

DEVELOPMENT OF A SUSTAINABLE MODEL FOR IRRIGATED SMALLHOLDER  
AGRICULTURAL ENTERPRISES IN THE VHEMBE DISTRICT,  
LIMPOPO PROVINCE OF SOUTH AFRICA

T J MAVHUNGU

DEVELOPMENT OF A SUSTAINABLE MODEL FOR IRRIGATED SMALLHOLDER  
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LIMPOPO PROVINCE IN SOUTH AFRICA

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## DECLARATION

I declare that the thesis hereby submitted to the University of the Free State for the **Ph.D. (Sustainable Agriculture)** degree has not previously been submitted by me for a degree at this or any other university, that it is my work in plan and execution, and all material, information and assistance contained herein has been duly acknowledged.

.....  
Tsumbedzo Jutas Mavhungu (Nevhudogwa)

.....  
Date

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## **DEDICATION**

For the commencement and conclusion of this study, I would like to thank God Almighty for giving me the strength, life, good health, peace and wisdom to persevere and successfully complete this study; my father, Frans Mavhungu (Nevhudogwa) (late) and my mother, Munzhedzi Luvhengo (late) who sparked an ever-burning desire for education in my life which inspired me to conduct this study. My wife, Livhuwani was very supportive throughout the study and her encouragement made it possible for this work to reach completion. Our three children, Vhuhwavho, Andisa and Wavhudi were able to go on without some of the privileges I could not provide, due to my deep commitment to this study. Pastor Kwindi M G, Brethren and Friends, who started to suffer long periods of separation while I was engaged in this study. Their sacrifice, love, prayer and encouragement meant everything to me during the study and completion.

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## ABSTRACT

The purpose of the study was to characterise irrigated smallholder agricultural enterprises led by women and youth (ISHAE-WY) in selected areas of Vhembe District Municipality, Limpopo Province. The characterisation focused on the geophysical environment and on participants in ISHAE-WY. The ISHAE-WY are suffering from a serious loss of traditional farming knowledge, which has been adequately replaced by knowledge of modern farming practices. Diverse agro-climatic zones with distinct seasons can grow a wide range of field crop commodities. It is vital to select crop commodities for cultivation according to the land suitability, so that maximum benefit can be achieved while maintaining ecological sustainability. Indeed, the greatest increases in water use in ISHAE-WY have not been from better irrigation technology or management, but rather from increased crop yields, due to better or efficient application of water to preferred field crops. Selected commodities potential of field crops on ISHAE-WY were evaluated based on the geophysical attributes (e.g., terrain form and soil), and climatic parameter of each type of field crop. This study used a combination of both primary and secondary data acquisition approaches. Long-term environmental and climate data, including topographical data was acquired from the Limpopo Department of Agriculture and Rural Development (LDARD). The data was developed by EnviroGIS as appointed to assist the LDARD in conducting field surveys and analyses to correct the national vector data to a local scale. A representative sample was based on the number of smallholder entrepreneurs per production area within the two identified agro-ecological zones. Primary data was collected using a questionnaire and transect walk (observation). At least 294 women and youth (W-Y) smallholder irrigation entrepreneurs were sampled for interviews and prompt responses were obtained on the influence of productivity and profitability of selected field crops (dry bean, sweet potatoes, and maize) on ISHAE-WY. An average selected mean output of irrigated smallholder agricultural product was determined. The study revealed that there is a great impact of climate on the suitability of the selected field crops in the study area. The potential effects of the high temperatures and low relative humidity are deleterious to the growth and development of young plants. Irrigation during such hot and dry months may not be able to overcome the potential negative effects of the atmospheric evaporative demand, together with high temperature stress on crops grown during this period.

Comparison between informal and formal markets show that the ISHAE-WY who rely on the informal markets are making more profit than with the latter. In selling through the formal market, the market deducts 5% of commission while the market agent deducts 7.5% of sales on the gross value of the sold product. This does not include the transportation charges to the market. The Farm Gate market opportunity seems to be the most predominant approach of marketing at ISHAE-WY. These results reaffirm that ISHAE-WY can also be an alternative employment to W-Y who remain at home, while their counterparts are looking for employment in cities. In the end, the study provides strong motivation that irrigated smallholder agricultural areas has a potential to change the lives of rural households and their local economy.

**Keywords:** Vhembe District, Irrigated smallholder agricultural enterprise, Madimbo Corridor, Mutale Upper Valley, Climatic parameters, Geophysical attributes, Agro-ecological suitability, Field crops, Temperature, Rainfall, irrigated smallholder agricultural entrepreneurs, socio-economic impact, informal and formal market.

## LIST OF ACRONYMS

ABET	-	Adult Basic Education and Training
CA	-	Conservation agriculture
CEC	-	Cation Exchange Capacity
CSA	-	Climate-smart agriculture
DAFF	-	Department of Agriculture, Forestry and Fisheries
DEFRA	-	Department of Environment, Food and Rural Affairs
DWAF	-	Department of Water and Forestry
EI	-	Ecological intensification
FAO	-	Food and Agriculture Organisation
GIS	-	Geospatial Information System
GMOs	-	Genetically modified organisms
Ha	-	Hectare
IBM	-	International Business Machine
IFPRI	-	International Food Policy Research Institute
IIED	-	International Institute for Environment and Development
IPCC	-	Intergovernmental Panel on Climate Change
IPM	-	Integrated pest management
ISAE	-	Irrigated smallholder agricultural enterprises
ISHAE-WY	-	Irrigated smallholder agricultural enterprises led by women and youth
IWMI	-	International Water Management Institute
KMO	-	Kaiser–Meyer–Olkin
LISA	-	Laser interferometer space antenna
LDARD	-	Limpopo Department of Agriculture and Rural Development
NGO	-	Non-governmental organisation
NRC	-	National Research Council
OECD	-	Organisation for Economic Cooperation and Development
SAJAE	-	South African Journal of Agricultural Extension
SAPs	-	Sustainable agricultural practices
SAR	-	Sodium adsorption ratio
SI	-	Sustainable intensification
SMME	-	Small medium micro enterprise
SPSS	-	Statistical Package for the Social Sciences
Stats SA	-	Statistics South Africa
TSSJ	-	Technium Social Science Journal
VDM	-	Vhembe District Municipality
UN DESA	-	United Nations Department of Economic and Social Affairs
UN	-	United Nations
UNEP	-	United Nations Environmental Programme
USDA	-	United States Department of Agriculture
WCED	-	World Commission on Environment and Development
WGS	-	World Geodetic System

- WMA - Water management area
- WRC - Water Research Commission
- W-Y - Women and Youth

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# CHAPTER 1

## 1. INTRODUCTION AND BACKGROUND

### 1.1 Introduction

This chapter introduces the study covering matters such as (1) overview of the study, which entails sustainability of the irrigated smallholder agricultural enterprises led by women and youth (ISHAE-WY); (2) a description of the study area (locality, socio-economic and ecological description), with an analysis of the condition focusing on ISHAE-WY' sustainability-related issues to guide the research project on designated production environment; (3) problem statement, purpose of the study and outlined study objectives which respond to the problems experienced by the ISHAE-WY at Vhembe District Municipality; (4) summary and (5) outline of the thesis which serves as a guide to the reader.

### 1.2 Overview on the sustainability of the irrigated smallholder agricultural enterprises

The modern irrigated smallholder agricultural entrepreneur (ISAer), especially in rural areas like Vhembe District Municipality, faces numerous challenges, among which is the progressive increase in the population; thus, there is an increase in food consumption and the expansion of conventional production. In agreement with the above, ISHAE-WY are one of the most essential practices for the future of humanity, but have major environmental impacts (Tilman, et. al., 2001). Natural resources are jeopardised (Kropff, Bouma and Jones, 2001), and different forms of environmental degradation became apparent (e.g. air and water pollution, soil depletion, diminishing biodiversity) (Horrigan, Lawrence, and Walker, 2002). The poor performance of many ISHAE-WY in terms of productivity and economic impact has been largely attributed to socio-economic and agro-ecological factors, as well as lack of farmer participation (Bembridge, 2000). At the same time, limited knowledge of crop production among farmers has been identified as one constraint to improved crop productivity in ISHAE-WY (Machethe et. al., 2004; Fanadzo, Chiduzza and Mnkeni, 2010). The poor performance of many ISHAE-WY causes low yields which is also attributed to prolonged droughts, longer dry spells, limited water and nutrient availability, degraded soils and inefficient farming practices (Moswetsi, Fanadzo and Ncube, 2017).

Producing and delivering adequate, high-quality food will be one of the most important challenges for humanity in the next century (Viola and Marinelli, 2016). This creates a high level of dependency among ISAErs on the government and poor performance when farmers are left to manage the schemes on their own.

These factors require shifting the progress of agriculture toward sustainability of ISHAE-WY. Sustainable agriculture can be viewed as restoration in ISHAE-WY; hence, one of the fundamental goals is to preserve main resources for future generations. Among this range of descriptions, the main point is that sustainable agriculture puts emphasis on the environmental, economic, and social issues in agriculture for the needs of present and future generations (Brodt, Six, Feenstra, Ingels and Campbell, 2011). These valuable resources are geophysical attributes (terrain and soil), water and climate. The International Water Management Institute (IWMI) (2000) shows that there is scope for doubling the productivity in many cases, and further indicates that significant increases in productivity may come from improved natural resource management and agronomic practices. The ISHAE-WY' characteristics and agro-climatic zone characteristics were the main factors influencing adoption of sustainable agricultural practices by smallholder farmers (Kaweesa, Mkomwa, Loiskandl, 2018). ISHAE-WY' sustainability may be reached through three basic factors: firstly, the preservation of the environment and ensuring its diversity. Such factors could be fulfilled through conservation of each available resource, considering protecting and developing such resources in order to provide safe nutrition. Over the long term, sustainable ISHAE-WY could preserve the surrounding environment and ensure the biodiversity. If they do not conserve the environment and its diversity, there will be no sustainability or continuity of ISHAE-WY' speculation, and thus no safe nutrition provided to feed their households and local communities. Sustainable agriculture features such factors as long-term protection of natural resources, optimal production with minimum production inputs, engendering sufficient income from each operation unit, and meeting all the demands of the rural population and other inevitabilities (Brown, 1987). It is essential that innovative technologies are used to ensure sustainable agriculture and productivity using modern irrigation systems, improved varieties, improved soil quality and conserving the environment using resource conservation technologies (Dover and Talbot, 1987). Secondly, ensuring economic viability, or profitability, whereas ISHAE-WY' activity shall be considered as an investment.

Sishuta (2005) indicated that reliance on ISHAE-WY as farmers contributed to major sources of income and had a strong influence on farm productivity, as the farmer would devote most of the resources to the farm to maximise his/her returns.

Thirdly, the creation of a new social order, acceptable and benefiting from these ISHAE-WY' activities, as well as providing work, development, and capacitation for targeted ISHAE-WY. The fact that there is a senior age group amongst household heads brings the advantages of experience and well-developed networks in the community. Its drawback is the inability of older people to adopt and take up new technologies and skills quickly, compared to those in a younger age group (Ncube, 2014). Also, the quantity of resources demanded for household consumption rises with an increase in the number of people living in the household; this may result in less availability of resources for agricultural production (Tshikolomo, Nesamvuni, Stroebel, and Walker, 2012).

### **1.3 Description of the study area**

The study will be carried out in Vhembe District Municipality of Limpopo Province. The specific area is the Musina Local Municipality at Madimbo Corridor smallholder irrigation schemes and Thulamela Local Municipality at Upper Mutale Valley smallholder irrigation schemes. The two areas were categorised as independent ISHAE-WY, each with a private water supply in the case of Madimbo Corridor and as ISHAE-WY which are served by communal water supply infrastructure in the case of Upper Mutale Valley. The two areas of Madimbo Corridor and Upper Mutale Valley irrigation schemes constitute a total of more than 2 270 ha of production area. Agro-ecological conditions at Nwanedi (semi-arid) and Tshiombo (sub-humid) are significantly different, and the farming enterprises per irrigated smallholder farming areas are not alike. This confirms that the variables of irrigated smallholder agricultural areas are affected by diversity and similarities attributed to different livelihood needs. The management systems of ISHAE-WY in the study area are viz schemes in which the farmers themselves are the decision-makers, especially at individual ISHAE-WY' production level. Water resources within an irrigation scheme are affected by the biophysical environment and human activities; their management must consider the relationships between socio-economic and agro-ecological factors.

## 1.4 Problem statement

### 1.4.1 Main problem statement

Conventional agriculture has had great success in producing plentiful low-cost food. But this success has resulted in expenses that raise concerns about the sustainability in agricultural production. It affects the environment, economy, and social aspects. Environmental effects include the degradation of groundwater, surface water, soils, and biological diversity; and deforestation has also contributed to climate change leading to unpredictable extreme events (drought, winds and floods). Economic effects include increased high-technology maintenance used in farming, high-input costs and high-cost food producing systems. Social effects include growing health hazards and rural unemployment, which has led to an unprecedented movement from rural to urban areas. The big concern is that current practices are unsustainable. The main question is “How can agriculture move to a path that is more environmentally friendly, economic viable and socially desirable?”

### 1.4.2 Specific problem statements

- (a) Lack of information on the examination of a Geospatial Information System (GIS) based on modelling to determine the selected crop suitability potential for ISHAE-WY in the study area. Such information would guide ISHAE-WY’ sustainability.
- (b) Lack of information on the investigation of demographic factors and their association with ISHAE-WY’ water utilisation and management in the study area. Such developed, efficient irrigation water supply and utilisation will provide sustainability at ISHAE-WY.
- (c) Lack of productivity and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays l.*) as selected field crops in ISHAE-WY in the study area. Productivity and profitability would guide the efficiency and viability programmes of these selected field crops in ISHAE-WY.
- (d) Lack of information on the evaluation of demography and livelihoods in association with the cultivation of maize (*Zea mays l.*) as selected field crop. Having this information would guide the development of ISHAE-WY.
- (e) Lack of information on the evaluation of demography and livelihoods in association with the cultivation of sweet potatoes (*Ipomoea batatas l.*) as selected field crop. Access to this information would guide the development of ISHAE-WY.

- (f) Lack of information on the evaluation of demography and livelihoods in association with the cultivation of dry bean (*Phaseolus vulgaris*) as selected field crop. Having such information would guide the development of ISHAE-WY.
- (g) Lack of information on the characterisation of Women and Youth (W-Y) households and their rural irrigation schemes. Obtaining such information would guide the development of relevant programmes on how ISHAE-WY benefit the entrepreneurs.

## **1.5 Objective of the study**

### **1.5.1 Main objective**

The main objective is to develop a Sustainable Model, which uses available natural resources productively and profitably, with the intention of increasing household food and nutrition security and farming effectiveness in ISHAE-WY.

### **1.5.2 Specific objectives**

- (a) To examine a GIS based on modelling to determine the selected crop suitability potential for ISHAE-WY in the study area—agricultural enterprise sustainability
- (b) To investigate demographic factors and their association with ISHAE-WY' water utilisation and management in the study area
- (c) To assess influence of productivity and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays l.*) as selected field crops in ISHAE-WY in the study area
- (d) To evaluate demography and livelihoods in association with the cultivation of maize (*Zea mays l.*) as selected field crop
- (e) To evaluate demography and livelihoods in association with the cultivation of sweet potatoes (*Ipomoea batatas l.*) as selected field crop
- (f) To evaluate demography and livelihoods in association with the cultivation of dry bean (*Phaseolus vulgaris*) as selected field crop
- (g) To characterise W-Y households and their rural irrigation schemes.

## 1.6 Summary of research problem statement, research-specific objective, data requirements, and data collection instruments

The summary of research problem statement, research-specific objectives, data requirements and data collection instrument is presented in Table 1.1

Table 1.1: Summary of Research problem statement, Research-specific objective, Data requirements, Research and Data collection instruments

<b>Research problem statement</b>	<b>Research-specific objective</b>	<b>Data required</b>	<b>Data collection instruments</b>
Lack of information on the examination of a GIS based on modelling to determine the selected crop suitability potential for ISHAE-WY in the study area. Access to this information would guide ISAE sustainability.	To examine a GIS based on modelling to determine the selected crop suitability potential for ISHAE-WY in the study area—agricultural enterprise sustainability	Geophysical attributes (e.g. terrain form and soil) and climatic parameter information	Desktop review and project visits
Lack of information on the investigation of demographic factors and their association with ISHAE-WY' water utilisation and management in the study area. Such developed efficient irrigation water supply and utilisation will provide sustainability at ISHAE-WY.	To investigate demographic factors and their association with ISHAE-WY' water utilisation and management in the study area	Water use, supply management and demography information	Questionnaire and project visits
Lack of information on the assessment of productivity and profitability of sweet potato ( <i>Ipomoea batatas l.</i> ), dry bean ( <i>Phaseolus vulgaris</i> ) and maize ( <i>Zea mays l.</i> ) as selected field crops in ISHAE-WY in the study area. Productivity and profitability would guide the efficiency and viability programmes of these selected field crops in ISHAE-WY.	To assess the influence of productivity and profitability of sweet potato ( <i>Ipomoea batatas l.</i> ), dry bean ( <i>Phaseolus vulgaris</i> ) and maize ( <i>Zea mays l.</i> ) as selected field crops in ISHAE-WY in the study area	Productivity and profitability information	Questionnaire and projects visits
Lack of information on the evaluation of demography and livelihoods in association with the cultivation of maize ( <i>Zea mays l.</i> )	To evaluate demography and livelihoods in association with the	ISHAEs' demography information	Questionnaire and project visits

<b>Research problem statement</b>	<b>Research-specific objective</b>	<b>Data required</b>	<b>Data collection instruments</b>
as selected field crop. Having this evaluation would guide the development of ISHAE-WY.	cultivation of maize ( <i>Zea mays l.</i> ) as selected field crop		
Lack of information on the evaluation of demography and livelihoods in association with the cultivation of sweet potatoes ( <i>Ipomoea batatas l.</i> ) as selected field crop. Having this evaluation would guide the development of ISHAE-WY.	To evaluate demography and livelihoods in association with the cultivation of sweet potatoes ( <i>Ipomoea batatas l.</i> ) as selected field crop	ISHAEs' demography information	Questionnaire and project visits
Lack of information on the evaluation of demography and livelihoods in association with the cultivation of dry bean ( <i>Phaseolus vulgaris</i> ) as selected field crop. Such evaluation would guide the development of ISHAE-WY.	To evaluate demography and livelihoods in association with the cultivation of sweet potatoes ( <i>Ipomoea batatas l.</i> ) as selected field crop	ISHAEs' demography information	Questionnaire and project visits
Lack of information on the characterisation of W-Y ISAEs' households and their rural irrigation schemes. Access to this information would guide the development of relevant programmes on how ISHAE-WY benefit the entrepreneurs.	To characterise W-Y ISAEs' households and their rural irrigation schemes in the study area	ISHAEs' demography information	Questionnaire and project visits

## 1.7 Outline of the Thesis

The outline of the thesis includes specific chapters. Some were written in a self-contained scientific publication format, while others were not. The chapters were written based on (a) a GIS based on modelling to determine the selected crop suitability potential for ISHAE-WY; (b) demographic factors and their association with ISHAE-WY' water utilisation and management; (c) productivity and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays l.*) as selected field crops in ISHAE-WY; (d) demography and livelihoods in association with the cultivation of maize (*Zea mays l.*), sweet potatoes (*Ipomoea batatas l.*) and dry bean (*Phaseolus vulgaris*) as selected field crop and (g) characterisation of ISHAEs' households and their rural irrigation schemes.

**Chapter 1** is the introduction and presents: (1.1) Chapter introduction; (1.2) Overview on the sustainability of the ISHAE-WY; (1.3) Description of the study area (geographic, socio-economic and environmental); (1.4) Problem statement; (1.5) Study objectives; (1.6) Table summary of research problem statement, research-specific objective, data requirements, data collection instruments; (1.7) Outline of the thesis; and (1.8) Publication and abstract published in conferences.

**Chapter 2** discusses the literature review with a focus on: (2.1) Introduction; (2.2) Sustainable agriculture definitions; (2.3) The evolution of sustainable agriculture; (2.4) Proposed model of sustainable agriculture for selected field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY; (2.5) Anticipated outcomes through moving from conventional agriculture to sustainable agriculture practices for field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY; and (2.6) Conclusion.

**Chapter 3** discusses the detailed research methodology to be used in this study. The focus will be the exploration and structure around summarised review of (3.1) Introduction; (3.2) Research process; (3.3) Research approaches; (3.4) Sampling strategy; (3.5) Data collection methods; (3.6) Data analysis and interpretation; (3.7) Triangulation approach; (3.8) Pilot study; (3.9) Validity and Reliability; (3.10) Ethical consideration; and (3.11) Conclusion.

**Chapter 4** discusses characterisation of ISHAEs' households and their rural irrigation schemes in Vhembe District, South Africa, the discussion being: (4.1) Introduction; (10.2) Methodology focusing on (a) Study area, (b) Sampling procedure, (c) Data collection, (d) Data analysis; (4.3) Results and discussion focusing on (a) Characterisation of the geophysical environment of location of smallholder agricultural enterprise, (b) Characterisation of participants in W-Y smallholder agricultural enterprises; and (4.4) Conclusion.

**Chapter 5** examines the agro-ecological suitability review of the maize (*Zea mays L.*), dry bean (*Phaseolus vulgaris*) and sweet potato (*Ipomoea batatas L.*) production potential as a selected field crop based on geophysical attributes (e.g. terrain form and soil), and climatic parameter at ISHAE-WY in Musina and Thulamela Local Municipality of Vhembe District, South Africa: (5.1) Introduction; (5.2) Methodology focusing on (a) Study site in context, (b) Data collection, (c) Data processing, (d) Data analysis; (5.3) Results and discussion focusing on (a) Climate parameter as determinant for suitability review of selected field crops, (b) The suitable climatic data required and available for the selected field crops at Musina and Mutale (now part of Thulamela) in Vhembe District, (c) Geophysical attribute (soil) as determinant for suitability review of selected field crops, (d) Geophysical attribute (terrain) as determinant for suitability review of selected field crops, (e) Suitability potential in hectares (ha) and associated percentages (%) of selected field crops in Musina and Mutale, (now part of Thulamela) Local Municipalities of the Vhembe District in Limpopo, (f) Risk factors associated with selected field crops; and (5.4) Conclusion.

**Chapter 6** discusses the evaluation of demography and livelihoods in association with the cultivation of maize (*Zea mays L.*) as selected field crop, the discussion being: (6.1) Introduction; (6.2) Methodology (site description, sampling procedure, data collection and data analysis); (6.3) Results and discussion (the production potential of maize crop by smallholder agricultural W-Y enterprises; (a) The association between cultivating maize and gender; (b) The association between cultivating maize and age; (c) The association between cultivating maize and education; (d) The association between cultivating maize and income; and (6.4) Conclusion.

**Chapter 7** discusses the evaluation of demography and livelihoods in association with the cultivation of sweet potato (*Ipomoea batatas L.*) as selected field crop, the discussion being: (7.1) Introduction; (7.2) Methodology (site description, sampling procedure, data collection and data analysis); (7.3) Results and discussion (the production potential of sweet potato crop by smallholder agricultural W-Y enterprises; (a) The association between cultivating sweet potato and gender; (b) The association between cultivating sweet potato and age; (c) The association between cultivating sweet potato and education; (d) The association between cultivating sweet potato and income; and (7.4) Conclusion.

**Chapter 8** discusses the evaluation of demography and livelihoods in association with the cultivation of dry bean (*Phaseolus vulgaris*) as selected field crop, the discussion being: (8.1) Introduction; (8.2) Methodology (site description, sampling procedure, data collection and data analysis); (8.3) Results and discussion (the production potential of dry bean crop by smallholder agricultural W-Y enterprises; (a) The association between cultivating dry bean and gender; (b) The association between cultivating dry bean and age; (c) The association between cultivating dry bean and education; (d) The association between cultivating dry bean and income; and (8.4) Conclusion.

**Chapter 9** discusses assessing the influence of productivity and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays l.*) as selected field crops in ISHAE-WY in Vhembe District, Limpopo province, South Africa, the discussion being: (9.1) Introduction; (9.2) Methodology focusing on (a) Locality, (b) Sampling frame and sampling procedure, (c) Data collection and analysis; (9.3) Results and discussion focusing on (a) Contextualization of the productivity and profitability of selected field crops cultivated by ISHAE-WY, (b) The objective of cultivating selected field crops, (c) Seasonal variation in fertiliser use to cultivate selected field crops, (d) Seasonal variation in pesticide use to cultivate selected field crops, (e) Seasonal variation in the market share of selected vegetable crops, (f) Seasonal variation in the management and division of labour of ISHAE-WY in the production of selected field crops, (g) Seasonal economic contribution of the three selected field crops to the ISHAE-WY and informal economy of the region; and (9.4) Conclusion.

**Chapter 10** discusses investigation of the ISHAEs' perceptions on irrigation water supply and utilisation in Vhembe District Municipality, Limpopo province of South Africa, the discussion being: (10.1) Introduction; (10.2) Methodology focusing on (a) Description of study area, (b) Sample frame and sample procedure, (c) Data collection and analysis; (10.3) Results and discussion focusing on (a) Water resource supply in the ISHAE-WY, (b) Water use in the ISHAE-WY, (c) Associations between demographic factors and main source of water for irrigation; and (10.4) Conclusion.

**Chapter 11** discusses conclusions and recommendations based on the provision of highlights of the main findings and their implications.

### **1.8 Publication of research work**

It must be stated that most of the chapters of this study were written in self-reliant published scientific articles (Chapters 4 to 10). The scientific publications arising from this study are as follows:

**Chapter 4:** Tsumbedzo J. M., Nesamvuni, A.E., Tshikolomo, K. A., Raphulu, T., van Niekerk, J., and Mpandeli, N. S., 2021. **Characterization of Irrigated Smallholder Agricultural Entrepreneur's Households Led by Women and Youth in Vhembe District.** South African Journal of Agricultural Extension **S. Afr. J. Agric. Ext., 49 (3): 104-122.**

**Chapter 5:** Agro-ecological suitability review of the maize (*Zea mays l.*), dry bean (*Phaseolus vulgaris*) and sweet potato (*Ipomoea batatas l.*) production potential as a selected field crop based on geophysical attributes (e.g. terrain form and soil), and climatic parameter at ISHAE-WY in Musina and Thulamela Local Municipality of Vhembe District, South Africa: This chapter was designed as self-contained published scientific articles and will form a potential publishable script, which is still going to be processed for publication of this thesis after the submission deadline.

**Chapter 6:** The evaluation of demography and livelihoods in association with the cultivation of maize (*Zea mays l.*) as selected field crop: This chapter was designed as self-contained published scientific articles and will form a potential publishable script, which is still going to be processed for publication of this thesis after the submission deadline.

**Chapter 7:** Demography and livelihoods at ISHAE-WY and their association with the cultivation of sweet potato (*Ipomoea batatas l.*) as selected field crop. This chapter was designed as self-contained published scientific articles and will form a potential publishable script, which is still going to be processed for publication of this thesis after the submission deadline.

**Chapter 8:** Demography and livelihoods at ISHAE-WY and their association with the cultivation of dry bean (*Phaseolus vulgaris*) as selected field crop. This chapter was designed as self-contained published scientific articles and will form a potential publishable script, which is still going to be processed for publication of this thesis after the submission deadline.

**Chapter 9:** the influence of productivity and profitability of sweet potato (*Ipomoea batatas* L.), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays* L.) as selected field crops in ISHAE-WY in Vhembe District, Limpopo province, South Africa: **Publisehd as** Tsumbedzo J. Mavhungu, Azwihangwisi E. Nesamvuni, Khathutshelo A. Tshikolomo, Ndivhudzannyi S. Mpandeli, Johan van Niekerk. 2022. **Productivity and profitability of sweet potato (ipomoea batatas l.), dry bean (Phaseolus Vulgaris) and maize (Zea mays l.) as selected field crops in irrigated smallholder agricultural enterprises (ISAEs) in Vhembe District, Limpopo Province, South Africa , Technium Social Sciences Journal: Vol. 29:** A new decade for social changes

**Chapter 10:** Investigation of the ISHAEs' perceptions on irrigation water supply and utilisation in Vhembe District Municipality, Limpopo province of South Africa: This chapter was designed as self-contained published scientific articles and will form a potential publishable script, which is still going to be processed for publication of this thesis after the submission deadline.

## CHAPTER 2

### 2. LITERATURE REVIEW

#### 2.1 Introduction

This literature review presents aspects and key issues that are critical to sustainable agriculture. The focus will be on (a) the definition of sustainable agriculture, (b) evolution of sustainable agriculture, (c) proposed sustainable model for selected field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY, (d) anticipated outcomes through moving from conventional agriculture to sustainable agriculture practices for field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY, and (e) chapter summary. There is a growing concern about the sustainability of agricultural production models worldwide (Silva, Vieira, Tashima, and Guilherme, 2017) due to the negative impacts and environmental liabilities derived from the implementation of the conventional agricultural model (Betancur, Girón, and Betancur, 2018). Sustainable agriculture tries to reverse the effect caused by conventional farming. Conventional agriculture is seen as the production model resulting from the implementation of the principles of the Green Revolution. According to Silva and Delate, (2017), the conventional model is characterised by the predominance of monoculture, the use of varieties with high yield potential (generally hybrids or transgenic), a high level of mechanisation, and an intensive use of external agricultural inputs (seeds, fertilisers, and agrochemicals for cultivation, pest, disease and weed control). Sustainable agricultural practices differ greatly from conventional practices, where large volumes of field crops are produced for sale using conventional techniques. However, there are a great number of problems that threaten this ability of agriculture to fulfil human needs now and in the future. These include climate change, a high rate of biodiversity loss, land degradation through soil erosion, compaction, salinisation and pollution, depletion and pollution of water resources, rising production costs, an ever-decreasing number of farms and, linked with that, poverty and a decrease in the rural population (Velten, Leventon, Jager and Newig, 2015).

The concept of sustainable agriculture is based on sustainable growth. This means that sustainable agriculture development is using the environment in a way that combines the use and maintenance of earth's resources for the present and future generations in the present or better state, but not worse (Lichtfouse, Navarrete, Debaeke, Souchère, Alberola, and Ménassieu, 2009).

Raman (2006) emphasised the need for clearly understanding the contextual nature of agricultural systems before proceeding to analyse the conditions and means to make these systems sustainable. Such an understanding of all aspects associated with sustainable agriculture is especially important to all stakeholders who need to have a notion of what is meant by the term to put it into practice (Allen, van Dusen, Lundy, and Gliessman, 1991). It is imperative that both synergistic and antagonistic relationships may be expressed simultaneously among the core principles. Raman, (2006) further shows that sustainability is not inherent in any set of practices or farming system, except that some forms of agriculture have more enabling factors for ecological sustainability than others. Vhembe District Municipality in South Africa is blessed with diverse agroclimatic zones with distinct seasons, in which one can grow a wide range of field crop commodities, including maize (*Zea mays l.*), dry bean (*Phaseolus vulgaris*) and sweet potato (*Ipomoea batatas l.*).

## **2.2. Sustainable agriculture definitions**

This section will attempt to define sustainable agriculture. Different definitions are used to outline what it is. Numerous definitions deserve some consideration for the purposes of giving direction to the context of ISHAE-WY. The Food and Agriculture Organisation (FAO) of the United Nations (UN) defines sustainable agriculture as the “management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant, and animal genetic resources are environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO, 2014)”. Based on this, the FAO has proposed five principles (FAO, 2014) for sustainable agriculture, namely: a) improving efficiency in the use of resources, b) conserving, protecting, and enhancing natural ecosystems, c) protecting and improving rural livelihoods and social well-being, d) enhancing the resilience of people, communities, and ecosystems, and e) promoting good governance of both natural and human systems.

The Director of the Laser Interferometer Space Antenna (LISA) Program for United States Department of Agriculture (USDA) notes that, " 'Sustainable' means the capability to continue producing food and fibre indefinitely and *profitably* without damaging the natural resources and *environmental* quality on which all of us depend" (Schaller, 1989).

Conway and Barbier, (1990) defined sustainable agriculture as the ability to maintain productivity, whether of a field, farm or nation, in the face of stress or shock such as increasing salinity, or erosion, or debt, or a new pest, or a rare drought or a sudden massive increase in input prices. The United Kingdom governmental Department of Environment, Food and Rural Affairs (DEFRA) defines several important attributes of sustainable agriculture: availability to the consumers of adequate supplies of wholesome, varied and reasonably priced food, produced in accordance with generally accepted environmental and social standards, a flexible and competitive industry which contributes to an economically viable rural society, effective protection of the environment and prudent use of natural resources, conserved and enhanced landscape, wildlife, cultural and archeological value of agricultural land and respecting of a high level of animal welfare, contributing to the long-term sustainability of rural communities (DEFRA, 2006). The Organisation for Economic Co-operation and Development (OECD) defines sustainable agriculture as agricultural production that is economically viable and does not degrade the environment over the long run (OECD, 2000).

### **2.3. The evolution of sustainable agriculture**

Sustainable agriculture is vital for future food production in South Africa and the world at large. The purpose of sustainable agriculture is to meet community food needs currently without compromising the ability of future generations to meet their own needs. Being in accord with the above, the (National Research Council - NRC, 2010) views sustainable agriculture as having various different purposes i.e. to satisfy human needs for food, feed and fibre, enhance environmental quality and sustain economic viability. This looks different to other forms of agriculture, but one thing is certain, practicing sustainable agriculture is necessary to ensure a socially acceptable, economically viable food supply and an environment sustainable for future generations. Due to increased demand worldwide for highly nutritious food, sustainable agriculture is projected to escalate in the future. Currently this is regarded as a chance and necessary to make sustainable agriculture a reality (Velten, *et al.*, 2015).

### (a) The Green Revolution

Previously, the traditional form of agriculture was involving the sustainable agriculture since farming commenced. This can be seen for instance in the traditional system of agriculture in Nepal which was organic (one of the sustainable agriculture approaches), but in the passing of time, the practices changed towards more inorganic ones, which are a direct threat to agriculture productivity, environmental quality, and human health (Paudyal., 2010).

After World War II, agriculture changed radically. These changes were referred to as important progresses made in agriculture since the mid-20th century and defined as the Green Revolution (Borlaug, 1970). The Green Revolution has been credited with creating the platform for the rapid economic development of several Asian countries (Turrall, Svendsen and Faures, 2010). It involved farmers increasing their use of chemical fertilisers, insecticides, fungicides, and herbicides, adopting high-yielding crop varieties, and purchasing machines for cultivating and harvesting their crops. This can be also referred as conventional or industrial agriculture. In support of the above, Dover and Talbot, (1987) show that one of the environment-related activities is modern commercial agricultural systems characterised by intensive tillage and cropping practices; also, high rates of mechanisation and chemical input use, which have resulted in excessive amounts of soil erosion and nutrient loss, impairing the productive capacity of soil resources, and placing greater emphasis on the use of purchased inputs. The effect of agriculture on the natural environment goes beyond the ISHAE-WY and apart from their productivity. Contamination of surface and ground water resources due to conveyance of chemical fertilisers from farm fields are damages related to sustainable agriculture. Loss of species' habitat and reduction in biological diversity are also concerns of those with an agro-environmental resource-based orientation toward sustainability. Even though there are effects due to these changes, there were improved crop varieties, modified management, and the use of external inputs (e.g., fertilisers, biocides) which led to increases in crop yields (Kropff, Bouma, Jones, 2001) and food production (Gold, 2016). The Green Revolution (or conventional practices) was highly successful in reaching its purpose to increase crop yield. For example, after applying Borlaug's semi-dwarf varieties and practices, Pakistan's wheat yields nearly doubled from 4.6 million tons in 1965 to 7.3 million tons in 1970. Borlaug even won the Nobel Peace Prize in 1970 for his work across the world.

This modern agriculture, as now practiced, has significant negative environmental impacts, both as a user of inputs and as a generator of pollution (Conway and Barbier, 1990). Regrettably, inadvertent side effects go along with these changes. Natural resources were jeopardised (Kropff, *et.al.*, 2001), and different forms of environmental degradation became apparent (e.g., air and water pollution, soil depletion, diminishing biodiversity) (Horrigan, Lawrence, and Walker, 2002). The concern of society for the environmental problems caused by conventional farming, in combination with the increased demand for achieving sustainability in the agricultural sector and for safe, high-quality foodstuffs, has led to the emergence of alternative farming systems in recent years (Parra-Lopez, Calatrava-Requena, and de-Haro-Gimenez, 2007). The debates about sustainable agriculture received additional incentive from the Brundtland Report and the idea of sustainable development (Paracchini, Bulgheroni, Borreani, Tabacco, Banterle, Bertoni, Rossi, Parolo, Oraggi, and de Paola, 2015). These debates and research involve theoretical contributions on how sustainable agriculture should be defined and understood (Velten, *et al.*, 2015). One of the environment-related activities in conventional agriculture is characterised by rigorous tillage and cropping practices, and high rates of mechanisation and chemical input use have resulted in excessive amounts of soil erosion and nutrient loss, impairing the productive capacity of soil resources, and placing greater emphasis on the use of purchased inputs (Dover and Talbot, 1987). Such systems of agriculture are increasingly regarded as unsustainable. The future evolution of this challenge towards 2050 (and beyond) will depend on how the world food system responds to a total population reaching around 9.7 billion, with sub-Saharan Africa set to experience a doubling of its population to about 2.2 billion individuals (United Nations Department of Economic and Social Affairs (UN DESA), 2019). Africa's food security needs invoke successes associated with the Green Revolution strategy in South Asia (Feldman and Biggs, 2012).

#### (b) The beginning of the Sustainable Agriculture Movement

Conventional agriculture was described by some as unsustainable (Ikerd, 1991) and the substitutes for conventional agriculture were often seen as being sustainable. Since some years ago, society is more vigilant as to how pesticide-contaminated farm runoff pollutes fresh-water resources, while nitrogen and phosphate fertilisers can poison the waters. Additionally, conventional farming has been heavily criticised for causing ecosystem loss, soil erosion, deforestation, climate change and more.

This is where the understanding of sustainable agriculture as an alternative type of agriculture thinking originated. Unlike conventional agriculture, sustainable agriculture does not depend on inorganic fertilisers, agrochemicals, genetically modified products; instead, it is a holistic way of sustainable agriculture techniques that sequester carbon in the soil, while improving soil health, crop yields, water resilience, and nutrient density.

Sustainable agriculture emerged as a concept in the 1930s, expanded as a science during the 1970s and 1980s, and became institutionalised and consolidated in the 1990s (Silici, 2014). The development of organic farming which is a sustainable agriculture approach drew heavily on the analysis of farming systems as introduced by agronomist King, (1927) and the composting and humus (composted plant and animal matter) research of agronomist Sir Howard (1940). The forestry experts of the 17th and 18th centuries such as Evelyn and Carlowitz, introduced the concept of sustainable yield in response to dwindling forest resources across Europe (Warde, 2011; Grober, 2012). The natural scientists and ecologists of the 19th and early 20th centuries helped to accelerate the split between the anthropocentric conservationists on the one hand, prescribing conservation of natural resources for sustainable consumption, and the bio-centric preservationists, who call for preservation of nature due to its inherent worth (Callicott and Mumford, 1997). The 1972 UN Conference on the Human Environment in Stockholm marked the first global summit to consider human impacts on the environment, and the first major attempt to reconcile economic development with environmental integrity, which were commonly regarded as incompatible (Caldwell 1984). Emerging from the conference was the concept of environmentally sound development, which by 1973 had been coined as eco-development (Mebratu, 1998). Eco-development was defined by Ignacy Sachs in 1978 as an approach to development aimed at harmonising social and economic objectives with ecologically sound management, in a spirit of solidarity with future generations, further calling for another kind of qualitative growth (Glaeser, 1984). Therefore, and as outlined in the UN's 1987 Brundtland report (World Commission on Environment and Development (WCED), 1987), sustainable agriculture should be able to meet the current needs of society without compromising the ability of future generations to meet their own needs. This seems to have received little attention from the agricultural establishment and the public, although there was a slow but steady increase in interest in the smaller farm community.

According to the UN, (1987), when the UN World Commission on Environment and Development published its report *Our Common Future* (the Brundtland Report), calling for a new era of economic growth, a growth that is forceful and at the same time socially and environmentally sustainable, the debate had come full circle: economic growth was no longer the problem, but it was the solution. Rodale, (1988) regards a sustainable agricultural production system as one in which the resources used in production are managed in such a way that they are self-generating and ensure continual improvement well beyond conventional expectation. In concurrence with the concerns above, the ecological perspective on sustainability suggests that natural resources should be protected in their own right and should not be placed at risk by agricultural activities which are not environmentally friendly (Neher, 1992).

(c) The reception and advancement of sustainable agriculture to date

The reception of sustainable agriculture can be recognised through the adoption of sustainable agricultural practices (SAPs). The reception and advancement can be used to understand the progress of adoption of sustainable agriculture. Increasing the reception and advancement rate of SAPs will lead to the reduction of the negative environmental impact of agriculture, which is the ultimate objective of reception and advancement in sustainable agriculture. In support of the above, the reception and advancement of SAPs can replace some or all external inputs in agriculture systems (Pretty, 2008). SAPs help to maintain the water table, increase carbon sequestration, improve soil fertility, and protect land from erosion-reducing sediment load from agriculture lands; they also bring socio-economic benefits, such as an increase in net present value, reduction of on-farm costs and saving on labour and time (Knowler and Bradshaw, 2007; Pretty, 2008).

Although it is difficult to quantify the reception and advancement rate of SAPs based on observation, they should also include their decision-making processes. These will be influenced by several factors, such as farmers' knowledge and skills, the existence of and connections to a market for the commodities they produce, agricultural policies and regulations, available resources, geographic features of the farm and economic, social, and conservation motivations (Lashgarara, 2011). ISHAE-WY are more likely to adopt soil conservation practices like cover crops (Carlisle 2016).

Socio-demographic factors such as age, and cognitive factors, such as knowledge and attitude toward a program, are also believed to influence the reception and advancement of SAPs (Kabii and Horwitz, 2006). Older farmers are less likely to adopt new practices with which they are unfamiliar (Baumgart-Getz, Prokopy, and Floress, 2012). Factors such as income, education level, access to information, capital, positive environmental attitudes, environmental awareness, and farm size generally have a positive impact on the adoption rate of SAPs (Carlisle, 2016). Educational attainment can be regarded as a clear distinction in their implementation. The formal educated farmer is more likely to adopt SAPs and becomes less risk-averse and more willing to accept innovation. In agreement with this, farmers with a higher level of formal education are positive and more likely to adopt SAPs (Soule, 2001).

#### **2.4. Proposed sustainable model of sustainable agriculture for selected field crop commodities (maize, dry bean, and sweet potatoes) in ISHAE-WY**

This section will cover the components of the proposed sustainability model for selected field crops and discuss the aspects on how the long-term sustainability can be achieved. The proposed model of sustainable agriculture in ISHAE-WY comprised Sustainable Agriculture Approaches which include amongst others 1) Agro-ecology, 2) Nature-inclusive agriculture, 3) Permaculture, 4) Biodynamic agriculture, 5) Organic farming, 6) Conservation agriculture (CA), 7) Regenerative agriculture, 8) Carbon farming, 9) Climate-smart agriculture (CSA), 10) High nature value farming, 11) Low external input agriculture, 12) Circular agriculture, 13) Ecological intensification, 14) Sustainable intensification, and 15) Agroforestry.

Sustainable Agricultural Practices entail 1) Crop rotation, 2) Increased crop diversity, 3) Use of cover crops, 4) No-till and reduced-till systems, 5) Integrated pest management (IPM), 6) Integration of livestock and crops, 7) Mulching, 8) Rainwater harvesting, 9) Water use efficiency, 10) Integrated nutrient management, and 11) Sustainable agroforestry practices. Lastly, the expected benefits of sustainable agriculture are 1) Environmental resource efficiency, (Maintenance of bio-physical productivity, Risk reduction or evasion, Natural resource protection), 2) Economic viability, and 3) Social acceptability. Our model talks about the three coherent subsystems within which agriculture is expected to benefit. They are environmental, economic, and social (Figure 2.1).

Sustainability is aimed at balancing social, economic, and environmental resource benefits. A sustainability model referred to a conversion paradigm in agriculture which was instigated through application of sustainable thinking in agriculture.

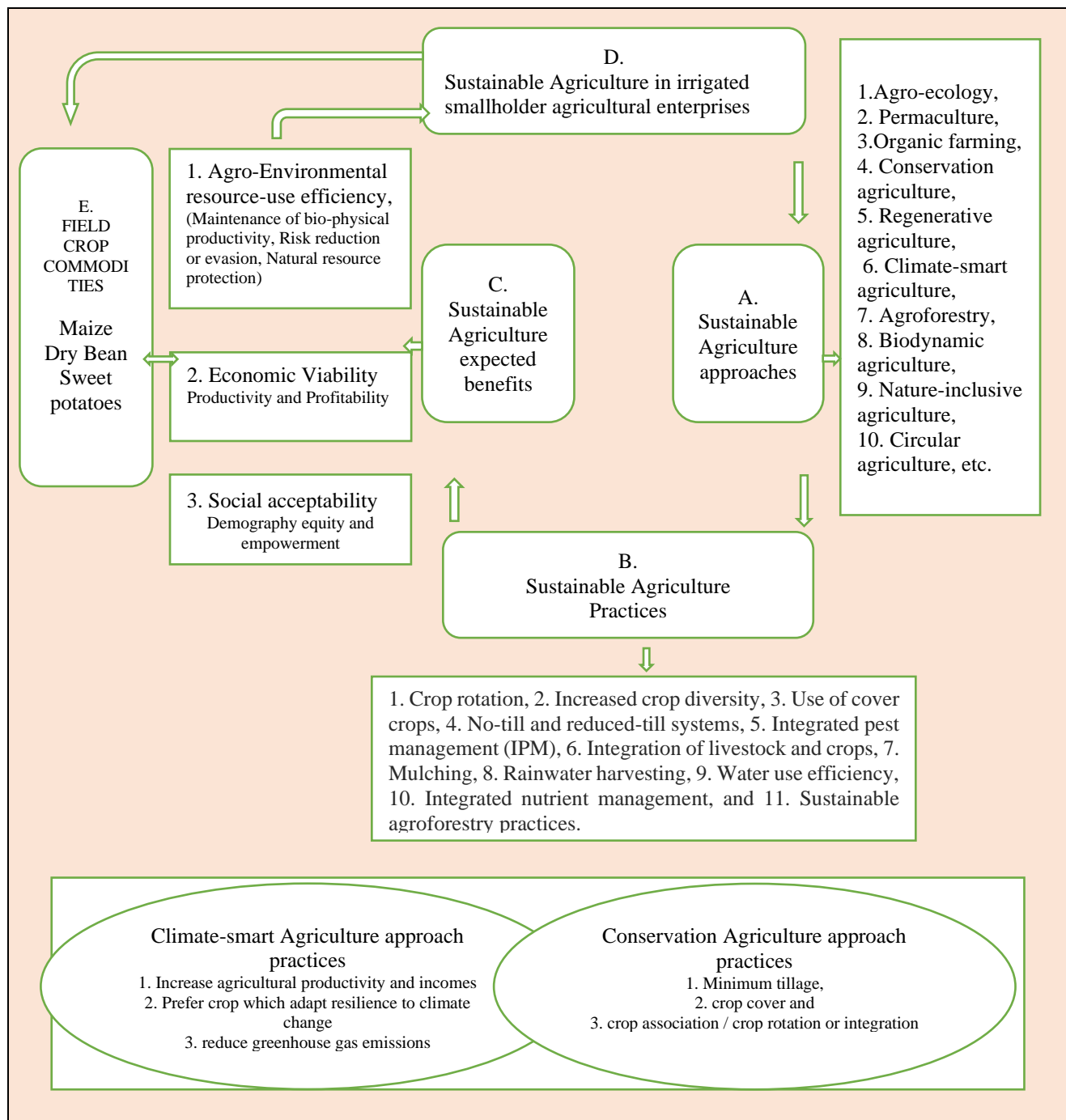


Figure 2.1: Proposed sustainable model of sustainable agriculture for selected field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY.

#### 2.4.1. Application analysis: sensitivity to sustainable agriculture approaches

According to Goldblatt, (2010), the population of South Africa is expected to grow from 57 million to 82 million by the year 2035. In order to feed this rapidly increasing population under social, climate and land use change, food production must be based on sustainable agricultural productivity (Goldblatt, 2010). Agricultural approaches are aiming at rationalising and improving agricultural practices and to contribute to a better world that has emerged over the past decades (Conway and Pretty, 1991). Application of a single or mixed approach should be the chosen way to achieve sustainable agriculture. As shown in Figure 2.1, climate-smart agriculture and conservation agriculture intersect; the practices can be combined or applied as stand-alone approaches. This is a viable approach of improving crop yields from the existing land through optimised external inputs and efficient use of available resources—while reducing adverse environmental impacts and building resilience, natural capital, and the flow of environmental services (Kassie, Teklewold, Marenja, Jaleta, and Erenstein, 2015).

Many approaches of sustainable agriculture are evolved or based on an agro-ecology approach. According to the International Institute for Environment and Development (IIED) (Silici, 2014), principles based on several authors of agro ecology are core to sustainable agriculture in the ISHAE-WY' approach. These approaches have also been pursued to enhance crop yield improvement advantages, as well as the added benefit of environmental protection. They include CA, CSA, sustainable intensification (SI) and ecological intensification (EI). The FAO, (2020), basing their findings on a series of FAO regional seminars on sustainable agriculture, proposed numerous elements or principles of sustainable agriculture that could help guide countries on the path to achieving it—at scale and to achieve a movement—it seeks a new way of considering agriculture and its relationship with society (Silici, 2014).

In each approach, there should be a system which differentiates with conventional practices. Rawlins, (1988) also emphasised that priority should be given to the application of systems science in the development of sustainable agricultural production systems and observed that today's complex problems cannot be solved unless people work together. The next section follows the sustainable agriculture in ISHAE-WY' practice, where the actual management occurs, where procedures, processes, and intensity can be adapted, and decisions can be changed to enable sustainable development (decision unit) (Repar, Jan, Dux, Nemecek, and Doluschitz, 2017).

## 2.4.2. Application analysis: sensitivity to sustainable agriculture practices

Driving sustainable agriculture does not seem to be easy, but rather a long-term and intricate process (Meul, Passel, Nevens, Dessein, Rogge, Mulier, Hauwermeiren, 2008). Sustainable agriculture in ISHAE-WY is designed and managed through the implementation of a structural and functional diversification of the biological components of production systems, such as crop rotation, increased crop diversity, use of cover crops, no-till and reduced-till systems, integrated pest management (IPM), integration of livestock and crops, mulching, rainwater harvesting, water use efficiency, and integrated nutrient management (FAO, 2020) (Figure 2.1, B).

Table 2. 1: Climate-smart agriculture and conservation agriculture practices

Climate-smart agriculture practices	Conservation agriculture practices
<b>Increased productivity:</b> Produce more and better food to improve nutrition security and boost incomes, especially of 75% of the world’s poor, who live in rural areas and mainly rely on agriculture for their livelihoods	Minimal soil disturbance
<b>Enhanced resilience:</b> Reduce vulnerability to drought, pests, diseases and other climate-related risks and shocks; improve capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns	Permanent ground cover—maintenance of a mulch of carbon-rich organic matter covering and feeding the soil (e.g. straw and/or other crop residues including cover crops)
<b>Reduced emissions:</b> Pursue lower emissions for each calorie or kilogram of food produced, avoid deforestation from agriculture and identify ways to absorb carbon out of the atmosphere	Crop rotation or sequences and associations of crops including trees, which could include nitrogen-fixing legumes

For enhanced sustainable agriculture, application of single or mixed practices (Figure 2.1, B) should be the chosen technique to acquire sustainable agriculture benefits. As an example, Table 2.1. below, CSA and CA intersect; the practices can be combined or applied as stand-alone approaches. In concurrence with the above, sustainable agriculture practices in ISHAE-WY have been explored and found to be economically viable, as they minimise input costs (Mthembu, Everson, and Everson, 2018a). ISAErs are said to be motivated by risk avoidance to adopt these approaches (Hitayezu, Zegeye, and Ortmann, 2016).

Läpple, Barham, and Chavas, (2020) mentioned that there are ways in sustaining agriculture that help with the improvements of the food system. This is by increasing knowledge through sciences and sustainable practices that allow for innovation—they are more likely to sustain agriculture as technologies are deemed to produce agriculture products efficiently, while at the same time reducing damages on biodiversity in the country. Table 2.2 indicates the examples of sustainable agriculture in ISHAE-WY' practice. Sustainable agricultural practice can also be classified as a societal behaviour because it implies the whole community may benefit from its adoption when protecting the environment for future generations (Piñeiro, Arias, Dürr, Elverdin, Ibáñez, Kinengyere, Opazo, Owoo, Page, and Prager, 2020).

Table 2. 2: Sustainable agriculture in ISHAE-WY' practice and its impacts

Sustainable agriculture in ISHAE-WY' practice	Impacts
Conservation tillage, no or minimum tillage	This SAPs improves soil structure and organic matter, reducing degradation and subsequent loss of productive agricultural land (Godfray, Beddington, Crute, Haddad, Lawrence, Muir, Pretty, Robinson, Thomas, and Toulmin, 2010).
Mixing crops in a single plot, such as intercropping/polycultures	This SAP improves biological complementarities, nutrient and input efficiency, use of space and pest regulation—as a result it enhances crop yield stability. There is a positive effect on biodiversity, ecosystem services, and the stability of ecosystems (Peterson, Eviner, and Gaudin, (2018).
Crop rotation and fallowing	This SAP enhances nutrients which are conserved from one season to the next, and the life cycles of insect pests, diseases and weeds are interrupted. This type of agriculture reduces occupational pesticide exposure (Greene and Kremen, 2003), which has been shown to be associated with acute and chronic illness in humans (Schreinemachers, 2003), and to damage wildlife, including damage to beneficial species (Baatrup and Junge, 2002). A sustainable practice like crop rotation has been noted as the cornerstone of sustainable agriculture as it keeps soils healthy and crops at their peak nutritional value (Merfeld, 2009), thereby improving crop productivity.
Efficient water harvesting	This SAP increases water use efficiency. There are increased amounts of nutrients in ground and surface water (Tilman, Fargione, Wolff, D'Antonio, Dobson, Howarth, Schindler, Schlesinger, Simberloff, and Swackhamer, 2001).
Agroforestry practices	This SAP enhances sustainable agriculture in ISHAE-WY, which maximises the use of sunlight and other resources; it maintains and improves soil fertility and structure—also modifying the microclimate for crops. The practice stimulates forest ecosystems in farmlands which the local communities felt enabled them to extract the beneficial effects of forests to the food crops (Wilken, 1977).
Use of local resources and renewable energy sources, composting, and waste recycling	This SAP allows a reduction in the use of some external inputs such as synthetic and chemical pesticides and fertilisers, as well as reducing pressure on the natural resource base. Compost, the product of organic waste composting, can act as a partial substitute for chemical fertilisers (Nakakubo, Tokai, and Ohno, 2012). It reduces negative environmental impacts from improper waste management and improving soil conditions.

<b>Sustainable agriculture in ISHAE-WY'practice</b>	<b>Impacts</b>
Cover crops and mulching	<p>This SAP reduces erosion, provides nutrients to the soil, and enhances biological control of pests. (Reicosky and Saxton 2006; Hobbs, Sayre, and Gupta, 2008): (1) minimal soil disturbance, (2) permanent soil cover, and (3) reduction in moisture evaporation. Cover crop management, including cover crop selection, seeding date and rate, termination date, equipment, fertilisation, and irrigation are critical to produce adequate biomass and achieve effective termination. Optimisation of these factors can improve weed suppression, soil fertility, and cash crop performance (Mirsky, Ryan, Curran, Teasdale, Maul, Spargo, and Moyer, 2012; Schmidt, Junge, and Finckh, 2019).</p>
Crop-livestock integration	<p>This SAP allows for optimal nutrient recycling, beyond economic diversification. It aims to increase resource-use efficiency and limit expansion of agricultural land area in part by leveraging ecosystem services (e.g., soil structure, nutrient cycling, rangeland restoration) and harnessing ecosystem resilience mechanisms such as soil carbon accrual (Sanderson, Archer, Hendrickson, Kronberg, Liebig, and Nichols, 2013).</p>
Integrated nutrient management	<p>This SAP enhances use of compost, organic manure and nitrogen-fixing crops allowing for the reduction or elimination of the use of chemical fertilisers. The practice of integrated nutrient management has been found to be quite promising, not only in maintaining higher productivity, but also in providing greater stability in crop production (Nambiar and Abrol, 1992).</p>
Biological management of pests, diseases, and weeds, such as integrated pest management, push and pull methods and/or allelopathy: decrease long-term incidence of pests	<p>This SAP reduces environmental and health hazards caused using chemical control. Negative interactions, such as intrigued predation, can be reduced in complex structured vegetation and complex food webs respectively, through avoidance between natural enemies and higher prey and host availability (Finke and Denno, 2002; Meyho and Hindayana, 2000). Therefore, these important results suggest that conservation of natural enemy biodiversity and pest control are compatible with each other and, in many cases, complementary goals (Straub, Finke, and Snyder, 2008).</p>

SAPs in ISHAE-WY have been recommended to enhance the productivity and resilience of agricultural production of smallholder farming systems, while conserving the natural resources (Moswetsi, Fanadzo, and Ncube, 2017). However, the impact of SAPs will only be recognised if most smallholder farmers accept and adopt these practices (Ntshangase, Muroyiwa, and Sibanda, 2018). The efforts were made to implement and promote these SAPs across the ISHAE-WY. Ntshangase, *et al.* (2018), shows that even though they acknowledge the well documented yield improvements, nitrogen and water-use efficiency and economic and environmental benefits attributed to these SAPs, adoption levels by South African smallholder farmers are still very low. The integration of indigenous knowledge and scientific agricultural management practices seems to be key for sustainable agricultural productivity of smallholder farmers (Thamaga-Chitja, 2012).

#### 2.4.3. Application analysis: sensitivity to sustainable agriculture expected benefits.

The basics of agricultural sustainability of this study focus on the state of three coherent subsystems within which agriculture is operating. They are agro-environmental, economic, and social (fig.1, point C). The ultimate objective or outcome of sustainable agriculture is to develop a farming model which at the end has benefits, which include among others, productivity, and profitability, conserving the agro-environmental resource base, protecting the environment, and enhancing health and safety, equity and empowerment—and to do so over the long-term. The means of achieving this is through using SAPs as mentioned above, which seek to optimise the management and use of on-farm production resources in ways that provide acceptable levels of sustainable crop yields and result in economically profitable returns. According to Khwidzhili and Worth, (2016), for agricultural production systems to be sustainable, such systems should meet the requirements of biological productivity, economic viability, protection of all natural resources, reduced levels of risk and be socially acceptable.

##### (a) Environmental resource efficiency

Agro-environmental parameters are essential measures of the potential of the crop production (He, Yao, Chen, and Ongaro, 2011), and they are expected to be the prime driving factors for the spatiality sustenance of sustainable agriculture in ISHAE-WY (Pan and Pan, 2012). The perception of environmental resource efficiency is about the natural environment and how it remains productive and resilient to support human life.

Environmental resource efficiency relates to ecosystem integrity and carrying capacity of the natural environment (Brodhag and Taliere, 2006). The concerns about the sustainability of the environment are increasing daily. Agro environment relates to *natural* assets (raw materials) occurring in nature which can be used for economic production or consumption. These agro-environment resources are subdivided into soil, water and climatological. If any agro-environment resource factor is less than optimum (e.g., too little water during critical growth period of a crop), it limits the growth. Extreme agro-environment resource conditions (e.g., higher temperature than expected during a dry spell) damage the potential of a crop commodity directly and make it more susceptible to disease or insect attack. The agro-environmental efficiency is composed of maintaining bio-physical productivity, reduced risk or evasion and protecting natural resources as clarified below.

(i) Maintenance of bio-physical productivity

Excess and shortage of the resources can hinder the productivity as already mentioned. It is extensively predictable that ecosystems directly or indirectly contribute to human well-being through the supply of vital ecosystem services (Díaz, Fargione, Chapin, Tilman, 2006). The sustainable agriculture necessitates that the biological productivity of the soil is maintained and, if possible, increased. Biological productivity refers to the ability of soil to promote microbial activities. Both biological communities play an important role in maintaining water quality and erosion control: two main elements of the ecological functioning in semiarid environments (Castro, Suguio, Seoane, Cunha, and Dias, 2014). The ISAER needs to discover ways to accomplish this. The most important thing is the amount of organic matter in the soil. The ISAER must understand the productivity status of the soil and take it into account. This information should, however, be implemented in concurrence with reactions to the other components. In agreement with the above, Moswetsi, *et al.* (2017) concluded in their study that the large gap between farmer yields and the biophysical potential could be reduced through better management practices.

(ii) Environmental resource efficiency risk reduction or evasion

Agricultural enterprise is by nature a risk activity; it operates under a situation of risk and uncertainty (Akcaoz and Ozkan, 2005). Agricultural production risk and uncertainty are therefore pervasive characteristics of agricultural production (Adesina and Quattara, 2000).

ISAER insights and response to risk are important in understanding the risk performance. Risk could arise due to production, market, financial, and human resource practices.

Poor farmers have few options for coping with significant losses, and to reduce their exposure to risk, they often waive opportunities to increase their productivity (Kanwar, 2005). Production risks relate to the possibility that the yield or output levels will be lower than predictable. Major sources of production risks arise from adverse weather conditions such as drought, frost, or excessive rainfall at harvest or planting. Production risks may also result from damage due to insect pests and disease, despite control measures employed and from failure of production infrastructure. Marketing risks are related to the possibility that you will lose the market for your products or that the price received will be less than threshold. Common sources of marketing risk are lower sales and prices due to increased numbers of competing growers or changing consumer preferences. These risks can also arise from loss of market access due to a wholesale buyer or processor relocating or closing, or if a product fails to meet market standards or packaging requirements. This leaves slight chances for growth and potential of entering formal markets, a trial that may be overcome through input subsidies (Rangoato and Oluwatayo, 2018), provision of post-harvest storage facilities (Achiano, Giliomee, and Pringle, 1999), and negotiating for pre-concluded contracts (Adewumi, Afolayan, and Masika, 2010).

Financial risks relate to not having sufficient cash to meet expected obligations, generating lower than expected profits, and losing equity in the farm. Sources of financial risk commonly result from production and marketing risks described earlier. In addition, financial risks may also be caused by increased input costs, higher interest rates, excessive borrowing, higher cash demand for family needs, lack of adequate cash or credit reserves, and unfavorable changes in exchange rates. According to Wenner, (2002), in the absence of institutional innovations (for example, crop insurance, disaster payments, and/or emergency loans) to cushion the impact of risk and uncertainty, risk management is a critical part of a farmer's decision-making. Human resource risks pertain to risks associated with individuals and their relationships to each other. These relationships include those with family members, as well as farm employees and customers.

Key sources of human resource risk arise from parting from each other. Employment has shifted from permanent to casual, and this type of employment leaves farm workers and their households vulnerable and insecure. The impact of this event can be devastating to ISHAE-WY. Human resource risks also include the negative impacts arising from a lack of people management skills and poor communication. In sustainable agriculture, the level of risks must be reduced or avoided; farmers are said to be motivated by risk avoidance to adopt these strategies (Hitayezu, Zegeye, and Ortmann, 2016). The risks are prevalent in ISHAE-WY.

(iii) Protection of natural resources

Sustainable agriculture requires protection of natural resources. Natural resources are soil, water, vegetation, climate sources and related ecosystem services, which are fundamental for improving livelihoods and achieving sustainable development in Africa (Sanginga, Ochola and Bekalo, 2010). Africa remains one of the most vulnerable continents with deepening poverty levels and worrying trends of degradation of natural resources—and natural resources are being depleted in rural areas (De Beer, 2012). The pressures on natural resources and on social and economic systems increased over the past decade, and scenarios for the future also project intensification of these changes (United Nations Environmental Programme (UNEP), 2010). Since the introduction of proficient natural resource conservation practices in the 19th century, various models and policy options have been advocated to try and conserve nature (Anthony, 2006), including the management of natural resources which has always been a concern for humans (Smith, 1993).

Food from traditional agriculture, fresh water, and erosion control which were available or practised before and have been found to be critical in the area because they were perceived as important for social well-being are no longer available or are degraded (Iniesta-Arandía, García-Llorente, Aguilera, Montes, and Martín-López, 2014). South Africa has been classified as one of the 30 driest countries in the world, with an annual average rainfall of less than 500 mm, which is a significantly lower amount than the global annual average rainfall of 860 mm (FAO, 2016), and which is expected to decrease due to climate change caused by global warming. Changes in climatic conditions that influence crop systems include rain quantity and distribution and consequently water availability, extreme events, such as floods and droughts, higher temperatures, and shifting seasons which all impact significantly on crop production.

Overall, agro-environmental perspective on sustainability suggests that natural resources should be protected and should not be placed at risk by agricultural activities which are not environmentally friendly (Neher, 1992).

#### (b) Economic viability

Economic viability implies a system of production that satisfies present consumption levels without compromising future needs (Lobo, Pietriga, and Appert, 2015). Economic viability is important. This variable (economic) governs the allocation of available resources to the ISHAE-WY. They need incentives to change their production methods and patterns in desirable directions. This includes productivity and profitability of irrigated smallholder enterprises. The procedures being developed to assess and monitor farm-level, agricultural sector and even national wealth, and the concept of ‘sustainability as opportunity’ needs to be further developed to balance the bias towards economic efficiency as a primary criterion for sustainability (Dumanski, 1997). In support of the above, economic viability requires decisions that are made in the most equitable and fiscally sound way possible, while considering the other aspects of sustainability (Zhai and Chang, 2019). Many researchers articulate sustainability of agriculture as assessing the economic returns of farming (Brklacich, Bryant, and Smit, 1991). In conventional agriculture, irrigated agricultural enterprises are unable to generate sufficient profits, because of low farm product prices, reduced yields, higher costs of production, or other reasons that are not self-sustaining. As a result, a requirement of sustainable agriculture is for better economic returns which are sufficient to sustain agricultural enterprises, and to adequately reward farming entrepreneurs (Ikerd, 1990).

#### (c) Social acceptability

Personal characteristics of farmers such as gender, age, and health status have some influence on farming decision-making and indeed, even the profitability of a farming enterprise. In a society, there is inequity among different groups (Malakar and Misha, 2017), populations belonging to different gender, age, education, and income level groups. This also includes groups differentiated by backgrounds, disability, economic, and employment status.

Groups who belong to backgrounds that include the aged, disabled, illiterate, those in poor health and unemployed are assumed to be the weaker sections of society, who either have less access to resources or are restricted by their physical incapability. These population differentiations impact agricultural productivity in a variety of ways.

Gender plays a major role in the agricultural sector. The finding by Bembridge and Tshikolomo (1998) showed that most owners (90%) of agricultural projects in the Phaswana area of the Limpopo Province were males. They further stated that gender has an influence on decision-making, with males responsible for major decisions, while females were responsible for relatively minor ones. Maele, Nesamvuni, Tshikolomo, Afful, and Norris, (2015), in their study of youth agricultural projects indicated that of the 50 youth agricultural projects sampled for the study, about three in four (74%) were male-owned, and hence, men were in the majority at ownership level. From a policy perspective, the South African democratic government promotes women empowerment and their equal participation in socio-economic activities; therefore, strategies should be sought for their increased participation in agricultural projects.

A study done by Dagada, Nesamvuni, Van Rooyen, and Tshikolomo, (2013) revealed that age plays an important role in the life of a person and determines how an individual behaves. The view of Dagada, *et. al.*, (2013) affirmed Bembridge, Graven, Hough, and Van Rooyen, (2008), who indicated that age has an influence on decision-making and the physical ability of individuals. Maele, *et. al.*, (2015) reported that a majority (45%) of youth owners of agricultural projects were 26–30 years of age, two in five (40%) were 18–25, while only 15% fell within the 31–35 age category. As was thought for gender, the age of smallholder farmers could have some influence on their decision-making on farming issues in general, and on irrigation water resource management. According to Dagada, *et. al.*, (2013), human development is influenced by the level of education.

Youths with only primary education, together with those who did not even disclose their educational status were about three in five (60%) and were in the majority. Youths with only primary education would at best possess very basic literacy skills; they would not easily access printed agricultural and other information, especially in languages other than their mother tongue.

Youths with low levels of education would also lack numeracy skills and therefore not be able to determine whether their agricultural businesses are making profit or not. The prospects for access to information and for success in the agricultural business would likely be higher for the 10% of the youths who attained tertiary education. Approximately 67% of individuals with tertiary education qualifications complained that they were under-utilised by the youth agricultural projects. Some 15% of the youths with tertiary education reportedly took interim responsibilities in agricultural projects while they searched for preferred jobs aligned to their qualifications. The role of education in farming decision-making inclusive of irrigation water management cannot be overemphasised.

Household income is a strong determinant of the access and use of agricultural resources (Tshikolomo, Nesamvuni, Stroebel, and Walker, 2012) and subsequently of agricultural productivity. It was argued for instance, that people could be water poor, not because there is no water in their area but because they are income poor. In other words, in spite of water being accessible within their production area, people may be unable to access it because they cannot afford the charge of accessing it. The success of any agribusiness enterprise is highly influenced by finance, as this determines the enterprise's ability to access important resources such as water. Improvement of human resource capacity is essential to meet the challenges of agricultural production and food security. More years of schooling are associated with higher rates of adoption of new technologies (Olaiton, 1984; Tompson, 2008). In the work done by Maele, *et. al.*, (2015), only 10% of the youth owners of agricultural projects had tertiary education. From the above assertion, it may be inferred that the level of household income is a strong determinant of success in crop farming—and this may be a result of improved access to production inputs, including irrigation water. For households with low incomes, the costs of inputs may impede adoption of new technologies (Hassan and Karanja, 1997). This was affirmed by Diale, (2011) who revealed that hybrid seed was costlier for low-income farmers to procure, and transport compared to open pollinated varieties. According to the findings by Hassan and Karanja, (1997), farming households at Manthlane Irrigation Scheme would better afford technologies and production inputs and would likely be more successful farmers.

Social acceptability incorporates ideas like equity, empowerment, accessibility, participation, cultural identity and institutional stability. The notion implies that people matter since development is about people (Benaim and Raftis, 2008). Essentially, social acceptability implies a system of social society that alleviates poverty (Littig and Grießler, 2005). The component revolves around the ISAERs whose demography and production practices are intricately linked. It is connoted that according to Benaim and Raftis, (2008), social acceptability is not easy to achieve because the social dimension seems complicated and overwhelming; social acceptability is not about ensuring that everyone's needs are met (Kolk , 2016). Relatively, it aims at providing enabling conditions for society to have the capacity to realise their needs if they so desire. The quantity and quality of these resources are conditioned by the characteristics of the household (size, age etc.), education and management skills, available labour, and attitudes of the ISAER household. The ISAER management skills and attitudes are initial factors that determine the nature of the ISHAE-WY' sustainability model, specially where there is a range of alternative operations and enterprises to increase productivity consistent with existing technical elements. The farmer could combine available resources in a manner that will maximise the objectives of the ISHAE-WY' household.

The inter-generational equity (youth) in agriculture should be taken into consideration which is referred to as the protection of the rights and opportunities of future generations to derive benefits from resources which are in use today (Keeney, 1989). Conventional agricultural practices which reduce long term prospects for food production or impair water quality or other natural resources, regardless of their short-term benefits, are not considered sustainable. The principle has been applied to describe the rights of less advantaged groups (W-Y) in society to basic food supplies, and to the opportunities and resources required to farm in ways which enhance prospects for sustainability (Francis, 1990).

#### 2.4.4. Application analysis: sensitivity to sustainable agriculture in irrigated smallholder agricultural enterprises

Figure 2.1. D, portrays sustainable agriculture as an umbrella term that encompasses many approaches. Consequently, sustainability cannot be associated with any set of farming approaches or practices (Ikerd, 1993), since the ability of a certain adoption to be sustainable will mostly depend on the distinctiveness of the context in which it is used. Human needs tend to increase but are currently constrained by the necessity of significantly reducing emissions of carbon dioxide into the atmosphere; there is a trend towards a transition to the sustainable, whereas sustainable agriculture in ISHAE-WY helps to reduce greenhouse gas emissions and human dependence on non-renewable resources (Sarkar, Poon, Lepage, Bilecki, and Girard, 2015). Sustainable agriculture in ISHAE-WY is aimed at achieving the transition through an integrated approach, involving its three dimensions i.e. agro-environmental, economic, and social (Larbodière, 2016). Sustainable agriculture has higher yields than its counterpart conventional agriculture, which is caused by extreme conditions generated by severe drought, excessive heat, torrential rainfall and dangerously cold weather. In conclusion, sustainable agriculture also has higher pest and disease resistance because crops are healthy and can defend themselves.

#### 2.4.5. Application analysis: sensitivity to sustainable agriculture in selected field crop commodities

In this study, the ISAEr has selected six (6) most important crops, of which three (3) are vegetable and three (3) are field crops (Table 2.3.). This study will only concentrate on field crops. In Figure 2.1. Point E. maize, dry beans, and sweet potatoes were selected as main field crops produced in Vhembe District. Nwanedi (Madimbo Corridor) and Tshiombo (Upper Mutale Valley) irrigated smallholder farming areas produce summer field crops even in winter production, because the area is warm in winter and there is no frost. Therefore, the comparison of influence of productivity and profitability on ISHAE-WY will be between winter and summer production of the same field crops. Commanding factors of producing these as most important fields crops at ISHAE-WY are that they are in high demand because they are staple food crops.

Table 2.3. Hectares of important crops in production according to ISHAE-WY

Variable	Frequency	Percentage
Tomatoes	138	46.9
Okra	131	44.6
Dry beans	97	33.0
Sweet potatoes	53	18.0
Maize	48	16.3
Butternut	42	14.3
Mustard	36	12.2
Hot chillies	33	11.2
Spinach	32	10.9
Green peppers	21	7.1
Cabbage	20	6.8
Onion	17	5.8
Beetroot	11	3.7
Watermelon	9	3.1
Groundnuts	8	2.7
Calabash	4	1.4
Black nightshade	7	2.4
Baby marrow	2	0.7
Kale	2	0.7
Garden peas	2	0.7
Cucumber	1	0.3
Sorghum	1	0.3
Orange	1	0.3
Patty pans	1	0.3
<b>Total</b>	<b>294</b>	<b>100.0</b>

(a) Overview of selected field crop production

(i) *Maize*

Maize is the most important grain crop in South Africa, being both the major feed grain and staple food for the majority of the South African population (DAFF, 2003). According to Statistics SA, (2018/2019), the total production of maize in South Africa amounted to 10.51 million metric tons. Free State had the highest production in all nine states with approximately 4 066 000 metric tons of overall production. Limpopo province had 200 000 metric tons; the Western Cape had the lowest amount, producing 34 000 metric tons.

*(ii) Dry bean*

The dry bean is at present regarded as one of the most important field crops in South Africa on account of its high protein content and dietary benefits. Among the annual leguminous food crops that are harvested for dry seed, the dry bean is by far the most important (DAFF, 2010). Field crops like dry beans are suitable protein supplements for lower-income households. They can also be used for soil improvement because of their nitrogen fixation ability and as green manure, increasing organic matter in the soil.

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### *(iii) Sweet Potato*

Sweet potatoes are cultivated throughout tropical and warm temperature regions wherever there is sufficient water to support their growth. The main producing regions are Northern Cape, Western Cape, Limpopo, Free State, Eastern Cape, and Gauteng. Sweet potato is also the world's major food crop. In South Africa, it is mainly produced in Limpopo (Hoedspruit, Marble Hall, Burgersfort, Levubu), Mpumalanga (Nelspruit), KwaZulu-Natal and Western Cape. (DAFF, 2011). Apart from simple starches, field crops like sweet potato are rich in complex carbohydrates, dietary fibre, beta carotene (a vitamin A equivalent nutrient), vitamin C, and vitamin B6. Pink, yellow and green varieties are high in carotene, the precursor of vitamin A. All of these can best be used in crop rotation, one following the other.

## **2.5. Anticipated outcomes through moving from conventional agriculture to sustainable agriculture practices for field crop commodities (maize, dry bean and sweet potatoes) in ISHAE-WY**

The assessment of those variables (Table 2.4) and the measure of their contribution to the spatiality of ISHAE-WY are instrumental in the quest to unlock the full potential of the sector. Gradually, the idea of sustainable agriculture has come to be associated with the maintenance of environmental quality of the ISHAE-WY. The shift from conventional agriculture to sustainable agriculture was motivated by the degradation and subsequent loss of productive agricultural land (Godfray, *et. al.*, 2010), adverse effects on biodiversity, ecosystem services, and the stability of ecosystems, (Bommarco, Kleijn and Potts, 2013). In accord with the above, increased amounts of nutrients and toxins in ground and surface water (Tilman, *et.al.*, 2001), and the reliance on external resources (e.g., fossil fuels) and freshwater (Mahon, Crute, Simmons, Islam, 2017), or the stagnation of the rate at which crop yield increases in many of the world's most productive regions (Brouder, 2017) further increase degradation in the environment.

Table 2.4. The summarised anticipated outcomes through moving from conventional agriculture to sustainable agriculture practices

<b>Pillars of sustainable agriculture</b>	<b>Variable</b>	<b>Practice outcome in conventional agriculture</b>	<b>Practice outcome in sustainable agriculture</b>
Agro-environmental resources	Humus content	The humus content is low due to high water run-off and aggressive tillage practices	The humus content is high due to minimum or zero tillage practices
	Long term sustainability	The sustainability of the current methods is uncertain	Promotes a healthy ecosystem and is sustainable. The soil ecosystem can supply the bulk of nutrients required by plants for growth.
	Water use	There are high run-off rates including topsoil	Water use is efficient due to high humus content
	Fertiliser inputs	The use of inorganic fertiliser input is high, due to increased depletion of soil ecosystem	The use of inorganic fertiliser input is low, because the soil ecosystem supplies most nutrients to the crop
	Production risk	Production risk is increased due to high run-off rates, erosion, and poor soil fertility	Production risk is reduced due to efficient water use and availability of nutrients in the soil which lowers the rate of crop failure
	Susceptibility to soil erosion	The susceptibility is high, due to low humus levels and compacted topsoil layer	The susceptibility is low due to high humus content, which allows for efficient water use
	Use of pesticides	Use of pesticides is high due to lack of soil nutrients which produces diseases and pest-susceptible crops	Use of pesticides is low because healthy soil produces healthy plants
Economic viability	Profitability	The profit received after selling the produce is limited due to rising costs of inputs and mechanisation	The profit received after selling the produce is increased due to higher yields and reduced costs, as there is less application of inputs and reduced mechanisation
Social acceptability	Quality of end produce	Quality of end produce is poor due to poor nutrients in produce, caused by poor nutrients in the soil	Quality of end produce is best due to rich nutrients provided by high soil fertility and healthy soil

## **2.6. Summary and conclusion**

With the agricultural sector facing the challenge of significantly increased demand for food, a move from conventional farming to sustainable agricultural needs to be considered. The ISHAE-WY through their decision making need to use a holistic approach model, in which agro ecosystem is regarded as priority, its health valued over the productivity of crops. The production system should be harmonised with the productive potential and physical limits of the surrounding landscape. The resource use such as nutrients and energy in the production area should be recycled and refined. This involves the recycling of biomass to optimise organic matter decomposition and nutrient cycling; minimise loss of energy, water, nutrients, and genetic resources through enhancing the conservation and regeneration of soil, water, and agro biodiversity. This will also reduce the use of agrochemical or other applications with a negative effect on the environment and health. The terrain orientation should enhance biological interactions and synergies among the components of agrobiodiversity, promoting key ecological processes and services. ISAERs should improve land use planning, better production, and responsible farming practices. These include developing best practice guidelines and standards and helping impact sectors understand what sustainable farming entails. The guidelines and standards should assist field crops—produced through sustainable agriculture by stewardship of natural and human resources—to be productive and nutritious.

## CHAPTER 3

### 3. RESEARCH METHODOLOGY

#### 3.1. Introduction

According to Kothari, (2004) research methodology is defined as a way to systematically solve the research problem; it is understood as a discipline of studying how research is done scientifically. Consequently, this section will strive to operationalise the theme of the research, as well as substantiate the choices made in the study. In this presentation, the research methodology will cover (a) Research process, (b) Research approaches, (c) Sampling strategy (d) Data collection methods, (e) Data analysis and interpretation, (f) Triangulation approach, (g) Pilot study, (h) Validity and reliability, (i) Ethical consideration and (j) Conclusion.

#### 3.2. Research process chart

The research processes indicate the proposed activities, the order in which they will be carried out, the relationship between activities as well as the benefits of each activity to the entire assignment. It is also worth mentioning that after each stage of the research processes, the impact would be monitored, evaluated and progress reports submitted. Figure 3.1 presents the process flow chart to be followed in this current study.



Statistical analysis permits researchers to discover complex causal relationships and to determine to what extent one variable influences another. The results of statistical analyses are presented in a standard way. The researchers should take great care to avoid their own presence, behaviour or attitude affecting the results (e.g., by changing the situation being studied or causing participants to behave differently). They also critically examine their methods and conclusions for any possible bias.

The validity of conclusions is shown to be dependent on one or more premises (prior statements, findings, or conditions) being valid. In most cases, random samples are preferred (so that each potential participant has an equal chance of participating), but sometimes researchers might want to ensure that they include a certain number of people with specific characteristics; this would not be possible using random sampling methods. The results should not only be limited to groups of potential participants, but also to the context based on situations.

### 3.3.2 Qualitative research

Qualitative research is associated with the socially constructed nature of reality. It is about recording, analysing, and attempting to uncover the deeper meaning and significance of human behaviour and experience, including contradictory beliefs, behaviours and emotions. Researchers should be interested in gaining a rich and complex understanding of people's experience and not in obtaining information which can be generalised to other larger groups.

The approach adopted by qualitative researchers tends to be inductive, which means that they develop a theory or look for a pattern of meaning based on the data that they have collected. This involves a move from the specific to the general and is sometimes called a bottom-up approach. The approach to data collection and analysis is methodical but allows for greater flexibility than quantitative research. Data is collected in textual form on the basis of observation and interaction with the participants e.g., through participant observation, in-depth interviews and focus groups. Data collection may be carried out in several stages rather than one. The researchers may even adapt the process mid-way, deciding to address additional issues or dropping questions which are not appropriate based on what they learn during the process. In some cases, the researchers in the data collection and analysis may continue until they find no new issues emerging.

Researchers will tend to use methods which give participants a certain degree of freedom and permit spontaneity, rather than forcing them to select from a set of predetermined responses (of which none might be appropriate or accurately describe the participant's thoughts, feelings, attitudes, or behaviour). They will try to create the right atmosphere to enable people to express themselves. This may mean adopting a less formal and rigid approach than that used in quantitative research. Qualitative research may often involve a smaller number of participants. This may be because the methods used such as in-depth interviews are time and labour intensive, but also because many people are not needed for the purposes of statistical analysis or to make generalisations from the results. The smaller number of people typically involved in qualitative research studies and the greater degree of flexibility do not make the study in any way "less scientific" than a typical quantitative study involving more subjects and carried out in a much more rigid manner. The objectives of the two types of research and their underlying philosophical assumptions are simply different.

### 3.3.3 Pragmatic approach to research (mixed methods)

The pragmatic approach is the science using the method which appears best suited to the research problem, rather than having philosophical debates about which is the best approach. Pragmatic researchers therefore grant themselves the freedom to use any of the methods, techniques and procedures typically associated with quantitative or qualitative research. They recognise that every method has its limitations and that the different approaches can be complementary. The study, which followed a pragmatic approach to research, combined quantitative and qualitative approaches. Quantitative approach is an enquiry based on testing a theory made up of variables, measured with numbers, and analysed using statistical procedures (Creswell, 2003; Leedy and Ormrod, 2010). On the other hand, qualitative approach is an enquiry process of comprehending a social problem based on building a holistic picture formed with words, and entails reporting detailed views of informants (Lincoln and Guba, 1985; Creswell, 2003). The approach uses different techniques at the same time or one after the other. For example, they might start with face-to-face interviews with several people; or have a focus group and then use the findings to construct a questionnaire to measure attitudes in a large-scale sample, with the aim of carrying out statistical analysis.

Depending on which measures have been used, the data collected is analysed in the appropriate manner. However, it is sometimes possible to transform qualitative data into quantitative data and vice versa, although it is not very common. Being able to mix different approaches has the advantage of enabling triangulation. Triangulation is a common feature of mixed method studies. The qualitative study involving in-depth interviews or focus group discussions might serve to obtain information which will then be used to contribute towards the development of an experimental measure or attitude scale, the results of which will be analysed statistically.

#### 3.3.4 Research approach adopted for this study.

In the context of the exploration of this study, it was noticeable that a solitary devoted research approach will not be sufficient to answer the research questions appropriately. Therefore, this study will adopt a pragmatic approach to research, and the study should also include the flexibility combination of the attributes of both quantitative and qualitative methods.

Pragmatic approach to research is more than simply collecting both qualitative and quantitative data. It is a type of research which uses the qualitative research paradigm for one phase of a study and a quantitative research paradigm for another. Kemper, Springfield and Teddlie (2003) define pragmatic approach to research as a method that includes both qualitative and quantitative data collection and analysis in parallel form (concurrent pragmatic approach to research in which two types of data are collected and analysed in sequential form). Bazely, (2003b) defines this method as the use of pragmatic approach to research (mixed methods) data (numerical and text) and alternative tools (statistics and analysis) but applying the same method.

As affirmed by Tshikolomo, (2012), quantitative and qualitative approaches may be mutually inclusive and complementary and may therefore be used together as a mixed approach. The pragmatic approach to research (mixed methods) as employed in this study entailed production of knowledge through collection and analysis of data using statistical procedures (quantitative) and interpretation of such information, based on detailed views of informants and with requisite insight into their experiences (qualitative). Research designs are techniques for collecting, analysing, interpreting and reporting data (Mouton, 2001) and provide guidelines to be followed in addressing research problems (Welman, Kruger, and Mitchell, 2005).

### 3.4 Sampling strategy

Sample representativeness is a requirement for research results to be credible and trustworthy (Leedy and Ormrod, 2010) and can only be achieved if a sample frame is born in mind (Welman *et al.*, 2005). As stated by Welman *et al.*, (2005), a sample frame is a complete list in which each unit of analysis is mentioned only once. Sampling means selection of individuals from the population in such a way that every individual has equal chance to be taken into the sample. The first step in sampling strategy will be to define the target population. Sampling is a crucial technique in research, which makes findings economical and accurate.

#### 3.4.1 Target population

In this research the target population was defined as an aggregation of population or parameters from which the sample is selected. The population in question was the ISHAE-WY led by W-Y at Vhembe District. The earmarked area is Nwanedi (Madimbo Corridor) irrigated smallholder farming area, which falls within the territory of Musina Local Municipality and Tshiombo (Upper Mutale Valley) irrigated smallholder farming area, which falls within the territory of Thulamela Local Mnicipality in Vhembe District Municipality of Limpopo Province. The focus was on the ISHAE-WY which are categorised in terms of their water supply. Two categories are found in Vhembe District Municipality: (a) ISHAE-WY served by communal water supply infrastructures, and (b) Independent ISAErs with a private water supply.

#### 3.4.2 Sample frame

Sampling was done as a process of selecting units from a population of interest, so that by studying it, the results obtained may be generalised to the population from which the sample had been chosen (Leedy and Ormrod, 2005). This research used both a probability and no-probability sample frame. The reason for applying probability sampling is because random sampling from a finite population gives each possible sample combination an equal probability of being picked up, and each item in the entire population to have an equal chance of being included in the sample. The simple random sampling method was applied to selected respondents in this study, guided by Guidelines for Sampling (Source: Stoker, (1985) as quoted by Strydom, and Delport, 2011). For this reason, a simple random sample was used to select ISHAE-WY, led by W-Y at Vhembe District Municipality.

A non-probability sampling procedure was also employed for the selection of knowledgeable and experienced participants. For this reason, a purposive sample were used to select those in the ISHAE-WY, who were knowledgeable and experienced ISHAE-WY in this field.

### 3.4.3 Sample size

The selected number of the ISHAE-WY depends on the total of the ISHAE-WY identified and interested in the development of a sustainable model for ISHAE-WY at Vhembe District Municipality, Limpopo province of South Africa study. The profile of the group consisted of 300 people to be interviewed, with youth being eighteen years old.

## 3.5 Data collection methods

Data collection methods refer to the behaviour and instruments used in selecting and constructing research data collection instruments. In this research, the data collection methods were used during studying and the objective of research will be used to arrive at a solution for a given problem. The most suitable data collection method selected in this research is the research survey method.

### 3.5.1 Research survey data collection methods

This study needs techniques of investigation by a direct observation of an occurrence or a systematic gathering of data from a population by applying personal contact and interviews when adequate information about a certain problem is not available. The survey is an important tool to gather evidence relating to the above.

### 3.5.2 Research survey data collection instruments

The main research survey data collection instrument used at ISHAE-WY was a questionnaire. The data obtained through research survey data collection methods was mainly qualitative and quantitative information.

#### (a) ISHAE-WY' walk/visit

The ISHAE-WY' walk/visit with the irrigated smallholder agricultural community was a primary data collecting instrument through carrying out physical observation of points of interest related to the development of a sustainable water use management model for ISHAE-WY in Vhembe District Municipality, South Africa study.

The walk/visit was carried out with a group of representatives from the irrigated smallholder agricultural community, who can explain relevant aspects of their ISHAE-WY. It was also useful to have informal interviews with ISAErs, or persons accompanying the walk, to obtain further information about their water resources management and utilisation on their irrigated smallholder agricultural enterprises.

#### (b) Questionnaire

The questionnaire was developed with insights on the characterisation of W-Y smallholder agricultural entrepreneurs in rural irrigation schemes, productivity, and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus vulgaris*) and maize (*Zea mays l.*) as selected field crops in ISHAE-WY, and ISAEr perceptions on irrigation water supply and utilisation in the study area.

The language used on the questionnaire was English, but the researcher translated it to Tshivenda when conducting interviews, as most participants were not proficient in English. There was only one type of questionnaire designed for primary data collection. Both primary and secondary data were also acquired from existing related documents and information from NGO offices, government departments and ministries, academic or research institutions, and use of personal advantage to contact the scholars, researchers, and friends who have done their research concerning these issues to get an in-depth understanding about this study. The documents and information augment the study and confirm the information furnished on the questionnaire.

#### (c) Desktop study

After conducting field surveys, the most cultivated crops were identified by the farmers. Data on the previous and current land use was acquired from the departmental archives. Selected field crops were also gauged based on possible economical value. A spatial modelling approach was used to model environmental resources on ISAE data. A model was an abstraction or simplification of reality. This used a combination of both primary and secondary data acquisition approaches. Long term environmental, topographical and climate data was obtained from the LDARD.

An agro-ecological suitability review of the maize (*Zea mays l.*), dry bean (*Phaseolus vulgaris*) and sweet potato (*Ipomoea batatas l.*) production potential as selected field crops based on geophysical attributes (e.g., terrain form and soil), and climatic parameter at ISHAE-WY were developed as part of this study. The chapter adopted the mixed research approach that comprised the qualitative and quantitative research design. A semi-structured household questionnaire was used to carry out the survey with an emphasis on W-Y in ISHAE-WY.

### **3.6 Data analysis and interpretation**

#### **(a) Data analysis**

According to Carl (1996), data processing incorporates the gathering and manipulation of data to generate meaningful and descriptive information. The input data comprised the spreadsheet defining the localities of the farmers and the shape files data of the agro-ecological parameters. The geodatabase was created for all the spatial data of the projects and converted to the World Geodetic System (WGS84). The localities of the ISHAE-WY' spreadsheet were converted to the point map (shape file) in ArcGIS.

#### **(i) Questionnaire-based data**

Quantitative data was transcribed into MS Excel and analysed statistically using the SAS Package (SAS, 2009). The procedure FREQ of SAS was used to generate simple frequency tables for variables of interest. Selected data was summarised in an Excel spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents—mainly the qualitative data.

#### **(ii) Soil-based data**

The data was extracted and derived from the various soil database structures that could not be directly combined (for example, adding wetness class to soil porosity), and needed to be converted to common units which express the suitability of the data regarding the goal (suitability of selected commodities potential of field crops on ISHAE-WY). Soils data was mined from the National Land Type database. A land type is a class of land in which the macro climate, the terrain form, and the soil pattern each display a marked degree of uniformity.



Long term agro-ecological and climate data, including the topographical data was acquired from LDARD.

The data was developed by EnviroGIS as appointed to assist the LDARD in conducting field surveys and analyses to correct the national vector data to a local scale. The relevant climatic variables were extracted from the LDARD climate database. All climate data was provided by the LDARD in a spatial raster data format. The following variables were extracted for input into the modelling process: (a) Mean annual precipitation, (b) Mean monthly rainfall (c) Monthly potential evapotranspiration (d) Monthly maximum temperatures (e) Monthly minimum temperatures, and (f) Frost duration.

#### (b) Interpretation

For the research survey methods, collected primary and certain secondary raw data was cleaned, captured using MS Excel statistical analysis Package 9.1 version (SAS 9.1) software (SAS Institute Inc. 2009), transcribed, and analysed. The procedure FREQ of SAS was used to generate simple frequency tables of occurrence in each class of demographic variables. The quantitative data was summarised and discussed, based on objective interpretations (Lee 1999; Leedy and Ormrod 2010). Qualitative data was summarised based on its content and a main theme addressed and discussed based on subjective interpretations. Analysis techniques in this study were also used to capture the perceptions of respondents mainly in the qualitative data. Additionally, descriptive analysis techniques were used which include chi-square test. This descriptive analysis method was used through application of Fischer Exact test. The Fischer Exact tests were employed to test demography (gender, age, education, and income) of ISHAE-WY and their association with the cultivation of selected field crops (sweet potatoes). The correlation between demography and livelihoods in association with the cultivation of sweet potatoes as a selected field crop in ISHAE-WY was determined.

### **3.7 Triangulation Approach**

Triangulation according to Easterby-Smith, Thorpe, and Lowe, 2002; Downward and Mearman, (2005) is a terminology used in navigation and surveying where three reference points are taken as a minimum to locate an object.

Triangulation is inherent in a mixed methods approach in the sense of complementarity of data giving better insight into the problem (Morse 1991; Creswell and Plano Clark, 2007).

According to Denzin 1970; Modell, (2005), the main reason for the usage of a triangulation approach is that it gives superior validity and reliability over a single methodological approach. Easterby-Smith et al., (2002); Ryan, Scapens, and Theobald, (2002); Downward and Mearman, (2009) identified four different classifications of triangulation: (a) theoretical, (b) data, (c) investigator and (d) methodological, which improve validity of research findings. The following section will discuss each one individually.

#### 3.7.1 Theoretical Triangulation:

Modell, (2005) explains theoretical triangulation as a process whereby models are borrowed from one discipline and used to explain circumstances in another discipline. In other words, investigator interpretations are enlightened by more than one theoretical insight (Modell, 2005).

#### 3.7.2 Data Triangulation:

Data triangulation is a process in which data for studies is collected over different time frames or from different sources. Downward and Mearman, (2005) give an example where survey data could be combined with time series data to give a researcher an understanding of different triangulated times about a whole time period. Another combination could be that of a survey and interview data.

#### 3.7.3 Triangulation by investigators:

This type of triangulation involves studies where different people collect data on the same situation and the results are then compared. This could be one of the advantages of a multi-disciplinary study team as it offers the prospect for investigators to study the same situation and to compare, develop and refine themes using perceptions gained from different viewpoints.

#### 3.7.4 Methodological triangulation:

Different methods used at different levels are used in data collection to maximise the amount and quality of data being collected. Several authors demonstrated how the techniques can be used in different disciplines and situations (Todd, 1979).

In the study at hand, two methods and techniques will be used—quantitative and qualitative—coupled with time series data and perceptions of ISHAE-WY.

### **3.8 Validity and reliability**

Triangulation as described in section 3.7. improves the validity and reliability over a single methodological approach. Validity is the degree to which a measure does what it is intended to do. This includes the fact that the measure should provide a good degree of fit between the conceptual and operational definitions of the construct, and that the instrument should be usable for the particular purpose for which it was designed. Different types of validity include: (a) Face validity, which is the extent to which a test is subjectively viewed as covering the concept it purports to measure. It refers to the transparency or relevance of a test as they appear to test participants; (b) Content validity, on the other hand, refers to the extent to which a measure represents all facets of a given social construct; (c) Construct validity is the degree to which a test measures what it claims, or purports, to be measuring and lastly (d) Criterion validity is a measure of how well one variable or set of variables predicts an outcome based on information from other variables.

Reliability is the dependability of a measurement instrument that is the extent to which the instrument yields the same results on repeated trials. There are several different types of reliabilities: test/retest reliability—instrument administered at different times, equivalent reliability—use of different but equivalent instruments, split half reliability—the instrument split in half to cover different sets of questions and internal reliability—also called internal consistency.

Reliability will also be ensured using time series data to check trends and the use of the perceived responses from interviews of the respondents. The questionnaire instrument was subjected to face validity. It was scrutinised by an expert who has been in the field with experience in doing research in development of a sustainable model for ISHAE-WY. To ensure content validity, all sustainability pillars were used to ensure that all parameters were appraised in full.

### **3.9 Ethical Considerations**

The research followed all the necessary steps to obtain ethical approval from the University. The researcher complied to ensure that the rights, needs, values and desires of the respondents and contributing institutes were respected.

#### 3.9.1 Ensuring participants have given informed consent.

A consent form was arranged for the respondents and participating institutes to sign before their participation in the study. They were apprised of the objective of the study, assuring them that the study was only for academic purposes and that their responses was not used for any other reason. Also, that their identity will be protected as individuals and as institutes or bodies.

#### 3.9.2 Ensuring no harm comes to participants.

Participants were ensured the right to ask questions and to obtain a copy of the results; also, that their privacy will be respected, and signatures of the respondents/participating organisations were solicited.

#### 3.9.3. Ensuring confidentiality and anonymity

The participants' rights were protected during the data collection process.

#### 3.9.4 Ensuring that permission is obtained.

Each member of the target population was ensured of their right to participate voluntarily, to refrain from answering any question they do not intend to answer and to withdraw at any time, so that they are not coerced into participating.

### **3.10 Pilot Study**

A pilot study was conducted to test the questionnaire as an instrument, using a few sampled ISHAE-WY in other areas. Adjustments were made to the questionnaire and other data collecting instruments based on the answers provided in relation to the desired answers. Editing together with typographical errors were also rectified to improve the data collecting instrument.

### **3.11 Conclusion**

This chapter explained the way the study was conducted, which was to investigate the development of a sustainable model for ISHAE-WY in Vhembe District of Limpopo province of South Africa. The research methodology includes research methods (data collection instruments), data analysis and interpretation results.

Specific, related research methods were identified to ensure the accomplishment of the main aim for this study, namely, to develop a sustainable model for ISHAE-WY, which use scarce water resources efficiently, beneficially, productively, and sustainably with the intention to increase household food security and farming profitability in ISHAE-WY led by W-Y.

## CHAPTER 4

### 4. CHARACTERISATION OF IRRIGATED SMALLHOLDER AGRICULTURAL ENTREPRENEUR'S HOUSEHOLDS LED BY WOMEN AND YOUTH IN VHEMBE DISTRICT

#### ABSTRACT

*The study was conducted at Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes. The purpose of the study was to characterise women and youth smallholder irrigation scheme entrepreneurs led by women and youth (ISHAE-WY) with the objective to develop and facilitate policy instruments for sustainable agricultural businesses. A structured household questionnaire, together with facilitation was used to carry out the survey on a sample, purposively focusing on women and youth smallholder irrigation scheme entrepreneurs. Total sample was (N=294) and respondents selected through general, gender and gender by age categories. The results indicated that most smallholder agricultural entrepreneurs (ISHAE-WY) hold the responsibility of being heads of households (59.52), followed by spouses (19.39), children (13.95), as compared to other positions such as nieces, nephews etc. (7.14). In this study, women constituted 94.9 percent of the ISHAE -WY, with men constituting five percent. Only 24.15% of the ISHA -WY interviewed were youth between the ages of 18 to 35 years. Most of the ISHAE-WY had an income of between R1 001 to R5 000 per month. In this study, 54.60% were self-employed with an associated 34.04% being full time ISHAE-WY. At least 38.83% of men owned one cell phone compared with 28.63% of women, with 33.3 of men owning two cell phones compared with 43.79 in women. In our study, 91.84% of the ISHAE-WY respondents indicated that they had adequate food supply. This group showed the ability to access key information and collectively self-organise. The study confirmed the potential of ISHAE-WY to create jobs for both beneficiaries and non-beneficiaries. Policies with Department Agriculture, Rural Development and Land Reform, together with Forestry, Fisheries and Environmentn can be reviewed and enhanced to support women and youth agricultural business.*

## **4.1 Introduction**

Improving household livelihood through smallholder irrigation schemes will remain a key strategy for rural poverty alleviation in most of the low-income countries, where most of the rural poor depend directly or indirectly on agriculture. In support of the above, WRC, (2009), indicated that in many decades, smallholder irrigation schemes have been considered to have the potential to generate economic development in poor and under-developed rural areas. The antiquity of smallholder irrigation schemes in South Africa specify that these suffered considerable neglect and were a mixture of success and failure during the post developmental planning and operation stage. These may cause the adverse effect of water unavailability, which will result in a decrease of agricultural production leading to food insecurity, unemployment, and poverty. The study was carried out in two kinds of communal irrigation schemes, which were established during the smallholder canal scheme era (1930–1969), as stated by Fanadzo *et al.*, (2010). With some improvements in infrastructure that has been done over the years, it was anticipated that access to reliable water for irrigation can enable ISHAE-WY to adopt new technologies, leading to increased productivity and greater returns from farming. Coupled with improvements in the ISHAE - WY's ability to innovate socially and technologically, it was postulated that the process will open new opportunities for both on-farm and off-farm income. These improvements in livelihoods and the quality of life in rural areas have also been corroborated by Hussain *et al.*, (2004). However, lack of information on ISHAE-WY, most of whom are based in irrigation schemes, is still dire. The purpose of this investigation was to characterise ISHAE-WY operating within the irrigation schemes. The characterisation of ISAE-WY would guide the development of relevant demographic, livelihood, and food security programs.

## **4.2 Methodology**

### **4.2.1 Study Area**

The study was carried out in Vhembe District Municipality of Limpopo province. The specific area was the Musina & Thulamela Local Municipalities at the Madimbo and Mutale Irrigation Schemes, respectively. The two areas were categorised as independent ISHAE-WY, each with a private water supply in the case of Madimbo and as irrigated smallholders who are served by communal water supply infrastructure in the case of Mutale.

The two areas of Madimbo Corridor and Upper Mutale Valley irrigation schemes constitute a total of more than 2 270 ha of production area.

#### 4.2.2 Sampling Procedure

Systematic purposive sampling was used to select ISHAE-WY within the district, with strong emphasis on W-Y. We used stratified sampling to obtain a representative sample of villages and households for interview (Leedy *et.al.*, 2005). A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The *PROC SUREVEYSELECT* allows selection of probability-based random sampling, where sampling in different categories or class depends on the number of units within that class. It is appropriate for handling selection bias.

#### 4.2.3 Data Collection

A structured household questionnaire was used to carry out the survey on purposefully sampled ISHAE-WY. The total number of ISHAE-WY interviewed were (N=294) and respondents selected with an emphasis of gender and age. Youth were of the age between 18 to 35 years. The numbers were youth (18–35) who were female (N=56); Youth (18–35) who were male (N=15), Adult-female (36–59) (N=153) and Pensioner female ( $\geq 60$ ) (N=68). For purposes of characterising the ISHAE -WY, geophysical characterisation was also done.

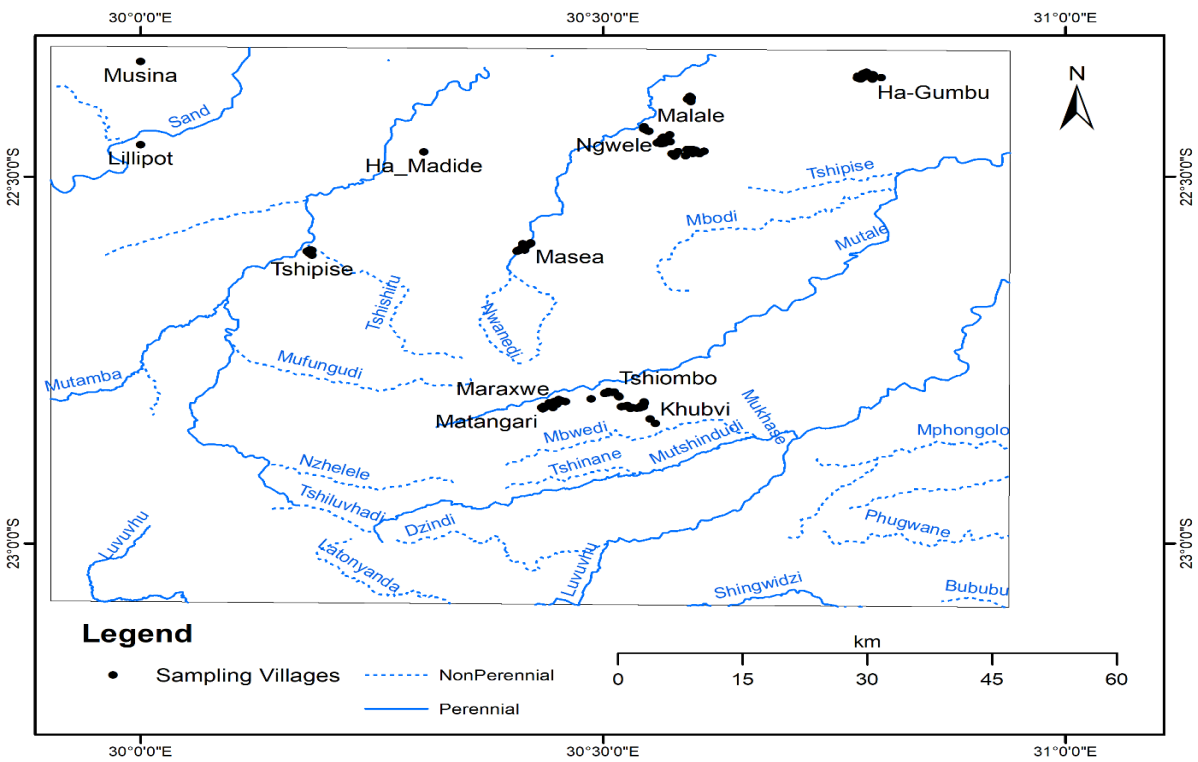
#### 4.2.4 Data analysis

Quantitative data was transcribed into MS Excel and analysed statistically using the SAS Package (SAS, 2009). The procedure *FREQ* of SAS was used to generate simple frequency tables for variables of interest. Selected data was summarised in an Excel spreadsheet. Descriptive analysis techniques were used to capture the perceptions of respondents—mainly the qualitative data.

### 4.3 Results and Discussions

This section covers the geophysical characterisation of the study area, ISHAE - WY demography, household livelihood and household food security. According to Randela *et. al.*, (2006), the characteristics and attributes for farming potential as represented by ISHAE-WY demography, livelihood, and food security influence the design and implementation of policies with regards to selection and development of the ISHAE -WY population.

Figure 4.1 shows the geographic location of the IISHAE-WY in relation to the river networks. It was observed that the relative distance of the ISHAE-WY interviewed at Ha-Gumbu were far from the river networks. It was also evident from the study that these ISHAE-WY relied more on underground water. The villages of Masea, Ngwele, and Malale are based on the Nwanedi river networks, whereas the Tshipise relied on their proximity to the Mbodi and Tshipise fountain river networks. These villages and their respective enterprises developed their irrigation schemes privately. The Mutale Valley Irrigation schemes, as per the name, depend on the Mutale River for their communal irrigation schemes.



**Figure 4.1:** Spatial distribution of smallholder agricultural enterprises within villages and the associated river network in the study area

#### 4.3.1 Women and youth smallholder irrigation entrepreneur’s demography (ISHAE-WY)

The demographic features of the Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes are explored in this section. This provides an overview of the socio-economic characteristics of the irrigation scheme communities, highlighting the strengths, opportunities, threats, and weaknesses. The summary assists in identifying smallholder irrigation scheme issues influenced by demographic dimensions. This section describes ISHAE-WY demography based on (a) Position and gender of ISHAE-WY at the household, through various aspects of their involvement in independent smallholder irrigation schemes with a private water supply, and (b) the irrigated smallholder who is served by communal water supply infrastructures.

#### 4.3.2 ISHAE-WY position in the household.

Table 4.1 shows the frequencies and respective percentages of ISHAE -WY position in the household. Most ISHAE-WY are heads of households (59.52), followed by spouses (19.39), children (13.95) as compared to other positions such as nieces, nephews etc. (7.14). According to Bembridge and Tshikolomo, (1998), heads of household are main decision makers in rural farming households; as a result, the information they provide is more likely to reflect on farming and other developmental decisions of the household.

**Table 4.1: Frequencies and respective percentages of ISHAE -WY position in the household and age**

Variable	VHEMBE DISTRICT	
	Frequencies	%
<b>Respondent position in the household</b>		
Head of the household	175	59.52
Spouse to the head of household	57	19.39
Child to the head of household	41	13.95
Others	21	7.14
<b>Total</b>	<b>294</b>	<b>100</b>
<b>Age of the ISHAE -WY</b>		
18–35 years	71	24.15
36–59 years	155	52.72
>60 years	68	23.13
<b>Total</b>	<b>294</b>	<b>100</b>

#### 4.3.3 Age of the ISHAE -WY

The frequencies and respective percentages of ISHAE-WY age is reflected in Table 4.1. Mulinyac, (2017) reported that ISHAE -WY within the ages of 30–34 years are likely to well understand the issues involved in farming; therefore, they are armed with the necessary information regarding climate change adaptation strategies that can be well achieved and adhered to. Only 24.15% of the ISHAE - WY interviewed were youth between the ages of 18 to 35 years. In the same category of youth only nine percent were found to be heads of households. The majority (52.72%) of the ISHAE - WY were adults of the ages between 36 to 59 years. ISHAE -WY older than 60 years were equivalent to that of youth at 23.13%. This observation agrees with Simotwo et al. (2018) who revealed that ISHAE - WY were aging, evident in our study by the majority (53.79%) towards the upper limit of 59 years.

#### 4.3.4 Educational information.

According to Ledwaba, (2013), the levels of education results indicate that people with better qualifications have also started to see farming as an alternative. In support of the above, Mupaso *et al.*, (2013), indicate that plot holders with better qualifications have now started to see farming as a substitute for other income incurred from off-farm employment. The frequencies and respective percentages of ISHAE-WY and their educational status is shown in Table 4.2. One in six (18.81%) ISHAE -WY were completely illiterate, about two in five (27.84%) had primary education at most, with one in four (39.86%) having had some secondary/high school education. Only 11.34% of respondents had college or university education Table 4.2. Based on these findings, four in five (65.70%) of the ISHAE -WY only had secondary education at best.

**Table 4.2: Frequencies and respective percentages of ISHAE -WY educational status highest education**

		<b>VHEMBE DISTRICT</b>	
<b>Variable</b>		<b>Frequency</b>	<b>%</b>
<b>Educational information</b>			
	Never went to school	46	15.81
	Adult Based Education and Training	15	5.15
	Primary education	81	27.84
	Secondary school	116	39.86
	Tertiary education	33	11.34
	<b>Total</b>	<b>291</b>	<b>100</b>

The importance of education in successful developmental activities such as farming cannot be overemphasised. The level of education has a strong influence on the extent to which a farmer can access new information and technology, not only through improved literacy that enables the ISHAE -WY to access written information, but also through the increased ability to search for information using modern information technologies. Citing Appleton and Balihuta (1996), Oduro-Ofori *et al.*, (2014) described the effect of education on agricultural productivity as cognitive and non-cognitive. Cognitive effects reportedly emphasise basic literacy and numeracy that ISHAE-WY achieve from education, while non-cognitive effects emphasise change in the attitude of ISHAE - WY who attended school due to improved discipline introduced by formal schooling. An agricultural entrepreneur’s level of education has a direct impact on his/her ability to properly manage a given irrigation technology, but lack of formal training in agriculture could pose a limitation to their productivity. This factor makes it easy for other stakeholders to effect capacity building programmes for the irrigators without worrying about issues of illiteracy (Ndlovu *et.al.*, 2015). Supplementary to the above, education plays a key role in the household’s decision to adopt technology—it creates awareness and encourages innovation and invention (Mengistie and Kidane, 2016).

#### 4.3.5 Women and youth smallholder irrigation entrepreneur's household livelihood (ISHAE-WY)

The purpose of examining ISHAE-WY' household livelihood characteristics was to provide an updated socio-economic profile and determine whether the smallholder irrigation plots' utilisation add value to the ISHAE -WY household. This will provide an overview of the current living standard, which includes identification of the comparative advantages, vulnerability and welfare of communities residing within the Madimbo Corridor and Upper Mutale Valley villages.

#### 4.3.6 Type of accommodation

Table 4.3 represents frequencies and respective percentages of ISHAE -WY' quality of housing. The quality of a house owned by a ISHAE -WY tends to be positively influenced by the amount of income earned and may have a beneficial impact on the adaptive capacity of the farmer to adverse effects of climate change and variability. ISHAE-WY earning higher incomes are expected to afford better quality houses compared to their lower income counterparts. Accordingly, livestock ISHAE-WY with higher incomes are expected to reside in better quality houses than their lower income counterparts. Livestock ISHAE-WY and other members of community may, however, be beneficiaries of government housing schemes and own higher quality houses, even if their income levels are low; hence, the interest in the source of funding for house construction. The majority of ISHAE-WY had multiple roomed houses (65.31%) and some (31.98%) had multiple roomed houses with separate rondavels. The building materials used were cement bricks with corrugated iron roof sheeting (54.42) and walls of cement bricks with tile roofs at 23.81. The majority (67.24%) had between five and eight rooms, followed by 18.43% with less than four rooms. The toilets were located outside in most households (89.46%) and only seven percent had inside flush toilet and outside pit toilet.

**Table 4.3: Frequencies and respective percentages of ISHAE -WY quality of housing owned**

<b>Type of accommodation</b>		<b>Frequency</b>	<b>Percent</b>
	Single roomed house	7	2.38
	Cluster of rondavels	1	0.34
	Multiple roomed house	192	65.31
	Multiple roomed houses with separate rondavels	94	31.98
	<b>Total</b>	<b>294</b>	<b>100</b>
<b>Type of building material used</b>			
	Walls of forest timber with thatch roof	5	1.70
	Walls of mud bricks with thatch roof	5	1.70
	Walls of mud bricks with roof of corrugated iron	29	9.86
	Walls of cement bricks with thatch roof	25	8.50
	Walls of cement bricks with roof of corrugated iron	160	54.42
	Walls of cement bricks with tile roof	70	23.81
	<b>Total</b>	<b>294</b>	<b>100</b>
<b>Number of rooms</b>			
	≤ 4	54	18.43
	5-8	197	67.24
	9-12	40	13.65
	>13	2	0.68
	<b>Total</b>	<b>293</b>	<b>100</b>

#### 4.3.7 Women and youth smallholder irrigation entrepreneur's household food security (ISHAE-WY)

The frequencies and associated percentages of ISHAE - WY food security is demonstrated in Table 4.4 The table makes use of the hunger scale—adequacy or inadequacy of food in a household. Questionnaire-based measures such as hunger scale, also known as food security scale, have been used to get information about experiences and behaviours that would indicate presence and severity of food insufficiency in households (Bickel *et.al.*, 2000). Frangillo *et al.*, (1999) in defining hunger as the extreme case of food insecurity, tested, and proved that hunger and food security questionnaire-based measures are valid in determining food insecurity and hunger in rural households. This tool was found to be sound also for cross-cultural and developing countries' use respectively (Ballard *et. al.* 2011). In our study, 91.84% of the ISHAE -WY respondents indicated that they had adequate food supply.

Respondents (79.09) also pointed out that they had no seasonal shortage of meals. Similarly, they (85.54) indicated that they never experienced situations where they must skip a meal or go to bed without a meal (97.08).

**Table 4.4 Frequencies and respective percentages of ISHAE – WY food security**

	Yes		No		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Adequate food supply	270	91.84	24	8.16	294	100
Seasons with fewer meals	60	20.91	227	79.09	287	100
Skip meals	36	14.46	213	85.54	249	100
Go to bed without meals	7	2.92	233	97.08	240	100

Table 4.5 shows the frequencies and the associated percentages of ISHAE -WY with food security indicators. The households (81.15) identified summer as the hardest season. The majority of ISHAE -WY (79.38) had three meals per day, followed by only (18.56) who had two meals a day. During the hardest period, 40.27% of the ISHAE-WY respondents had three meals per day, a significant reduction from 75.77% in other periods. On the other hand, 49.56% of the respondents had two meals per day, which was an increase to compensate for the reduction of the households that had the full complement of three meals. In other periods, only 19.38 ISHAE-WY had two meals.

**Table 4.5: Frequencies and respective percentages of ISHAE -WY food security**

	Frequency	Percent
<b>Hardest season</b>		
None	1	0.82
Autumn	8	6.56
Winter	14	11.48
Summer	99	81.15
<b>Total</b>	<b>122</b>	<b>100</b>
<b>Number of meals per day</b>		
One	1	0.34
Two	54	18.56
Three	231	79.38
Four	3	1.03
Five	2	0.69
<b>Total</b>	<b>291</b>	<b>100</b>
<b>Meals per day hardest period</b>		
None	1	0.44
One	18	7.96
Two	112	49.56
Three	91	40.27
Four	4	1.77
<b>Total</b>	<b>226</b>	<b>100</b>
<b>Meals per day another period</b>		
None	1	0.44
One	7	3.08
Two	44	19.38
Three	172	75.77
Four	3	1.32
<b>Total</b>	<b>227</b>	<b>100</b>

Table 4.6 gives the frequencies and respective percentages of ISHAE-WY reasons for lesser meals. The challenge seems to be affordability, where ISHAE -WY respondents (95.89) lacked enough money to buy food. The same was true (25%) of households lacking money to buy food in the hardest season in summer. However, food availability was true for 54.40% of the ISHAE - WY, who indicated that summer is the production season and then food is not yet ready. This gives an indication that ISHAE-WY may be producing, not only for market, but also for household consumption and/or market produce for income purposes to empower themselves to purchase.

**Table 4.6: Frequencies and respective percentages of ISHAE - WY’ reasons for lesser meals**

<b>Food Security</b>		<b>Frequency</b>	<b>Percent</b>
<b>Reasons for lesser meals</b>			
	Lack of enough money to buy food	70	95.89
	Shortage of food	3	4.11
	<b>Total</b>	<b>73</b>	<b>100</b>
<b>Reasons indicating the hardest season</b>			
	Lack of enough money to buy food	55	25.20
	Shortage of food	3	1.10
	Summer days are longer and require more food than other seasons	43	19.30
	Produce on the farm not yet ready	116	54.40
	<b>Total</b>	<b>217</b>	<b>100</b>

#### **4.4 Conclusion and Recommendations**

##### 4.4.1 Conclusion

ISHAE-WY based in the Madimbo Corridor (Ha-Gumbu, Malale, Ngwele, Tshipise, Masea and the Musina–Nwanedi) villages use more underground water to supplement the surface water river systems than the Mutale (Tshiombo, Matangari, Maraxwe). The study showed that Madimbo Corridor and Upper Mutale Valley ISHAE-WY’s households are characterised by diversity and similarities attributed to different conditions, among them, demography—such as position of farmer in the household, age of the farmer and educational status of the head of household. Two-thirds of the ISHAE-WY respondents hold responsibility of being heads of households and main decision makers. The implications were that the information they provided was more likely to reflect on farming and other developmental decisions of the ISHAE-WY. In this study, only 24.15% of the ISHAE-WY were within the ages of 30–34 years—the category likely to understand issues involved in farming and with the necessary information regarding climate and business risks. The majority (52.72%) of the ISHAE-WY were adults of the ages between 36 to 59 years and therefore aging. Using the same logic, over two-thirds (65.70%) of ISHAE-WY had secondary education, which is the level of education with a strong influence on the extent to which a farmer is able to access new information and technology. This group, therefore, could be able to read and write, showing the ability to access information available in written and electronic media and to use that information for the exercise of their citizenship.

The ISHAE -WY where the most food secure with the majority having three meals per day with no experience of going to bed without a meal. The study confirmed the potential of ISHAE-WY to create jobs for both beneficiaries and non-beneficiaries as well.

#### 4.4.2 Recommendations

The study recommends that (a) the characterisation of irrigated smallholder agricultural entrepreneurs guide the development of relevant demographic, livelihood, and food security programs; and (b) that policies with Agriculture, Rural Development and Land Reform, together with Forestry, Fisheries and Environment, can be reviewed and enhanced to support Women and Youth Agricultural Entrepreneurs.

## CHAPTER 5

### 5. CLIMATE AND SOIL SUITABILITY FOR MAIZE (*ZEA MAYS L.*), DRY BEAN (*PHASEOLUS VULGARIS*) AND SWEET POTATO (*IPOMOEA BATATAS L.*) PRODUCTION UNDER SMALLHOLDER AGRICULTURAL ENTERPRISES IN VHEMBE DISTRICT MUNICIPALITY OF LIMPOPO PROVINCE, SOUTH AFRICA

#### ABSTRACT

*Desktop research was conducted to investigate the climate and soil suitability for production of maize, dry bean, and sweet potato at Madimbo Corridor (Musina Local Municipality) and Upper Mutale Valley (Thulamela Local Municipality) in Vhembe District Municipality of Limpopo province. The study employed a mixed-methods approach in which both quantitative and qualitative data was used. While winter temperatures were generally lower, summer temperatures were a minimum  $>17.4$  °C and maximum of about 31 °C (both sites) and generally suitable for production of the three selected crops. Madimbo Corridor received less rainfall (201–400 mm per annum) than the minimum required by each of the three crops—maize (350–450 mm), dry bean (400–500 mm) and sweet potato (360–400 mm per annum) and was generally not suitable for rainfed production. Rainfall at the Upper Mutale Valley (401–600 mm and 601–800 mm per annum) sufficed for production of all three crops under study. Soils at Madimbo Corridor generally possessed less clay ( $\geq 5$  and  $\leq 10$  percent) and higher pH ( $\geq 7.0$  and  $\leq 8.94$ ) than the clay proportion ( $\geq 10\%$ ) and pH ( $\geq 5.8$  and  $\leq 7.0$ ) required for maize production. To the contrary, soils at the Upper Mutale Valley had a clay percentage  $\geq 16$  and  $\leq 32$ , effective depth  $\geq 120$  cm, and pH  $\geq 5.7$  and  $\leq 7.2$  and were suitable for maize production. Also, soils at Madimbo Corridor were less suitable for production of dry bean, with a requirement of 15-35% clay and pH of 5.5-7.5, while those at the Upper Mutale Valley were suitable. Similar results were also reflected for sweet potato. Generally, the Upper Mutale Valley was appropriate for production of maize, dry bean and sweet potato, while the Madimbo Corridor was not. It was recommended that climatic and soil suitability be assessed to decide on crops to be produced in any area. Where justifiable, crops may be selected for production in an area where a factor of climate or soil may not be acceptable,*

*and measures should be in place for minimising the adverse effects of the less suitable factor on crop production.*

## **5.1 Introduction**

Vhembe District Municipality in South Africa is blessed with a diverse climate and soils that suit production of a wide range of field crop commodities. The climate and soil types influenced the agro-ecological conditions and associated range of potentials and constraints for cropping (FAO, 1996). The potentials and constraints of an agro-ecological zone for production of a specific crop is influenced by the extent to which the climate and soils of that zone match the requirements of the crop (Nyahunda and Tirivangasi, 2020). An agro-ecological zone offering the climate and soils required by a crop presents potential and is regarded suitable for production of the crop; one offering climate and soils not required by the crop presents a constraint and is regarded unsuitable.

Rankoana, (2016) suggested that smallholder farming in Limpopo province—and indeed in Vhembe District Municipality—has been dominated by women, and these would, therefore, be most affected by the climate and soil suitability for production of their crops as they are most vulnerable. Statement by Mpandeli and Maponya, (2013) revealed that the study area encountered one of the worst droughts during the 1991/92 austral summer rainfall season, and that affected production of smallholder farmers in negative ways. As affirmed by Nyahunda and Tirivangasi, (2019), smallholder farmers in the study area experienced water scarcity and loss of livestock, due to unfavourable climatic conditions, characterised by low rainfall and high temperatures.

The climate and soil suitability could probably also be described based on crop suitability modelling defined as the congruence between the crop requirements and the geoclimatic conditions necessary for such crops (FAO 1976). It is vital to select crop commodities for cultivation based on suitability in a particular production area, so that maximum benefit could be achieved while maintaining the ecological sustainability. The extent of crop suitability to geoclimatic condition of an area influences the production performance of the crop in that area (He, Yao, Chen, and Ongaro, 2011). The purpose of the study was to assess the climate and soil suitability for production of maize (*Zea mays l.*), dry bean (*Phaseolus vulgaris*) and sweet potato (*Ipomoea batatas l.*) under smallholder agricultural enterprises in Vhembe District Municipality of Limpopo province, South Africa.

The rationale for conducting the suitability assessment was to determine the potential and limitations of climate and soils for production of the selected crops in the study area (Pan and Pan, 2012) and to avoid environmental stresses (FAO, 2007; Elsheikh, Shariff, Amiri, Ahmad, Balasundram and Soom, 2013).

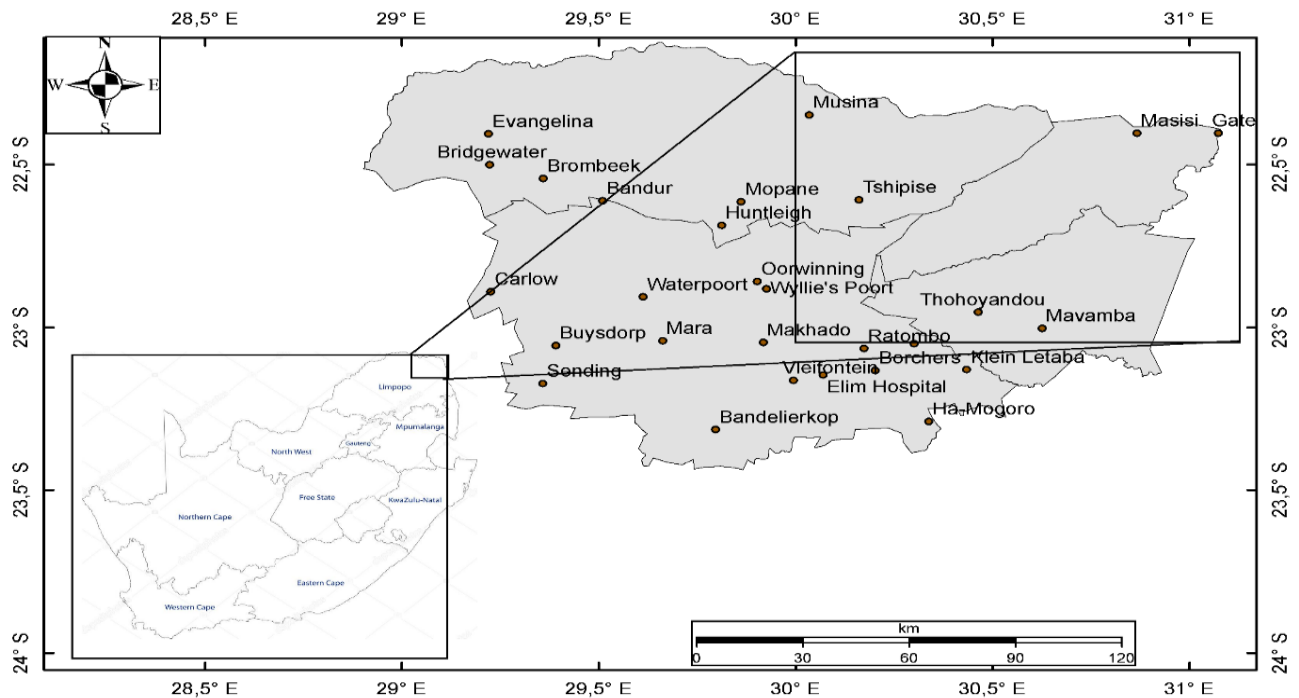
## **5.2 Methodology**

### **5.2.1 Research approach**

The study followed a mixed-methods approach that combines the quantitative and qualitative approaches in one study (Tashakkori and Teddlie, 1998). The quantitative approach was defined as an enquiry into a problem based on testing a theory made up of variables, measured with numbers and analysed using statistical procedures, to determine whether the predictive generalisations of the theory hold true (Creswell, 2003; Leedy and Ormrod, 2010). The qualitative research approach was defined as an enquiry process of comprehending a problem or phenomenon based on building a complex holistic picture formed with words, reporting detailed views of informants, and conducted in a natural setting (Lincoln and Guba, 1985; Creswell, 2003; Smith, 1983). The mixed approach as used in this study included (1) review of literature that presented mainly qualitative information from scientific journals, books and reports and (2) presentation of mainly quantitative climate and soil information (Hurmerinta-Peltomaki and Nummela, 2006; Leedy and Ormrod, 2010).

### **5.2.2 The study site in context**

The study was conducted in the Madimbo Corridor under Musina Local Municipality and the Upper Mutale Valley under Thulamela Local Municipality. Musina Local Municipality is in the north while the Thulamela Local Municipality is in the north-eastern part of Vhembe District Municipality of the Limpopo province of South Africa (Figure 5.1). The Vhembe District Municipality is strategically located close to international borders with Botswana in the north-west, Zimbabwe in the north and Mozambique in the north-east. Within South Africa, the district municipality borders Mopani District Municipality in the south-east, Capricorn District Municipality in the south, and Waterberg District Municipality in the west.



**Figure 5.1** Location of Madimbo Corridor and Upper Mutale Valley

The other municipalities in Vhembe District Municipality are Makhado Local Municipality south of Musina and Collins Chabane Local Municipality south of Thulamela Local Municipality.

### 5.2.3 Data collection

The data required for the research included that of climatic and soil conditions in the study area. Also important were the requirements of the three selected field crops (maize, drybean, and sweet potato) for the climate and soil types. Suitability assessment of the climate and soils for production of the selected crops would match the crop requirements of the two factors against the condition offered by the study sites regarding the factors.

#### 5.2.4 Climate and soil data for the study sites

The climate and soil data were quantitative in nature and described through maps sourced from the GIS Directorate of the LDARD.

##### **(a) Climate**

Maps for climatic factors of temperature and rainfall were generated from data collected over 20 years in numerous weather stations located in the province. Temperature maps were for minimum and maximum summer and winter temperatures. Within each map, the temperatures were split into categories from lower to higher temperatures, with the different temperature values shown in various sites within the study area.

The rainfall map, on the other hand, presented annual rainfall values in the same map without splitting it according to seasons. The study was conducted in a summer rainfall area with minimum rainfall received in winter; hence, it was deemed unnecessary to split the seasons. Also, the rainfall was split into categories (e.g., 0–200 mm, 201–400 mm per annum etc.) with different values presented for various sites within the study area.

##### **(b) Soil types**

Up to 73 soil forms were reported for the South African classification, and those could be placed into 14 groups. Soils in the study area were presented in a map sourced from the GIS Directorate, and the enlisted soils were calcareous, eutrophic, mesotrophic, and non-calcareous soils, with some transitional soil types, such as dystrophic to mesotrophic and mesotrophic to eutrophic also included.

#### 5.2.5 Crop requirements

The information regarding requirements of the three selected crops for climate and soil types was mostly also quantitative in nature, with some qualitative information included, mostly in the form of descriptions and explanations. All the information was sourced from relevant reports and literature. With regards to climate, the minimum and maximum temperature requirement and ideal rainfall range for each of the three selected field crops was presented.

As for soil requirements, recommended soils were presented based on texture (with a focus on average clay percentage), effective soil depth, and pH.

#### 5.2.6 Data processing for suitability assessment

According to Carl, (1996), data processing incorporates the gathering and manipulation of the data to generate meaningful and descriptive information. The processing of data entailed comparing the climate and soil information observed for the study area with that reportedly required by the selected field crops. The purpose of the comparison was to determine if there was a congruence or fit between the climate and soil condition observed in the study area and that required by the selected crops. If there was a match, it would suggest that the study area is suitable for production of the crop regarding that factor.

Lack of congruence, on the other hand, would require further consideration and not automatically imply lack of suitability. For instance, if a crop requires a minimum rainfall of 400–500 mm per annum and a rainfall of 700 mm per annum was observed in a site in the study area, the crop will likely produce more with the relatively higher rainfall than the minimum required, and the site would be regarded as more suitable. While the collected data was mostly quantitative, the processing and suitability assessment was mostly qualitative; hence, the study employed mixed methods.

### 5.3 Results and discussion

As alluded to earlier, the results and their discussion focused on climate and soil factors prevailing in the study area and the growth requirements of the selected crops for those factors.

#### 5.3.1 Climatic conditions and suitability for selected crops

##### 5.3.1.1 Climatic conditions

Climate is the primary variable for assessing suitability of crops in an area (Chapman, Birch, Pope, Sallu, Bradshaw, Davie and Marsham, 2020). As stated by Shahi, (2011), climatic conditions are based on what people observe in their local environment. Agriculture is deeply interconnected with climate as an important driver of agricultural production (Selvaraju, Gommès and Bernardi, 2011).

Agricultural production depends on climatic conditions, such as temperature and rainfall (Mpandeli and Maponya, 2015). Climate is a primary determinant of agricultural productivity, and any significant change in climate tends to influence crop productivity (Jayne *et al.*, 2003). The trends on climate change in Southern Africa project an increase of temperatures, occurrence of droughts, and an increase in the intensity and frequency of extreme weather events (Nhamo *et. at.*, 2020).

The impact of climatic conditions such as rainfall on agriculture can no longer be ignored as agricultural production is largely dependent on the amount of water available (Shrestha, Thin and Deb, 2014). Adverse climatic conditions resulted in declines in crop yield, and that increased the global occurrence of food insecurity (Bhatt, Maskey, Babel, Uhlenbrook and Prasad, 2014). Such negative impacts were more significant in arid and semi-arid areas, and those included the study areas of Madimbo Corridor under Musina Local Municipality and Upper Mutale Valley under Thulamela Local Municipality. As stated by Nana, Corbari and Bocchiola (2014), crops such as maize, sweet potato and dry bean require a conducive climate for production.

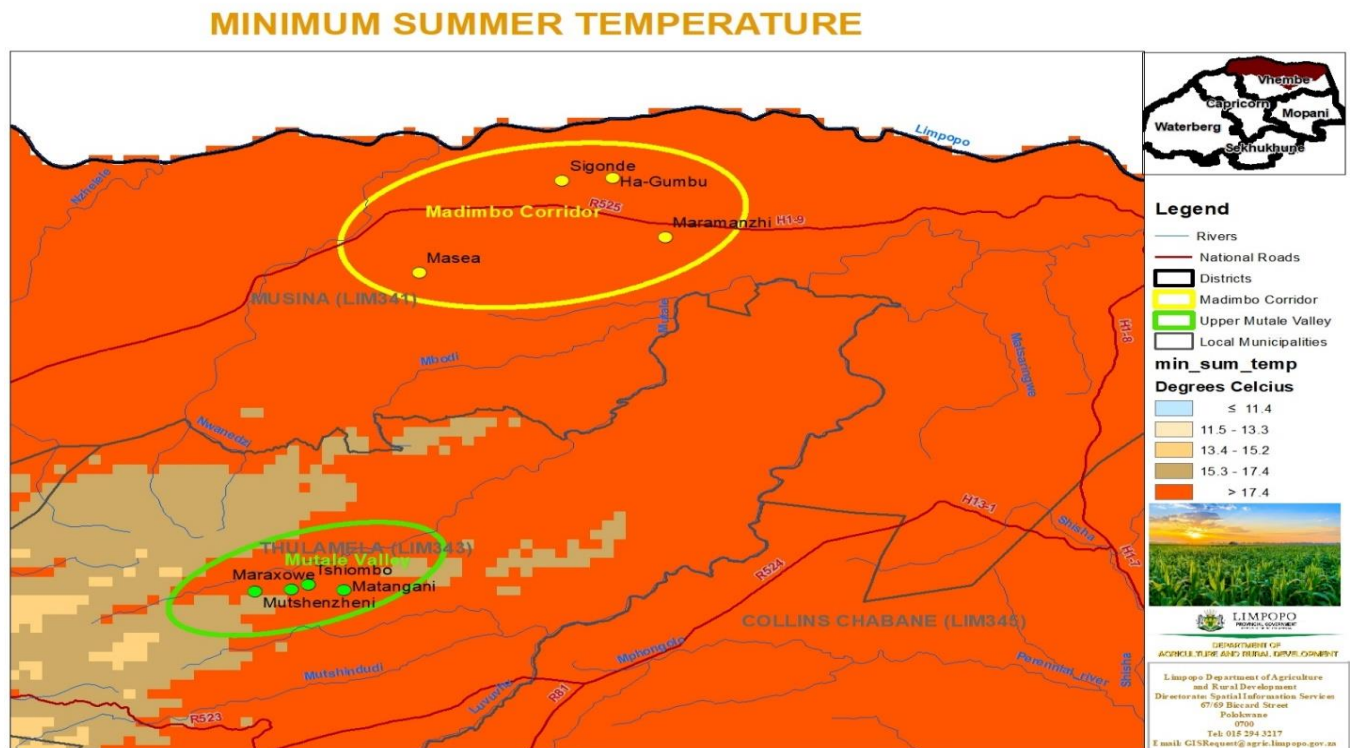
#### **(a) Temperature**

The effect of increasing temperature is argued to have a pronounced negative impact on field crop yields, particularly in semi-arid and arid regions. Smallholder farmers are vulnerable to the impacts of increased temperature (Vermeulen, Campell and Ingram, 2012) often associated with drought (Ziervogel, New and Van Garderen, 2014). Increased temperatures are among the recent pervasive stressors with which rural communities must cope with (Maponya and Mpandeli, 2013). However, Lynam and Brown, (2011) believed that perceptions of increased temperature were shaped by observations of changing weather patterns. The increase in temperatures has a detrimental effect on agricultural sector performance and economic development (Faramarzi, Abbaspour, Vaghefi, Farzaneh, Zehnder, Srinivasan and Yang, 2013). As affirmed by (Nhamo, Nhamo, Ndlela, Nhemachena, Mabhaudhi, Mpandeli and Matchaya, 2018), the projected increases in warming conditions across most parts of the region would worsen the challenges associated with water insecurity (mainly due to reduced rainfall), adversely affecting both rainfed and irrigated agriculture production, as well as negatively impacting energy generation.

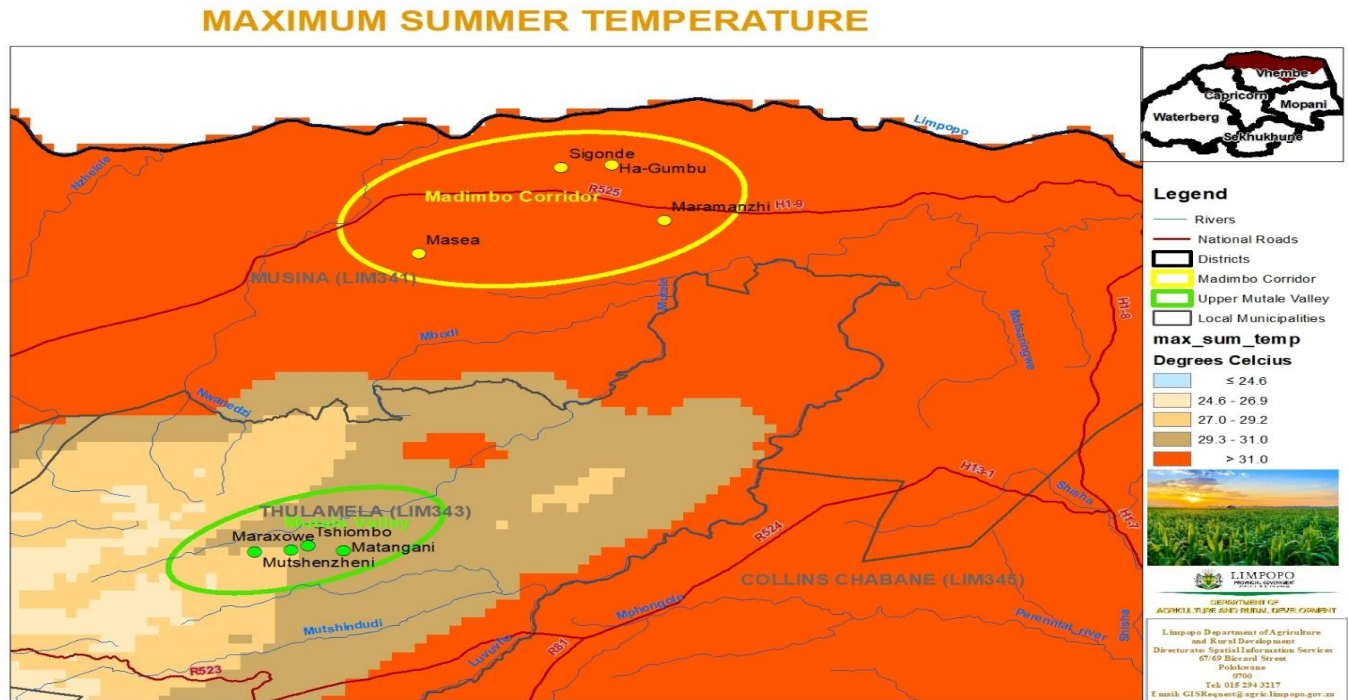
The temperature increases are expected to be higher in the arid regions of the African continent compared to the rate of global average increases (Almazroui, Saeed, Saeed, Islam, Ismail, Klutse and Siddiqui, 2020). Furthermore, there is a remarkable ecological variability because of increased temperature and associated drought, which resulted from increased evapotranspiration (Intergovernmental Panel on Climate Change - IPCC, 2013), and these threaten the livelihoods of rural communities (Lasage, Muis, Sardella, van Drunen, Verburg and Aerts, 2015), including the ISHAE-WY in the area under study. Also, temperature extremes may result in frosts and heat waves, and these may cause damage to crop plants.

**(i) Summer temperatures in the study area**

The summer temperatures tend to influence the selection of crops to be planted in those areas during the summer season. Based on the findings of the study, such temperatures may be diverse (Figure 5.2 and Figure 5.3).



**Figure 5.2** Minimum summer temperature at Madimbo Corridor and Upper Mutale Valley in Thulamela



**Figure 5.3:** Maximum summer temperature at Madimbo Corridor and Upper Mutale

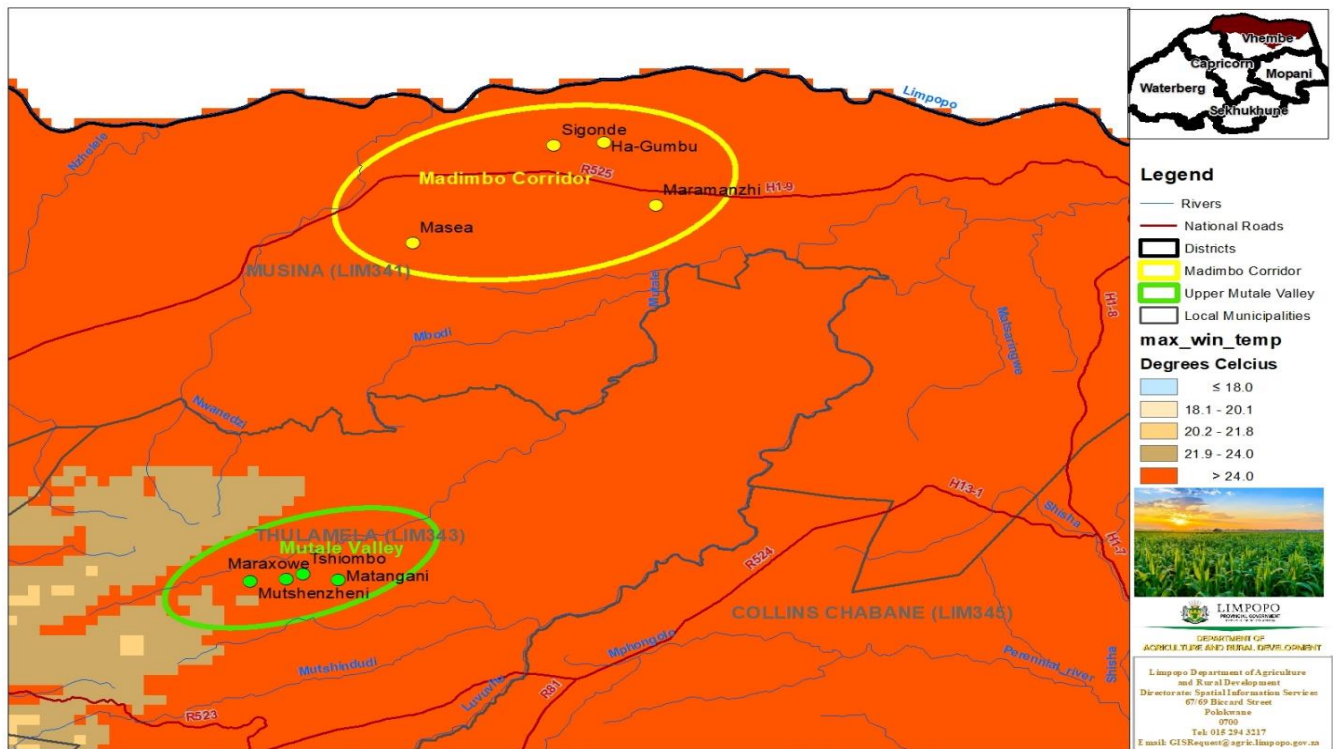
The minimum temperature in summer at Madimbo Corridor was  $>17.4\text{ }^{\circ}\text{C}$  with the maximum of  $>31\text{ }^{\circ}\text{C}$ . At Upper Mutale Valley, minimum temperature in summer was also  $>17.4\text{ }^{\circ}\text{C}$  with temperatures of  $15.3\text{--}17.4\text{ }^{\circ}\text{C}$  in some surrounding areas (Figure 5.2). The maximum summer temperatures at Upper Mutale Valley were observed to be  $29.3\text{--}31.0\text{ }^{\circ}\text{C}$  (close to that of Madimbo Corridor) with temperatures of  $27.0\text{ }^{\circ}\text{C}\text{--}29.2\text{ }^{\circ}\text{C}$  and those  $>31.0\text{ }^{\circ}\text{C}$  recorded in some surrounding areas (Figure 5.3).

**(ii) Winter temperatures**

As was the case for summer, the winter temperatures in the area under study had a strong influence on the types of crops selected for planting during the season. The occurrence of certain minimum and maximum winter temperatures (Figure 4.4 and Figure 4.5) tended to influence the dates by which certain crops should be planted.



## MAXIMUM WINTER TEMPERATURE



**Figure 5.5** Maximum winter temperature at Madimbo Corridor and Upper Mutale Valley

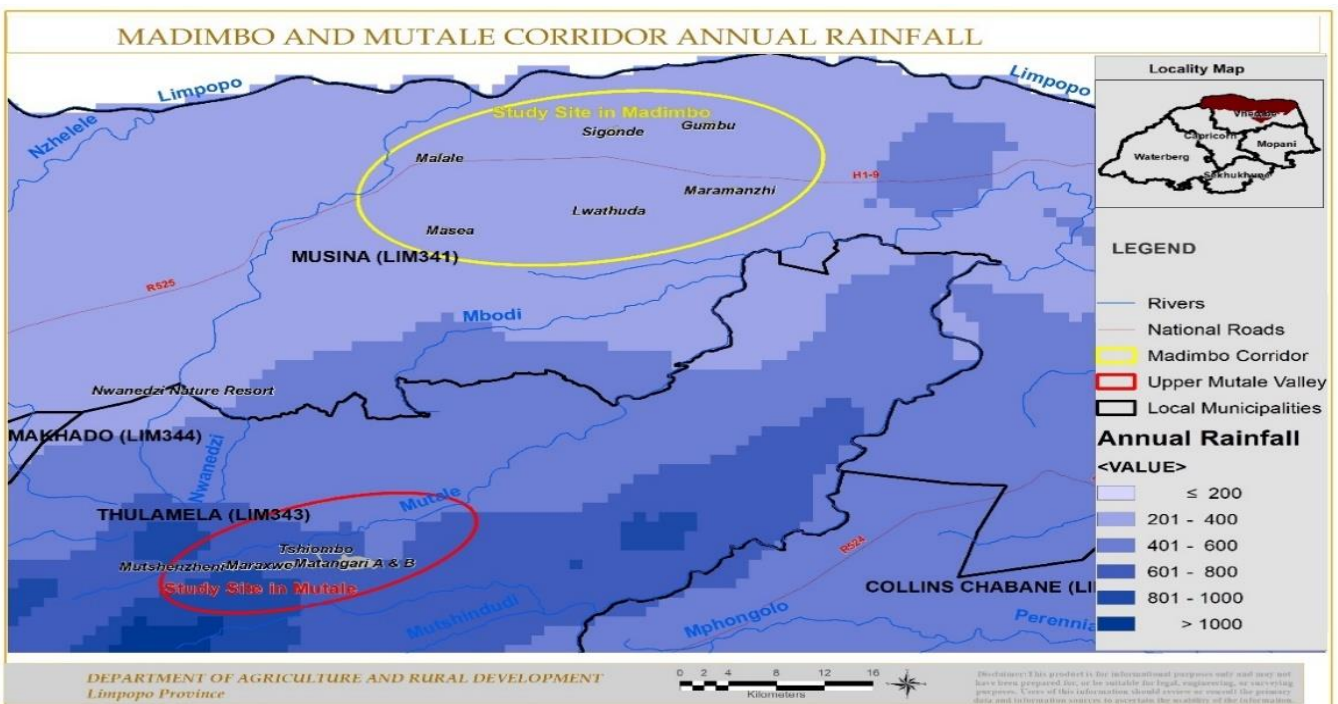
The minimum temperature in winter at Madimbo Corridor was like that of the Upper Mutale Valley at  $>10\text{ }^{\circ}\text{C}$  with lower temperatures ( $7.5\text{--}10.0\text{ }^{\circ}\text{C}$ ) recorded for some parts around the valley. Similarly, maximum winter temperatures were  $>24.0\text{ }^{\circ}\text{C}$  for both sites with lower temperatures ( $21.9\text{--}24.0\text{ }^{\circ}\text{C}$ ) recorded in some parts around the Upper Mutale Valley.

Within each of the study sites, temperatures could vary across specific localities influenced by aspects such as terrain. North-facing slopes optimise the repose angle with the sun, which increases sunlight and temperature (Inger, Ikha, Chanda, Ram, Kailash and Bharat, 2015). Also, altitude is a critical variable for growth and yield potential of crops (Smith and Donahue, 1991; Terashima, Masuzawa, Ohba and Yokoi, 1995; Sakata and Yokoi, 2002). Gale, (2004) implies that although altitude is often overlooked in assessment of crop production potential, it contributes immensely to good health and plant growth.

## (b) Rainfall

Rainfall (trend and quantity) influences the state of water resources at any given locality (Omokanye, Yoder, Sreekumar, Vihvelin and Benoit, 2018). There is a strong relationship between precipitation and the prevalent agro-ecological setting (Kala, 2012). According to He, Joshi, and Zhang, (2013), rainfall is a primary factor in rain-fed agriculture. Daccache, Ciurana, Rodríguez, Díaz, and Knox (2012) inferred that the distribution and quantity of precipitation influenced crop yields, especially in semi-arid regions. Elwell (1994) established a linear relationship between crop yields and precipitation.

According to Mosase and Ahiablame, (2018), the Limpopo River Basin, of which the study area forms a small part, received monthly rainfall more than 100 mm for some rainy months. Proper selection of crops to be produced in Madimbo Corridor (Musina Local Municipality) and Upper Mutale Valley (Thulamela Local Municipality) necessitated information on rainfall received in the study area (Figure 5.6).



**Figure 5.6:** Annual rainfall distribution at Madimbo Corridor and Upper Mutale Valley

Madimbo Corridor received rainfall of 201–400 mm per annum, whereas the Upper Mutale Valley received higher rainfalls varying between 401–600 mm and 601–800 mm per annum, although some localities around the valley received 201–400 mm of rainfall per annum (Figure 5.6). In accordance with its low rainfall, Madimbo Corridor was characterised by a severe lack of water resources. This lack was exacerbated by higher rates of evapotranspiration associated with relatively higher temperatures (Derya, Mehmet, Süha, Sermet and Tomohisa, 2009). Production of most crops would, therefore, be difficult in the Madimbo Corridor—except under irrigation. In semi-arid tropics, unreliable rainfall combined with high evaporative demand result in a high risk of water deficit at any stage of crop growth (Muchow and Bellamy, 1991). As alluded to previously, in addition to seasonal rainfall variability, higher growing season temperatures can have dramatic impacts on agricultural productivity (Battisti and Naylor, 2009).

Research findings have illustrated the occurrence of climate change and variability quite broadly. Spatial considerations have comprehensively demonstrated climate variability. For instance, temperatures were reportedly higher in arid and semi-arid regions of the African continent (which includes the study area) compared to those of other continents (Almazroui, Saeed, Saeed, Islam, Ismail, Klutse and Siddiqui, 2020). Also, temporally, climate has been reported to be changing. Lynam and Brown, (2011) indicated to increases in temperature over time that tend to serve as a stressor with detrimental effects on agricultural production. According to Nhamo, et al., (2018), the general trend indicates increasing rainfall variability with incidences of floods and droughts. Accordingly, some variability was observed even between the two study sites.

Stresses brought about by climate change were, in fact, reported to have adverse effects on broader agricultural sector performance and economic development (Faramarzi, Abbaspour, Vaghefi, Farzaneh, Zehnder, Srinivasan and Yang, 2013). As affirmed by Nhamo, et/ al., (2018), projected increases in warming conditions across most parts of the region would worsen the challenges associated with water insecurity (mainly due to reduced rainfall), adversely affecting both rainfed and irrigated agricultural production.

#### 5.3.1.2 Climate suitability for selected field crops

With the climatic condition of the study area assessed, determination of the suitability of the area for production of the selected crops based on climate necessitates knowledge of the climatic requirements of the designated crops. Such determination entails comparison of their climatic requirements with the climatic condition in the study area (Table 5.1).

**Table 5.1.** Climatic suitability of Madimbo Corridor and Upper Mutale Valley in Vhembe District Municipality of Limpopo province for production of maize (*Zea mays L*), dry bean (*Phaseolus vulgaris*), and sweet potato (*Ipomoea batatas L*)

Period	Climatic factor	Production area climatic condition		Selected crops required climatic condition		
		Madimbo Corridor	Upper Mutale Valley	Maize	Dry bean	Sweet potato
Summer	Min temperature (°C)	>17.4	>17.4 (15.3–17.4)	21–32	18–24	21–30
	Max temperature (°C)	>31.0	29.3–31 (27–29.2; >31)			
Winter	Min temperature (°C)	>10.0	>10.0 (7.5–10)	350–450	400–500	360–400
	Max temperature (°C)	>24.0	>24.0 (21.9–24)			
Annual	Rainfall (mm/annum)	201–400 (401–600)	401–600 601–800 (201–400)			

**(a) Temperature suitability**

Temperature is one of the major environmental factors affecting the growth, development and yields of crops, especially the rate of development (Luo, 2016). According to du Plessis, (2003,) maize is a summer crop and requires a frost-free period of 120 to 140 days to prevent damage. Maize crop production requires a minimum of 21 °C and a maximum of 32 °C for optimal growth. In comparison with the temperature in the area, the minimum temperature in summer at Madimbo Corridor was >17.4 °C with a maximum temperature of >31 °C. At Upper Mutale Valley, minimum temperature in summer was also >17.4 °C (the same as Madimbo Corridor) with temperatures of 15.3–17.4 °C recorded in some localities around the valley. The maximum summer temperature in the Upper Mutale Valley was 29.3–31°C, with some localities around the valley having recorded temperatures of 27–29.2 and 31 °C (Figure 5.2, Figure 5.3).

The minimum winter temperatures were  $>10\text{ }^{\circ}\text{C}$  at both Madimbo Corridor and Upper Mutale Valley, while the maximum temperatures were  $>24\text{ }^{\circ}\text{C}$  for both sites. Based on temperature conditions, maize may reasonably be considered for production in the study area during the summer season, and this affirms the statement by du Plessis, (2003). The minimum summer temperatures of the study sites were slightly lower than the requirement for optimum growth of the maize plant. Accordingly, production of the maize crop should involve manipulation of planting dates—to avoid the colder spells—and choice of cultivars that are more adaptable to the temperatures in these areas. Higher temperatures can cause severe yield reductions; their effects on silk-tasseling are difficult to identify because of the short duration of that phase (Porter and Semenov, 2005). The frequency of extreme temperatures may reduce yield, but a direct relation is not quantifiable because temperature and water availability act together in a nonlinear manner to crop response (Bonfante, Monaco, Alfieri, De Lorenzi, Manna, Basile, and Boumax, 2015).

The dry bean is a crop which thrives in a warm climate. With a temperature requirement of  $18\text{ }^{\circ}\text{C}$  to  $24\text{ }^{\circ}\text{C}$ , the crop can successfully be produced in both study sites, provided the colder winter temperatures are avoided. Temperatures during the flowering stage that were too high led to abscission of flowers and a low pod set, resulting in yield loss. Day temperatures below  $20\text{ }^{\circ}\text{C}$  delayed maturity and caused empty mature pods to develop. The sweet potatoes adapted well in the warm climate. The crop is sensitive to cold and should not be planted until the danger of frost is over. Best growth temperatures are  $21\text{--}30\text{ }^{\circ}\text{C}$ , and the crop can, therefore, be successfully produced in the area(s) under study. Sweet potatoes require four months of frost-free growing season (120 days). Due to high temperatures sometimes experienced in the production area, smallholder agricultural entrepreneurs should plant in early or late summer to avoid extreme temperatures. This can also increase a chance of earning high profit due to producing off-season when the crop is not produced in other areas.

#### **(b) Rainfall suitability**

Field crops are native to specific areas in geological time (Raihana, Marikkar, Amin and Shuhaimi, 2015) and are known to be suitable in marginal areas characterised by severe dry spells and flash floods (Massawe, Mayes and Cheng, 2016). South Africa is considered a dry country with more of its area experiencing below average annual rainfall.

Low-lying coastal areas receive moist air from the east and south of the Limpopo Basin, giving rise to a better rainfall distribution and longer growing season (Tadross, Hewitson, and Usman, 2005). In these areas, rainwater harvesting can play a significant role in reducing production risk in smallholder cropping systems (Bouma, Hegde, and Lasage, 2016). The high variability in the length of the growing season further confirms the need for adopting production risk mitigating measures, such as growing drought tolerant crops, staggered planting and soil water management. The amount of water required to produce one kilogram of the three selected crops was estimated at 1.5 m<sup>3</sup>, 1.0 m<sup>3</sup> and 2.5 m<sup>3</sup> respectively (Bouman, 2009). It was, therefore, anticipated that areas with limited water availability due to climate change impacts would experience significant losses of crop yields, and that would compromise food security in the long term (Olabanji, Ndarana, and Davis, 2021).

Maize requires a minimum of 350–450 mm of rainfall per annum to produce optimum yield. In comparison with the rainfall in the study area, the available average rainfall was 201–400 mm in Madimbo Corridor and between 401–600 mm and 601–800 mm in the Upper Mutale Valley. Based on the rainfall condition, the Madimbo Corridor was too dry for dryland maize production, while the Upper Mutale Valley tended to be suitable. At maturity, maize requires enough water to maximise grain filling. Evapotranspiration was estimated at 365.3 mm at the Upper Mutale Valley and 456.4 mm at Madimbo Corridor.

As indicated by DAFF, (2010), dry beans cultivated under rain-fed conditions required a minimum of 400–500 mm rainfall during the growing season; however, an annual total of 600–650 mm was considered ideal. The rainfall condition at Madimbo Corridor was too low for rainfed production of this crop, while that at the Upper Mutale Valley was adequate. Low relative humidity led to flower abscission and low pod set, which is aggravated by low soil moisture.

Also, rainfall at the Madimbo Corridor was too low for dryland production of sweet potato, while that at the Upper Mutale Valley seemed adequate.

### 5.3.2 Soil conditions and suitability

#### 5.3.2.1 Soil conditions

The important role of soils in crop production includes the source of support (anchor) to the plant and the supply of nutrients, water, and oxygen. The extent to which the soil can play these roles in the production of crops tends to be influenced by its properties. The soil properties could be categorised as physical, chemical and biological. Physical properties include texture, structure, bulk density and porosity; chemical properties include pH, cation exchange capacity (CEC), base saturation, sodium adsorption ratio (SAR), salinity, and the concentration of specific plant nutrients (e.g. nitrogen, phosphorus, potassium, etc.), while biological properties include content of organic matter, active total carbon, and occurrence of earthworms, nematodes, fungi and bacteria. The various properties are influenced by soil types occurring in the study area (Figure 5.7).

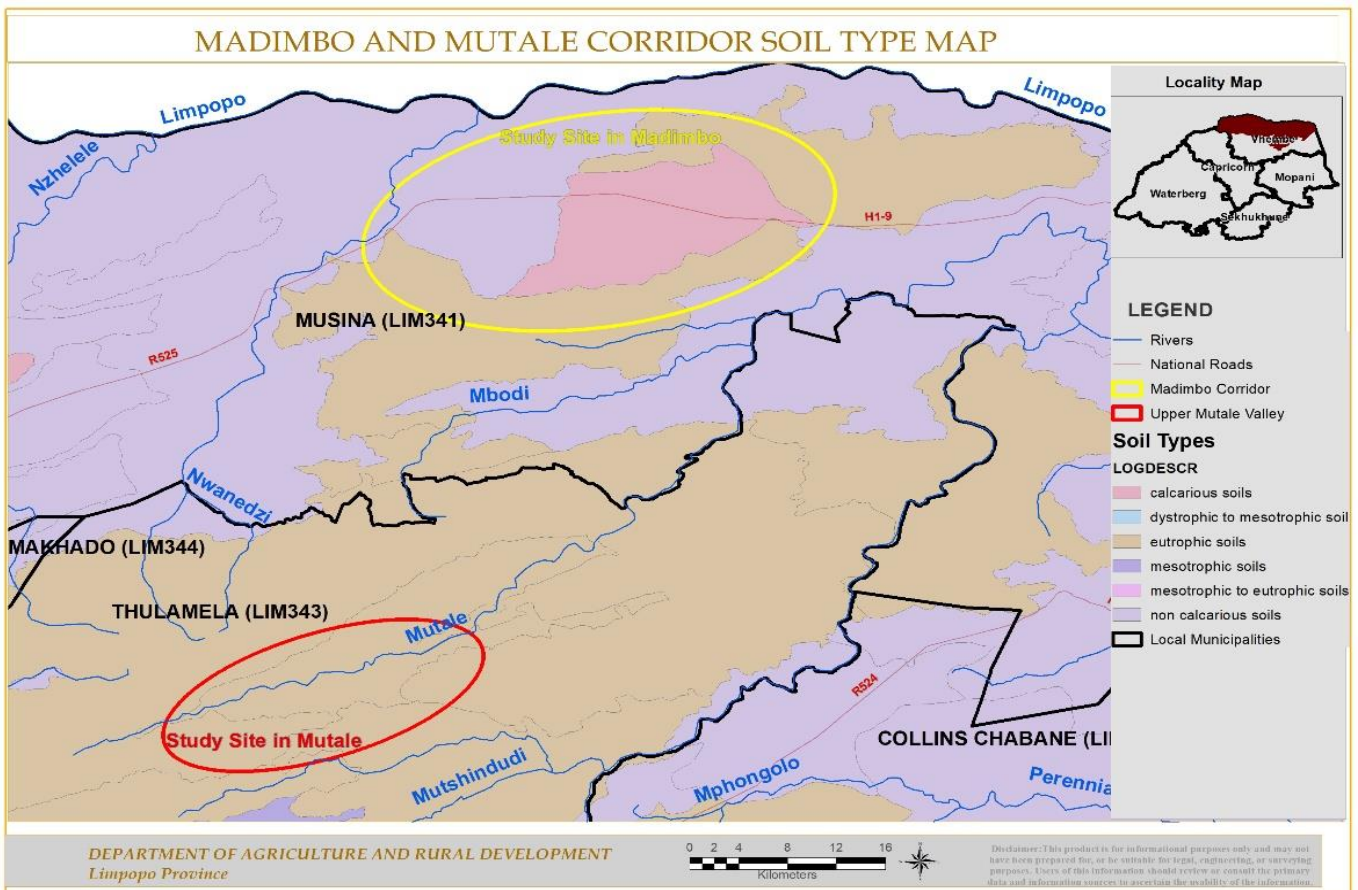


Figure 5.7: Soil types at Madimbo Corridor and Upper Mutale Valley

As mentioned, soil type determines the capacity of the soil to store water and nutrients, and the level of aeration, drainage, and ease of working on the field. In Madimbo Corridor, the soil types were predominantly calcareous and eutrophic, whereas in Upper Mutale Valley the soil type was solely eutrophic (Figure 5.7). Calcareous soils as observed in Madimbo Corridor have higher contents of calcium carbonates (lime). The soils tend to be in flocculated condition (granulated), have high porosity and are, accordingly, more permeable to water and air; these could be favourable attributes for field crop production. The soils tend to have high pH and are sometimes referred to as alkaline soil. Calcareous soils are formed in arid areas; hence, their occurrence in the low rainfall Madimbo Corridor. Madimbo Corridor had fine-grained sandstone with calcareous concretions (Johnson, Stallwood, Kimura and Hallberg, 2006).

Within the Corridor, the Gumbu Group was characterised predominantly by marbles and calc-silicate rocks with minor greywacke—and for most of the site, the geology was covered by quaternary sediments in which mainly sandy soils have formed (van 't Zelfde, 2019). With regards to the Upper Mutale Valley, soils were described as deep and well drained, with small portions of moderately drained soils in some places (Nethononda and Odhiambo, 2011).

Eutrophic soils were observed in both the Madimbo Corridor and the Upper Mutale Valley and were described as soils with high nutrient loading, resulting in increased availability of the nutrients to plants. The word 'eutrophic' is a Greek word that means 'well fed' (Weaver and Summers, 2001); hence, the eutrophic soils were regarded to be rich with nutrients such as nitrogen and phosphorus. Also, eutrophication can be defined as 'the nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, among which increased production of algae and macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water uses' (OECD, 1982). The adverse effects of eutrophication of water bodies necessitate proper management of agricultural soils to reduce the flow of nutrients to the water bodies.

#### 5.3.2.2 Soil suitability

Land suitability assesses the appropriateness of land for production of crops (Ziadat, 2007). Precisely, land suitability evaluates land capability as well as other factors such as land quality (Malczewski, 2006). Suitability of the soils for production of crops, including those selected for this study, was influenced by soil properties, whether physical or chemical (Table 5.2).

**Table 5.2** Soil suitability for production of maize (*Zea mays L*), dry bean (*Phaseolus vulgaris*), and sweet potato (*Ipomoea batatas*) at Madimbo Corridor and Upper Mutale Valley in Vhembe District Municipality of Limpopo province, South Africa

Suitable soil data required and available for selected field crops						
Variables	Category	Soil data required by selected crops			Soil condition at production area	
		Maize	Dry bean	Sweet potato	Soil condition at Madimbo Corridor	Soil condition at Upper Mutale Valley
Soil physical status	Average clay %	≥10	≥15 and ≤35	≤25	≥5 and ≤10	≥16 and ≤32
	Effective soil depth	≥60 and <90 cm	≥40 cm	≥60 cm	≥30 and <150 cm	≥120 cm
Soil chemical status	pH	≥5.8 and ≤7.0	≥5.5 and ≤7.5	≥4.5 and ≤7.5	≥7.0 and ≤8.94	≥5.7 and ≤7.2

The soil required for optimal maize production should texturally have ≥10 percent clay, effective depth of at least 60 cm and a pH of between 5.8 and 7.0. The soil condition at Madimbo Corridor was observed to possess a lesser clay proportion (≥5 and ≤10) and higher pH (≥7.0 and ≤8.94) than the crop requirements. Production of the crop in this area tends to require some corrective measures to the soil to allow for optimum yields. To the contrary, the soils at the Upper Mutale Valley were observed to be suitable for maize production considering all the properties— clay percentage (≥16 and ≤32), effective depth (≥120 cm), and pH (≥5.7 and ≤7.2). Although large-scale maize production takes place in soils with a clay content of greater than 10% (sandy soils) or more than 30% (clay and clay-loam soils), the texture classes between 10% and 30% have air and moisture regimes that are optimal for healthy maize production (DAFF, 2003).

Dry bean was reported to require a soil with a clay percentage of between 15 and 35, effective depth of at least 40 cm, and a pH between 5.5 and 7.5. Soils at Madimbo Corridor would be less favourable for dry bean production, especially when clay percentage and pH were considered, while those at the Upper Mutale Valley were suitable in all respects. Sandy loam, sandy clay loam or clay loam soils with a clay content of between 15% and 35% are suitable (DAFF, 2010). As stated in DAFF, (2010), beans grow well in soils with a depth of at least 90 cm, which have no deficiencies and are well drained. As for sweet potato, the soil pH seemed to be a challenge affecting suitability for optimum production of this crop, especially at Madimbo Corridor. Heavy clay soil should be avoided as they can retard root development (DAFF, 2011).

#### **5.4. Conclusion and Recommendations**

##### **5.4.1 Conclusion**

###### **(a) Climate suitability**

The results for climate suitability for maize, dry bean, and sweet potato production in Madimbo Corridor and Upper Mutale Valley varied for the two assessed climatic factors—temperature and rainfall. The temperature conditions, especially summer temperatures that were minimum  $>17.4^{\circ}\text{C}$  and maximum of about  $31^{\circ}\text{C}$  (both sites) were generally suitable for production of the three selected crops. Proper management of agronomic practices such as planting dates and cultivar selection would be necessary for critical growth stages of the crops not to coincide with unfavourable temperature conditions.

With regards to moisture, Madimbo Corridor received less rainfall (201–400 mm per annum) than the minimum required by each of the three crops—maize (350–450 mm), dry bean (400–500 mm) and sweet potato (360–400 mm per annum) and would generally not be suitable for rainfed production. Contrary to the situation at Madimbo Corridor, the rainfall at the Upper Mutale Valley (401–600 mm and 601–800 mm per annum) sufficed for production of all the three crops under study.

**(b) Soil suitability**

Results for soil suitability varied for the two study sites. Soils at Madimbo Corridor possessed a rather less clay proportion ( $\geq 5$  and  $\leq 10$ ) and higher pH ( $\geq 7.0$  and  $\leq 8.94$ ) than the clay proportion of  $\geq 10\%$  and pH of  $\geq 5.8$  and  $\leq 7.0$  respectively as required for maize. To the contrary, the soils at the Upper Mutale Valley were observed to be suitable for maize production considering all the properties—clay percentage ( $\geq 16$  and  $\leq 32$ ), effective depth ( $\geq 120$  cm), and pH ( $\geq 5.7$  and  $\leq 7.2$ ). Also, soils at Madimbo Corridor were less suitable for production of dry bean with a requirement of 15%–35% clay content and pH of 5.5–7.5 while those at the Upper Mutale Valley were suitable. Similar results were also reflected for sweet potato.

5.4.2 Recommendations

Based on the results of the study, it is recommended that:

- (a) Decisions on crops to be produced in any area should consider climatic and soil suitability of such areas.
- (b) Where justifiable, crops may be selected for production in an area where a factor of climate or soil may not be suitable, and measures should be in place for minimising the adverse effect of the less suitable factor on crop production. Such measures may include provision of resources for correcting the less suitable climate and soil factors or use of pertinent agronomic practices for minimising adverse effects of such factors.

## CHAPTER 6

### 6. DEMOGRAPHY AND LIVELIHOODS AT IRRIGATED SMALLHOLDER AGRICULTURAL ENTERPRISES AND THEIR ASSOCIATION WITH THE CULTIVATION OF MAIZE (*ZEA MAYS L.*) AS SELECTED FIELD CROP

#### **ABSTRACT**

*The study was conducted at the Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes. The purpose of the study was to characterise smallholder agricultural women and youth enterprises under irrigation (ISHAE-WY). A semi-structured household questionnaire together with facilitation was used to survey a sample, purposively focusing on ISHAE-WY. The sample comprised 294 respondents with sub-samples selected through gender, age, and gender by age categories. The study revealed that the ISHAE-WY are characterised by small plot (average size of one hectare) under cultivation. Participation of women was 15% compared to 20% of men in the winter production of maize. Production participation by ISHAE-WY farmers for summer revealed that women were participating at 66.7% compared with 86.75% for men. The participation of ISHAE-WY around the ages of 36–59 years was at 17.4%, while that for ages >60 years was at 13.2% in winter; in summer the ages of 36–59 years were at 71.6%, while that for ages >60 years was at 73.5%. The main source of variation may be the level of experience that the said age group of ISHAE-WY may have in the production of maize compared to 16.9% in winter and 53.5% in summer of 18–35-year participants. About 69.1% of ISHAE-WY were at the level of Adult Basic Education and Training (ABET). Around 69.8% of the ISHAE-WY earned less than R5 000 compared with 60.9% earning more than R5 000. The crop was more aligned to food security than market oriented. Market channels and access, not only to informal but also commercial mill markets, should be promoted for ISHAE-WY to enable the quantity of maize.*

## 6.1 Introduction

Maize is described as a cereal crop from the family *Graminea* with the botanical name, *Zea mays L* (Macauley, 2015). It is the most important grain crop in South Africa, being both the major feed grain and staple food for most of the South African population (DAFF, 2003). In support of the above, it is also the most important summer crop in terms of the area devoted to the crop and number of growers (Machethe, Mollel, Ayisi, Mashatola, Anim and Vanasche, 2004; Fanadzo, Chiduzza, Mnkeni, Van der Stoep, and Stevens, 2010a). Moreover, it is produced throughout the country under diverse environments (Beinart, 2018). Successful maize production depends on applying the correct sustainable practices that will sustain the environment, as well as agricultural production. These sustainable practices include soil tillage system, rainwater harvesting technique and water-use efficiency, integrated pest management and integrated nutrient management. A sustainable practice like crop rotation has been noted as the cornerstone of sustainable agriculture, as it keeps soils healthy and crops at their peak nutritional value (Merfeld, 2009), thereby improving crop productivity. Maize requires 450–600 mm of rainfall per production season, which is mostly acquired from the soil moisture reserves (DAFF, 2003). If the production area receives less rainfall than the potential required, irrigation should supplement available moisture. Improving water use efficiency in irrigation farming is more imperative than ever (de Villiers, Eloff, Barnard, Mulibana, Mkhize and Msomi, 2004). Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19 °C or where the mean of the summer months is less than 23 °C (DAFF, 2003).

DAFF, (2003) shows that in developing countries, including South Africa, maize is consumed directly and serves as the staple diet for some 200 million people. In contrast to the above, developed countries consumed maize mainly as second cycle produce, after meat, eggs and dairy products, including breakfast cereal. However, in a processed form it is also found as fuel (ethanol) and starch. Starch, in turn, involves enzymatic conversion into products such as sorbitol, dextrin, sorbic and lactic acid and appears in household items such as beer, ice cream, syrup, shoe polish, glue, fireworks, ink, batteries, mustard, cosmetics, aspirin and paint (DAFF, 2003). Higher-yielding cultivars are a prerequisite to achieving high maize yields as noted by USDA (2003).

This means that the producers must be successful at both the sophisticated crop production process as well as at contracting with agribusiness that controls the marketing of high value food chains (Cartwright, 2002).

According to Sihlobo (2022), maize planted at 2,60 million hectares in the 2022/23 season, and this area is slightly below the 2021/22 season of 2,62 million hectares. Sihlobo (2022), Further indicated that South Africa's maize harvest could amount to 15,00 million tonnes in the 2022/23 season, marginally down from 15,33 million tonnes of the 2021/22 season. The maize industry is becoming increasingly important and currently a major earner of foreign exchange, through the export of maize and maize products (Macauley, 2015). Since maize is the dominant staple crop in South Africa, it could have substantial positive impacts on the livelihoods and food security of smallholder farmers (Zuma, Kolanisi and Modi, 2018). The objective of this study was to determine the demography and livelihoods at ISAE-WY in association with the cultivation of maize as selected field crop. The information generated from the study is important for guiding future research, ISAE-WY development, and the rehabilitation of maize commodity in Vhembe District Municipality.

## **6.2 Methodology**

### **6.2.1 Site description**

The research project was conducted at Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes. Madimbo Corridor is situated at Musina Local Municipality, whereas Upper Mutale Valley is based at Thulamela Local Municipality. All these municipalities are situated in Vhembe District Municipality of Limpopo province in South Africa. The agro-ecological condition at Madimbo Corridor is semi-arid, whereas Upper Mutale Valley is sub-humid. Observations show that conditions are significantly different. This confirms that the variables of smallholder irrigation enterprises are affected by diversity and similarities attributed to different demographic and livelihood needs.

### **6.2.2 Sampling procedure**

Systematic purposive sampling was used to select ISHAE-WY within districts with strong emphasis on women and youth. We used stratified sampling to obtain a representative sample of villages and households for interview (Leedy and Ormrod, 2005).

A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The *PROC SURVEYSELECT* allows selection of probability-based random sampling where sampling in different categories or class depends on the number of units within that class. It is appropriate for handling selection bias.

### 6.2.3 Data Collection

A semi-structured household questionnaire was used to survey with an emphasis on ISHAE-WY. The total number of ISHAE-WY interviewed were two hundred and ninety-four (N=294) with a response rate of 75 per cent. The sample was made up of 71 youths aged 18–35 years old (56 females and 15 males) and 223 women of whom 153 were adults (36–59 years) and 70 pensioners ( $\geq 60$  years old).

### 6.2.4 Data analysis

The Statistical Package for the Social Sciences (SPSS) Version 22 was used to analyse quantitative data. Descriptive statistics included frequency tables and measures of central tendency. Inferential statistics were in the form of chi-square analyses, which assessed the association between major demographic variables (gender, age, education, and income) and vegetable/field crop production, water resources and governance. Fischer Exact tests were interpreted in cases where the assumptions for chi-square analysis had been violated. A Bonferroni adjustment was made to prevent a type I error; therefore, significance was considered when  $p < 0.013$ .

## 6.3 Results and discussion

It should be noted that the Bonferroni correction was made due to multiple comparisons with the same dependent variable (cultivating maize); this correction decreases the possibility of making a type I error. Therefore, the significant value of 0,05 was adjusted to 0,013 (0,05/4). This level of significance was too steep for the effects of the demographic traits to be significance.

### 6.3.1 The production potential of maize crop by ISHAE-WY

The average area of maize production was found to be 0.75 ha per farmer. The production potential was found to be about 800 kg per ha. This shows that the commodity seems to be more for household food security than market oriented.

The average price earned for the production was R3 200.00 in an informal market priced at R4.00 per kilogram. The formal market potential for ISHAE-WY tended to decline due to a lower price offer of R2.88 per kilogram, which then would offer a lower income of R2 304.00.

### 6.3.2 The association between cultivating maize and gender

A chi-square test was conducted for association between cultivating maize and gender in winter and summer (Table 6.1).

Table 6.1: Association between gender of ISAE-WY and seasonal cultivation of maize crop in Vhembe District Municipality of Limpopo Province, South Africa

GENDER	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
MALE	Count	9	6	2	13
	Expected count	12.6	2.4	4.8	10.2
	% within gender of the respondent	60.0%	20.0%	13.3%	86.75%
	% within season's crop: maize	3.5%	12.5%	2.1%	6.5%
	% of total	3.1%	2.0%	7%	4.4%
FEMALE	Count	237	42	92	186
	Expected count	233.4	45.6	90.2	188.8
	% within gender of the respondent	84.9%	15.1%	33.3%	66.7%
	% within season's crop: maize	96.3%	87.5%	97.9%	93.9%
	% of total	80.6%	14.3%	31.6%	63.3%
TOTAL	Count	246	48	95	199
	Expected count	246.0	48.0	95.0	199.0
	% within gender of the respondent	83.7%	16.3%	32.3%	67.7%
	% within season's crop: maize	100.0%	100.0%	100.0%	100.0%
	% of total	83.7%	16.3%	32.3%	67.7%
			$\chi^2(2) = 0,628,$ $p = 0.730$		<b>Not Significant</b>

The results for the winter season indicated that not all the expected cell frequencies were greater than five to comply with the chi-square test. The assumption for the test was violated and the Fischer Exact test conducted. After a Bonferroni correction, the Fischer Exact test showed that there was no statistically significant association between cultivating maize and gender,  $p = 0.022$ . It was determined that that 40.0% males cultivated maize compared to 15.1% females. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.149$ ,  $p = 0.011$ . Similarly, for the summer season, the assumption was violated for chi-square test. The Fischer Exact test showed that there was no statistically significant association between cultivating maize and gender,  $p = 0.156$ . It was determined that 86.7% males cultivated maize compared to 66.7% females. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.094$ ,  $p = 0.107$ .

The chi-square tests generated provided insights into different socio-economic and biophysical features of ISHAE-WY. Odendo, de Groote and Odongo, (2002) showed that there are different roles played by gender in ISHAE-WY. Their findings were corroborated by the World Bank, (2002) stating that the primary pathway through which gender systems affect growth are by influencing the productivity and efficiency of the economy. Gender plays an important role in development and would therefore influence the profitability of ISHAE-WY. This participant includes those females who are divorced, single or widowed.

The female inclusion could be that most men work far away from their homes and women are the ones left at home to take care of the children and farm. The involving of women's participation in the smallholder irrigation farming practices can reduce the men's burden of being the only source of income in the rural household. This also can alleviate poverty and grow the local economy of Vhembe District.

### 6.3.3 The association between cultivating maize and age

A chi-square test was conducted for association between cultivating maize and age (Table 6.2).

Table 6.2: Association between the age of ISAERS W-Y and seasonal cultivation of maize crop in Vhembe District Municipality of Limpopo Province, South Africa

AGE (YEARS)	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
18–35	Count	59	12	33	38
	Expected count	59.4	11.6	22.9	48.1
	% within gender of the respondent	83.1%	16.9%	46.5%	53.5%
	% within season's crop: maize	24.0%	25.0%	34.7%	19.1%
	% of total	20.1%	4.1%	11.2%	12.9%
36–59	Count	128	27	44	111
	Expected count	129.7	25.3	50.1	104.9
	% within gender of the respondent	82.6%	17.4%	28.4%	71.6%
	% within season's crop: maize	52.0%	56.3%	46.3%	55.8%
	% of total	43.5%	9.2%	15.0%	37.8%
>60	Count	59	9	18	50
	Expected count	59.9	11.1	22.0	46.0
	% within gender of the respondent	86.8%	13.2%	26.5%	73.5%
	% Within season's crop: maize	24.0%	18.8%	18.9%	25.1%
	% of total	20.1%	3.1%	6.1%	17.9%
TOTAL	Count	246	48	95	199
	Expected count	246.0	48.0	95.0	199.0
	% within gender of the respondent	83.7%	16.3%	32.3%	67.7%
	% within season's crop: maize	100.0%	100.0%	100.0%	100.0%
	% of total	83.7%	16.3%	32.3%	67.7%
			<b><math>\chi^2(2) = 0,628, p = 0.730</math></b>		<b><math>\chi^2(2) = 8,668, p = 0.013</math></b>

In winter, a chi-square test for association was conducted between cultivating maize and age. All the expected cell frequencies were greater than five, complying with the assumption of the chi-test.

The results indicated that there was no statistically significant association between cultivating maize and age,  $\chi^2 = 0,628$ ,  $p = 0.730$ . It was determined that 16.9% of 18–35-year participants cultivated maize, compared to 17.4% and 13.2% of 36–59 year participants and >60 year participants respectively. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.046$ ,  $p = 0.730$ . Therefore, in summer, a chi-square test for association was conducted between cultivating maize and age.

Similarly, after a Bonferroni adjustment, there was no statistically significant association between cultivating maize and age,  $\chi^2 = 8,668$ ,  $p = 0.013$ . It was determined that 53.5% of 18–35-year participants cultivated maize compared to 71.6% of 36–59-year participants and 73.5% of >60 year participants. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.172$ ,  $p = 0.013$ .

The age of an individual is one of the most important factors that determine the way he or she thinks and behaves (Dagada, Nesamvuni, Tshikolomo, van Rooyen and Stroebel, 2015). In support of the same narrative, Agbugba, Nweze, Achike and Obi, (2018) indicated that age was found to be an important factor in diverse agricultural enterprises. It was also stated that most socio-economic studies have shown age to be inversely related to performance. The types of decisions made by elderly people and their behaviour tend to be different from their younger counterparts. The age of ISHAE-WY has a strong effect on the family's agricultural productivity and profitability, and this could be a result of the influence of age on such variables as education and farming experience. The involvement of pensioners (above 60 years of age) might indicate that they are still willing to work hard and provide for their families while they are old, even though they might not be able to work for longer hours. Mpinyane and Terblanche (2005) as cited by Nesamvuni, Tshikolomo, Belete and Motaung, (2014) confirm that negative correlation (Pearson  $r = -0.272$ ;  $p = 0.037$ ) was found between age and the level of education, indicating that older farmers tended to have lower levels of education. Age has a negative impact on the achievement of sustainable agriculture for smallholder farmers (Odoemenem and Adebisi, 2011).

Young farmers are reported to be more responsive to new ideas and practices, while older farmers are more conservative and less responsive to the adoption of new ideas and practices (Amaza, Olayemi, Adejobi, Bila and Iheanacho, 2007). Substantiating the above, ISHAE-WY are observed to be operating less productively due to their age, in comparison to youthful age, which seems to be more productive. Most of the youth in the area may not be interested in farming work, having left the area in search of higher paying employment (Obi and Pote, 2012) for white-collar jobs, thereby creating a gap.

#### 6.3.4 The association between cultivating maize and education

A chi-square test was conducted for association between cultivating maize and household head education, both in winter and in summer (Table 6.3). In winter, a chi-square test for association was conducted between cultivating maize and household head education. All the expected cell frequencies were greater than five and did not violate the chi-test assumptions. The results showed that there was no statistically significant association between cultivating maize and household head education,  $\chi^2 = 3.622$ ,  $p = 0.305$ . It was determined that 13.1% of participants with household head having no/primary education cultivated maize, while 14.7% of participants with household head having secondary education cultivated maize, and 27.3% and 16.0% of participants with household heads with tertiary education and ABET respectively cultivated maize. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.112$ ,  $p = 0.305$ . Similarly, for the summer season there was no statistically significant association between cultivating maize and household head education,  $\chi^2 = 0.364$ ,  $p = 0.948$ . It was determined that 68.9% of participants with household heads having no/primary education, while 65.5% of participants with household heads having secondary education and 66.7% and 69.1% of participants with household heads with tertiary education and ABET respectively.

Table 6.3: Association between the education of ISAE-WY and seasonal cultivation of maize crop in Vhembe District Municipality

EDUCATION	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
PRIMARY	Count	53	8	19	42
	Expected count	51.1	9.9	19.9	41.1
	% within gender of the respondent	86.9%	13.1%	31.1%	68.9%
	% within season's crop: maize	21.7%	17.0%	20.0%	21.4%
	% of total	18.2%	2.7%	6.5%	14.4%
SECONDARY	Count	99	17	40	76
	Expected count	97.3	18,7	37.9	78.1
	% within gender of the respondent	85.3%	14.7%	34.5%	65.5%
	% within season's crop: maize	40,6%	36.2%	42.1%	38.8%
	% of total	34.0%	5.8%	13.7%	26.1%
TERTIARY	Count	24	9	11	22
	Expected count	27.7	5.3	10.8	22.2
	% within gender of the respondent	72.7%	27.3%	33.3%	66.7%
	% within season's crop: maize	9.8%	19.1%	11.6%	11.2%
	% of total	8.2%	3.1%	3.8%	7.6%
ABET	Count	68	13	25	56
	Expected count	67.9	13.1	26.4	54.6
	% within gender of the respondent	80.4%	16.0%	30.9%	69.1%
	% within season crop: maize	27.9%	27.7%	26.3%	28.6%
	% of total	23.4%	4.5%	8.6%	19.2%
TOTAL	Count	244	47	95	196
	Expected count	244.0	47.0	95.0	196.0
	% within gender of the respondent	83.8%	16.2%	32.6%	67.4%
	% within season's crop: maize	100.0%	100.0%	100.0%	100.0%
	% of total	83.8%	16.2%	32.6%	67.4%
		$\chi^2(3) = 3,622, p = 0.305$		$\chi^2(3) = 0,364, p = 0.948$	

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.035$ ,  $p = 0.948$ . A review of literature shows that education is a vital force to reckon with in effective farming household performance and could inform on how best a new technology is adopted (Abugba, Christian and Obi, 2020). According to Alam, (2010), education enables farmers to appreciate the advantages of new technologies. In this study, there were 68.9% of ISHAE-WY that had no education or primary level.

Low levels of farmers' education were reported in several studies as a limiting factor, resulting in inability to interpret market information to be used in production planning and marketing in South Africa (Mngqawa, et. al., 2016). Better education may, therefore, be associated with improved adaptive capacity to adverse effects of climate change and variability. A farmer's level of education has a direct impact on his/her ability to properly manage a given irrigation technology, but lack of formal training in agriculture for most farmers could pose a limitation to their productivity.

### 6.3.5 The association between cultivating maize and income

A chi-square test was conducted for association between cultivating maize and monthly income in winter and in summer (Table 6.4).

Table 6.4: Association between monthly income of ISAE-WY and seasonal cultivation of maize crop in Vhembe district

INCOME	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
<R5 000	Count	186	39	68	157
	Expected count	188.3	36.7	72.7	152.3
	% within gender of the respondent	82.7%	17.3%	30.2%	69.8%
	% within season's crop: maize	75.6%	81.3%	71.6%	78.9%
	% of total	63.3%	13.3%	23.1%	53.4%
>R5 000	Count	60	9	27	42
	Expected count	57.7	11.3	22.3	46.7
	% within gender of the respondent	87.0%	13.0%	39.1%	60.9%
	% within season's crop: maize	24.4%	18.8%	28.4%	21.1%
	% of total	20.4%	3.1%	9.2%	14.3%
TOTAL	Count	246	48	95	199
	Expected count	246.0	48.0	95.0	199.0
	% within gender of the respondent	83.7%	16.7%	32.3%	67.7%
	% within season's crop: maize	100.0%	100.0%	100.0%	100.0%
	% of total	83.7%	16.3%	32.3%	67.7%
		$\chi^2(1) = 0,711, p = 0.399$		$\chi^2(1) = 1,916, p = 0.166$	

In winter, a chi-square test was conducted for association between cultivating maize and monthly income. All the expected cell frequencies were greater than five and did not violate the chi-test assumptions. The results indicated that there was no statistically significant association between cultivating maize and monthly income,  $\chi^2 = 0.711$ ,  $p = 0.399$ . It was determined that 17.3% of participants earning <R5 000 a month cultivated maize, compared to 13.0% of those earning >R5 000 a month.

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.049$ ,  $p = 0.399$ . Similarly, in summer there was no statistically significant association between cultivating maize and monthly income,  $\chi^2 = 1.916$ ,  $p = 0.166$ . It was determined that 69.8% of participants earning <R5 000 a month cultivated maize, compared to 60.9% of those earning >R5 000 a month. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.081$ ,  $p = 0.166$ . The results seem to corroborate the trend that support the commodity as a food security aligned crop. Family enterprises that earn less than R5 000 had higher participation at 17.3% as compared to 13%. The exceptional role played by smallholder farmers in developing Africa's agriculture, brings about high economic interest and, indeed, raises additional incomes at the farm or farmer level, all things remaining equal (Ezihe, Agbugba and Idang, 2017). This could be because farmers who use ISAE-WY can intensify and diversify their agricultural activities, which increases their production. In South Africa, the potential grain yields that can be obtained under irrigation maize farming could range from 7–12 tons per ha (Fanadzo, Chiduzza and Mnkeni, 2009). Therefore, youths' increased access to formal education will likely make these communities more productive, and more amenable to accept, initiate, and manage development projects as opposed to the less economically active groups (Chimonyo, Mutengwa, Chiduzza and Tandzi, 2020). According to Nouman, Siddiqi, Asim, and Hussain, (2013), household income is also one of the determinants of the amount of credit that can be borrowed by the farmers. Farmers with higher incomes are likely to embrace and will be interested in adapting by changing practices and modern methods such as irrigation to cope with the changing climate (Gbetibouo and Ringler, 2009).

#### **6.4 Conclusion**

The results of the study indicated that gender, age, education, and income did not statistically influence the production of maize in the Madimbo Corridor in Musina Local Municipality and Mutale Valley in Thulamela Local Municipality. The study revealed that the ISHAE-WY are characterised by small land areas under maize cultivation. In return, youth farmers should help transfer technology and information to older farmers. Market channels and access should be promoted for ISHAE-WY to enable them to earn income through formal markets.

## CHAPTER 7

### 7. DEMOGRAPHY OF SMALLHOLDER WOMEN AND YOUTH AGRICULTURAL ENTERPRISES AND THEIR ASSOCIATION WITH THE CULTIVATION OF SWEET POTATO FIELD CROP

#### **ABSTRACT**

*The study was conducted at the Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes. The purpose of the study was to characterise smallholder agricultural women and youth entrepreneurs (ISHAE-WY) and their association with the cultivation of sweet potato field crop. A semi-structured household questionnaire together with facilitation was used to survey a sample, purposively focusing on ISHAE-WY. The sample comprised 294 respondents with sub-samples selected through gender, age, and gender by age categories. The study revealed that the ISHAE-WY are characterised by small land areas (on average 0.53 ha) under cultivation. The production potential was 2.5 tons per ha with an average income earned of R10 000 per production in an informal market priced at R4.00 per kilogram. The potential for ISHAW-WY in the formal market would be projected at R16 800 with an improved price of R6.72 per kilogram. The Fischer Exact test showed that there was a statistically significant association between cultivating sweet potato and gender,  $p = 0.009$ . It was determined that in winter 46.7% males cultivated sweet potato compared to 16.5% females. The participation rate in summer was less determined at 33.3% males who cultivated sweet potato compared to 16.8% females. The results showed that there was no significant association between age variable and cultivating sweet potato. It was determined that in winter 19.7% of 18–35-year participants cultivated sweet potato compared to 18.1% and 16.2% of 36–59 participants and >60-year participants respectively. Similarly, it was determined that in summer, 15.5% of 18–35-year participants cultivated sweet potato compared to 19.4% of 36–59-year participants and 16.2% of >60-year participants. There was no statistically significant association between cultivating sweet potato and household head education in both winter and summer seasons.*

*It was determined that in winter 13.1% of participants with household heads having no/primary education, while 17.2% of participants with household heads having secondary education and 30.3% and 16.0% of participants with household heads having tertiary education and ABET respectively. In summer, the results showed 14.8% of participants with household heads having no/primary education, while 19.0% of participants with household heads having secondary education and 24.2% and 13.6% of participants with household heads having tertiary education and ABET respectively. There was no statistically significant association between cultivating sweet potato and monthly income in both seasons. It was determined that 17.8% of participants earning < R5 000 a month cultivated sweet potato, compared to 18.8% of those earning >R5 000 a month in winter. In summer, 17.3% of participants earning <R5 000 a month cultivated sweet potato, compared to 18.8% of those earning >R5 000 a month. Sweet potato seems to be aligned with women, suggesting empowerment programs for women, extension, and literacy support through training input assistance for ISHAE-WY.*

## 7.1 Introduction

Sweet potato (*Ipomea batata L.*) is a vibrant traditional crop that is cultivated usually by small-scale farmers, primarily for family consumption. It is customarily viewed as a crop for the rural poor as it is typically grown and consumed by resource-poor families, and especially by women. Sweet potato is a crop that has a wide ecological adaptation, drought tolerance and short maturity period of three to five months (Agili, Nyende, Ngamau, and Masinde, 2012). In the semi-arid agro-ecological zone, this crop depends mostly on irrigation, and it gives satisfactory yields under adverse climatic and soil conditions, as well as under low or non-use of external inputs (Githunguri and Migwa, 2004; Carey *et al.*, 1999; Ndolo *et al.*, 2001; Kung'u, 1999). As a crop suitable for food security, it can be harvested in phases depending on the needs of the household. The crop offers a flexible source of food and income to rural families who are mostly susceptible to crop failure, and subsequently unstable cash income. It is also an exceptional source of vitamin A, especially the orange-fleshed varieties (Ndolo *et al.*, 2001). However, Stathers *et al.* (2005) indicated that most varieties in sub-Saharan Africa are white-fleshed, low yielding and lacking beta-carotene, the precursor of vitamin A.

Sweet potato is cultivated throughout tropical and warm temperature regions, wherever there is sufficient water to support growth. The major production areas of sweet potato in South Africa are Limpopo (Hoedspruit, Marble Hall, Burgersfort, Levubu), Mpumalanga (Nelspruit), KwaZulu-Natal and Western Cape (DAFF, 2011). The South African sweet potato production statistics (National Department of Agriculture, 2006) indicate that the industry is comparatively small. The average annual production was recorded as 51 000–56 000 tons in 2005.

The value and average price of sweet potato sold on the fresh produce market for 2005 was 26 938 tons, averaging a value of R 30 076 072—which calculates to a price of R 11 271 per ton. It has been reported that the informal sweet potato sector in South Africa produces large quantities and is marketed informally (Domola, 2003). It was projected that the total land under cultivation in this sector could be 2 000–3 000 ha, with an average yield of 5–10 tons per ha. The average yield within the commercial sector was 40 tons per ha, with land parcels of about 30 ha (Laurie in NidelWieser, 2004; Domola, 2003).

Though rural households and farmers did not cultivate the crop on large pieces of land, they produced it on any piece of land available in the home garden. This is done for own consumption and to generate income (Domola, 2003). The study conducted by Laurie *et al.* (2017) showed that (a) the informal marketing and sales are very irregular, (b) the size of storage was limiting and (c) it is dependent on the place of sale and type of customers. On average, farmers harvested the crop for home consumption with excess sold to the local market. According to Jansen (2022), Sweet potato volumes are usually lower than usual on the fresh produce markets of South Africa. The available volumes on the market had more than halved compared to a years ago while prices rose by 87%. Jansen (2022) further indicated that Johannesburg market agent are currently supplied by a single producer from the northern parts of Limpopo. Popular South African sweet potatoes cultivar sells for between R120 to R150 for a 15kg bag. This shows that an average price is estimated to be R8040 to R10050 per ton.

Central to the cultivation of sweet potato by rural households for food security and income is the demography of the farmers producing the crop. It is evident that W-Y in rural areas should not be neglected lest their social and economic conditions worsen. Socio-economic factors play a critical role in determining the levels of production undertaken and the sort of crops planted. von Braun and Mirzabaev, (2015) indicated that the production levels are not the only areas affected, but also the way business enterprises are managed, which puts the socio-economic characteristics of the smallholder farmers and entrepreneurs into focus. Previous studies (Mwaniki, 2006; Abdulai *et al.*, 2013; Asante *et al.*, 2013; Onumah *et al.*, 2013) have resolved that if assistance is to be extended to crop producers, their demography is worth investigating to fully comprehend their needs.

The relationship between demography and socio-economic factors will be described in this study to produce appropriate policy information for agricultural stakeholders and the government. The main objective of this study was, therefore, to assess the demography of women and youth agricultural enterprises and the association with the cultivation of sweet potato under irrigation.

## 7.2.1 Methodology

### 7.2.1 Site description

The study was conducted at Madimbo Corridor and Upper Mutale Valley smallholder irrigation schemes where the agro-ecological situations are significantly different. The conditions at Upper Mutale Valley are sub-humid and Madimbo Corridor smallholder irrigation scheme is semi-arid. This confirms that the variables of smallholder irrigation schemes are affected by diversity and similarities attributed to different livelihood needs. The Madimbo Corridor irrigated smallholder agricultural area is situated north-east of the Soutpansberg Mountains. It is located between 22°26'45.34"S latitude and 30°31'18.47"E longitude. Upper Mutale Valley area is located north of Thohoyandou in the Vhembe District Municipality of Limpopo. This irrigated smallholder agricultural area lies between 22°47'53.36"S latitude and 30°28'13.21"E longitude.

### 7.2.2 Sampling procedure

Stratified random sampling was used to obtain a representative sample of villages and households for interview (Leedy *et. al*, 2005), with the target population being ISHAE-WY. A two-stage random sampling process was conducted using SURVEYSELECT procedure of SAS. The PROC SUREVEYSELECT allowed for probability-based random sampling where sampling in a category or class depended on the number of units within that class. The sampling was regarded as appropriate for handling selection bias.

### 7.2.3 Data collection

A semi-structured household questionnaire was used to survey with an emphasis on ISHAE-WY. The total number of ISHAE-WY interviewed were two hundred and ninety-four (N=294) with a response rate of 75 per cent. The sample was made up of 71 youths aged 18 to 35 years old (56 females and 15 males) and 223 women, of whom 153 were adults (36-59 years) and 70 pensioners ( $\geq 60$  years old).

### 7.2.4 Data analysis

The Statistical Package for the Social Sciences (SPSS) Version 22 was used to analyse quantitative data. Descriptive statistics included frequency tables and measures of central tendency.

Inferential statistics were in the form of chi-square analyses, which assessed the association between major demographic variables (gender, age, education, and income) and vegetable/field crop production, water resources and governance. Fischer Exact tests were interpreted in cases where the assumptions for chi-square analysis had been violated. A Bonferroni adjustment was made to prevent a type I error; therefore, significance was considered when  $p < 0.013$ .

### **7.3 Results and discussion**

It should be noted that the Bonferroni correction was made due to multiple comparisons with the same dependent variable (cultivating sweet potato); this correction decreases the possibility of making a type I error. Therefore, the significant value of 0,05 was adjusted to 0,013 (0,05/4). This level of significance was too steep for the effects of the demographic traits to be significance.

#### **7.3.1 The production potential of sweet potato crop by ISHAE-WY**

The average area of production under irrigation was 0.53 ha per farmer. The production potential was 2.5 tons per ha, with an average income earned of R10 000 per production in an informal market, priced at R4.00 per kilogram. The potential for ISHAE-WY in the formal market would be projected at R16 800, with an improved price of R6.72 per kilogram.

#### **7.3.2 Association between gender and cultivation of sweet potato crop in winter and summer**

A chi-square test was conducted for association between cultivating sweet potato and gender in winter and summer is shown in Table 1.

Table 7.1: Association between gender and cultivation of sweet potato crop in winter and summer

GENDER	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
MALE	Count	8	7	10	5
	Expected count	12.3	2.7	12.3	2.7
	% within gender of the respondent	53.3%	46.7%	66.7%	33.3%
	% within season's crop: sweet potato	3.3%	13.2%	4.1%	9.6%
	% of total	2.7%	2.4%	3.4%	1.7%
FEMALE	Count	233	46	232	47
	Expected count	228.7	50.3	229.7	49.3
	% within gender of the respondent	83.5%	16.5%	83.2%	16.8%
	% within season's crop: sweet potato	96.7%	86.8%	95.9%	90.4%
	% of total	79.3%	15.6%	78.9%	16.0%
TOTAL	Count	241	53	242	52
	Expected count	241.0	53.0	242.0	52.0
	% within gender of the respondent	82.0%	18.0%	82.3%	17.7%
	% within season's crop: sweet potato	100.0%	100.0%	100.0%	100.0%
	% of total	82.0%	18.0%	82.3%	17.7%

Not all the expected cell frequencies were greater than five; therefore, the assumption was violated and the Fischer Exact test conducted. The Fischer Exact test showed that there was a statistically significant association between cultivating sweet potato and gender,  $p = 0.009$ . It was determined that 46.7% males cultivated sweet potato compared to 16.5% females. Although statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.173$ ,  $p = 0.003$ .

Similarly, in summer, not all the expected cell frequencies were greater than five; therefore, the assumption was violated, and the Fischer Exact test conducted. The Fischer Exact test showed that there was no statistically significant association between cultivating sweet potato and gender,  $p = 0.104$ . It was determined that 33.3% males cultivated sweet potato compared to 16.8% females.

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.095$ ,  $p = 0.103$ . Literature indicates that in most cases, females tend to be sidelined in terms of land ownership due to cultural norms, though they usually provide most of the farm labour (Deribe, 2008). The prominence of the climate scourge to ISHAE-WY makes it a necessary to establish the differences in the roles played by males and females in farm households. These gender differences are likely to influence their capacity to adapt to climate change, as well as their choices of climate change adaptation strategies (IFPRI, 2009). The involvement of women's participation in the smallholder irrigation farming practices can reduce the men's burden of being the sole source of income in the rural household. This also can alleviate poverty and grow the local economy of Vhembe District Municipality.

#### 7.3.4 Association between age and cultivation of sweet potato

A chi-square test was conducted for association between age of ISHAE-WY and cultivating sweet potato in winter and summer is shown in Table 7.2.

Table 7.2: Association between age and cultivation of sweet potato crop in winter and summer

AGE (YEARS)	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
18–35	Count	57	14	60	11
	Expected count	58.2	12.8	58.4	12.6
	% within gender of the respondent	80.3%	19.7%	84.5%	15.5%
	% within season's crop: sweet potato	23.7%	26.4%	24.8%	21.2%
	% of total	19.4%	4.8%	20.4%	3.7%
36–59	Count	127	28	125	30
	Expected count	127.1	27.9	127.6	27.4
	% within gender of the respondent	81.9%	18.1%	80.6%	19.4%
	% within season's crop: sweet potato	52.7%	52.8%	51.7%	57.7%
	% of total	43.2%	9.5%	42.5%	10.2%
>60	Count	57	11	57	11
	Expected count	55.7	12.3	56.0	12.0
	% within gender of the respondent	83.8%	16.2%	83.8%	16.2%
	% within season's crop: sweet potato	23.7%	20.8%	23.6%	21.2%
	% of total	19.4%	3.7%	19.4%	3.7%
TOTAL	Count	241	53	242	52
	Expected count	241.0	53.0	242.0	52.0
	% within gender of the respondent	82.0%	18.0%	82.3%	17.7%
	% within season's crop: sweet potato	100.0%	100.0%	100.0%	100.0%
	% of total	82.0%	18.0%	82.3%	17.7%
		$\chi^2(2) = 0,295, p = 0.863.$		$\chi^2(2) = 0,637, p = 0.727.$	

A chi-square test was conducted for association between cultivating sweet potato and age in winter. All the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and age,  $\chi^2 = 0.295, p = 0.863$ . It was determined that 19.7% of 18–35-year participants cultivated sweet potato compared to 18,1% and 16.2% of 36–59 participants and >60-year participants respectively. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.032, p = 0.863$ .

Similarly, in summer, all the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and age,  $\chi^2 = 0.637$ ,  $p = 0.727$ . It was determined that 15.5% of 18–35-year participants cultivated sweet potato compared to 19.4% of 36–59-year participants and 16.2% of >60 year participants. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.047$ ,  $p = 0.727$ .

The involvement of pensioners (above 60 years of age) might indicate that they are still willing to work hard and provide for their families while they are old, even though they might not be able to work for longer hours. Having this senior age group amongst household heads brings the advantages of experience and well-developed networks in the community. Its drawback is the inability of older people to adopt and take up new technologies and skills quickly, compared to those in a younger age group (Ncube, 2014). Ncube, (2014) further indicated that farmers within the ages of 30–34 years are likely to understand the issues involved in farming well, and therefore are armed with necessary information regarding climate change adaptation strategies that can be well achieved and adhered to. Farm productivity has been shown to deteriorate with the farmer's age, especially among the smallholders who largely rely on their own physical labour to execute many farming responsibilities (Uddin, Bokelmann, and Entsminger, 2014).

#### 7.3.5 Association between education and cultivation of sweet potato crop in winter and summer

A chi-square test was conducted for association between level of education of ISHAE-WY and cultivating sweet potato in winter and summer is shown in Table 7.3. According to work done by Ledwaba, (2013), better qualified individuals seem to be recognising farming as an alternative occupation. In support of the above, Mupaso, (2014) indicated that plot holders with better qualifications have now started to see farming as a substitute for other income generation incurred from off-farm employment. The advantage with higher level of education was that it tends to have a strong influence on the extent to which a farmer was able to access new information and technology. That was not only due to the ability of the farmer to access written information, but also through increased ability to search for information using modern information technologies.

Corroborating the above, low adoption among older South-Kivu farmers could be associated with their predominantly low education level. Katungi and Akankwasa, (2010) found that educated and younger Ugandan farmers adopt more new innovations than less educated and older farmers (Mugumaarhahama et. al., 2021). Better education may, therefore, be associated with improved adaptive capacity to adverse effects of climate change and variability. A farmer's level of education has a direct impact on his/her ability to properly manage a given irrigation technology, but lack of formal training in agriculture for most farmers could pose a limitation to their productivity.

This factor makes it easy for other stakeholders to effect capacity building programmes for the irrigators, without worrying about issues of illiteracy (Ndlovu, et.al., 2015). Supplementary to the above, education plays a key role in the household's decision to adopt technology; it creates awareness and encourages innovation and invention (Mengistie and Kidane, 2016). A chi-square test was conducted for association between cultivating sweet potato and household head education in winter and summer (Table 7.3). In winter, all the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and household head education,  $\chi^2 = 4.677$ ,  $p = 0.197$ . It was determined that 13.1% of participants with household head having no/primary education cultivated sweet potato, while 17.2% of participants with household head having secondary education cultivated sweet potato, and 30.3% and 16.0% of participants with household head having tertiary education and ABET respectively cultivated sweet potato.

Table 7.3: Association between education and cultivation of sweet potato crop in winter and summer

EDUCATION	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
PRIMARY	Count	53	8	52	9
	Expected count	50.3	10.7	50.5	10.5
	% within gender of the respondent	86.9%	13.1%	85.2%	14.8%
	% within season's crop: sweet potato	22.1%	15.7%	21.6%	18.0%
	% of total	18.2%	2.7%	17.9%	3.1%
SECONDARY	Count	96	20	94	22
	Expected count	95.7	20.3	96.1	19.9
	% within gender of the respondent	82.8%	17.2%	81.0%	19.0%
	% within season's crop: sweet potato	40.0%	39.2%	39.0%	44.0%
	% of total	33.0%	6.9%	32.3%	7.6%
TERTIARY	Count	23	10	25	8
	Expected count	27.2	5.8	27.3	5.7
	% within gender of the respondent	69.7%	30.3%	75.8%	24.2%
	% Within season's crop: sweet potato	9.6%	19.6%	10.4%	16.0%
	% of total	7.9%	3.4%	8.6%	2.7%
ABET	Count	68	13	70	11
	Expected count	66.8	14.2	67.1	13.9
	% within gender of the respondent	84.0%	16.0%	86.4%	13.6%
	% within season's crop: sweet potato	28.3%	25.5%	29.0%	22.0%
	% of total	23.4%	4.5%	24.1%	3.8%
TOTAL	Count	240	51	241	50
	Expected count	240.0	51.0	241.0	50.0
	% within gender of the respondent	82.5%	17.5%	82.8%	17.2%
	% within season crop: sweet potato	100.0%	100.0%	100.0%	100.0%
	% of total	82.5%	17.5%	82.8%	17.2%
			$\chi^2(3) = 4,677, p = 0.197.$	$\chi^2(3) = 2,406, p = 0.492$	

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.127$ ,  $p = 0.197$ . In summer, all the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and household head education,  $\chi^2 = 2.406$ ,  $p = 0.492$ . It was determined that 14.8% of participants with household head having no/primary education cultivated sweet potato, while 19.0% of participants with household head having secondary education cultivated sweet potato, and 24.2% and 13.6% of participants with household heads having tertiary education and ABET respectively cultivated sweet potato. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.091$ ,  $p = 0.492$ .

#### 7.3.6 Association between level of income and cultivation of sweet potato crop in winter

A chi-square test was conducted for association between cultivating sweet potato and monthly income in winter and summer (Table 7.4). According to Mango et.al., (2018), the adoption of small-scale irrigation farming was found to have a significant positive impact (at a 5% level) on agricultural income. This could be because farmers who use small-scale irrigation farming can intensify and diversify their agricultural activities, which increases their production. Sweet potato farming has a good prospect for increasing farmer income (Chasanah, *et al.*, 2018). Results of the study by Mavhungu et.al., (2022) also showed better income for ISHAE-WY at informal markets, with sweet potato fetching an average of R10 000, compared to dry beans earning R9 000 and maize fetching R3 200 per unit of production. ISHAE-WY households—if they can afford technologies and production inputs—would likely become successful farming entrepreneurs. However, access to markets has been found to be the major constraint on income enhancement for farmers (FAO, 2000).

Table 7.4: Association between level of income and cultivation of sweet potato crop in winter

INCOME	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
< R5 000	Count	185	40	186	39
	Expected count	184.4	40.6	185.2	39.8
	% within gender of the respondent	82.2%	17.8%	82.7%	17.3%
	% within season's crop: sweet potato	76.8%	75.5%	76.9%	75.0%
	% of total	62.9%	13.6%	63.3%	13.3%
>R5 000	Count	56	13	56	13
	Expected count	56.6	12.4	56.8	12.2
	% within gender of the respondent	81.2%	18.8%	81.2%	18.8%
	% within season's crop: sweet potato	23.2%	24.5%	23.1%	25.0%
	% of total	19.0%	4.4%	19.0%	4.4%
<b>TOTAL</b>	Count	241	53	242	52
	Expected count	241.0	53.0	242.0	52.0
	% within gender of the respondent	82.0%	18.0%	82.3%	17.7%
	% within season's crop: sweet potato	100.0%	100.0%	100.0%	100.0%
	% of total	82.0%	18.0%	82.3%	17.7%
		$\chi^2(1) = 0,040, p = 0.841$		$\chi^2(1) = 0,082, p = 0.774.$	

In winter, all the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and monthly income,  $\chi^2(1) = 0,040, p = 0.841$ . It was determined that 17.8% of participants earning < R5 000 a month cultivated sweet potato, compared to 18.8% of those earning > R5 000 a month. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.012, p = 0.841$ . In summer, all the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between cultivating sweet potato and monthly income,  $\chi^2(1) = 0,082, p = 0.774$ .

It was determined that 17.3% of participants earning < R5 000 a month cultivated sweet potato, compared to 18.8% of those earning > R5 000 a month. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.017$ ,  $p = 0.774$ .

#### **7.4 Conclusion**

The results of the study reflected some overbearing conclusions about the demographic profile of the ISHAE-WY and their association with the production of sweet potato. The study indicated that gender had an influence on its production. However, age, education and income did not statistically influence the production of sweet potato in the Madimbo Corridor in Musina Local Municipality and Mutale Valley in Thulamela Local Municipality. The study revealed that the ISHAE-WY are characterised by small land areas under sweet potato cultivation with potential for improved incomes. Market channels and access should be promoted for ISHAE-WY to enable throughput of sweet potato, not only to informal but also fresh produce and retail markets.

## CHAPTER 8

### 8. DEMOGRAPHY OF SMALLHOLDER WOMEN AND YOUTH AGRICULTURAL ENTERPRISES AND THEIR ASSOCIATION WITH THE CULTIVATION OF DRY BEANS FIELD CROP

#### ABSTRACT

*The study was conducted at Upper Mutale Valley and Madimbo Corridor smallholder irrigation schemes. The purpose of the study was to characterise smallholder agricultural women and youth entrepreneurs (ISHAE-WY) and their association with the cultivation of dry beans field crop. A semi-structured household questionnaire together focus group discussion was used to survey a sample, purposively focusing on ISHAE-WY. The sample was made up of 294 respondents with sub-samples selected through gender, age, and gender by age categories. The average area of dry bean production under irrigation was 1.61 ha per farmer. The production potential was 1.2 tons per ha with an average income per production earned of R9 000; this was in an informal market priced at R7.50 per kilogram. The potential for ISHAE-WY in the formal market would be projected at R14 000 per production cycle, with an improved price of R12 per kilogram. The study, using the chi-square test of association, showed weak association (Cohen, 1988) between gender ( $\phi = 0.097$ ,  $p = 0.096$ ), age ( $\phi = 0.152$ ,  $p = 0.033$ ), education ( $\phi = 0.182$ ,  $p = 0.022$ ), and income ( $\phi = 0.081$ ,  $p = 0.163$ ) with the planting of dry beans by ISHAE-WY. The Fischer Exact test for gender showed that there was no statistically significant association between cultivating beans and gender,  $p = 0.156$ . It was determined that 13.3% males cultivated beans compared to 34.1% females. In terms of the chi-square test for association between cultivating beans and age, there was no statistically significant association ( $\chi^2 = 6.826$ ,  $p = 0.033$ ). It was determined that 21.1% of 18–35-year participants cultivated beans, compared to 38.7% and 32.4% of 36–59 participants and >60 year participants respectively. The chi-square test for association between cultivating beans and household head education was not statistically significant ( $\chi^2 = 9.608$ ,  $p = 0.022$ ). It was determined that 42.6% of participants with household head having no/primary education cultivated beans, while 37.9% of participants with household head having secondary education cultivated beans, and 27.3% and 21.0% of participants of household heads with tertiary education and ABET cultivated beans respectively.*

*The association between cultivating beans and monthly income was also not statistically significant ( $\chi^2 = 1.945$ ,  $p = 0.163$ ). It was determined that 35.1% of participants earning < R5 000 a month cultivated dry beans, compared to 26.1% of those earning > R5 000 a month. Trends based on participation to plant dry beans shows the potential for youth to middle aged <60 years— ISHAE-WY with no primary education, and for ISHAE-WY with less than R5 000 to plant, grow, market, and have income from dry beans. The trends suggest empowerment programs for women, extension and literacy support through training and input assistance for ISHAE-WY.*

## 8.1 Introduction

For many decades, ISHAE-WY have been considered to have the potential to generate economic development of the poor and under-developed rural areas (WRC, 2009). Pittock, Bjornlund, Stirzaker and van Rooyen, (2017) further indicated that most ISHAE-WY produce traditional food crops for the local market, compared to growing improved varieties of vegetable and field crops. The dry bean was identified as one of the most important field crops in Vhembe District Municipality on account of its high protein content and dietary benefits. It was selected as one of the six most important field and vegetable crops by ISHAE - WY (Nesamvuni, et. al. 2022). South Africa produces only 75 % of the dry beans consumed in the country, with 25% being imported (DAFF, 2010). The average yield increased from the 0.6 tons per ha obtained in the early seventies to approximately 1.2 tons per ha in the eighties (DAFF, 2010).

At a commercial level, farm gate value for good grades of dry beans is between R12 000 and R14 000 per ton if sold to merchants that clean, pack and remarket the seed. Farmers can usually average between 1.8 tons per ha and 2.2 tons per ha of saleable seed with good dryland production practices (Grain SA, 2019). The economic implication is that farmers can achieve a gross income of about R26 000 per hectare, which compares very well with the income from other dryland crop production options (Grain SA, 2019). A continuous effort is being made to obtain higher production yield in irrigated smallholder agricultural production areas to increase profitability and to meet the ever-increasing demand for food. On average the ISHAE-WY produce dry beans on 1.61 ha and produce about 1.2 tons per ha; they fetch a lower price of R9 000 at the informal markets (about R7.50 per kilogram). The value could increase to R14 400 at the formal market due to a good price of about R12.00 per kilogram.

It has, however, become increasingly difficult for the ISHAE-WY in this production area to provide enough dry beans within production villages. Socio-economic factors continue to play a critical role in determining the levels of production undertaken and the type of crops planted. This was corroborated by von Braun and Mirzabaev, (2015) who stated that the production levels are not the only areas affected, but also the way business enterprises are managed—which brought the socio-economic characteristics of ISHAE-WY into focus. There are several farmer demographic factors associated with the production of selected field crops.

These include gender, age, education, and level of income. According to Nakazi, Njuki, Ugen, Aseete, Katungi, Birachi, Kabanyoro, Mugagga and Nanyonjo, (2017), dry beans can be clearly identified as a women's crop by looking at the proportions of men and women participation intensities of its production. In their study, Nakazi *et. al.*, (2017) further showed that women have significant participation in bean production activities of planting, weeding, harvesting, transporting from the garden, threshing, winnowing, sorting and post-harvest handling as compared to men. The UN, (2015) showed that investing in the quality of education and ensuring a sustainable source of funding are also essential to improved levels of crop production. The relationship between ISHAE-WY demography and the participation in the production of dry beans will be assessed in this study, to produce appropriate policy information for agricultural stakeholders and the government.

## **8.2 Methodology**

### **8.2.1 Site description**

The study was conducted at Upper Mutale Valley and Madimbo Corridor smallholder irrigation schemes where the agro-ecological situations are significantly different. The conditions at Upper Mutale Valley are sub-humid and Madimbo Corridor smallholder irrigation scheme is semi-arid. This confirms that the variables of smallholder irrigation schemes are affected by diversity and similarities attributed to different livelihood needs. The Madimbo Corridor irrigated smallholder agricultural area is situated north-east of the Soutpansberg Mountains. It is located between 22°26'45.34"S latitude and 30°31'18.47"E longitude. The Upper Mutale Valley area is located north of Thohoyandou in the Vhembe District Municipality of Limpopo. This irrigated smallholder agricultural area lies between 22°47'53.36"S latitude and 30°28'13.21"E longitude.

### **8.2.2 Sampling Procedure**

Stratified random sampling was used to obtain a representative sample of villages and households for interview (Leedy *et al.*, 2005) with the target population being ISHAE-WY. A two-stage random sampling process was conducted using SURVEYSELECT procedure of SAS. The PROC SUREVEYSELECT allowed for probability-based random sampling where sampling in a category or class depended on the number of units within that class. The sampling was regarded as appropriate for handling selection bias.

### 8.2.3 Data collection

A semi-structured household questionnaire was used to survey with an emphasis on ISHAE-WY. The total number of ISHAE-WY interviewed were two hundred and ninety-four (N=294) with a response rate of 75 per cent. The sample comprised 71 youths aged 18 to 35 years old (56 females and 15 males) and 223 women, of whom 153 were adults (36-59 years) and 70 pensioners ( $\geq 60$  years old).

### 8.2.4 Data analysis

The Statistical Package for the Social Sciences (SPSS) Version 22 was used to analyse quantitative data. Descriptive statistics included frequency tables and measures of central tendency. Inferential statistics were in the form of chi-square analyses, which assessed the association between major demographic variables (gender, age, education, and income) and vegetable/field crop production, water resources and governance. Fischer Exact tests were interpreted in cases where the assumptions for chi-square analysis had been violated. A Bonferroni adjustment was made to prevent a type I error; therefore, significance was considered when  $p < 0.013$ .

## 8.3 Results and discussion

It should be noted that the Bonferroni correction was made due to multiple comparisons with the same dependent variable (cultivating beans); this correction decreases the possibility of making a type I error. Therefore, the significant value of 0,05 was adjusted to 0,013 (0,05/4). This level of significance was too steep for the effects of the demographic traits to be significance.

### 8.3.1. The production potential of dry bean crop by smallholder agricultural women and youth enterprises

The average area of production under irrigation was 1.61 ha per farmer. The production potential was 1.2 ton per ha. The average income earned was R9 000 at an informal market, priced at R7.50 per kilogram. The potential for ISHAE-WY in the formal market would be projected at R14 000, with an improved price of R12 per kilogram.

### 8.3.2. Association between gender and cultivation of dry beans in winter and summer

A chi-square test was conducted for association between cultivating dry beans and gender in winter and summer is shown in Table 8.1. Fischer Exact test was conducted when cell frequencies were found to be less than five. The Fischer Exact test showed that there was no statistically significant association between cultivating beans and gender,  $p = 0.156$ . It was determined that 13.3% males cultivated beans compared to 34.1% females. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.097$ ,  $p = 0.096$ . Similarly, in summer, the Fischer Exact test also showed that there was no statistically significant association between cultivating beans and gender,  $p = 0.100$ . It was determined that no males cultivated beans compared to 4.7% females. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.05$ ,  $p = 0.392$ .

Literature indicates that in most cases females tend to be sidelined in terms of land ownership due to cultural norms, though they are usually the ones who provide most of the farm labour (Deribe, 2008). The prominence of the climate scourge to ISHAE-WY makes it necessary to establish the differences in the roles played by males and females in farm households. These gender differences are likely to influence their capacity to adapt to climate change, as well as their choices of climate change adaptation strategies (IFPRI, 2009). The involvement of women's participation in the smallholder irrigation farming practices can reduce the men's burden of being the only source of income in the rural household. This also can alleviate poverty and grow the local economy of Vhembe District Municipality.

Table 8.1: Association between gender and cultivation of dry beans in winter and summer

GENDER	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
MALE	Count	13	2	15	0
	Expected count	10.1	4.9	14.3	7
	% within gender of the respondent	86.7%	13.3%	100.0%	0.0%%
	% within season's crop: dry beans	6.6%	2.1%	5.3%	0.0%
	% of total	4.4%	7%	5.1%	0.0%
FEMALE	Count	184	95	266	13
	Expected count	186.9	92.1	266.7	12.3
	% within gender of the respondent	65.9%	34.1%	95.3%	4.7%
	% within season's crop: dry beans	93.4%	97.9%	94.7%	100.0%
	% of total	62.6%	32.3%	90.5%	4.4%
TOTAL	Count	197	97	261	13
	Expected count	197.0	97.0	281.0	13.0
	% within gender of the respondent	67.0%	33.0%	95.6%	4.4%
	% within season's crop: dry beans	100.0%	100.0%	100.0%	100.0%
	% of total	67.0%	33.0%	95.6%	4.4%

### 8.3.3 Association between age and cultivation of dry beans crop in winter and summer

A chi-square test for association between cultivating dry beans and age in winter and summer is indicated in Table 8.2. In conducting the chi-test, all the expected cell frequencies were greater than five, which complied with the assumption for the test. However, since multiple (n=4) analyses using the same dependent variable were conducted, a Bonferroni correction was made to eliminate the chance of a type I error, resulting in an altered significant value of 0,013 (0,05/4). After a Bonferroni adjustment, there was no statistically significant association between cultivating beans and age,  $\chi^2 = 6.826$ ,  $p = 0.033$ . It was determined that 21.1% of 18–35-year participants cultivated beans compared to 38.7% and 32.4% of 36–59 participants and >60 year participants respectively.

Table 8.2: Association between age of the respondent and cultivation of dry beans in winter and summer

AGE (YEARS)	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
18–35	Count	56	15	67	4
	Expected count	47.6	23.4	67.9	3.1
	% within gender of the respondent	78.9%	21.1%	94.4%	5.6%
	% within season's crop: dry beans	28.4%	15.5%	23.8%	30.8%
	% of total	19.0%	5.1%	22.8%	1.4%
36–59	Count	95	60	149	6
	Expected count	103.9	51.1	148.1	6.9
	% within gender of the respondent	61.3%	38.7%	96.1%	3.9%
	% within season's crop: dry beans	48.2%	61.9%	53.0%	46.2%
	% of total	32.3%	20.4%	50.7%	2.0%
>60	Count	46	22	65	3
	Expected count	45.6	22.4	65.0	3.0
	% within gender of the respondent	67.6%	32.4%	95.6%	4.4%
	% within season crop: dry beans	23.4%	22.7%	23.1%	23.1%
	% of total	15.6%	7.6%	22.1%	1.0%
<b>TOTAL</b>	Count	197	97	281	13
	Expected count	197.0	97.0	181.0	13.0
	% within gender of the respondent	67.0%	33.0%	95.6%	4.4%
	% within season's crop: dry beans	100.0%	100.0%	100.0%	100.0%
	% of total	67.0%	33.0%	95.6%	4.4%

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.152$ ,  $p = 0.033$ . Since this difference is not statistically significant, it is likely to be due only to chance, and not an actual difference between age.

For the summer season, the rows in Table 8.2 indicate that less than 80% of the cells are greater than five. Therefore, in summer production, chi-square test of association was not interpreted for these variables. However, Table 8.2 does show that 5.6% of 18–35-year participants cultivated dry beans compared to 3.9% of 36–59-year participants and 4.4% of >60-year participants. The significance of age on the cultivation of crops has been corroborated by Nesamvuni, Tshikolomo, Belete, and Motaung, (2014) who documented that head of household age has a strong effect on the family’s agricultural productivity; this could be a result of the influence of age on such variables as education and farming experience. In agreement of the above, its drawback is the inability of older people to adopt and take up new technologies and skills quickly, compared to those in a younger age group (Ncube, 2014). As stated by Mphinyane and Terblanche, (2005), a highly significant correlation exists between different age categories and farming experience ( $r = 0.450$ ;  $p = 0.001$ ), and this means that older farmers are more experienced.

#### 8.3.4 Association between education and cultivation of dry beans in winter and summer

A chi-square test for association between cultivating dry beans and household head education in winter and summer is shown in Table 8.3. In conducting the test, it was evident that all the expected cell frequencies were greater than five complying with the assumptions of the test. After a Bonferroni adjustment, there was no statistically significant association between cultivating beans and household head education,  $\chi^2 = 9,608$ ,  $p = 0.022$ . It was determined that 42.6% of participants with household head had no/primary education, while 37.9% of participants with household head having secondary education, and 27,3% and 21,0% of participants with household heads having tertiary education and ABET respectively. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.182$ ,  $p = 0.022$ . According to Ledwaba, (2013), the levels of education may be associated with improved adaptive capacity to adverse effects of climate change and variability. A farmer’s level of education has a direct impact on his/her ability to properly manage a given irrigation technology, but lack of formal training in agriculture for most farmers could pose a limitation to their productivity.

Also, level of education has a strong influence on the extent to which a farmer can access new information and technology, not only through improved literacy that enables the farmers to access written information, but also through increased ability to search for information using modern information technologies. Urassa, (2015), corroborates the same narrative that education levels can influence individuals' or households' choice of a livelihood strategy. Mutambara and Munodawafa, (2014) as quoted by Moyo, van Rooyen, Moyo, Chivenge and Bjornlund, (2017) note that low levels of education limit access to information and understanding of commercial farming concepts, which are both critical to sustaining high production levels.

Table 8.3: Association between education and cultivation of dry beans crop in winter and summer

EDUCATION	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
PRIMARY	Count	35	26	59	2
	Expected count	40.9	20.1	58.3	2.7
	% within gender of the respondent	57.4%	42.6%	96.7%	3.3%
	% within season's crop: dry beans	17.9%	27.1%	21.2%	15.4%
	% of total	12.0%	8.9%	20.3%	7%
SECONDARY	Count	72	44	108	8
	Expected count	77.7	38.3	110.8	5.2
	% within gender of the respondent	62.1%	37.9%	93.1%	6.9%
	% within season's crop: dry beans	36.9%	45.8%	38.8%	61.5%
	% of total	24.7%	15.1%	37.1%	2.7%
TERTIARY	Count	24	9	33	0
	Expected count	22.1	10.9	31.5	1.5
	% within gender of the respondent	72.7%	27.3%	100.0%	0.0%
	% within season's crop: dry beans	12.3%	9.4%	11.9%	0.0%
	% of total	8.2%	3.1%	11.3%	0.0%
ABET	Count	64	17	78	3
	Expected count	54.3	26.7	77.4	3.6
	% within gender of the respondent	79.0%	21.0%	96.3%	3.7%
	% within season's crop: dry beans	32.8%	17.7%	28.1%	23.1%
	% of total	22.0%	5.8%	26.8%	1.0%
TOTAL	Count	195	96	278	13
	Expected count	195.0	96.0	278.0	13.0
	% within gender of the respondent	67.0%	33.0%	95.5%	4.5%
	% within season's crop: dry beans	100.0%	100.0%	100.0%	100.0%
	% of total	67.0%	33.0%	95.5%	4.5%

For the summer season, the results of a chi-square test of association showed that less than 80% of the cells were greater than five. Therefore, the chi-square test was not interpreted for these variables. Table 8.3 does, however, show that 3.3% of participants with household head had no/primary education, while 6.9% of participants with household head had secondary education, no participants with household heads had tertiary education and 3.7% participants with household head had ABET. The level of education determines the level of assimilation of technical skills required to maintain the system. Moreover, these levels can also determine the ability to practice productive farming (Chidavaenzi, Mazenda, and Ndlovu, 2021). According to Diale, (2011), farmers with more years of schooling in the Sekhukhune District Municipality of Limpopo had more use of hybrid seed technology, and this resulted in increased crop yield. This affirmed the findings by Ekoja, (2004) that the rate of adoption of new technology is positively related to the level of education. Nesamvuni, *et al.*, 2014 affirmed that educated farmers were able to read and understand the contents of the print media that is rich in technical information for the agricultural sector; hence, they used hybrid seed technology more than their less schooled counterparts.

#### 8.3.5 Association between level of income and cultivation of dry beans in winter

A chi-square test for association between cultivating dry beans and income in winter and summer is shown in Table 8.4. In the winter season the test showed that all the expected cell frequencies were greater than five; therefore, the assumption of the test was not violated. There was no statistically significant association between cultivating dry beans and monthly income,  $\chi^2 = 1,945$ ,  $p = 0.163$ . It was determined that 35.1% of participants earning < R5 000 a month cultivated dry beans, compared to 26.1% of those earning > R5 000 a month. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.081$ ,  $p = 0.163$ . While in summer, not all the expected cell frequencies were greater than five; therefore, the assumption was violated, and the Fischer Exact test conducted. The Fischer Exact test showed that there was no statistically significant association between cultivating dry beans and monthly income,  $p = 0.312$ . It was determined that 5.3% of participants with a monthly income < R5 000 cultivated beans compared to 1.4% of participants earning > R5 000 a month.

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.08$ ,  $p = 0.170$ . As affirmed by Steiner and Solem, (1988), a successful farmer is someone likely to have access to adequate financial services and competitive advantage. Household income is a strong determinant of the access and use of agricultural resources (Tshikolomo, Nesamvuni, Stroebel and Walker, 2012) and subsequently of agricultural productivity (Nesamvuni, *et al.*, 2014). This could be because farmers who use small-scale irrigation farming can intensify and diversify their agricultural activities, which increases their production. Smallholder agricultural enterprise households would afford technologies and production inputs and would likely become successful farming entrepreneurs— if they make profit.

Table 8.4: Association between level of income per month of the respondent and cultivation of dry beans in winter

INCOME	VARIABLE	WINTER		SUMMER	
		NO	YES	NO	YES
< R5 000	Count	146	79	213	12
	Expected count	150.8	74.2	215.1	9.9
	% within gender of the respondent	64.9%	35.1%	94.7%	5.3%
	% within season's crop: dry beans	74.1%	84.1%	75.8%	92.3%
	% of total	49.7%	26.9%	72.4%	4.1%
>R5 000	Count	51	18	68	1
	Expected count	46.2	22.8	65.9	3.1
	% within gender of the respondent	73.9%	26.1%	98.6%	1.4%
	% within season's crop: dry beans	25.9%	18.6%	24.2%	7.7%
	% of total	17.3%	6.1%	23.1%	3%
<b>TOTAL</b>	Count	197	97	281	13
	Expected count	197.0	97.0	281.0	13.0
	% within gender of the respondent	67.0%	33.0%	95.6%	4.4%
	% within season's crop: dry beans	100.0%	100.0%	100.0%	100.0%
	% of total	67.0%	33.0%	95.6%	4.4%

## 8.4 Conclusions

The results of the study reflected some compelling conclusions about the demographic profile of the ISHAE-WY and their association with the production of dry beans. The study showed that gender, age, education, and income did not statistically influence the production of dry beans in the Madimbo Corridor in Musina Local Municipality and Mutale Valley in Thulamela Local Municipality. The study disclosed that the ISHAE-WY are characterised by small land areas under dry bean cultivation. Policy efforts to promote youth should be enhanced—the participation of the age groups was 21.1% of 18–35-year participants compared to 38.7% and 32.4% of 36–59 years and >60-year participants respectively. Farmer field schools and other partnership models should be promoted by the government for the transfer of skills from experienced farmers to youth. In return, youth farmers should help transfer technology and information to older farmers. The increased level (42.6%) of ISHAE-WY with no primary education emphasises the need for enhanced skills training on-farm to complement the farmer's experience with the cultivation of dry beans. It was determined that 35.1% of participants earning < R5 000 a month cultivate dry beans, compared to 26.1% of those earning > R5 000 a month. Market channels and access should be promoted for ISHAE-WYs to enable them to earn their income through formal markets.

## CHAPTER 9

### 9. PRODUCTIVITY AND PROFITABILITY OF SWEET POTATO (*IPOMOEA BATATAS L.*), DRY BEAN (*PHASEOLUS VULGARIS*) AND MAIZE (*ZEA MAYS L.*) AS SELECTED FIELD CROPS IN IRRIGATED SMALLHOLDER AGRICULTURAL ENTERPRISES IN VHEMBE DISTRICT MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

#### **ABSTRACT**

*The study was conducted as part of assessing the productivity and profitability of irrigated smallholder agricultural enterprises (ISHAE-WY) in the Vhembe District Municipality. Agro-ecological conditions at Upper Mutale Valley (sub-humid) and Madimbo Corridor smallholder irrigation schemes (semi-arid) are significantly different. This confirms that the variables of smallholder irrigation schemes are affected by diversity and similarities attributed to different livelihood needs. The purpose of the study was to assess the influence of productivity and profitability on ISHAE-WY in the Vhembe District Municipality. A representative sample was based on the number of irrigated smallholder irrigation entrepreneurs per production area within the two identified agro-ecological zones. Primary data was collected using a questionnaire and village walk (observation). At least 294 ISHAE-WY were sampled for interviews and prompt responses on the influence of productivity and profitability of selected field crops (dry bean, sweet potato, and maize) on ISHAE-WY. The study applied both primary and secondary data collection instruments. An average selected mean output of irrigated smallholder agricultural product was determined. The results through comparison between informal and formal markets show that the ISHAE-WY who rely on the informal market are making more profit. In selling through the formal market, it deducts 5% of commission, while the market agent deducts 7.5% of sales on the gross value of the sold product. This doesn't include the transportation charges to the market. The Farm Gate market opportunity seems to be the most predominant approach of marketing at ISHAE-WY. These results reaffirm that ISHAE-WY can also be alternative employment to women and youth in rural areas.*

## 9.1 Introduction

Irrigated smallholder agricultural enterprises led by women and youth (ISHAE-WY) have failed to reduce operator poverty and to use land and water resources sustainably. The failure has been attributed to various reasons, ranging from limited production and other operator skills to poor market access (Bjornlund, van Rooyen and Stirzaker, 2017; Stirzaker and Pittock, 2014). The entrepreneurs operating the ISHAE mostly started their agribusinesses using their own or family capital and built them up over time.

According to World Bank, (2005), an estimated 78% of the world's extreme poor (with incomes of less than an equivalent of USD 1.25 per person per day) lived in rural areas and most of them were involved in farming. Although poverty continued to decline in many countries, major progress was yet to be made in rural parts of sub-Saharan Africa and South Asia, and these are areas where large proportions of the population were extremely poor and dependent on smallholder farming (FAO, 2012). The establishment of ISHAE-WY was, therefore, important for the promotion of food security and household incomes. Continued establishment and improved operation of ISHAE-WY positively impacted the livelihoods of the poor through increased food availability and farming incomes, and this tended to be influenced by the types of crops planted. The objective of the study was to assess the productivity and profitability of sweet potato (*Ipomoea batatas l.*), dry bean (*Phaseolus Vulgaris*) and maize (*Zea mays l.*) as major crops produced in ISHAE-WY in Vhembe District Municipality of Limpopo province.

## 9.2 Methodology

### 9.2.1 Locality

The study was conducted at the Vhembe District Municipality in Limpopo, specifically in the Madimbo Corridor and Upper Mutale Valley irrigated smallholder agricultural areas. The agro-ecological conditions in these areas are significantly different (Figure 9.1). The conditions at Upper Mutale Valley are sub-humid and the Madimbo Corridor smallholder irrigation scheme is semi-arid. The semi-arid area is characterised by a severe lack of water resources—to the extent of limiting agricultural production.

Such a lack is brought forth by the predominance of the evapotranspiration to the rate of the precipitation (Derya, Mehmet, Süha, Sermet and Tomohisa, 2009). Agricultural production in this category is impossible, except where there is irrigation.

This area is characterised by low erratic mean annual rainfall patterns which are the main factors that hinder farming in the semi-arid regions. Griffins, (1985), defines the semi-arid region as an area whose evapotranspiration supersedes the potential precipitation. Consequently, the Madimbo Corridor often experiences extended spells of the dry season and shorter wet periods. In the same logic, Upper Mutale Valley which is semi-humid has ideal agricultural zones. Farming in this area is possible with the sole dependence on rain-fed practices. These areas are not immune to drought, but dry spells are infrequent.

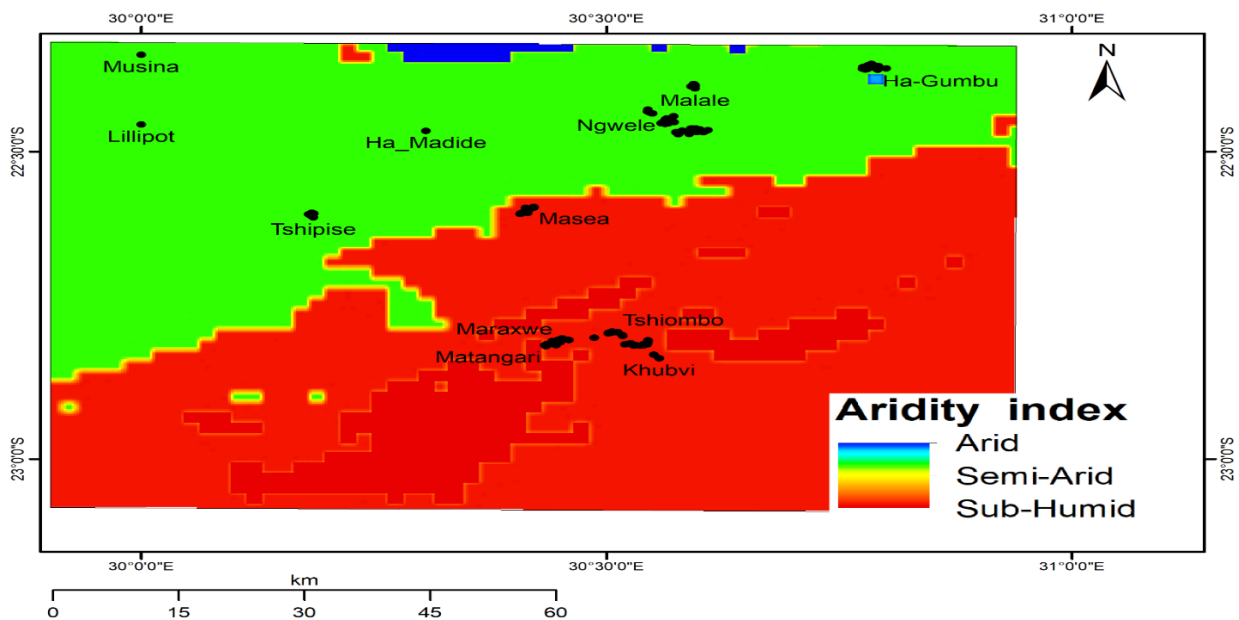


Figure 9.1: Aridity index in the Madimbo Corridor villages and Mutale Valley

The total irrigated smallholder agricultural area in the Madimbo Corridor is estimated to be above 1 000 ha. This ISAE obtains bulk water from the Nwanedi-Luphephe Dams. They release water to the Cross Dam (Gondoza Dam), which provides balancing storage and distributes water to ISHAE-WY using different electric pumps which belong to each farmer.

On the other side of the Madimbo Corridor, which is the Gumbu area, they depend on underground water only, because there is no river next to the production area. The irrigated smallholder agricultural area at Upper Mutale Valley is also estimated to be above 1 270 ha. It obtains its bulk water from the Mutale River. The water weir is used to distribute water to ISHAE-WY using canal irrigation water. The two areas of irrigated smallholder agricultural production are categorised differently i.e., Madimbo Corridor is listed as independent irrigated agricultural entrepreneurs, where each depends on private water supply, and at Upper Mutale Valley, where they are served by communal water supply infrastructures.

## 9.2.2 Sample frame and sampling procedure

### 9.2.2.1 Sample frame

Welman, Kruger, and Mitchell, (2005), define a sampling frame as a complete list of units of analysis in which each unit is mentioned only once. The sampling frame for this study was conducted at the Vhembe District Municipality of Limpopo province, in Thulamela and Musina Local Municipalities. Two smallholder irrigation schemes were identified here, namely, the Madimbo Corridor irrigation scheme and the Upper Mutale Valley irrigation scheme. Madimbo Corridor irrigation schemes form part of Ha-Gumbu, Malale, Masea, Ngwele, Tshipise, Masea and the Musina–Nwanedi villages and the Upper Mutale Valley covers areas such as Tshiombo, Matangari, Maraxwe Mutshenzheni and Rambuda villages. A representative sample was based on total W-Y ISAERS available in both smallholder irrigation schemes. A total of 294 women and youth ISAERS were available for interview after sampling.

### 9.2.2.2 Sample procedure

To ensure proper selection of respondents chosen in such a way that they represent the total population as well as possible, a two-stage simple random sampling process was conducted using *SURVEYSELECT* procedure of SAS. According to Statistical Analysis System (SAS), 2009, *PROC SUREVEYSELECT* allows selection of probability-based random sampling where sampling in different categories or classes depends on the number of units within that class and is appropriate for handling selection bias. This includes primary area selection of municipalities (both district and local), location selection of irrigation schemes and respondents' selection of ISAE. In simple random sampling, study units are chosen randomly, as the name implies.

A simple random sampling was used to select respondents and a total group of 294 was randomly selected for this study. Within this group, adult women were 223 and youth were 71, while 15 were male youth and 279 were females (adult and youth). This means that the female youth was 56. The respondents were also selected with an emphasis on gender and age. Youth were of the age between 18 to 35 years. The numbers were (a) Youth female (age 18–35 years) where N=56; youth male (age 18–35 years) where N=15, Adult-female (age 36–59 years) where N= 153 and Pensioner female (age above 60) where N=68. Sampling was done as a process of selecting units from a population of interest, so that by studying the sample, the results obtained from it may be generalised to the population from which the sample had been chosen (Leedy and Ormrod, 2010). The best time for sampling was immediately after harvest when the farmers still remembered most of the things that happened during the production period.

### 9.2.3 Data collection and analysis

The study applied both primary and secondary data collection instruments. Primary data was collected using a questionnaire and village walk (observation). The questionnaire was developed to collect qualitative and quantitative data. A semi-structured questionnaire was used to collect primary data at these two smallholder irrigation schemes. The questionnaires were administered with face-to-face interviews which embraced both open- and closed-ended questions.

As revealed by Leedy and Ormrod (2010), the closed-ended questions collected quantitative data while the open-ended questions recorded qualitative data. The questionnaire was developed based on the productivity and profitability of field crops in ISHAE-WY. The path village and smallholder irrigation scheme walk are a primary data collecting instrument for carrying out physical observation of points of interest related to productivity and profitability of field crops in ISHAE-WY. The walk was carried out with a group of representatives from the Madimbo Corridor and Upper Mutale Valley irrigation schemes, who explained the relevant social and economic aspects. During the walk, the physical observations regarding productivity and profitability of field crops in ISHAE-WY were noted. Some of them verified the information furnished on the questionnaire. Informal interviews with people encountered along the way also form part of the primary data collected.

In many cases, it was useful to have informal talks with ISAE-WY who visit, or persons accompanying the walk, to further probe into examples of how ISAE-WY survived through smallholder irrigation schemes. For secondary data collection, existing related documents were collected from some NGO offices, government departments and ministries, academic or research institutions, journals, and use of personal advantage to contact the scholars, researchers and friends who have done their research concerning these issues to get in-depth understanding about this study. The above-related documents and information collected also served as triangulation to information furnished by ISAE-WY. Quantitative data was transcribed into MS Excel and analysed statistically using the Statistical Analysis System (SAS) Package. The Procedure FREQ of SAS was used to generate simple frequency tables for variables of interest. Selected data were summarised in an Excel spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents, mainly the qualitative data.

### **9.3 Results and discussion**

#### **9.3.1 Contextualisation of the productivity and profitability of selected field crops cultivated by ISHAE-WY**

Irrigated Smallholder Agricultural Entrepreneurs (ISHAE-WY) in Limpopo Province, particularly in the Vhembe District Municipality produce field crops as one of their staple foods. This would require, among other things, paying special attention to improving the productivity and profitability of these field crops. Raising irrigated smallholder agricultural productivity is necessary if the production area is to overcome the problems of poverty and food insecurity. An important question to address in smallholder agriculture is whether ISAE provides sufficient income for household livelihood.

In this study, maize, dry beans, and sweet potato were selected as the main field crops produced in the Vhembe District Municipality. Nwanedi (Madimbo Corridor) and Tshiombo (Upper Mutale Valley) irrigated smallholder farming areas produce summer field crops even in winter production, because the area is warm in winter and there is no frost. Therefore, the comparison of the influence of productivity and profitability of ISHAE-WY will be between winter and summer production of the same field crops. This will determine which one influences productivity and profitability of ISAE in which production season.

### 9.3.2 The objective of cultivating selected field crops.

Maize, dry beans and sweet potato are the most important field crops in South Africa and are produced in many parts of the country in diverse environments—mainly for consumption due to their high protein content, starch, and dietary benefits.

**Table 9.1:** Uses of selected crops (maize, dry beans, and sweet potato) produced in ISHAE-WY in Vhembe District Municipality

Crop Use	Winter						Summer					
	Maize		Dry Beans		Sweet Potato		Maize		Dry Beans		Sweet Potato	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Mainly own consumption	0,0	0,0	1,0	1,0	0,0	0,0	7,0	3,5	1,0	7,7	1,0	1,9
Exclusively own consumption	1,0	2,1	2,0	2,1	0,0	0,0	6,0	3,0	0,0	0,0	0,0	0,0
Exclusively sale	6,0	12,5	29,0	29,9	5,0	9,4	50,0	25,1	4,0	30,8	7,0	13,5
Mainly sale	40,0	83,3	62,0	63,9	48,0	90,6	136,0	68,3	8,0	61,5	44,0	84,6
Non-response	1,0	2,1	3,0	3,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
<b>Total</b>	<b>48,0</b>	<b>100,0</b>	<b>97,0</b>	<b>100,0</b>	<b>53,0</b>	<b>100,0</b>	<b>199,0</b>	<b>99,9</b>	<b>13,0</b>	<b>100,0</b>	<b>52,0</b>	<b>100,0</b>

ISAErs were identified as producers for mainly home consumption and income, which may be used to supplement their households. These are smallholder entrepreneurs in loose value chains in irrigated smallholder agricultural produce for home consumption with added income. Some are smallholder farmers who are market-oriented and are in tight value chains that produced field crops mainly for income, with leftovers for home consumption. Household income through farming is a strong determinant of the access and use of agricultural resources (Tshikolomo, Nesamvuni, Stroebel and Walker, 2012) and, subsequently, of agricultural productivity. ISHAE-WY may develop a continuous effort to obtain higher production per unit area to increase profitability, and to meet the ever-increasing demand for food, forming a key staple and poverty-relief crop in the Vhembe District Municipality.

Maize is consumed directly and serves as a staple diet for some 200 million people, whereas many people regard it as a breakfast cereal (DAFF, 2003). In Table 9.1, in winter production, most participants cultivate maize (83.3%), beans (63.9%) and sweet potato (90.6%). for sale. Similar, in summer production participants cultivated maize (68.3%), beans (61.5%) and sweet potato (84.6%). Based on a comparison of the results of this study, we can easily categorise the ISHAE-WY as those that are market-oriented and are in loose value chains that produced field crops mainly for income and leftovers for exclusively own consumption. The value chains are loosely based on proximity to the market, infrastructure, and transport costs. According to DAFF, (2011), roadside stands, farmers' markets and local stores are other possible markets for sweet potato in ISHAE-WY. The lower local supply rate and high demand for dry beans in South African markets usually results in a realistic price increase (DAFF, 2010).

Agriculture is deeply interconnected with weather and climate, as the main drivers of agricultural production, but also as the dominant factors in the overall variability of food production (Selvaraju, Gommès and Bernardi, 2011). Based on the percentages, production in the ISHAE-WY was higher in winter than in summer for the selected field crops. This may be due to high temperatures that are experienced in the production area in summer. The other reason may be that it is too expensive to cultivate field crops in summer, due to the number of pesticides and fungicides required to produce certain crops, because of rain and high temperatures. The reason for more products in winter may be because the environment is suitable then, since the temperature is warm, and no frost is experienced.

### 9.3.3 Seasonal variation in fertiliser use to cultivate selected field crops

According to Crosby, de Lange, Stimie and van der Stoep, (2000), the interaction of moisture supply and nutrient supply is reciprocal: "if the farmer cannot irrigate, it is a waste to fertilise; if a farmer cannot fertilise, it is a waste to irrigate." Thus, if small-scale irrigation farmers are to realise higher yields, there should be a balance between water application and fertiliser management. Therefore, for cropping systems to remain productive and sustainable, it is necessary to replenish the nutrients removed from the soil.

Most crops grown in ISHAE-WY are field crops that take large quantities of nutrients from soils, leading to a great demand for fertiliser. The results of this study indicated that most of the ISHAE-WY combined the application of manure and chemical fertilisers in winter, which was in the order of 72.9% for maize, 86.6% for dry bean, and 79.2% for sweet potato respectively. There are no significant changes in summer—79.9% for maize, 61.5% for dry bean and 88.5% for sweet potato (Table 9.2). According to Siambi, Mpandeli, Simalenga, Mkhari and Ramugondo, (2009), soil fertility management has emerged over the past years to be the main management constraint responsible for the very poor yields obtained in Africa. Insiza District had a higher proportion (58.3%) of households that used manure in the 2004/05 season, followed by Gwanda (31.6%) (Siambi *et al.*, 2009). Despite the high levels of awareness on mineral fertiliser use, the proportion of ISAEr households that have used fertiliser at least once remain limited.

In South Africa, for example, most households learnt about the use of manure from neighbouring farmers and their parents (Mpandeli and Maponya, 2014; Siambi *et al.*, 2009). Considering the issue of unaffordability of chemical fertilisers, plot holders in ISHAE-WY would likely use alternative materials such as manure. The extent of manure use would be influenced by availability in nearby communities.

**Table 9.2** Types of fertilisers used for selected crops (maize, dry beans and sweet potato) produced in ISHAE-WY in Vhembe District Municipality

Fertiliser used	Winter						Summer					
	Maize		Dry beans		Sweet potato		Maize		Dry beans		Sweet potato	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Manure	7,0	14,6	3,0	3,1	8,0	15,1	32,0	16,1	5,0	38,5	3,0	5,8
Chemical <sup>1</sup>	4,0	8,3	7,0	7,2	3,0	5,7	5,0	2,5	0,0	0,00	3,0	5,8
Combined <sup>2</sup>	35,0	72,9	84,0	86,6	42,0	79,2	159,0	79,9	8,0	61,5	46,0	88,5
Non-response	2,0	4,2	3,0	3,1	0,0	0,00	3,0	1,5	0,0	0,00	0,0	0,00
<b>Total</b>	<b>48,0</b>	<b>100,0</b>	<b>97,0</b>	<b>100,0</b>	<b>53,0</b>	<b>100,0</b>	<b>199,0</b>	<b>100,0</b>	<b>13,0</b>	<b>100,0</b>	<b>52,0</b>	<b>100,1</b>

<sup>1</sup>Chemical fertilisers = Inorganic Fertilisers, <sup>2</sup>Combined = combined use of manure and inorganic fertilisers

#### 9.3.4 Seasonal variation in pesticide use to cultivate selected fields crops

Effective management of crop pests and diseases is critical for the success of ISHAE-WY. The focus of the study was to assess the extent of the use of pesticides in the selected field crops in ISHAE-WY as these have a strong influence on crop yields. ISAE which is in tropical areas with high pest pressure leads to heavy use and reliance on pesticides over traditional methods of pest control. This presents several challenges. Considerable evidence links pesticide uses to chronic health problems in farmers, and pesticides are known to bio-accumulate in soil and water, and also be very harmful to ecosystems and wildlife.

**Table 9.3** Pesticide use on selected crops (maize, dry beans and sweet potato) produced in ISHAE-WY in Vhembe District

Was any pesticide used?	Winter						Summer					
	Maize		Dry beans		Sweet potato		Maize		Dry beans		Sweet potato	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Yes	47,0	97,9	87,0	89,7	52,0	98,1	189,0	95,0	12,0	92,3	50,0	96,2
No	0,0	0,0	8,0	8,2	1,0	1,9	4,0	2,0	1,0	7,7	1,0	1,9
Non-response	1,0	2,1	2,0	2,1	0,0	0,0	6,0	3,0	0,0	0,0	1,0	1,9
<b>Total</b>	<b>48,0</b>	<b>100,0</b>	<b>97,0</b>	<b>100,0</b>	<b>53,0</b>	<b>100,0</b>	<b>199,0</b>	<b>100,0</b>	<b>13,0</b>	<b>100,0</b>	<b>52,0</b>	<b>100,0</b>

Fanadzo, Chiduzza and Mnkeni, (2010) citing Machete, Mollel, Ayisi, Mashatola, Anim and Vanasche, (2004), indicate that the report seems to suggest that farmers had the chemicals to control all these pests, but does not clarify how effective the control was, in terms of application time and effectiveness. In Table 9.3, both participants in winter and summer production use chemicals for pest and disease control—maize (97.9%), dry bean (98.1%) and sweet potato (89.7%) in winter, while in summer, it is maize (95.0%), dry bean (92.3%) and sweet potato (96.2%) respectively. As noticed by Ngowi, Mbise, Ijani, London and Ajayi, (2007); and Smart, Snyder, Goeb and Tschirley, (2018), smallholder farmers operate within a lax regulatory environment, and many do not possess adequate knowledge of optimal spray regimens or safety behaviour. Thus, most do not take adequate safety precautions.

### 9.3.5 Seasonal variation in the market share of selected vegetable crops

With the policy of commercialisation of smallholder agricultural farmers from 2004, government managed to increase the participation of the same farmers to available markets from farm gate to retail and fresh produce markets (Nesamvuni Oni, Odhiambo and Nthakheni, 2003). This was coupled with policy instruments such as the farmer's support policy which was approved in 2016. The policy covers production input support such as seeds, fertiliser, pesticides etc., on-farm infrastructure support such as irrigation systems, pack-sheds, ablution facilities etc., mechanisation support, anchor marketing support—such as packing and packaging facilities, processing facilities

etc., and mentorship and training of farmers. The policy has the main objective of increased production of strategically identified commodities. Marketing plays a serious role in meeting the overall goal of food security, poverty alleviation and sustainable agriculture, mainly among small-scale farmers in emerging countries (Altshul, 1998) and Lyster, 1990). As stated by Makhura, (2001), marketing by small-scale producers is inhibited by deprived infrastructure, distance from market, deficiency of assets and transport and insufficient marketing material. The challenge that affects vegetable production is the incapability of small-scale farmers to enhance the ability to reach markets and be vigorously involved in them.

The farm gate market opportunity seems to be the most predominant approach to marketing. In winter, which is the predominant season in the study area, 56.3% of the maize was sold at the farm gate, followed by 40.2% of dry bean and 73.6% of sweet potato. Hawkers were the next market channel with 43.2% of the maize sold at the farm gate, followed by 30.8% of dry bean and 71.2% of sweet potato, respectively (Table 9.4). Marketing of produce for most farmers, particularly the food plot-holders, was a serious problem. It is clear from the findings that depending on hawkers may be due to the market generally not being well-organised and poorly developed, based on the availability of buyers. Backeberg, Bembridge and Bennie, (1996) stated that ‘an unfavourable economic location renders the profitable production of many products impossible.’ The proposal by van Averbeke, M’marete, Igodan and Belete, (1998) indicated that a general need for the identification of suitable crops that can be grown profitably, without being sensitive to market conditions and distance, is valid. The success of any business venture hinges on the efficient functioning of the marketing system.

**Table 9.4** Market share of selected crops (maize, dry beans, and sweet potatoes) produced in ISHAE-WY in Vhembe District

Type of market	Winter						Summer					
	Maize		Dry beans		Sweet potato		Maize		Dry beans		Sweet potato	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Farm gate	27,0	56,3	39,0	40,2	39,0	73,6	86,0	43,2	4,0	30,8	37,0	71,2
Fresh produce	2,0	4,2	3,0	3,1	2,0	3,8	13,0	6,5	2,0	15,4	0,0	0,0
Contracts	6,0	12,5	0,0	0,0	0,0	0,0	1,0	0,5	0,0	0,0	0,0	0,0
Hawkers	0,0	0,0	14,0	14,4	1,0	1,9	38,0	19,1	2,0	15,4	6,0	11,5
Export	0,0	0,0	25,0	25,8	0,0	0,0	26,0	13,1	3,0	23,1	0,0	0,0
Non-response	13,0	27,1	16,0	16,5	11,0	20,8	35,0	17,6	2,0	15,4	9,0	17,3
<b>Total</b>	<b>48,0</b>	<b>100,1</b>	<b>97,0</b>	<b>100,0</b>	<b>53,0</b>	<b>100,1</b>	<b>199,0</b>	<b>100,0</b>	<b>13,0</b>	<b>100,1</b>	<b>52,0</b>	<b>100,0</b>

### 9.3.6 Seasonal variation in the management and division of labour of ISHAE-WY in the production of selected field crops

Crops in this category include maize, dry beans and sweet potato, which are categorised as field crops. They are produced as cash crops for the farm gate market. Harvesting of these crops is very labour-intensive. Mupaso, Nyamutowa, Masunda, Chipunze and Mugabe, (2014), confirm that the introduction of ISHAE-WY contributed to employment creation for both beneficiaries and non-beneficiaries as well. The production may also require high investments for inputs and protection.

**Table 9.5** Division of labour for selected crops (maize, dry and sweet potato) produced in ISHAE-WY in Vhembe District

Division of labour	Winter		Summer	
	<i>f</i>	%	<i>f</i>	%
Exclusively men	2,0	0,7	0,0	0,0
Mainly men	6,0	2,0	2,0	0,7
Mainly women	113,0	38,4	147,0	50,0
Exclusively women	133,0	45,2	112,0	38,1
Men and women equally	8,0	2,7	9,0	3,1
Non-response	8,0	2,7	24,0	8,2
<b>Total</b>	<b>270,0</b>	<b>91,7</b>	<b>294,0</b>	<b>100,1</b>

The investment in inputs and protection may guarantee minimum prices, which depend on the quality. This means considerable management skills are required to organise plant production, harvesting on time, and examining every single plant—at which point it should be taken care of or harvested. The results of the study indicated that in both seasons, most ISAE-WY(45,2%) indicated that production is managed exclusively by women, followed by 38,4% who said mainly women manage. Whereas, in the summer, half of the ISAE-WY (50,0%) indicated that mainly women manage production, together with 38,1% who mentioned that production is exclusively managed by women (Table 9.5). Contrary to the above, in most cases, females tend to be sidelined in terms of production field management due to cultural norms, though they are usually the ones who provide most of the farm labour (Deribe, 2008). These results reaffirm that women make essential contributions to agriculture and rural agricultural enterprises. However, it should be noted that it is also alternative employment for females who remain at home, while their husbands are looking for employment in cities, and other groups who were previously employed.

### 9.3.7 Seasonal economic contribution of the three selected field crops to the ISHAE-WY and informal economy of the region

#### 9.3.7.1 Production indicators for selected field crops in winter

The estimates of output and income levels for selected field crops produced by ISHAE-WY in the Madimbo Corridor and Mutale Upper Valley are shown in Table 9.6. For the three crops under investigation, maize is the most important grain crop in South Africa, being both the major feed grain and staple food for the majority of the South African population (DAFF, 2003). According to StatsSA, (2018/2019), the total production of maize in South Africa amounted to 10.51 million metric tons. Free State was the province with the highest production in all nine states with approximately 4 066 000 metric tons of the overall production. Limpopo had 200 000 metric tons with the Western Cape producing the lowest amount of 34 000 metric tons. In Table 9.6, the mean maize area irrigated was  $\pm 0.75$  ha. On average, ISAErs had a total production of 10 of 80 kg bags.

The dry bean is at present regarded as one of the most important field crops in South Africa on account of its high protein content and dietary benefits. Among the annual leguminous food crops that are harvested for dry seed, the dry bean is by far the most important (DAFF, 2010). The mean dry bean production area was 1.61 ha. In Table 9.6, most ISAE-WY had a total production of 15 bags (80 kg). Sweet potatoes are cultivated throughout tropical and warm temperature regions wherever there is sufficient water to support their growth. The main producing regions are Northern Cape, Western Cape, Limpopo, Free State, Eastern Cape, and Gauteng. Sweet potato is also the world's major food crop. In South Africa, sweet potato is mainly produced in Limpopo (Hoedspruit, Marble Hall, Burgersfort, Levubu), Mpumalanga (Nelspruit), KwaZulu-Natal and Western Cape provinces as the major production areas (DAFF, 2011). The mean sweet potato area irrigated was 0.53 ha (Table 9.1)—mean total production of 100 crates (25 kg). The causes of the low productivity of these field crops among other factors can be attributed to unproductive agronomic practices. Attention should be given to increasing the amount of land per ISHAE-WY if farming is to generate sufficient household income. However, raising the productivity of field crops could increase household income and food security significantly.

This supports the conclusion of the research by Monde, Mtshali, Mnkeni, Chiduzza, Modi, Brutsch, Dladla and Mthembu, (2005), that in both dryland and irrigated environments in the Peddie district, agriculture does contribute to the income of many households, but rarely constitutes a livelihood.

Table 9.6: Estimates of productivity and income levels for selected field crops produced by ISHAE-WY in the Madimbo Corridor and Mutale Upper Valley

PRODUCTION INDICATORS	SELECTED AGRONOMIC CROPS		
	Maize	Dry beans	Sweet potato
<sup>1</sup> Estimated mean cultivated area (ha)	0.75 ha	1.61 ha	0.53 ha
<sup>2</sup> Estimated mean output (kg)	(10 bags X 80 kg) 800	(15 bags X 80 kg) 1 200	(100 crates X 25 kg) 2 500
<sup>3</sup> Estimated mean income from agronomic crops (rands)	R350 per 80 kg R4.00/kg	R600 per 80 kg R7.50 /kg	R100 per 25 kg 4.00 /kg
<sup>4</sup> Estimated adjusted income based on mean output	R3 200	R9 000	R10 000
<sup>5</sup> Estimated proportion of ISHAE-WY cultivating the stated agronomic crop	0.66	0.09	0.02
<sup>6</sup> Estimated total area (ha) cultivated in the Vhembe District by ISHAE-WY	37 940	692	9.3.8 180
<sup>7</sup> Adjusted total area (ha) cultivated with selected crops	25 040.4	62.28	103.6
<sup>8</sup> Estimated total output (kg) adjusted cultivated area in Vhembe District	26 709.76	46 419. 87	488 679.25
<sup>9</sup> Informal market price	R4.00/kg	R7.50/kg	R4.00/kg
<sup>10</sup> Estimated total value earned by ISHAE-WY in Vhembe District (rands)	106 839 040.00	348 149.06	1 954 716. 98
<sup>11</sup> Market price	R2.88/kg	R12/kg	R6.72/kg
<sup>12</sup> Estimated total value earned by ISHAE-WY in Vhembe District using market price (rands)	R76 924 109	R1 856 795.03	R3 283 924.53

<sup>1</sup>Estimated mean cultivated area (ha) = estimated from data analysis mean cultivated area

<sup>2</sup>Estimated mean output (kg) = number of kilograms multiplied by the weight of kilograms

<sup>3</sup>Estimated mean income from agronomic crops = informal market price

<sup>4</sup>Estimated adjusted income based on mean output = (2) X (3)

<sup>5</sup>Estimated proportion of ISHAE-WY cultivating the crop out of total in Vhembe District ( ISHAE-WY = 230 000)

<sup>6</sup>Estimated total area (ha) cultivated in Vhembe District = estimated from crop suitability model

<sup>7</sup>Adjusted total area (ha) cultivated in Vhembe District = estimated to be the proportion (5) X estimated area (ha) in Vhembe District (6)

<sup>8</sup>Estimated total output (kg) adjusted to cultivated area in Vhembe District = [(2) X (7)] / (1)

<sup>9</sup>Informal market price

<sup>10</sup>Estimated total value earned by ISHAE-WY in Vhembe District (rands) = (8) X (9) (informal market price)

<sup>11</sup>Market price

<sup>12</sup>Estimated total value earned by ISHAE-WY in Vhembe District (rands) = (8) X (11) (market price).

#### 9.3.8.1 Production indicators for selected field crops in summer

The low yields realised by smallholders have been concrete evidence of poor farmer performance on smallholder irrigation schemes (Crosby et al., 2000). Agricultural production output is usually expressed in yield per ha; in the ISHAE-WY included in this study, it is generally not satisfactory. This is especially so with crops such as maize, where productivity is below the expected average for the country. In this study, productivity was determined by estimated mean output in kilograms— this entails the number of kilograms multiplied by the weight by which the product is mainly sold. In Table 9.6, the average is 0.75 ha of maize, the mean output of farmers is 10 bags, and maize on average is sold locally in 80 kg quantities. Therefore, the total production mean output of maize is 800 kg, which after conversion is 0.75t/ha (three-quarter ton). The reason for the low kilograms of maize can be that most of it is sold while still on the cob. This was confirmed by van Averbek, (2008), who explained the relationship by pointing out that the monetary value of a green cob was about five times higher than a cob harvested for grain. He reported that most farmers at Dzindi sold 25% of their maize as green cobs.

Dry bean is cultivated on the estimated mean area of 1.61 ha. The mean output of the farmer is 15 bags and dry bean on average is sold locally in 80 kg amounts. Therefore, the total production mean output of maize is 1 200 kg, which after conversion is 0.75t/ha (three-quarter ton). With sweet potatoes, the mean output of the farmer is 100 crates, and they are sold locally on average in 25 kg quantities. Therefore, the total production mean output of sweet potato is 2 500 kg, which after conversion is 4.7t/ha. The productivity of ISAEs is one of the most important reasons for the failure of most production areas to achieve food security. Consideration should be given to increasing the amount of land per irrigated smallholder entrepreneur if farming is to generate sufficient household income. However, raising the productivity of field crops could increase household income significantly.

#### 9.3.9 Seasonal economic indicator comparisons for the contribution of the selected field crops through informal and formal markets in summer

According to Nesamvuni, Tshikolomo, Belete and Motaung, 2014), the level of profitability of farming among rural households has a strong influence on farming income. Most maize farmers in the ISHAE-WY do not seem to make a profit from maize production. The fact that maize productivity was low also contributed to many farmers experiencing income loss. In Table 9.7, the estimated total output (kg) of maize production, adjusted in the cultivated area at Vhembe District Municipality, is 26 709 760 and the average price of 80 kg of maize bags is R350. Therefore, the total mean output of maize grain is R4.00/kg. The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R106 839 040.

For dry beans the estimated total output is 46 419. 875 kg and the average price of 80 kg bags is R600. Therefore, the total mean output of dry bean grain is R7.50/kg. The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R348 149.06. The estimated total output of sweet potato is 488 679.245 kg and the average price of a 25 kg crate of sweet potatoes is R120. Therefore, the total mean output is R5.00/kg. The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R1 954 716. 98. Table 9.7, also estimated the formal market of the selected field crops. Estimated total output (kg) adjusted to the cultivated area in Vhembe District Municipality in maize was multiplied by R2.88/kg for estimating the formal market price.

Table 9.7 Estimates of productivity and income levels for selected agronomic crops produced by ISHAE-WY in the Madimbo Corridor and Mutale Upper Valley

PRODUCTION INDICATORS	SELECTED AGRONOMIC CROPS		
	Maize	Dry Beans	Sweet Potato
<sup>1</sup> Estimated mean cultivated area (ha)	0.75 ha	1.61 ha	0.53 ha
<sup>2</sup> Estimated mean output (kg)	(10 bags X 80 kg) 800	(15 bags X 80 kg) 1 200	(100 crates X 25 kg) 2 500
<sup>3</sup> Estimated mean income from agronomic crops (rands)	R350/80 kg R4.00/kg	R600/80 kg R7.50/kg	R100/25 kg R4.00/kg
<sup>4</sup> Estimated adjusted income based on mean output	R3 200	R9 000	R10 000
<sup>5</sup> Estimated proportion of ISHAE-WY cultivating the stated agronomic crop	0.66	0.09	0.02
<sup>6</sup> Estimated total area (ha) cultivated in the Vhembe District by ISHAE-WY	37.940	692	5.180
<sup>7</sup> Adjusted total area (ha) cultivated with selected crops	25 040.4	62.28	103.6
<sup>8</sup> Estimated total output (kg) adjusted cultivated area in Vhembe	26 709.760	46 419. 875	488 679.245
<sup>9</sup> Informal market price	R4.00/kg	R7.50/kg	R4.00/kg
<sup>10</sup> Estimated total value earned by ISHAE-WY in Vhembe District (rands)	R106 839 040	R348 149.06	R1 954 716. 98
<sup>11</sup> Market price	R2.88/kg	R12/kg	R6.72/kg
<sup>12</sup> Estimated total value earned by ISHAE-WY in Vhembe using market price (rands)	R76 924 109	R1 856 795.03	R3 283 924.53

<sup>1</sup>Estimated mean cultivated area (ha) = estimated from data analysis mean cultivated area

<sup>2</sup>Estimated mean output (kg) = number of kilograms multiplied by the weight of kilograms

<sup>3</sup>Estimated mean income from agronomic crops = informal market price

<sup>4</sup>Estimated adjusted income based on mean output = (2) X (3)

<sup>5</sup>Estimated proportion of ISHAE-WY cultivating the crop out of total in Vhembe ( ISHAE-WY = 230 000)

<sup>6</sup>Estimated total area (ha) cultivated in the Vhembe District = estimated from crop suitability model

<sup>7</sup>Adjusted total area (ha) cultivated in the Vhembe District = estimated to be the proportion (5) X estimated area (ha) in Vhembe (6)

<sup>8</sup>Estimated total output (kg) adjusted to cultivated area in Vhembe District = [(2) X (7)] / (1)

<sup>9</sup>Informal market price

<sup>10</sup>Estimated total value earned by ISHAE-WY in Vhembe District (rands) = (8) X (9) (informal market price)

<sup>11</sup>Market price

<sup>12</sup>Estimated total Value earned by ISHAE-WY in Vhembe District (rands) = (8) X (11) (market price)

The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R76 924 109. For dry beans, the amount was multiplied by R12/kg as the price in the formal market. The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R1 856 795.03. Sweet potato estimated total output was multiplied by R6.72/kg to gauge the formal market price. The estimated total value earned by ISHAE-WY in Vhembe District Municipality through the informal market is R3 283 924.53. In comparing the two above, the ISHAE-WY who rely on the informal market are making more profit than with the formal one. The challenge may be that the market is not reliable. In selling through the formal market, it deducts 5% of commission, while the market agent deducts 7.5% of sales on the gross value of the sold product. This does not include the transportation charges to the market.

#### **9.4 Conclusion**

The consequences of the observed diversity in livelihoods through some improved livelihood outcomes, either directly in the form of food or income for ISAEs, should tailor the socio-economic profile. The purpose of examining productivity, profitability, and perception for sustainable crop production at ISHAE-WY in Vhembe District Municipality, was to provide an updated socio-economic profile and determine whether the ISHAE-WY' utilisation add value to the ISHAE-WY household livelihoods. These provided an overview of the current living standard of the community that resides within the Nwanedi (Madimbo Corridor) and Tshiombo (Upper

Mutale Valley) irrigated smallholder farming areas. This will allow identifying the comparative advantages, vulnerability and welfare within these community's residential areas.

## **9.5 Recommendations**

The study recommends that the productivity, profitability, and perception of crop production at ISHAE-WY guide the development of relevant livelihood and food security programs.

## CHAPTER 10

### INVESTIGATION ON THE IRRIGATED SMALLHOLDER AGRICULTURAL ENTREPRENEUR INSIGHTS INTO IRRIGATION WATER SUPPLY AND UTILISATION IN VHEMBE DISTRICT MUNICIPALITY, LIMPOPO PROVINCE OF SOUTH AFRICA

#### **ABSTRACT**

*The irrigated smallholder agricultural enterprises ( ISHAE-WY) are suffering from a serious loss of traditional farming knowledge, which has been adequately replaced by knowledge of modern farming practices. Water use on the ISHAE-WY can be increased by obtaining more production with the same amount of water, or by reallocating water to preferred field crops, in order to gain more yield. Indeed, the greatest increases in water use in ISHAE-WY have not been from better irrigation technology or management, but rather from increased crop yields, due to better or efficient application of water to preferred field crops. The purpose of the study was to investigate irrigated smallholder agricultural entrepreneur (ISHAE-WY) insights towards irrigation water supply and utilisation in their smallholder irrigation schemes at Vhembe District Municipality. Effective use of water is necessary for the success of ISHAE-WY. A representative sample was based on the number of ISAErs per irrigated smallholder irrigation production area within the two identified production areas. Primary data was collected using a questionnaire and village walk (observation). At least 294 ISHAE-WY were sampled for interviews and prompt responses obtained on water use management and their association with demography at ISHAE-WY in the study area. Chi-square test was used as a descriptive analysis method through application of the Fischer Exact test. The Fischer Exact tests were employed to test water supply, use and their association with the demography at ISHAE-WY' production season of selected field crops. The findings show that a chi-square test was conducted for association between the main source of irrigation water and gender, age, education level of household heads and monthly income of households. All the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between the main source of irrigation water and gender, age, education level of household heads and monthly income of households.*

*In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size. Based on the results of the study, the following conclusions were drawn. The surface water generally emerged as the most used (55.4%); groundwater (used by 44.2% of respondents) was also an important source of irrigation water. Groundwater had better supply quantity compared to surface water, while also always available. The irrigation scheduling was generally poor and based on intuition and practices of rotation, without being backed by science. The competition for irrigation water seemed to be an issue, although not yet at the level of causing major conflicts among the ISHAE-WY. The fact that the ISHAE-WY across gender and age categories reported their main sources as having the most supplies, indicated that they explored the best sources (with highest supplies) in the area under study and should be regarded as a positive result.*

## 10.1 Introduction

Farming has traditionally been a thriving sector; in the current situation, many depend on the entrepreneurial direction of the individual farming enterprises. Agriculture in our country, South Africa, is a long-term investment, which must consider events such as ecological factors, i.e., availability of water to ISHAE-WY. Water is a primary input to every economic good (Birol, Karousakis, and Koundouri, 2006). According to Machethe, Mollel, Ayisi, Mashatola, Anim and Vanasche, (2004), unavailability of water for crop growth and development during the growing season is a major limiting factor in crop production in semi-arid Vhembe District Municipality. Growing scarcity and competition for water threatens advances in poverty eradication, public health and food production (Ward, 2007). The situation is further worsened by the increasing human population which has resulted in simultaneous increased demand for water for domestic and productive use. Water availability is also linked with poverty, with poor people spending a high proportion of their time, income and other resources securing water to meet their basic needs (Hope, 2006). The general assumption was that there is a desire to maximise the expected utility of adopting new technologies, such as small-scale irrigation farming, given the persistent drought in the region (Mango, Makate, Tamene, Mponela and Ndengu, 2018). In harmony with the above, farmers in the traditional schemes have adopted some knowledge and technological aspects of improved irrigated agriculture (Mosha, Vedeld, Kajembe, Tarimo and Katani, 2016). ISHAE-WY are generally and consistently known for achieving crop yields well below natural resource potential. It is also important to assess the appropriateness of a particular irrigation technology to farmers and its associated energy requirements and water use efficiencies (FAO, 1999).

Increasing demand for water from alternative users and prevailing poverty and unemployment in rural areas of South Africa, means that there is a strong need to increase the efficiency of resource utilisation and productivity in smallholder irrigation farming (Hedden-Dunkhorst and Mphahlele, 2000; Backeberg, 2006). Country wide, irrigated smallholder agriculture is often more efficient than large-scale commercial agriculture, and given sufficient support in the water use management, substantial improved production yields can be achieved. In agriculture, more especially in smallholder irrigation schemes, water is one of the most indispensable substances for human daily life and survival (Aiga and Umenai, 2002). This is the subject of the more general concept of water use management on the smallholder irrigated enterprises.

Access to adequate supplies of water is a universal indicator of human well-being and development (Potter and Darmame, 2010). Water use management on the ISHAE-WY can be increased by obtaining more production with the same amount of water, or by reallocating water to preferred field crops to gain more yield. Indeed, the greatest increases in the water use management in ISHAE-WY have not been from better irrigation technology or management, but rather from increased crop yields due to better or efficient application of water to preferred field crops. Lack of access to safe and improved water supplies in developing countries is a major concern, since water is a basic need for sustenance (Mazvimavi and Mmopelwa, 2006).

The objective of this study was to investigate irrigated smallholder agricultural entrepreneur (ISAEr) insights towards irrigation water supply and Utilisation in their smallholder irrigation schemes at Vhembe District Municipality. Effective use of water use is necessary for the success of ISHAE-WY. Water use which includes irrigation frequency and efficiency, as well as use of conservation practices and conservation measures, are needed to be considered.

## **10.2 Research methodology**

### **10.2.1 Description of study area**

The study area was described based on locality and ecological description, with an analysis of the situation. The focus is on the ISHAE-WY' water supply, use and association in demography in Vhembe District Municipality. All water resources are linked to each (Figure 10.1) and are affected by the biophysical environment and human activities. Water use must be managed considering the relationships between water and ecological factors.

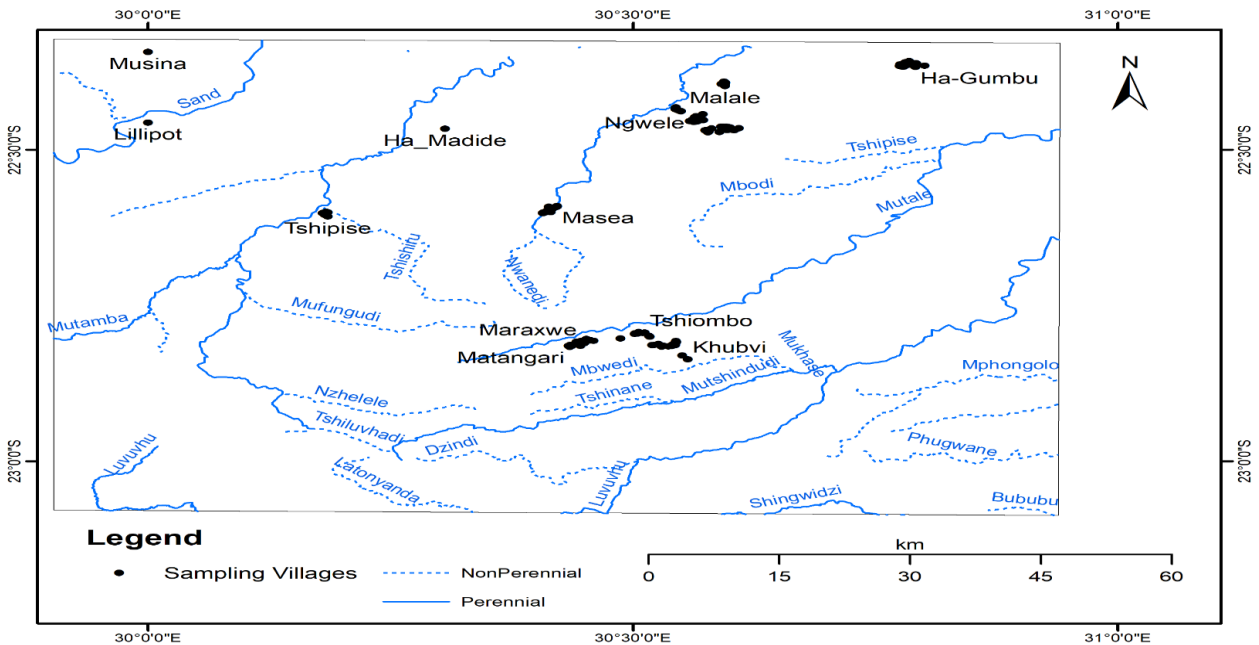


Figure 10.1: Perennial and non-perennial rivers which supply water to Madimbo Corridor and Upper Mutale Valley ISHAE-WY

Environmental and natural resource conditions in Vhembe District Municipality are generally subtropical but show considerable local variation. The variation is triggered by elevation in the region where the difference drops from the top of the mountains to the river valley levels. This vast difference in elevation causes a significant variability in micro-climate and affects water use in ISHAE-WY. The research project was specifically conducted at Madimbo Corridor and Upper Mutale Valley ISHAE-WY.

## 10.2.2 Sample frame and sample procedure

### 10.2.2.1 Sample frame

A sampling frame is defined as a complete list of units of analysis in which each unit is mentioned only once (Welman, Kruger, and Mitchell, 2005). The sampling frame for this study was conducted at Vhembe District Municipality of Limpopo province, in Thulamela and Musina Local Municipalities. Two smallholder irrigation schemes were identified, namely, Madimbo Corridor and Upper Mutale Valley irrigation schemes.

The Madimbo Corridor irrigation scheme forms part of Ha-Gumbu, Malale, Masea, Ngwele, Tshipise, Masea and the Musina–Nwanedi villages and the Upper Mutale Valley covers area such as Tshiombo, Matangari, Maraxwe Mutshenzheni and Rambuda villages. A representative sample was based on total W-Y ISAErs available in both ISHAE-WY.

#### 10.2.2.2 Sample procedure

In order to ensure proper selection of respondents chosen in such a way that they represent the total population as well as possible, a two-stage simple random sampling process was conducted using *SURVEYSELECT* procedure of SAS. According to Statistical Analysis System (SAS), 2009, *PROC SUREVEYSELECT* allows selection of probability-based random sampling, where sampling in different categories or class depends on the number of units within that class and is appropriate for handling selection bias. This includes primary area selection of municipalities (both district and local municipalities), location selection of irrigation schemes and respondents who serve as ISHAE.

In simple random sampling, study units are chosen randomly, as the name implies. A simple random sampling was used to select respondents and a total unit of 294 was randomly selected for this study. In this total number of 294, adult women were 223 and youth were 71. Out of 294 as the total number, 15 were male youth and 279 were females (adult and youth). This means that female youth were 56. The respondents were also selected with an emphasis on gender and age. Youth were of the age between 18 to 35 years. The numbers were (a) Youth female (age 18–35 years) where N=56; youth male (age 18–35 years) where N=15, Adult-female (age 36–59 years) where N= 153 and Pensioner female (age above 60) where N=68. Sampling was done as a process of selecting units from a population of interest, so that by studying the sample, the results obtained may be generalised to the population from which the sample had been chosen (Leedy and Ormrod, 2005). The best time for sampling was immediately after harvest when the farmers still remembered most of the things that happened during the production period.

### 10.2.3 Data collection and analysis

The study applied both primary and secondary data collection instruments. Primary data was collected using a questionnaire and village walk (observation). The questionnaire was developed to collect qualitative and quantitative data. A semi-structured questionnaire was used to collect ISHAE-WY' primary data at these two smallholder irrigation schemes. The questionnaires were administered with face-to-face interviews which embraced both open- and closed-ended questions. As revealed by Leedy and Ormrod, (2010), the closed-ended questions collected quantitative data while the open-ended questions recorded qualitative data. The questionnaire was developed based on the environmental, social and economic characteristics as the other assets of the livelihoods' framework and household food security.

The path village and smallholder irrigation scheme walk are a primary data collecting instrument, through carrying out physical observation of points of interest related to social and economic characteristics. The walk was carried out with a group of representatives from the Madimbo Corridor and Upper Mutale Valley irrigation schemes, who explained relevant social and economic aspects of their irrigation schemes. During the walk, the physical observations regarding social and economic characteristics were noted. Some of these verified the information furnished on the questionnaire. Informal interviews with people encountered along the way also formed part of primary data collected. In many cases, it was useful to have informal talks with enterprise representatives, or persons accompanying the walk, to further probe into examples of how ISHAE-WY survived.

For secondary data collection, existing related documents were collected from some NGO offices, government departments and ministries, academic or research institutions, journals and use of personal advantage to contact the scholars, researchers and friends who have done their research concerning these issues, in order to get in-depth understanding about this study. The above related documents and information collected also served as a means of triangulation to information furnished by ISAE-WY.

Collected primary and certain secondary raw data was cleaned, captured using MS Excel statistical analysis Package 9.1 version (SAS 9.1) software (SAS Institute Inc., 2009) and transcribed. The Procedure FREQ of SAS was used to generate simple frequency tables for variables of interest.

Selected data was summarised in an Excel spreadsheet to develop figures. Descriptive analysis techniques were used in the study to capture the perceptions of respondents—mainly the qualitative data. Further, the descriptive analysis techniques were also used in the study which includes chi-square tests. This descriptive analysis method was used through application of the Fischer Exact test. The Fischer Exact tests were employed to test demography (gender, age, education and income) of ISHAE-WY and their association with the cultivation of selected field crops (maize, dry bean and sweet potato).

### **10.3 Results and discussion**

This chapter presents the results of the study, according to its objective. The supply of water in an area is dependent on the quantity of runoff, and this is, in turn, influenced by rainfall (Tshikolomo, Walker and Nesamvuni, 2013). In addition to the supply of water, the amount of water supply depends on the availability of storage infrastructure such as dams (Mostert, 2008). The quantity of the water source usually has significant impact on the ISHAE-WY. An area is water stressed when annual supplies per capita drop below 1 700 m<sup>3</sup>, is water scarce when the supplies decrease below 1 000 m<sup>3</sup> and has absolute scarcity when the supplies are below 500 m<sup>3</sup> (FAO, 2007). The average annual rainfall is 450 mm and is well below the world average of about 860 mm (DWAf, 2004). Therefore, Limpopo province is also situated in a low rainfall area, with lesser rainfall recorded in the western located Limpopo Water Management Agency (WMA) compared to that received by the eastern located Luvuvhu-Letaba WMA (DWAf, 2003). Field crop water use is needed continuously and best utilised in an irrigation system which incorporates frequent applications during the production season. ISHAE-WY often need a technological intervention in the smallholder agricultural system for improved field production yield. New technologies mean new direction and increase in efficiency in the field crop produced. If the ISAErs are not sufficiently adaptable to change, some irrigation water may be misused. The results of this investigation on the water supply, use and association with the demography of ISHAE-WY will assist with the design and implementation of a model for long-term sustainability of the enterprises.

### 10.3.1 Water resource supply in ISHAE-WY

#### 10.3.1.1 Overview of the main and alternative water sources at ISHAE-WY

The ISHAE-WY usually obtain water from surface and underground water sources. Farmers with secure access to water have higher agricultural productivity than those without, the difference being attributable to increased area under cultivation, greater crop intensity and fewer crops lost (Namara, Hanjra, Castillo, Ravnborg, Smith and van Koppen, 2010). In Table 10.1, more participants' (55,6%) main source of water for irrigation was surface water, compared to those whose main source was groundwater (44,4%). Surface water was perceived to have relatively less operational costs than groundwater (Stevens, 2007). In groundwater sources, conservation and recharge of groundwater resources have been necessary to prevent rapid declines on aquifer levels, as the declines could have significant negative implications for the sustainability of irrigated agriculture (Rouhi Rad, Araya and Zambreski, 2020).

More participants using surface water source is because ISHAE-WY obtain bulk water from the Nwanedi-Luphephe Dams. These release water to the Cross Dam (Gondoza Dam). The Cross Dam provides balancing storage and also distributes water to ISHAE-WY. Those who obtain bulk water from the Mutale River, use the water weir to distribute water to ISHAE-WY. ISAErs at Madimbo Corridor use electric and diesel pumps for conveying water to their ISHAE-WY, while Upper Mutale Valley use canals. Some of the other areas like Gumbu in Madimbo Corridor use underground water, due to absence of rivers, which form part of the surface water next to their ISHAE-WY. According to de Lange, (1998), as much as 95% of water for irrigation is used by large-scale farmers, while smallholder farmers only have access to the remaining five percent.

Table 10.1: Main source of water to ISHAE-WY

Variable	Category	Frequency	Percentage
Main source of water to ISHAE-WY	Surface water	163	55.6
	Underground water	130	44.4
	<b>N=</b>	<b>293</b>	<b>100.0</b>
Additional or alternative irrigation water source to ISHAE-WY	Yes	76	27.0
	No	205	73.0
	<b>N=</b>	<b>281</b>	<b>100.0</b>

Intensification of the water sources may increase sustainability of water to ISHAE-WY. Even though it may cost to have infrastructure on different water sources, in the end, the water for irrigation can be available in reliable quantities. Harvesting rainwater can be another alternative to supplement the available water sources and it can also relieve the burden on the preferred water sources. At Garside, spring water was used as a supplementary source (van Averbeker, 2012). The principle of using alternative sources was acknowledged by Pandel, Pandit and Hinson (2016) who showed that sources of water for nursery crops in the United States included surface, ground, recycled and piped water supply from municipal sources. Table 10.1 indicated that 27.0% of the ISAErs require and/or use more water during irrigation than their water source can provide. The results show that the intensification of water sources in the remaining 73.0% is low or poor. Poor intensification of irrigation water shows that if the preferred or main water sources dry up, the ISHAE-WY' activities will cease, and business will be halted for a period of time. Water scarcity seriously affects agricultural production, especially in arid and semi-arid areas (Abdelkhalik, Pascual, Nájera, Domene, Baixauli and Pascual-Seva, 2020).

#### 10.3.1.2 Variability water supply evaluation during production season

The water supply availability from the main source in all production seasons stabilizes the enterprise production practices and income. It also enhances the chances of producing off-season when climatic conditions allow.

Table 10.2: Variability water supply evaluation during production season

Variable	Category	Surface water				Groundwater			
		Winter		Summer		Winter		Summer	
Variability water supply evaluation during production season	Very high	10	6.6	24	15.9	42	34.7	68	56.2
	High	106	70.2	25	16.6	36	29.8	11	9.1
	Always the same	10	6.6	12	7.9	42	34.7	41	33.9
	Low	17	11.3	89	58.9	1	.8	1	0.8
	Very low	8	5.3	1	0.7	0.0	0.0	0	0.0
	<b>Total</b>		<b>151</b>	<b>100.0</b>	<b>151</b>	<b>100.0</b>	<b>121</b>	<b>100.0</b>	<b>121</b>

According to Keller, Sakthivadivel and Seckler, (2000), water is stored in dams during rainfall seasons when and where the economic value of the resource is low; it is reallocated at times and places when and where its economic value is high. This increases the fortunes of earning high profit due to increased demand when the product is not available from the markets. The variability of water supply evaluation during production season on the ISHAE-WY is dependent on the quantity of water in the water source; this is, in turn, influenced by rainfall occurrence in that area. The importance of rainfall was stated by Schulze, (1995), who described it as the fundamental driving force and important input behind most hydrological processes. In Table 10.2, the ISHAE valued the variability water supply evaluation during the winter (70.2%) production season as high and during summer (58.9%) as low in surface water sources. As far as underground water is concerned, the ISHAE-WY appreciated variability water supply evaluation during winter (34.7%) production season as very high or always the same, and during summer (56.2%) as very high. The reason behind this may be the occurrence of rainfall to this area, which tends to occur late summer, with water supply still available in winter. This is an advantage to the ISAEr, because in winter it is warm and they can produce summer crops.

#### 10.3.1.3 Power source and conveyance technology of water supply from the main source to ISHAE-WY

The irrigation water from the water source to the ISHAE-WY needs to flow. There should be some source of energy to boost the flow to the desired place. Different ISAEr use different methods of conveyance. This depends on the nature and resources that the entrepreneurs have. Many ISHAE-WY are being irrigated directly from rivers and springs or from earth furrows. Some ISHAE-WY have pumping equipment and water is pumped either into a reservoir or directly into a distribution network of pipes and tap stands. In Table 10.3, most participants whose main source was surface water (57.2%) indicated that it was powered by gravity; participants whose main source was groundwater (94.5%) indicated that it was powered by electricity. Those who prefer diesel/petrol engines are minimal. Most of the participants whose main source was surface water (67.41%) indicated that their conveyance technology was to pipes, whereas the participants whose main source was groundwater (100.0%) indicated their conveyance technology was to pipes.

The sharing of a common water source by a group of entrepreneurs' limits members' flexibility in terms of irrigation, but the choice of suitable know-how can be important to ensure as much suppleness for each individual entrepreneur as possible.

Table 10.3: Power source and conveyance technology of water supply from the main source to ISHAE-WY

Variable	Category	Surface water		Groundwater	
		Frequency	Percentage	Frequency	Percentage
Irrigation water from source conveyance to ISHAE-WY	Diesel/petrol engine	28	18.4	7	5.5
	Gravity	87	57.2	0	0.00
	Electricity	37	24.3	121	94.5
	<b>N=</b>	<b>152</b>	<b>100.0</b>	<b>128</b>	<b>100.00</b>
Conveyance technology of water to ISHAE-WY	Canal/furrow	29	32.59	0	0.0
	Pipes	60	67.41	84	100.0
	<b>N=</b>	<b>89</b>	<b>100.0</b>	<b>84</b>	<b>100.0</b>

### 10.3.2 Water use in the ISHAE-WY

#### 10.3.2.1 Water source utilisation by ISHAE-WY

Effective management of water source utilisation is necessary for the success of ISHAE-WY. Important aspects of water source utilisation include intensifying water sources and uses of water sources other than irrigating ISHAE-WY, as well as variability water supply evaluation during production season.

Table 10.4: Intensifying water sources and uses of water sources other than ISHAE-WY

Variable	Category	Frequency	Percentage
Uses of water sources other than ISHAE-WY	Domestic water use	175	81.40
	Productive water use, e.g. livestock drinking	40	18.60
	<b>N=</b>	<b>215</b>	<b>100.0</b>

According to Danison and Manona, (2007), conventional technical approach to water supply is to provide water for a single purpose, either domestic water or irrigation. They further explore that evidence in both the irrigated and the domestic water supply scenarios shows that people use whatever water is available for many things, such as domestic use, gardening, car washing, animal watering and brick fabrication. Supplementary to the above idea, Table 10.4 shows that 81.40% use ISHAE-WY' water source for domestic water use, not forgetting that some also use them for other productive use, such as livestock drinking.

The main drivers of envisaged water shortages can be anticipated due to population growth, leading to more domestic use, increased other productive use and global warming, which in combination are leading to both greater demand for and reduced supply of water.

#### 10.3.2.2 Irrigation water use management at ISHAE-WY

An important aspect of irrigation water management in ISHAE-WY is to improve water efficiency by increasing crop yield per unit of irrigation water applied. Knowledge on irrigation water management and practical irrigation scheduling at scheme level in South Africa is weak (Fanadzo, Chiduzza and Mkeni., 2010). Fanadzo et al., (2010) further indicated that farmers at Zanyokwe irrigation scheme did not practice any irrigation scheduling, and they seemed to be ignorant of the dangers of over-irrigation. Concurring with this, Stevens, (2007), said that irrigation water is the major production constraint for most of the irrigators in South Africa, and the potential saving of water through on-farm irrigation scheduling entailed additional areas that could be irrigated with the potential increase in total net income. Proper irrigation scheduling could prolong irrigation capability and might be an important method for improving crop production (Crouch, Guerrero, Amosson, Marek, and Almas, 2020), and prolonged irrigation capability would be a result of increased water use efficiency associated with proper irrigation scheduling (Levidow, Zaccaria, Maia, Vivas, Todorovic and Scardigno, 2014). The majority of ISAERS reported that they irrigated twice (surface water (45.63%) and groundwater (52.30%)) when the water source had water in a period of one week, implying that there might be cases where irrigation was once a week (Table 10.5). The ISAERS probably irrigated weekly in cases where the supply of water did not allow for more frequent irrigation. With the prospects of less frequent irrigation, low crop yields would be obtained. The persistent dependence on intuitive and rotational scheduling could probably be exacerbated by their lack of knowledge on crop yield response to different water management practices (Levidow *et al.*, 2014).

Table 10.5: Frequency of irrigation water use management at ISHAE-WY

Variable	Category	Surface water		Groundwater	
		Frequency	Percentage	Frequency	Percentage
Frequency of irrigation to ISHAE-WY	Once a week	55	39.29	21	16.15
	Twice a week	63	45.63	68	52.30
	Three times a week	18	12.89	23	17.69
	Four times a week	4	2.19	18	13.86
	<b>N=</b>	<b>140</b>	<b>100.0</b>	<b>130</b>	<b>100.0</b>

### 10.3.2.3 ISHAE-WY' water use competition from other sectors

Irrigated smallholder agriculture is regarded as one of water-consumption during production, but ISHAE-WY have been and will continue to be critical to achieving food security. Many irrigation systems appear to use water inefficiently, so that field crops themselves consume a relatively low fraction of the water. For example, with surface water applications, only one- to two-thirds of the water applied at field level goes directly for crop growth, with the rest seeping away or evaporating. In Table 10.6, most participants whose main source was surface water (67.1%) indicated that the water sources are used by farmers and other sectors, whereas most participants whose main source was groundwater (73.8%) indicated that water source are used by farmers only. The surface water is commonly used by groups of farmers. Therefore, the demand for water use is not limited only to irrigations, but also to recreational activities, livestock, car washing and small industry use like salons. As far as groundwater is concerned, irrigation use is privately owned and only used for that particular purpose.

Table 10.6: ISHAE-WY' water use competition from other sectors

Variable	Category	Surface Water		Ground water	
		Frequency	Percentage	Frequency	Percentage
ISHAE-WY' water use competition from other sectors	Water source used by farmers only	53	32.9	90	73.8
	Water source used by farmers and other sector	108	67.1	32	26.2
	<b>N=</b>	<b>161</b>	<b>100.0</b>	<b>122</b>	<b>100.0</b>

#### 10.3.2.4 ISHAE-WY' water use agricultural technology adaptation

Study on agricultural technology applications has in the past focused on commercial irrigated agriculture, which was the domain of white farmers. This tactic has deprived ISHAE-WY of appropriate technologies for their production systems. To determine whether ISHAE-WY were aware of some of the technologies available, they were asked to indicate whether they knew, use and still use the technology. The responses are outlined in Table 10.7. The participants (69.0%) knew about mulching, (49.0%) had used mulching and less participants (19.0%) are using mulching. Mulching reduces the evaporation in the soil. This indicates that through mulching, more water is retained in the soil and, during irrigation, more water will be available for field crop use. This will also assist in soil conservation. In using the evaporation pan, less participants (19.7%) knew about an evaporation pan, less participants (19.0%) had used an evaporation pan and less participants (4.1%) are using an evaporation pan. This shows that the technology is aged—those who knew and use it may be old farmers. This technology is no longer popular in ISHAE-WY because of being replaced by weather stations.

Table 10.7: ISHAE-WY knowing, using, and still using water use agricultural technology for both surface and groundwater

Variable	Category	Knowing agricultural technology		Using agricultural technology		Still using agricultural technology	
		Freq	Percentage	Freq	Percentage	Freq	Percentage
Mulching	Yes	203	69.0	144	49.0	56	19.0
	No	91	31.0	150	51.0	238	81.0
	N=	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>
Evaporation pan	Yes	58	19.7	56	19.0	12	4.1
	No	236	80.3	238	81.0	282	95.9
	N=	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>
Tensiometer	Yes	65	22.1	62	21.1	30	10.2
	No	229	77.9	232	78.9	264	89.8
	N=	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>
Water harvesting	Yes	229	77.9	206	70.1	86	29.3
	No	65	22.1	88	29.9	208	70.7
	N=	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>	<b>294</b>	<b>100.0</b>

As far as a tensiometer is concerned, less participants (22.1%) knew about it, few participants (21.1%) had used one and only a small number of participants (10.2%) were using one. This seems to be expensive and mostly used by commercial farmers. ISHAE-WY who are illiterate can find it difficult to use this technology.

Regarding water harvesting, most participants (77.9%) knew about it, most participants (70.1%) had used it and less participants (29.3%) were using it. In surface water sources, adoption of new technology is hindered by the positioning of the ISHAE-WY' production areas. The layout of these areas makes it difficult for agricultural entrepreneurs to irrigate their production areas according to their own individual requirements—due to sharing of water sources. Subsequently, it seems that either increasing irrigation efficiency or reducing water losses (such as through new irrigation technology or management practices) would free up significant water for other uses, especially in surface water sources. Therefore, overall basin-level efficiencies are generally much higher than they seem, leaving less “unused” water than is assumed (Seckler, 1996).

### 10.3.3 Associations between demographic factors and main source of water for irrigation

Following discussion of the results on water resources supply and use in the ISHAE-WY, it was thought necessary to conduct some analysis to determine possible associations between selected demographic factors and main sources of irrigation water. The correlation of gender, age, education of household head and monthly income of the household as a demographic factor to main source of water was determined and analysed.

#### 10.3.3.1 Association between gender and main source of irrigation water

The gender approach of agencies and projects, as well as the local class and gender hierarchies, are also one of the causes of gender-related inequities in access to water resources in sub-Saharan Africa (van Koppen, 2002). According to Bembridge and Tshikolomo, (1998), gender has influence on decision making, with males responsible for major decisions, while females were responsible for relatively minor ones. Since male irrigators had better relations with the irrigators' committee and with the water delegate, they were often more successful in negotiating day turns (Zwarteveen, 1997). Females were not usually adequately included in decision making on farming and water management; hence, their concerns were not usually considered (Khandker, Gandhi and Johnson, 2020). Khandker et al., (2020), further indicated that formal participation of women in water users' associations would enhance their social and economic standing, achieve greater gender balance, expand their awareness of water management, and contribute to better decision-making in the water institutions.

Table 10.8 Gender by main source of irrigation water use by ISHAE-WY in Musina and Thulamela Local Municipalities of Vhembe District Municipality.

Gender of respondent		Main sources of water for irrigation–Source 1		Total
		Surface water	Groundwater	
Male	Count	9	6	15
	Expected count	8.3	6.7	15.0
	% within gender of the respondent	60.0%	40.0%	100.0%
	% within main sources of water for irrigation–Source 1	5.5%	4.6%	5.1%
	% of total	3.1%	2.0%	5.1%
Female	Count	154	124	278
	Expected count	154.7	123.3	278.0
	% within gender of the respondent	55.4%	44.6%	100.0%
	% within main sources of water for irrigation–Source 1	94.5%	95.4%	94.9%
	% of total	52.6%	42.3%	94.9%
Total	Count	163	130	293
	Expected count	163.0	130.0	293.0
	% within gender of the respondent	55.6%	44.4%	100.0%
	% within main sources of water for irrigation–Source 1	100.0%	100.0%	100.0%
	% of total	55.6%	44.4%	100.0%

As assumed by Khandker et al., (2020), the participation of women in water users’ associations and related water forums would probably expand their awareness of water management and contribute to better decision-making in water issues, including choices of main sources of irrigation water. Due to their distinctive engagements with the natural environment, women’s experience and knowledge are critical for environmental management (UNEP, 2004). As part of the study. it was, therefore, necessary to conduct pertinent analysis to determine if there was some association between gender and the main source of irrigation water used by the ISHAE-WY in the Musina and Thulamela local municipalities. With the data used in the study being mainly categorical, the Pearson chi-square was used to test for association, and this entailed cross tabulation of the gender categories and main sources of irrigation water used (Table 10.8) followed by the chi-square test. For the results of a chi-square test of association to be valid, all cells need to have expected cell counts greater than five.

As evident in Table 10.9, all expected count frequencies were more than five and the assumption had therefore not been violated. The result of the chi-square test of association could be interpreted. Also, it could be seen that 60.0% of males indicated their main source of water for irrigation to be surface water, compared to 55.4% females.

Table 10.9: Gender by main source of irrigation water use by ISHAE-WY in Musina and Thulamela Local Municipalities of Vhembe District Municipality, Limpopo province—chi-square tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson chi-square	0.122 <sup>a</sup>	1	0.727		
Continuity correction <sup>b</sup>	0.007	1	0.934		
Likelihood ratio	.0123	1	0.726		
Fisher's Exact test				0.795	0.471
Linear-by-linear association	0.122	1	0.727		
N of valid cases	293				

A chi-square test was conducted for association between the main water source for irrigation and gender. All of the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between the main water source for irrigation and gender,  $\chi^2(1) = 0.122$ .  $p = 0.727$ . It was determined that 60.0% of males indicated their main source of water for irrigation to be surface water, compared to 55.4% females. Since the difference in the number of males and females who cited surface water as their main source is not statistically significant, it is likely only to be due to chance, and not an actual difference between genders. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.02$ .  $p = 0.727$ .

### 10.3.3.2 Association between age and main source of irrigation water

Age determined the age groups of ISHAE-WY involved in irrigation water resource management. The age of ISHAEWY- could have some influence on their decision making on farming issues in general, and on irrigation water resource management in particular. According to Ugwoke, Adesope and Ibe, (2005), this is not a good index to improved productivity, because farmers' productivity is deemed to decrease as they age.

Table 10.10: Age by main source of irrigation water use by ISHAE-WY in Musina and Thulamela Local Municipalities of Vhembe District Municipality, Limpopo province—cross tabulation

Age (yrs)		Main sources of water for irrigation— Source 1		Total
		Surface water	Groundwater	
18–35	Count	34	37	71
	Expected count	39.5	31.5	71.0
	% within age category?	47.9%	52.1%	100.0%
	% within main sources of water for irrigation— Source 1	20.9%	28.5%	24.2%
	% of total	11.6%	12.6%	24.2%
36–59	Count	89	65	154
	Expected count	85.7	68.3	154.0
	% within age category?	57.8%	42.2%	100.0%
	% within main sources of water for irrigation—Source 1	54.6%	50.0%	52.6%
	% of total	30.4%	22.2%	52.6%
>60	Count	40	28	68
	Expected count	37.8	30.2	68.0
	% within age category?	58.8%	41.2%	100.0%
	% within main sources of water for irrigation—Source 1	24.5%	21.5%	23.2%
	% of total	13.7%	9.6%	23.2%
<b>Total</b>	Count	163	130	293
	Expected count	163.0	130.0	293.0
	% within age category?	55.6%	44.4%	100.0%
	% within main sources of water for irrigation—Source 1	100.0%	100.0%	100.0%
	% of total	55.6%	44.4%	100.0%

In affirmation, Bembridge, Graven, Hough and Van Rooyen, (2008) indicated that age has an influence on decision making and the physical ability of individuals. As pronounced by Dagada, Nesamvuni, van Rooyen and Tshikolomo (2013), age plays an important role in the life of a person and determines how an individual behaves. Fasina, (2005) and Nwachukwu, (2008) stated that the drift of youth to towns and cities has made the use of family labour impossible, as farming activities are left in the hands of old or aged people. A test of association between age and the main sources of irrigation water used by the ISHAE-WY in the study area was therefore deemed necessary. Again the Pearson chi-square test was used and that entailed the age by main source of irrigation water cross-tabulation (Table 10.10) followed by the chi-square test. Again, all cells have expected cell counts greater than five. As shown in Table 10.11, all expected count frequencies were greater than five. This assumption of expected count frequencies being greater than five had, therefore, not been violated, and the result of the chi-square test of association could be interpreted.

Table 10.11: Age by main source of irrigation water use by ISHAE-WY in Musina and Thulamela Local Municipalities of Vhembe District Municipality, Limpopo province—chi-square tests

	<b>Value</b>	<b>df</b>	<b>Asymp. Sig. (2-sided)</b>
Pearson chi-square <sup>0</sup>	2.297 <sup>a</sup>	2	0.317
Likelihood ratio	2.287	2	0.319
Linear-by-linear association	1.709	1	0.191
N of valid cases	293		

A chi-square test for association was conducted between the main water source for irrigation and age. All the expected cell frequencies were greater than five; therefore, the assumption of expected cell frequencies being greater than five was not violated. There was no statistically significant association between the main water source for irrigation and age,  $\chi^2(2) = 2.297$ .  $p = 0.317$ . It was determined that 52.1% of the 18–35-year participants indicated groundwater as their main source

of water for irrigation, while 57.8% of 36–59-year participants and 58.8% of  $\geq 60$  year participants indicated surface water to be their main water source for irrigation.

In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.09$ .  $p = 0.317$ .

#### 10.3.3.3 Association between level of education of household head and main source of irrigation water

Education plays a key role in the ISHAE-WY' decision to adopt technology and encourages innovation and invention. In support of the above statement, Ndegwe, Mureithi and Green, (1985), showed that education is a basic need in its own right, a way of meeting other basic needs, and an activity that sustains and accelerates overall development. This statement was affirmed by Olaiton, (1984) and Tompson, (2008), who indicated that more years of schooling are associated with higher rates of adoption of innovations than are fewer. These also include irrigation water management in the ISHAE-WY. According to Dagada *et al.*, (2013), human development is influenced by level of education. Improvement of human resource capacity is essential to meet the challenges of agricultural production and food security. More years of schooling are associated with higher rates of adoption of new technologies (Tompson, 2008). Confirming this, Olayide, Ewewa, and Bello-Osagie, (1980) supported the fact that low level of education has been cited as one major reason for low level of technology adoption by older farmers. With heads of households being major decision makers in their families, it was, therefore, deemed important to assess the association between their level of education and the main sources of irrigation water used by the ISHAE-WY in the study area.

As highlighted by Qureshi, (2018), ISHAE - WY should be educated on suitable mixing ratios to achieve targeted water quality for irrigation and avoid secondary salinisation and fostering crop production. Again, the assessment used the Pearson's chi-square test that entailed the cross-tabulation of highest level of education of head of household by main source of irrigation water (Table 10.12) followed by the chi-square test. Also, all the expected count frequencies were greater than five. The assumption of all expected frequencies being greater than five had, therefore, not been violated, and the interpretation of the result of the chi-square test of association could continue.



Table 10.12: Level of education of head of household by main source of irrigation water used by ISHAE-WY in Musina and Thulamela local municipalities of Vhembe District Municipality.

Education level		Main sources of water for irrigation–Source 1		Total
		Surface water	Groundwater	
No/ primary education	Count	33	28	61
	Expected count	33.9	27.1	61.0
	% within the highest level of education of the head of household?	54.1%	45.9%	100.0%
	% within main sources of water for irrigation–Source 1	20.5%	21.7%	21.0%
	% of total	11.4%	9.7%	21.0%
Secondary education	Count	68	48	116
	Expected count	64.4	51.6	116.0
	% within the highest level of education of the head of household?	58.6%	41.4%	100.0%
	% within main sources of water for irrigation–Source 1	42.2%	37.2%	40.0%
	% of total	23.4%	16.6%	40.0%
Tertiary education	Count	21	12	33
	Expected count	18.3	14.7	33.0
	% within the highest level of education of the head of household?	63.6%	36.4%	100.0%
	% within main sources of water for irrigation–Source 1	13.0%	9.3%	11.4%
	% of total	7.2%	4.1%	11.4%
ABET	Count	39	41	80
	Expected count	44.4	35.6	80.0
	% within the highest level of education of the head of household?	48.8%	51.3%	100.0%
	% within main sources of water for irrigation–Source 1	24.2%	31.8%	27.6%
	% of total	13.4%	14.1%	27.6%
<b>Total</b>	Count	161	129	290
	Expected count	161.0	129.0	290.0
	% within the highest level of education of the head of household?	55.5%	44.5%	100.0%
	% within main sources of water for irrigation–Source 1	100.0%	100.0%	100.0%
	% of total	55.5%	44.5%	100.0%

Table 10.13: Level of education of head of household by main source of irrigation water used by ISHAE-WY in Musina and Thulamela local municipalities of Vhembe District Municipality

Analysis	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	2.867 <sup>a</sup>	3	0.413
Likelihood ratio	2.874	3	0.412
Linear-by-linear association	0.605	1	0.437
N of valid cases	290		

In Table 10.13, a chi-square test was conducted for association between the main source of irrigation water and education level of household heads. All the expected cell frequencies were greater than five; therefore, the assumption was not violated. There was no statistically significant association between the main source of irrigation water and the education level of household heads,  $\chi^2(3) = 2.867$ .  $p = 0.413$ . It was determined that 54.1% of participants with a household head education level of no/primary education indicated that their main source of water for irrigation was surface water. Similarly, 58.6% of participants with a household head education level of secondary education and 63.6% of participants with a household head education level of tertiary education also indicated surface water as their main source for irrigation. For participants with a household head education level of ABET, most (51.3%) indicated groundwater to be their main water source for irrigation. In line with the result not being statistically significant, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.10$ .  $p = 0.413$ .

#### 10.3.3.4 Association between household monthly income and main source of irrigation water

Kwaw, (2006) stated that on the local market, small-scale income generation projects continue to face tough competition with established chain stores selling similar products to those that are the main focus of community projects. The income source of the household monthly income serves as a remunerative income from work done, which also includes ISHAE-WY.

The household monthly income also grows its contribution to the livelihood of the household, and practising precision farming. Household income is a strong determinant of the access and use of agricultural resources (Tshikolomo, Nesamvuni, Stroebel, and Walker, 2012). The level of monthly income earned by an ISHAE-WY determines the extent to which he/she can afford farming infrastructure and operational costs. As alluded to earlier, some sources of irrigation water could be associated with certain costs; hence, decisions on choice of irrigation water sources management would be influenced by the level of income earned. The employment status of members of agricultural projects played an important role in their economic wellbeing (Maele, Nesamvuni, Tshikolomo, Mpandeli, Afful and Norris, 2020) and that was dependent on the level of income earned.

Table 10.14: Household monthly income by main source of irrigation water used by ISHAE-WY in Musina and Thulamela local municipalities of Vhembe District Municipality

Income categories		Main sources of water for irrigation–Source 1		Total
		Surface water	Groundwater	
< R5000 a month	Count	115	109	224
	Expected count	124.6	99.4	224.0
	% within household monthly income	51.3%	48.7%	100.0%
	% within main sources of water for irrigation–Source 1	70.6%	83.8%	76.5%
	% of total	39.2%	37.2%	76.5%
> R5000 a month	Count	48	21	69
	Expected count	38.4	30.6	69.0
	% within household monthly income	69.6%	30.4%	100.0%
	% within main sources of water for irrigation–Source 1	29.4%	16.2%	23.5%
	% of total	16.4%	7.2%	23.5%
<b>Total</b>	Count	163	130	293
	Expected count	163.0	130.0	293.0
	% within household monthly income	55.6%	44.4%	100.0%
	% within main sources of water for irrigation–Source 1	100.0%	100.0%	100.0%
	% of total	55.6%	44.4%	100.0%

It was, therefore, regarded necessary for the study to assess the association between the level of household income earned by smallholder ISHAE-WY and the sources of irrigation water they used. The assessment of the association was conducted using Pearson chi-square test (Table 10.14). As evident from Table 10.14, all expected count frequencies were greater than five. The assumption of frequency had therefore not been violated, and the results of the chi-square test of association could be interpreted.

A chi-square test was conducted for association between main water source for irrigation and monthly income (Table 10.15). All expected cell frequencies were greater than five; therefore, the assumption was not violated. After a Bonferroni adjustment, there was a statistically significant association between the main water source for irrigation and monthly income,  $\chi^2(1) = 7.10$ .  $p < 0.013$ . It was determined that 51.3% of the participants with less than R5 000 a month indicated surface water as their main source of water for irrigation, compared to 69.6% of participants with a monthly income of more than R5 000. Although there is a statistical association, the effect size showed a weak association (Cohen, 1988), as measured by the Phi measure of effect size,  $\phi = 0.156$ .  $p = 0.008$ .

Table 10.15: Household monthly income by main source of irrigation water used by ISHAE-WY in Musina and Thulamela Local Municipalities of Vhembe District Municipality, Limpopo province—chi-square tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.099 <sup>a</sup>	1	0.008		
Continuity Correction <sup>b</sup>	6.380	1	0.012		
Likelihood Ratio	7.289	1	0.007		
Fisher's Exact Test				0.008	0.005
Linear-by-Linear Association	7.075	1	0.008		
N of Valid Cases	293				

## **10.4 Conclusions and recommendations**

### 10.4.1 Conclusions

The exploration exposed that a system of simple agreements managing the irrigation water among ISHAE-WY and the routine use of the irrigation system could form the appropriate basis for sustainable water use efficiency by ISAErs. A glaring weakness was the lack of adequate expertise to manage water use in their irrigation system—clearly appropriate training on irrigation water use enterprise is needed. The responsible use of water is a major effect on irrigation sustainability. Managing water carefully can improve the yield and lower water wastage when irrigating the crops in the schemes. The water capacity must be maintained to absorb and retain moisture, which saves water. This can be done through increasing organic content in the soil and reducing crusting or compaction. All this aims to ensure that the soil can act as reservoir for moisture during water and nutrient stress periods.

Based on the results of the study, the following conclusions were drawn. The surface water generally emerged as the most used (55.4%); groundwater (used by 44.2% of respondents) was also an important source of irrigation water. Groundwater had better supply quantity compared to surface water, while also being always available. The irrigation scheduling was generally poor and based on intuition and practices of rotation, without the backing of science-based information. The competition for irrigation water seemed to be an issue, although not yet at the level of causing major conflicts among the ISHAE-WY. The fact that the ISHAE-WY (across gender and age categories) reported their main sources as having the most supplies, indicated that they explored the best sources (with highest supplies) in the area under study, and should be regarded a positive result.

### 10.4.2 Recommendations

Based on the findings of the study, three major recommendations for policy could be made. They are: (a) ISHAE-WY should be capacitated to use water harvesting techniques, which can reduce the surface water supply to their schemes. Such capacity development could include provision of techniques and skills-based information, together with materials for moisture storage where possible; (b) With supplies from surface water mostly regarded moderate and at times clearly

reported to be insufficient, it would be recommended for runoff and available storage capacity of river catchments in the study area to be assessed, to determine prospects for development of additional storage capacity that would increase the volume of surface water available for irrigation. Similar studies conducted by Tshikolomo, Walker and Nesamvuni, (2013), in fact, already revealed that the Mutale River had sufficient streamflow to allow construction of a dam; hence, it would be necessary for policy implementers to take the above into consideration, to ease the burden of Upper Mutale Valley ISHAE-WY with irrigation water; (c) Although supplies from groundwater sources were regarded to be very high, the sources are not inexhaustible. It would therefore be recommended that the aquifers be monitored, and ISHAE-WY be guided on strategies for increasing water use efficiency so as not to deplete the aquifers; and (d) ISHAE-WY should be capacitated to apply science-based irrigation scheduling, as the current intuition and rotational based schedules would be expected to be highly inefficient with regards to water use. Such capacity development could include provision of science-based information together with equipment for moisture measurement where possible.

## CHAPTER 11

### 11. CONCLUSION AND RECOMMENDATIONS

#### 11.1. The background narrative to sustainable agriculture

This section presents aspects and key issues that are critical to agricultural sustainability of W-Y agricultural entrepreneurs in ISHAE-WY. Central to this study should, therefore, be the definition and components of sustainable agriculture. There is no one commonly accepted definition of sustainable agriculture. Several definitions deserve some consideration for the purposes of giving direction to the context of SHAE-WY sustainability.

FAO defines sustainable agriculture as the “management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO, 2014). Based on this, the FAO has proposed five principles (FAO, 2014) for sustainable agriculture, namely: 1) improving efficiency in the use of resources, 2) conserving, protecting and enhancing natural ecosystems, 3) protecting and improving rural livelihoods and social well-being, 4) enhancing the resilience of people, communities, and ecosystems, and 5) promoting good governance of both natural and human systems.

The Director of LISA Program for the United States Department of Agriculture (USDA) notes that "'sustainable' means the capability to continue producing food and fibre indefinitely and *profitably* without damaging the natural resources and *environmental* quality on which all of us depend" (Schaller, 1989). Conway and Barbier, (1990) defined sustainable agriculture as the ability to maintain productivity, whether of a field, farm or nation, in the face of stress or shock such as increasing salinity, or erosion, or debt, or a new pest, or a rare drought or a sudden massive increase in input prices.

The definition of the United Kingdom governmental DEFRA signifies several important attributes of sustainable agriculture: availability to the consumers of adequate supplies of wholesome, varied and reasonably priced food, produced within accordance of generally accepted environmental and social standards, flexible and competitive industry—which contributes to an economically viable rural society, effective protection of the environment and prudent use of natural resources, conserved and enhanced landscape, wildlife, cultural and archeological value of agricultural land and respecting of high level of animal welfare, contributing to the long-term sustainability of rural communities (DEFRA, 2006).

The OECD definition of sustainable agriculture says that this is agricultural production that is economically viable and does not degrade the environment over the long run (OECD, 2000). To sum up all the contributions on the definition and components of sustainability of agriculture, the study was focused on the state of three coherent subsystems on which sustainable agriculture is based. These aspects contribute to the agricultural sustainability of the enterprises led by W-Y entrepreneurs. For the purposes of this study, three coherent subsystems within which smallholder agriculture operate were considered for conclusions and recommendations. They are environmental, economic, and social.

## **11.2. The agricultural sustainability of ISHAE-WY**

### **11.2.1. Enhancing the environmental sustainability of ISHAE - WY**

#### **(a) Conclusion**

The study analysed the climatic resource conditions, soil and water use and management around the suitability of the selected commodities potential of field crops on ISAE in Vhembe District Municipality—preferably the Madimbo Corridor and Upper Mutale Valley as production areas—and searched literature according to the purpose of the study. The aim was to discover the responsible factors of climatic resource for suitability on the selected commodities potential of agronomical crops on ISAE in Vhembe District Municipality. The observation was confirmed by long-term recorded climatic data. The physical factors were terrain form and soil, which also determine the total suitability and potential of crop production. The key factors that should be carefully considered during the planning stage of the farming operation are: site selection (soil and terrain), land capability and crop suitability.

The survey shows that a system of simple agreements managing the irrigation water among ISHAE-WY and the routine use of the irrigation system form the appropriate basis for sustainable water use efficiency by ISHAE-WY. The accurate use of water is a main effect in irrigation sustainability. Managing water carefully can improve the yield and lower water wastage when irrigating crops in the schemes. The increase of organic content in the soil and reduction of crusting or compaction maintains the absorption and retain moisture in the soil. All this aims to ensure that the soil can act as reservoir for moisture during water and nutrient stress periods. Based on the results of the study, groundwater had better supply quantity compared to surface water, while always being available. The irrigation scheduling was generally poor and based on intuition and practices of rotation, without the backing of science-based information. The competition for irrigation water seemed to be an issue, although not yet at the level of causing major conflicts among the ISHAE-WY. The fact that the ISHAE-WY (across gender and age categories) reported their main sources as having the most supplies, indicated that they explored the best sources (with highest supplies) in the area under study and it should be regarded a positive result.

#### (b) Recommendations

Based on the findings of the study, major recommendations for policy could be made. These are: (a) ISHAE-WY should be capacitated to use water harvesting techniques, which can reduce the surface water supply to their schemes. Such capacity development could include provision of techniques and skills-based information, together with materials for moisture storage where possible; (b) with supplies from surface water mostly regarded as moderate, and at times clearly reported to be insufficient, it would be recommended for runoff and available storage capacity of river catchments in the study area to be assessed, to determine prospects for development of additional storage capacity that would increase the volume of surface water availed for irrigation; (c) although supplies from groundwater sources were regarded to be very high, the sources are not inexhaustible. It would therefore be recommended that the aquifers be monitored, and ISHAE-WY be guided on strategies for increasing water use efficiency so as not to deplete them; (d) ISHAE-WY should be capacitated to apply science-based irrigation scheduling, as the current intuition and rotational based schedules would be expected to be highly inefficient with regards to water use.

Such capacity development could include provision of science-based information, together with equipment for moisture measurement where possible; (e) the results of this study will assist with the development of a cropping calendar, focusing on off-season production, so that it should adapt resilience to climate change of the field crops commodity enterprises. The study also recommends agriculture as the rural nature of the Vhembe District Municipality can create the potential for future growth of the agricultural sector, if considered. Vhembe District Municipality and LDARD can encourage young ones more especially to assist in the farming, as this would help (f) to develop interest in farming, (g) increase number of youth involved in farming for better succession plan; and (h) reduce the costs of labour in order to increase profit. Lastly, plot holders are also encouraged to diversify, as the importance of livestock assets is that (i) they provide kraal manure which supplements inorganic fertiliser to the smallholder irrigation schemes; and (j) they are also used as another source of plot holders' household income, and are vital as an investment or form of savings in deeply rural areas.

#### 11.2.2. Enhancing the economic sustainability of ISHAE - WY

##### (a) Conclusion

The consequences of the observed diversity in livelihoods through some improved livelihood outcomes, either directly in the form of food or income for ISAERs, should tailor the socio-economic profile. The purpose of examining productivity, profitability, and perception for sustainable crop production at ISHAE-WY in Vhembe District Municipality, was to provide an updated socio-economic profile and determine whether the ISHAE-WY' utilisation adds value to the irrigated smallholder agricultural entrepreneurs ISAERs' household livelihoods. These provided an overview of the current living standard of the community that resides within the Nwanedi (Madimbo Corridor) and Tshiombo (Upper Mutale Valley) irrigated smallholder farming areas. This will allow identifying the comparative advantages, vulnerability and welfare within these communities' residential areas.

##### (b) Recommendations

The study recommends that (a) the productivity and profitability of crop production at ISHAE-WY guide the development of relevant livelihood and food security programs; and (b) that government policies to be reviewed to support the designated groups (women, youth and disabled).

### 11.2.3. Enhancing the social sustainability of ISHAE - WY

#### (a) Conclusion

The results of the study reflected some overbearing conclusions about the demographic profile of the ISHAE-WY and their association with the production of selected field crops (maize, sweet potato and dry bean). The study indicated that gender had an influence on the production of sweet potato. However, age, education, and income did not statistically influence the production of selected field crops in the Madimbo Corridor in Musina Local Municipality and the Mutale Valley in Thulamela Local Municipality. The study revealed that the ISHAE-WY are characterised by small land areas under selected field crop cultivation with potential for improved incomes. Market channels and access should be promoted for ISHAE-WY to enable throughput of selected field crops, not only to informal, but also to fresh produce and retail markets.

#### (b) Recommendations

The study recommends that (a) the characterisation of ISHAE-WY guide the development of relevant demographic, livelihood, and food security programs; and (b) that policies with Agriculture, Rural Development SMME and Environment, Forestry and Fisheries can be reviewed to support W-Y agricultural business.

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## 12. ANNEXURE A



### RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

#### **DATE**

November 2020

#### **TITLE OF THE RESEARCH PROJECT**

Development of a Sustainable Model for Irrigated Smallholder Agricultural Enterprises in Vhembe District, South Africa

#### **PRINCIPLE INVESTIGATOR/RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):**

Tsumbedzo Jutas Mavhungu                      2007074897                      072 342 5201

#### **FACULTY AND DEPARTMENT:**

Faculty of Natural and Agricultural Science

Department of Sustainable Food Systems and Development, Centre for Sustainable Agriculture

#### **STUDY LEADER(S) NAME AND CONTACT NUMBER:**

Prof. Nesamvuni A E

082 924 9898

Prof. Johan van Niekerk

051 401 3765

#### **WHAT IS THE AIM/PURPOSE OF THE STUDY?**

The aim of the study is to develop a sustainable model, which is efficient, beneficial and productive—with the intention of increasing household food security and farming profitability in irrigated smallholder agricultural enterprises.

#### **WHO IS DOING THE RESEARCH?**

I “T J Mavhungu”, serve as the sole owner of the research

### **HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

No. This serves as Ethical Clearance application. Data collection has not yet started and will only commence after ethical clearance has been granted.

**Approval number:** UFS-HSD2020/2171/21

### **WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?**

The reason for taking part is that in these two study areas, conventional agriculture has had great success in producing plentiful low-cost food. But this success has resulted with expenses that raise concerns about the sustainability in agricultural production. It has an effect on the environment, economy and social aspects. Environmental effects include the degradation of groundwater, surface water, soils, biological diversity; deforestation has also contributed to climate change, leading to unpredictable extreme events (drought, winds and floods). Economic effects include increased high-technology maintenance used in farming, high-input costs and high-cost food producing systems. Social effects include growing health hazards and rural unemployment, which has led to an unprecedented movement from rural to urban areas. The big concern is that current practices are unsustainable—how can we move to a path that is more environmentally friendly, economic viable and socially desirable?

### **WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?**

The participants who will take part in this study are women and youth who are irrigated smallholder agricultural entrepreneurs at Musina Local Municipality i.e. Madimbo, and Upper Mutale Valley irrigated smallholder agricultural enterprises in Thulamela Municipality. Both areas are situated in Vhembe District in Limpopo, South Africa. The two areas of Madimbo Corridor and Upper Mutale Valley irrigation schemes constitute a total of more than 2 270 ha of production area. A structured questionnaire will be used to carry out the survey with open- and closed-ended questions.

### **CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?**

Yes, the participants will be requested to take part willingly and freely; they have the right to choose not to answer any questions, and by doing so, they will not be affected in any way whatsoever. If they agree to participate, and afterwards decide to discontinue with the interview, they may stop at any time and ask not to go on with it. If they do this, there will be no penalties or prejudice in any way.

**WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?**

There are potential benefits. Although participants will not directly benefit from this study, I will do my best to ensure that it contributes to (a) guiding the development of relevant demographic, livelihood and food security programs; (b) assisting with the economic production menus and programs for long term sustainability of the field crops commodity enterprises; (c) policies with Agriculture, Rural Development SMME and Environment, Forestry and Fisheries that can be reviewed to support women and youth agricultural business.

**WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?**

None

**WILL WHAT I SAY BE KEPT CONFIDENTIAL?**

Yes, all information given will be kept confidential and participants will not be identified by name or address in any of the reports that are planned to be written

**HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?**

Hard copies of all questionnaires will be without names of the participants; in other words, codes will be used to avoid identification of participants. They will be stored by the researcher for a period of five years or until the completion of the study in a locked storeroom for research or academic purposes. Electronic information will be stored on a password-protected computer. After completion of the study or after five years, paper records will be destroyed/disposed of in a manner that leaves no possibility for reconstruction of information. Appropriate methods for destroying/disposing of paper records will include: shredding, then cross shredding, pulping and burning. For electronic data, destruction/disposal will include destroying or deleting data permanently and irreversibly. Methods will include overwriting data with a series of characters or reformatting the disk (destroying everything on it). Pulverising the hard disk will be the best method of destroying hard disk data.

**WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?**

No. This is an unfunded academic study for a student. There are no incentives to be paid as the student has no financial sponsor.

**HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS/RESULTS OF THE STUDY?**

The study results will be presented to Agricultural Council conferences and seminars, Department of Agriculture and Rural Development conferences and seminars, Farmers' days and information days, with all participants and other stakeholders invited, and to any platform which can disseminate the information to relevant stakeholders for debate and upscaling (learning alliance to mainstream and leverage financing streams for irrigated smallholder agricultural enterprise water use, e.g., IDPs.)

**Thank you**

**13. CONSENT TO PARTICIPATE**

**on the**

**Development of a Sustainable Water Use Management Model for Irrigated Smallholder  
Agricultural Enterprises in Vhembe District, South Africa**

I, \_\_\_\_\_ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet. I have had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable). I am aware that the findings of this study will be anonymously processed into a research report, journal publications and/or conference proceedings.

I agree to the recording of the insert specific data collection method.

I have received a signed copy of the informed consent agreement.

Full Name of Participant:

\_\_\_\_\_

Signature of Participant: \_\_\_\_\_ Date: \_\_\_\_\_

Full Name(s) of Researcher(s):

\_\_\_\_\_

Signature of Researcher: \_\_\_\_\_ Date: \_\_\_\_\_

**14. ANNEXURE B: QUESTIONNAIRE**

SURVEY ON DEVELOPMENT OF A SUSTAINABLE MODEL FOR IRRIGATED  
SMALLHOLDER AGRICULTURAL ENTERPRISES IN VHEMBE DISTRICT, SOUTH  
AFRICA

FOR OFFICE USE ONLY

PARTICIPANT CODE			
INTERVIEWEE CONTACT No.			
GPS COORDINATES			
MUNICIPALITY			
VILLAGE			
AREA-SPECIFIC LOCATION OF FARM			
QUESTIONNAIRE NO.			
DATE OF INTERVIEW			
		ENUMERATOR CODE	

**SECTION A: IRRIGATED SMALLHOLDER HOUSEHOLD CHARACTERISATION**

**A 1 DEMOGRAPHIC CHARACTERISATION OF IRRIGATED SMALLHOLDER HOUSEHOLDS**

A1-01	Gender of the respondent?	Male	Female
A1-02	Are you the head and main provider of the household?	Yes <i>If yes, go to A1-06</i>	No
A1-03	If you are not the head of household, would you say the head of household is male or female?	Male	Female
A1-04	What position do you occupy in the household?	Head of family	Spouse to head
		Child	Other, specify:
A1-05	What is your age category?	18-35 yrs	
		36-59 yrs	
		>60 yrs	
A1-06	What would you say is the age category of the head of household?	19-35 yrs	
		36-59 yrs	
		>60 yrs	
A1-07	What would you say is the highest level of education of the head of household?	Never went to school	Primary education
		ABET	Secondary education
		Tertiary education	
A1-08	What is your occupation?		
A1-09	What is the total number of family members that live in your household, including grandparents,		

	children and others?		
A1-10	In what category would you say is your household's total monthly income? <i>(include salaries, services (e.g. Tuckshop, car wash etc. if available) but exclude money sent by family members that out-migrated to work, social grants and farm products sold (e.g. crops)</i>	<1 000 R	1 000–5 000 R
		5 000–8 000 R	8 000–15 000 R
		15 000–30 000 R	>30 000 R
A1-11	Do you have family members that migrated away from the village? <i>(e.g. migrated to Jo'burg)</i>	Yes	No <i>If no, go to A1-15</i>
A1-12	If yes, why did they migrate? <i>Several answers possible (e.g., work, study, other)</i>		
A1-13	Are they regularly sending money to your household?	Yes	No <i>If no, go to A1-15</i>
A1-14	If yes, how much and how regularly are they sending money?	..... R every ..... months	
A1-15	Does your household receive social grants?	Yes	No <i>If no, go to A1-17</i>
A1-16	If yes, what are they for and how much is it in total per month?	... R per month for.....	
A1-17	What is your nationality? <i>(can be double)</i>		
A1-18	What is your race?		
A1-19	What is your tribe?		

## A 2 HOUSEHOLD FOOD SECURITY

A2-01	Would you say you are a family with adequate food supply?	Yes	No
A2-02	How many meals do you normally have per day?	<i>(number)</i>	
A2-03	Are there seasons in the year that you have fewer meals per day than in other season?	Yes	No <i>If no, go to A2-05</i>
A2-04	If yes, why?		
A2-05	Which seasons (months) are hardest?		
A2-06	Give reasons why		
A2-07	How many meals per day do you have in that hardest period?	<i>(number)</i>	
A2-08	How many meals per day do you have in the other periods with more food?	<i>(number)</i>	
A2-09	Do you or any household member ever skip a meal in a day?	Yes	No <i>If no, go to A2-11</i>
A2-10	If yes, why?		
A2-11	Do you or any household member ever go to bed without a meal?	Yes	No <i>If no, go to A3-01</i>
A2-12	If yes, why?		

<b>RESOURCE SYSTEMS</b>							
<b>B 1 PRODUCTIVITY OF IRRIGATED CROPS DURING WINTER MONTHS</b>							
B1-01	What are the six most important crops planted last winter season, total cropped area irrigated, total winter production and average price per unit?	Crop	Total cropped area irrigated (specify ha or m <sup>2</sup> )	Total winter production (specify unit e.g., bag, kg, crate)	Average price per unit (specify e.g., R/kg, R/crate, R/bunch, R/head, etc.)		
		1.					
		2.					
		3.					
		4.					
		5.					
		6.					
B1-02	What is the use of the cultivated crop? Choose one of the following:	<b>Crop</b>	<b>Use of the cultivated crop</b>				
		1.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		2.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		3.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		4.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		5.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		6.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
B1-03	Which fertiliser did you use?	<b>Crop</b>	<b>Fertilisers used</b>				
		1.	Manure	Chemical	Both	No fertilisers	

		2.	Manure	Chemical	Both	No fertilisers
		3.	Manure	Chemical	Both	No fertilisers
		4.	Manure	Chemical	Both	No fertilisers
		5.	Manure	Chemical	Both	No fertilisers
		6.	Manure	Chemical	Both	No fertilisers
B1-04	Did you use chemicals against plant disease?	1.	Yes		No	
		2.	Yes		No	
		3.	Yes		No	
		4.	Yes		No	
		5.	Yes		No	
		6.	Yes		No	
B1-05	Where do you sell your produce?	<b>Crop</b>	<b>Main Market</b>			
		1.	Farm gate	Fresh produce	Contracts	Hawkers Export
		2.	Farm gate	Fresh produce	Contracts	Hawkers Export
		3.	Farm gate	Fresh produce	Contracts	Hawkers Export
		4.	Farm gate	Fresh produce	Contracts	Hawkers Export
		5.	Farm gate	Fresh produce	Contracts	Hawkers Export
		6.	Farm gate	Fresh produce	Contracts	Hawkers Export

B1-06	Who manages the production?	Exclusively men	Mainly men	Mainly women	Exclusively women	Men and women equally
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**B 2 PRODUCTIVITY OF IRRIGATED CROPS DURING SUMMER MONTHS**

B2-01	What are the six most important crops planted, last summer season, total cropped area irrigated, total summer production and average price per unit?	Crop	Total cropped area irrigated (specify ha or m <sup>2</sup> )	Total summer production (specify unit e.g., bag, kg, crate)	Average price per unit (specify e.g, R/kg, R/crate, R/bunch, R/head, etc.)
		1.			
		2.			
		3.			
		4.			
		5.			
		6.			

B2-02	What is the use of the cultivated crop? Choose one of the following:	<b>Crop</b>	<b>Use of the cultivated crop</b>				
		1.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		2.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		3.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale

		4.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		5.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
		6.	Mainly own consumption	Exclusively own consumption	Exclusively sale	Mainly sale	Exclusively sale
B2-03	Which fertiliser did you use?	<b>Crop</b>	<b>Fertilisers used</b>				
		1.	Manure	Chemical	Both	No fertilisers	
		2.	Manure	Chemical	Both	No fertilisers	
		3.	Manure	Chemical	Both	No fertilisers	
		4.	Manure	Chemical	Both	No fertilisers	
		5.	Manure	Chemical	Both	No fertilisers	
		6.	Manure	Chemical	Both	No fertilisers	
B2-04	Did you use chemicals against plant disease?	1.	Yes			No	
		2.	Yes			No	
		3.	Yes			No	
		4.	Yes			No	
		5.	Yes			No	
		6.	Yes			No	
B2-05		<b>Crop</b>	<b>Main Market</b>				

	Where do you sell your produce?	1.	Farm gate	Fresh produce	Contracts	Hawkers	Export
		2.	Farm gate	Fresh produce	Contracts	Hawkers	Export
		3.	Farm gate	Fresh produce	Contracts	Hawkers	Export
		4.	Farm gate	Fresh produce	Contracts	Hawkers	Export
		5.	Farm gate	Fresh produce	Contracts	Hawkers	Export
		6.	Farm gate	Fresh produce	Contracts	Hawkers	Export
B2-06	Who manages the production?	Exclusively men	Mainly men	Mainly women	Exclusively women	Men and women equally	

**Section C: WATER SUPPLY AND WATER UTILISATION**

**C 1 MAIN AND ALTERNATIVE WATER SOURCES CHARACTERISATION**

C1-01	Please indicate your main sources of water for irrigation  <i>e.g. river/spring (surface water), borehole (groundwater)</i> <i>Write in full</i>	1.					
		2.					
C1-02	If it is groundwater, what is the water level in m?						
C1-03	Was the borehole pumping test conducted?	Yes			No		
C1-04	Please provide your ranking of seasonal water supplies of each source; rank these sources	<b>Water source</b>		<b>Seasonal water supply ranking during summer</b>		<b>Seasonal water supply ranking during winter</b>	

	according to their volumes (1=very high, 2=high, 3=always the same, 4=low, 5 =very low)				
		1.			
		2.			
C1-05	Please list the advantages and disadvantages of each source <i>(e.g., availability year-round, reliability, quantity, distance to irrigated smallholder agricultural enterprise, costs, labour, etc.)</i>	<b>Water source</b>	<b>Advantages</b>	<b>Disadvantages</b>	
		1.			
		2.			
C1-06	Is the main source the most available water supply?	Yes <i>If yes, go to B1-09</i>	No		
C1-07	If no, what is the most available water resource on your farm?				
C1-08	Why is the most available water resource not the main source of water on your farm?				
C1-09	Is the source powered by engine, gravity, electricity or solar?	Engine	Gravity	Electricity	Solar
C1-10	What is the conveyance technology from the source to the use point?				
C1-11	Is your main water resource available throughout the year or seasonally variable?	Available throughout the year		Seasonally variable	
C1-12	If seasonally variable, specify the months when the most important				

	source provides water			
C1-13	How often do you irrigate in a month when the important water source has water?			
C1-14	How much water do you use to irrigate from the main source? (litres)			
C1-15	Are you the only water user from the main source?	Yes	No	
C1-16	Do you face water use competition from other sectors?	I am the only user from the source	Farmers and other sectors use water from this source	I, together with other farmers use water from this source
C1-17	If yes, are there some instances you do not get water in time because others are still using the water?	Yes	No <i>If no, go to B1-19</i>	
C1-18	How are the conflicts addressed?			

## C 2 IRRIGATION WATER MANAGEMENT

C2-01	How often do you irrigate your crops in your production plot?	Every day	Every 2 days
		2 times per week	Once a week
		Other, specify	

C2-02	Who usually irrigate your crops at your production plot?	Adult man	Adult woman
		Boy (<16)	Girl (<16)
		Other, specify	
C2-03	Do you use more water during irrigation than your water source has? <i>(e.g. surface water or underground water, rainwater harvesting, etc.)</i>	Yes	No <i>If no, go to C1-08</i>
C2-04	What do you do to supplement your water sources? <b>Write in full</b>		
C2-05	What are the other uses at these water sources? <i>e.g., cattle drinking, car washing, laundry, bathing, brick making etc.) Write all uses!</i>	1.	
		2.	
		3.	
		4.	
C2-06	Based on the main and secondary water resources provided at B1 and B2, how much quantity of water (barrels, litres) does each water source bring to your production plot?	<b>Water sources</b> <i>(as mentioned in B1-01)</i>	<b>Water quantities</b> <b>supplied for irrigation</b>

C2-07	How far is the source from the production plot (km)?	.....(km)		
C2-08	Is the outlet of your main source of water far from your production plots?	Yes	No <i>If no, go to C1-12</i>	
C2-09	Using the infrastructure mentioned in B1-10, how long does it takes to reach your production plots?	----- seconds/minutes		
C2-10	How strong would you say is the competition of other users for this water source?	No competition <i>if no, go to C2</i>	Some competition	
		Seasonal competition	All year-round competition	
C2-11	Did you take any action to try and solve this competition among users?	Yes	No <i>if no, go to C2</i>	
C2-12	If yes, what kind of action did you undertake?			
C2-13	Who else do you feel should undertake action to solve the competition, and what action?			
<b>C3 USE OF AGRICULTURAL TECHNOLOGIES (IRRIGATION SCHEDULING)</b>				
		<b>Technology/Management Practice</b>		
C3-01	Do you know this technology?	Mulching	Yes	No
		Water harvesting	Yes	No
		Evaporation pan	Yes	No
		Tensiometer	Yes	No

		Probe	Yes	No
C3-02	Have you ever used this technology?	Mulching	Yes	No
		Water harvesting	Yes	No
		Evaporation pan	Yes	No
		Tensiometer	Yes	No
		Probe	Yes	No
C3-03	Are you still using this technology?	Mulching	Yes	No
		Water harvesting	Yes	No
		Evaporation pan	Yes	No
		Tensiometer	Yes	No
		Probe	Yes	No

*Thank you very much for your time taken for this interview*

*We will ensure that the overall conclusions and recommendations will be communicated to the officials involved in the day-to-day irrigated smallholder agricultural enterprises operational practices, policy development and planning*

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**15. ANNEXURE C: LETTER FOR APPROVED STUDY AREA PERMITTED TO OBTAIN DEPARTMENTAL CLIMATIC DATA AND COMMISSIONED REPORTS FOR THE STUDY**