that income from HVCs facilitates the purchase of staple food products and provide a mechanism for meeting long term food security goals at both household and national levels. The study focuses on land out of the four drivers of production *i.e.*, land, labour, capital and enterprise, and highlights how aspects of the land resource drive the two farming systems in South Africa and the pathway of agricultural enterprise. Results have emphasized the importance of land as a driver of production for sustainable agriculture. There is great potential for ensuring a positive future for South African farming systems and consequently food security in the sustainable production of HVCs. According to Ba (2016) [52] in order for African countries to commercialise their agricultural sectors sustainably there is need for farmers to adopt a stable, productive agricultural resource base. This requires a targeted investments in such as into the cultivation of HVCs amongst small-scale farmers which will prove highly beneficial.

Author Contributions

FM and MCS contributed to conception and design of the study on which the manuscript is based. FM wrote the first draft of the manuscript. Both authors contributed to manuscript revision, read and approved the submitted version.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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5.2 Postscript

The paper provides a characterization of farming systems in the Vhembe district by showing where large-scale commercial and small-scale farms are located i.e., those selected for the study and discussing selected characteristics of these farms based on the value of land as a driver of both production and sustainability. The main findings of the paper reiterate the importance of land tenure security as a factor that heavily impacts the sustainability of both farming systems, and more specifically small-scale farming systems. The paper also shows how rainfall variability can impact on production shedding some light on how the impacts of climate change have direct implications on how the respective farming systems will respond to the drivers of production and as a result determine their long-term sustainability. Finally, through the paper an initial demonstration of the interactions within and between the two farming systems is provided which is further presented in more detail in the subsequent chapter. FM and MS conceptualized the study. FM collected the data and conducted the initial analysis. FM and MS conducted further analyses and prepared drafts of the paper for submission to the journal. FM worked on revisions of the paper after peer review.

CHAPTER 6 – SCENARIOS FOR FUTURE SUSTAINABLE FARMING SYSTEMS IN SOUTH AFRICA USING A SYSTEMS DYNAMICS LENS

6.1 Preface

This chapter seeks to test the conceptual framework of the study i.e., the feasibility of discontinuing the dichotomous nature of South African farming and a move towards the two farming systems operating as joint ventures. The paper was aimed at providing evidence that suggests there is extensive collaboration between the two types of farmers in South Africa despite farming practices that are deeply embedded in past apartheid policies. The paper serves as an example of how systems analysis analytical tools such as CLDs can be particularly helpful in understanding the nature of the interactions between variables in a system. It presents an innovative approach to decision making for agricultural development that can be adopted across a broad spectrum of stakeholders.

The paper also presents the use of conceptual scenarios, presented as a result of the study, as additional tools to inform policy development. The paper examined the important findings for two of the three commodities in the study that allowed contrast for scenarios namely macadamia nuts and mangos. Due to a considerable amount of overlap between the findings for avocados and macadamia nuts it was decided to exclude them from the paper. However, the key findings from the data collected on avocados that were not developed into a full scenario publication were:

1) small-scale farmers have a heavy reliance on large-scale commercial farmers who are closely linked to processing plants in order to meet international processing standards; 2) due to the highly perishable characteristic of avocados, transport constraints make it difficult for small-scale farmers to transport produce to the pack houses in time often leading to high losses or being limited to the supply of local vendor markets. Agri-business stakeholders offer services for renting transport to collect produce from small-scale farmers at a cost. Small-scale farmers who are able to afford this option make use of it. There is an opportunity for effective collaboration if commercial stakeholders make this option easily accessible; 3) there is a demand for avocado supply at fresh produce markets in different provinces across the country. Farmers who are unable to meet export standards, in most instances small-scale farmers, resort to local market supply; 4) avocados are highly vulnerable to pests; this necessitates the implementation of effective pest management approaches. Small-scale farmers mostly do not have the financial resources to invest in chemicals needed for pest control and; 5) theft of the

crop is a major threat to farmers. Large-scale farmers invest in security to manage this, while small-scale farmers usually have little or no security on their farms making them susceptible to people stealing produce to sell to local markets. The CLD for avocados is presented as Appendix 6.

The paper was submitted to the journal Agriculture for consideration in a special issue titled Sustainable Agriculture: Theories, Methods, Practices and Policies and is under peer review. The unpublished manuscript is presented below.

Scenarios for future sustainable farming systems in South Africa using a systems dynamics lens: a case study of the Vhembe district, Limpopo South Africa

Abstract:

Agriculture is arguably one of the most important economic sectors for South Africa's development as it is directly linked to food security. Farming systems in South Africa have been characterized by a duality where large-scale commercial farmers and small-scale farmers co-exist. The conventional approach to understanding agricultural production in the country has always viewed the two farming systems as mutually exclusive. The study argues that there are various points of interaction between the two kinds of farmers and by using a systems dynamics approach to evaluate the two farming systems this can be applied to agricultural decision making. Data were used to identify and characterise small and large-scale farming systems of two tree crops (mangos and macadamia nuts) in the Vhembe district of Limpopo South Africa. The interactions between the two different farmers are illustrated using Casual Loop Diagrams (CLDs) of the two farming systems under similar commodities. Results, presented as four conceptual scenarios, show that there are multiple points of interaction, such as the interdependence of farmers of macadamia nuts to meet export demands. Policy recommendations to strengthen collaboration between small-scale mango farmers and implement irrigation expansion for farmers who depend on rain-fed farming are discussed and present opportunities for the co-functioning of the two farming systems.

Keywords: interactions, agriculture, systems thinking, agricultural development, sustainability

1. Introduction

Agricultural productivity plays a crucial role in South Africa's food system and sustaining the country's food security. Farming systems in South Africa are characterized by a dichotomy where large-scale commercial farmers and small-scale farmers co-exist. This is part of the legacy of the apartheid system which relegated small-scale farmers to small portions of poor-quality land in what are known as the former homeland areas or Bantustans. The result of this has been the parallel functioning of these two kinds of farmers within the context of continuous change. Large-scale commercial agriculture is regarded as the main driver of national food security in South Africa (PLAAS, 2009). In contrast to this, economically, small-scale agriculture in South Africa enhances local economic development as it is a source of employment and keeps most of the income local as the market is predominantly localised (Aliber & Hall, 2012). Hendriks (2014) suggests that small-scale agriculture contributes to food security at a household level as socially, especially on traditional lands, the produce is first meant to feed the household. The two farming systems are therefore indispensable. According to Dixon et al., (2001) farming systems are defined as "…*a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households."*

High value horticultural crops are becoming increasingly significant to the South African agricultural economy as there is a demand for them on the global market (Hewett, 2012). Examples of in demand high value crops in South Africa include subtropical fruits like avocados, mangos, litchis, papayas, bananas and nuts like pecans and macadamias. Some of the most popular high value crops grown in the country that are in high demand are avocados, mangos, litchis, pecan nuts, papayas, bananas and macadamia nuts. A number of these are cultivated in the Limpopo province of South Africa due to a favourable subtropical climate. Both large and small-scale farmers are engaged in farming high value crops in the province intended for both export and supply to local markets. Land, though not the only driver, is a key driver of agricultural production in South Africa (Materechera and Scholes, 2022). There are numerous factors pertaining to land that impact farmers' ability to successfully produce and contribute to the country's food system which include land tenure and its associated rights, soil quality, vegetation, topography, rainfall variability and water availability amongst various others. Government policy interventions and cross-sectoral initiatives have been targeted towards addressing these land factors with increasing focus on how small-scale farmers are affected by them. Examples of government policy initiatives geared at addressing land as a driver of production include the Upgrading of Land Tenure Rights Act, Act No. 112 of 1991 and the Restitution of Land Rights act, Act No. 22 of 1994 which was later amended in 2014 (SA Government, 2022).

The common understanding of the context of South African farming systems is that the two farmers operate farming systems that are mutually exclusive. The current study challenges this notion by suggesting that the two kinds of farmers do interact on various levels and this can be seen in the case of agriculture in the Vhembe district of Limpopo, South Africa. According to Labadarios et al., (2011) one of the characteristics of farming systems is that they are able to produce the same outcomes in different ways provided they are exposed to similar conditions. It can be inferred that the variables and processes that comprise these systems will be different based on the scale at which the farmers operate therefore necessitating management practices that are specific to the farming systems. However, farming systems that exist in the same geographical location and may be exposed to the same vagaries such as extreme weather events due to climate change in South Africa, may experience overlap in the processes and management practices that are employed.

By using a systems lens to view farming systems in the Vhembe district of Limpopo, it is possible to conceptualize the future of South African agriculture and its contribution to food security by considering the plausibility of coupling the two kinds of farming systems. This is the conceptual basis of this study. The study aims to highlight the connectivity between the two main farming systems in South Africa using systems analysis as a tool for understanding. To this end, this paper will address two objectives namely to identify the interactions between the two farming systems using Casual Loop Diagrams (CLDs) and to develop conceptual scenarios for the co-functioning of the two farming systems under similar commodities farmed in the Vhembe District of Limpopo South Africa. In understanding the nature of the interactions within and between the two farming systems it is possible to determine the feasibility of the two systems being coupled to achieve the goal of jointly meeting the country's food security needs at all levels. Scenarios can inform future decision making, research and policy recommendations.

2. Materials and Methods

2.1 *The Study area*

Limpopo is one of the largest crop producing areas in South Africa and can be regarded as a key agricultural hub. The study took place in the Vhembe district which is a district municipality located in the Northern most region of the Limpopo province of South Africa (Figure 1.)

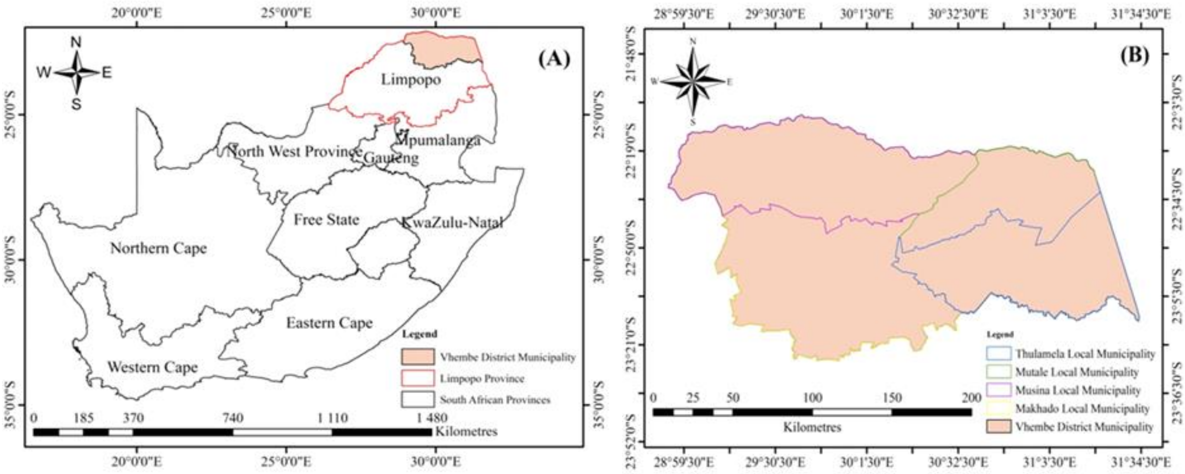


Figure 1. Map showing the location of (A) The Republic of South Africa' provinces and provincial boundaries, highlighting the location of the Limpopo province and the Vhembe district within the Limpopo province of South Africa and (B) shows the location of the four local municipalities within the Vhembe district.

The Vhembe district borders with Zimbabwe and Botswana to the north-east and Mozambique to the south-east passing through portions of the Kruger National Park (Maponya, 2021). The Limpopo province is comprised of five district municipalities of which the Vhembe district is one. The Vhembe district is further sub-divided into four local municipalities namely: Musina, Makhado, Mutale (renamed Collins Chabane) and Thulamela. According to the South African governance structure local municipalities are constituted by towns and their surrounding rural areas (IEC, 2016).

The Vhembe district has a land area of 2,140,708 ha of which only 247,757 ha is arable (Setshego et al., 2020). Agriculture is central to the livelihoods of the people in the Vhembe district and is a key contributor to employment. A reported 90% of rural communities located in the Vhembe district are dependent on agriculture to generate household income and sustain their livelihoods (Vhembe district municipality, 2020). This is aligned with the geographical context of the Vhembe district where the district is located in an area that is predominantly rural (Rusere et al., 2019). Smallholder agriculture accounts for 70% of farming activities in the district while commercial agriculture accounts for the remaining 30% (Odhiambo & Mag, 2008; Oni et al., 2012; Olofsson, 2018). Numerous subtropical crops that contribute significantly to South Africa's agricultural economy particularly through exports are produced in the Vhembe district. Amongst these crops include commodities such as mangos, avocados, bananas, litchis, macadamia and pecan nuts. The census of commercial agriculture in 2017 recorded subtropical fruit and citrus as the biggest crop output in the district (Stats SA, 2017). The Vhembe District Municipality's Local Economic Development Strategy in 2019 (Vhembe district municipality, 2019) reported that the Vhembe district produces 8.4% of the country's sub-tropical fruits and 6.3% of its citrus; overall amounting to 4.4% of South Africa's total agricultural output. Kom et al., (2020) indicates that it is the southern side of the district i.e., the local municipalities of Thulamela and Makhado that is typically comprised of well-established white commercial horticulture farming. In contrast to this, the northern side is mostly semi-arid and is mainly utilized for livestock farming and game ranching. Horticulture in the northern region is very limited and restricted to areas where water is available.

In terms of water availability for agriculture, geographically the Vhembe district is located in a semi-arid area. Occasional droughts usually occur from May to August (Rusere eta al., 2019). According to Moeletsi et al., (2013) and Mpandeli (2014) small-scale farmers in the district mostly practice rainfed agriculture relying on seasonal rainfall which typically falls between November and March. Moeletsi et al., (2013) documents that the average seasonal rainfall for the southern side of the district, identified earlier as the horticulture hub, ranges from 400mm to 600mm. With regard to soils, according to Odhiambo & Mag, (2008) the soils found in the southern region of the district vary significantly from one place to another; those with a higher clay and loam content tend to be found in the east and more sandy soils towards the west.

2.2 *Study design*

Primary and secondary data were used to identify and characterise both small and large-scale farming systems of three tree crops in the study area i.e., avocados, mangos and macadamia nuts. For the purpose of this paper avocados were excluded in the discussion as there was significant overlap between the interactions between large and small-scale farmers of avocados and macadamia nuts in the study area. Mangos and macadamia nuts were selected as there were substantial differences in the interactions be-tween the farmers of these tree crops which provided useful means for comparison be-tween commodities that enrich the discussion of the paper. Analysis was aimed at high-lighting the connectivity of interactions within and between the two main farming systems with respect to the four drivers of production namely land, labour, capital and enter-prise. Secondary data were derived from the official database of subtropical crops from the local Department of Agriculture, soil data and land type maps from the Agricultural Re-search Council (ARC), climate data from the Institute of Soil, Climate and Water (ISCW), related peer reviewed research papers and books. The target population was comprised of a combination of large-scale commercial and small-scale farmers of the three tree crops in the district. An initial broad characterisation of the farming systems was achieved based on data extracted from the subtropical database. This included location of farms (village, town and local municipality), farm size (ha), farmer gender and farmers' personal contact details. Using a purposive sampling method (Ames et al., 2019) the criteria for site selection were deter-mined namely commodity, farm size, gender of the farmer and farm location. This information was available for six subtropical commodities, namely bananas (23), litchis (92), avocados (204), mangos (528), macadamia nuts (184) and citrus (90). According to the database there are a total of 1121 documented subtropical crop farmers in the Vhembe district. The database also showed that the three commodities selected in the study were the most commonly grown commodities in the district. Mangos were selected because they formed the largest number of farms documented in the database (528 farmers). Macadamias were selected based on their significance to the South African agricultural economy as high value export crops.

A systematic random sampling procedure was used to select farms to ensure equal representation of farm size This was done because the required both farmers with small-holdings and larger holdings. Initially three size categories based on the sizes that exist in the database were selected namely, small (1-5 ha), medium, (6-13 ha) and larger (14-20 ha and above). This was later narrowed to two categories i.e., small-scale (1-10 ha) and large-scale (11 ha and above) as these provided a continuum that was context specific to the study. The classification of small-scale farmers in the South African context is complex as size is not the only factor used to determine what constitutes a small-scale farm. Other factors such as enterprise, level of mechanization and technology employed, income from farming etc. are also taken into consideration (Kirsten and van Zyl, 1998). This is further reflected in the use of numerous terms to describe these kinds of farmers such as subsistence, semi-commercial, emerging etc. (Olofsson, 2018). For this reason, the researcher used their own criterion of size to classify small-scale farmers for the specific purpose of this study. In terms of location, farms were selected that reflected equal representation of the four local municipalities located within the Vhembe district namely Musina, Makhado, Thulamela and Mutale. Lastly, with regard to the criterion of gender of the farmers, a random number generation method was used to allow for the equal representation of the genders across all farms. This was achieved by allocating each farmer a number using the previously mentioned criteria and placing the written numbers in a container. Numbers were then randomly picked out by the researcher to add up to a total of 12 farms. Twelve farms were selected and were made up of four samples of each of the three tree crops across the four municipalities with two small-scale and two large-scale farms and an equal distribution of male and females. After completing the site selection, a more detailed characterisation of the two farming systems based on the three commodities in relation to the four factors of production followed. Primary data were obtained by way of in-depth, on-site interviews with individual farmers. Using a snowball sampling method (Etikan et al., 2016) interviews were conducted with the aim of maintaining the originally selected sample size, The result of the snowball sampling technique that was employed produced the following samples: avocados (8), macadamia nuts (7) and mangos (4). In total 19 farmers were selected for participation in the in-depth interviews based on their willingness to participate and availability. Due to numerous challenges in accessing farms based on their extremely rural locations data were collected at only one point in time. This influenced the exceptionally small sample size which the authors acknowledge. For the purpose of this paper the sample refers to a total of 11 farmers (7 macadamia nut farmers and 4 mango farmers)

2.2.1 *Data Collection*

Face- to- face farmer interviews were conducted over the duration of the two visits to the Vhembe district between October and November 2020. Ethical clearance was obtained through the University of the Witwatersrand ethics committee (protocol number: H19/09/26). Clearance was also obtained from the local Department of Agriculture through an official letter of approval. A questionnaire was used as the main data collection instrument comprised of closed and open-ended questions with the aim of collecting qualitative and quantitative data. Open-ended questions were used to obtain more de-tailed responses from participants while close-ended questions were used to gather statistical information. The questionnaire was sub-divided into four key sections: land, labour, capital and enterprise.

Interviews were conducted by the researcher alongside a local who served as an interpreter due to language barriers. Interviews were mostly conducted in the local language of Vhenda. Key informant interviews were conducted with managers from processing plants for macadamia nuts and avocados. Study group meetings for the respective commodities were attended by the researcher in order to develop scenarios. These were information sharing sessions with various stakeholders (farmers, equipment suppliers, extension officers, researchers, grower association representatives, and government officials from the local Department of Agriculture) that allowed for interaction.

2.2.2 *Causal Loop Diagram (CLD) construction*

The causal loop diagram (CLD) analytical tool used to represent the relationship be-tween system variables and their dynamic feedback structures was constructed using Vensim modelling software (Ventana Systems Inc. 60 Jacob Gates Road Harvard, MA, 01451, USA, http://www.ventanasystems.com/). The overall structure of the CLD (Figure 2 and Figure 3) represents the links between large-scale and small-scale farmers of the two commodities (macadamia nuts and mangos) and the broader farming system. The CLDs hypothesize system behaviour and identify balancing and reinforcing feedbacks.

2.2.3 *Development and analysis of scenarios*

Scenarios were constructed using a scenario method known as ‘deductive’ (van der Heijden, 2012). The deductive process uses multiple iterations of scenario drafts that are typically developed through stakeholder engagement facilitated through workshops (van der Heijden, 2012). Workshops allow for scenario deconstruction and revision which provide an opportunity to validate the plausibility of the scenarios. In the current study scenarios were created drawing from three iterations of scenario drafts based on 1) predominant themes on production issues arising within the farming systems of the selected commodities based on farmer interviews and secondary data 2) key informant interviews and 3) interactive study group meetings. Each narrative provided as much detail as possible with the aim of developing equally plausible futures based on a chosen time frame of 10 years (2022-2032). The 10-year time frame was preferred over a longer projected time as it provides a more realistic time-frame to imagine plausible futures based on current trends.

The process of creating scenarios involved three steps. In the first step key drivers and uncertainties surrounding production that emerged from interview responses were noted. Secondly, notes from conversations with key informants who were interviewed during field visits were used to give further detail to what these key drivers are which produced an outline of the narrative for each scenario. Key informants included technical managers for processing plants of macadamia nuts (Green Farms Nut Company and The Royal Macadamia) and representatives from the respective growers’ associations (Macadamias South Africa i.e., SAMAC and the South African Avocado Growers Association i.e., SAA-GA. Lastly, primary information was obtained from multistakeholder participation at local information sharing sessions termed study group meetings for the respective commodities which the researcher attended during the duration of the field work. These were used to further corroborate what the key drivers and uncertainties are and to produce the final two storylines outlining plausible scenarios for farming systems of the respective commodities in the Vhembe district by the year 2032.This iterative process is illustrated in Figure 2. below. The key driving forces of production were continuously narrowed with each iteration based on the most common themes recurring from feedback from the different participants. Themes were used as direction for what the key issues that the scenario would address should be. A 2x2 quadrant of four key drivers based on a scale of uncertainty vs impact ranging from low to high (Figure 2.) was used to establish what the main subject of the scenarios would be. Issues for which farmers' responses reflected a high level of uncertainty were typically used as conversation points during information sharing sessions to probe what kind of solutions could be explored to address the challenge. These aided the writing of the scenario narratives. The interactions between farmers highlighted in the CLDs were used to evaluate the scenarios.

2.2.4 *Data Analysis*

Descriptive statistics (Sarka, 2021) were used for the analysis of quantitative data by calculating percentages, averages and standard errors. Chi-squared and student t-tests (Shen et al., 2021) were used to compare the means across the two farm sizes and between the three commodities. Thematic analysis was used to analyse qualitative data (Groda et al., 2021). Participants responses to open-ended questions concerning land variables relevant to the different commodities were transcribed. Thereafter recurring responses that were mentioned were identified as major themes. Based on the themes, percentages were calculated to classify them in order of importance. Predominant themes were triangulated with quantitative data from the questionnaire and secondary data to explain phenomenon.

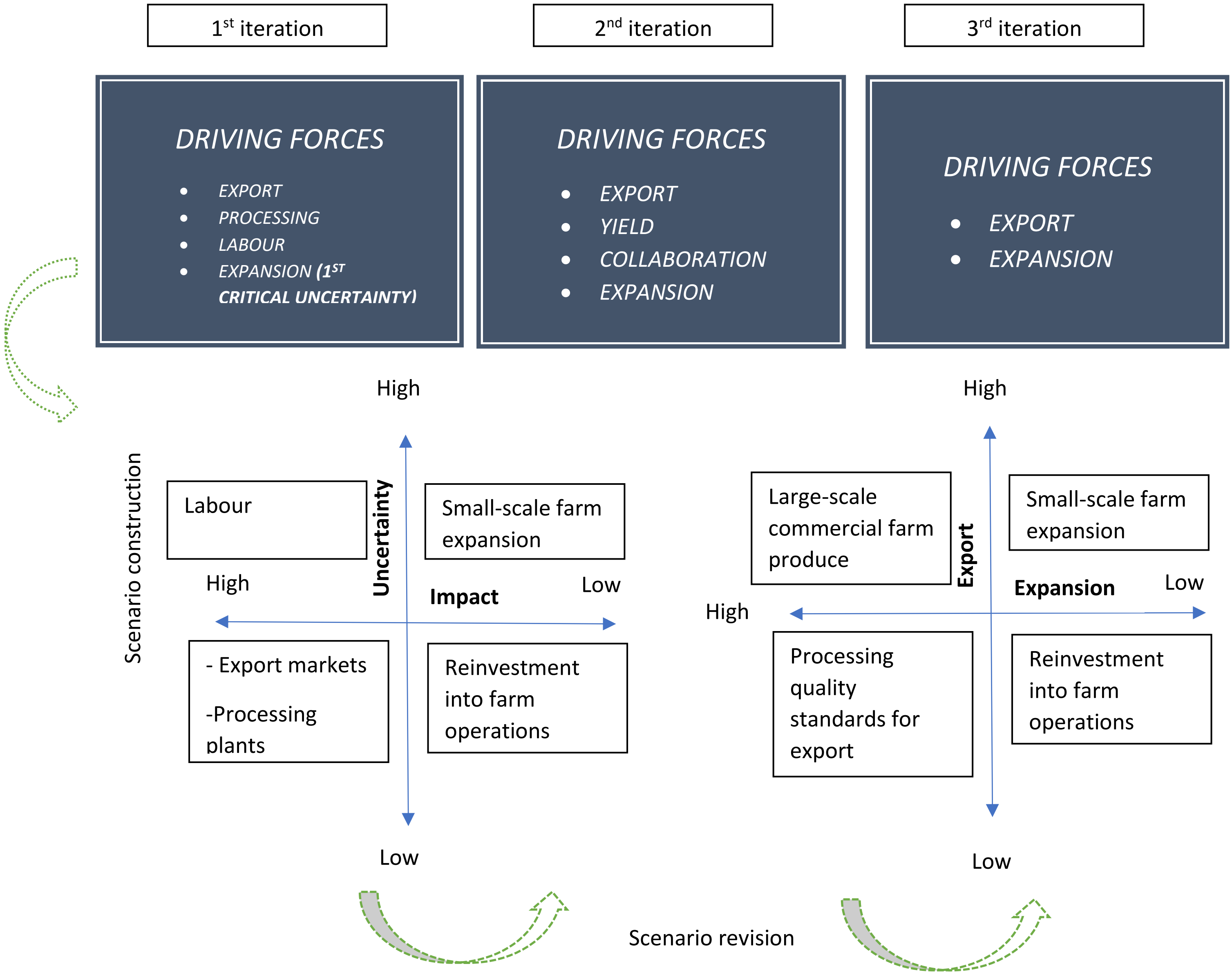


Figure 2. An example of the three iterations of the scenario development using the 2x2 quadrant of uncertainty vs impact used for scenario construction for macadamia nuts based on the key drivers and uncertainties identified from interviews. Adapted from Rameriz et al., (2015).

2.3 *Conceptual Framework*

The two main farming systems that currently exist in South Africa can be found across the country. According to the FAO (2019), both farming systems extend across the Northern part of the country where the Limpopo province is located. The two farming systems are impacted by the same drivers of production i.e., land, labour, capital and enterprise (Dariusz, 2015) however respond to these drivers differently. The manner in which the two farming systems respond to the drivers of production may reveal the connectivity between the systems. A systems thinking approach is best suited to illustrate the connectivity between the farming systems and is therefore used for the study. Arnold and Wade (2015) define systems thinking as *"a system of thinking about systems"*. The same authors make the assertion that systems thinking must have three components in order to be defined namely elements i.e., characteristics, interconnections i.e., the way these interactions feed back into each other or relate, and a function or purpose. System dynamics (SD) is the understanding of the relationship between integrated systems elements and how they impact each other's behaviour (Simonovic, 2012). The integration of systems elements is done by the incorporation of concepts such as stocks, flows, feedbacks, and delays, enabling the analysis of the dynamic behaviour of the system elements over time (Ford, 2009). The approach is used to describe, model, simulate, and analyse complex systems with multiple interacting elements in terms of processes, information, organisational boundaries, and strategies (Lagnika, 2017). This conceptual understanding of systems thinking and systems dynamics is applied in the current study as a means by which to understand the systems being analysed. The farming systems in South Africa operate against the backdrop of constantly changing economic, political, environmental and socio-economic conditions. This is the context in which the current research is positioned. Although farming systems research and farming systems analysis are well established research fields (Bawden, 1996), little attention has been paid to how farming systems will respond to change in the future with respect to drivers of production. The study seeks to provide foresight into future farming systems in a developing country with constantly changing parameters. According to Schweizer and Kriegler (2012) when scenario analysis is used in environmental change research an important objective is exploration. Scenarios can potentially assist users to consider surprising discontinuities and developments. Scenarios are defined as *"a set of conceptual systems of equally plausible future contexts often presented as narrative descriptions typically for the purpose of providing inputs for future work*" (Ramirez, 2015). By using scenarios derived from a systems thinking viewpoint as a tool, the study identifies four scenarios for production, for two different commodities, in farming systems in the Vhembe district of Limpopo South Africa.

3. Results and discussion

Results are presented here in three sub-sections. Firstly, a general (for South Africa and the Vhembe district) and more detailed (by yield and income) characterization of macadamia nut and mango farming systems is presented. Secondly, CLDs are presented and the rein-forcing and balancing feedback loops are described to improve our understanding of the interconnected variables impacting production of the respective commodities in the Vhembe district. Lastly, scenario narratives derived from the key factors highlighted by the CLDs and the iterative process of scenario development are presented.

3.1 ***Characterization of macadamia nut and mango farming systems***

Results revealed that by 2019 South Africa was the largest macadamia producer in the world with 19 500 ha under cultivation, producing over 50 000 tonnes per year. Over 95% of South Africa's macadamia nut production is exported annually (Jaskiewicz, 2015). According to The Macadamia Newsletter (2020) the average yield for macadamia nuts in South Africa was 1.43 tonnes per hectare in 2019. Only 7% of macadamia nuts grown in the country are consumed by the local market. The Limpopo province is the second largest macadamia nut production area in the county after the Mpumalanga province and the Vhembe district ranks third in order of the highest macadamia nut contributing districts in the province (Vhembe district municipality, 2014).

Results showed that mango production in South Africa has been unstable in recent years. In 2019 a total volume of 68 633 tonnes of mangos was produced in the country during that production season (DAFF, 2017). This may be attributed to unfavourable weather conditions. The industry makes an important contribution to direct employment in mango production and processing. In terms of the market structure, the annual crop is either sold fresh through the national fresh produce markets and as exports or processed into atchar, juice or dried mangos. The majority of mangos exported from the Limpopo province are mainly from the Mopani and Vhembe district municipalities respectively. The total export value reported by the Limpopo province was R62 million in 2019 of which R3 million was reportedly from the Vhembe district (DAFF, 2017). Below is a summary of the characterization of the two sets of farms based on selected criteria from the farms selected in the study.

Table 1. Characterization of farm size, farm type, tonnage, yield and income by commodity for one year (2019).

Commodity	Farm size (ha)	Farm type Small-scale	Large-scale	Tonnage (t)	Yield (t/ha)	Gross annual income (ZAR)
Macadamia	4	✓		0	0	0
Macadamia	5	✓		2	0.4	10 000
Macadamia	5	✓		2	0.4	150 000
Macadamia	6	✓		4.2	0.7	200 000
Mean ± SD	5 ± 0.8			2.7 ± 1.3	0.5 ± 0.2	120 000
Macadamia	34		✓	17	0.5	300 000
Macadamia	93		✓	47	0.5	3 5 000 000
Macadamia	1600		✓	806	0.5	40 000 000
Mean ± SD	575.7 ±887.6			290±447.1	0.5 ± 0	25 100 000
Mango	2	✓		3	1.5	12 000
Mango	2	✓		3	1.5	10 000
Mango	10	✓		4	0.4	150 000
Mean + SD	4.7 + 4.6			3.3 + 0.6	1.1 + 0.6	57 333
Mango	15		✓	4.5	0.3	20 000

*The first farmer appearing on the table was a first-time farmer who had planted trees 2 months prior to the interview and therefore did not have any yield to record.

The average gross annual income from farming amongst participants ranged between R10 000 and R40 million between the two commodities. Results revealed that macadamia farmers obtained the highest farming incomes, in both large-scale farms, average of R25,100,000, and small-scale, average of R120,000 compared to mango, R20,000 for the large-scale farmer and an average of R57,333 amongst small-scale farmers, farmers. Results of the Pearson Correlations analysis show that there is a positive statistically significant correlation between average gross annual income and farm size amongst macadamia farmers ($r = 0.763$, $p < 0.01$) and a positive significant correlation between average gross annual income and farm size amongst mango farmers ($r = 0.346$, $p < 0.01$).

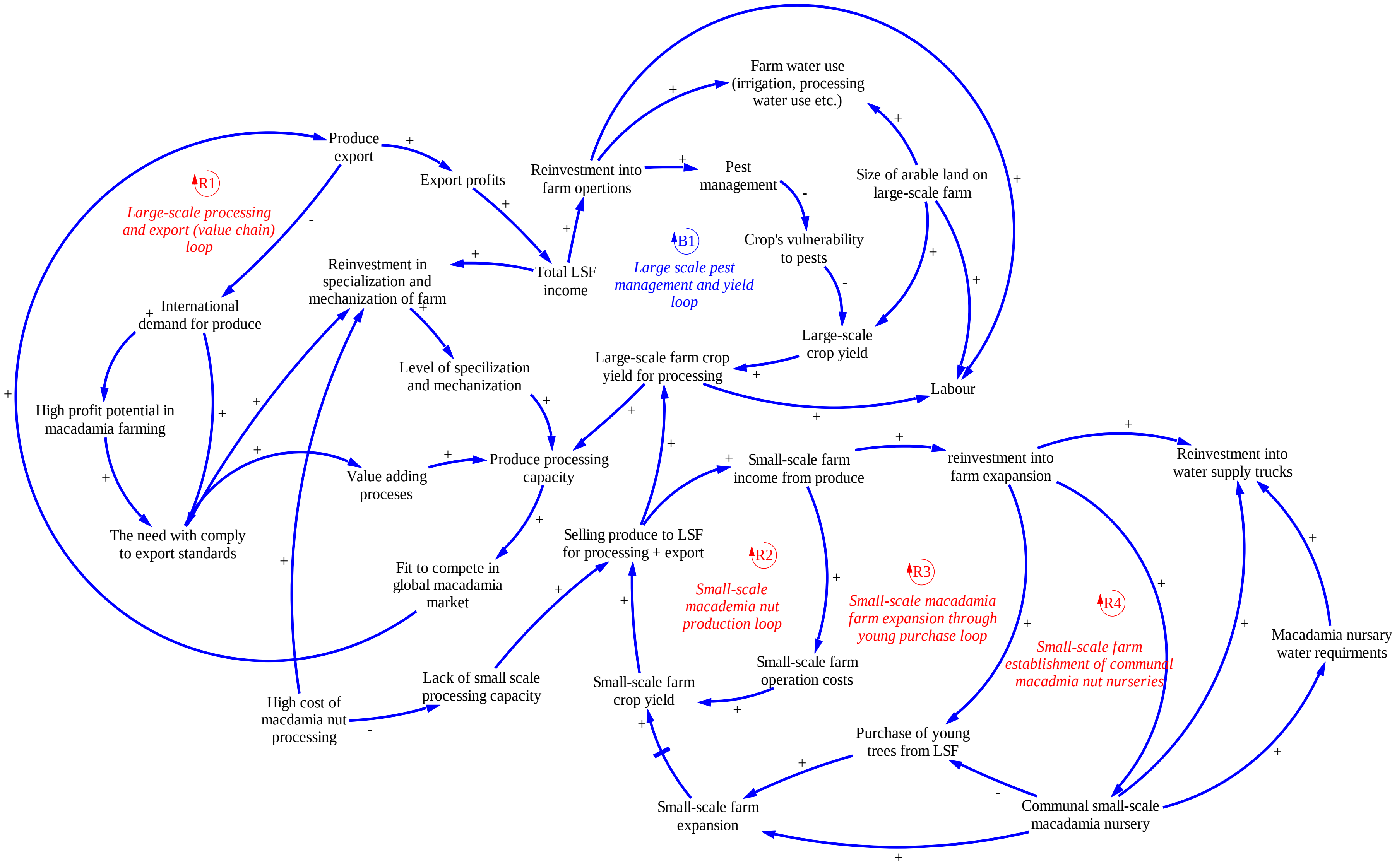

Produce export
Export profits
Reinvestment into farm opertions
Farm water use (irrigation, processing water use etc.)
Pest management
Size of arable land on large-scale farm
Crop's vulnerability to pests
Large-scale crop yield
Labour
Total LSF income
Reinvestment in specialization and mechanization of farm
International demand for produce
High profit potential in macadamia farming
The need with comply to export standards
Value adding proceses
Produce processing capacity
Level of specilization and mechanization
Large-scale farm crop yield for processing
Fit to compete in global macadamia market
High cost of macdamia nut processing
Lack of small scale processing capacity
Selling produce to LSF for processing + export
Small-scale farm income from produce
reinvestment into farm exapansion
Reinvestment into water supply trucks
Macadamia nursary water requirments
Small-scale farm operation costs
Small-scale farm crop yield
Purchase of young trees from LSF
Small-scale farm expansion
Communal small-scale macadamia nursery
R1
Large-scale processing and export (value chain) loop
B1
Large scale pest management and yield loop
R2
Small-scale macademia nut production loop
R3
Small-scale macadamia farm expansion through young purchase loop
R4
Small-scale farm establishment of communal macadmia nut nurseries

Figure 3. Causal loop diagram (CLD) showing macadamia nut farming systems in the Vhembe district, Limpopo. Arrows connect two or more variables of interest and are causal links that run in the stated direction. '+' = a positive relationship, indicating that the causality runs in the same direction (i.e., an increase in variable A will cause an increase in variable B and vice versa); '–' = a negative relationship, indicating that the causality runs in the opposite direction (i.e., an increase in variable A will cause a decrease in variable B and vice versa). The balancing feedback loops are numbered Bn and labelled in blue font. The reinforcing feedback loops are numbered Rn and labelled in red font (Selebalo et al., 2019). *LSF=Large-scale farm/farming

3**.2** ***Macadamia nut farming systems***

R1 Large-scale processing and export loop

Macadamia nuts is the fastest growing tree crop industry in the country and their production is lucrative. The demand for macadamia nuts globally is high and South Africa is currently the largest producer (in tonnes per hectare) in the world (Parshotam, 2018; The Macadamia Newsletter, 2020; Shabalala et al., 2022). Large-scale macadamia farmers in the Vhembe district produce macadamia nuts for export and are also owners or partners in processing plants such as the Royal Macadamia located in Thohoyandou, Limpopo and Green Farms Nut Company in Levubu, Limpopo. Some profits from export sales are reinvested into farm operations of which pest management forms a component. The most common pest control strategy used by large-sale farmers is integrated pest management (IPM). Large scale farmers contract experts to monitor their fields and thereafter recommend management interventions. This IPM approach combines techniques such as the use of resistant varieties, biological control and habitat manipulation etc. to effectively tackle pest problems. Crop vulnerability to pests such as stink bugs is decreased through investments into pest management which resultantly impacts the total annual yield positively. There is a positive causal link between the large-scale farm yields and the capacity to process the nuts for export. Large-scale farmers are able to meet processing quality standards therefore making them fit to compete in global export markets and to make profit from export sales thus reinforcing a cycle of export market participation.

R2 Small-scale macadamia nut production loop

Small-scale macadamia farmers in the Vhembe district contribute to the macadamia nut value chain in the province reinforcing the interdependence of the two types of farmers. Nuts, produced by small-scale farmers, are transported and processed at plants owned by large scale farmers as small-scale farms do not have the required equipment for processing and export requirements (indicated by the negative relationship "-" that is shown in the arrow between the variables high cost of macadamia nut processing and lack of small-scale processing capacity). Income made from nut sales is used to finance farm operational costs.

R3 Small-scale macadamia farm expansion through young tree purchase loop

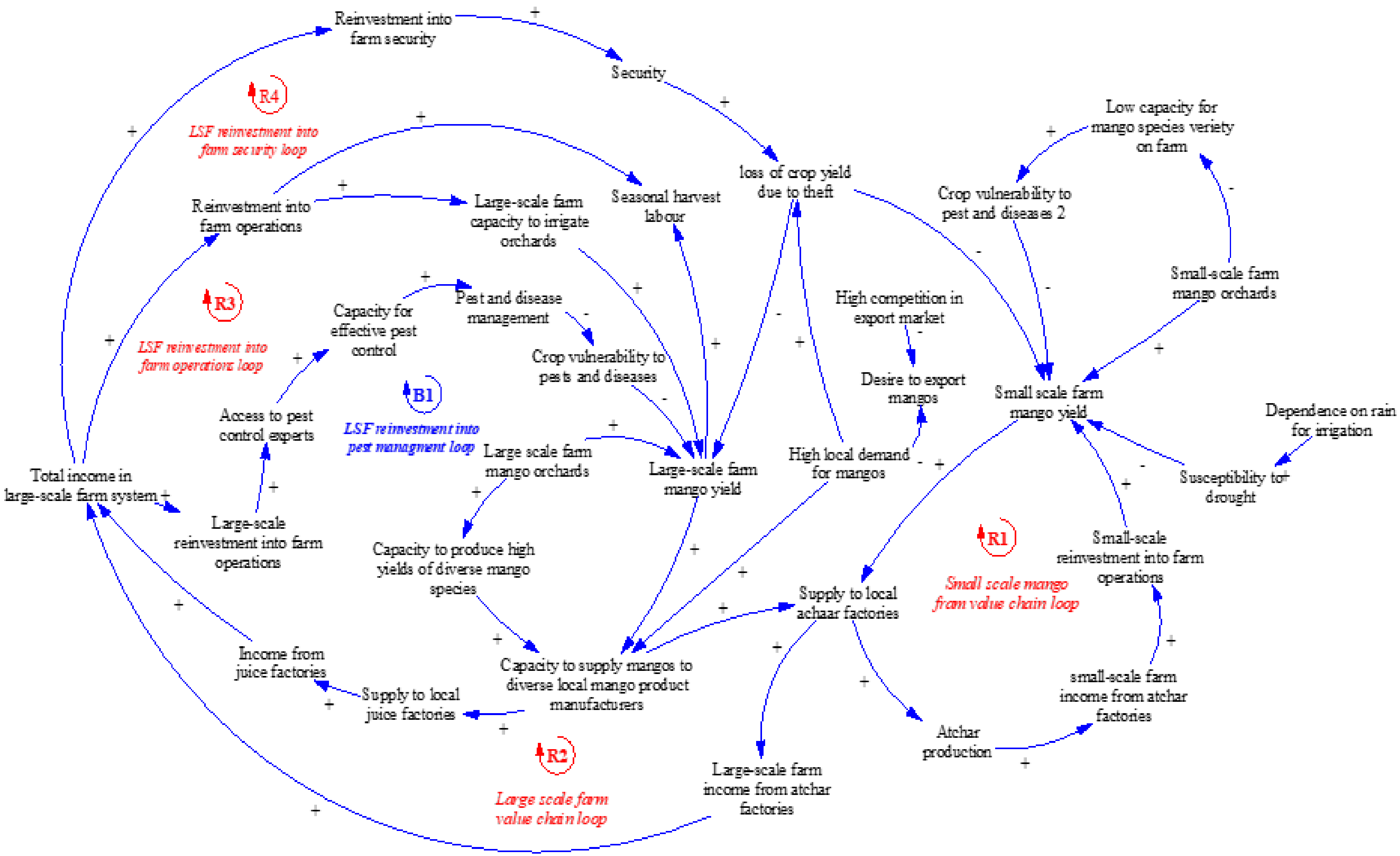
Small-scale macadamia farmers in the Vhembe district use some of the profits from nut sales to reinvest in the expansion of their farms by purchasing young macadamia trees from large-scale commercial nurseries in the province (these are found in Tzaneen and are sold at a cost of R60/tree). The expansion of small-scale macadamia farms will positively impact the yield over time as trees mature, this is indicated by the delay in the CLD (the short blue line across the positive arrow between small-scale farm expansion and small-scale farm crop yield) as the causal link between farm expansion and yield is not immediate. Macadamias are long-term crops taking on average four to five years from panting before cropping commences and six to seven years before commercially viable yields are produced. This reinvestment of profits reinforces a loop of continuous farm expansion.

R4 Small-scale macadamia farm establishment of communal macadamia nut nurseries

Some small-scale farmers have opted to establish their own nurseries through planting trees from the yield of previous harvests and grafting. Small-scale farmers then sell young trees to other small-scale farmers within close proximity eliminating the transport costs to nurseries further afield. The establishment of macadamia nut nurseries fosters interaction and interdependence between small-scale farmers and promotes growth in the small-scale macadamia enterprise thus reinforcing a loop of continuous expansion.

B1 Large-scale pest management and yield loop

Large-scale commercial macadamia nut farmers in the Vhembe district are able to reinvest income from export profits into pest management to control prevalent pests and diseases. The more farmers are able to invest in integrated pest management programs the less vulnerable the orchards become to invasion by pests. As pest vulnerability is continually reduced through pest management, yield is increased through larger numbers of trees able to produce nuts in a balancing loop in the CLD.



Reinvestment into farm security
Security
loss of crop yield due to theft
Low capacity for mango species veriety on farm
Crop vulnerability to pest and diseases 2
Small-scale farm mango orchards
R4
LSF reinvestment into farm security loop
Reinvestment into farm operations
Large-scale farm capacity to irrigate orchards
Seasonal harvest labour
High competition in export market
Desire to export mangos
Small scale farm mango yield
Dependence on rain for irrigation
Susceptibility to drought
R3
LSF reinvestment into farm operations loop
Capacity for effective pest control
Pest and disease management
Crop vulnerability to pests and diseases
B1
LSF reinvestment into pest managment loop
Access to pest control experts
Large scale farm mango orchards
Large-scale farm mango yield
High local demand for mangos
Total income in large-scale farm system
Large-scale reinvestment into farm operations
Capacity to produce high yields of diverse mango species
R1
Small scale mango from value chain loop
Small-scale reinvestment into farm operations
Supply to local achaar factories
Income from juice factories
Supply to local juice factories
Capacity to supply mangos to diverse local mango product manufacturers
small-scale farm income from atchar factories
Atchar production
R2
Large scale farm value chain loop
Large-scale farm income from atchar factories

Figure 4. Causal loop diagram (CLD) showing mango farming systems in the Vhembe district, Limpopo. Arrows connect two or more variables of interest and are causal links that run in the stated direction. '+' = a positive relationship, indicating that the causality runs in the same direction (i.e., an increase in variable A will cause an increase in variable B and vice versa); '–' = a negative relationship, indicating that the causality runs in the opposite direction (i.e., an increase in variable A will cause a decrease in variable B and vice versa). The balancing feedback loops are numbered Bn and labelled in blue font. The reinforcing feedback loops are numbered Rn and labelled in red font. (Selebalo et al., 2019) *LSF=Large-scale farm/farming

3.3. *Mango farming systems*

R1 Small-scale mango farm value chain loop

Small-scale mango farmers in the Vhembe district are the main suppliers of the local mango atchar (a pickled mango paste that is commonly eaten in the province forming part of a typically South African diet and sold at supermarkets) processing companies. Mango atchar processing factories (such as Gratchar located in Letaba, Mango Magic Atchar in Tzaneen and Levubu Atchar Veraardigers in Levubu) are located within the district therefore more easily accessible to the farmers. Farmers are able to make a profit from mango sales to atchar processing factories which are later reinvested into farm operations. An increased investment in farm operations results in better annual yields which ensures continued supply to processing companies creating a reinforcing loop.

R2 Large-scale mango farm value chain

Large-scale mango farmers in the Vhembe district produce larger annual yields compared to small-scale farmers; these are comprised of more than one variety of mango species therefore enabling them to supply mangos to diverse markets i.e., juice manufacturers, dried fruit and mango atchar processing factories within the district, fresh produce markets, informal markets and supermarkets in other provinces. None of the farmers interviewed indicated that they supply mangos for export. The total income made from the sales to these diverse markets is used to reinvest in farm operations of which irrigation forms a part., only the large-scale farmers indicated that they irrigate while all small-scale farmers stated that they rely on rainfed agriculture. With an increased capacity to irrigate there is an increase in yield which allows farmers to supply the diverse markets creating a reinforcing loop.

R3 Large-scale mango farm reinvestment into farm operations loop

Large-scale mango farmers in the Vhembe district are able to reinvest profits from sales into farm operations which include labour. Large-scale farmers are able to reinvest in paying seasonal labour during harvest time unlike small-scale mango farmers who rely on family members to harvest mangos.

R4 Large-scale farmer reinvestment into farm security loop

Large-scale mango farmers are able to reinvest the profits from selling produce into improving security on the farm. Theft is an ongoing challenge to the mango farmers as mangos can be sold locally by vendors in the district. The lack of adequate fencing means that surrounding communities can easily access the trees and steal large quantities of mangos (one farmer reported *"last year I was only able to harvest about a quarter of my whole farm, the rest was stolen. All that work for nothing."*) significantly impacting the quantities of mangos available for sale to markets. When farmers increase the investment in security i.e., fencing, patrol guards and watch dogs this decreases the loss of the crop due to theft and increases the overall annual yield creating a reinforcing loop.

B1 large-scale farmer reinvestment into pest management

One of the areas in which large-scale mango farmers in the Vhembe district reinvest their profits from sales is in pest management. Farmers are able to outsource pest control experts to inform their pest management activities therefore increasing their capacity for effective pest management by implementing an integrated pest management approach that is capital intensive. Results showed that farmers made use of both spraying of pesticides and herbicides to this end. Continuous investment into effective integrated pest management decreases the vulnerability of orchards to pest invasion which creates a balancing loop that ensures good annual yields enabling continued supply of mangos to the diverse markets that large-scale farmers have access to.

3.4. Scenarios

3.4.1 The macadamia gold rush

The global demand for macadamias continues to increase as there is an increasing public knowledge of the numerous health benefits of tree nuts and nut oils. This demand has been the key factor in market expansion. According to Grand review research (2022), the global macadamia nut market is expected to grow at a compound annual growth rate of 10.7% from 2021 to 2028 to reach USD 2.95 billion by 2028. South Africa remains one of the largest producers in the world and this can influence future production trends as farmers in the country aim to align with global market demands. Small-scale farmers' heavy reliance on large-scale farmers for processing in order to participate in global market supply will continue if there are no opportunities created for them to compete in terms of processing capacity. A wide range of role players need to be involved within the macadamia nut industry in order to make it competitive, efficient and dynamic. Small-scale farmers can only expand the industry if they have access to land and tenure security; results revealed that higher proportions of small-scale farmers (71%) farmed on communal land compared to large-scale farmers (29%). This speaks to the on-going land tenure reform dialogues in South Africa and the need to urgently address tenure rights of small-scale farmers in the country. In order to sustain large-scale and small-scale macadamia farmer interdependence in a manner that is mutually beneficial and equally beneficial to the country's agricultural economy, small-scale farmers need to be incorporated into the value chain in a more prominent way.

3.4.2 Exploring the possibilities of strengthening small-scale farmer collaboration

There is an increase in interest to farm macadamia nuts amongst small-scale farmers as the monetary gains become increasingly evident. This is well depicted in participant's contribution at a study group meeting; *"everyone is going into macadamias now because that's where the money is. If I could, I would convert my whole farm into only macadamias".* The move towards expansion of macadamia nut farming is seen in the establishment of nurseries amongst small-scale farmers from the yields of previous harvests. This is an attempt at breaking away from their dependence on commercial tree suppliers and creating a level of independence. If successful, this initiative has the potential to grow small-scale farmer's producing capacity over time. Establishing their own nurseries also presents a premise for small-scale farmer collaboration that may yield better production results. If small-scale farmers came together to increase their yields, they can continue to supply large-scale commercial processors and enter the export market at a more competitive level. The benefits of the outcomes of this interaction and interdependency between the two kinds of macadamia famers are not balanced. Small-scale farmers may not obtain profit to the full value of their produce as they only provide raw produce and are paid accordingly. Their large-scale farmer counterparts on the other hand obtain a higher profit as the produce that is sold to export markets is now value added after processing. Based on this imbalance, there is a need to explore more innovative approaches to collaboration between small-scale farmers for the purpose of enabling them to process macadamia nuts independently. Small-scale farmers could potentially band together to either rent or co-own processing facilities that they would collectively use instead of solely relying on large-scale commercial farmers for processing. This should serve as a model to inform government support for capacity building amongst small-scale farmers; with the aim to enable them to increase their profits from growing macadamias so that there is a balance in the benefits derived from growing macadamia nuts for both large and small-scale growers. Lastly, although the main focus of macadamia supply in recent years has been international markets, there is potential for macadamias to become a highly sort after commodity in local markets with changes in the South African food system leaning towards a more healthier food focus. Both large and small-scale farmers can work together to explore how to optimize opportunities and risks.

3.4.3 Mango supply driven by the demand of the market

Mangos are highly perishable therefore necessitating careful control of packaging, transportation and distribution. This influences the South African mango value chain significantly. Unlike macadamia nuts, the market demand for mangos from farmers in the Vhembe district appears to be more localized than international. The ability to grow different cultivars based on favourable climatic conditions enables farmers in the district (both large and small-scale) to target specific markets based on the type of mangos they produce e.g., juice making factories, processing factories (for dried fruit and mango atchar), local and provincial fresh produce markets. Currently large-scale mango farmers from the Vhembe district supply produce to juice processing factories while small-scale famers supply atchar processing factories. This mainly an issue of accessibility as most atchar processing companies are located within the district much closer to where the small-scale farms are situated. They are therefore able to transport the produce to these factories faster. This becomes a more economically viable option for small-scale farmers as mangos rot easily and therefore may result in losses when they attempt to transport to further distances where the juice processing factories are found (in some cases outside of the district and province where they live). Agro-processing is the single largest market for mangos in South Africa (DAFF, 2017). According to the database of local subtropical fruit farmers, mango farmers make up the largest number of farmers in the district presenting an opportunity for economic gain; this however does not align with the success of the mango market distribution when compared to that of macadamia nuts and avocados. The economic profitability of processing mangos into juice is high as value is added to the raw produce once it is in the form of juice and can be preserved for longer than the mangos in their natural state. Atchar is also highly profitable as it is a popular choice as part of a low to medium income South African diet. It has a long shelf life due to the manner in which it is preserved therefore presenting a viable economic investment. There is also potential for atchar to be sold as an export product to other countries in the region and abroad. Exploring possibilities of collaboration between farmers and agro-processors can possibly expand the value chain for the benefit of all stakeholder. Given the heterogeneity of the local mango demand, farmers in the district can invest in a more targeted approach to growing mangos, focussing on the niche markets. Mango cultivars that ripen earlier in the season are more favourable for atchar processing as opposed to cultivars that ripen mid to late season which are more suitable for the juice market, however the risks associated with ripe fruit are high e.g., theft, flies, pests etc. Solutions need to be found to minimize theft and may be associated with price control.

3.4.4 Focus on irrigation

One of the greatest challenges for both large and small-scale mango farmers is their reliance on rainfed agriculture as the area is semi-arid and prone to droughts. One of the numerous impacts of climate change is that rainfall patterns are shifting therefore sole reliance on rainfall for cultivation is not beneficial. This is a constraint that is already recognized and is an ongoing concern for mango farmers of different scales however, small-scale farmers are particularly vulnerable to this problem and therefore need be given more attention. Irrigation is a critical factor in farmers' success and capacity to supply markets. Systems thinking is a valuable tool for finding solutions where trade-offs are involved. The mango industry needs to collaborate with water management representatives in order to maximise on production.

4. General Discussion and Conclusions

The value of systems thinking is illustrated in the CLDs and the scenarios for the two commodities, macadamia nuts and mangos. In understanding the interconnections be-tween variables and the degree to which they impact each other in the present, it becomes possible to adopt a more holistic approach to decision making that informs policy and action for the future. The current study provides evidence that suggests that the coupling of large and small-scale farmers is a viable option for agricultural development in South Arica. If both farmers can equitably contribute to the country's agricultural economy albeit through different means, it is possible to envision an economy that is supplied by the joint operation of both kinds of producers. The success of this kind of approach is hinged on the implementation of a multi-pronged intervention strategy which addresses related issues simultaneously. Examples of the need for this multi-pronged intervention strategy have been highlighted in the scenarios through 1) the need to address small-scale macadamia farmer tenure security in order for small-scale farmers to successfully expand their industry and to collaborate with one another alongside prioritizing supplying export markets 2) the need to combine water management and distribution planning with farming agendas in order to capacitate mango farmers who mostly rely on rain-fed agriculture i.e., mostly small-scale farmers, to supply diverse markets that are available.

The government model for land redistribution in South Africa over the past two decades has been centred around the need to address historical inequalities in land distribution that favoured a minority of large-scale commercial farmers over the majority of small-scale farmers who were predominantly black. This is a highly contentious and politicized issue considering South Africa's history of an apartheid system. According to Materechera and Scholes (2022), the issue of overlapping use rights on communal land further com-plicates the challenge of a lack of tenure rights for small-scale farmers. Small-scale farmers have to contend with other community members who use the land for multiple other purposes e.g., firewood and grazing before they can consider participating in commercial activities. This presents itself a great constraint. Existing policy interventions surrounding land tenure security have mostly been targeted at land reform to improve the commercial status of previously disadvantaged farmers located in the former homeland areas. In order to be successful in this, policy directives should also include socio-economic strategies to address the issue of overlapping use rights in communal land. There is an urgent need for expansion as far as small-scale farmer irrigation systems are concerned. The potential for sustainable irrigation expansion thus becomes a factor that should inform research, decision making and policy development so that small-scale mango farmers can increase their yields and improve their market competitiveness. The application of innovation for more climate change friendly irrigation systems that are affordable and accessible to small-scale farmers becomes a necessity. The adoption of "soft-path" water harvesting for irrigation (Rosa et al., (2020) is a plausible solution. This approach to bringing irrigation to rain-fed croplands involves capturing water resources in small and check dams as an alternative to the conventional centralized, capital-intensive irrigation projects that tend to be large.

Integrated pest management has the potential to be mutually beneficial for both farmers provided they are co-located. For example, a large-scale commercial farmer who implements IPM on their farm can have a positive knock-on effect on an adjacently located small-scale farmer of the same commodity. Small-scale farmers can use less capital-intensive, non-chemical approaches to IPM such as the cultivation of push and pull crops (Ehler, (2006); Deguine et al., (2021)) in order to augment the activities of large-scale farmers that tend to be more capital-intensive. The implementation of this approach cancels the necessity of every area un-der cultivation with the same commodities to have a comprehensive IPM system in place. There may be areas without extensive IPM but benefit from being adjacent to farms that do. If farmers are willing to collaborate and make this trade-off, potentially with agreement on a certain kind of compensation for the benefits received, this interaction can foster future coupling of the two farming systems to achieve a common goal. There is potential here for future research. Historically, the needs of the two kinds of farming systems have been addressed independently. This has contributed to the way in which they have continued to operate as separate entities. The study proposes that a systems thinking approach should inform decision making in the future.

Ultimately the question of whether coupling of the two farming systems in the con-text of meeting the country's food security needs at both national and household levels is a viable option is revisited. In understanding both the positive and negative implications of the interactions between the two groups of farmers, the scenarios derived in the study at-tempt to present evidence to support the conclusion of whether or not the two systems can ultimately work collaboratively in achieving food security at all levels in the future as op-posed to doing so independently as the current situation suggests. If decision making is informed by the application of systems analysis this may be an achievable goal.

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6.2 Postscript

The paper is a crucial addition to the dissertation as it attempts to address the fourth objective of the study i.e., to develop conceptual scenarios for sustainable farming systems in the Vhembe district in Limpopo. The findings could be scaled up and out to inform decision making for agricultural development in the country. FM and MS conceptualized the study. FM collected the data and conducted the initial analysis. FM and MS conducted further analyses and prepared drafts of the paper for submission to the journal. FM worked on revisions of the paper after peer review. The following chapter provides a synthesis of the entire study and presents the key findings, general conclusions, recommendations.

CHAPTER 7 – GENERAL DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

7.1 Synthesis of the findings from the study

7.1.1 The dynamics of land as a driver of production in South Africa's farming systems

The concept of farming systems has not been fully embraced in South Africa's approach to agricultural development as yet. This is reflected in the development of policy frameworks for agriculture which have a heavy focus on land and more specifically land reform as a means of addressing problems associated with farming (Hall, 2004). Examples of these policies include the Upgrading of Land Tenure Rights Act, Act No. 112 of 1991, Land Reform: Provision of Land and Assistance Act, Act No 126 of 1993 and the Restitution of Land Rights act, Act No. 22 of 1994 which was later amended in 2014, (South African Government, 2022). The problem with this outlook on agriculture is that it is limited in, not only the decision-making and resource allocation processes, but also the application of tools and methods for farming system design and management. This study has shown that farming comprises the entire pathway of agricultural enterprise for commodities including production, management practices, marketing, value addition, financial resources, and policies in addition to land ownership.

The study confirms land as an essential driver of production amongst the four drivers in the South African context and has shown that this driver interacts with numerous other factors in shaping the management of a sustainable farming system. Although highly politicized and encompassing a broad spectrum of issues, land, if considered in its entirety, has direct implications on the sustainability of the two kinds of farming systems found in the country. The study has further highlighted some key aspects of land unique to the South African context including the link between land availability, ownership and farm size; and decision-making and resource allocation within the land management practices adopted by the two types of farmers. Unlike more traditional approaches to viewing agricultural productivity, yield cannot be considered in isolation, but should take into account the uncertainties associated with climate change and socio-economic factors e.g., household income from non-farming activities. The synthesis of the key findings of the study and their implications for the future of agricultural development in the country are discussed below.

7.1.1.1 Land availability, ownership and size of farms

The study revealed that communal land ownership is the most common land tenure system amongst small-scale farmers in the Vhembe district while large-scale commercial farmers generally tend to own the land they farm on. This is a common aspect of the inequalities of the country's historical land distribution framework and is typical of the current land tenure distribution in the former homeland areas (May and Roberts, 2000; Hall and William, 2003; Hall, 2013; Greenberg, 2013; Van den Berg, 2013). Most small-scale farmers find it difficult to invest in farming infrastructure as there is no tenure security on communal land. Aliber and Hall (2012) stipulate that a key consequence of this lack of tenure security amongst small-scale farmers is the inability to source funding from banks. This leads to small-scale farmers being characterized as having poor access to inputs and credit. Alternatively, large-scale commercial farmers in the study who owned the land were in a better position to finance their farming activities in the long term. This link between tenure security and finance is one of numerous examples of how land as a driver of production cannot be viewed in isolation.

By applying a systems thinking perspective it has been possible to view how there are feedbacks between individual aspects of land and how they are connected to other factors such as finance in this example. Another good illustration of the feedbacks between the numerous variables that constitute land as a driver of production is presented in the study through the challenge of land tenure security for small-scale farmers and its overlapping with land use rights on communal land. Burger (2021) indicates that in communal land ownership, rights and responsibilities are entrusted to the traditional authorities, which limits the commercial activities of small-scale farmers because the land can be used for multiple uses by neighboring community members. Numerous other studies where the issue of overlapping land uses on communal land have been explored include the work of Andrew et al. (2003); Cousins (2009); Aliber and Cousins (2013); Shackleton (2020); and de Jong et al. (2021).

Existing approaches to tenure reform, tend to address the issue in isolation from the broader question of how to reconcile the divide between overcrowded and under-resourced communal areas, and the wealthy commercial farming areas. Land reform interventions in communally owned land needs to incorporate the possibility of shifting control of land from the traditional authorities to the farmers. This illustrates how socio-economic factors are tied to land factors in determining productivity. In using systems thinking it becomes possible to see how land policy frameworks aimed at redressing the disparities of the past affect the two kinds of farmers differently and therefore presents a useful tool to inform decision making. In the case of this study, it was found that a small proportion (26%) of large-scale commercial farmers owned the land they farmed on across all three commodities. Responses during interviews revealed that most of these farmers had obtained finance to purchase farms, without much difficulty, during the time of the apartheid government administration. Greenberg (2013) points out that historically production finance was provided by a range of state and statutory institutions under apartheid including the Land Bank, the Agricultural Credit Board and the co-ops. These institutions provided members with credit and excluded black producers. According to the same author, the Land Bank continued to play a valuable role in agricultural financing however most of the funds are given to commercial farmers. A result of this state approved finance advantage for large-scale commercial farmers has been their ability to cope and adapt to changes in the agricultural economy brought about by shocks such as the covid-19 pandemic.

According to Tripathi et al., (2021) South African commercial farmers with access to more capital were able to use financial resources to preemptively buy inputs ahead of the country-wide lockdown and to build storage infrastructure. Small-scale farmers on communally owned land on the other hand did not have such opportunities and as a result suffered greatly from restrictions imposed by the lockdown. Systems thinking provides a means of seeing how these aspects are interrelated in such instances.

7.1.1.2 Land management and sustainability of the farming systems

It is evident from the study that the different land management practices adopted by the two types of farmers will also influence their sustainability. Land is a finite resource that cannot be increased indefinitely. Efforts to increase production therefore need to target changes in land management, which should incorporate a range of considerations such as training, the incorporation of organic farming and climate smart practices, intercropping systems, access to finance, the use of higher inputs and changed technologies. The study has presented a few insights into land management practices employed by the two kinds of farmers within the respective farming systems. Small-scale farmers for example rely on sales of non-tree crops such a vegetables like cabbage, carrots, spinach and tomatoes as a short-term strategy to generate small amounts of income until tree crops reach maturity which can take between 2 and 4 years. The diversification of small-scale farmer livelihoods by ways of finding other sources of income outside of farming, is seen in farmers being employed as teachers at primary and secondary school levels (Olofsson, 2018), as a management practice that is aimed at optimizing their sustainability. Large-scale farmers on the other hand, have adopted a commodity-focused approach towards land management where farming is centered on specific commodities, generally HVCs, that are particularly significant to the agricultural economy (Pereira, 2014; Olofsson, 2021). This market-led strategy is the most common approach to farming for large-scale farmers characterized by the adoption of mechanization and high inputs that increase profits and may improve sustainability through diversification. Through these examples the study has shown that land management needs to be explored as an aspect that drives production that cannot be regarded in isolation. It is suggested that the way in which production will be approached by the two types of farmers as they respond to their preferred management practices will differ albeit the production of the same commodities. This is exemplified in the study in the banding together of small-scale macadamia nut farmers to develop their own nurseries to supply trees versus large-scale commercial farmers relying on well-established orchards.

7.1.2 The connectivity between large-scale commercial and small-scale farmers in South Africa

One of the key findings of the study is that contrary to the historic dualistic view of the two types of farmers in South Africa, the study has revealed that there are interconnections between the types across the farming systems. This is because of the multi-variable nature of the processes within the farms and the non-linear interconnectedness that exists between them. The study found that there are numerous points of interaction within and between the farming systems and systems analysis can be used as an analysis tool to tease out the nature of such connectivity. This was shown through the use of CLDs for each of the commodities evaluated in the study. A systems thinking approach aids in understanding systems and the drivers that impact them more holistically (Monat and Gannon, 2015). This can inform stakeholders to ensure sustainability of the two farming systems and to create opportunities for them to benefit from the different ways in which they produce outcomes. Agri-business stakeholders for example can benefit from knowing the ways in which supply from the respective farmers is impacted by different variables.

The conceptual framework of the study is built around the concept of small-scale and large-scale commercial farmers and the interconnectedness of the two systems. An essential consideration is that the sites selected in the study were co-located in the Vhembe district on farms growing the same commodities despite being of different sizes. This showed how the drivers of production will facilitate the degree of connectivity.

There are examples of collaboration between farmers within the respective farming systems for macadamia nut production. This can be seen through the study in small-scale farmers working together to establish their own nurseries to optimize production and large-scale commercial farmers working together to share information. Regarding connectivity between the two farming systems, the study revealed that small-scale macadamia nut farmers have a heavy reliance on large-scale commercial farmers for processing in order to participate in global market supply. This is due to the commercial farmers' connection to agri-business processing facilities. The benefits derived from this interdependence appear to be one sided as opportunities for small-scale farmers to participate competitively in terms of processing capacity are seemingly non-existent, however, this study showed that opportunities exist for collaboration and a wide range of role players need to be involved within the macadamia nut industry in order to make it competitive, efficient and dynamic. Both farming systems contribute to the country's agricultural economy albeit through different means and make the industry more sustainable.

The connectivity between the systems could be further explored around the concept of integrated pest management (IPM). There is the possibility that on co-located farms from the two systems that if one uses capital intensive approaches to IPM and the other uses more indigenous and low-cost interventions that overall, a more productive and sustainable agroecological system may emerge.

The evidence of the connectivity between large-scale commercial and small-scale famers in South Africa presents an opportunity for the coupling of pure and mixed cropping systems towards the creation of a new, integrated farming system that is more sustainable and will meet the country's food security needs. This is a scenario that can be explored to inform policy development and action.

7.1.3 Conceptual scenarios as a tool to inform design of future farming systems in South Africa

Another key contribution of the study is the usefulness of conceptual scenarios. The scenarios developed in the study were informed by the CLDs and could serve the purpose of exploring plausible future farming systems based on the three commodities studied in the research. The scenarios have incorporated the challenges and opportunities for collaboration best presented through the application of systems thinking and this presents an innovative approach to informing decision making across all stakeholders in the value chain. The scenarios supported by evidence from systems analysis present what Rameriz et al., (2015) deem *"interesting research"* i.e., research that is innovative and develops theory while being both useable and rigorous. The iterative process of scenario development employed in the study through numerous points of interaction with different stakeholders provides a guided approach to addressing complex issues in uncertain contexts by accommodating and comparing different perspectives (Carter et al., 2001; Abildtrup et al., 2006). Since South African farming systems operate against the backdrop of constantly changing socio-economic, political and environmental conditions, therefore future developments in these systems are inherently unpredictable. The use of scenarios embraces this unpredictability and informs decision making in a manner that does not disregard the characteristic of farming systems being dynamic and complex.

7.2 Reflections on the methodology adopted in the study

7.2.1 The use of systems analysis and conceptual scenarios

In applying systems thinking through the use of CLDs to understand the connectivity between farming systems in South Africa required one to explicitly examine the 4 drivers of productivity. This approach added value as the majority of agricultural research in South Africa is focussed on the production of the crop and large-scale economic analyses. The approach taken forced one to examine each of the farming systems separately as well as to explore the overlaps and interactions.

The ability to adapt builds resilience and sustainability in a system. Global change will have a marked impact on agricultural production in South Africa because of the increases in temperature, which are twice the global average, together with an overall reduction in rainfall. Social vulnerability is also high. The development of scenarios is a useful tool to explore the possible points of intervention and the trade-offs that would be required. Scenarios also assist in setting the boundaries of potential change and combining scenario development together with systems analysis should be used when proposing landscape management plans for the future.

7.3 Limitations of the study

Due to the extremely rural location of the site, challenges in accessing farms and farmers as well as language barriers and cultural norms, resulted in a very small sample size and data being collected at only one point in time. Data collection was also exacerbated by the Covid-19 pandemic and the government restrictions on travel across provincial boundaries.

Data analyses were conducted using both the quantitative and qualitative data derived from the interviews and a mixed methods approach. It is acknowledged that a larger sample size would have provided stronger evidence to support the conceptual framework, however, the findings from this study do add value to the knowledge base and provide a new way of viewing agricultural production in South Africa.

The study does not make use of any economic data to inform the CLD construction. This was due to limitations in access to such data as it is regarded as highly sensitive information and therefore difficult to derive from primary sources. Farmers who were interviewed were mostly uncomfortable with divulging precise financial information e.g., profit margins resulting in most of the data obtained from interviews being anecdotal. There were also ethical and time limitations in obtaining such data from secondary sources. It is acknowledged that an understanding of the financial systems that govern the farming systems analysed in the study would be highly beneficial in informing both the CLDs and the scenarios.

The issue of the large disparity in farm size between large-scale commercial and small-scale farmers in South Africa is significant. As a result of this disparity, it becomes challenging to quantify the comparisons. Small-scale farmers in the context of the study were determined based on the size of the farmed land (1-5ha) decided by the researcher for the purpose of the study. In reality, small-scale farmers in South Africa are not determined by size alone but an array of socio-economic considerations are taken into account, e.g., their ability to participate commercially in the food value chain and to access local markets (Cousins, 2010). There is therefore a level of complexity in factoring in South Africa's size typologies into a study such as this. There is also a conceptual constraint, people research small-scale farmers (usually defined by land size) and large-scale commercial farmers (usually defined by economic analysis), this confounds results. There are very few studies on medium-scale farmers, where land size and economics are combined. Systems analysis will help in clarifying the major constraints in the system.

7.4 Recommendations

7.4.1 Recommendations to stakeholders

The findings of the study will be communicated to the various stakeholders in this study as follows: 1) For the farmers in the Vhembe district, a simplified report of the opportunities for collaboration that the study suggests may serve as a point of initiating mobilization in already existing farmer associations. 2) Feedback to the local department of agriculture in the form of a report of the summary of the research findings would help to inform action planning. 3) Agri-business stakeholders can benefit from a similar report on the research findings as they are key role-players in the value chain.

Recommendations for reach of the above listed stakeholders are detailed as follows:

1) Large-scale commercial farmers to be more informed about the points of connectivity with small-scale farmer activities in order to explore mutually beneficial points of interaction for sustainable agricultural production systems.
2) Small-scale farmers to be better supported for more collaborative initiatives amongst themselves to increase their capacity to participate in the food system more significantly.
3) Summary of the findings can benefit both policy makers and implementors in provincial and national government, particularly those dealing with land. Findings can be used to inform the next iteration of the Agriculture and Agro-processing Master Plan of the Department of Agriculture Land Reform and Rural Development (DALRRD).
4) Service providers to the farming community e.g., the ARC, growers associations, traditional leaders, retailers of farming implements and agrichemicals can benefit from knowing the level of connectivity between the farmers in order to make informed decisions that will level the playing field for stakeholders.

7.4.2 Recommendations for future research studies

Future studies on farming in South Africa should view farming as systems incorporating the whole value chain of any commodity. This should include the social, financial and environmental values and impacts. The conceptual scenarios developed in the study could be a basis for further evaluation to determine their feasibility under various predicted changes such as those presented by the present and foreseeable impacts of climate change. The use of scenarios is recommended as a tool to inform similar studies on farming systems in South Africa e.g., trade-offs in the adoption of IPM. Future studies must collate data from a larger sample size.

7.5 Conclusions

The study promotes the viability of the coupling of large-scale commercial and small-scale farming systems in South Africa for the future of agricultural development in the country. This is a novel perspective on the traditional view of the duality of South Africa's farming systems presenting opportunities for the future. The study presents a valuable addition to existing literature on studies of farming in the Vhembe district. The publications that have emerged from the study have been widely read and cited, in both the published literature and on social media, suggesting that it makes a marked contribution to existing knowledge on the subject matter.

The following general conclusions can be drawn from the objectives presented by the study: 1) both large-scale commercial and small-scale farmers exist in the Vhembe district in Limpopo and have been characterised in the study. 2) The drivers of production for the respective farming systems in the Vhembe district were identified in the study. These drivers can be understood using the lens of the four drivers of production (land, labour, capital and enterprise) and included issues such as land ownership, water availability, a commodity-focused approach, access to capital and diversification of livelihoods through non-farm income. 3) There is connectivity within and between large-scale commercial and small-scale farming systems in the Vhembe district. Applying systems analysis has shown that there are numerous points of collaboration across the two types of farmers. The use of systems analysis has also shown that the respective farmers who are co-located respond to the drivers of production differently though farming the same commodity. 4) Conceptual scenarios developed in the study can help to inform the design of farming systems in South Africa in the future that take into account global change.

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APPENDICES

APPENDIX 1

APPROVAL LETTER FROM LOCAL DEPARTMENT OF AGRICULTURE

Ref: 12R

Enquiries: Dr Thomas Raphulu

07 October 2019

Ms Fenji Materechera
Witwatersrand University
Johannesburg

RE: APPLICATION TO CARRY OUT RESEARCH UNDER THE DEPARTMENT OF AGRICULTURE & RURAL DEVELOPMENT IN VHEMBE DISTRICT.

I. The research proposal "Farming Systems in South Africa beyond 2020: A scenario based study, using systems analysis, of the connectivity between farming systems in the Mpumalanga and Limpopo Provinces of South Africa" was presented at the meeting held on the 17 of September 2019, Matsika, Vhembe District.

2. Kindly take note that your request to conduct research in Vhembe District, Limpopo Province has been granted and you will be expected to hand over a copy of your final report to the Department for record purposes as well as for reporting. You may also be invited to share your findings in the Departmental Research Forum.

3. The Department is prepared to embark on any activity which could assist our smallholder farmers to improve their farming systems and production at large.

4. Hoping that you will find this in order.

Kind regards

07/10/19

Dr. T. Raphulu
Chairperson: Research Committee

Date

67/69 Biccard Street, POLOKWANE, 0700, Private Bag X9487, Polokwane, 0700

Tel: (015) 294 3135 Fax: (015) 294 4512 Website: http://www.lda.gov.za

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APPENDIX 2

ETHICS CLEARANCE CERTIFICATE FROM UNIVERSITY OF THE WITWATERSRAAND

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Materechera

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/09/26**
PROJECT TITLE	Farming systems in South Africa beyond 2020: A scenario study, using systems analysis, of the connectivity between farming systems in the Mpumalanga and Limpopo Provinces of South Africa
INVESTIGATOR(S)	Miss F Materechera
SCHOOL/DEPARTMENT	Animal, Plant and Environmental Science/
DATE CONSIDERED	13 September 2019
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	21 October 2022

DATE 22 October 2019 **CHAIRPERSON** pp (Professor J Knight)

cc: Supervisor : Professor M Scholes

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature ______ Date ___/___/___

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

APPENDIX 3

CONSENT FORM FOR RESEARCH PARTICIPATION BY INTERVIEW

Title of Project: An evaluation of the processes and interactions within and between large-scale commercial and small-scale farmers in the Mpumalanga and Limpopo Provinces of South Africa.

Name of researcher: Fenji Materechera

I, ____ hereby agree to participate in this research project. The details of the research have been explained to me and I understand what my participation will entail.

Please circle your response below

I agree that my participation is voluntary	YES	NO
I agree that I may stop the interview at any point	YES	NO
I agree that my participation will remain anonymous	YES	NO
I agree that the researcher may use anonymous quotes in her research project	YES	NO
I agree that the interview may be audio recorded	YES	NO

Signature ____

Date ____

APPENDIX 4

FIELD INSTRUMENT FOR FARMING SYSTEMS BEYOND 2020 STUDY

Location of interview: ______________________________

Date of interview: ______________________________

Farming system: ______________________________

Participant ID: ______________________________

1. SECTION 1: LAND AS A DRIVER OF PRODUCTION

1.1 DEMOGRAPHICS AND SOCIO-ECONOMIC CHARACTERISTICS OF FARMER AND HOUSHOLD

Gender:

M	F

Age Range:

18-25	26-35	36-50	51 and above

Ethnicity:

Sotho	Pedi	Tswana	Venda	Xhosa	Zulu	Tsonga	Ndebele
Afrikaans	Swati	English					

Educational level:

Informal	Primary	Secondary	Tertiary	Other

If other, Specify: ______________________________

Do you have any formal training in agriculture?

Yes	No

If yes, please specify what kind of training ______________________________

How many years of farming experience do you have? ______________________________

Is this your only form of employment?

Yes	No

How many people live in your household?

1-2	2-3	3-4	4-5	5 and above

Are you the head of the household?

Yes	No

If no, who is? ______________________________

Gender of household head: | M | F |

What is the age of the household head? | 18-25 | 26-35 | 36-50 | 51 and above |

What kind of ownership do you hold on the farm? | Communal | Commonage | Own land |

1.1.1 ROLES AND RESPONSIBILITY

What is your role on the farm? ______________________________

1.1.2 INCOME

Do you do have another source of income other than farming? | YES | NO |

If you answered yes, please specify ______________________________

1.1.3 FOOD SECURITY

Would you say you are able to meet the household food requirements throughout the year from agriculture? | YES | NO |

Would you say this is because of the commodity you farm? | YES | NO |

1.2 NATURAL RESOURCE BASE OF THE FARM

1.2.1 LAND TENURE

How did you get land to farm?

Inherited	Bought	Apply from chief	Rented	Other

If other please specify

____

1.2.2 TOPOGRAPHIC LOCATION OF THE FARM

Describe the terrain on which your land is located:

Mountainous	Flat	Water logged	Valley	Other

If other please specify

____

1.2.3 VEGETATION

What is the main kind of vegetation on the farm?

Bush	Trees	Grass	Shrubs	Other

If other please specify ______________________________

1.2.4 SOILS

Describe the type of soil found on your farm: [ ] Sandy [ ] Loam [ ] Clay [ ] Other

If other please specify

____

What is the main color of the soil on the farm? [ ] Red [ ] Grey/white [ ] Dark brown [ ] Other

If other please specify

____

1.2.5 THREATS/HAZARDS

Which of the following threats mostly affects your land?

[ ] Pests [ ] Diseases [ ] Droughts [ ] Frost [ ] Erosion [ ] Flooding [ ] Wind [ ] Theft [ ] Other

If other please specify

____

1.2.6 WATER AND IRRIGATION

What is the main source of water on the farm?

[ ] River [ ] Dam [ ] Tanks [ ] Borehole [ ] Taps [ ] Other

If other please specify

____

Do you use this water for irrigation of crops? [ ] Yes [ ] No

What kind of irrigation do you use? ______________________________

2. SECTION 2: LABOUR AS A DRIVER OF PRODUCTION

2.1 LABOURERS

What is the main source of labour on the farm? [ ] Family [ ] Contract [ ] Hired [ ] Community [ ] Other

What is the nature of this labour? [ ] Seasonal [ ] All year

Where do the labourers come from? ____

How many labourers are involved in the following activities:

Activity	**Estimated number of labourers**
Land preparation	
Ploughing	
Planting	
Fertilizer application	
Weeding	
Spraying	
Harvesting	
Post Harvest Packaging	
Book keeping	
Managing finances	
Communication	
Purchasing (of farm inputs)	
Repairing of equipment	

2.1.1 CONFLICT

Do conflicts arise between you and the labourers? Yes No

Do conflicts arise amongst the labourers? Yes No

2.1.2 CHALLENGES AND SUPPORT

What are the challenges related to labour you encounter on this farm?

____

What support systems do you use to manage your labour?

Unions | Department of agriculture | Co-op | Other farmers | Other

If other, please specify

____

2.2 INPUTS

Indicate the agricultural assets that you own

Asset	**Yes**	**No**
Plough		
Tractor		
Ox drawn implement		
Hand hoe		
Boom sprayer		
Other (specify)		

What inputs do you use for your farming?

Input	**Yes**	**Where do you obtain it from?**	**No**	**What do you use instead?**
Seed				
Fertilizers				
Herbicide				
Pesticide				
Tractor				
Other (Specify)				

2.3 TRANSPORT

Which form of transport do you use for your farming activities?

Truck	Car	Cart	On foot
Other(Specify)			

2.4 MECHANIZATION, TECHNOLOGY AND INNOVATION

Do you use machinery to farm where possible?

Yes	No

If yes, do you own the machinery you use for farming?

Yes	No

If no, who owns the machinery? ______________________________

Who maintains the machinery? ______________________________

What technology do you use to minimize the cost of labour?

Activity	**Type of technology of any**	**Do you own this technology**
Land preparation		
Planting		
Weeding		
Pest and disease control		
Fertilization		
Harvesting		
Processing		
Packaging		

3. SECTION 3: CAPITAL AS A DRIVER OF PRODUCTION

How did you finance the farm? | Savings | Bank loan | Inheritance | Government funding | Other |

If other, please specify ______________________________

What kind of insurance do you have for your farm?

____

What does this insurance cover?

____

Have you benefited from this insurance? | Yes | No |

Where do you get the finance to operate the farm?

| Family | Savings | Loans | Profits from sales | Government funding | Co-op | Other |

If other, please specify

____

4. SECTION 4: ENTERPRISE/MANAGEMENT AS A DRIVER OF PRODUCTION

4.1 FARMING AND CROPPING SYSTEMS

What system of farming do you practice? | Crop | Livestock | Both |

If crops, please specify what crops you grow. If livestock, please specify which livestock you own

____

What cropping system do you practice on your farm? | Mixed | Rotational | Sole/Puree | Other |

4.2 INFORMATION SOURCING

Where do you get information on managing the farm?

| Extension workers | ARC | Study group | Media | Other farmers | Other |

If other, please specify ______________________________

Is there any kind of indigenous knowledge that you use in managing different aspects of the farming activities? | YES | NO |

If yes, what kind?

____

4.3 FARM MANAGEMENT

Do you have experience in managing a farm as a business?

Did you receive training for how to manage a farm as a business?

YES	NO

If yes, where did you get this training from? _______________________

What kind of training was it? _______________________

4.4 MARKET ACCESS

Do you have access to markets?

Yes	No

If yes, where do you usually sell your produce?

Retail shops	Pack house	Co-op	Public market	Other

4.5 MARKETING

What challenges do you encounter in marketing your produce?

____

4. 6 DECISION MAKING

Who is involved in decision making on the farm?

____

4.7 TRANSPORT

How is the produce transported to the marketing points?

Own transport	Hired vehicles	Public transport	Buyer's transport
On foot	Cart	Other (specify)	

4.8 VALUE ADDING

Before selling your produce what value adding activity do you perform?

Washing	Sorting	Packaging	None	Other (Specify)

Do you store the produce on the farm?

Yes	No

What storage facility do you have? ______________________________

4.10 FARMER'S ASSOCIATIONS

Do you belong to any farmer's association or group? [Yes] [No]

If yes, what is the name of the association/group? ______________________________

4.11 COMMUNICATION

What mode of communication do you use to communicate with labourers on the farm?

____

What mode of communication do you use to communicate with other stakeholders?

____

Do you experience conflict when engaging with other stakeholders? [Yes] [No]

4. 12 TECHNOLOGIES

What management technologies do you use on your farm?

Smart phone Apps	Computers	GPS hardware	Computer Software	Other

If other, please specify ______________________________

4.13 YIELD

What is the annual yield and tonnage for this commodity? ______________________________

Are you satisfied with this yield? [Yes] [No]

5. SECTION 5: FUTURE SCENARIOS /FORECASTING FOR FARMING SYSTEMS IN THE AREA

What do you think the future holds for this particular enterprise?

____

What are your concerns in the industry?

____

What needs to be done for improvement?

APPENDIX 5

INTERVIEW GUIDE FOR FARMING SYSTEMS BEYOND 2020 STUDY

1. SECTION 1: LAND AS A DRIVER OF PRODUCTION

1.1 DEMOGRAPHICS AND SOCIO-ECONOMIC CHARACTERISTICS OF FARMER AND HOUSHOLD

Education

What is the highest level of education you have completed? Do you have any kind of formal training in agriculture? How many years of farming experience do you have?

Household

How many people live in your household?

Who would you say is the head of the household?

Ownership

Do you think farmers that own their farms are more successful than farmers who rent their farm land?

1.1.1. Roles and responsibilities

What would you say is your main responsibility on the farm? Is there a farm manager? Do you do your own accounts and record keeping for the farm activity? If no, who does this for you?

1.1.3 Income

Can you say roughly how much money you make from farming in a year? What is the contribution of this other source? Why did you choose this other source of income?

1.1.4Food security

Do you buy the food for the house? What is the main source of food?

1.2 NATURAL RESOURCE BASE OF THE FARM

1.2.1 Land tenure

What is the common form of land tenure in this area? / What is the most common way in which people get land to farm in this area?

1.2.2 landscape/ topography (ask to take pictures)

1.2.3 Vegetation

Besides the crops that you farm, what are the other types of vegetation found on the farm? What kind of trees do you find? Do you have a lot of weeds? Do the other trees and plants affect your crops in any way?

1.2.4 Soil type

How did you come to know the soil type in you farm? Is it the same soil type in the whole farm or are there different types in different parts of the farm?

1.2.5 Threats/hazards

What would you say is the biggest threat to your produce? How do you respond to this threat? How do you control pests? Do you use professional pest control products or techniques? How do you manage in times of extremely high temperatures? What kind of diseases affect your crops/ livestock?

1.2.6 Water and irrigation

The climate data for the area shows that the rainfall in the aria is varied, what is your experience? How you cope high rainfall amounts or drought?

2. SECTION 2: LABOUR AS A DRIVER OF PRODUCTION

2.1 Labourers

How do you manage labourers in peak times? Do workers in your farm obtain any other benefits besides being paid for their labor? How do you pay the labourers for the work they do? Is it only money used to pay labourers? If no, how else are they compensated? How do you manage the labour on the farm? (If for example there is shared labour). What challenges do you experience in getting labour? E.g., is there competition etc.?

2.1.1 Conflict

When conflicts arise between you and the labourers, how do you manage it? What is the nature of the conflicts that arise among the labourers?

2.1.2 Challenges and support

What is the nature of the support you get?

2. 2 Inputs

In cases where you do not have a specific asset e.g., a plough, where do you get them from? Do you ever have to rent these? or borrow? How do you secure these inputs?

2.3 Transport

Do you own your own transport that you use for farming? If not, who owns it and how do you access it?

2.4 Mechanization, technology and innovation

Do you maintain your machinery regularly? Are you able to do it yourself or do you need to use outside people (outsource)? Do you think it's important to keep up with newest advancements in technology to be successful in farming? If yes, why do you think so and in what ways are you trying to keep up to date?

3. SECTION 3: CAPITAL AS A DRIVER OF PRODUCTION

4. SECTION 4: ENTERPRISE/MANAGEMENT AS A DRIVER OF PRODUCTION

4.1 Farming and cropping systems

Why did you choose this particular kind of farming system? Why did you choose this type of cropping system?

4.2 Information sourcing

Which is the most useful source of information to you?

4.5 Marketing

How do you deal with this challenge?

4.6 Decision making

What is the nature of their involvement?

4.7 Transport

Do you own the transport?

4.10 Farmer's associations

What benefits do you get from being a member?

4.11 Communication

"Other stakeholders" include Government, co-ops, suppliers of inputs, markets etc. What is the nature of the conflict you experience in engaging with other stakeholders?

4.13 Yield

What are you planning to do to improve your yield?

APPENDIX 6

CLD FOR AVOCADOS

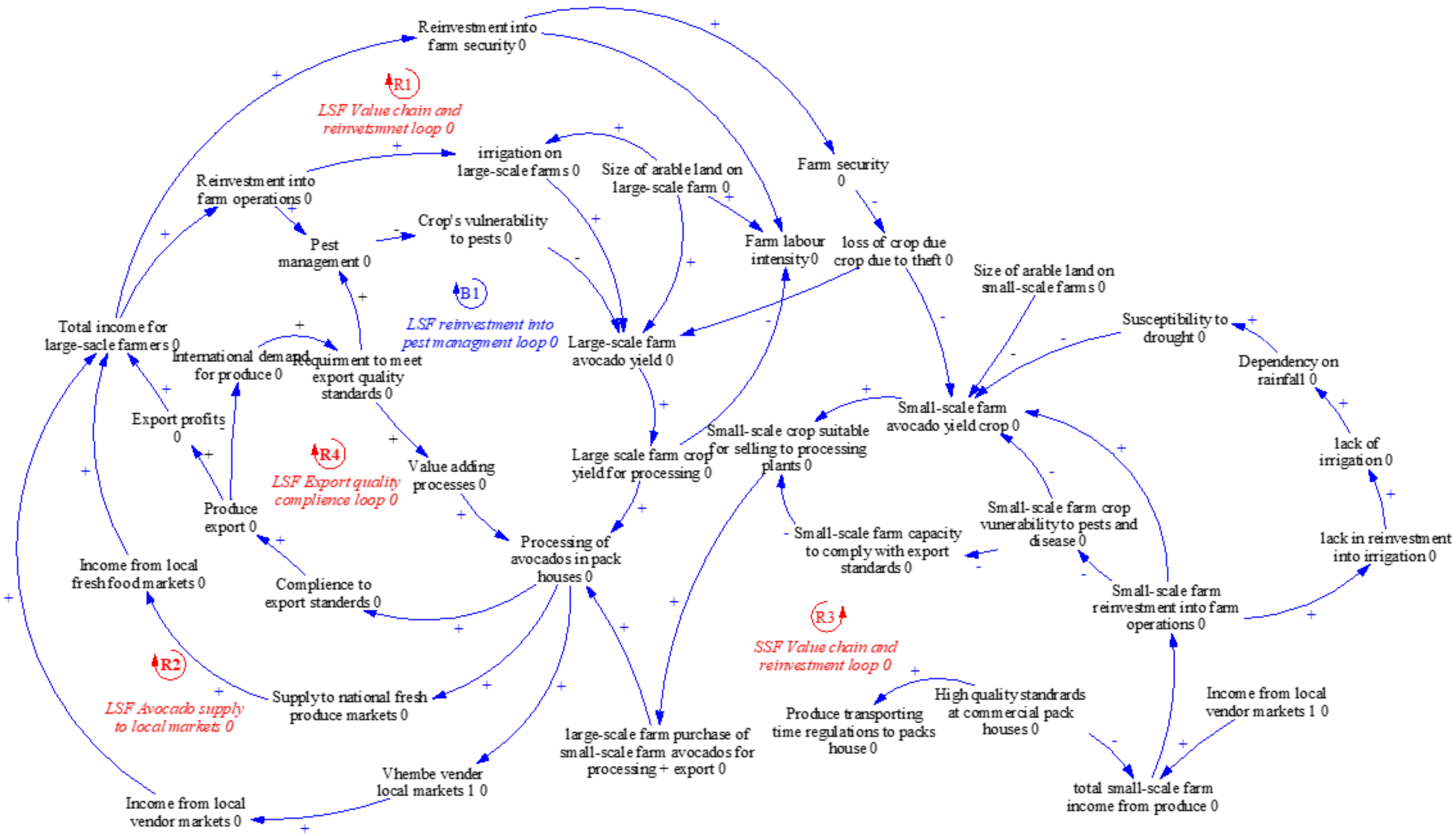


Figure 3. Causal loop diagram (CLD) showing avocado farming systems in the Vhembe district, Limpopo. Arrows connect two or more variables of interest and are causal links that run in the stated direction. '+' = a positive relationship, indicating that the causality runs in the same direction (i.e., an increase in variable A will cause an increase in variable B and vice versa); '–' = a negative relationship, indicating that the causality runs in the opposite direction (i.e., an increase in variable A will cause a decrease in variable B and vice versa). The balancing feedback loops are numbered Bn and labelled in blue font. The reinforcing feedback loops are numbered Rn and labelled in red font. (Selebalo et al., 2021) *LSF=Large-scale farm/farming

APPENDIX 7

PICTURE GALLARY OF FIELD WORK


Figure 4. Small-scale (4 ha) macadamia farmer next to a young tree on his farm **Figure 5.** A small-scale (4.5 ha) macadamia orchard intercropped with avocados on a steep mountain slope **Figure 6.** The researcher alongside a farmer on a large-scale (37 ha) macadamia farm



Figure 7. Small-scale mango orchard (10 ha) on flat land **Figure 8.** 4 ha of land under cultivation of sweet potatoes adjacent to a small-scale mango farm with no fencing **Figure 9.** A mature, large-scale (15 ha) mango orchard as an example of rainfed agriculture

Figure 10. Cabbage cultivated next to a small-scale (5 ha) avocado orchard as an example of a mixed cropping approach **Figure 11.** A successful small-scale (4.5 ha) avocado farmer using the irrigation system that they purchased for their farm **Figure 12**. An example of a non-capital-intensive pest management method being used by a small-scale avocado farmer as an alternative to costly chemical usage

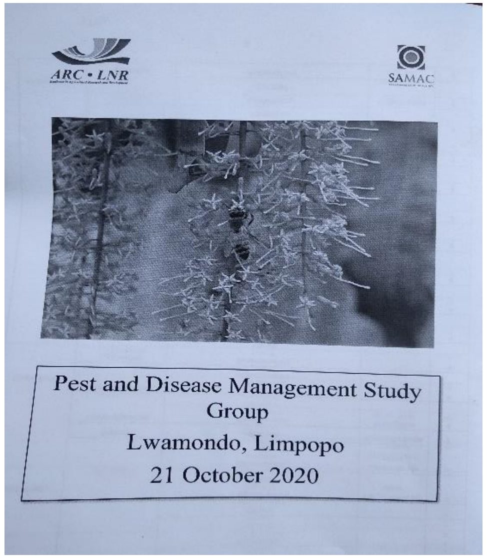
Figure 13. An example of the sophisticated electric fencing as security on a large-scale (1023 ha) macadamia farm **Figure 14.** The researcher in conversation with a female small-scale (5 ha) mango farmer during an on-farm interview **Figure 15**. An employed farm labourer on a small-scale (4 ha) macadamia farm with pipes as a form of irrigation preparing a field for the planting of new trees that were recently purchased from a local nursery



Figure 16. An example of mixed cropping on a small-scale (5 ha) mango farm where vegetables are being grown next to the orchard as a means to augment the household food security **Figure 17**. A small-scale (5 ha) mango orchard collocated to a large-scale tea plantation separated by a fence as an example of the duality of South African farming systems **Figure 18**. An example of the limited security on a small-scale avocado farm where the erected fencing is dilapidated increasing farmer vulnerability to theft



Figure 19. A small-scale (4 ha) macadamia orchard **Figure 20**. Macadamia farmers gathered at a study group meeting listening to a presentation from a representative of the local growers association. Study group meeting were attended by the researcher to interact with stakeholders as part of the scenario development process **Figure 21**. An advert outside of a local atchar processing facility inviting local farmers to supply mangos



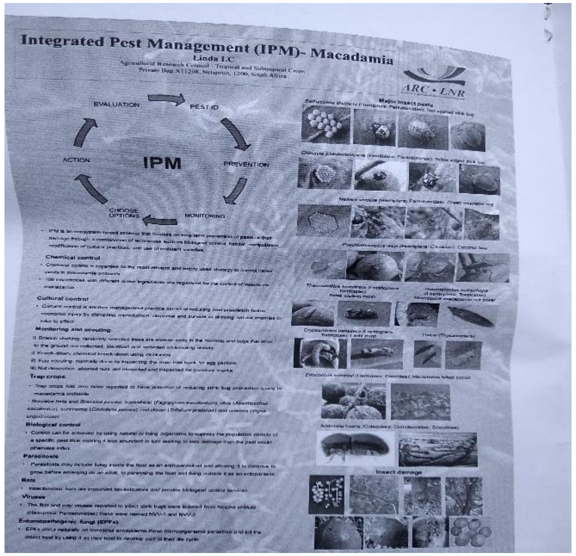


Figure 22. An information pamphlet that was distributed to farmers in attendance at a study group meeting **Figure 23**. Information about IPM shared with farmers at a study group meeting **Figure 24**. An example of the most common pest, *Halyomorpha hays* (commonly known as stink bugs) found on both large and small-scale farms in the study area

Figure 25. A large-scale (37 ha) macadamia farmer showing the irrigation system used on their farm **Figure 26**. A small stream that flows through a small-scale (4 ha) macadamia farm where the farmer sources water **Figure 27.** An example of macadamia nut nursery planted by a collective of small-scale macadamia farmers