WATER USAGE IN POST-HARVEST HANDLING OF GROUNDNUTS AND BEANS AT LUVHADA IRRIGATION SCHEME, LIMPOPO PROVINCE, SOUTH AFRICA.

BY

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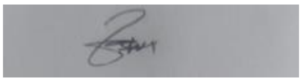
DECLARATION

I, Wish Sibuyi, hereby declare that this dissertation for Masters in Rural Development (AGMARD) submitted to the Institute for Rural Development at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained therein has been duly acknowledged. The dissertation was approved by the School of Agriculture Higher Degrees Committee.

Signature  Date 08 June 2022

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ABSTRACT

Water is central to sustainable agricultural intensification, as it directly influences several dimensions of sustainability, including social, economic, health and environmental aspects. Therefore, lack of water is the greatest constraint to growth and primary productivity of agricultural crops across the globe. In agriculture, and especially in cropping systems, grain legumes play a greater role in meeting global aims of increased sustainable production of nutritious food. Global increase in grain legume yields are currently met almost exclusively through increased planting area. Grain legumes popularly known as pulses are a major source of dietary protein in the daily diet of human beings as well as animal feed. Rural small-scale farmers face various challenges related to agricultural water access and these challenges are not given enough attention to understand how water insecurity affects small-scale crop value chains hence most small-scale farmers lack knowledge on how to secure and sustain water to achieve water security. The main objective of this study was to assess water insecurity in post-harvest handling of Groundnuts and Beans at Luvhada irrigation scheme, Limpopo Province, South Africa. The specific objectives were to analyse water usage in post-harvest handling of Groundnuts and Beans at Luvhada irrigation scheme, South Africa. To determine water security challenges faced in post-harvest handling of Groundnuts and Beans and to suggest possible solutions to water insecurity in post-harvest handling of Groundnuts and Beans. A mixed method design was utilised in this study. Snowball sampling technique was used to select study respondents. The referral system was used as few contacts for the respondents were initially obtained. Accordingly, at least 42 of the 79 farmers who grow leguminous crops at the irrigation scheme, were interviewed. Data was collected using telephone interviews. Collecting data through telephone was necessitated by the Covid-19 pandemic regulations. A questionnaire, which comprised of both closed and open-ended questions was used as a data collection tool. Data from open ended questions was analysed using Atlas-ti version 8 software wherein coding, analysing transcripts and creating network diagrams were computed. Quantitative data was analysed using Statistical Package for the Social Sciences (SPSS) version 27.

The majority of the farmers were male aged between 55 and 64 years. It also emerged that all the respondents were full-time farmers and the proceeds from selling farm produce was their major source of income. Farmers grow legumes because they are good for business and can be grown with minimal water in comparison to other horticultural crops. Sources of water used on post-harvesting activities were farmers' domestic taps, Nzhelele River, paying money to the nearby car wash owner to utilise the tap water, and water canals at the irrigation scheme.

Results of the study revealed that farmers used water mainly for cleaning and cooking in post-harvest activities. Moreover, farmers did not measure or know the exact amount of water used in post-harvest activities either due to lack of interest or due to lack of proper water infrastructure that can allow farmers to record the amount used. Water security challenges faced during post-harvest activities are exacerbated by the absence of water storage facilities and underdeveloped infrastructure to access water at post-harvest. This subsequently embed post-harvest activities, and the impacts were poor quality products, drying of crops as well as damage and loss of stock. The coping strategies adopted by farmers included the use of residential water sources, use of open water sources and sourcing water from other business premises. Thus, proposed strategies to enhance water security in post-harvest activities were the provision of water pump, dam construction, provision of storage water facilities, upgrading of irrigation infrastructure and installation of drip irrigation, water rationing and sharing facilities. It was, therefore, recommended that government, private sectors and other relevant stakeholders should assist the irrigation scheme to improve on water usage in post-harvest activities.

Keywords: Leguminous crops, Luvhada irrigation scheme, post-harvest, small scale farmers**;** water security.

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DEDICATION

I dedicate my work to God.

I dedicate my work to my mother Sibuyi Josphina.

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ABBREVIATIONS AND ACRONYMS

ARC: ISCW - Agriculture Research Council: Institute for Soil, Climate and Water

BNF - Biological Nitrogen Fixation

DAFF - Department of Agriculture, Forestry and Fisheries

DALRRD – Department of Agriculture, Land Reform and Rural Development

DFFE - Department of Forestry and Fisheries and Environment

DWA - Department of Water Affairs

DWAF- Department of Water Affairs and Forestry

FAO - Food and Agriculture Organization

HLPE - High Level Panel of Experts

PHL - Post-Harvest Losses

RSA - Republic of South Africa

SAGI - South African Government Information

SAICE - South Africa Institution of Civil Engineering Infrastructure report card for South

SPSS - Statistical Package for the Social Sciences

SSA - Sub-Saharan Africa

WWAP - World Water Assessment Programme

CHAPTER 1: INTRODUCTION

1.1. Background of the study

Water is central to sustainable agricultural intensification, as it directly influences several dimensions of sustainability, including social, economic, health and environmental aspects (World Water Assessment Programme (WWAP), 2015). The High Level Panel of Experts (HLPE), (2015) emphasize that water is essential to plant growth; in sufficient quantity and at the right time, both of which depend on plant species, varieties, agronomic practices and climate. Therefore, the limited availability of water is the greatest constraint to the growth and primary productivity of crops across the globe (Mueller *et al.,* 2012). Agricultural water is utilized in various stages of crop value chains including production, post-harvest and processing. The current study focused on the post-harvest stage of the value chain which has received very little attention in most water security studies. Water in post-harvest is critical for cleaning the produce, preserving as well as processing. Water availability in the post-harvest is just as critical as water in the production stage as it facilitates the conveyance of quality crop produce from the farmers to the factories and consumers. Yet, little information on water security at the post-harvest stage exists particularly among small-scale farmers in South Africa (Verner *et al.,* 2018). This limits the effectiveness of government initiatives to address water insecurity as most of them are drawn from top-down approaches that exclude farmers and those involved in post-harvest crop handling. To close this gap, the current study sought to assess water usage at the post-harvest stage with particular attention on leguminous crops which are critical for food security and nutrition among small-scale farming societies.

Meeting the food demand of a rapidly increasing global population is emerging as a big challenge to mankind. The population is expected to grow to 9.1 billion people by the year 2050, and about 70% extra food production will be required to feed these people (Govindaraj *et al.,* 2017). Most of this population rise is expected in developing countries, several of which are already facing issues of hunger and food insecurity. Increasing urbanization, climate change and land use for non-food crop production intensify these concerns of increasing food demands. In the last few decades, most of the countries have focused on improving their agricultural production, land use, and population control as their policies to cope with this increasing food demand (Ramankutty *et al.,* 2018). Therefore, sustainable intensification of agriculture is needed to meet the growing demand for food. However, increasing production is not sufficient to ensure food security. The equitable distribution of food and the preservation of ecosystem services is essential. The availability of water to meet increasing food demands is the focus of much of the discourse on agricultural water management, particularly in regions with increasing competition for water and where it is difficult to negotiate Transboundary water agreements (Food and Agriculture Organization (FAO), 2011).

In agriculture, and especially cropping systems, grain legumes play a greater role in meeting global aims of increased, yet sustainable, production of nutritious food. Consequently, global increase in grain legume yields are currently met almost exclusively through increased planting area (Foyer *et al.,* 2016). Grain legumes play a significant role in the 2030 agenda for sustainable development due to their high nutritional value and various environmental and sustainability benefits (FAO, 2016). Leguminous crops provide a considerable quantity of protein requirements as well as flavour and colour (FAO, 2013). Their promotion could alleviate the high prevalence of malnutrition reported in regions such as sub-Saharan Africa and South Asia where 23.2% and 34.5% of the population, respectively are malnourished (Swe *et al.,* 2021). These regions are expected to carry more than 70% of the world's expected 2 billion population growth by 2050 (Huang *et al.,* 2019). This requires the need for more nutritious food to feed the growing population and alleviate malnutrition. Since grain legumes are rich sources of protein and micronutrients. Increasing their production could contribute to the regions' food and nutritional requirements (Foyer *et al.,* 2016).

Among the various crops, grain legumes contribute to small-scale crop production, nutrition as a cost-effective source of protein accounting for about 15% of protein consumption and income as a high-value crop being the third-largest export crop next to coffee and sesame (Getachew, 2019). In addition, legumes have functions such as soil fertility improvement through biological nitrogen fixation (BNF), livestock feed, soil erosion control, source of fuel and a range of other benefits (Muoni *et al.,* 2019).

According to Singh (2012) water scarcity decreases the final leaf area, net photosynthesis, light use efficiency, pod retention and filling by reducing the availability of assimilates and distorting the hormonal balance of leguminous crops. Water limitations considerably reduce the grain yield of cultivars, due to large reductions in growth, grain filling duration, grain weight and grains per plant (Saeidi & Abdoli, 2018). The superiority of well-watered plants in growth and grain filling duration resulted in the production of comparatively more and larger grains and consequently higher grain yield per unit area (Mustafavi *et al.,* 2013). They further stated that drought stress has become the major limiting factor on plant growth and yield. While on the other hand, Daryanto *et al.* (2015) argued that water deficit during reproductive growth is considered to have the most adverse effect on leguminous crops productivity. This study focused on groundnuts and beans as they are the most grown legumes in the study area. Legumes were preferred in this study because few studies were done in water security and post-harvest of legumes. Post-harvest activities of legumes that need water are the cleaning process where the legumes such as groundnuts are washed for fresh produce. Storages also require water as the crops need to be stored in hygiene areas.

Buyukbay *et al.* (2011) elaborated that post-harvest system encompasses a sequence of activities and operations that can be divided into two groups: the technical activities which include harvesting, field drying, threshing, cleaning, additional drying, storage, processing, and quality control and the economic activities that include transporting, marketing, information and communication, administration and management. Effective post-harvest management, therefore, maintains the quality of food crops from when they are harvested to when they reach the consumer (Gustavsson *et al.,* 2011). This study established water usage issues such as the state of water security, challenges and possible solutions at a local level.

Globally, the value chain concept in agriculture is widely applied. Kiplinsky & Morris (2001) defined a value chain as a full range of activities necessary to bring a product or service from conception through different phases of production, processing, marketing and utilization. It involves a combination of the physical transformation of products and the input of various producer services. Abang *et al.* (2014) argued that value chain analysis in agriculture provides a basis for accessing the efficiency of value-added operations as well as systematic competitiveness along specific chains. Dekker (2003) further argued that structural issues such as cost objectives, budgets, and value cost drivers are important to ensure that an effective value chain analysis is performed.

South Africa is prone to droughts and recently experienced one of the worst droughts in history. Provinces such as Limpopo, Mpumalanga, Free State, North West and Kwazulu Natal have been declared as disaster areas due to the drought (Maponya & Mpandeli, 2016). They further state that the situation has thrown the country into pandemonium as the water scarcity debate has taken centre stage with every sector looking for ways of conserving water. Agriculture is one of the sectors that has been hardest hit by the drought. Agriculture uses more than 60% of freshwater, and most of this water is used in irrigation (Elliott *et al.,* 2014). Therefore, the current drought has had the most devastating impacts on the agriculture industry because of the effects on the food production chain (ARC-ISCW, 2016). Piesse (2016), explains that South Africa is the region's largest food producer, therefore when severe climatic conditions in this case being drought, hit the country agricultural production is hugely affected. Piesse (2016) further emphasized that if South Africa is to transition to a new climate pattern, the feasibility of producing alternative food crops, the ones that will require less water usage will need to be explored. This study adds to the various efforts for addressing water scarcity through understanding water use and associated challenges along the crop value chain.

In the Limpopo province, water is a major limiting resource which often results in crop production losses and lower incomes in vulnerable areas. Yet, many people in the province depend on producing indigenous crops for their livelihood. The adoption of agricultural production systems that are more productive, efficient in resource use, resilient to risks and have less variability but greater stability in their outputs is required if productivity in this farming system is to be realized and maintained (FAO, 2013). Apart from agriculture playing an essential role and serving as a critical economic sector in the Limpopo Province, it contributes towards employment opportunities within local communities as stated by Baloyi (2010) Agriculture remains highly labour intensive, and a source of economic relief from poverty for the majority of people residing in rural areas of Limpopo Province (Limpopo Environmental Outlook Report, 2016). Therefore, water needs to be available at all times for agricultural activities as agriculture contributes significantly to the province economy. Because most studies in the province have focused on water security at the crop production level (e.g. Nephawe *et al.,* 2021, Mwale *et al.,* 2021 & Kativhu *et al.,* 2020), the current study provides knowledge on water usage at the post-harvest stage of leguminous crops. This can be the first step towards finding water management solutions that are informed by local realities along the entire value chain among small-scale farmers.

1.2. Statement of the research problem

Despite the increasing threats of water scarcity across the world, little is known about water use and associated challenges along the entire crop value chain by the South African agricultural sector. The situation is dire in small-scale farming communities which have limited resources to effectively cope with water scarcity in the present and future. The need for understanding water scarcity challenges, situations and trends has become even more urgent given the recently announced climate change trajectories and projections. The United Nations (2021) reports that water scarcity has reached a critical point, with recent global warming projects indicating that heatwaves, flooding and droughts are set to intensify as the world is set to hit the 1.5 Celsius global warming within the next 20 years. Yet, rural small-scale farmers are facing various water access challenges but little attention is given to understanding how water security relates to rural small-scale crop value chains especially the post-harvest activities (Hilson, 2016). Furthermore, there is limited awareness regarding how the structure and function of the value chains of rural small-scale crop farming strongly influence the quantity and quality of water.

Despite the growing concerns about water security in Limpopo Province, there is little, if any, knowledge on crop characteristics, water use and required agronomic practices for the production of leguminous crops. As such, further research and development of the production and marketing are required. Although studies have generated critical agronomic data on water use of traditional grain and legume food crops in South Africa (Chibarabada *et al.,* 2017) there are limited research studies on water use at post-harvest stages particularly in the Limpopo Province where several irrigation schemes for small-scale farmers exist. The current study seeks to assess water use and associated challenges at post-harvest activities of groundnuts and beans at Luvhada irrigation scheme. The irrigation scheme was established long time ago and has more farming activities at a less scale than other schemes in the area. It is also situated between both sources of water. These two are the commonly grown legumes in the area. Understanding water security in the area could be contributes towards smart water management and improving the quality of post-harvest handling of legumes and related crops and thus, upscaling the large external marketability of such crops to supermarkets.

1.3. Justification of the study

The main challenge faced by agricultural researchers, policymakers and economic developers is how to safely feed 9.1 billion people by the year 2050 (Parfitt *et al*., 2010). Therefore, the study helps the PEER project members, farmers, and Nzhelele Ha-Mphaila community members by giving them knowledge and skills concerning water security and how to achieve water security as well as how to assess water for post-harvest activities and how to utilize water efficiency in post-harvest handling of leguminous crops. The study will also help relevant stakeholders and those who are interested in farming to know water security challenges faced in post-harvest and how to overcome those challenges. The study will also provide information to help the Department of Forestry and Fisheries and Environment (DFFE) to make an informed decision regarding water security.

1.4. Research objectives

The main objective of this study was to assess water insecurity in post-harvest handling of Groundnuts and Beans at Luvhada irrigation scheme, Limpopo Province, South Africa.

Specific objectives

1. To analyse water use in post-harvest handling of groundnuts and beans at Luvhada irrigation scheme.

2. To determine water security challenges faced in post-harvest handling of the leguminous crops.

3. To suggest possible solutions to water insecurity in post-harvest handling of the leguminous crops.

1.5. Research questions

1. How is water used at the post-harvest stage of the leguminous crops at Luvhada irrigation scheme?
2. What are the water security challenges faced in post-harvest handling of the leguminous crops?
3. What are the possible solutions to improve water security in post-harvest handling of the leguminous crops?

1.6. Theoretical framework of the study

In this study, Catastrophe theory was adopted. The Catastrophe theory originated as a branch of topology designed to deal with discontinuous dynamic systems governed by a potential energy-like function (Wang *et al.,* 2011). In the catastrophe theory, system function variables are divided into dependent state variables which are the internal token variables of the system, and control variables which are the external influence factors while the system is running (Hui, 2008). For example, in this study, water usage was the internal variable and post-harvest activities such as cleaning, storage, e.t.c. are the control variables. In the catastrophe theory, the dependency of state variables on control variables is determined by the catastrophe fuzzy membership functions. This type of uncertainty has long been handled appropriately by probability theory and statistics. Though, in many areas such as water security, water scarcity, etc., human judgment, evaluation, and decisions often employ linguistic variables or subjective perception which cannot be solved with probability theory. In the present study, catastrophe theory was used to determine fuzzy membership functions that define the relationship between state variables (water usage) and control variables (post-harvest activities such as cleaning, storage, etc). The theory assisted the farmers in choosing activities and identification and mitigation risks at an early stage. Therefore, the benefits of the theory were to have the ability to explain and more accurately predict phenomena, help to recognize, understand, and explain new situations, compare and contrast different experiences, help explain decisions and actions to others, and help to identify gaps in our knowledge and research.

1.7. Key terms and concepts

1.7.1. Water Security: is the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production coupled with an acceptable level of water-related risks (Foster & MacDonald, 2014).

1.7.2. Post-harvest handling: is defined as the stage of crop production immediately following harvest. This process of post-harvest begins as soon as a crop is removed from the ground or separated from its parent plant (Kimiywe, 2015).

1.7.3. Leguminous crops: Leguminous crops or legumes are crops that belong to the family Fabaceae (Syn. Leguminosae). This family includes a large number of flowering trees, vines, shrubs, etc. Legumes are grown agriculturally, primarily for their grain seed called pulse, for livestock forage and silage, and as soil-enhancing green manure (Escalante, 2019).

1.8. Outline of the dissertation

This research dissertation consists of seven chapters, the reference section, and appendices. Chapter one is composed of the background of the study, statement of the research problem, justification of the study, research objectives and associated questions as well as definition of key terms and concepts used in the study. Chapter 2 deals with the review of literature on water usage in post-harvest handling and consumption of leguminous crops. Chapter 3 highlights the methodology that was used in the research, description of the study site, research design, data collection, and ethical considerations and data analysis. Chapter 4 outlines the findings and the discussions of objective 1. Chapter 5 provides the findings and the discussions of objective 2. Chapter 6 outlines the findings and discussions of objective 3. Chapter 7 is composed of a conclusion and recommendations. References used to support facts and ideas are listed. Data collection tools, consent form and ethics certificate are presented in the appendix.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter provides a review of literature related to this study. The chapter gives an overview of the following; water security is explained in detail generally and in relation to agriculture; angles of water security are articulated as well. How food value chain process play a crucial role for understanding markets, their relationships, the participation of different actors and the critical constraints that limit the growth of agricultural production and consequently the competitiveness of small-scale farmers is elaborated. Types of leguminous crops (Groundnuts and Beans) which the study focused on are discussed. Post-harvest handling process/methods of leguminous crops post-harvest losses as challenges faced by farmers and solutions to water security in post-harvest handling of leguminous crops were reviewed as well.

2.2. Water security

The concept of water security has received increased attention in recent years in both policy and academic debates (Cook & Bakker, 2012; Cook & Bakker, 2013). Varady *et al*. (2016) has defined water security as access to adequate safe water at an affordable cost ensuring that the natural environment is protected and enhanced thus incorporating ecological dimensions. UN-Water (2013) also defined water security as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development. This ensures protection against water-borne pollution and water-related disasters, preserves ecosystems in a climate of peace and political stability. Thus balancing the needs for water management related to socio-economic development, health, disasters and ecosystems.

Water availability is a broad topic, encompassing the biophysical supply of water, the demand for water, and access to water. Therefore, increasing water availability has the potential to alleviate the impacts of water scarcity (Conway *et al.,* 2015). Water availability is multifaceted, so there are many potential approaches to increasing it. Historically, water availability was increased through supply management and through building dams and canals to access new water sources (Mehta, 2014). Moreover, at Luvhada irrigation scheme canals were built for accessing water from the fountain. Gleick (2003) argues for a different approach that emphasizes demand management such that more water is effectively available. On the other hand, Falkenmark & Rockstrom (2006) pointed out that it is critical to focus on managing green water (the rainwater that is directly used by crops) and not focusing exclusively on water available in lakes, streams, and reservoirs.

According to Tyagi *et al.* (2013) apart from the quantity of water available for use, the quality of water is also important. Poor quality water that is not fit for purpose effectively reduces the amount of water available. They further elaborated that water quality includes all physical, chemical and biological factors that influence the beneficial use of water. Poor water quality may stem from inadequate domestic waste-water treatment, industrial effluent pollution and eutrophication as a result of high levels of fertilizer application (Withers *et al.,* 2014). The use of poor quality water in the food sector has several adverse health effects. This depends on the form of contamination, these may range from toxically high metal concentrations to endocrine disruptors which impact development in humans and animals and microbial contamination such as Salmonella (Kabir *et al.,* 2015).

Agriculture does not require the tertiary treatment demanded by domestic water supply, though poor quality water does pose a particular risk in the export market (Allende & Monaghan, 2015). Poor irrigation water quality may impact the ability of farmers to export their products because they do not meet stringent export regulations. This has a damaging effect on the sector and may impact the trade balance of agriculture. Due to the multiplier effect in agriculture, a large number of jobs such as cleaners, operators etc may also be at risk. Therefore, poor water quality has a detrimental effect on the health of the crop and on the ability to meet regulatory requirements for export (Baleta & Pegram, 2014; Allende & Monaghan, 2015). In South Africa, Agriculture is the largest sector which uses more water for different agricultural activities (Nhemachena *et al.,* 2020). Therefore, in agriculture access to water is crucial such that crops need water to grow. Small-scale farmers usually access water from fountains, dams, rivers as well as from the ground. While at Luvhada irrigation scheme members have access to water from the fountain and nearby river (Nzhelele River). This study focused on assessing water usage in post-harvest handling of leguminous crops.

2.3. Food value chain

After harvesting, the crops go through some sort of transformation from their original state to a more valuable state. This is referred to as value addition (Bac *et al.,* 2014). Bakos *et al*. (2014) elaborated that value addition can be viewed as the benefits obtained from a product concerning quality, form and functionality. This includes the transformation of food to nutrients that are utilized by the body (Marco *et al.,* 2017). Chibarabada *et al.* (2017) further argued that value addition includes agro-processing which describes the manufacturing processes involved to derive products from agricultural raw products. There are several stages in the food value chain which include inputs, production, processing and distribution, marketing and finally consumption stage. Conclusively processing and distribution, marketing consumption stage form part of the post-harvest of crops.

According to the FAO (2010), a value chain in agriculture identifies the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product. This can involve processing, packaging, storage, transport and distribution. Therefore, water is used at every stage of the chain. Embedded water or virtual water represents the water embodied in the inputs required to produce the final product (Mubako *et al.,* 2013). Agricultural products generally have a significantly larger water footprint attributed to the crop production stage than the processing stage (Herath *et al.,* 2013).

Food value chains do not comprise only the stakeholders directly involved in the production of products in question, but smallholder farmers can be involved in the value chains as wage labourers in production and processing also as providers in the service markets that support value chains (Seville *et al*., 2011). Therefore, value chain mapping is essential in the understanding of markets, their relationships, the participation of different actors and the critical constraints that limit the growth of agricultural production and consequently the competitiveness of small-scale farmers. McComick & Schmitz (2001) defined value chain mapping as creating a visual representation of the connections between actors in value chain analysis as well as other stakeholders. Therefore, value chain mapping is considered a standard tool in value chain research and analysis. Moreover, it helps in explaining and understanding the process by which a product goes through before and until it reaches the final consumer. Value addition to legumes after harvest is gaining importance due to diversity in socio-economic conditions, industrial growth and urbanization. It is not only to satisfy the producers or processors by getting high monetary return but also with better taste and nutrition (Brat *et al.,* 2005).

2.4. Types of leguminous crops

Legumes can be grown in various environments. Approximately 30-grain legumes are grown in the semi and arid tropics across different ecological niches (Chibarabada *et al*., 2017). Chickpea, dry bean, groundnut, pigeon pea, cowpea and soybean account for more than 90% of grain legume production (Cernay *et al*., 2016). The remainder of the grain legumes e.g. Fababean, Bambara groundnut, common pea and lablab, lentil account for less than 10% of legume production (Singh & Singh, 2014). Pea, cowpea and beans (Indian bean and French bean) are the important leguminous vegetables in Africa (Abate *et al.,* 2012). According to Das *et al,* (2018) the other beans of lesser economic importance include cluster bean, broad bean, Lima bean, winged bean, etc. Pea and broad Beans are cool-season crops while other Beans are warm-season crops (Gotame *et al*., 2018). Legumes that are found at Luvhada irrigation scheme are Groundnuts, Beans and Bambara nuts. The study focused on Groundnuts and Beans as they are the most grown legumes in the study area.

2.4.1. Groundnuts (*Arachis hypogaea L*)

Groundnuts which are also known as peanuts, earthnuts, monkey-nuts and goobers, is an important cash crop and an annual leguminous oil crop. Its seeds are a rich source of edible oil of about 43-55% and protein of about 25-28% (Kandakoo *et al.,* 2014). It is considered one of the world's most significant oilseed crops (Upadhyaya *et al*., 2010). About two-thirds of world production is crushed for oil and the remaining one-third is consumed as food such as peanut butter, sweet snacks roasted, salted, or in sweets (Williams, 2013). Furthermore, in other parts of the world, they are boiled, either in the shell or unshelled. Its cake is used as a feed or for making other food products and haulms provide quality fodder. Surendranatha *et al*. (2011) state that groundnut is ranked as the 4th most important food crop. The crop is approximately grown on 25.2 million hectares global with a total production of about 35.9 million metric tons. Groundnuts at Luvhada are grown with other crops such as beans, maize, onions, sweet potatoes, cabbages, butternuts and indigenous vegetables like Muxe (Nephawe, 2019). Furthermore, groundnuts are grown in the summer rainfall regions under irrigated or rain fed conditions. The crop is produced for home consumption and marketing.

Groundnuts are relatively tolerant to drought as far as survival is concerned but their pod yield reduction is very high if proper soil moisture is not maintained especially during critical growth stages (flowering, pegging of pod development) (Prasad *et al.,* 2010). Moreover, Suleiman *et al*. (2013) stated that the amount of water used by the crop is determined by the potential evapotranspiration during the crop period and the degree of soil cover. Furthermore, the water requirement reaches a maximum during flowering and continues up to pod formation. Groundnut requires on an average 400-500 mm of water but it varies with soil type, agro-climates and genotype. In addition, total rainfall to a tune of 400-600 mm well-distributed over the entire growth period during kharif results in good yield. However, during summer, the water use of Groundnuts is 450-830 mm depending upon soil type and agro-climatic conditions (Joshi *et al.,* 2015).

2.4.2. Beans

Beans are a globally and nationally important source of protein and culturally significant food items (Vainio *et al.,* 2016). Beans are the most important food legume for direct consumption in the world. They are regarded as one of the most important field crops in South Africa on account of their high protein content and dietary benefits (Bouchenak & Lamri-Senhadji, 2013). Bouchenak & Lamri-Senhadji (2013) further argue that beans are warm-season annual legumes with upright or bush as well as the creeping type or indeterminate growth habit. However, Frame (2019) added that the first true leaf formed after the cotyledons emerge from the soil is simple or unifoliate and all subsequent leaves are compound.

Small flowers (self-pollinated) are produced in clusters at various nodes on the plant and maybe either white or lavender in colour. Mature pod colour, seed colour and seed size or shape vary depending upon the market class and/or variety (Mohan *et al.,* 2013). The crop requires between 85 and 120 days from planting to maturity depending on the variety. The first half of this period is vegetative development and the latter half is reproductive. In vine types, there is an overlap of the two periods because continued vegetative growth occurs after flowering begins (Hatfield & Prueger, 2015). Flowering continues for 2 to 3 weeks so there can be new pods, half developed pods and fully developed pods as well as newly opened flowers present on many plants in early August. Pods are initially green changing to light brown or tan as they mature. Each pod can contain 2 to 4 seeds depending on variety (Hatfield & Prueger, 2015). Beans at Luvhada irrigation scheme are grown for home consumption as well marketing like other crops of which they generate income.

According to Haghverdi *et al.* (2013) since irrigation is not 100% efficient, provision of water should be made for about 450 mm. Rainfall is not included in these recommendations. If it rains, the amount should be taken into consideration. On the other hand, Truc *et al.* (2013) pointed out that water consumption is determined by climatic conditions. In the very warm bushveld of northern and eastern South Africa, the water consumption will be higher than discussed. In the Highveld, lower values can be expected. Therefore, frequent, light watering should be avoided. Avoiding irrigating during the middle of the day is essential because evaporation losses are usually highest then (Worthington, 2013). However, if it has not rained for a week or two weeks where it is hotter, beans should be irrigated more often (Beebe *et al.,* 2013). Therefore, farmers at Luvhada must have water for better growth of beans and also in post-harvest to clean the legumes.

2.5. Post-harvest handling process/methods of leguminous crops

The post-harvest system encompasses a sequence of activities and operations that can be divided into two groups: the technical activities which include harvesting, field drying, threshing, cleaning, additional drying, storage, processing, and quality control and the economic activities including transporting, marketing, information and communication, administration and management.

2.5.1. Threshing

Threshing is the primary processing of leguminous crops of which the pod threshing and de-hulling of the whole seeds take place. Threshing, as defined by Paulsen *et al*. (2015) is the process where the grain is separated from the straw. The threshing of food legumes is usually carried out manually using long wooden sticks, thereby increasing grain damage. Furthermore, manual threshing is the most common practice in developing countries. The purpose of the threshing process is to peel the grain from the panicles (Shah, 2013). Delay in threshing after harvesting results in a significant loss of the quantity and quality of the crop, because the plant is exposed to atmospheric and biotic factors such as rodents, birds, and insects (Alavi *et al.*, 2012). Consequently, lack of mechanization is the main cause of this delay, which causes significant losses. Pratap *et al*. (2016) further state that advances in post-harvest technology have made available threshing machinery that separates the seeds from the pods. However, crops must have optimum moisture content in their grains to minimize threshing damage.

Threshing operations also vary both within and among developing countries. It varies from the age-old procedure of using sticks and racks to the modern power threshers (Nur, 2017). For instance, in India the small-scale and marginal farmers do manual threshing using sticks and rakes (Carter, 2019). Although variations also exist in stripping pods from the plant. After harvest bunch type plants are stacked in heaps with the pod-end exposed. After the crop has remained in this state for a week or so the pegs become brittle and the pods are plucked from the plants with labor (Nur, 2017). In most of the legumes growing (such as groundnut) areas in India for example the states of Andhra Pradesh, Maharastra and Gujarat, the harvested plants are allowed to dry well on the threshing floor, the dried mass is beaten with flails. After making sure that the pods have been detached from the plants, pods are separated from the beaten mass by winnowing (Kabir & Fedele, 2018).

2.5.2. Cleaning

According to Goodburn & Wallace (2013) cleaning criteria and cleaning methods are crucial to getting a high-quality product and contribute to food safety. Therefore, after the legumes are threshed, grains are generally impure, due to the presence of straw, stones, inert matter, etc. Then the legumes need to be cleaned (Afzal *et al.,* 2019). Cleaning of legumes is done by removing the dust and foreign substances to improve the physical properties of the products. Traditionally in most rural areas, sieves are used for small-scale primary processing. Therefore, screening is the most common cleaning method in developing countries. Screening is another common method that can be done manually or mechanically (Lim *et al.,* 2015). Lim *et al.* (2015) further elaborated that clean, healthy and high-quality products have a high level of nutritional value, encourage sustainable agriculture and contribute to the reduction of the effects of climate-changing scenarios.

According to Kumar & Kalita (2017) in developing countries, less attention has been paid to cleaning material by the machines before storage. They further stated that cleaning of groundnuts with sand-screens at ground level and employing additional elevators are mostly the effective cleaning method, especially in developing countries. In Senegal, a rotary cleaner made by SISMAR®, is used which can be operated by hand. This machine has a double sieve designed to separate groundnut from the husk and other rubbish (Palaniswamy, 2018).

2.5.3. Drying

Drying is an important element of post-harvest work to maintain high crop quality, minimize storage losses, and reduce transport costs (Bala *et al*., 2010; Gliński *et al*., 2014). Drying can be done naturally (in the sun or the shade) or using a mechanical dryer. Natural drying or drying in the sun is a traditional and economical practice of drying the harvested crops and is the most popular method in developing countries (Lipinski *et al*., 2013). The entire crops without threshing remain in the field only to dry. On the other hand, Dhaliwal & Kular (2014) argued that some farmers use mats or plastic sieves to sift the grain, which reduces dust pollution and facilitates the drying of legumes. Solar drying requires large manpower, it is slow, and it depends on the weather, and causes large losses. Grain lying in the open sun is eaten by birds and insects, as well as contaminated by mixing stones, dust, and other foreign materials. Rain or adverse weather conditions can limit proper drying, and yields are stored in high humidity, which leads to large losses caused by the growth of moulds (Lipinski *et al.,* 2013). Mechanical drying solves some of the limitations of natural drying and offers benefits such as reducing losses, better control over the air temperature. However, the disadvantage is the limitations associated with the high initial and maintenance costs of the dryer and the lack of knowledge about their operation. For this reason, dryers are rarely used by small producers in developing countries (Alavi *et al.,* 2012; Grudzińska & Barbaś, 2017).

2.5.4. Packing & Processing/ Grading

Both cleaned grains with hull and whole and split de-hulled grains are graded and packed for consumers (Fıratlıgil-Durmus *et al.,* 2010). Therefore, grading and packaging operations are common steps in both primary and secondary processing (Kadlec *et al*., 2006). Nasar-Abbas (2009) states that based on consumer demand, cleaned grains are graded for uniformity of specific diameter or thickness of grain. The principal roles of food packaging are to protect food products from outside influences and distribution damage, to contain the food, and to provide consumers with ingredient and nutrition information. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact (Ashaye, 2011). This grading is based on grain size, which can incur additional costs to the final product, and demand for sizing can be very specific. As in the case of Groundnuts, farmers in Spain prefer to separate the big and small Groundnuts (Bertioli *et al.,* 2019). Bertioli *et al.* (2019) further state that the size of groundnuts and bean grains also determines consumer preference, as large-seeded varieties require longer cooking times than small-seeded. To this end, efforts have been made to develop sizing and grading machines and now both, hand- and power-operated graders are available commercially (Ali, 2004). The grading of legume grains is based on colour; machinery that sort by colour is available, having been adapted from other industries.

After grading, legume food grains are packed in polypropylene or jute bags as whole grains or spilled forms (Pratap *et al.,* 2016). In Canada, the packaging of whole legumes grains is done as per local or export specifications. For this purpose, various types of bagging, containerization and shipping methods are used (Prentice & Hemmes, 2015). Moreover, exported legumes are generally packaged in polypropylene bags of 25–100 kg. Consumer-ready packages are typically sold in 500 or 1000 g polypropylene bags, or possibly up to 15 kg, particularly for the restaurant and institutional sector (Vandenberg, 2009). Private firms in Turkey supply all types of dry legumes in 1 kg packets or 25–50 kg polythene bags. In India, food legume grains are consumed as whole grains as well as in split dhal form; the cleaned and graded legumes are packed in 50 or 100 kg jute bags for wholesale and retail traders (Pratap *et al.,* 2016).

2.4.5. Storage

Before primary processing, the harvested grain legumes are stored in steel bins, jute bags, earthen pots, mud bins, and bamboo baskets or other types of receptacles at farmer, trader and industry levels (Ansari *et al.,* 2015). According to Aulakh *et al*. (2013) storage plays a vital role in the food supply chain. In most places, leguminous crops are conducted seasonally, and after harvest, the grains are stored for a short or long period as food reserves and as seeds for the next season (Grover & Singh, 2013). Thus, under proper storage conditions, grain legumes can be stored for up to three years (Summerfield, 2012). Considering the predicted increase in drought occurrences, this is an important attribute as stored grain can be consumed during drought and when there is shortage of food. However, weevils, rats, bruchids and other storage pests can be a problem in storage and proper chemicals need to be used to control them (Summerfield, 2012). A poor storage environment can result in colour loss, moisture absorption, and desorption as well as hardness or case hardness issues (McCormack, 2004).

In developing countries such as India, about 50-60% of seeds are stored in traditional structures such as Kanaja, Kothi, Sanduka, clay flower pots, Gummi, and Kacheri at household and farm level for self-seeding and consumption (Grover & Singh 2013). On the other hand, Grover & Singh (2013) argue that local storage structures are made of locally available materials with grass, wood, clay, e.t.c. and cannot guarantee crop protection against pests for a long time.

2.4.6. Transportation

Transport is a vital operation of the legumes grain supply chain, as the goods have to be transferred from one stage to another, for example, from the field to processing crops, from the field to warehouses, and processing plants to the market (Ayaz *et al.,* 2019). Consequently, lack of proper transport infrastructure can cause damages to food products through bruising and losses caused by spillage. Grain legumes are usually transported in sacks from field warehouses to processing plants in combat vehicles, bicycles, small motor vehicles, or open trucks (Baloch & Thapa 2014; Glińskietal, 2014). At the field level in South Asian countries, most legumes crops are transported in combat vehicles or open trolls (Neergaard, 2017).

2.6. Post-harvest losses

Kiaya (2014) defined post-harvest losses (PHL) as the quantitative and qualitative loss of food in various post-harvest operations. On the other hand, "food loss" defined too as food is available for human consumption, but not consumed (Lipinski *et al.,* 2013). Postharvest losses are not just a loss of valuable food, but also of all the resources invested in producing the food. Crop postharvest systems cover a range of different activity stages and are typically spread spatially and temporally across different locations and actors. Thus, the systems are complex and dynamic (Affognon *et al.,* 2015). They include harvesting, transporting from the field, drying, threshing/shelling, cleaning and sorting, storage, packaging, marketing, processing, and consumption of the crop. Losses can occur in a multitude of ways at each activity stage and due to a host of diverse reasons (Gustavsson *et al.,* 2011). Additionally, Gustavsson *et al.* (2011) notes that to decide how to reduce PHLs, and which investments and policies to implement, it is important to understand not just how much food is being lost through postharvest, but at which activity stages these PHLs are occurring, how, and why. Thus, pre-harvest management of legume grain crops should be taken into consideration for obtaining improved quality and quantity in postharvest products (Hodges & Stathers, 2013). Conclusively, Luvhada irrigation scheme should take into consideration the pre-harvest management of their legumes to maintain and obtain the quality and quantity of legumes.

Post-harvest losses in pulses are estimated to the extent of about 25-30% (Verma, 2018). These losses decrease the availability of good quality products, forcing national policymakers to import such commodities and this may have serious impacts on the earnings of local pulse growers of different states. By reducing the high post-harvest losses of crops particularly protein-rich legumes, nutritional security in India and other developing countries can only be achieved (Lal & Verma, 2007). There is a lack of knowledge and information among field staff, extension workers, farmers and rural entrepreneurs regarding the post-harvest management, processing of pulses and derivation of value-added products. So, improving the different postharvest aspects of pulses is the most important way forward. Therefore, reducing food losses will offer an important gateway of not only improving nutrition but also alleviating poverty in the sub-Saharan Africa (SSA) region.

Post-harvest losses occur at different stages at harvesting, threshing, cleaning, winnowing, packaging, transportation, storage, processing and marketing. For example, in Groundnut the losses during harvesting are due to left-out pods in the soil. It has been estimated that post-harvest pod losses in harvesting vary from 16 to 47%, in curing / drying 5 to 50 percent (Ansari *et al.,* 2015). However, in transportation, the losses occur on account of pilferage, leakage of gunny bags and rough handling. The losses during storage are mainly due to drainage loss and damage by rodents and pests. Damage also occurs due to dampness which develops the moulds, leading to contamination with Aflatoxin (Kiaya, 2014).

Post-harvest losses are regarded as the major contributing factor to food and income insecurity in SSA. Physical grain losses from insects, mould, and rodents are estimated at 10-20% of production (World Bank, 2011). Furthermore, calls have been made to increase investment in harvesting, processing, storage technologies and training in developing countries to address this key constraint to food security (Lybbert & Sumner, 2012). Storage insects in particular cause significant losses for grain and legume producers (Affognon *et al.,* 2015). Poor storage conditions may also affect the seed quality.

2.7. Water security challenges faced in post-harvest handling of leguminous crops

South Africa is experiencing one of the worst droughts in history. Therefore, agriculture is one of the industries that has been hardest hit by the drought (Botai *et al.,* 2016). Agriculture uses more than 60% of freshwater, and most of this water is used in irrigation StatsSA (2007). Moreover, the drought has had the most devastating impacts on the agriculture industry because of the effects on the food production chain. Drought has emerged as one of the main challenges to the Limpopo Province farmers. Another major challenge of the South African Government in recent times has been to develop and maintain appropriate policies to protect South African freshwater resources (Maponya & Mpandeli, 2013). Water security and governance', restoring citizens' trust in government intentions and capability to deliver water-related services was the most significant challenge. The lack of technology involvement in small-scale farmers also poses challenges to the production of those farmers (Maponya & Mpandeli, 2013.)

2.8. Solutions to water security in post-harvest handling of leguminous crops

The shortage of water can be augmented from wastewater utilization after suitable treatment (FAO, 2012). Some of the techniques like artificial recharge and the use of unconventional water are effective solutions to minimize the impact of such problems (Misra, 2014). Jhansi & Mishra (2013) argued that recycling and reuse of wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes and replenishing a groundwater aquifer can help to minimize the impact of climate change on crop yield and water resources. They added that recycling water for irrigation requires less treatment than recycled water for domestic purposes. Water, being considered an Eco social asset, should be exploited in an environmentally sustainable pattern to preserve it for future generations. According to Scott *et al.* (2015) to improve water security in post-harvest handling countries should make the initial investment required for regulating water resources and water storage, then for water supply for human settlements and industrial production, food and energy. Therefore, it will invest in associated institutions needed to manage water resources and the related infrastructure to reach a perceived level of water security. Water security can be achieved with the creation or acquisition of an appropriate level of a mix of infrastructure and water management capacity (Barthel & Isendahl, 2013). Thus, water security is achieved when communities are resistant to the impact of water resources, so that lack of access to water and water-related services and vulnerability to the adverse impacts of water (drought, floods, disease, etc.) cannot create significant barriers to growth (Frone & Frone, 2012).

2.9. Summary of Literature Review

Agriculture in South Africa is important in alleviating poverty through the creation of jobs and income generation. However, the agriculture sector is expected to feed the growing population. Therefore, increasing water availability has the potential to alleviate the impacts of water scarcity and improve water security in post-harvest. The water must be conserved especially for post-harvest activities to prevent post-harvest loss of legume crops and ensure food security. Different activities are done in post-harvest such as cleaning the legumes, storage, packaging, etc of which water is needed to clean legumes for fresh produce as well as cleaning the legumes storage hence it is important for water security to be achieved to small-scale farmers. Water security is achieved when communities are resistant to the impact of water resources, so that lack of access to water and water-related services and vulnerability to the adverse impacts of water (drought, floods, disease, etc.) cannot create significant barriers to growth. The section that follows, presents the methodology used to gather data for this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

This chapter presents the research design as well as the methodology that was utilised in this study. Schwardt (2007) defines research methodology as a way in which an inquiry should proceed. It involves analysis of the assumptions, principles and procedures in a particular approach to inquiry. In this chapter a description of the study area, research design, population and sampling procedures, how data was collected, data analysis, and ethical considerations were elaborated for ease of conducting the study and subsequently achieving objectives of the study. The study assessed water usage in post-harvest handling of leguminous crops at Luvhada irrigation scheme, Vhembe district, Limpopo, South Africa.

3.2. Description of the study area

Limpopo Province covers an area of approximately 125 755 km^2 which is about 10.3% of the country's total area (Limpopo Province, an overview 2020). The province is the fifth largest in the country in terms of population size. The Vhembe District Municipality is a Category C municipality located in the northern part of the Limpopo Province. It shares borders with Zimbabwe and Botswana in the northwest and Mozambique in the southeast through the Kruger National Park (Vhembe District Municipality, 2020). The Limpopo River valley forms the border between the district and its international neighbours (Rasimphi & Tinarwo, 2020). It is comprised of four local municipalities: Musina, Thulamela, Makhado and Collins Chabane. The district municipal offices are located in the town of Thohoyandou. Luvhada irrigation scheme is within Makhado Local Municipality.

Luvhada irrigation scheme is found at Nzhelele Ha-Mphaila village (30°9'0"E & 22°54'0"s) in Limpopo Province, South Africa. The Scheme is situated between the Nzhelele River and Mphephu Resort. It supplies its products to different local markets in the Dzanani area which includes, Thohoyandou, Louis Trichardt and Musina. The farmers access water for their agricultural activities from the Lulumba fountain, out of which a hot spring oozes water constantly. However, when the water reaches the field it would have cooled down. The scheme has about 79 members, each owning 0.4 or more ha of land (Nephawe, 2019). They produce maize as their main crop. They also produce beans, onions, sweet potatoes, cabbages, groundnuts, Bambara nuts, butternuts and indigenous vegetables like Muxe (Nephawe, 2019). The scheme is situated in an area with 18 other irrigation schemes in Nzhelele, and it is one of the 3 successful schemes. It was preferred for this study because, despite being established long back, the farmers face countless water-related challenges but they are still into agricultural production. The following map (Figure 3.1) displays the study area.

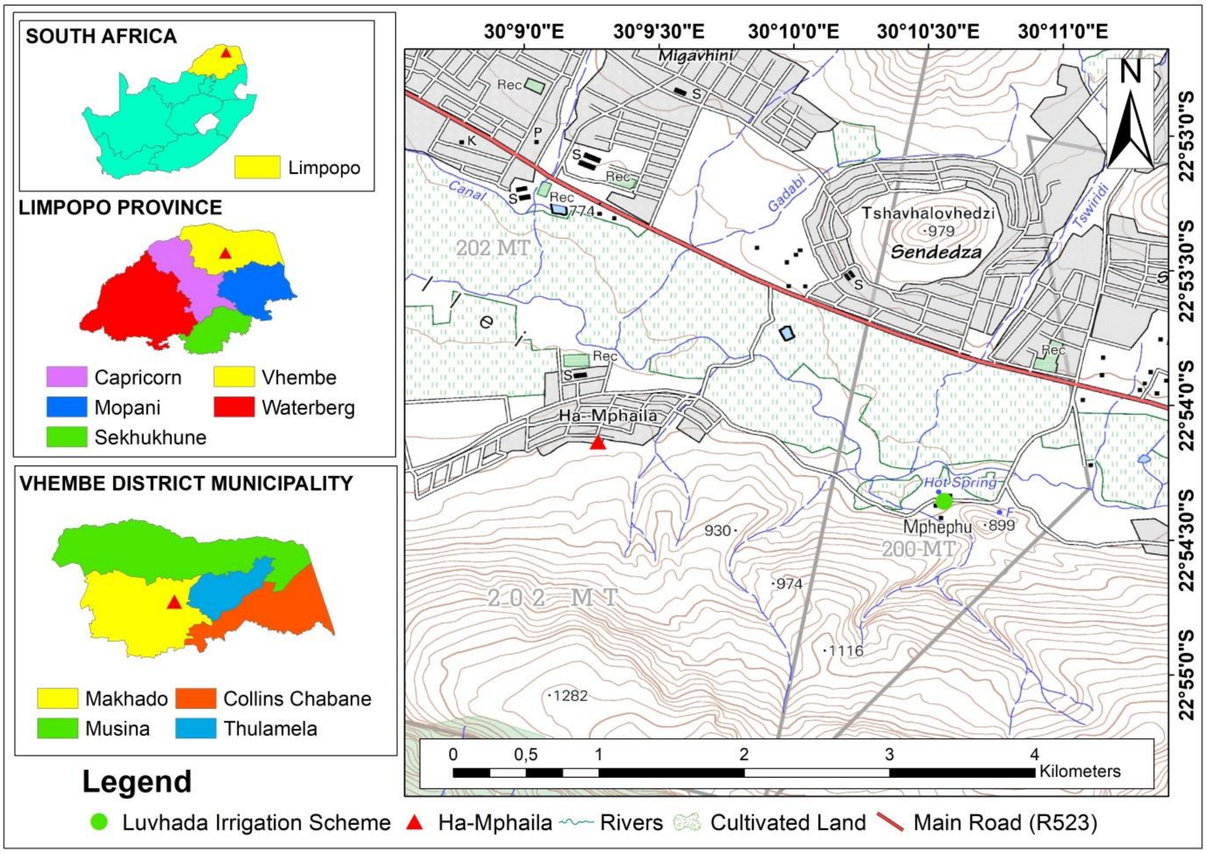

Figure 3.1: Map showing the study area (Nzhelele Ha-Mphaila village)

Source: (https://www.google.co.za/search?q=Nzhelele+Ha-Mphaila+village+&biw=1366&bih=657&sxsrf=ALeKk00bEwv)

3.3. Ethical considerations

Application for ethical clearance was submitted to the university of Venda research ethics committee seeking permission to conduct the study. An ethical clearance certificate (ethical clearance no: FSEA/21/IRD/16/2911) was issued. Permission to interview the scheme members was granted by the extension officers. The officers also assisted in the identification of the initial respondents for the study. Respondents were informed that participating in the study was voluntary, and they were free to discontinue the interviews any time they wished. The study ensured that respondents were identified by pseudonyms and their true identities were not revealed in the course of the report. Data collected was kept safe and details provided by respondents were not put to any other use other than the one for which it was collected.

3.4. Research design

A mixed-method design was utilized in this study. The use of both quantitative and qualitative design provides a better understanding of research problems than using either one design. Creswell & Plano (2011) described that the mixed method entails collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies. The use of both quantitative and qualitative design provides a better understanding of research problems than using either design. Creswell & Plano (2011) described that the mixed method entails collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies. In this study qualitative design was adopted to answer the what, why and when questions of water usage in post-harvest handling of leguminous crops at Luvhada irrigation scheme. Quantitative design provided answers to the question, how much? And how many? And the results thereof were expressed in absolute numbers, percentages and ratios. The study adopted a quantitative approach to creating records of the demographic profile of different farmers.

Creswell & Poth (2016) defines research design as a plan for a study, providing the overall framework for collecting data. On the other hand, MacMillan & Schumacher (2001) define it as a plan for selecting subjects, research sites, and data collection procedures to answer the research question(s). They further indicate that the goal of a sound research design is to provide results that are judged to be credible. The study followed a case study design. According to Babbie & Mouton (2010) case studies normally focus on one or two issues that are essential to understanding the phenomenon being examined. Case studies can be exploratory, explanatory, or descriptive (Creswell & Plano, 2011). An exploratory case study design was utilized to understand the unknown water usage in post-harvest handling of leguminous.

3.5. Population and sampling procedures

The population of the study is 79 small-scale farmers who are part of the irrigation scheme. According to Flick (2015) population refers to the total number or universality of subjects or subjects in question. Sampling is a process of selecting subjects or cases to be included in the study of the representative of the target population (Martínez-Mesa *et al.,* 2016). The Snowball sampling technique was used to collect data from respondents. Snowball sampling is a non-probability method for developing a research sample where existing study subjects recruit future subjects from among their connections (Ortman *et al*., 2014). This sampling technique is often used in hidden populations that are difficult for researchers to access such as drug users or commercial sex workers (Bagheri *et al*., 2015). It was used in the study as a referral system as few contacts for the respondents were obtained. Non-probability sampling is often associated with case study research design and qualitative research (Taherdoost, 2016). Forty-two farmers out of the total 79 farmers at the scheme were interviewed. These farmers were referrals in that they grew leguminous crops at the irrigation scheme and they are the ones who were available during data collection.

3.6. Data collection

Due to the Covid-19 pandemic, data was collected using telephone individual interview schedules in adhering to the regulation of no face-to-face interaction. A telephone interview is a data collection method when the interviewer communicates with the respondent on the telephone following the prepared questionnaire or data collection tool (Bramlett *et al*., 2014). According to Alshenqeeti (2014) interviewing is the most important data collection method. The interview tools that were utilized to collect data were questionnaires comprised of both close and open-ended questions. Open-ended questions gave room for searching for clarification and further discussion of important and relevant issues that possibly aroused during the interviews. Therefore, quantitative and qualitative data were collected. Questions were explained to suit a particular respondent to gather valid data. Furthermore, telephone interviews enabled the respondents to be free and give more information which was valid and helpful. A cell phone was used to keep necessary data, after seeking consent from the research respondents.

3.7. Data analysis

The collected data required qualitative and quantitative analysis. Gandomi & Haider (2015) define data analysis as a process of evaluating data using analytical or statistical tools to discover useful information; while Perelet *et al.* (2014) define data analysis as a process of inspecting, cleansing, transforming and modelling data to discover useful information, informing conclusions and supporting decision-making. Objective 1 of the study was comprised of both close and open-ended questions, therefore the collected data required quantitative and qualitative analysis. Thus, thematic content analysis was used to analyze the qualitative data while descriptive statistics were used for quantitative data. Statistical Package for the Social Sciences version 27 (SPSS) was used. Descriptive statistics such as mean and frequencies were tested on demographic characteristics of farmers such as age, level of education, gender and farming income. Objective 2 had open-ended questions and therefore, required qualitative analysis. The data was analysed using Atlas ti version 8 software and the thematic approach was applied. Data was first cleaned and entered into Excel, thereafter it was imported to the software. Network diagrams were created to visualize the linkages of outcomes. Objective 3 was analyzed using both Atlas ti version 8 and SPSS version 27. Atlas ti version 8 software was used to apply the thematic approach therefore network diagrams were created using the network diagram tool after cleaning data from Excel sheets before importing it into the software.

3.8. Limitations of the study

The study was conducted at the Luvhada irrigation scheme, Vhembe District, Limpopo, South Africa. Out of all the 79 farmers, only 42 farmers were interviewed. Since data was collected through telephone interviews. It was difficult to collect the data because the researcher did not have all the contact details of farmers. Also, some famers refused to share contact details of their colleagues while some were not available.

3.9. Summary of the methodology

This chapter presented a description of where the study was conducted, research design and tools used to collect data in the study. Furthermore, population and sampling procedures were also presented in this chapter, as well as the software used to analyze data. Moreover, ethical considerations and limitations encountered during data collection were presented. The next chapters 4, 5 and 6 provide the findings and discussions of all objectives of the study.

Table 3.1: Summary of methodology to each objective

Objectives	1. To assess water use in post-harvest handling of leguminous crops at Luvhada irrigation scheme.	2. To determine water security challenges faced in post-harvest handling of leguminous crops.	3. To suggest possible solutions to water security in post-harvest handling of leguminous crops.
Population and sampling procedures	1. Snowball sampling.	2. Snowball sampling.	3. Snowball sampling.
Data collection tools	1. The questionnaire used comprised of both open and closed questions.	2. The questionnaire comprised of both open and closed questions.	3. The questionnaire comprised of both open and closed questions.
Data collection methods	1. Telephone individual interview.	2. Telephone individual interview.	3. Telephone individual interview.
Data analysis	1. Close-ended questions were analyzed using Statistical Package for the Social Sciences version 27 (SPSS) (Descriptive statistics such as mean and frequencies were tested). Atlas-ti version 8 was utilized to analyze qualitative data gathered through open-ended questions (Network diagrams created).	2. Atlas-ti version 8 was utilized to analyze qualitative data gathered through open-ended questions (Network diagrams created).	3. Atlas-ti version 8 was utilized to analyze qualitative data gathered through open-ended questions (Network diagrams were created) while quantitative data gathered through close-ended questions was analyzed using Statistical Package for the Social Sciences version 27 (SPSS) (descriptive statistics such as frequencies were performed).

CHAPTER 4: ANALYSIS OF WATER USE IN POST-HARVEST HANDLING OF LEGUMINOUS CROPS. A CASE OF LUVHADA IRRIGATION SCHEME, SOUTH AFRICA

Abstract

Between 80-90% of the world's fresh water is used by humans globally. Most of it is used in agriculture for crop production. However, climate change and unsustainable water usage in agriculture pose a threat to water security in most communities. On the other hand, leguminous crops are an alternative food source that significantly contributes to food and nutrition security. Although they are applauded for their low water consumption at the production stage, it is unclear how water is utilized by these leguminous plants during the post-harvest period. The study assessed water usage in post-harvest handling activities of leguminous crops at the Luvhada irrigation scheme, South Africa. The study adopted an exploratory mixed-method design and utilized structured and semi-structured questions to solicit answers from the respondents. Thematic content analysis was used to analyze qualitative data while descriptive statistics were used for quantitative data. The results revealed at the post-harvest phase, farmers used water mainly for cleaning and cooking. Moreover, farmers did not measure the exact amount of water used in post-harvest activities either due to lack of interest or due to lack of proper water infrastructure that can allow them to record the amount used. More than half (22) of the farmers relied on river water for post-harvest activities. It is, therefore, recommended that observational and participatory studies be conducted to monitor the activities of a farmer over some time to accurately predict the amount of water used in post-harvest activities. These farmers do not know the amount of water they are using per day or per millimetres.

Keywords: Legumes crops, Luvhada irrigation scheme, post-harvesting, water use.

4.1 Introduction

Less developed countries such as those in Asia and sub-Saharan Africa are battling with water scarcity problems. South Africa like most parts of sub-Saharan Africa, is described as a water-stressed country that is heading towards aridity and water scarcity (Hodgson & Manus, 2006). Water has severely and negatively impacted agricultural production threatening global food security. In recent years, drought has become a common phenomenon in rural South Africa and this trend is set to continue at least into the foreseeable future (Schulze, 2011; Botai *et al.,* 2020). Currently, it is estimated that there are 7.8 billion people globally and in 2050 this population will increase by almost 2 billion (da Cunha Dias *et a*l., 2021). Thus, if water is not used sparingly, global food security will be affected with adverse effects on people's health and survival. Grain legumes offer the world an alternative food source in meeting global aims of increased, yet sustainable, production of nutritious food. Although several studies on improving water productivity in crop production have been conducted, water usage efficiency is not known in post-harvesting activities. In post-harvest activities, water is used mainly for activities such as storing, transportation, marketing, and retail or roadside selling. This study, therefore, seeks to provide an analysis of water use in post-harvesting activities in leguminous crops among small-scale farmers.

Leguminous crops provide a considerable quantity of protein requirements as well as flavour and colour (FAO, 2013). Regions with higher levels of malnutrition such as sub-Saharan Africa (23.2%) and South Asia (34.5%) stand to benefit from leguminous crops (Ahmad *et al.,* 2015). This is particularly, true especially given the fact that these regions are estimated to carry the 70% of the total 2 billion population increase by 2050. Moreover, their production is likely to contribute significantly to poverty alleviation in rural communities and improve soil fertility that is currently facing degradation. For instance, its nitrogen-fixing capabilities reduce soil erosion and offer wider environmental benefits as well as result in improved water use efficiency (Muoni *et al.,* 2019). The importance of legumes is also seen by their contribution to food security. For example, in Ethiopia grain legumes account for about 15% of protein consumption, have a high market value and it is the third-largest export crop next to coffee and sesame global (Getachew, 2019). Hence, knowing and understating the water use efficiency in leguminous crops in the entire value chain (production to consumption) forms part of the critical components in water use management. It is crucial for achieving food security and simultaneous release of water to other uses such as in the industries and at home. Therefore, this study assesses the water use by farmers in selected leguminous plants. Improving water use in water-scarce regions leads to improved agronomic practices, irrigation management, and post-harvesting water use in leguminous crops (Passioura, 2006; Molden *et al.,* 2010; Descheemaeker *et al.,* 2013).

In sub-Saharan Africa including South Africa, major grain legumes are Soybean, Groundnut, and dry Bean (Chibarabada *et al.,* 2017). Also, there are indigenous grain legumes that originate from the semi- and arid tropics however, they are neglected or underutilized in various dimensions (geographic, social, and economic) (Padulosi *et al.,* 2002), even though they are well-adapted to water-limited conditions (Chivenge *et al.,* 2015; Massawe *et al.,* 2016). Several researchers have studied yield, water use, and water use efficiency of grain legumes under different environments with varying outcomes (Munoz-Perea *et al.,* 2007; Abayomi *et al.,* 2008; Patel *et al.,* 2008; Obalum *et al.,* 2011; Mabhaudhi *et al.,* 2013), however studies focusing on value chain particularly in post-harvesting activities are scant. This is particularly true among small-scale farmers in Vhembe district, Limpopo Province of South Africa. Climate variability and change have been cited as some of the threat posed to climate sensitive sectors such as Agriculture, Water, Energy and Biodiversity. This study, therefore, provides an analysis of water use activities in post-harvesting activities in leguminous crops at Luvhada irrigation scheme in Limpopo. The next section outlines the methods used in the study.

4.2 Methods and Material

This study was carried out at Luvhada irrigation scheme, which is in Nzhelele Ha-Mphaila village (30°9'0"E & 22°54'0"s) in Limpopo Province, South Africa. Exploratory mixed methods were followed to answer the objectives of the study. A complete detailed description of the methods, study population, population sampling, data collection, and analysis is given in Chapter 3 section 3. The following section presents the result of the study.

4.3 Results and discussions

The study findings are sequentially presented starting with the demographic information, characteristics of leguminous farming, and water use analysis.

4.3.1 Respondents' demographic profile

Forty-two farmers participated in the study. Most of the farmers were males (25) and whereas (17) were females. This shows that the scheme is dominated by males. Equally, most were aged between 55 and 64 years (20) (Figure 4.1). It is mostly the older individuals and not the youth who are engaged in farming or who own plots of land. In fact, all the interviewed farmers in the irrigation scheme are above the age of 35 years. This shows that younger people might not view farming as a career option as none of the respondents were younger than 35.

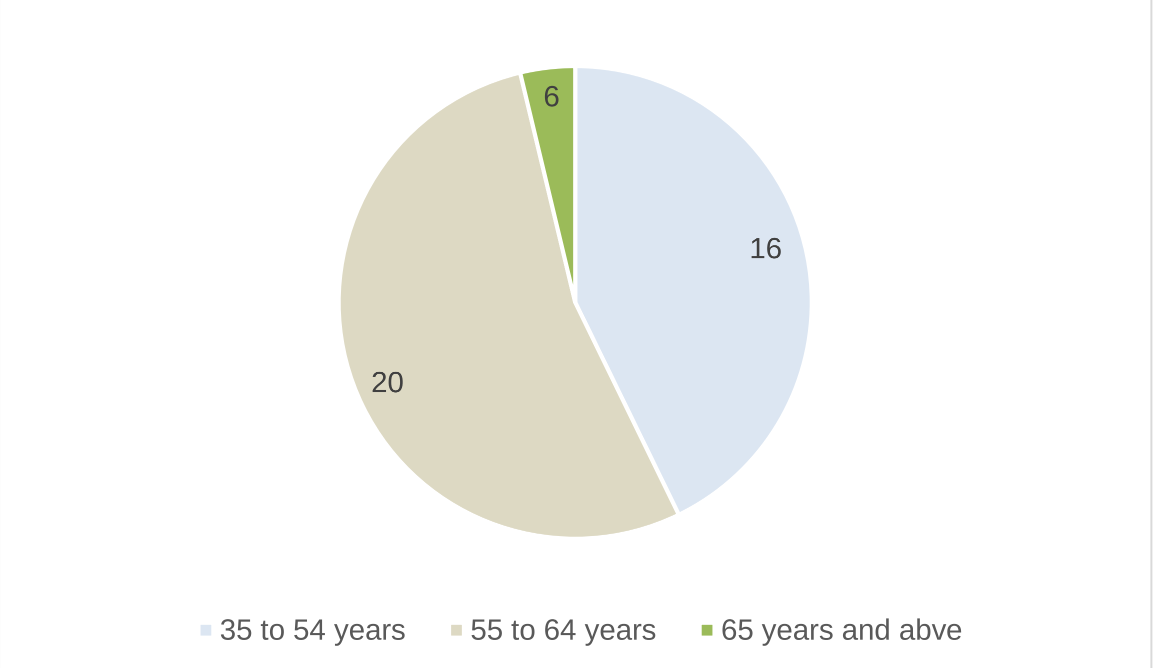

Figure 2.1: Age of the respondents

Furthermore, they might be far from the area due to academic reasons or employment opportunities. Moreover, only one farmer was disabled. It also emerged that all the respondents were full-time farmers and the proceeds from selling farm produce formed the bulk of their household income. Out of all the interviewed farmers, few of them did not go to school (6) while half of the farmers had primary education (21). However, some of the interviewed farmers had secondary education (14). While only one farmer had a tertiary qualification. Table 4.1 gives the detailed interviewed farmers' level of education.

4.3.2 Farming characteristics

An understanding of the descriptive statistics was important to link the behaviour of the farmers to specific value chain activities. When asked about the number of years into farming, about 9 out of 10 had been involved in the scheme for more than 5 years while only (2) had less than five years. In terms of planting seasons, most farmers stated that they planted during autumn (39) and others in summer while all farmers harvested their crops in summer. Farmers stated that the main reason for growing legumes was because they were good for business and can be grown with minimal water in comparison to other horticultural crops. Farmers used phrases such as

> "*High market demand*" (Respondent 6);

> "*They are good for business*" (Respondent 20);

> "*Are easy to maintain and require less water given the fact that we have water problems in the scheme" (*Respondent 4*)*

Table 4.2 shows that depending on the size of the land and water availability, individual farmers earned an estimated amount of between R 800.00 to R28 000.00 annually. Grouping of the farmers' earnings was difficult as most farmers estimated varying ranges of income. For instance, Respondent 6 said,

> *"My monthly or annual income is R2000 to R5000"*

Respondent 15 reported,

> *"I earn from the legumes I generate R3000 to R10000"*

While respondent 19 said,

> *"I generate R1000 to R15000 and it depends on the challenges we face"*

The income earned was used mainly to support the families of farmers. For instance, the respondent said,

Table 4.1: Level of education for Luvhada Irrigation Scheme Interviewed Farmers

Level of education	Frequency	Proportion (%)
No schooling	6	14.3
Primary	21	50.0
Secondary	14	33.3
Tertiary	1	2.4
Total	**42**	**100.0**

Table 4.2: Monthly income of the respondents

Income		Frequency	Proportion (%)
	R800 to R28 000	21	50
	Difficult to say	12	30.6
	I get different amounts after selling.	7	16.7
	No income	2	4.8
	Total	**42**	**100.0**

"*The money I get is used to support my family and pay school fees for my children*". Also, other farmers stated that apart from supporting family*, respondents 9 and 39 indicated that the money was reinvested into the farm''.*

Respondent 8 indicated that legumes are "*drought-tolerant',* and this influenced the respondent's decision to grow legumes. Moreover, some farmers grow legumes too, *"supporting their families*" (Respondent 11) through income from the sale of leguminous crops (Groundnuts and Beans) and direct "*consumption"* (Respondent 19) of the products were the main motivating factors behind the growth of legumes.

The participants also responded to questions about the characteristics of their farms. On average, the farm size was 0.5 hectares with a range from 0.4 ha to 1 ha (Table 4.3). Most of the farmers had half a hectare.

Beans and groundnuts were the main legumes produced by farmers at the Luvhada irrigation scheme. They prefer them because are easy to maintain and do not require regular irrigation. Among these, the majority combined beans and groundnuts (33) whereas few (8) focused on groundnuts only. Only one farmer produced three legumes namely beans, groundnuts and Bambara nuts (Figure 4.2).

Table 2.3: Farm sizes

Hectares	Frequency	Proportion (%)
0.4	10	23.8
0,5	29	69.0
1	3	7.1
Total	**42**	**100.0**

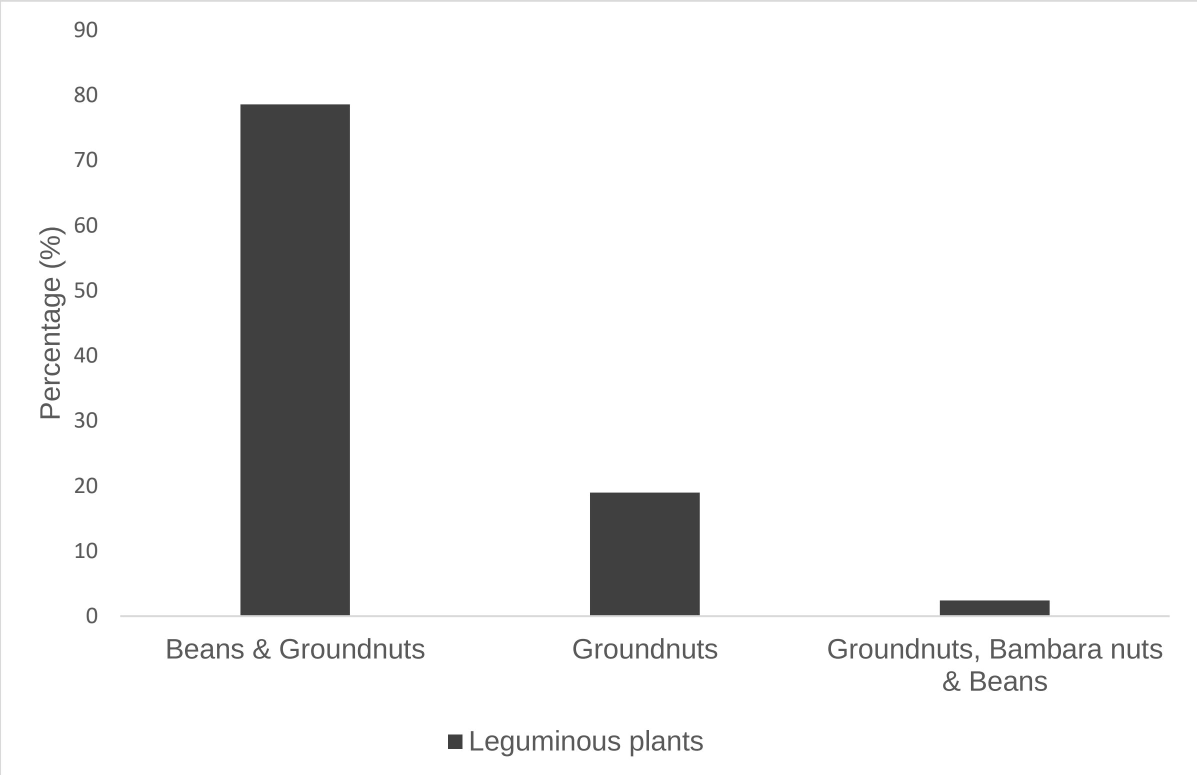

Figure 4.2: Types of legumes farmed at Luvhada irrigation scheme

4.4 Water use analysis

4.4.1 Groundnuts and Bambara nuts

The study also investigated water use practices in the post-harvesting of leguminous crops at the irrigation scheme. Firstly, respondents were asked to identify the post-harvest activities involved in their leguminous crops. Threshing, cleaning, drying, packing & processing, grading, storage and transportation were the post-harvesting activities practiced by farmers. For groundnuts, for example, the most common post-harvest activities were cleaning and drying whereas fewer farmers stated that they added value to nuts by threshing them. A respondent (No. 41) described the process that they follow as farmers at post-harvesting and said,

> "*The main activity we do after we harvest is cleaning. We clean the nuts by shaking off the soil when harvesting first thereafter we wash them in water. We don't sell our groundnuts if they are not cleaned. Most of my nuts are sold as they are but I remove the cover (shelling) to sell to special customers who want such Groundnuts and Beans".*

Respondent 16 added,

> "*Generally I sell groundnuts after cleaning. However, some customers ask that I thresh them, so I make special arrangements for such customers"*.

Although, most farmers (33) only cleaned and sold the groundnuts in their natural state, some added value through threshing, roasting, and boiling (9) part of their products before selling them. Both Groundnuts and Bambara nuts were boiled either with shells or after threshing before being sold to consumers in a nearby market. One of the farmers sold cooked nuts to the "Spaza shop" in the village. The common threshing method used was manual pod removal. The results show that those who only cleaned their groundnuts, mainly sold them in bulk while those that boiled or roasted them sold to the local market directly to the consumers. Regarding groundnuts, cleaning and boiling were the post-harvest activities that utilized water among farmers.

4.4.2 Water use in the Beans post-harvest value chain

Post-harvesting practices for beans were cleaning, threshing and boiling. Water was used in cleaning and boiling.

> "*We take our beans to the river sometimes when that car wash is not busy, the owner allows me to use water and wash my beans together with my groundnuts*" (Respondent 17).

This shows that water was used in cleaning crops. Moreover, farmers did not measure the amount of water used when cleaning by the riverside, at home, or the car wash.

> "*To us, it is not about the water, we want our nuts and beans to be clean. We don't measure how much water we use. We wash until we are convinced it's clean with our eyes"* (Respondent 31).

Farmers used different types of cleaning, for example, respondent 5 said,

> "*In general I use different amounts, I do not measure per se, but it depends. For example, when it's a 20-liter bucket full of beans, I think I use about 3 of the 20-liter buckets to get them clean*".

When using water from the tapes, at home farmers said they minimize water usage by half-filling and dipping the nuts and beans in water like in a vertical halved 200-liter drum and leaving them for some time. This allowed the impurities to soak away.

> "*At home, I use a half-full half drum to wash my groundnuts or beans. When in the field, I clean mainly the groundnut. I block the furrows with sand on both ends temporarily to stop water from escaping. In this way, sand and other impurities loosen up or remain in the water. I then use one 20-liter of water to rinse*".

Another said,

> "*I mainly wash my beans with running water from the tapes. I make sure that they are washed with fresh clean water from the municipality. I do this because I sell my beans green so customers want them clean for use at home. When they are clean, they don't have a lot of work to do. They can simply rinse and use beans in their relish*".

This was highlighted by Respondent 18 a farmer with more than 5 years in legumes cultivation. It is difficult to estimate the exact amount of water used by farmers due to the casual nature of the water usage in post-harvest activities. The results reveal that hygiene was a priority in their post-harvest of leguminous crops at the scheme and it consumed much of the water at post-harvesting. Results suggested that farmers generally did not measure the amount of water used in post-harvest activities.

4.4.3 Water sources used in post-harvesting activities of leguminous crops

Farmers also identified the sources of water used on post-harvesting activities. Domestic sources, rivers, nearby car wash, and water canals at the irrigation scheme represent the main sources of water used during post-harvesting processes of leguminous plants. Most of the farmers used water from the rivers as the only source of water (Table 4.4).

Table 4.4: Respondents who use various water sources for post-harvest activities

Water sources	Number of users (Frequency)	Proportion (%)
River	22	52.4
River and home	8	17.1
Water canals and home	6	14.3
Water canals	3	7.1
Water canals and nearby car wash.	2	4.8
Home	1	2.4
Total	**42**	**100.0**

One farmer used water from domestic taps at home as the source of water for post-harvest activities for leguminous plants. However, farmers noted the water was not enough for their post-harvest activities. This could perhaps explain why some farmers used a combination of all the sources in their post-harvest activities. High competition,

> "*We have a problem of water shortages because we have access to water occasionally, so it is not enough*" (Respondent 1).

> "*The water is not enough at all because we have to wait for our turn to use the water in the scheme*" (Respondent 3).

> "*There is not enough water as more water is required for irrigation only at the scheme*" (Respondent 5).

"'There is not enough water at the scheme, so I use water from the river. I take my harvested legumes to the river to wash them'' (Respondent 14). The results show that farmers would pay to use tap water either at home or at a nearby car wash where they pay money to the car wash owner to use the tap water. Generally, farmers know the amount of water used, as they could estimate the amount of water used. On the other hand, when cleaning using river water, the amount was not known, farmers generally focused on cleaning the crops until they are cleaned without measuring the amount of water used. This result suggests that water availability directly influences the amount of water used by farmers in the Luvhada irrigation scheme during post-harvest activities of leguminous crops. Hence, there is a need to educate farmers on quantifying water as this will help raise awareness on the need to save water. Extension officers in the area need to come up with the programme of action regarding water saving techniques due to limited water availability and accessibility.

4.4.4 Water quality

It was also clear from the results that farmers generally believed that water was clean from all the water sources from where it was drawn. Farmers mentioned that they did not measure the quality of water, but generally used observation as the only quality assessment tool.

> "*We do not measure the quality of water using machines (scientific equipment) but we use clean water from the municipality*. *At the river, we know areas and spots where the water is not contaminated and is clean. We first observe if the water is clean or not in the area, if it is dirty we go to another spot where the water is clean"*.

Therefore, farmers measured water quality from the river by physically observing its turbidity. However, the chemical properties of water were unknown to them. In a similar view, another farmer added:

> “*You see, we are very careful about the quality of water. We thoroughly obverse the water we use. We check for dead living organisms and plants. We check if the water is not muddy and allow the water to settle where necessary’’ (Respondent 11).*

Moreover, results show that eroded rocks along the river were also used as a form of quality check. This was highlighted by respondent 13, who said,

> “*There is a spot which I prefer when cleaning my groundnuts. There is a small cave in the rock in Nzhelele River, when the water gets there it slows down and it has a lot of sand that purifies the water*”.

4.5 Discussion of results

The chapter analyzed water use practices in the post-harvest processes of leguminous plants. The results revealed that the majority of the leguminous plants found at the scheme included groundnuts, beans, and Bambara nuts. Most farmers grew these crops because of their higher market demand and drought resilience. The other issue is that the majority of these legume crops use less water. Nguyen *et al*. (2020) concur that legumes grow in marginal cropping zones and are drought tolerant. The scholars further argue that their resilience to unstable annual weather patterns, puts legumes as the current and future protein choice amid climate variability, and hence their high demand is expected to continue growing. Similarly, Feldman *et al.* (2019) add that Bambara nuts like other nuts are drought resistant and occupy a significant farmland area in arid and semi-arid regions among many rural farmers including Southern Africa. Ansari *et al.* (2015) state that South Africa is a major producer of groundnuts, thus it is not surprising that farmers at the Luvhada scheme preferred these types of legumes as they are a natural choice in the locality. The results further indicate that leguminous crops such as Groundnuts are an important cash crop that has the potential to offer more income for farmers in the future and contribute towards poverty alleviation.

The results revealed that farmers mainly cleaned and dried their groundnuts before selling. As part of cleaning, groundnuts were manually cleaned immediately after uprooting by shaking off the soil before washing with water. This practice is common as cited by the global and the United Nations Industrial Development Organisations (UNIDO), which states that it is important to shake off soil from the pods to discourage fungal growth. Also, this presents the advantage that when the soil is removed and pods cleaned, the drying period is shortened. Although manual threshing is common in developing nations, they are practiced differently. Contrary to the current study, although it caused brain damage. Shah (2013) found that farmers still used long wooden sticks to thresh groundnuts and beans. This is the common post-harvest practice used as a method for peeling the grain from the panicles in sub-Saharan Africa.

Farmers did not measure the amount of water they used in post-harvest practices at the Luvhada irrigation scheme. Depending on the source of water, farmers regulate their water use. When using municipal tape water at home, farmers were more cautious not to use more water as opposed to when they clean by the river. This could be attributed to costs associated with municipal water. Given these results, it can be concluded that more water is used when cleaning is done using river water than tape or other sources. The findings of this study, indicate that without measurement tools in place and unreliable estimates from farmers, it is difficult to estimate the water use efficiency in post-harvest activities. It also emerged that there were challenges associated with water quality used in post-harvest practices. Although farmers exercised greater caution in monitoring the quality of water and used municipal water to clean beans, the chemical properties of the users were not known. The main reason was that farmers did not have the advanced tools, material and scientific knowledge on the actual testing of water quality. Allende & Monaghan (2015) cautions that even though water used in agriculture does not require tertiary treatment, poor quality water poses a risk to the health of consumers and may fail in the export market because of export regulations. Baleta & Pegram (2014) point out that using poor quality water may affect the sector and cause many agriculture jobs to be lost. Therefore, it is important that water used in the post-harvest of leguminous crops Luvhada farmers be of high quality to guard against the health of the consumers and enable farmers to generate more income by selling at the export market. The available water in a nearby river such as Nzhelele indicates that water problems at the scheme are not about unavailability and quality but the inability to access due to poor infrastructure. The other problem in the Luvhada irrigation scheme is the allocation of water which makes it difficult for the majority of small-scale farmers to access water and this affects crop productivity, income and product quality.

4.6 Conclusions

The study analyzed how water is used in post-harvest activities of leguminous crops at the Luvhada irrigation scheme in Limpopo province, South Africa. Farmers cultivated legumes such as groundnuts and beans and these were planted mainly in autumn. Moreover, the results revealed that water for post-harvest use was mainly accessed from the scheme canals, nearby car wash, and at home. Cleaning before drying and boiling before selling (Bambara and Groundnuts) were the main water use activities associated with post-harvesting in leguminous crops studied. Moreover, farmers did not measure or know the exact amount of water used in post-harvest activities either due to lack of interest or due to lack of proper water infrastructure that farmers can use to record the amount used. It is, therefore, recommended that an observational study be conducted to monitor the activities of framers to predict the amount of water used in post-harvest activities. Also, farmers were not aware of the chemical properties of the water they used in these activities. This poses a health hazard to farmers themselves as well as consumers as they are likely to be exposed to hazards such as *E. coli* infections and other forms of water pollution. Also, this limits the growth potential of the framers as they stand to miss out from the export market due to failure to meet high-quality requirements by the international market. It is, therefore, recommended that government and the private sector join hands with farmers in erecting proper water infrastructure to improve water access and quality at the scheme. The next chapter presents the findings and discussions of objective 2 of the study.

CHAPTER 5: DETERMINING WATER SECURITY CHALLENGES FACED AT POST-HARVEST HANDLING OF LEGUMINOUS CROPS

Abstract

Water is an essential component of the planetary life support system. Increasing agricultural water security through irrigation to complement soil moisture deficit has driven improved agricultural production in large regions of the world. Water scarcity has a huge impact on food production. Without water, people do not have means of watering their crops and, therefore, providing food for the fast-growing population. The study aimed at determining water security challenges faced at post-harvest handling of leguminous crops. The exploratory mixed-method study design was adopted for the research and semi-structured questions were utilized to ask questions from the respondents. Data were collected from farmers at Luvhada irrigation scheme. The snowball sampling technique was used to select the study respondents. This sampling technique was used as a referral system because few contacts for the respondents were obtained at the commencement of the study. Data were collected through telephonic individual interview schedules using an open questionnaire. The data collected was qualitative, therefore it was analyzed using Atlas ti version 8 software and network diagrams were created. Results of the study revealed that water security challenges faced at post-harvest activities were the absence of water storage facilities, physical storage such as water tanks and underdeveloped access infrastructure of water canals. The results further revealed that those challenges led to the negative impacts of water security at post-harvest activities at the scheme. The negative impact of water scarcity was poor quality products of legumes due to drying and getting damaged, and loss of stock. Conclusively, water at the scheme is not enough mainly due to a lack of water storage and infrastructure facilities. Therefore, it is recommended that water storage and infrastructure facilities that are required and appropriate for the scheme should be provided.

Keywords: Effects, Leguminous crops, post-harvest, water security challenges.

5.1 Introduction

The essence of water security is a concern for the resource base itself and is coupled with concern that services the resource base for human survival and well-being, as well as for agriculture and another economic enterprise. Therefore, it should be developed and managed in an equitable, efficient and integrated manner (Ray & Shaw, 2019). Water security is a pre-condition of any effective poverty reduction strategy, and of effective environmental sanitation, wastewater management and flood control to reduce water scarcity (Connor, 2015).

Globally, many regions are facing increasing challenges related to water-limiting conditions as well as degradation of water quality, which makes it more challenging to use existing water resources for irrigation and post-harvest activities. Moreover, some regions are facing greater challenges than others. For example, countries like India, South Africa, and Ethiopia to mention but a few are some of the countries facing greater challenges of water scarcity. India ranks 13th for overall water stress and has more than three times the population of the other extremely highly stressed countries combined (Pugsley *et al.,* 2016). About two-thirds of the world's population is exposed to high levels of water scarcity for at least one month of the year (Mekonnen & Hoekstra, 2016). Therefore, water scarcity at post-harvest can cut food production and badly impact food security worldwide.

The water scarcity scenario according to Greve *et al*. (2018) argues that most countries in the Near East and North Africa experience acute water scarcity. Others such as Pakistan, Mexico, South Africa, and huge parts of China and India also experience chronic water problems. The misuse of water resources, lack of infrastructure to supply water and also climate change are some of the reasons for water scarcity, despite the vast amount of water on the planet (Mancosu *et al.,* 2015). As the results of chapter 4 revealed that the Luvhada farmers used water mainly for cleaning and cooking in post-harvest activities. Moreover, farmers did not measure or know the exact amount of water used in post-harvest activities either due to lack of interest or due to lack of proper water infrastructure that can allow them to record the amount used. Another contributing factor for not measuring the amount of water used is the level of education among the majority of small-scale farmers in the Luvhada irrigation scheme. The farmers relied mainly on river water for post-harvest activities. This shows that water scarcity has a huge impact on food production (Hoekstra, 2014). Without water, people do not have means of watering their crops and providing food for the fast-growing population.

Water security has always been an issue of concern in South Africa but, in recent times, it is increasingly exerting a serious threat to the economy. South Africa is one of the water-stressed countries in the world; ranked as the 30th driest country globally, where agriculture is the dominant water user. It is important to note that the way a farmer or trader handles their produce post-harvest affects the quality of the produce. Therefore, water in post-harvest of legumes plays an essential role in maintaining the quality, value and shelf life of fresh legumes crops produce. A lot of studies have been done on post-harvest losses and post-harvest handling of vegetables but rarely do we find studies on legumes crops in South Africa. Furthermore, studies that are aimed at accounting for the amount of water used and challenges faced in the process of post-harvest handling or post-harvest value chain are not readily available. This study bridges that gap by not only mapping the post-harvest value chain of selected legumes crops but also accounting for the amount of water that participants in the chain use. As a result, the study aimed to determine water security challenges faced in post-harvest handling of leguminous crops at Luvhada irrigation scheme, specifically in groundnuts and beans as they are the main legumes grown at the scheme. The study area was preferred because within the other schemes at Nzhelele, Luvhada irrigation scheme is one of the developed schemes despite all the challenges they faced.

5.2 Methods and materials

An exploratory mixed-method study design was followed to answer the objectives of the study. A complete detailed description of the methods, study population, population sampling, data collection, and analysis is given in Chapter 3. The following section presents the results of the study.

5.3 Results and Discussions

5.3.1 Demographic Information of participants

The demographic information is described in Chapter 4.

5.3.2. Water challenges in Post-harvest of leguminous crops

The interviewed farmers revealed water challenges faced in post-harvest activities at the irrigation scheme. The main aim was to identify all the challenges faced at the irrigation scheme for water during post-harvest handling of leguminous crops. The identified challenges are discussed below and supported by respondents verbatim in Figure 5.1.

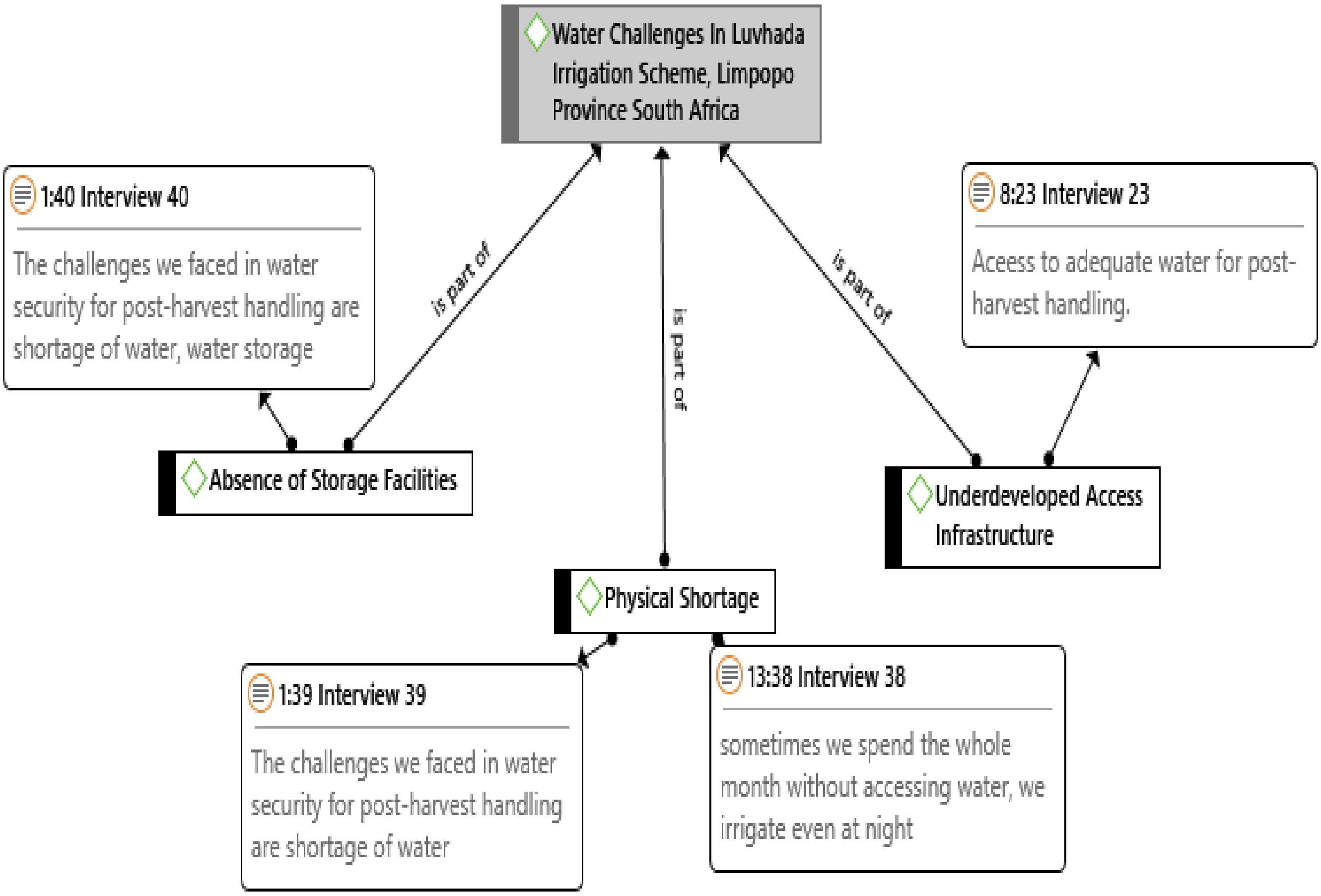

Figure 5.1: Water challenges in post-harvest activities of leguminous crops at Luvhada irrigation scheme in Limpopo province of South Africa

5.3.2.1. Absence of storage facilities

Interviewed farmers argued that the absence of water storage such as tanks contributes to water challenges faced in post-harvest activities. At the scheme, there are no water storage facilities and this negatively impacts legume farming activities at the post-harvest stage. The majority of the farmers believe that if there could be water storage facilities in the area, such as tanks to store water, water and food security could be achieved. They added that the water storage can store water for post-harvest activities because it is not easy to carry the harvested legumes from the scheme to the river to wash them because some of the plots are far from the river. The absence of storage facilities is a problem in the scheme. This is worsened by the fact that the majority of the farmers are the elderly and carrying the legumes to the river for washing can be a challenge hence they would need to hire people to assist them. This means that water availability is a problem in the scheme. The respondents' verbatim words below support the statement of the absence of storage facilities at the scheme:

> *"The challenges we face in water security for post-harvest handling are shortage of water for irrigation as well as for post-harvest activities, water storage and access to water for post-harvest activities".*
>
> *Respondent 15*

5.3.2.2. Physical shortage and underdeveloped water access infrastructure

The shortage of water in post-harvest activities at Luvhada irrigation scheme is the main problem. Farmers pointed out that at the scheme there is shortage of water for irrigation. This challenge is not exceptional, it is important to note that water shortage has been reported in other irrigation schemes in the Vhembe district, especially in irrigation schemes such as the Rabali and Tshiombo (Mpandeli & Chikoore, 2006). The water they get is not enough to irrigate the planted legumes, therefore, when it comes to post-harvest, it is very challenging since the small amount they acquire from the scheme is used to irrigate only and still it is not enough for irrigation. Hence, farmers resort to utilizing water outside their schedule, for example irrigating at night. Sometimes farmers spend the whole month without getting water and this is not good for the quality of the legumes as it affects productivity as well as quality and quantity of legumes. During interviews, farmers pointed out that the underdeveloped infrastructure of canals also poses challenges to access water in post-harvest activities of legumes. They further stated that at the scheme they use canals from the fountain to the scheme and some of the canals are not paved and it takes time for some of the farmers to get water. Therefore, this affects the productivity of the scheme. Thus, they only use the water from the fountain for irrigation because the water is not enough for irrigation which makes it impossible to use the same water for post-harvest activities. Farmers pointed out that if they could have the proper infrastructure they can plant different varieties of crops rather than the ones they are growing. They believed that with improved crop varieties they can generate more income and be able to meet their customers' demands.

5.3.3. Effects of water challenges to post-harvest activities

The farmers who were interviewed pointed out the effects of water challenges on post-harvest activities at the scheme. The identified effects are discussed below and supported by Figure 5.2.

5.3.3.1. Poor quality products

Lack of water post-harvest poses many challenges for farmers and the majority of the interviewed farmers were not happy with the quality of their legumes. Farmers pointed out that they wash the legumes before taking them to the market because they sell fresh legumes. Therefore, lack of adequate water affects the quality of the legumes because sometimes they are forced to dry the crops without being washed and this affects their business as their customers prefer freshly cleaned legumes. To support the statement Respondent 12 said:

> *"Sometimes our legumes get dried without being washed and it affects our business as most of our customers prefer freshly cleaned legumes".*

5.3.3.2 Drying and getting damaged

Farmers argued that due to water insecurity at the post-harvest stage of leguminous crops at Luvhada, they are facing many difficulties. These include their crops becoming dry and getting damaged (shrivelling and weight loss) before selling. After harvesting, the farmers have to wash the legumes to be clean, look fresh and appetizing to the customers to satisfy them, earn more income and get more customers on the other hand. They further stated that it is very difficult to access water from the scheme and once the legumes get dry without being washed they lose customers as well as the quality of the legumes and this is more challenging to them. There is need for devising strategies to circumvent challenges of water for post-harvest activities at the scheme because the farmers have been having this problem for the past 60 years since the scheme was established.

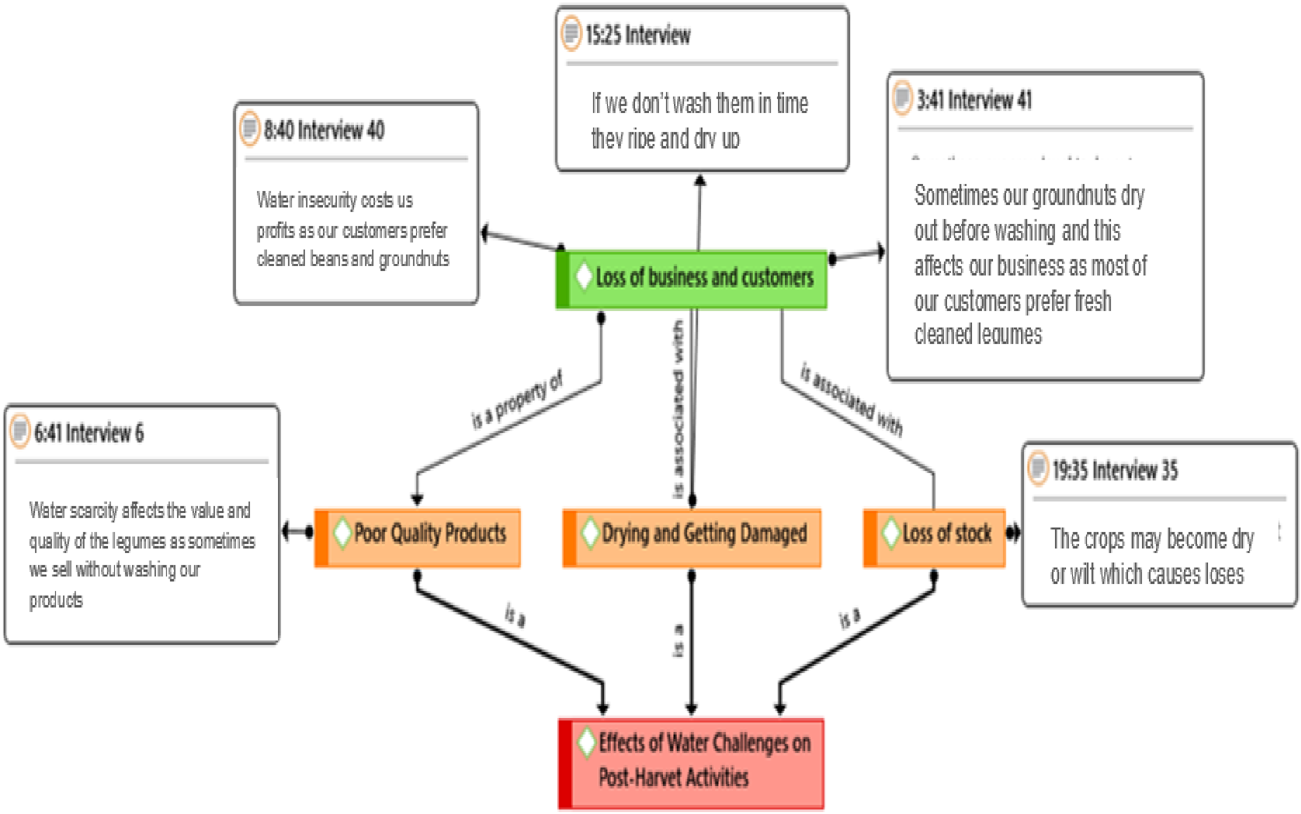

Figure 5.2: Effects of water challenges to post-harvest activities

5.3.3.3 Loss of stock

Due to the lack of water at the scheme farmers noted how water insecurity affects post-harvest activities. Loss of stock was one of the effects they face. After harvesting, the crops are dirty and they require water to clean them yet, there is little water. Conclusively, it is clear that water insecurity at the scheme does affect the post-harvest handling as well as other water activities that are taking place at the irrigation scheme. The irrigation scheme is the main source of income. Therefore, when they are not getting the water they lose stock and in return, they lose customers which reduces their income. Thus farmers must access water for post-harvest activities. Below are responses from respondents emphasising the loss of stock:

> *"The legumes may become dry and don't look appetizing to the buyers"*
>
> *Respondent 22*

> "*Water insecurity affects our business as our customers require cleaned legumes"*
>
> *Respondents 9 and 41*

5.4. Discussions of results

5.4.1 Water challenges in Post-harvest of leguminous crops

Farmers at Luvhada irrigation scheme are experiencing water access challenges in the post-harvest of leguminous crops. The challenges include the absence of storage facilities, physical storage such as tanks and underdeveloped access infrastructure such as canals. During interviews, farmers stated that they have access to water from the fountain and they use canals that are too old and some are not paved which results in low water pressure at the scheme. Poor access to water for post-harvest handling at the scheme led to the underdevelopment of the scheme. Jiménez Cisneros *et al.* (2014) argued that the misuse of water resources, the lack of infrastructures to supply water and climate change are some of the reasons for water scarcity, despite the vast amount of water on the planet. The farmers further stated that due to lack of appropriate infrastructure at the scheme, they sometimes utilize water at night and it is difficult for them because they cannot perform post-harvest activities at night. The provision of proper infrastructure is needed in the scheme because utilizing water at night is not safe at all. Farmers can be targeted by criminals as well as be attacked by snakes. South African institution of civil engineering (SAICE) infrastructure report card for South (2017) adds that poor state of water infrastructure has several implications on South Africa's small-scale farmer's water security. Specifically, poor and aging infrastructure are jointly spreading inefficiencies through increases in water losses. Old and poorly maintained water systems are resulting in high incidences of leakages and bursting of pipes leading to the recorded high non-revenue water for the country.

Farmers also pointed out that at the irrigation scheme there are no water storage facilities. The lack of storage facilities poses water challenges in post-harvest activities because they only get water for irrigation from the scheme, not for post-harvest activities and they could use the storage to store water to use in post-harvest activities rather than taking the legumes to the river, home as well as a nearby car wash to wash them with the tap water (Chapter 4). Stored water can also be re-used, for example, after cleaning the legumes they can use that water for irrigation. According to Mancosu *et al.* (2015) some countries that are projected to experience physical water scarcity are already experiencing economic water scarcity. Economic water scarcity occurs when investments in infrastructure development for example water supply pipe networks and reservoirs needed to cope with the growing water demand are constrained by financial, human, or institutional capacity. Even though infrastructure might exist, high vulnerability to seasonal water fluctuations can lead to water scarcity for agriculture and domestic purposes (Liu *et al*., 2017). Mancosu *et al.* (2015) further argued that when infrastructure is inadequate, malnutrition can exist, even when water resources are abundant relative to water needs.

5.4.2. Effects of water challenges to post-harvest activities

While fulfilling the food demand of an increasing population remains a major global concern, consequently, food is lost or wasted in post-harvest operations. The Luvhada farmers indicated that due to lack of adequate water for post-harvest activities at the scheme they experience effects of water challenges to post-harvest activities which include poor quality products, drying and the legumes getting damaged and loss of stock. In support of stock loss, Abass *et al.* (2014) state that post-harvest quantitative loss of up to 15% in the field, 13-20% during processing, and 15-25% during storage have been estimated. This leads to a huge amount of food loss and decreases food quality, which contributes to food insecurity for the farm household. Kumar *et al.* (2017) concurs that approximately one-third of the food produced about 1.3 billion tons is lost globally during post-harvest operations every year.

Findings from the study indicated that farmers suffer from water insecurity which results in loss of business. Thus, improvement in agricultural practices for small-scale farmers is essential to achieve an efficient grain supply chain with increased grain yields, reduced grain losses during storage and handling, and reduced time and effort to accomplish harvest and post-harvest operations. Loss during grain storage is one of the main contributors to total post-harvest grain losses (Kumar *et al.,* 2017).

Reducing the post-harvest losses, especially at Luvhada irrigation scheme, as well as other small-scale farmers and developing countries, could be a sustainable solution to increase food availability. This could reduce pressure on natural resources, eliminate hunger and improve farmers' livelihoods. Conclusively this can be achieved if farmers have access to adequate water for their post-harvest activities. Post-harvest loss accounts for direct physical losses and quality losses that reduce the economic value of the crop or may make it unsuitable for human consumption (Govindaraj *et al.,* 2017). In severe cases, these losses can be up to 80% of the total production (Fox, 2013). From the foregoing, it is clear that the irrigation scheme needs to seriously look at ways to improve its water security status at the post-harvest stage of the leguminous crops going forward.

5.5. Conclusions

The study focused on determining water security challenges faced in post-harvest handling of leguminous crops at Luvhada irrigation scheme. The results revealed that water security challenges in post-harvest activities at the scheme were due to a lack of adequate water supplies during the post-harvest handling processes. Water at the scheme is not enough due to the lack of water storage and infrastructure facilities. The challenges resulted in legumes drying before they are washed due to lack of water, loss of fresh stock as customers prefer freshly cleaned legumes. Therefore, it is recommended that an observational study be conducted to monitor how farmers access to water and which storage and infrastructure facilities are required and appropriate for the scheme. This is because, the main problem is how to access water from the source to cover all the water activities at the scheme. The next chapter presents the findings and discussions of objective 3 of the study which are the strategies for managing water in post-harvest handling of leguminous crops.

CHAPTER 6: STRATEGIES FOR MANAGING WATER IN POST-HARVEST HANDLING OF LEGUMINOUS CROPS

Abstract

Water is a critical input for agricultural production and it plays an important role in food security. The challenge of today is to increase crop productivity and improve agribusiness more sustainably to achieve food security. Healthy soil and availability of freshwater are some of the vital aspects of this aim. The ability to improve water management in agriculture is constrained by inadequate policies, major institutional under-performance, and financing limitations. The study, therefore, aimed at providing strategies for managing water security in the post-harvest of leguminous crops at Luvhada irrigation scheme. An exploratory mixed-method design was used in this study. Structured and semi-structured questions questionnaires were utilized to ask questions from the respondents. Snowball sampling was used to select respondents. Data were collected using telephone interviews using a questionnaire with open and close-ended questions. The data collected were analyzed using Atlas ti version 8 software and the Statistical Package for the Social Science (SPSS) (descriptive statistics and frequencies). Results of the study revealed that the scheme lacked support from the government. Furthermore, the results also showed that coping strategies included the use of residential water sources, use of open water sources, sourcing water from other businesses for use in post-harvest agricultural processes. Thus, proposed strategies to water security in post-harvest activities were the provision of water pumps, dam construction, and provision of water storage facilities, sponsorship with irrigation materials and water rationing and sharing. Hence, the scheme should be assisted financially and provided with appropriate water materials to reduce water insecurity.

Keywords: Exploratory mixed method design, Managing, post-harvest, stakeholders, strategies, structured and semi-structured questionnaires, water security.

6.1 Introduction

As water is an essential component of the planetary life support system, water deficiency constitutes insecurity that has to be overcome in the process of socio-economic development (Asthana, 2019). Water security may be seen as a tolerable water-related risk to society. Water's social and productive potential meets human society in two main ways: on the one hand, as liquid (blue) water to meet hygienic, health and economic requirements (including irrigation and post-harvest activities), and, on the other hand, as the infiltrated rainwater in the soil (green water) that operates the production of food and other biomass (Grey, 2013).

Globally, agriculture encounters immense challenges. How to secure the supply of agricultural products and improve the sustainability of agricultural development under the constraints of limited resources and environmental sustainability is the most important challenge that has to be overcome. Water is a vital factor in agricultural production, and water shortage has seriously affected the agricultural production of countries like China. Agriculture is facing a serious problem for global food security and scarce water resources (Kang *et al.,* 2017), therefore how to make the efficient use of limited water resources has become a great concern to international organizations, governments, and scientists around the world. To solve the current water crisis and ensure agricultural sustainable development and food security globally, it is essential to identify the key issues related to highly-efficient water utilization in agriculture, understand the mechanisms of water transformation and consumption in grain production at different scales, and improve water use efficiency through scientific and technological advancements and management reform.

Most developed countries in the world face the challenge of reducing the water security threat to biodiversity while maintaining established water services for human needs (Zeitoun *et al.,* 2016). Therefore, a successful integrated water management system must consider strategies to ensure an adequate water supply to meet agricultural production demands while protecting natural resources. Many presentations at the Global Water Security Conference revolved around water security challenges (Baig *et al.,* 2020). Achieving water security thus requires cooperation between different kinds of water users, and between those sharing river basins and aquifers, within a framework that allows for the protection of vital ecosystems from pollution and other threats (Harshadeep & Young, 2020). On the other hand, Basco-Carrera *et al.* (2017) stated that water security will only be reached when high-level decision-makers take the lead, make the tough decisions about the different uses of water and follow through with financing and implementation. Thus, water management is the key to ensuring that more food can be produced for the growing population; there is no food security without water security.

To cope with future estimates of water shortages, some measures aimed at streamlining and optimizing the efficiency of water consumption in the agricultural sector are critical given the large volumes of water required for the production of crops. Ways of reducing water scarcity risks vary between their type and scales and might be thought of as components of a web of water security (Hoekstra *et al.,* 2018). Food and Agriculture Organization (FAO) stresses that there is a whole range of major strategies to cope with global water scarcity, including desalination of saline waters, re-use of wastewater, virtual water and food trade, increase in agricultural yields and improved water use efficiency in agriculture including the use of biotechnology (Sofroniou & Bishop, 2014).

Water management strategies and allocation policies that support agricultural intensification at post-harvest are required for building resilient agrarian communities in sub-Saharan Africa. Hence, reservoirs promote diversification of agricultural post-harvest activities of legumes through multi-purpose use, including dry seasons (de Fraiture *et al.,* 2014; Douxchamps *et al.,* 2014). Results of the previous chapter revealed the challenges of water security at post-harvest faced by Luvhada irrigation scheme activities (absence of storage facilities, physical storage and underdeveloped water access infrastructure). Moreover, those challenges led to the effects of water at post-harvest activities. These include poor quality products of legumes, drying and getting damaged and loss of stock. Therefore, the main aim of the study was to come up with strategies for managing water security in post-harvest handling of leguminous crops at Luvhada irrigation scheme. Luvhada irrigation scheme was preferred for this study because it is the most developed scheme among other schemes situated at Nzhelele.

6.2 Methods and materials

An exploratory mixed-method design was adopted for the study. A complete detailed description of the methods, study population, population sampling, data collection, and analysis is provided in Chapter 3. The following section presents the results of the study.

6.3 Results and Discussions

6.3.1 Demographic profile

The demographic information is described in Chapter 4.

6.3.2 Current Strategies from different stakeholders

Farmers were asked about current strategies by stakeholders like the government and private sector in assisting them at post-harvest activities and the challenges they face about the lack of water. They stated that there is no assistance from the government, however, promises were made. The government has been promising the farmers to solve the problem of water at the irrigation scheme so that they will have access to adequate water for all the activities that require water. From the respondents, it is clear that the government is aware of the problem but nothing has been done yet to solve the challenge. The scheme members try to manage water through rationing and sharing with other farmers. Some of the views expressed by the farmers are presented below:

> *"There is nothing that the government is doing, they know our problem but still now there is nothing they have done*".
> *Respondent 9*

On the other hand, another respondent said:

> "*Government is aware of their problems but keep on promising farmers things that they don't deliver at the end*".
> *Respondent 23*

6.3.3 Water coping Strategies at the post-harvest stage of leguminous crops

The interviewed farmers' revealed challenges faced when accessing water for irrigation at the scheme. The identified coping strategies are discussed below and supported by quotations from the farmers in Figure 6.1.

6.3.3.1. Use of residential water and open water sources

The interviewed farmers indicated that due to water shortages at the scheme, the majority of them are using residential water sources. They pointed out that after harvesting they take the harvested legumes home to wash them as well as prepare for selling after sorting the legumes. Some farmers believed that due to lack of adequate water at the scheme, the use of both river and home water is a suitable way to overcome the challenge. Some interviewed farmers stated that they utilize water from the Nzhelele River to wash the legumes because the river is nearby the scheme. The only uncertainty is the quality of the river water. This would need to be verified in future studies. The alternative use of open water sources seems to be working for them rather than depending on one source.

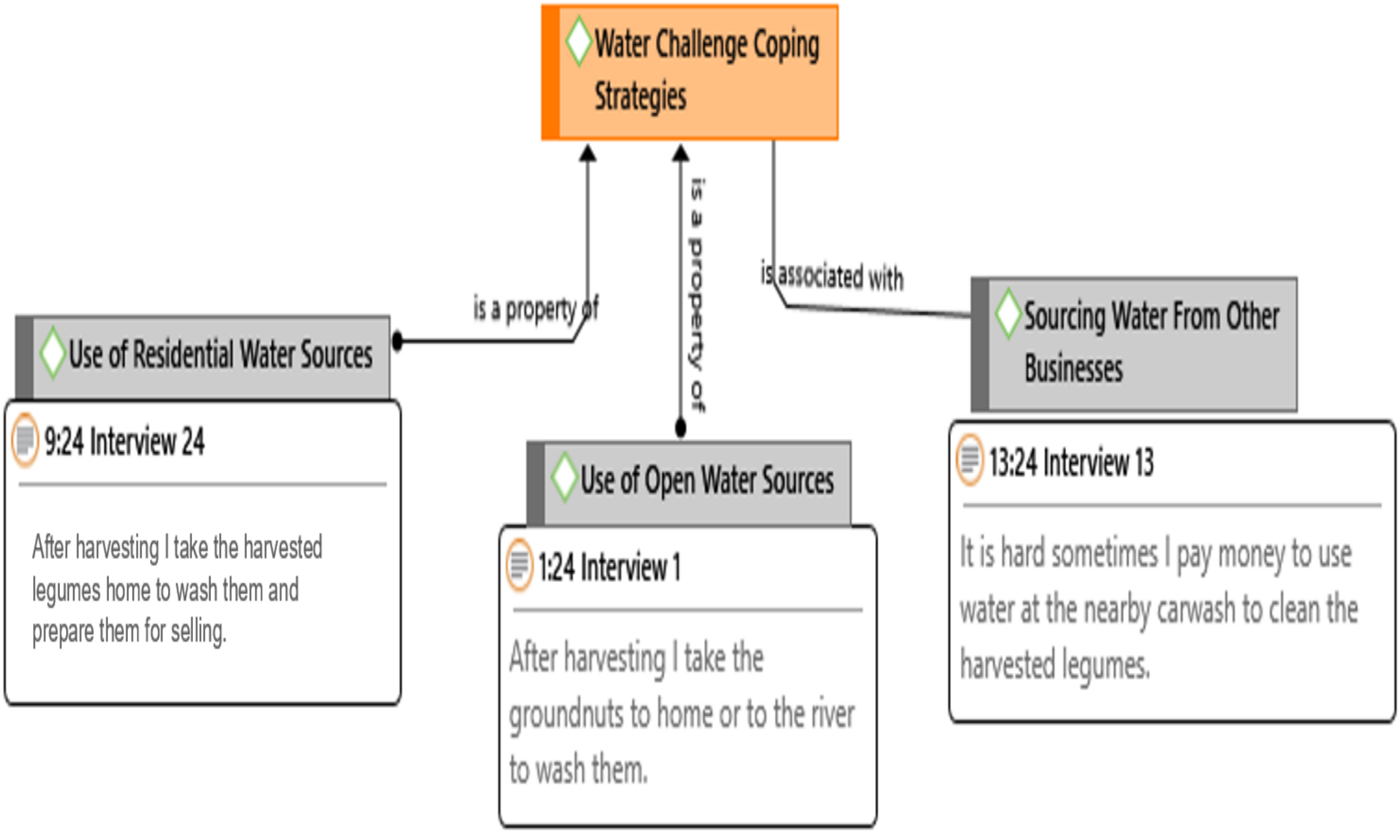

Figure 6.1: Strategies used to cope with water challenges in post-harvest activities of leguminous crops in Luvhada irrigation scheme in Limpopo Province, South Africa

The open water source at Luvhada irrigation scheme is supported by the quotation below from one of the respondents:

> *"It is hard without water; we wait for our turn to use water so we take the legumes after harvest home to wash them".*
>
> *Respondents 39*

6.3.3.2. Sourcing water from other business

Sourcing water from other businesses was also a strategy adopted by the farmers. Farmers also utilized water from the nearby carwash to wash their produce. They further stated that it is better to pay money at the carwash to access clean water than to lose the legumes because once they lose them they also lose their source of income. The use of water from the local car wash was common among those with plots that were far from the river. At the same time, most farmers are old and cannot carry their produce to the river, hence, they preferred utilizing water from a nearby car wash. The below quotation by Respondent 26 emphasizes the sourcing of water from other businesses:

> *"It is hard sometimes I pay money to use water at the nearby carwash to clean the harvested legumes".*

6.3.4 Proposed Strategies

The researcher also sought proposed strategies to improve water access in post-harvest activities for groundnuts and beans at Luvhada irrigation scheme. Farmers proposed the following strategies: provision of water pump, dam construction, sponsorship with irrigation materials, and provision with storage facilities, water rationing and sharing. Table 6.1 supports the proposed strategies of water challenges at post-harvest handling. Dam construction was suggested as the main strategy to alleviate water insecurity at the scheme, it was suggested by 11 farmers.

Table 3.1: Water access strategies proposed by farmers at Luvhada Irrigation Scheme, Limpopo Province South Africa.

Frequency	Proportion (%)	
The building of a dam could help to improve water security at the scheme.	11	26.2
By increasing water storage system with tanks and a dam.	10	23.8
As we access to water from the fountain only, more water sources should be implemented	7	16.7
Building a dam, implementing drip irrigation, boreholes and tanks could solve our problems when it comes to water.	3	7.1
If the government can build a dam for us water security can be improved.	2	4.8
To improve water security at the scheme we should be provided with tanks and drips.	2	4.8
Building water storage systems such as a borehole and dam also if we can get drips as they save water can help to improve water security at the scheme.	1	2.4
Department of Water and Sanitation can help in solving the problem of water at the irrigation scheme.	1	2.4
If the government can build a dam and provide us with tanks so that water security can be improved.	1	2.4
If we can get a borehole and dam to store water, water security can be improved.	1	2.4
Our main problem is water access at the scheme, so we need tanks and pumps to pump water from the river and store it inside the tanks our problem can be resolved.	1	2.4
The government should provide us with tanks and pumps to pump water from Nzhelele river.	1	2.4
Government can assist us with funding and materials to build a storage system.	1	2.4
Total	**42**	**100.0**

Figure 6.2 (network diagram) further emphasizes water strategies proposed by the farmers at Luvhada irrigation scheme. The figure portrays the verbatim words alluded to by the farmers.

6.3.4.1. Provision of water pump

At Luvhada irrigation scheme the fountain is their main source of water. During interviews, farmers suggested that pumps should be provided at the scheme so that they can pump additional water from the Nzhelele River. The provision of water pumps could be crucial to all the farmers as they can have better access to water for their post-harvest activities. Moreover, water security and food security could be achieved. When farmers have access to water they grow more crops and in turn, more people have food and the farmers gain more customers and income.

6.3.4.2. Dam construction

The construction of a dam is the main strategy that the farmers suggested. Almost all the farmers suggested that constructing a dam could alleviate the challenges of water at the scheme. Farmers further noted that since they have been pleading with the government to build a dam for them but nothing has been accomplished yet. The construction of the dam may not be the solution at the Luvhada irrigation scheme, farmers need to share water accordingly.

6.3.4.3. Sponsorship with irrigation materials

The majority of the farmers suggested that sponsorship with irrigation materials could assist to alleviate water challenges at the scheme. The scheme only depends on the fountain as the source of water and this is not sufficient for all the farmers as the canals they are using to access water from the fountain are old and some are not paved resulting in leakages of water. According to the farmers, the irrigation scheme management tried to divide the scheme into blocks so that all the farmers can have access to the small amount of water they have, but this seems to not work because they get water once a month and the pressure of water in the canals is slow. The interviewed farmers suggested that they need funding from the government and other private business stakeholders that are willing to assist them. Below are some of the farmers' suggestions:

> *''Stakeholders can assist with funding so that we will be able to improve water access at the irrigation scheme''.*
>
> *Respondent* 37.

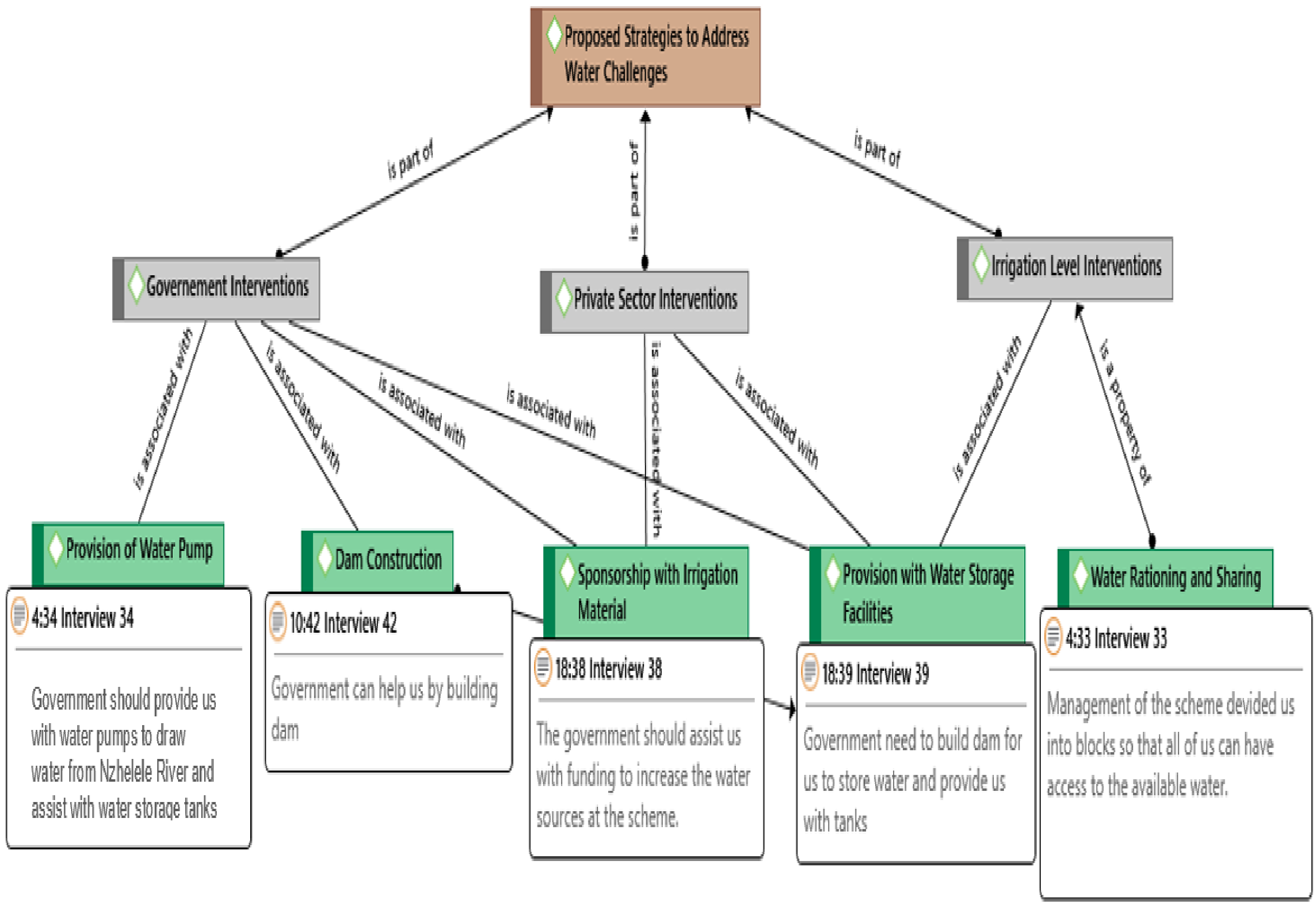

Figure 6.2: Water access improvement strategies proposed by farmers at Luvhada Irrigation Scheme, Limpopo Province South Africa

6.3.4.4. Provision with storage water facilities

Due to limited water storage facilities at the irrigation scheme, the majority of respondents suggested that they needed water storage facilities such as tanks to store water. The water storage facilities could reduce the conflicts among community members and farmers, and the night irrigation is dangerous especially for women and those who reside far from the irrigation scheme. Provision with storage water facilities can also reduce the poor quality of legumes where the legumes of the farmers become dry before they are washed. The storage facilities could likewise reduce the time wasted by farmers from the scheme while going to Nzhelele River to wash the harvested legumes as well as saving them from paying the nearby car wash to utilize their water.

6.3.4.5. Water rationing and sharing

Water rationing and sharing were some of the coping strategies pointed out by farmers. Management of the scheme divided the scheme into blocks for all the farmers to utilize water. The scheme is divided into four blocks of which each block gets water once a month, they access the water during the day and night. The implementation of water rationing and sharing was meant to help and give all the farmers an equal chance to get water.

6.4. Discussions of the results

6.4.1. Current Strategies from different stakeholders of water security at post-harvest of leguminous crops

Lack of support from the government is one of the reasons small-scale farmers are not developing. Most of the small-scale farmers are situated in rural areas and they play a crucial role in meeting food demand yet they are not getting proper support from the government. In particular, Luvhada irrigation lacks financial support from the government. This shows that the financial support currently rendered to small-scale farmers is inconsistent with the visions expressed in policy statements (Greenberg, 2010). On the other hand, Fanadzo & Ncube (2018) argued that despite clear evidence showing that budget allocations for training, management and institutional development need to be 40-50% of the total intervention budget, the core focus of the government has largely been on rehabilitation of irrigation infrastructure, hence at Luvhada they are not benefiting from the government’s budget because their infrastructure is not restored.

6.4.2. Coping Strategies at post-harvest of leguminous crops

Irrigation schemes remain one of the most important means of meeting the food requirements of an expanding world population. Therefore, the irrigation schemes must have access to water to continue achieving the goal of meeting the food requirements to maintain food security. Irrigation schemes in South Africa face problems of low water-use efficiency and cost recovery of government investments. Research results indicate that small-scale farmers are prepared to pay considerably higher water prices if these are connected to improvements in the water rights and they are assured of reliable access to water for irrigation and post-harvest activities (Speelman *et al.*, 2010). It is clear that indeed farmers are prepared to pay for water because at Luvhada they are already buying water for their post-harvest activities at the nearby cash wash. Furthermore, they hire people to take their harvested legumes to Nzhelele River or home for cleaning.

Addressing water scarcity, goes beyond ensuring the physical availability of water. Many farmers, particularly in large parts of the developing world including rural small-scale farmers are unable to access and manage existing water resources for productive use because of economic or institutional barriers (Giordano *et al.,* 2019). Farmers at Luvhada opt to use residential water sources as a strategy to cope with water scarcity at the scheme. They take their harvested crops home to wash and sort them as well as prepare for market. The water scarcity in post-harvest handling at the scheme is mainly caused by lack of adequate infrastructure to access water from the fountain to the scheme. Cosgrove & Loucks (2015) support that this form of water scarcity results from lack of infrastructure, financial resources, appropriate institutions, and capacity that in conjunction limit the development of available water resources or that result in inequitable distribution. They further stated that economic water scarcity impacts about 1.6 billion people worldwide. Therefore, improving water security requires better understanding not only of water supply and demand but also of the linkages within the small-scale farmers, and of the aspects which can be addressed to achieve overall improvements in water security. Nepal *et al.* (2021) highlighted how poor governance has hindered Nepal in achieving water security. The article considers some specific measures to improve water security in different sectors. It provides some insights into the role of groundwater in agricultural water security and its relationship to energy provision, and the important role of governance in addressing water security using a holistic and integrated approach.

The farmers at Luvhada also adopted the strategy of using open water sources as a way of coping with water scarcity. They alternatively use both river and pipes at home where the harvested legumes are taken to those water sources to perform the required post-harvest activities. When water demand increases, water managers traditionally consider the possibility of withdrawing more water from the river system (Gohari *et al.,* 2013). Falkenmark (2013) argued that however there is a limit because aquatic ecosystems depend on river water as their habitat. Increasingly, a certain part of the river flow is today being reserved to protect aquatic habitats in South Africa. On the other hand, Gaupp *et al.* (2015) stated that when a river basin can supply water to meet withdrawal demands and maintain its ecological functions, it is considered an open basin. Moreover, a river basin is closing when allocations begin to impinge on ecological needs and closed when this limit is reached or breached (El Gayar, 2020). Therefore, when all the water in a river basin is already allocated, water management will have to be transformed and adapted to the actual water situation through allocation changes including, for example, withdrawal reductions, caps on irrigation, wastewater re-use and use of remote raw water sources for municipal water supply systems.

6.4.3. Proposed Strategies to address water challenges in post-harvest handling of leguminous crops

The irrigation scheme lacks adequate water due to the lack of proper infrastructure to access water. The scheme is situated near Nzhelele River, so they can use that opportunity to access water from the river through using pumps to pump water. Although Burney *et al.* (2010) argued that the use of strong technological equipment such as high-powered pumps for the abstraction of groundwater in the majority of the vulnerable countries resulted in the continuous unsustainable drawdown of aquifers and causes damages underground. These pumps allowed faster drafting from aquifers, rivers, canals e.t.c. and disturb the natural equilibrium of recharge and discharge. This clearly shows that the pumping of water can pose negative impacts to the natural equilibrium while on the other hand can bring positive change to the irrigation scheme as they will be able to have better access to water in post-harvest activities.

The construction of a dam can also play a major role in assisting water security at the scheme. A dam can store enough water for the farmers to use in post-harvest activities as well as water usage in general. Investments are needed to support small-scale farmers to cope with water scarcity both physical and economic for achieving food security, livelihood benefits, and poverty reduction goals (de Fraiture & Giordano, 2014; Haensch *et al.,* 2016; Woodhouse *et al.,* 2017). Thus, the irrigation scheme lacks financial support from key stakeholders. They have been struggling with water issues for a long time ever since the scheme was established. However, the farmers do not have the financial resources to test and implement technologies that maximize water-use efficiency. This makes extension and government-funded research and development programs essential. Greenberg (2010) states that the response of the national government, at a time of economic contraction, has been to reallocate resources from agriculture to other priority areas of the economy.

Farmers on an irrigation scheme are dependent on each other because they share the water distribution system. This interdependence requires a willingness on the side of farmers to work collectively to achieve their objectives (Van Averbeke *et al.,* 2011), while at the same time also sustaining the collective production. Rules to govern collaboration and structures to enforce these rules are necessary for the effective and sustainable functioning of collective action. In support of the statement, Luvhada irrigation scheme adopted a strategy of dividing the scheme into blocks where they access to water once a month according to their blocks. This shows that farmers depend on each other and are working together to share the available water.

Irrigation schemes without water storage facilities such as tanks usually are associated with poor performance because they depend on one source of water and once that source fails to provide water to the whole scheme, the scheme loses production, quality as well as quantity of the crops. The Luvhada irrigation scheme does not have storage and this contributes to some of the poor performance of the scheme. Therefore, storage facilities are urgently needed to store water, with this water they can use post-harvest. With small-scale farmers diversity is needed, this diversity means that different kinds of interventions are necessary to respond to varying farmers' needs, resources and agricultural contexts (Van Averbeke *et al.,* 2011). A lack of appreciation of the diversity in small-scale farming is what has led to the Government's core focus on rehabilitation, with the concomitant result of repeated failure of state-funded interventions to achieve farmer development objectives (de Satgé & Phuhlisani, 2020). Thus, a better understanding of the Luvhada irrigation scheme water challenges issues in post-harvest activities that contribute to the resource scarcities faced by the farmers will offer important insights on where and how public and private sector investors can best support and leverage the scheme for greater impact.

6.5. Conclusions

The study aimed to establish how farmers are managing water security challenges in post-harvest handling of leguminous crops, current strategies from different stakeholders of water security in post-harvest of leguminous crops and the proposed coping strategies to assist with water security challenges in post-harvest handling were identified. The farmers pointed out that the government is aware of the water security challenges but has done nothing about it yet. Promises to build a dam for them are yet to be fulfilled. However, they adopted some strategies to cope with water scarcity in post-harvest handling of legumes, where they take the harvested legumes to the river and home and also to the nearby car wash to perform those post-harvest activities. Conclusively they proposed strategies that they believe can assist in their water challenges. The strategies include construction of a dam, provision of pumps, and financial assistance from the government as well as businesses or other stakeholders, provision of storage facilities and rationing and sharing of water. The construction of the dam could take time, therefore the provision of pumps to pump water from Nzhelele River and provision of storage may be prioritized. Moreover, since the canals are old, broken and some are not paved, the construction of new canals could also alleviate the challenges of water at Luvhada irrigation scheme. The following chapter presents the general discussions, conclusion and recommendations of the study.

CHAPTER 7: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

This chapter highlights the general discussions, conclusions and recommendations for the study on assessing water usage in post-harvest handling of leguminous crops. The study aimed to assess water usage at post-harvest handling of leguminous crops at Luvhada irrigation scheme. The conclusions and recommendations for the study are based on the key findings.

7.2. General discussions

7.2.1. Analysis of water use in post-harvest handling of leguminous crops

The study aimed to assess water usage in post-harvest handling of leguminous crops at Luvhada irrigation scheme. The results revealed that the main legumes grown by the farmers are beans and groundnuts, while only few are growing Bambara nuts. Most farmers grow these legumes because of high market demand and because they are drought resistant. Although, some farmers grow them because they are easy to maintain compared to other crops, inexpensive to plant as well as to harvest. Altieri (2018), points out that legumes can adapt and grow vigorously under a wider range of environments and on relatively poor soils without supplemental nitrogen, which is particularly advantageous for consistent agricultural practices in remote areas. While Jouzi *et al.* (2017) stated that they require a low water supply which offers small-scale farmers opportunities to grow them and earn a living by selling them and achieving food security as well. Muchara *et al.* (2017) supported that with water being a scarce resource at the national level (South Africa) drought-tolerant crops such as groundnuts should be produced in masses to ensure food security and minimal use of water, especially at post-harvest. It is further highlighted that the improvement of water conservation, water quality and water-use efficiency is of key national priority. The sources of water used at post-harvesting activities mentioned by the respondents are domestic water taps, rivers, water taps at the nearby car wash, and water canals at the irrigation scheme. They opted to use those various sources because at the scheme there is not enough water. The farmers use water from the sources to wash the legumes, especially the groundnuts, as well as boiling them sometimes. Water is used during post-harvest handling of legumes. For example, washing and for general cleaning, and disinfection of bacteria purposes (Kumar *et al.,* 2019). Respondents pointed out that water that is used post-harvest is not measured. They manually observe the water, checking whether it will be enough or not to wash the legumes based on how dirty the legumes are.

7.2.2. Determining water security challenges faced at post-harvest handling of leguminous crops

Challenges of water security faced at post-harvest handling of legumes crops were the absence of storage facilities such as tanks and underdeveloped water access infrastructure such as canals. Farmers pointed out that there is no single water storage at the scheme which results in a lack of proper water for post-harvest activities. This has a negative impact on the legumes as they sometimes become dry and damaged without being washed. This is not good for business as their customers prefer freshly cleaned legumes. Kumar & Kalita (2017), gave the crucial example that cracked grains such as groundnuts or beans may be sold in the marketplace, though at cheaper rates. There are no total losses since they have alternative uses, often at lower prices. The selling of the cracked legumes at a cheaper rate could play a vital role in their income because they will get that small amount rather than getting nothing at all. Moreover, food security would be achieved as well because those who do not afford the good quality legumes will go for the rejected ones. It is estimated that nearly 1.3 billion tons of food is globally lost or wasted per year along the post-harvest chain (Gustavasson *et al.,* 2011), which accounts for over 30 % of total crop production (Foresight, 2011; Gustavsson *et al.,* 2011).

7.2.3. Strategies for managing water in post-harvest handling of leguminous crops

Based on an analysis of water use and challenges faced by farmers in post-harvest handling of leguminous crops it was, therefore, necessary to look into the strategies they adopted to cope with water insecurity and proposed strategies to overcome the water insecurity. The results of the study revealed that due to water insecurity in post-harvest activities of legumes, farmers came up with strategies to cope. Use of residential water, open water sources and sourcing water from other businesses were the adopted strategies. According to Molden (2013) water management is the key to ensuring that more food could be produced for the growing population. Therefore, improving agricultural water post-harvest is an important measure for ensuring global water safety and food security (Kiaya, 2014). There are water strategies that were proposed by farmers which are the provision of water pumps, dam construction, provision with storage water facilities, sponsorship with irrigation materials and water rationing and sharing. Farmers believe that those proposed strategies can assist to achieve water security at the scheme. Since the scheme is situated between two sources of water (Nzhelele River and Lulumba Fountain); pumping of water from Nzhelele River could assist to eliminate water insecurity. Provision of storage facilities such as tanks could also play a vital role to achieve water security in this way farmers will store water that they can use for their post-harvest activities. This will also reduce the loss of income by paying the businesses to get water and hiring people to take their harvested legumes to the river. New investments in agricultural infrastructure and enhanced water management can reduce the impact of water scarcity (Namara *et al.,* 2010).

7.3. Conclusions

The study focused on assessing water security in post-harvest handling of leguminous crops in Luvhada irrigation scheme. Water is a key resource for the development of any human activity. In many countries, the available water supply and the uneven distribution of this resource in time and space are pressing issues. It is projected that a large share of the world's population, up to two-thirds, will be affected by water scarcity over the next several decades. The availability of water for farming is an essential condition for achieving satisfactory and profitable yields, both in terms of unit yields and quality. The findings of the study highlighted that at Luvhada irrigation scheme water was mainly accessed from the scheme canals, nearby car wash, and at home. Legumes were cleaned before boiling and drying and then sold. Moreover, farmers did not measure or know the exact amount of water used in post-harvest activities. This could either be due to lack of interest or lack of proper water infrastructure that farmers could use to record the amount used. The study further revealed that the challenges that were faced by the farmers for water in post-harvest handling of leguminous crops were lack of adequate water and this was caused by lack of proper infrastructure such as canals because the ones they were currently using were old and some were not paved of which was causing loss to water. Water storages were not available at the scheme so farmers did not store water. They ended up coming with a strategy of dividing the scheme into blocks for all the farmers to access the available water.

It was, therefore, recommended that a dam should be constructed to store water augment water from the fountain so that farmers would not only depend on the fountain as their main source of water. The provision of water pumps to pump water from Nzhelele was also a coping strategy that was recommended by the farmers. It was also pointed out that most of the farmers were old unemployed people who depend on the scheme for survival hence they do not have enough money to solve all the water problems. Therefore, it was recommended that government and the private sector that is willing to assist should fund the irrigation scheme to solve water challenges that the schemes faces.

7.4. Recommendations

The following recommendations are based on the findings of this study. It is expected that these recommendations may be used as guidelines for the government (Department of Agriculture and Rural Development) and other stakeholders involved in irrigation development to achieve water security in post-harvest handling of leguminous crops.

7.4.1. Recommendations for the Department of Agriculture, Land Reform and Rural Development

Poor infrastructure is the main problem in the scheme and this is mainly caused by a lack of financial support from the government. Thus, positioning of the effective implementation of infrastructure by creating a centre of water intelligence, taking into account the importance of water in all aspects of irrigation schemes, especially the South African schemes. This will further involve the development and refinement of national indicators on water security and redirecting the various institutions mandated to carry out the water business, including stakeholders, public and private sectors as well as citizens. Creating a planning and monitoring framework that is robust to ensure that water-related risks are avoided or mitigated. Aligning local government legislation and national legislation. There is also a need to strengthen the institutions that govern water at the local level.

7.4.2. Recommendations for further research

While this study only covered areas of water use in post-harvest activities, it may also be important for future research to focus on the determinants contributing to the underdevelopment of the scheme and what could be done to improve progress at the scheme as well as food security. In addition, studies on the adoption of improved agricultural technology to enhance agricultural productivity should be done to meet food demand and ensure food security. Moreover, determinants of water insecurity and water infrastructures that are suitable for the scheme should be established.

7.4.3. Recommendations for Luvhada Irrigation Scheme

The irrigation scheme was established decades ago and there is no improvement in terms of water provision. Farmers are not getting water to use in post-harvest activities from the scheme because the water they are getting is not enough. The irrigation scheme is situated near two sources of water, Nzhelele River and Lulumba fountain. The farmers should agree to contribute funds to buy pumps to pump water from the Nzhelele River. They can also ask for donations from businesses as well as government departments and NGOs. By contributing funds, they can draw attention to those who want to help as it will show that they are serious and in need of infrastructure.

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9. APPENDICES

9.1. Questionnaire (English version)

This questionnaire seeks to assist the researcher to get necessary data that will provide answers on water security in post-harvest of leguminous crops (Groundnuts and Beans) at Luvhada irrigation scheme. The information you will give will be confidential and will be used for academic purposes only. Your identity and personal information will not be revealed to any other person.

INSTRUCTIONS

(i) Please answer all questions.

(ii) Choose the answer(s) that is applicable by ticking **X** in box (es) provided.

(iii) Write down the information required in the space provided on the dotted lines.

(iv) All answers are correct from the respondents. There is no wrong or right answer.

PART ONE: BIOGRAPHICAL INFORMATION

1.1. Age group:

15-34 years		35-54 years		55-64 years		Oder than 65	

1.2. Race:

African		White		Coloured		Other	

1.3. Gender:

Male		Female	

1.4. Disability:

Yes		No	

1.5. Educational qualification:

Never went to school		Primary		Secondary		Tertiary level		Abet	

1.6. Occupation of the respondent:

Full time farmer		Part time farmer		Employed	
Unemployed		Self-employed		Pensioner	

1.7. What is your source of income?

Full time farmer		Part time farmer		Employed	
Unemployed		Self-employed		Pensioner	

1.8. What is the monthly or annual income from the farm, from each crop leguminious?...
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....

1.9. Uses of income generated from the farm especially for leguminous plants…………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………..………

PART TWO: Water security and post-harvest of leguminous crops (Groundnuts and Beans)

2.1. Farming details

2.1.1. Do you have own land?

Yes		No	

2.1.2. How many hectares do you have? …………………………………………………………

2.1.3. Which leguminous crops are you growing? Mention them ………………………………

……………………………………………………………………………………………………

………………………………………………………………………………………………...........

2.1.4. How many years have you been farming leguminous crops?

0-12 Months		1-5 years		More than 5 years	

2.1.5. How many hectares of land do you use to produce leguminous?

0.1 - 0.9 hectares		1-5 hectares		More than 5 hectares	

2.1.6. Which season do you plant the leguminous crops?

Autumn		Winter		Spring		Summer	

2.1.7. When do you harvest leguminous crops?

Autumn		Winter		Spring		Summer	

2.1.8. Why you grow leguminous crops? …………………………………………………………....

2.2. Value chain

2.2.1. Do you add value in the post-harvest of the leguminous crops?

Yes		No	

2.2.2. Where do you add value in the leguminous crops post-harvest process?

Threshing		Cleaning		Drying	
Packing & Processing/ Grading		Storage		Transportation	

2.2.3. Why do you add value in process you chose? ……………………………………………..

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2.3. Water security in leguminous crops (Groundnuts and Beans)

2.3.1. Where do you get water to use in post-harvest activities? …......................................

…………………………………………………………………………………………………

2.3.2. Is the water enough in those activities?

Yes		No	

2.3.3. Please explain your answer ……………………………………….............................

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2.3.4. What are the challenges faced in water security for post-harvest handling?

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……………………………………………………………………………………………….

2.3.5. How do you cope with the challenges? …..

…………………………………………………………………………………………………

……………………………………………………………………………………………….

2.3.6. How does water insecurity affects the post-harvest activities?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………...

2.4. Post-harvest of leguminous crops (Groundnuts and Beans)

2.4.1. Do you use labour?

Yes		No	

2.4.2. If yes, what kind?

Hired labour		Family labour		None		Others	

2.4.3. If others, please specify ……………………………………………………………………

2.4.4. How many people do you hire? ………………………………………………………………

2.4.5. Where do you use water most in those post-harvest processes?

Threshing		Cleaning		Drying	
Packing & Processing/ Grading		Storage		Transportation	

2.4.6. Please explain your answer in 2.4.5 ………………..

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……
……

2.4.7. What is the quantity of water used in the post-harvest processes?

post-harvest processes	Quantity of water used in each post-harvest processes
Threshing	
Cleaning	
Drying	
Packing & Processing/ Grading	
Storage	
Transportation	

2.4.8. What do you do with your legumes after harvesting………………………………………

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2.4.9. What is the government doing to help in relation to water shortage in the irrigation scheme? ……………………………………………………………………………………………
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2.4.10. What is the irrigation scheme doing to help in relation to water shortage in the irrigation scheme? ……………………………………………………………………………………..

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2.4.11. What do you think the government can do to help in relation to water?

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2.4.12. How do you intend to solve this problem at the scheme?

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2.4.13. What do you think can be done to improve water security at the scheme?

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2.4.14. Which stakeholders you think can be approached to assist in solving the problem of water in the irrigation scheme? ……………………………………………………………………….

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………………………………………………………………………………………………………..

2.4.15. Based on the answer in 2.4.14 what the stakeholders can assist within the irrigation scheme? ……………………………………………………………………………………......................

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………………………………………………………………………………………………………..

Thank you

9.2. Questionnaire (mbudziso) (Venda version)

Tshipikwa tsha mbudziso idzi ndi u thusa mugudi (researcher) uwana mawanwa ane ado thusa kha thodisiso ya water security in post-harvest of leguminous crops (Nduhu na Nawa) ngei Luvhada irrigation scheme. Phindulo dzine dzado fhiwa dzi do tsireledziwa nahone dzi do shumisiwa kha thodisiso iyi fhedzi. Madzina na zwidodombedzwa zwido dzumbiwa.

NDAELA

(i) Vha fhindule mbudziso dzothe.

(ii) Kha vha topole phindulo yo teaho nga u shumisa **X** kha zwibogisi zwo nekedzwaho.

(iii) Vha nwale fhasi phindulo dzo teaho kha zwikhala zwo nekedzwaho.

(iv) Phindulo dzothe dzine vhado dzi nekedza ndi dzone. Ahuna phindulo dzisi dzone.

TSHIPIDA TSHA U THOMA: NGANEAVHUTSHILO KHA MAFHUNGO

1.1. Minwaha:

15-34		35-54		55-64		65 na ntha	

1.2. Murafho:

Vharema		Vhatshena		Coloured		Dzinwe	

1.3. Mbeu:

Munna		Mufumakadzi	

1.4. Vhuholefhali:

Ee		Hai	

1.5. Pfunzo:

Athingo thaphudza		Phuraimari		Sekondari		Tesheri		Abet	

1.6. Mushumo.

Mulimisi		Mulimisi nga tshifhinga		Ndi a shuma	
Athi shumi		Ndi adi shuma		Phenseni/ Mundede	

1.7. Hune vha wana hone muholo/tshelede?

Mulimisi		Mulimisi nga tshifhinga		Ndia shuma	
Athi shumi		Ndi a di shuma		Phenseni/ Mundede	

1.8. Vha hola vhugai nga nwedzi kana nga nwaha masimuni kha zwimela zwine vha tavha?..
....
....

1.9. Muholo/masheleni ane vha awana masimuni a zwimela vha ashumisa mini?
……………………………………………………………………………………………………….
……
…………………………….…………………………………………………………………………

TSHIPIDA TSHA U VHUVHILE: TSIRELEDZEA A MADI ZWIPIDA KHA NDUHU NA NAWA

2.1. Talusa ya Zwa vhulimi

2.1.1. Vhana tsimu ine yavha yavho?

Ee		Hai	

2.1.2. Vhana hectare nngana? ……………………………………………………………………

2.1.3. Vha tavha zwimela de? Khavha zwibule …………………………………………………

……
…..……………………………………………………………………………………….............

2.1.4. Vhana minwaha mingana vhatshi tavha zwimela afho masimuni?

0-12 minwedzi		1-5 minwaha		Ufhira minwaha ya 5	

2.1.5. Ndi hectare nngana dzine vha dzishumisa u tavha zwimela izwo?

0.1 - 0.9 hectares		1-5 hectares		Fhiraho 5 hectares	

2.1.6 Ndi khalanwaha ifhio ine vha ishumisa u tavha zwimela izwo?

Tshifhefho		Vhuria		Lutavula		Tshilimo	

2.1.7. Ndi line hune vha kana zwimela izwo?

Tshifhefho		Vhuriha		Lutavula		Tshilimo	

2.1.8. Ndingani vha tshitavha izwo zwimela? ……………………………………………………

2.2. Ndeme ya zwa tevhekana

2.2.1. Vhaya engedza vhuvha ha zwimela musi vhono kana?

Ee		Hai	

2.2.2. Ndigai hune vha engedza vhuvha ha zwimela izwo?

U fhula		U tanzwa		U omisa	
U nanguludza nau paka		U vhea		Uzwi endedza	

2.2.3. Ndi ngani vha tshi engedza vhuvha ha zwimela? ………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.3. U vhulunga madi kha zwimela (legumous Nduhu and Nawa)

2.3.1. Ndi ngafhi hune vha wana hone madi u shumisa kha zwimela musi vhono kana? ……………………………………………………………………………………………………

………………………………………………………………………………………………………

2.3.2. Ayo madi aya lingana kha u a shumisa?

Ee		Hai	

2.3.3. Kha vha talutshedze ………………………………………………..

………………………………………………………………………………………………………

………………………………………………………………………………………………………

2.3.4. Ndi dzifhio khaedu dzine vha tangana nadzo malugana na madi musi vhono kana zwimela?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

2.3.5. Vha kona hani u shuma na idzi khaedu? …...

………………………………………………………………………………………………………

…...……………………………………………………………………………………………………

2.3.6. Khaedu dzine vhatangana nadzo malugana na madi, dzi vha nea vhukondi vhungafhani?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

……………………………………………………………………………………………………..

2.4. Zwipida zwa Nduhu na Nawa

2.4.1. Vhana vhashumi?

Ee		Hai	

2.4.2. Arali vhanavho, ndi vhashumi de?

Vhashumi vhe vha vhathola		Mashaka		Athina		Vhanwe nga nnda ha vhe vha tholiwa	

2.4.3. Arali hu vhanwe kha vha vhabule ……………………………………………………………

2.4.4. Ndi vhangana vhathu vhane vha thola? ……………………………………………………

2.4.5. Ndi ngafhi hune shumisesa musi vhono kana?

U fhula		U tanzwa		U omisa	
U paka & limagani li itaho		Uvhea		U endedza	

2.4.6. Khavha talutshedze phindulo kha 2.4.5 ……………..

……

……

………..………………………………………………………………………………………………

2.4.7. Ndi madi mangafhani and vha ishumisa kha zwipida zwa musi vhono kana?

Zwipida zwa musi vhono kana	Madi mangafhani kha izwo zwipida
U fhula	
U tanzwa	
U omisa	
U paka	
Kha u vhea	
U endedza	

2.4.8. Vha itani nga zwimela musi vhono kana legumous? ………………………………………

……

……

2.4.9. Muvhuso u khou itani malugana na uthusa ngaha vhukondi ha madi kha tshikimu? ……

……

……

……

……….

2.4.10. Tshikimu shone tshi khou itani malugana na u vhathusa kha vhukondiha madi? ……………………………………………………………………………………………………..

……
………

2.4.11. Vha humbula unga muvhuso unga itani u vhathusa malugana na madi?

……
………
………

2.4.12. Vhone vha vhona unga vhanga itani u thusa tshikimu kha thaidzo iyi?

……
……
……

2.4.13. Vha vhona unga hunga itiwa mini u khwinifhadza tshiimo tsha madi afho tshikimuni?

……
……
……

2.4.14. Ndi zwifhio zwiimiswa zwine vha vhona unga zwinga kwamiwa malugana na thaidzo iyi ya madi afho Tshikimuni? …………………………………………………………………………

……
………..

2.4.15. Uya nga phindulo ye vha inea afho nntha kha 2.4 5.14 vha vhona unga izwo zwiimiswa zwinga thusa hani tshikimu kha thaidzo iyi?

…………………………………………………………………………………......................................
……
………..

Ndo livhuwa

9.3. Consent form (English version)

FACULTY OF SCEINCE, ENGINEERING AND AGRICULURE

INSTITUTE FOR RURAL DEVELOPMENT

ASSESSING WATER USAGE IN POST-HARVEST HANDLING OF LEGUMINOUS CROPS AT LUVHADA IRRIGATION SCHEME, VHEMBE DISTRICT, LIMPOPO, SOUTH AFRICA

Dear Respondent,

My name is **Sibuyi W.** I am doing Masters in Rural Development at the University of Venda (UNIVEN). I am conducting a research on **assessing water usage in post-harvest handling of leguminous crops in Luvhada irrigation scheme, Vhembe district, Limpopo, South Africa**

The aim of the study is to assess water usage in post-harvest handling of leguminous crops in Luvhada irrigation scheme. This study is only for academic purposes and the respondents who will take part in this study will not be forced to participate, but will participate on voluntary basis and the information provided for, by the respondents will be treated with confidentiality and not be used for anything else other than for this study. Your identity and personal information will not be revealed to any other person.

This is to confirm that I [Name (optional)] ………………………………………………….. Have read through and understood the purpose of this questionnaire and I give my agreement to participate in the study.

Respondent signature ……………………………..… Date ……………………………………….

Cell no ……………………………….……………………………………………….………………......

Thanks for your cooperation

9.4. Vhurifhi ha thendelo (Venda version)

University of Venda
Creating Future Leaders

FACULTY OF SCEINCE, ENGINEERING AND AGRICULURE

INSTITUTE FOR RURAL DEVELOPMENT

ASSESSING WATER USAGE IN POST-HARVEST HANDLING OF LEGUMINOUS CROPS AT LUVHADA IRRIGATION SCHEME, VHEMBE DISTRICT, LIMPOPO, SOUTH AFRICA

Aa/Ndaa,

Dzina langa ndi pfi **Sibuyi W.** Ndi mutshudeni wa University ya Venda (UNIVEN) ndi khou gudela Masters ya Rural Development. Ndi khou ita thodisiso (Research) fhasi ha thoho ine ya pfi **assessing water usage in post-harvest handling of leguminous crops in Luvhada irrigation scheme, Vhembe district, Limpopo, South Africa**

Tshipikwa tsha thodisiso iyi ndiu sedzulusa kushumisele kwa madi kha zwimela musi zwono kaniwa. Thodisiso iyi ndi tshipida tsha ngudo dzanga, nahone vhavhudziswa vhane vhadovha tshipida tsha thodisiso iyi avhanga kombetshedziwi udzhenelela. Zwidodombedzwa zwa vhane vhado dzhenelela zwido tsireledziwa nahone azwinga do shumisiwa hunwe fhethu nga nnda ha kha thodisiso iyi.

Hezwi zwi khou khwathisedza uri nne [Dzina]... Ndo vhala nahone ndo pfesesa tshipikwa tsha dzi mbudziso idzi nahone ndi khou tenda uvha tshipida tsha iyi thodisiso.

Tsaino ………………………………..……… Datumu…………………………………………………

Nomboro dza Lutingo ……………………………………………………………………………………………….................

Ndo livhuwa

9.5. Checklist for telephonically data collection

1.Questionnaire	
2. Consent form	
3. Pens	
4. Phone	
5. Airtime	
6. Contact details of despondence	
7. Tape recorder	

9.6. Ethical clearance certificate

ETHICS APPROVAL CERTIFICATE

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms W Sibuyi

STUDENT NO:
16013556

PROJECT TITLE: **Assessing water usage in post-harvest handling of leguminous crops at Luvhada irrigation scheme.**

ETHICAL CLEARENCE NO: FSEA/21/IRD/16/2911

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr M Manjoro- Mwale	University of Venda	Supervisor
Dr S. Kativhu	University of Venda	Co-Supervisor
Dr B. Muchara	University of Venda	Co-Supervisor
Ms W Sibuyi	University of Venda	Investigator – Student

Type: Masters Research
Risk: Minimal risk to humans, animals or environment (Category 2)
Approval Period: November 2021 – November 2023

The Animal, Environmental and Biosafety Research Ethics Committee (AEBREC) hereby approves your project as indicated above.

General Conditions
While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following.

- The project leader (principal investigator) must report in the prescribed format to the REC:
  - Annually (or as otherwise requested) on the progress of the project, and upon completion of the project
  - Within 48hrs in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
  - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the REC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the REC and new approval received before or on the expiry date.
- In the interest of ethical responsibility, the REC retains the right to:
  - Request access to any information or data at any time during the course or after completion of the project.
  - To ask further questions, Seek additional information, Require further modification or monitor the conduct of your research or the informed consent process.
  - withdraw or postpone approval if:
  - Any unethical principles or practices of the project are revealed or suspected.
  - It becomes apparent that any relevant information was withheld from the REC or that information has been false or misrepresented.
  - The required annual report and reporting of adverse events was not done timely and accurately.
  - New institutional rules, national legislation or international conventions deem it necessary.

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE
Date Considered: October 2021

Name of the AEBREC Chairperson of the Committee: Prof Irene Bamhoorn

Signature: ______________

UNIVERSITY OF VENDA
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RESEARCH AND INNOVATION
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Thohoyandou 0950