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

Fenji Materechera, Mary Cathrine Scholes

School of Animal, Plant and Environmental Sciences (APES), University of the Witwatersrand, Johannesburg, South Africa
Email: Fenjibles@gmail.com, Mary.Scholes@wits.ac.za

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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 database 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 production 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 commodities. Age distribution results showed an aging population of farmers mostly (90%) above the age of 51. Communal land ownership was the dominant (74%) land ownership amongst participants. Yield is not solely dependent on farm size and requires consideration of a broader array of land management 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 production 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 research [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 order 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 agricultural 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, Malamulele, 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]. 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

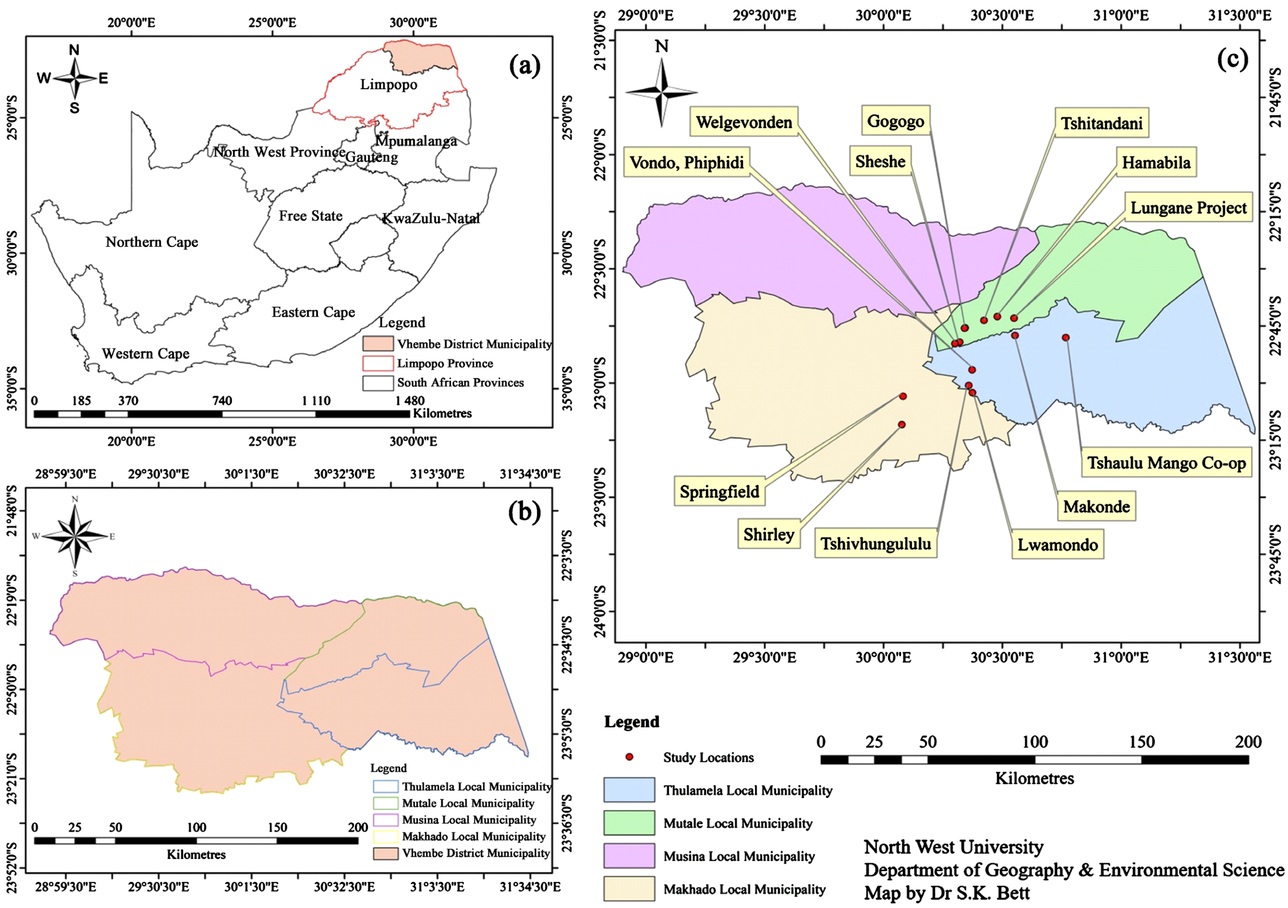


Figure 1. Map showing the location of (a) The Republic of South Africa' Provinces and provincial boundaries, highlighting the location of the Limpopo Province and the Vhembe district within the Limpopo Province of South Africa (b) shows the location of the four local municipalities within the Vhembe 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 locations 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 predominant 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 compared 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.

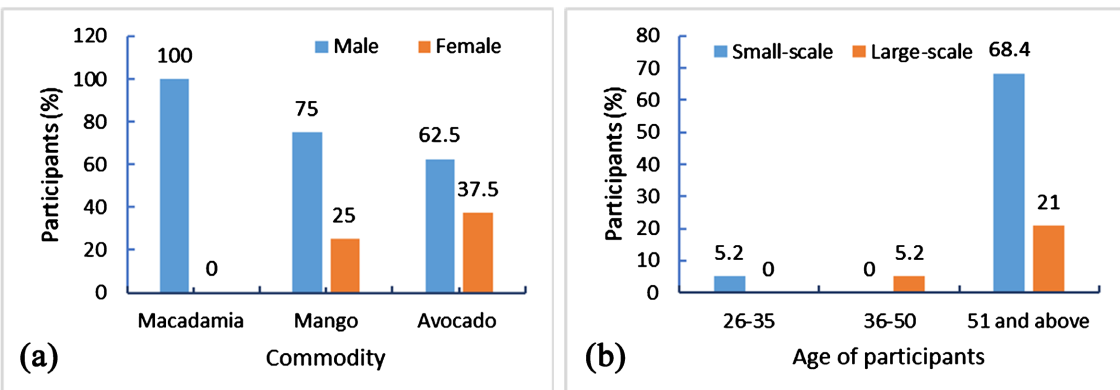


Figure 2. (a) Distribution of gender of participants (%) in the study across three commodities. (b) Distribution of age of participants (%) in the study within the two farm sizes. (n = 19).

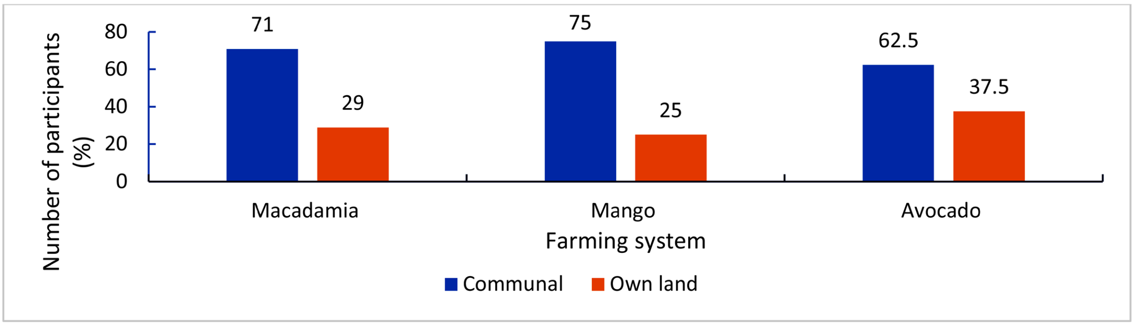


Figure 3. Distribution of land ownership (%) of participants across three commodities in the study.

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 services 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 income (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 researcher by the ISCW for the period 1973-2004 (Ab, Ib, Fa, Ea), the broad description 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

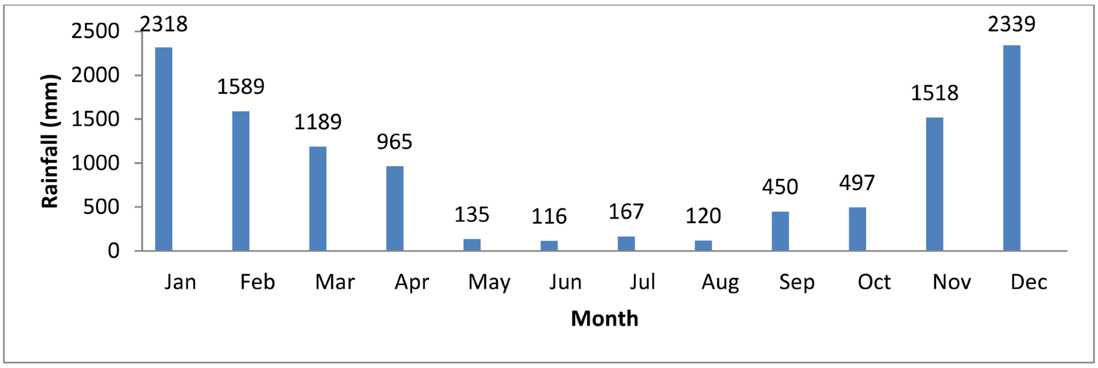


Figure 4. Total Monthly Rainfall (mm) at Makwarela between 2009 and 2019.

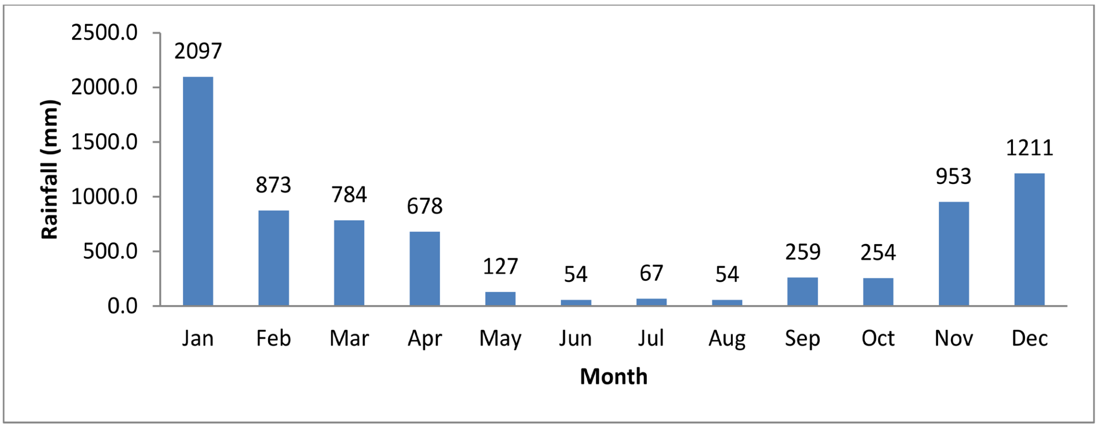


Figure 5. Total Monthly Rainfall (mm) at Mutale between 2009 and 2019.

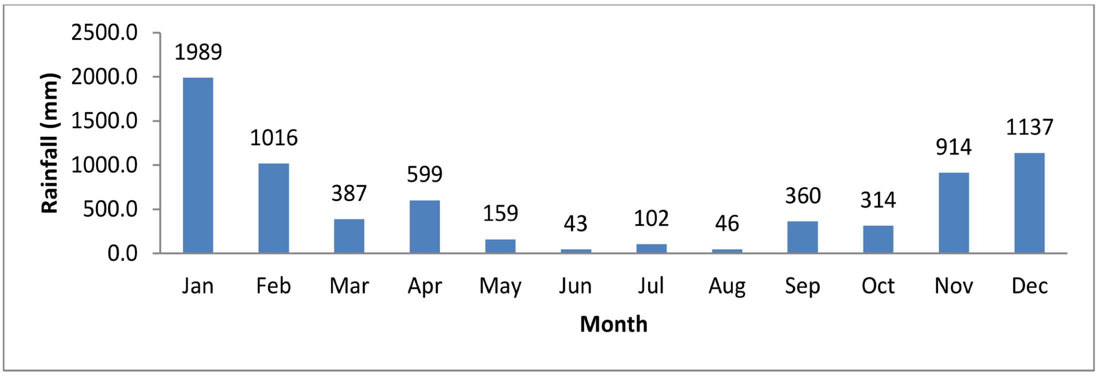


Figure 6. Total Monthly Rainfall (mm) at Malamulele between 2009 and 2019.

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 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 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.

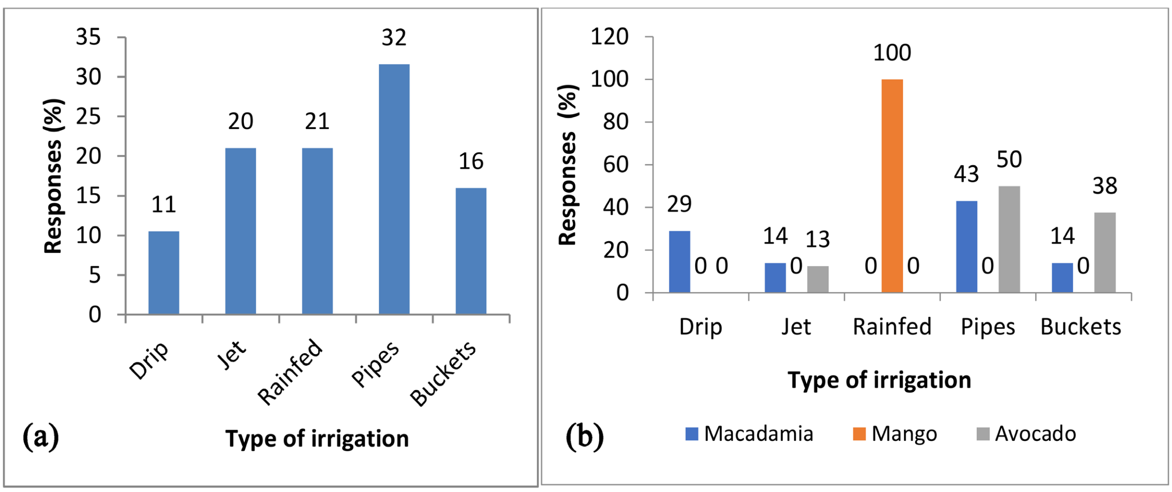
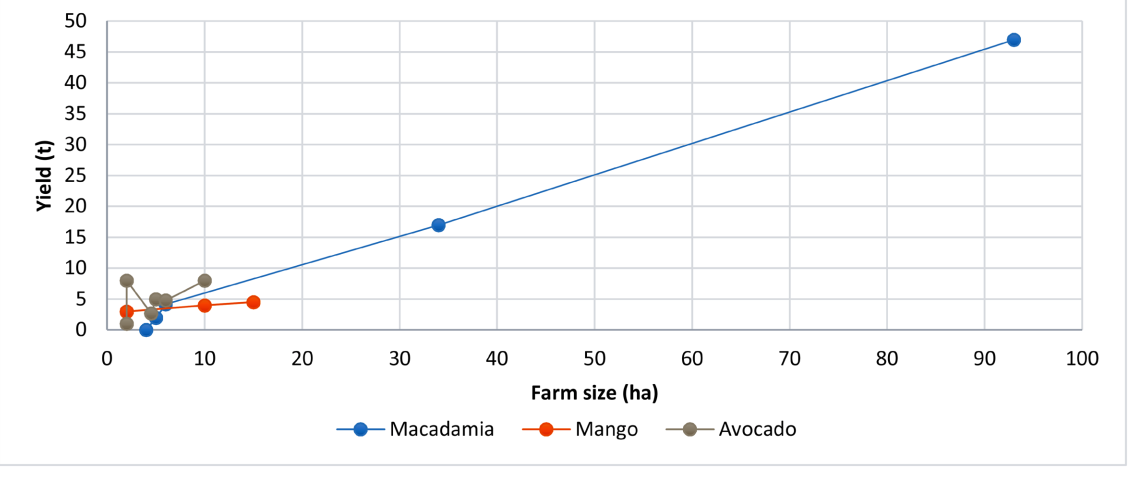


Figure 7. (a) Main type of irrigation practiced on farms in the study. (b) Main type of irrigation practiced on farms in the study across commodities. (n = 19).

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



*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).

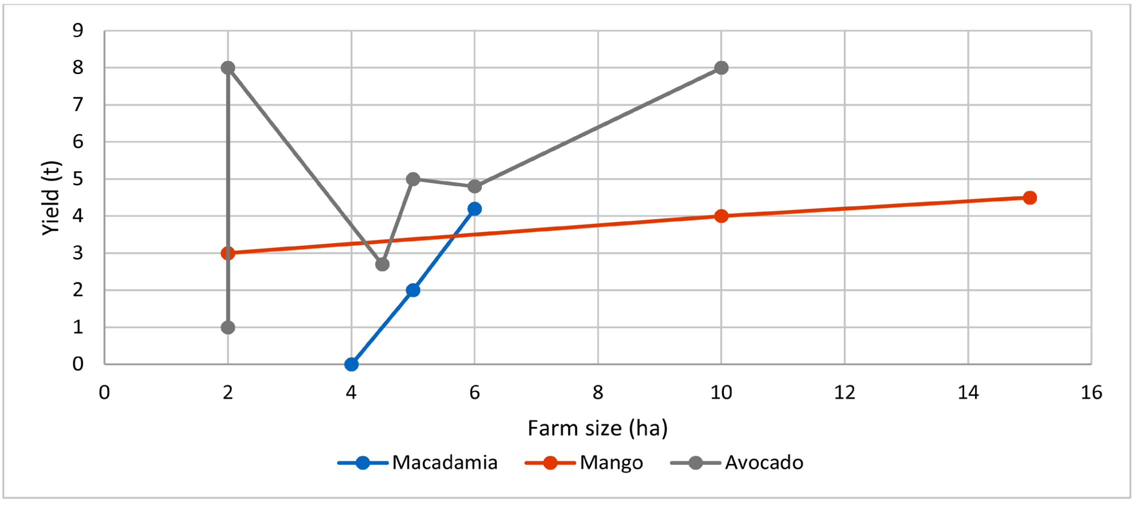


Figure 9. Annual tonnage (t) compared to farm size (ha) for farms less than 20 hectares across different commodities in the study (n = 19).

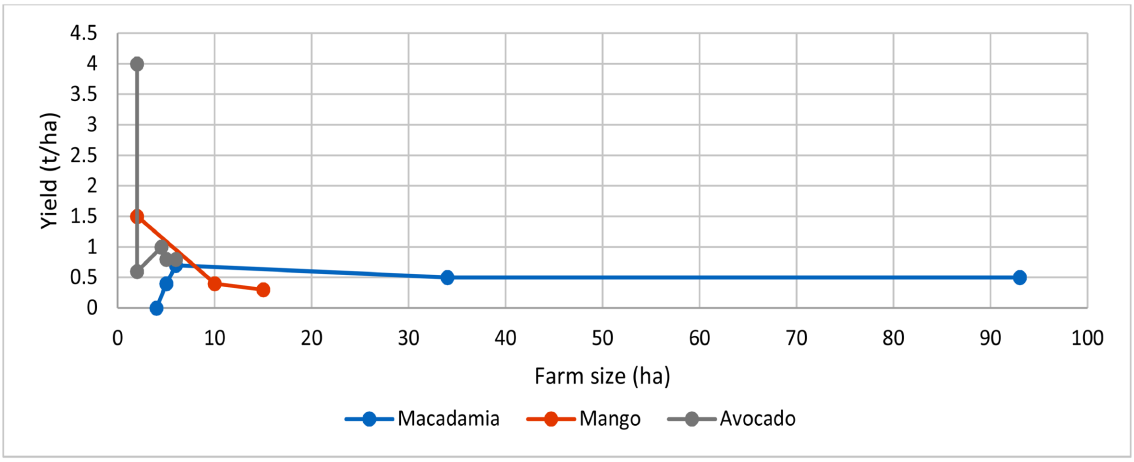


Figure 10. Annual yield (t/ha) compared to farm size (ha) across different commodities in the study (n = 19).

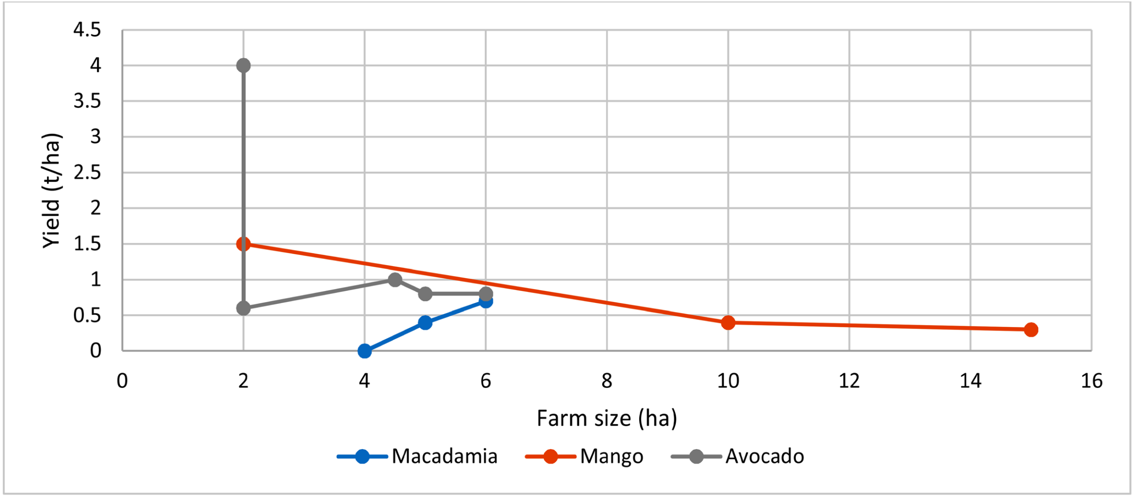


Figure 11. Annual yield (t/ha) compared to farm size (ha) for farms less than 20 hectares across different commodities in the study (n = 19).

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).

management, soil and water conservation, pest and disease control and technology usage amongst others.

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.

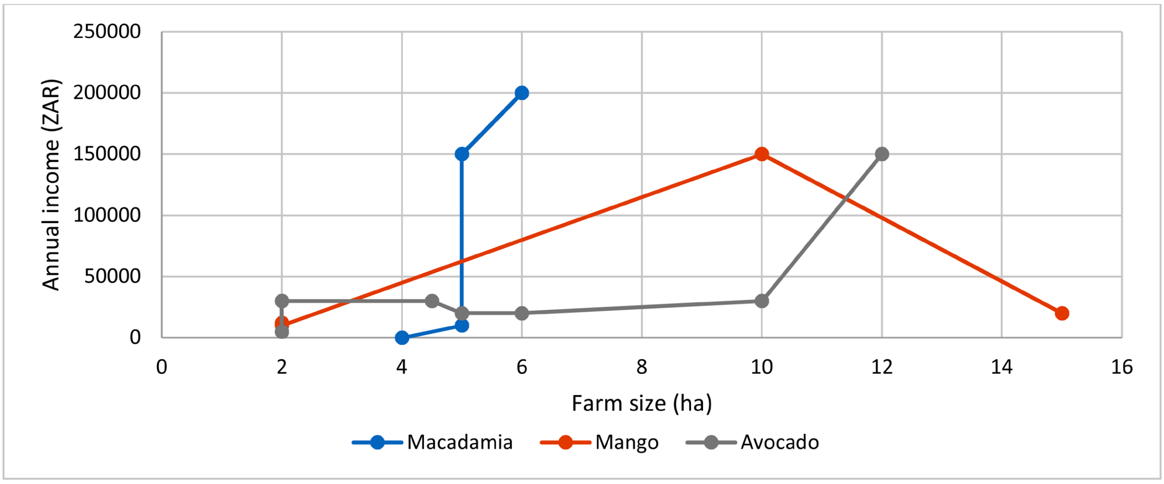


Figure 12. Average gross annual income from farming (ZAR) compared to farm size (ha) of less than 20 hectares across different commodities in the study.

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 production conditions. According to [47] the adverse effects of climate change on agricultural productivity in South Africa are on the increase. These include rainfall 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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