University of Venda

Small-Scale Farmers' Perceptions on Sustainable Agriculture: The Case of Vhembe District Municipality, Limpopo Province, South Africa

By

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Declaration

I, **Unarine Mudau**, declare that the entitled **"Small-Scale Farmers' Perceptions on Sustainable Agriculture: The Case of Vhembe District Municipality, Limpopo Province, South Africa"** is my original work and has not been submitted for any degree at any other university or institution. The project does not contain other persons' writing unless specifically acknowledged and referenced accordingly.

Signed (Student): .... Date: 14 May 2022

Supervisor's signature: Date: 17 May 2022

Co-Supervisor's signature: Date: 17 May 2022

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Abstract

This study deals with different perceptions that the small-scale farmers of Vhembe District Municipality have towards the practice and adoption of sustainable agricultural practices. Farmers' perceptions towards sustainable food production are crucial in achieving 'zero hunger' for the growing world's population. Therefore, the investigation is concerned with the farmers' understanding of sustainable agricultural practices and the sustainable agricultural practices that have been adopted to date among the small-scale farmers of Vhembe District Municipality. To achieve this, field observations were conducted and about 25% of the population (plot holders and extension officers) were interviewed from each of the four irrigation schemes, namely, Dzindi, Folovhodwe, Rabali, and Makuleke. Stratified sampling was used to select the sample since there was a variation within the population in terms of their responsibilities within the irrigation scheme. Simple random sampling was carried out to select farmers or plot holders who were interviewed. Extension officers were not randomly selected, but they were all interviewed because each scheme had one officer. In total, 95 individuals were interviewed, of which 91 were plot holders, and four were extension officers. Both quantitative and qualitative research approach were used to analyse data. Chi-square analyses were performed to assess differences across the four irrigation schemes. Qualitative data from field observation and open-ended questions were manually coded using a pen and paper. Coding involved the derivation of meaning from raw data, give the data labels and classify the data according to their labels. The results showed that most farmers do not know what sustainable agriculture is and tend to ignore it. In general, farmers practiced unsustainable agriculture and they were not concerned about their inappropriate farming practices (e.g. farming close to water bodies, excessive use of synthetic fertilizer and pesticides). Furthermore, farmers and extension officers reported that they could not advocate for sustainable environmental practices as they are not environmental officers. The transdisciplinary approach that involves environmentalists, hydrologists, and farmers should be implemented to emphasize the importance of conserving the natural environment while still making profit.

Keywords: Conservation agriculture, organic agriculture, extension officers, sustainability, socio-economic benefits.

Chapter 1: Introduction

1.1. Background

Approximately 821 million people worldwide are unnourished (FAO, 2017). About, 98% of this unnourished people are located in developing countries, with approximately 520, 243 recorded cases and over 43 million people in Latin America, Asia and Africa are starving, respectively (FAO, 2017). As the population grows, consumption worldwide also grows. Therefore, fuel and food demand increases. Furthermore, diets are changing in the developing countries, and people are putting more demand on natural resources by eating more dairy and meat (Godfray et al., 2010; Seufert et al., 2012).

Food security for the estimated 9-10 billion people by 2050 is a big concern (Godfray et al., 2010). From around 3 billion people in 1960 to 6.8 billion people in 2010, the human population has increased dramatically. Increased income and dietry changes were followed by major agricultural and animal production intensifications (Foresight, 2011). If the estimated population of 9 billion by 2050 is to be maintained, the same rate of growth will be required.

In the past, food increase was met through the expansion of agriculture into natural ecosystems such as forest, grassland and savanna as well as agricultural intensification. According to Bruinsma (2003), the expansion of agriculture into natural ecosystems has contributed significantly to the loss of biodiversity and ecosystem services such as freshwater supply, habitat for biota, air and soil quality maintanance, disease control, and crop pollination. As a result, it has been proposed that future food supply intensifications be done without increasing cultivating area, for example, to get more agricultural yield from the same amount of land (Godfray et al., 2010; Smith et al., 2010). The historical paradigm of agricultural intensification, with greater mineral fertiliser inputs, modified crops, chemical pesticides, and tractors for ploughing, cannot be repeated in the future (Smith, 2013).

Since the future production of food must be done sustainably, sustainable agriculture through the process of sustainable intensification is proposed to be the solution for combating food insecurity challenges. Sustainable agriculture, also known as agroecology, is a method of farming that takes into account the ecological, economic, and social aspects of the food chain. As a result, it is viewed as a system that eliminates food poverty and malnutrition for all people, while also taking into account the economic, social, and environmental foundations of such systems for future generations (Pouw et al., 2019). Natural processes are used in sustainable agriculture to achieve biological interactions between the many constituents of agricultural systems (de Schutter, 2010). The goal of sustainable agriculture (Cândido et al., 2015) is to give an alternative to conventional agricultural techniques while also promoting ecologically sustainable agriculture.

Several studies reported that small-scale farmers in unindustrialised countries play a significant role in alleviating hunger (Altieri, 2009; Tscharntke et al., 2012; Azadi et al., 2015). Concerning small-scale farmers, the word “small” can refer to various aspects such as the total of money used to start up the whole farming process, the size of the land and the quantity of employees within the farm (Jouzi et al., 2017). The Food and Agriculture Organization (FAO) (2008) defines small-scale farming as an agricultural practice performed on an agricultural land smaller than 2 ha. Even though small-scale farms are crucial in developing regions, we still find the majority of people in the world who experience food insecurity located in underdeveloped countries (FAO, 2017). As indicated by the American Society for Nutritional Sciences (2001), food insecurity is defined as a lack of nutritious and satisfying food options or an inability to have these food alternatives. Around half of the world's hungry people are thought to live on small farms (Garduno-Diaz and Garduno-Diaz, 2015).

Land, water, and capacity constraints have hindered food production in a number of countries. Furthermore, due to the unfavourable socio-economic situations that small-scale farmers experience, have a tendency to engage in unsustainable farming techniques, leading to more environmental degradation (Jouziet et al., 2017). To combat global food insecurity, there is a need for researchers to make further investigations on the adoption of sustainable agricultural practices on small-scale farmers in developing countries to find a solution to a problem.

1.2. Problem statement

Several studies on Vhembe irrigation schemes in Limpopo Province of South Africa stress adopting improved agricultural practices (advanced technology) (Odhiambo and Magandini, 2008; Randela et al., 2008; Oni et al., 2011; Berg, 2013; Chauke et al., 2013). The studies recommend for the government to provide credits and grant subsidies for improved agriculture. The credits and subsidies requirement could be reduced if the farmers can fully opt for sustainable practices. There is an insufficient focus on sustainable agricultural practices in Vhembe irrigation schemes. Studies focus mostly on improving agricultural production by promoting the use of high agricultural inputs that contribute to environmental degradation. This supports the statement by Gaffeney et al. (2019) that African countries do not practice organic agriculture by choice, but simply because they do not afford the external inputs, hence their organic agriculture practices with poor yield cannot be regarded as being sustainable.

1.3. Hypothesis

Small-scale farmers in Vhembe District Municipality do not have a good perception of sustainable agriculture and are not practising it.

1.4. Aim

The aim of this study is to investigate the knowledge and the perception of sustainable agricultural practices and their adoption among small-scale farmers.

1.5. Objectives

- To investigate the small-scale farmers' understanding of sustainable agricultural practices.
- To investigate the sustainable agricultural practices that have been adopted to date.

1.6. Research questions

- What is the perception of small-scale farmers towards sustainable agricultural practices?
- What is the impact of small-scale farming on the farmers' socio-economic status?
- Do extension officers transfer sustainable agriculture knowledge to farmers?

1.7. Significance of the study

This study intends to help provide information on whether the small-scale farmers are practising or have a positive attitude towards sustainable agriculture. It will also be useful to inform researchers and extension officers on how best they can assist small-scale farmers in adopting and effectively implementing sustainable agricultural practices. The study will also help the government invest resources geared towards promoting effective implementation of sustainable agriculture.

Chapter 2: Literature review

2.1. Introduction

Sustainable agriculture in literature started back in the 1920s, but known as agroecology (Wezel and Soldat, 2009). According to Mockshel (2018) the term was initially used to refer to a scientific discipline whereby ecology was applied in agriculture. Agroecology has then promoted or vigorously encouraged as the science of sustainable agriculture after the concept of sustainability gained recognition after the Earth Summit in Rio de Janeiro held in 1992 (Altieri, 1995 in Mockshel et al., 2018). Agroecology is a scientific subject that applies ecological perceptions and principles to the design and management of sustainable food systems (Francis et al., 2003; Altieri and Nicholls, 2005; Gliessman, 2016). Because agroecology is primarily based on farmers' processes and traditional knowledge, most agroecology techniques existed before the concept of agroecology was formed (Mockshel et al., 2018). Sustainable agriculture has two main practices, namely, conservation agriculture and organic agriculture.

2.2. Sustainable agricultural practices

Conservation agriculture

Conservation agriculture (CA) is the result of the slow transformation of conservation tillage (CT), a practice that was introduced to reduce wind erosion (Chauhan et al., 2012; Mockshel et al., 2018). The CA was adoptd by the FAO and the European Conservation Agriculture Federation's inaugural World Congress on Conservation Agriculture, held in Madrid in 2001. CA systems are also known as zero-tillage farming systems or no-till farming systems. This simply entails producing crops from year to year without causing soil degradation through plowing (Kassam et al., 2009). Planting crop seeds directly on untilled land, mulching, and crop rotation are all part of the no-tillage method. The CA is a method that promotes agricultural production that is low on resources. It aims to achieve satisfying earnings through high and consistent production levels while also ensuring food security without causing environmental damage (Kassam et al., 2009; FAO, 2016). The

CA is intended to be a holistic approach to farming that takes into account numerous interactions among homes, crops, and livestock in order to create a long-term agricultural system (Hobbs et al., 2008). Although there is no global definition of CA since definitions differ by country or location, they always adhere to the three conservation agriculture principles of minimal soil disturbance, permanent soil cover, and crop rotation (Anderssona & D'Souza, 2013).The goals of conservation agriculture are defined by the FAO as:

> Conservation agriculture attempts to protect, enhance, and make more effective use of natural resources by combining integrated soil, water, and biological resource management with external inputs. It helps to protect the environment while also enhancing and sustaining agricultural productivity. It's also known as resource-effective or resource-efficient agriculture (Hobbs et al., 2007; Kassam et al., 2009; Palm et al., 2014). External inputs such as agrochemicals and mineral or organic matter nutrients are applied at an optimal level and in a method and amount that does not interfere with or disrupt biological processes, and mechanical soil-disturbing tillage is minimized to an absolute minimum (Kassam et al., 2009).

The CA adheres to three principles that complement each other in defining the characteristics of conservation agriculture. The three major factors are: minimum soil disturbance from mechanical tillage, intercropping, and preservation of a persistent organic soil layer (e.g., crop residues). This might be a living or dead crop. Its purpose is to shield the soil from the sun, rain, and wind while also feeding the soil biota (micro-organisms and fauna). Tillage and soil nutrient balance are taken up by soil microorganisms and fauna. Crop species diversity through crop rotations is the last factor. This is crucial to prevent infections and pest problems (FAO, 2008; Kassam et al., 2009; Chauhan et al., 2012; Anderssona and D'Souzab, 2014; Tambo and Mockshell, 2018). Conservation agriculture, unlike organic agriculture, does not prohibit the use of artificial fertilizers, genetically modified crops, or chemical pesticides, but it does so with caution.

Organic Agriculture

Organic agriculture is a production technique that promotes and enhances the health of agroecosystems, including biodiversity and soil nutrient cycling (FAO, 2016). External agricultural inputs such as chemical fertilizers, pesticides, and genetically engineered crops are forbidden in organic crop cultivation. Essentially, organic agriculture is based on universally accepted criteria (Luttikholt, 2007; Mockshel et al., 2018). Although the requirements may differ from country to country, they are always based on the International Federation of Organic Agriculture Movements (IFOAMs) guidelines (Luttikholt, 2007; Meemken and Qaim, 2018).

Luttikholt (2007) stated the four ideologies of organic agriculture are formulated by the International Federation of Organic Agriculture Movements as:

1 Health Principle: Natural agribusiness should to maintain and upgrade the wellbeing of living organisms, human beings, and the physical environment. This rule stresses that the wellbeing of people, plants and animals cannot be isolated from the well being of their natural environment. Meaning, healthy soil will give incredible crops.

2 Ecological principle: Natural agribusiness ought to be based on living environmental frameworks and cycles, work with them, imitate them and offer them assistance support. It accentuates that generation of food is to be grounded on environmental process.

3 Fairness principle: Organic agriculture should be based on partnerships that provide equity in terms of the shared environment and life possibilities." Fairness, respect, and concern for the common good characterize justice, both among humans and in their interactions with other living species.

4 Care Principle: Organic agriculture should be managed with prudence and responsibility to safeguard present and future generations' health and well-being, as well as the environment. Organic agriculture practitioners can boost production

and proficiency, but this should not come at the expense of the environment's health and well-being.

These principles are used together and are made up of moral principles to motivate action (Luttikholt, 2007).

Organic agriculture is defined by the use of agroecological rules or principles. It's also possible to think of it as an agroecological intensification system that limits the usage of external agricultural inputs (Mockshel et al., 2018). Although the ecological benefits of organic agriculture in terms of the provision and preservation of ecological services are well established (Sandhu et al., 2010), organic agriculture yields are lower than conventional agriculture yields (Mockshel et al., 2018). This has sparked a debate about organic agriculture's potential to achieve global food security without increasing agricultural area (Meemken and Qaim, 2018; Gaffeney et al., 2019).

2.3 Factors that influence the adoption of sustainable agriculture in small-scale farmers

Sustainability has long been acknowledged as a means of adaptation (Holling, 2001), with three key aspects: economic, environmental, and social (Lyson, 2002). Developing agricultural production systems that are flexible and address each of these characteristics necessitates thorough examination of the variables that influence the creation and execution of effective production techniques (Sassenrath et al., 2010; Hosseini et al., 2011).

2.3.1 Economic

Government policies (price and income supports), technology, a steadily consolidated market structure, and changeable consumer demand are all examples of economic factors that work both inside and outside the farm (Halloran and Archer, 2008). Economic drivers are also one of the most prominent factors that manufacturers consider when making decisions. For producers, economic problems encompass obtaining the money to start production, reducing risk, selling the products and total revenue (Sassenrath et al., 2010). (Sassenrath et al., 2010). Sassenrath et al. (2010), for example, interviewed producers in the Northeast and Southeast of the United States who recognized the need to diversify output in order to mitigate risk. Crops, livestock, and other enterprises were all diverse in all of the study's production systems. Producers from all production systems cited the necessity to make a reasonable livelihood for their family as the primary motivation for participating in agricultural product diversification (Sassenrath et al., 2010).

2.3.2 Environmental

Natural resources such as soil and water, the impact of production on the environment, and the impact of the environment on production through climate, pests, or invasive species are all environmental variables that affect the adoption of specific agricultural methods (Hendrickson et al., 2008). The interaction between soils, landscape, and climate impact the sorts of crops produced in a region and optimal management approaches (Padbury et al., 2002). In Maine, for example, Sassenrath et al. (2010) found that harsh conditions like extremely cold temperatures and a short growing season are limiting factors for crop production. This necessitated the employment of alternate methods to lengthen the growing season, such as hoop buildings and barns. The additional cost of changing environmental conditions to the production system hindered the capacity of producers with insufficient capital to extend their operations.

2.3.3 Social

Consumers’s attitudes and social values are some of the social factors affecting farmer’s decision on whether to adopt a particular farming practice or not. Farmers' decisions on whether or not to adopt a particular farming practice are influenced by a variety of social factors, including consumer attitudes and social values. These social elements (customer attitudes and societal values) affect policies as they are incorporated into regulations such as those aimed at reducing the environmental effect of manufacturing processes (Sassenrath et al., 2010). Farming and extension/educational factors could also explain the social aspect of sustainable agriculture (Hossein et al., 2010). Famers cannot adopt technologies and strategies they do not know how they operate. This emphasizes the need for educational support to the farmers to enhance the adoption of a particular farming strategy (Oni et al., 2011). Age is also a social factor that influences the adoption of the new farming strategy. Oni et al. (2011) reported that young farmers are the ones who are more likely to adopt the new or advanced farming practices as compared to the old age farmers.

Land ownership falls among factors that influence the adoption of sustainable agriculture. In cases where farmers are renting the land, about half of all tenants who show interest in sustainable agriculture have concerns about discussing such a management strategy with their landlord (s) for fear of potentially jeopardizing their status as tenants (Carolan, 2005). In other words, there is a practice of self-censorship among certain tenants by their unwillingness to bring upon the subject of ‘‘sustainable agriculture’’ with their landlords. This unwillingness to discuss alternative farm management strategies for fear of losing one’s lease may also indicate a lack of trust between the two parties (or, more specifically, indicate a lack of trust by the tenants toward their landlords) (Carolan, 2005).

2.4 Benefits of sustainable agriculture adoption to sustainable food systems

2.4.1 Improved soil health

When the three principles of CA are adhered to, there is an improvement in soil quality (fertility and health) and crop yields with a decrease in input costs (Palm et al., 2013). The same applies to organic agriculture when all four principles of organic agriculture are followed, directly or indirectly. They enhance the quality of both the soil's physical, chemical, and biological characteristics (Luttikholt, 2007). The CA principle of retaining crop remains on the soil surface (permanent soil cover) in combination with the two other CA principles is planned to increase organic inputs and enhance ecological benefits such as soil nutrients, enhanced soil and water retention, and improve biodiversity (Palm et al., 2013). Interestingly, the consistent application of the CA principles can sustain higher soil quality by reprocessing nutrients and improved crop produce more than conventional practices (Ngwira et al., 2013).

When households consistently apply the principles of minimum soil disturbance and permanent soil cover with crop remains or leaves, there is a chance to minimize soil erosion and improve soil fertility in their agricultural fields which would result in higher crop produces (Naab et al., 2017). Nutrient cycling, as emphasized by principle number two of organic agriculture, plays a vital role in soil health improvement (Luttikholt, 2007). In CA, improved soil health due to nutrient cycling is attained through crop rotation or intercropping (Naab et al., 2017). Besides, a higher biological diversity in organic agriculture and CA fields contributes to improved soil health (Tscharntke et al., 2012; Mockshell et al., 2018; Nyanga et al., 2020). However, it must also be taken into consideration that there are differences in situations where CA is fully practised compared to when CA is partially practised. In this case, the benefits of CA may not be fully recognised in situations where smallholders partially adopt CA (Tambo and Mockshell, 2018; Nyanga et al., 2020).

2.4.2 Economic benefits

Increased food production through conventional agricultural intensification is geared toward high-input agriculture, whereas low-input agriculture practiced by the poor is heavily reliant on biodiversity and related ecological processes (e.g., valuable trophic interactions, soil food webs, and crop genotypes that thrive in harsh environmental conditions) (Jackson et al., 2007). Furthermore, it is well acknowledged that small farms with a high diversity of crops generate more agriculture per plot than vast monocultures. The 'paradox of scale' or the 'inverse farm size-productivity connection' is a term used to describe this occurrence (Halweil, 2006; Barrett et al., 2010; de Schutter, 2011; Horlings and Marsden, 2011).

Fertilizers and pesticites from conventional intensified agricultural fieldscontaminate different spheres of environment and affect human health (Dutcher, 2007; Gibbs et al., 2009; Geiger et al., 2010; Meehan et al., 2011). Sutton et al. (2011) observed the environmental costs of all nitrogen losses in Europe to be estimated at €70– €320 billion per year, which is more than the direct profit resulting from the use of nitrogen in agriculture. These high societal costs are due to losses in air quality, water quality and particularly human health triggered by conventional agriculture (Tscharntke et al., 2012).

In this case, agroecological intensification, which involves conservation agricultural practice and organic agriculture can play an important role. For example, agroecological intensification can involve the replacement of chemical fertilizer by nitrogen fixing plants and switching pesticides by bio control for pests, e.g., using predators (Pretty, 2008; Silici, 2014). This can reduce the environmental costs (economic loss) that results when conventional agriculture is practised (Tscharntke et al., 2012).

Implementing agroecological values in agriculture, i.e. eco-efficient and environmentally friendly farm management with a focus on more varied cropping systems (Letourneau et al., 2011; Ratnadass et al., 2012), can significantly advance production and contribute to closing yield gaps (Foley et al., 2011; Mockshel et al., 2018) and encouraging agroecosystem resilience (Tscharntke et al., 2011). This will not only help the region's economy, but it will also improve food supply and lower food prices.

2.4.3 Food variety and poverty reduction benefits

Climate change may affect the production of specific foods, feeds, fibers, and fuels in different parts of the world (Wheeler and von Braun, 2013). This move will have an impact on family finances, food availability, and diet variety. Sustainable agricultural intensification strategies can help mitigate this effect by increasing agricultural production. Farmers that embrace sustainable agricultural techniques might expect harvest increases of 50 percent to 100 percent, according to Altieri and Toledo (2011). Better-quality crops may help farmers earn more money, reduce poverty, and assure food and nutrition security (Mockshell et al., 2018).

Through the adoption of crop-livestock integration (such as rice and fish integration) and the adoption of nitrogen fixing plant (legume) and maize intercropping, creates an opotunity for farmers to yield diversified production and to have multiple sources of income (Mockshell et al., 2018; Nyanga et al., 2020). These techniques not only help farmers diversify their income and cope with adversity, but they also improve their access to a diverse and healthy food (Nyanga et al., 2020). Farmers may be able to boost their gross margins by using agroecological systems, such as organic agriculture, especially if they do not utilize external inputs or adopt sustainable agricultural practices (Tscharntke et al., 2012; Mockshell et al., 2018). For example, Adamtey et al. (2016) found that high-input organic agriculture in Kenya had higher projected profit margins than the high-input conventional system. The market premium for certified organic items contributed significantly to the strong gross margins (Mockshell et al., 2018).

2.5 The scale of sustainable agriculture adoption in small-scale farms

The topic of whether or not to embrace sustainable agriculture was highlighted by the environmental devastation caused by traditional agriculture. By conserving and increasing the natural resource base and ecosystem services, the CA has been used as a sustainable food production system (Palm et al., 2013). Despite its rapid acceptance in Australia, the United States, and South America over the last three decades, CA uptake in undeveloped or poor nations in Sub-Saharan Africa has been gradual (Gaffeney et al., 2019; Nyanga et al., 2020). Yet it is among African small-scale farmers, sustainable agriculture, particularly CA, could enhance ecosystem services, improve farm productivity, and resolve food insecurity issues. In sub-Saharan Africa, Tambo and Mockshell (2018) found the average level of adoption of conservation agricultural practices. Amongst the household surveyed in Ethiopia, Ghana, Kenya, Malawi, Mozambique, Nigeria Tanzania, Uganda, and Zambia, 80% of these households' farmers have adopted at least one of the conservation agricultural practices, while only 8% of the households practice pure conservation agriculture. This results in low agricultural productivity since CA gives positive effects when it is adopted fully (Tambo and Mockshell, 2018; Nyanga et al., 2020). Crop productivity among small-scale African farmers is currently the lowest in the world. This is because their unsustainable organic agriculture that is their traditional agricultural practices have diminished soil productivity due to a lack of nutrients and are unable to naturally sustain crop productivity (Naab et al., 2017; Gaffeney et al., 2019; Nyanga et al., 2020).

2.6 Conclusion

The literature has has shown the full benefits of practising sustainable agriculture. Due to its desirable environmental, economic and social benefits, sustainable agriculture has a greater potential of achieving sustainable development goals when compared to the traditional and conventional systems of farming. Although sustainable agriculture adoption in small-scale farms of the developing countries, generally, is lower, alleviating hunger and boosting the local economy with minimal negative effects to the natural environment can still be achieved if small-scale farmers are given the necessary support to be able to adopt the sustainable system of farming.

Chapter 3: Materials and methods

3.1. Description of the study area

The study was carried out in four irrigation schemes found in the Vhembe District Municipality of Limpopo Province in South Africa (Figure 3.1). The district is located futher north of the Limpopo Province. The district has four local municipalities, namely Makhado, Musina, Thulamela and Collins Chabane (Figure 3.1). Vhembe district spread over an area of 21 407 km^2. Vhembe District is predominantly rural, with semi-arid conditions (Chauke et al., 2013). Small-scale farmers of Vhembe district practice farming in relatively small farming plots of about 1.5 ha (Chauke et al., 2013).

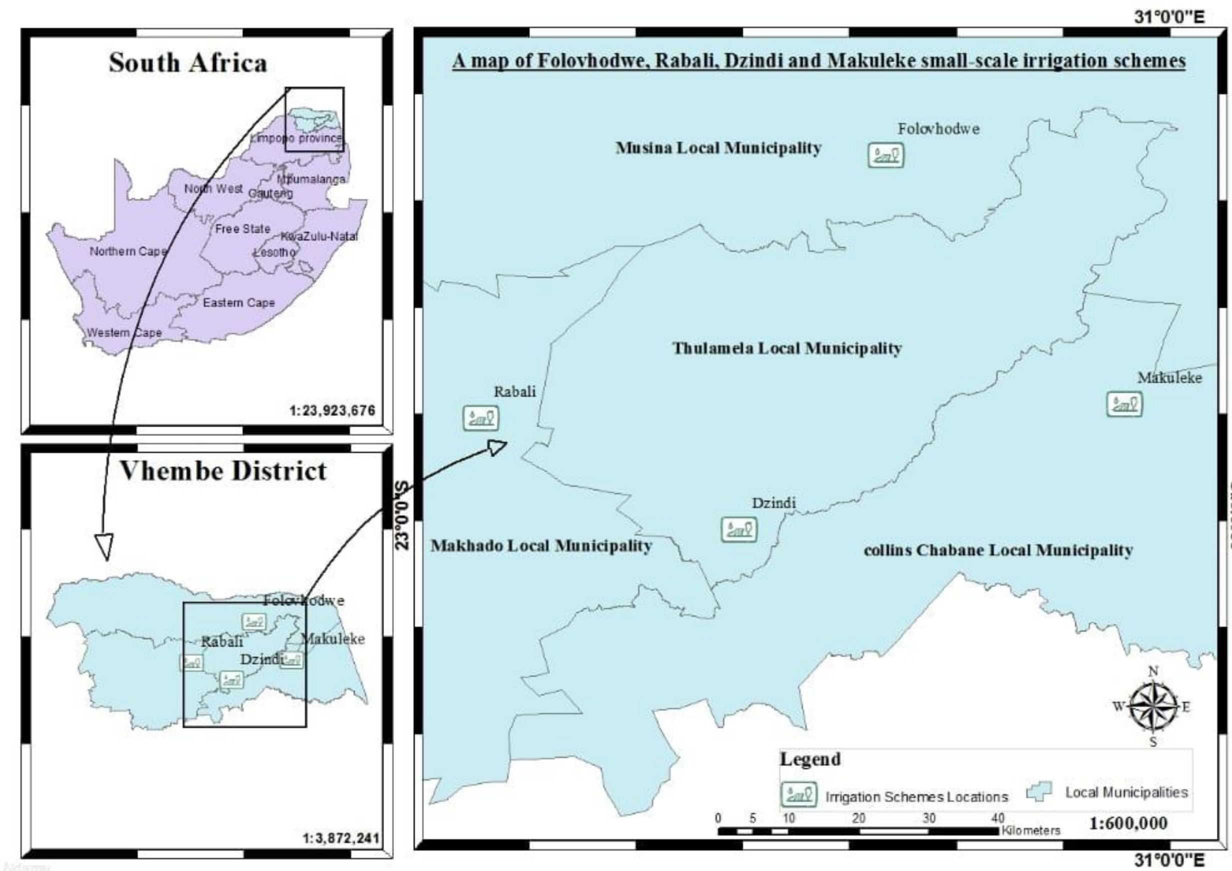

Figure 3 1. Study area map depicting the four study areas, namely, Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) Irrigation Schemes.

3.2. Research design

To achieve the study's aim, and its objectives and research questions, both qualitative and quantitative techniques were used. The qualitative technique allows the study to be conducted in a natural setting, interpreting the phenomena in terms of the views that the respondent gives to the researcher (Alawi, 2014). The method is very useful in obtaining detailed descriptions of complex phenomena (Alawi, 2014).

3.3. Sampling of the population

The population of the study included all extension officers and farmers (plot holders) of irrigation schemes found in all local municipalities (Thulamela, Makhado, Musina and Collins Chabane) of the Vhembe District Municipality. Within each local municipality, one irrigation scheme per municipality was surveyed. Approximately 25% of the people in each irrigation scheme were interviewed and they were selected using a stratified sampling strategy. Since there is a variation within the population in terms of their responsibilities (extension officers are advisors while farmers do the actual farming) within the irrigation scheme, stratified sampling ensured that every stratum is adequately represented. Simple random sampling was carried out to select plot holders. Plot holders were allowed to pick the small pieces of paper from the box which were written "interview" or "no interview". Individuals who picked a piece of paper written "interview" formed part of the sample that was interviewed. Extension officers did not pick pieces of papers, but they were all interviewed because each scheme had one officer.The total number of individuals interviewed was 95 and from this, 91 were plot holders, and four were extension officers. Interview was conducted using two local languages, that is Tshivenda for the Venda speaking people and Xitsonga for the Tsonga people.

3.4. Sampling procedure regarding COVID-19 Regulations

Since we were facing a global pandemic, COVID-19, all precautionary measures ordered by the South African government to limit the spread of the virus were adhered to during the process of data collection. The researcher provided hand sanitisers and face masks for every individual participating in the data collection process. When choosing a sample, ten respondents at a time were sanitised and queued at the interval of two meters from each other as they waited to pick up small pieces of paper from the box. Face-to-face interview was conducted while the researcher and the respondent were at a distance of two metres away from each other and with their face masks on. To minimise contact, the researcher filled in the names of the respondents in the consent form, then respondents only put in their signatures in the consent form.

3.5. Methods

3.5.1. Field observation

The researcher visited the selected irrigation schemes and observed the setting or the design and management strategies of the farms to see whether they were sustainable. The observation was based on the three aspects of sustainability which are: environmental, economic and social. In other words, the observation was based on whether the irrigation schemes boost the local economy by providing jobs and increasing household income for farmers and the local people. The presence of sustainable practices and strategies within the irrigation schemes were observed based on the agricultural practices list developed by Kassam et al. (2009) and Mockshell et al. (2018). The practices include:

- Mulching to enhance soil nutrients and to reduce soil moisture , intercropping, crop rotations.
- Soil and water management.
- Integrated pest management and biological control strategies, and cautious use of pesticides.
- Use of carbon-based inputs and well-adjusted and more effective use of fertilizers.

3.5.2. Interview method of data collection

Face-to-face interviews with the extension officers and farmers (plot holders) of the irrigation schemes were conducted. The interview questions were open-ended semi-structured questions, allowing the researcher to alter the interview questions' wording and order (see appendix 1 for interview questions). The questions were designed to get the perceptions of the targeted population towards their knowledge of and adoption of sustainable agriculture.

3.6. Data analysis

Data were quantitatively analysed using Microsoft Excel. The quantifiable data from the interview questionnaire (e.g. demographic data) were entered in excel. Data was then represented in frequencies and percentages that were then presented in the form of graphs. Chi-square analyses were performed to assess the different levels of perceptions on sustainable agriculture across schemes. The Bonferroni corrections were used to separate irrigation schemes with significant differences. The analyses were performed in MicroSoft Excel 2020. Data from field observation and interview respondents were analysed qualitatively. Data were manually coded using a pen and paper. Manual coding involves the derivation of meaning from raw data, giving data labels and classify the data according to their labels (Blair, 2015). After reading and making some notes and comments, data were coded to categorize data to facilitate analysis. Example of coding that was conducted: Responses to open-ended questions were coded under similar answers with coding 1 for "affirmative response" and 0 for "no answer/response". The interpretation was done by looking at the codes, summaries and notes.

3.7. Research ethics

The research project interview questions were approved by the University of Venda's Research Ethics Committee (Ethical clearance number: SES/20/ERM/16/2701). The data will be kept confidentially and the respondents were anonymised. The study was strictly voluntary, and no incentives were given to the respondents. The researcher respected the dignity and worth of all people involved in this research by being aware of their age, gender, education, beliefs, cultural or language background, disability or social-economic status. Respondents were informed when conducting the interviews that the information they gave the researcher will be used for the purpose of the study, and get appropriate permission to use the information that was gathered from the respondents. I ensured that the work I produced is my own by summarizing and writing information in my own words.

Chapter 4: Results

4.1 Demographic results

4.1.1 Gender and age

The overall number of male farmers interviewed was lower (32.97%) than those of females (67.03%). Dzindi was the only scheme with the highest percentage of male farmers (69.23%) (Figure 4.1). The schemes were populated mostly by pensioners (aged 60 and above; 51.65%) and very few farmers who were younger than 40 years of age (7.69%) (Figure 4.2). Makuleke had the highest percentages (75%) of farmers above 60 years. The scheme that had a small percentage of farmers aged 60 years and above was Rabali with 35.29% (Figure 4.2).

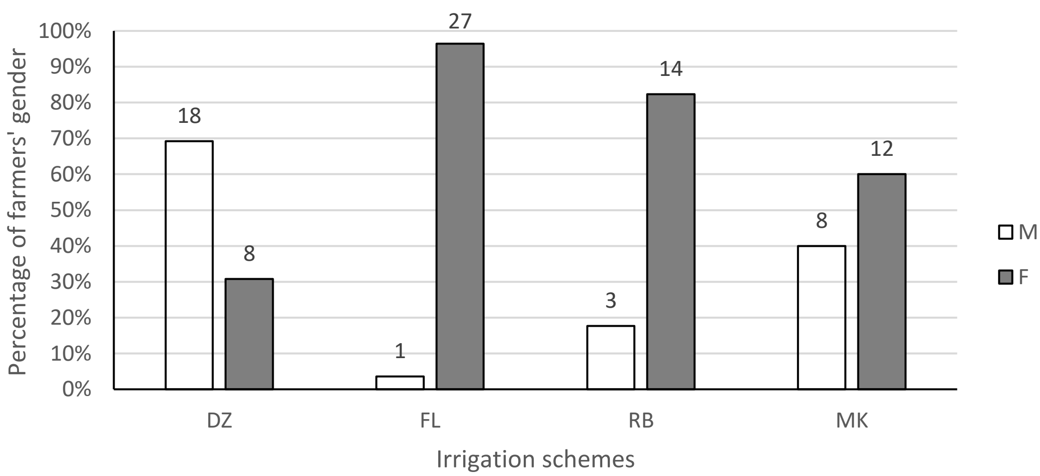

Figure 4. 1. Farmers' gender across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes. M = Male and F = Female.

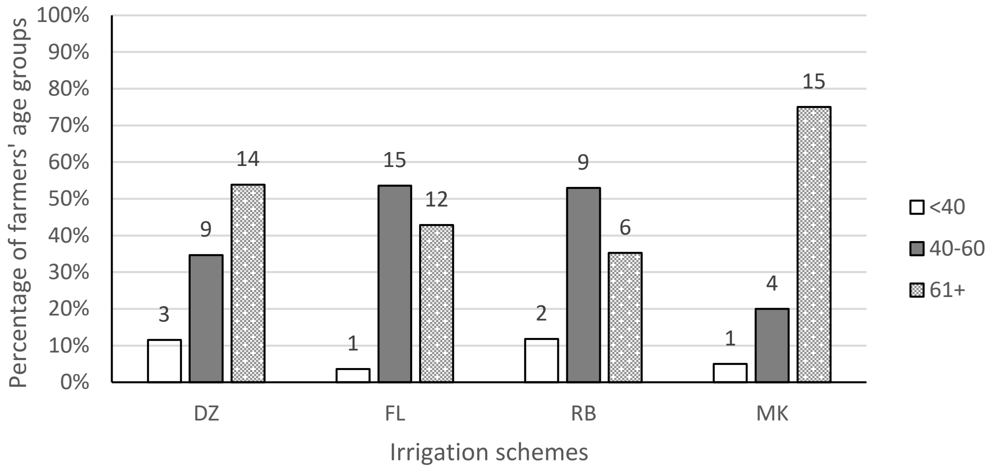

Figure 4. 2. Farmers' age across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.1.2. Educational levels

Primary and secondary education levels were the most common levels that most farmers obtained. Makuleke had the highest percentage (30%) of farmers who had no formal education. Dzindi and Rabali were the only two schemes with farmers who obtained tertiary education at 15.38% and 17.65%, respectively (Figure 4.3).

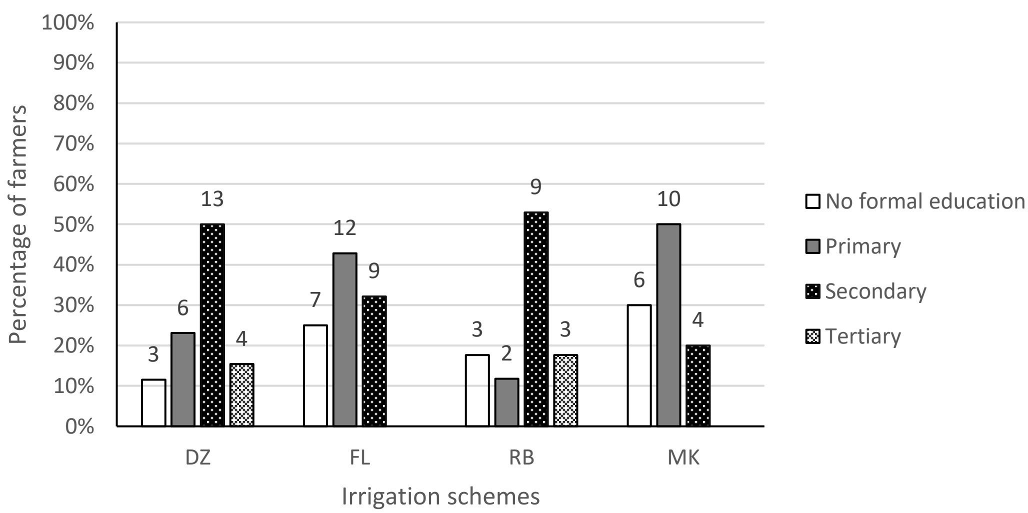

Figure 4. 3. Educational Levels that farmers in Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) obtained.

4.1.3 Number of days spent at the farm

All farmers in Rabali (100%), 92.31% in Dzindi and 89.29% in Folovhodwe spent 5-7 days a week in the field (Figure 4.4). Makuleke had the highest percentage of farmers (60%) who spent 3-4 days a week in the field and it was the only scheme with farmers (5%) who spent 1-2 days a week in the field (Figure 4.4).

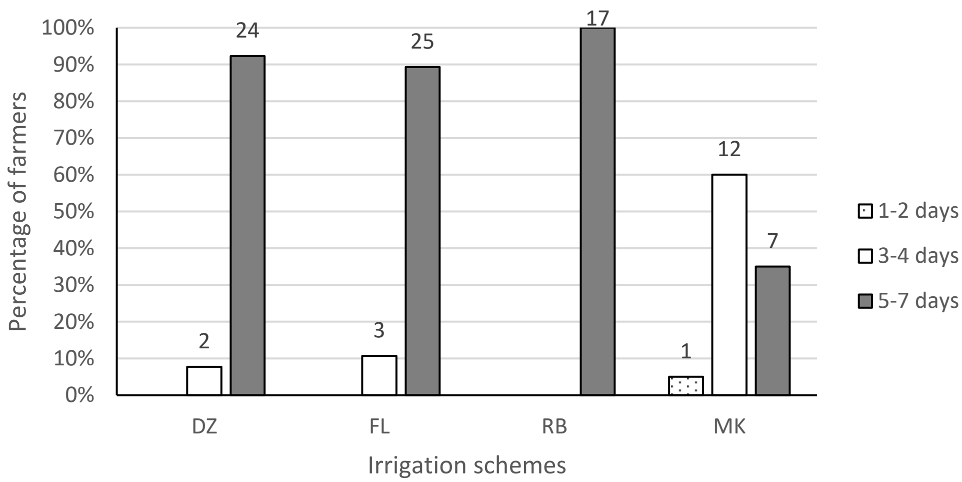

Figure 4. 4. The number of days in a week that farmers spent in the field in Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.2 The impact of small-scale farming on farmers' socio-economic status

4.2.1. Farmers' primary sources of household income

Farming and pension were the common primary sources of household income in Dzindi, Folovhodwe and Rabali irrigation schemes (Figure 4.5). Dzindi was the only scheme with farmers who had farming and employment as their primary source of household income

(Figure 4.5). On the other hand, Makuleke was the only scheme that had the least number of farmers depending on both pension on farming (Figure 4.5).

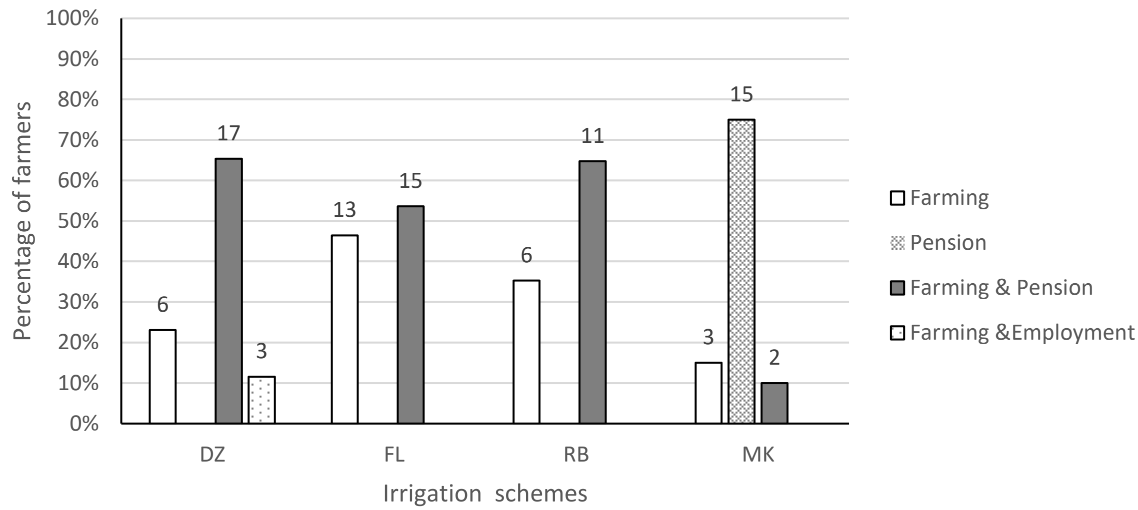

Figure 4. 5. Farmers' primary sources of income across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.2.2. Purpose of crop production and marketing of agriculture produce

All farmers in Dzindi, Folovhodwe and Rabali cultivated crops for selling and household consumption (Figure 4.6). Farmers who sell and consume their produce did not have records of the percentage of the produce that they sell and the percentage they consume. Nevertheless, they reported that the produce consumed is very little compared to the produce they sell, but were unable to estimate. Maize and vegetables such as cabbage, spinach, groundnuts, sweet potatoes and tomatoes were the common crops grown across all four irrigation schemes. Dzindi and Folovhodwe had a very good market for their agricultural produce. Hence, all the farmers within these irrigation schemes sell their produce and not just cultivate it for household consumption (Figure 4.6).

On the other hand, only 30% of Makuleke irrigation scheme's farmers sell their produce (but not all the time), while the additional 70% only cultivate for household consumption (Figure 4.6). Folovhodwe was the best scheme in terms of marketing because the scheme had volunteered personnel to help them with marketing. All farmers in Makuleke and half of Rabali farmers complained about not having a good market for their agricultural produce.

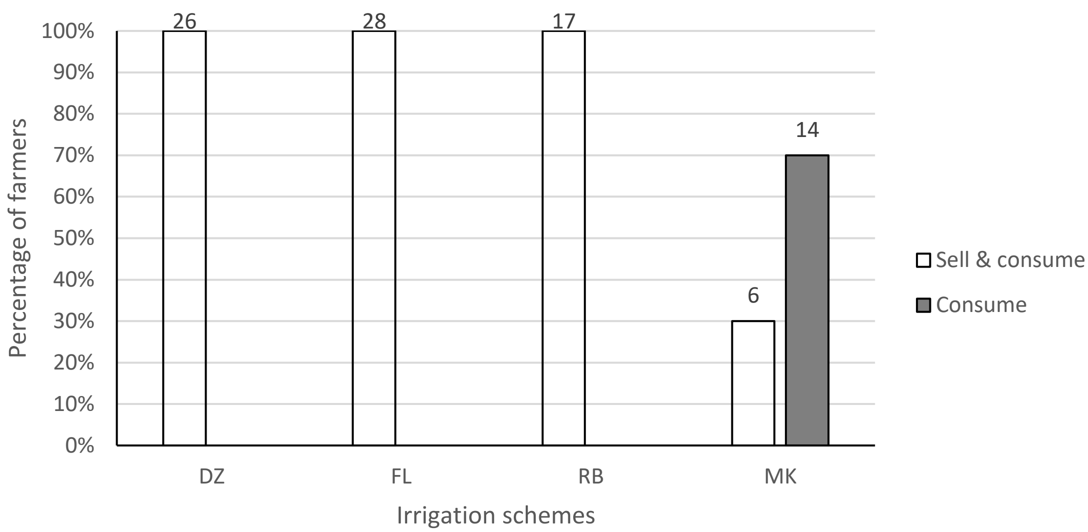

Figure 4. 6. Farmers' reasons for growing crops across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes. Sell & consume- farmers who grow crops for selling and household consumption; Consume - farmers who only grow crops for household consumption.

4.2.3. Farmers' production cost and profit

Farmers across all the four irrigation schemes reported the need to be taught book-keeping since their production costs and profits were not well recorded. Farmers used rough estimates to calculate their annual production cost and profit. Based on the estimated average money spent and the profit made, Folovhodwe irrigation scheme's farming was the most profitable farming activity, followed by Dzindi and Rabali, respectively (Figure 4.7). The profit money resembles the agricultural peak year (a year of maximum yield). Farmers reported that they do not consistently profit from their money towards farming expenses but lose drastically during agricultural drought years. Makuleke was the least scheme in terms of productivity and the profit made from agricultural produce (Figure 4.7). This is because the Makuleke irrigation scheme no longer receives government support in fertilizers, pesticides and irrigation water from the dam. Makuleke farmers did not have clear answers as to why the scheme is no longer receiving government's support like the other irrigation schemes such as Dzindi, Folovhodwe and Rabali.

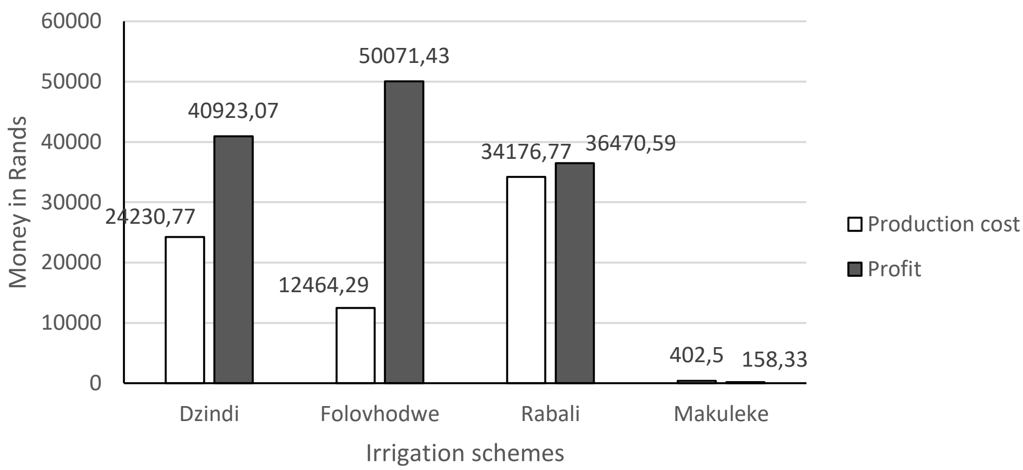

Figure 4. 7. The average production cost and profit per farmer per year in each irrigation scheme.

4.2.4. Activities that farmers spent on their production cost

4.2.4.1. Hiring ploughing tractors

All farmers in Dzindi, Folovhodwe and Rabali used tractors for soil preparation, while Makuleke had 60% of farmers who used tractors (Figure 4.8). The other 40% of Makuleke farmers used hand hoes for soil preparation because they said hiring a tractor was too expensive for them (Figure 4.8). Generally, farmers complained about the high prices of hiring a tractor, estimated to be R2100 per hectare, making it R4200 per hectare per year since farmers have two crop growing seasons (summer and winter).

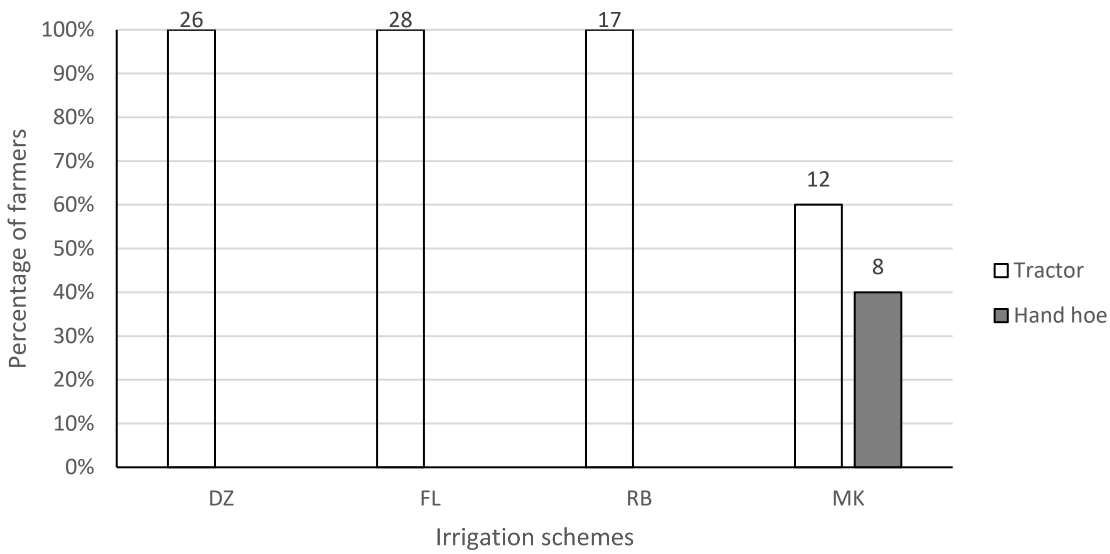

Figure 4 8. Equipment (tractor and hand hoe) used by farmers for preparing the soil across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.2.4.2. Seeds

Farmers across all four irrigation schemes bought hybrid seeds produced by commercial companies each growing season. They did not believe in storing seeds (e.g., maize and butternut) from their harvest for the next growing season like their forefarthers did. Farmers reported that seeds from the previous harvest did not produce a good yield and are often not viable.

4.2.4.3. Fertilizers and pesticides

Besides buying seeds every cropping season, farmers also bought synthetic fertilizer and used it more than crop residuals and animal manure for soil fertility improvement. During a field visit to the Dzindi irrigation scheme, farmers mentioned that they no longer accept meeting invites without incentives like fertilizers. This means that if the meeting host provides at least one bag of fertilizer to each farmer, that is when they will consider a meeting worthy of attending. Similarly, farmers buy pesticides more than those who do not control pests. The majority of them occupied lower levels of education, making it difficult for them to follow all the correct application procedures (e.g., the proper dosage and sprayer calibration). Depending on pesticides than is expected, cabbage farmers across all four irrigation schemes reported spraying chemicals twice a week. Farmers also spent money on hiring individuals to assist them in applying fertilizers and pesticides, weeding, irrigating, and harvesting. Unfortunately, farmers did not have records of money spent on these activities.

4.3 Farmers knowledge and perception of sustainable agriculture and their adopted agricultural practices

4.3.1. Observed sustainable agricultural practices that farmers practice in the field

Mulching or the use of crop residues for soil fertility improvement and intercropping of maize and groundnuts were the only sustainable agricultural practices practised in the field. These sustainable practices were only observed in a few plots. There were no integrated pest management, biological control strategies, and judicious use of pesticides. The balance between the use of organic input and synthetic fertilizers was also not there. Synthetic fertilizers were used more than compost and animal manure. Although farmers knew some of the strategies for rain-water harvesting and prevention of soil erosion caused by water runoff, there were no soil and water conservation strategies in the field.

4.3.2. General knowledge and perceptions on Sustainable Agriculture

There was no significant difference in knowledge and understanding of sustainable agriculture across the four schemes (χ^2 = 8.909883, P = 0.178). Approximately 79% of the farmers from all irrigation schemes did not know sustainable agriculture. Most of them said they had never heard anything about sustainable agriculture. Only a small percentage of farmers in Dzindi and Folovhodwe (3.85% and 3.57%, respectively) had good knowledge and understanding of sustainable agriculture (Figure 4.9). These farmers had advanced knowledge and understanding of sustainable agricultural practices, their benefits, and also knew the negative environmental impact associated with unsustainable agricultural practices. No farmer showed a good knowledge of sustainable agriculture at Rabali and Makuleke.

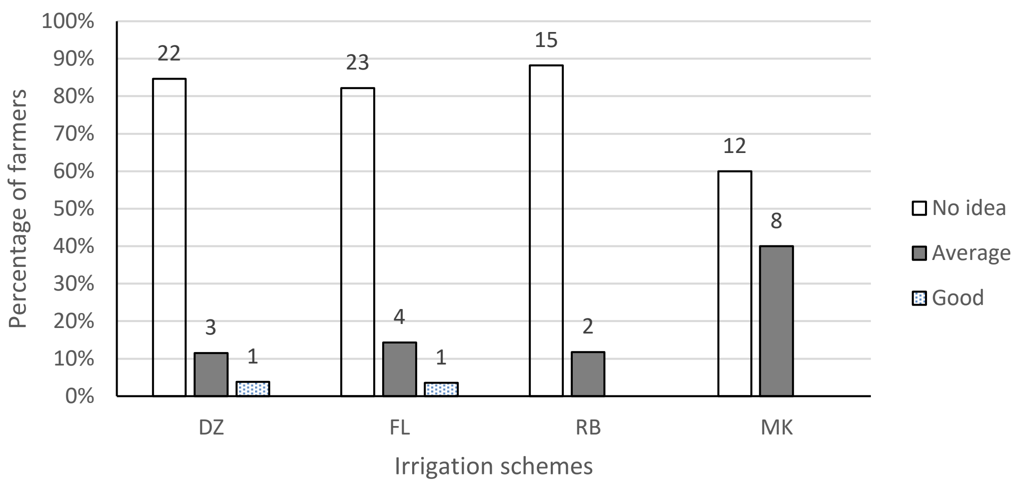

Figure 4. 9. Farmers' knowledge and understanding of sustainable agriculture across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.3. Agricultural knowledge transfer

In all four irrigation schemes, farmers highly recommended farmers' meetings (92.31%) to transfer any agricultural knowledge. There was no significant difference (χ^2 = 7.74705, P = 0.559) regarding sources of agricultural knowledge or the methods used to transfer agricultural knowledge across all four irrigation schemes. The second preferred source of agricultural information was peers, i.e., farmers copying or learning new farming strategies from their fellow farmers. Indigenous knowledge was the third source of agricultural knowledge relied upon by farmers. Farmers gained agricultural knowledge and practices from their parents when growing up. A very small percentage of farmers read agricultural information on their own (self acquisition) on the internet and agricultural magazine (especially Farmers' Weekly), 3.85% and 11.76% in Dzindi and Rabali, respectively, while none of the farmers in Folovhodwe and Makuleke read for themselves (Figure 4.10).

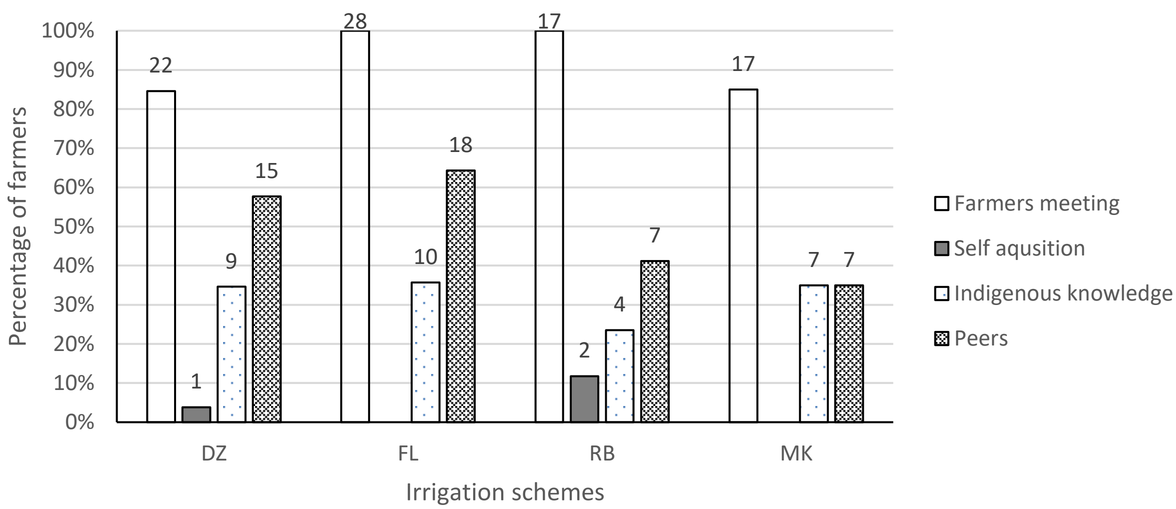

Figure 4. 10. Different means of acquiring agricultural information by Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes' farmers.

4.3.4. Transfer of sustainable agriculture knowledge by extension services.

Generally, a few farmers across all four schemes claimed that extension officers transfer sustainable agriculture knowledge to the farmers (Figure 4.11). There was no significant difference (χ^2 = 6.070657895, P = 0.108) across all four irrigation schemes in sustainable agricultural knowledge transfer. All farmers from Rabali, 84.62% from Dzindi and 82.14% from Folovhodwe reported that extension officers do not transfer sustainable agriculture knowledge. These farmers claimed that they receive another sort of agriculture knowledge and information such as pesticides and fertilizers application intervals from the extension officers but not the sustainable agriculture information. Makuleke, amongst the four irrigation schemes, had the highest percentage (30%) of farmers who claimed that extension officers transfer sustainable agriculture knowledge. The transferred sustainable agriculture knowledge was referred to practices such as the efficient use of crop residuals and minimum tillage for soil nutrients retention.

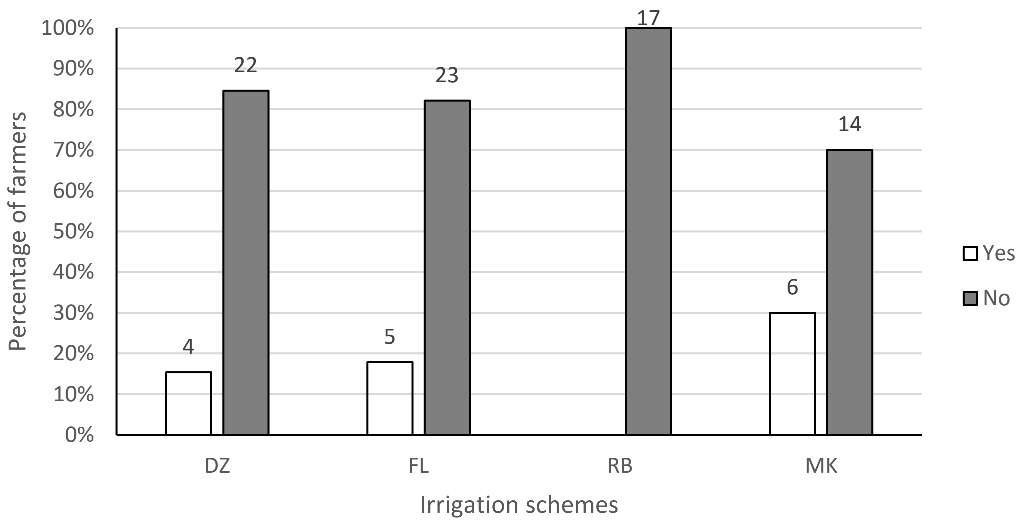

Figure 4. 11. Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) farmers' responses to whether extension officers transfer sustainable agriculture knowledge or not.

4.3.5. Knowledge of the impact of sustainably produced products on the market access and produce prices

There was no significant difference (x^2 = 1.836312, P = 0.607) across all four schemes regarding the knowledge of sustainable agriculture and its impact on the market and produce prices. A very small percentage (14.29%) of farmers across all four schemes had a good knowledge of sustainable agriculture and its market and prices of the sustainably produced crops. In comparison, 85.71% were not concerned (had any knowledge) about sustainable agriculture and its impact on the market and produce prices (Figure 4.12).

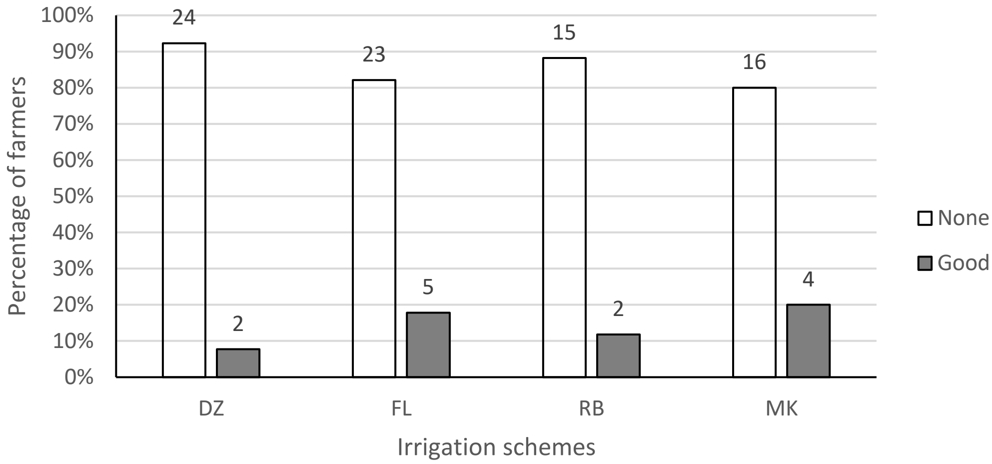

Figure 4. 12. Farmers knowledge of sustainable agriculture and its impact on the market and produce prices across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.6. Farmers perceptions on the benefits of on-farm biodiversity conservation.

There was a significant difference (χ^2 = 18.16296218, P = 0.005) across all irrigation schemes regarding their perceptions on the benefits of on-farm biodiversity conservation. Dzindi and Folovhodwe had a significant percentage (53.85% and 53.57%, respectively) of farmers who knew biodiversity conservation benefits but disregarded the knowledge (Figure 4.13). Most of the farmers said they knew about the crop residuals' contribution to soil microorganisms diversity and nutrient cycling, but they disregard this 'old knowledge' because they have access to new technology like synthetic fertilizers. Dzindi, Rabali and Makuleke farmers significantly (26.92%, 52.94% and 40%, respectively) believed that biodiversity conservation benefits are only theoretical (Figure 4.13). They claimed not to see the benefits brought by adopting biodiversity conservation practices. Makuleke and Folovhodwe (50% and 32.14%, respectively) significantly acknowledged the benefits of conserving biodiversity. These farmers reported that burying of crop residuals enhances soil microorganisms that then contribute to nutrient cycling. Also, the presence of native trees in the riparian zone regulates temperature and support the river from drying out.

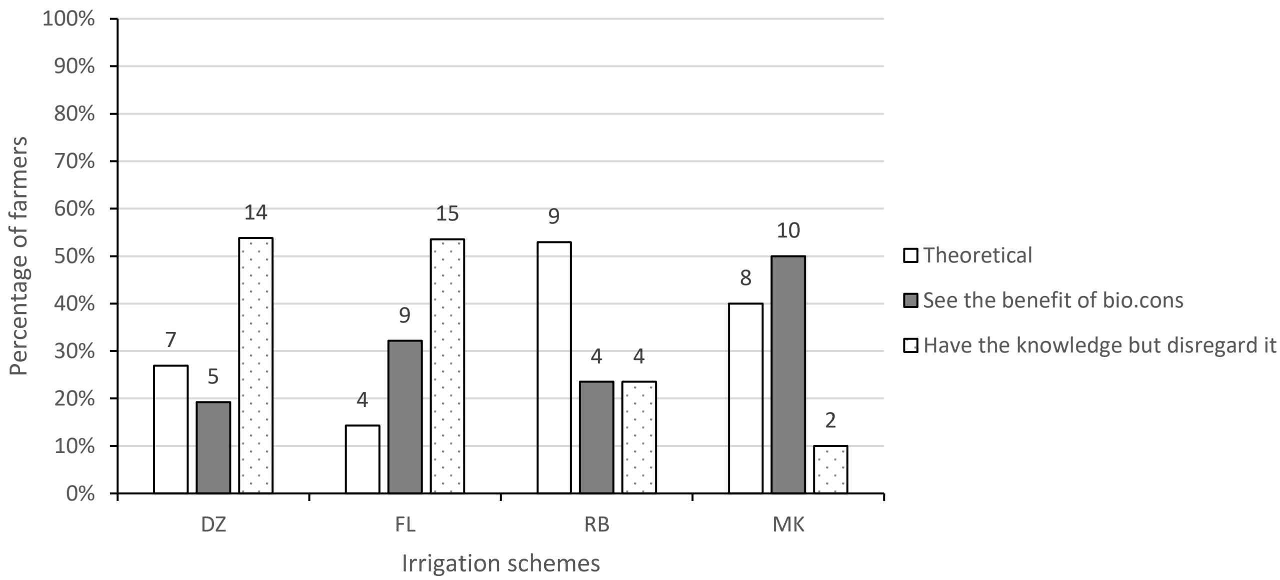

Figure 4. 13. Famers' perception on benefits of biodiversity conservation (bio.cons.) across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.7. The impact of farming activities on the environment

All farmers in Folovhodwe and Rabali (100% in each irrigation scheme), 96.15% and 90% in Dzindi and Makuleke, respectively, claimed not to contribute to either negative or positive environmental impacts (Figure 4.14). There was no significant difference (χ^2 = 4.377651515, P = 0.223) in farmers who claimed not to contribute to environmental impact across all four schemes. Few percentages of farmers (10% and 3.85%) in Makuleke and Dzindi, respectively, agreed that their agricultural practices had the potential to contribute to negative environmental impact (Figure 4.14).

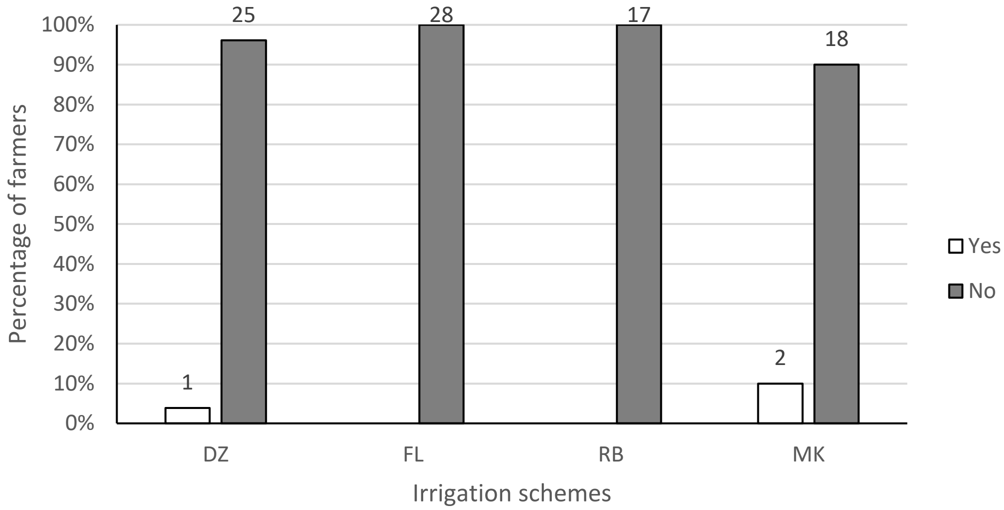

Figure 4. 14. Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) farmers' responses to whether their agricultural activities contribute to environmental impact or not.

There was a significant difference (χ^2 = 13.83083075, P = 0.031) in farmers' knowledge on soil erosion and prevention across all four irrigation schemes. All farmers in Dzindi and Folovhodwe and 90% in Makuleke had significantly more knowledge about soil erosion and prevention than farmers in Rabali (76.47%) (Figure 4.15). Most of them reported that they do not practice soil erosion measures because they do not experience soil erosion challenges where they cultivate their crops. Only few farmers (11.54%, 14.29% and 10%) in Dzindi, Folovhodwe and Makuleke, respectively, took soil erosion and prevention knowledge into practice (Figure 4.15).

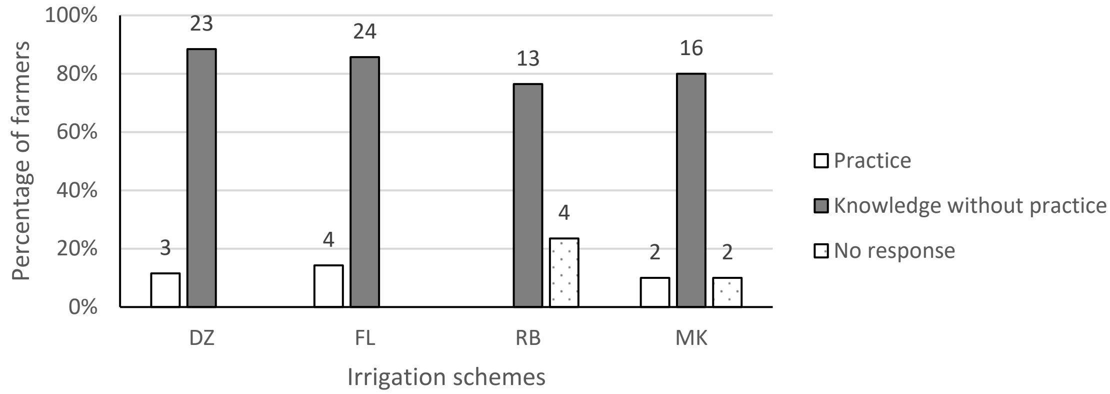

Figure 4. 15. Farmers' knowledge for soil erosion and prevention measures across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.8. Water use and management

Dzindi, Folovhodwe and Rabali farmers relied on furrow irrigation water from the river while Makuleke relied on rain (i.e. dryland farming) (Figure 4.16). There were no water conservation strategies in all four irrigation schemes (Figure 4.16).

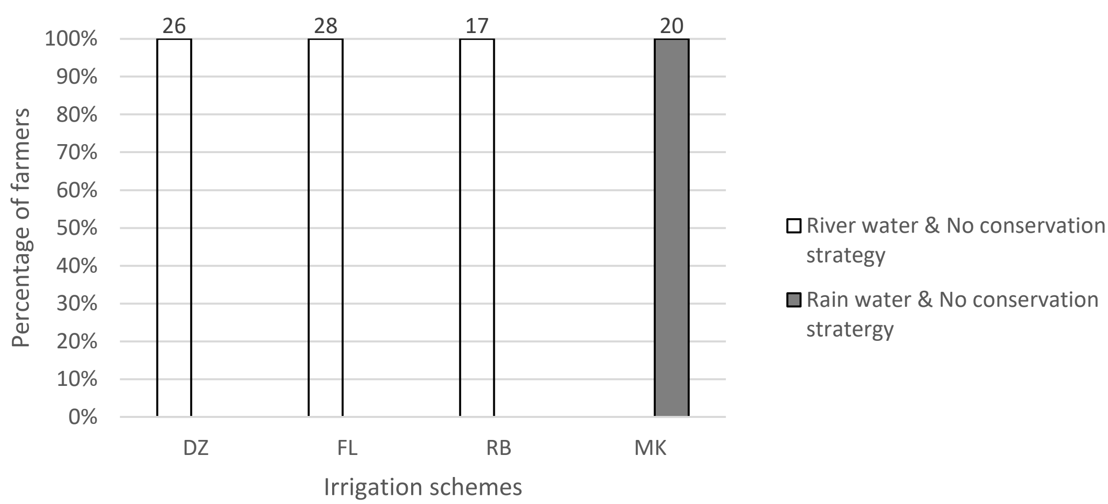

Figure 4. 16. Sources of irrigating water and water conservation strategies across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

There was a significant difference across all four irrigation schemes (χ^2 = 17.73997564, P = 0.006) concerning their perception in cultivating close to water bodies. Dzindi and Folovhodwe had a significantly higher percentage of farmers who did not mind cultivating close to water bodies than Rabali and Makuleke farmers (Figure 4.17). Farmers knew about the 30 metres buffer zone from a water body but still see no problem cultivating within the buffer. Most farmers said they were forced to cultivate in the buffer zone due to a lack of space to cultivate. Due to the lack of enough plots to cultivate, the demonstration plot in Folovhodwe was given away to another farmer, leaving the scheme without a plot for running trials and practical demonstrations. Rabali, Makuleke and Dzindi had a significant percentage (65%, 60% and 31%, respectively) of farmers who would not cultivate close to water bodies than Folovhodwe farmers (Figure 4.17). The reasons for not wanting to cultivate close to water bodies were as follows: farmers did not want their crops to be washed away by flooded rivers; inundated environment hinders crop growth; lastly, farmers acknowledged the importance of not polluting water bodies.

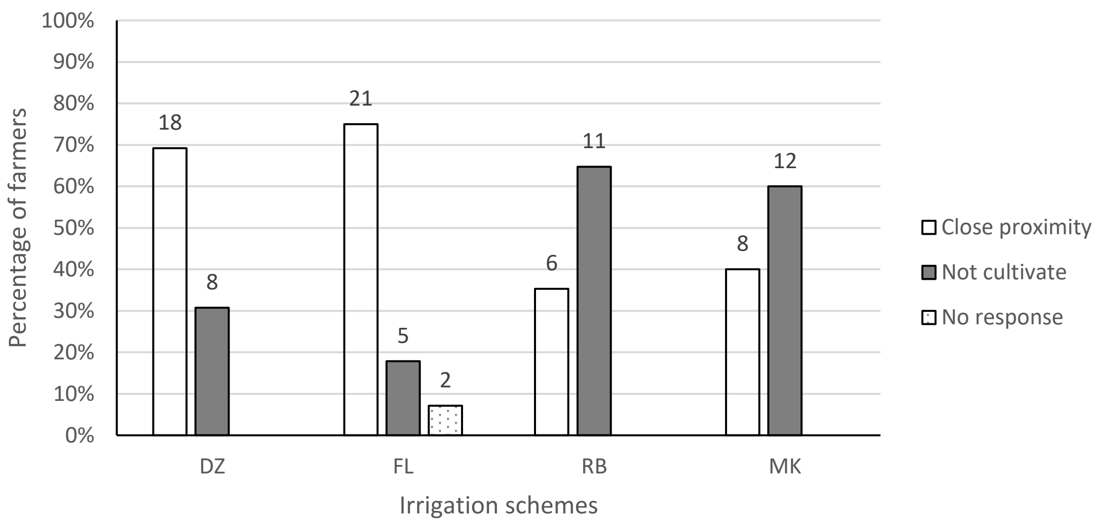

Figure 4. 17. Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) farmers' perception of cultivating in close proximity to water bodies. Close proximity - farmers who did not mind cultivating close to water bodies, Not cultivate- farmers who would not cultivate close to water bodies.

4.3.9. Nutrient cycling

4.3.9.1 Intercropping

There was a significant difference (χ^2 = 9.479429066, P = 0.023) across all four schemes regarding intercropping practice. Farmers in Dzindi and Folovhodwe irrigation schemes did not practise intercropping (Figure 4.18). Only a few percentages, (15% and 18%) in Makuleke and Rabali, respectively, practised intercropping (Figure 4.19). Groundnuts and maize were the only intercropped crops in Makuleke and Rabali irrigation schemes. Farmers in Dzindi and Folovhodwe reported that it is their norm within the irrigation scheme that they plant different types of crops separately (not intercropping) because they believe intercropping hinders crop growth.

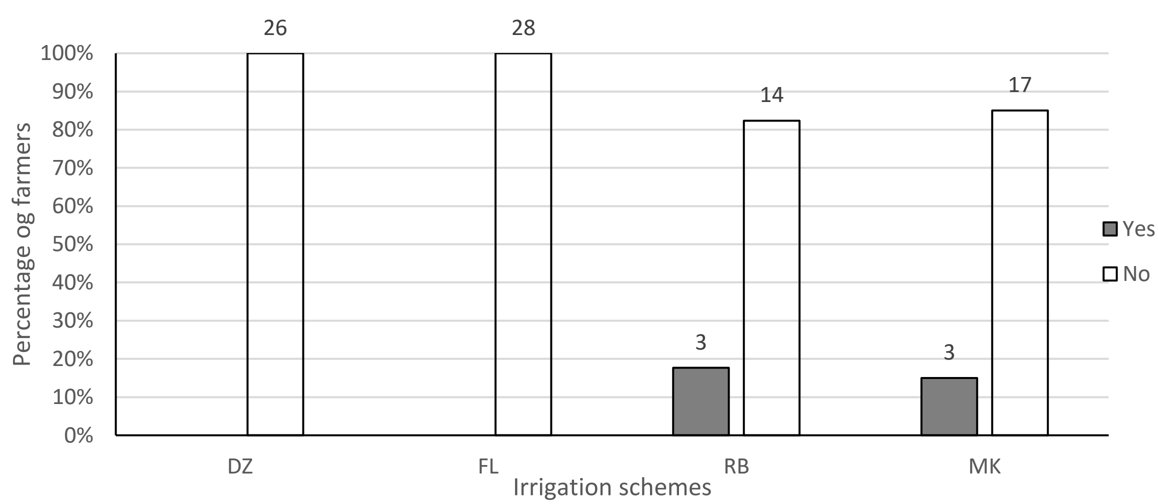

Figure 4. 18. Farmers' cropping systems (intercropping and no intercropping) across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.9.2. Crop residue management.

There was a significant difference (χ^2 = 14.43723605, P = 0.002) across all four irrigation schemes in the use of crop residuals to improve soil fertility. Dzindi and Makuleke had a significantly higher percentage of farmers who used crop residuals for soil nutrient cycling than Folovhodwe and Rabali farmers (Figure 4.19). On the other hand, Dzindi, Folovhodwe and Rabali had a significantly higher percentage of farmers who burned crop residuals instead of utilizing them for enhancing soil nutrients than Makuleke farmers.

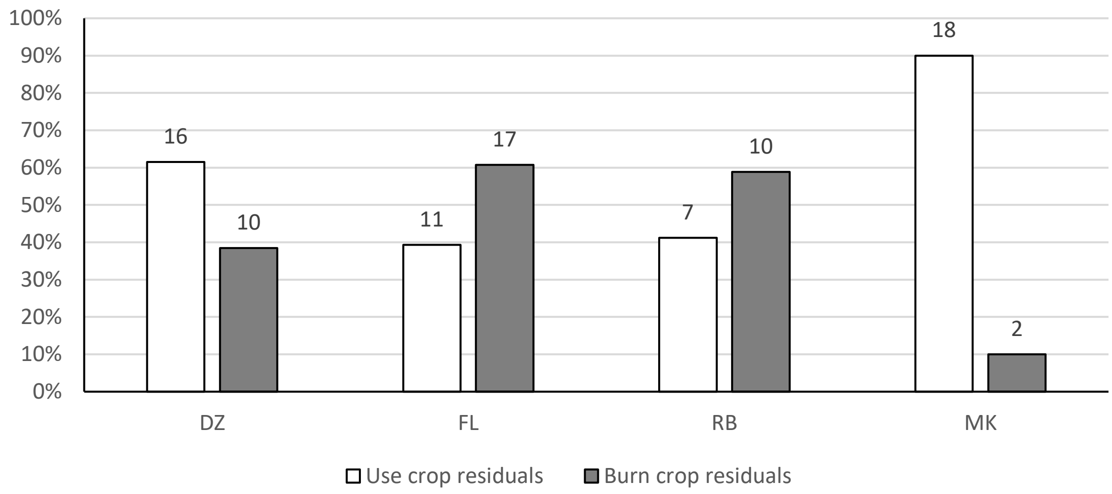

Figure 4. 19.The use of crop residues for nutrient cycling across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.9.3. Fertilizer use

There was a significant difference (x^2 = 14.06839403, P = 0.028) across all the irrigation schemes in fertilizers used to improve soil fertility. In Dzindi and Folovhodwe, a significantly higher percentage of farmers used synthetic fertilizers only than Rabali and Makuleke (Figure 4.20). The use of only animal manure to improve soil fertility was generally low and did not differ across all four irrigation schemes (Figure 4.20). Folovhodwe and Rabali had a significantly higher percentage of farmers who used both synthetic fertilizers and animal manure than Dzindi and Makuleke.

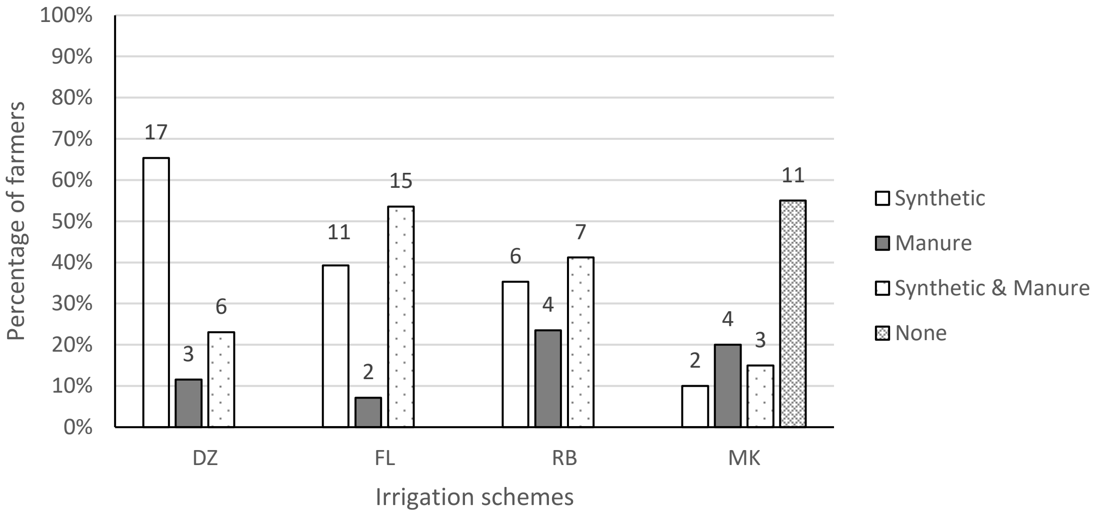

Figure 4. 20. Fertilizers used to improve soil fertility in Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.10. Environmental pollution from agricultural chemical use

4.3.10.1. Pest control

There was a significant difference (x^2 = 26.31971545, P = 0.0001) across all four irrigation schemes with regards to insect pest control methods employed. Dzindi and Rabali farmers depended 100% on pesticides for pest control, while 96.43% in Folovhodwe and 60% in Makuleke use pesticides (Figure 4.21). Amongst the four irrigation schemes, Makuleke was the only scheme that showed a significantly higher percentage (40%) of farmers who did not use pesticides to control pests (Figure 4.21). Most of the farmers who did not use pesticides for pest control said that pesticides were expensive. All the farmers interviewed across all four irrigation schemes used hands (hand pulling) and hand hoe for weeding.

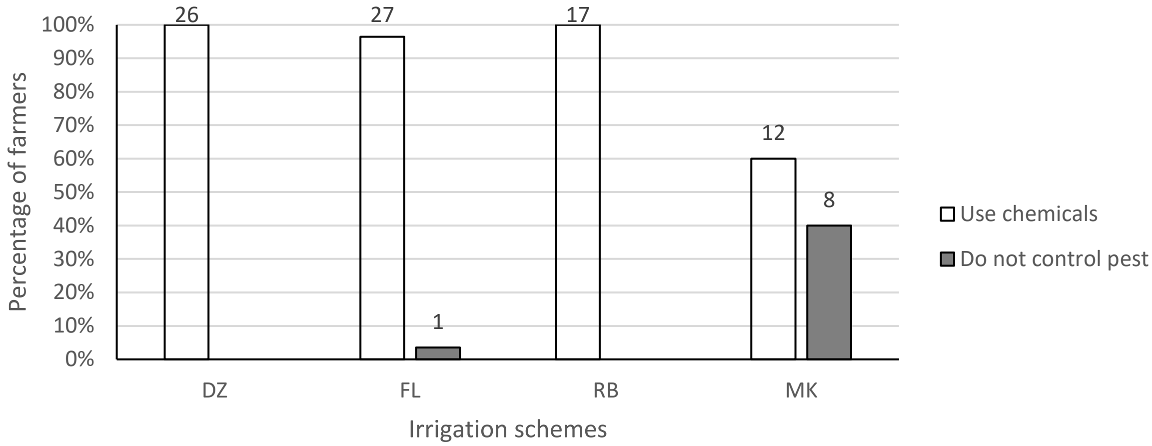

Figure 4. 21. Farmers' methods for controlling insect pests (use chemicals and do not control pest) in Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation scheme.

4.3.10.2. Disposal of chemical waste

There was a significant difference (χ^2 = 58.32790237, P = 0.0001) across all four irrigation schemes regarding farmers' methods of chemical waste disposal. Significant percentages (29% and 27%) of farmers in Rabali and Dzindi, respectively, buried chemical containers than Makuleke farmers. Folovhodwe and Rabali had a significantly higher percentage (100% and 53%) of farmers who burned chemical wastes than farmers in Dzindi and Makuleke (Figure 4.22). Throwing of chemical containers was the most (54%) practised method of disposing of chemical waste in the Dzindi irrigation scheme (Figure 4.22). Farmers believed that throwing chemical containers away, out of reach of children (in a very dense and impenetrable bush), was the safest method of disposing of the agricultural chemical wastes. All farmers in Folovhodwe disposed chemical containers inside the bins collectively and burned them, while Rabali farmers burned them individually in their respective plots.

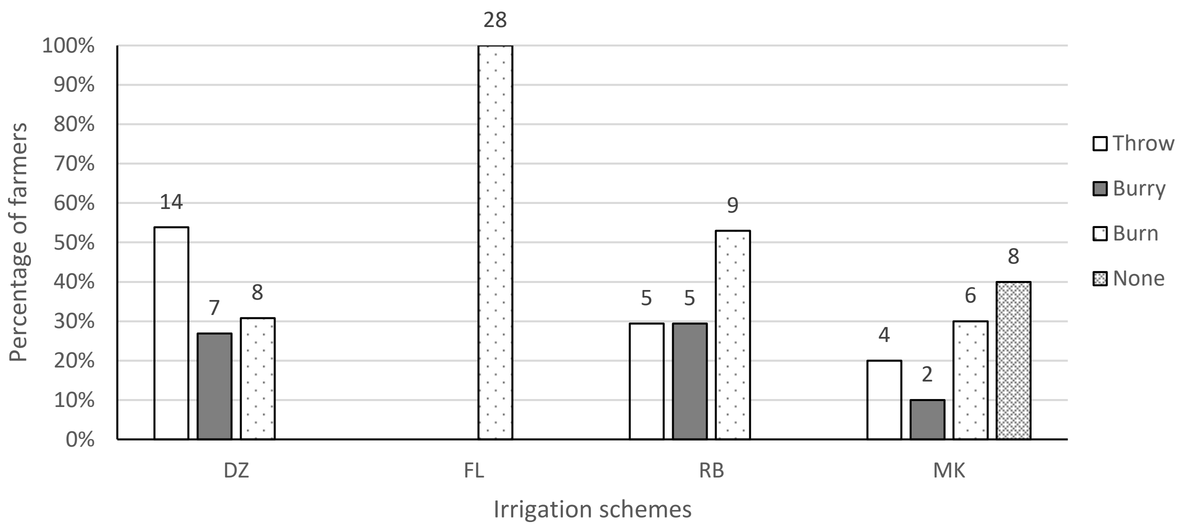

Figure 4. 22. Methods that farmers use to dispose of chemical waste (throw, burry and burn) across Dzindi (DZ), Folovhodwe (FL), Rabali (RB) and Makuleke (MK) irrigation schemes.

4.3.11. Biodiversity conservation within the farm

All the farmers from Dzindi, Rabali and Makuleke irrigation schemes did not want trees around their plots because they believed trees provide shades that hinder crop growth. Only 7.14% of farmers in Folovhodwe had positive views towards having trees around their plots (Figure 4.23). They reported that native trees within the scheme help with water retention.

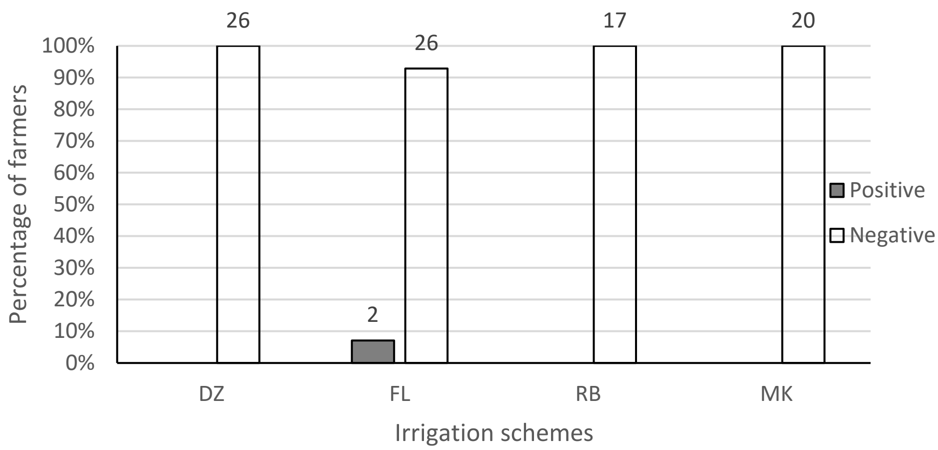

Figure 4. 23. Farmers's perceptions on the presence of native trees around the plots at Dzindi, Folovhodwe, Makulelek and Rabali irrigation schemes.

4.4 Extension officers knowledge of sustainable agriculture

4.4.1. Demographic data

Four extension officers were interviewed (one officer per scheme) from Dzindi, Folovhodwe, Rabali, and Makuleke irrigation schemes. They were all males aged between 40-60 years. The interviewed extension officers had tertiary education and they all had more than twenty-one years of experience working as irrigation schemes' extension officers.

4.4.2. General extension officers' knowledge and perceptions on sustainable agriculture

Based on the personal understanding of sustainable agriculture, extension officers from Rabali and Makuleke had average knowledge of sustainable agriculture, while the other two extension officers from Dzindi and Folovhodwe showed good knowledge and understanding of sustainable agriculture. Like with Dzindi, Folovhodwe, Rabali and Makuleke's farmers, farmers' meeting was the most popular method of acquiring agriculture-related matters by extension officers. There was only one extension officer from Dzindi irrigation scheme who relied only on reading online agricultural literature (especially Farmers' Weekly) for himself. The extension officer from Folovhodwe preferred both farmers' meeting, workshops and acquiring knowledge for himself.

The Rabali extension officer, from his point of view, said that farmers in all Vhembe irrigation schemes are practising farming just for fun or passing the time. He added that the current farming practice of Vhembe irrigation schemes' farmers, in general, is not sustainable because it does not have considerable economic benefits. Referring to Dzindi farmers specifically, the extension officer from Dzindi mentioned that farmers did make some money but not a lot. Folovhodwe officer considered the Folovhodwe irrigation scheme profitable to the farmers. The officer said that the money from farming in the irrigation scheme sustains many families and takes children to school. There is low productivity in the Makuleke irrigation scheme due to a lack of irrigation water.

4.4.3. Knowledge transfer to farmers

All four extension officers from four irrigation schemes claimed to transfer or share sustainable agriculture knowledge with farmers. However, one extension officer from the Dzindi irrigation scheme said he could not advocate for the environment being a farmer himself. He further suggested that the Department of Forestry, Fisheries and Environment and the Department of Water and Sanitation collaborate with the Department of Agriculture, Land Reform and Rural Development to emphasize the importance of sustainable agriculture pertaining to water conservation and the protection of the environment at large. Extension officers from Rabali, Dzindi, and Makuleke complained about the difficulties they face when they try to transfer new agricultural knowledge or practices to farmers since they were dominated by the old-age group that often resists change. Folovhodwe extension officer reported the opposite case with other extension officers when he said Folovhodwe farmers are enthusiastic about agricultural matters and try to acquire new knowledge when he shared with them regardless of their age.

4.4.4. Use of chemical fertilizers and pesticides

Farmers use synthetic fertilizers and pesticides a lot than they use the organic fertilizers such as crop residues and animal manure or biological control rather than pesticides that mostly they lack knowledge of applying. Dzindi extension officer added that he offered farmers an opportunity to consult him regarding proper application of any pesticide that might be new to farmers since most of the farmers cannot read English. The officer reported that although he put that offer on the table, neither of the farmers came for consultation. For that reason, he said he is skeptical about buying the produce from Dzindi irrigation scheme because the indiscriminate use of agrochemicals renders the agricultural produce unsafe for human consumption. The officer added that farmers and consumers do not consider the safeness of the agricultural produce because some of the diseases like cancer are not seen immediately but develop after prolonged exposure to agrochemicals.

4.4.5. Disposal of chemical waste

The extension officer from the Folovhodwe irrigation scheme preferred burning as disposal or management of chemical waste. One of the management strategies in the Folovhodwe irrigation scheme was the use of dustbins for throwing in chemical waste by farmers so that they can be burnt collectively. The extension officer from Rabali irrigation scheme encouraged the farmers to burry chemical containers underground. According to Rabali officer, burrying chemical waste is safer than just throwing anywhere children can reach. In the case of the Dzindi irrigation scheme officer, the officer did not encourage farmers to practice any disposal method, whether burning, burying or throwing away chemical wastes on their own. For that reason, the management has fenced a small area behind the irrigation scheme's office for farmers to put their empty pesticides containers, preventing farmers from disposing the chemical waste everywhere. Just like the case of consultation for pesticides before use, the officer said all farmers were not disposing the chemical waste in the place that was constructed for that.

4.4.6. Water conservation

All the four irrigation schemes' officers knew the environmental consequences of cultivating close to water bodies (within 30m buffer zone). The extension officers acknowledged the issue of conserving water as a scarce resource in the country. The extension officers also encouraged farmers to practice rainwater harvesting where possible. Dzindi irrigation scheme's extension officer mentioned a failed rainwater harvesting project that was introduced to farmers by the officials from the Vhembe Local Department of Water and Sanitation. Again, the Dzindi officer mentioned that the issue of rainwater harvesting as a way of conserving water resources should also be treated as a transdisciplinary matter that involves officials from different fields of study to teach or emphasize the necessity of putting rainwater harvesting strategies in place.

4.4.7. Biodiversity conservation

Three extension officers from Dzindi, Folovhodwe and Makuleke acknowledged the benefits of conserving biodiversity within the farm or cultivating plot and they claimed to see it happening in their gardens. They all mentioned the scenario of micro-organisms that facilitate nutrient cycling when these microbes act on a piled crop residue to make compost. On the other hand, the Rabali extension officer claimed not to see the benefits of conserving biodiversity within the farm, and as a result, the officer considers the benefits of conserving biodiversity to be only theoretical.

Chapter 5: Discussion

5.1. The impact of small-scale farming on farmers' socio-economic status

5.1.1. Activities that farmers spent their production cost on.

5.1.1.1. Ploughing tractors

The majority of farmers are not employed and depend mostly on farming and pension as their main source of household income; therefore, agricultural inputs can be expensive for them. Odhiambo and Magandini (2008) reported that more than 85% of small-scale farmers in the Vhembe District Municipality, South Africa, funded their agricultural practices with money they generated after selling what they produced. Nonetheless, a drought year would make acquiring inputs for the next season more difficult (Odhiambo and Magandini, 2008). The majority of farmers rely entirely on expensive tractors for ploughing and thiscontributes to higher production costs.

Tractors can have a detrimental influence on agriculture production since compacted soil can't sustain a plant production system properly (Raper, 2005).Across the four irrigation schemes, frequent use of tractors in the farm indirectly cost farmers good harvest due to soil compaction that hinders crop growth, thus resulting in low yield. Shah et al. (2017) reported the following tractor impacts: stunted shoot growth, poor root proliferation, shallow root system, reduced leaf area, reduced plant biomass accumulation, and reduced yield in crops grown on compacted soil. In this case, minimum or no-tillage could lessen the money spent on hiring a tractor since the tractor will only be hired for strip cultivation (in minimum tillage) rather than ploughing the whole plot. Giller et al. (2009) noted that minimum tillage with permanent soil cover could lead to the same or more crops as high-input agricultural practices. Small-scale maize and soybean farmers in northwestern Ghana, reported increased production and revenues with a no-tillage system (Naab et al., 2017). If farmers across the irrigation schemes opt for minimum tillage, it would reduce the cost of hiring the tractor and minimize soil disturbance, resulting in good yield.

5.1.1.2. Seeds

Buying seeds every growing season is not profitable since this requires transportation when a farmer moves from the field (village) to town to buy seeds. Small-scale farmers in the Vhembe District Municipality suffer with transportation money for their external agricultural supplies, according to Odhiambo and Magandini (2008). (e.g., hybrid seeds, chemical fertilizers and pesticides). Across the four irrigation schemes, farmers' reported that seeds from their harvest have low viability and produce low yield. Low viability could be due to a lack of seed storage knowledge to maintain viability, or farmers are no longer considering the utilization of on-farm produced seed due to low yield associated with the F_2 generation and the subsequent generations. Wambugu et al. (2009) found that treating seeds with Mortein Doom® (aerosol insecticides containing Allethrin (C19H26O3) and Resmethrin (C22H26O3) active ingredients manufactured by Mortein company) and cow dung ash, then storing them in airtight containers, improves seed viability and vigour when compared to hybrid seeds. The study also revealed that cow dung, which is readily available on most farms, is an efficient seed protectant and successfully protects seed quality throughout storage (Wambugu et al., 2009). Farmers who cannot afford Mortein Doom® might treat their seeds with cow dung ash and then store them in an airtight container to improve seed quality.

5.1.1.3. Fertilizers and pesticides

A higher dependence on synthetic fertilizers while disregarding cheaper and environmentally friendly alternatives such as crop residues and mulch for enhancing soil nutrients can be regarded as unsustainable farming. The higher demand for synthetic fertilizers (e.g., even demanding them from farmers' meetings hosts) symbolizes that farmers believe that crop production can only be successful under synthetic fertilizers. In the same way with fertilizers, farmers depend more on pesticides than they should due to a lack of knowledge. Farmers are spending unnecessarily on pesticides, especially those who also grow cabbages, as they reported spraying chemicals twice a week.

Although these farmers complain about the expensive agriculture external inputs, they do not seem to be willing to give up the act of using too much of these inputs (see Odhiambo and Magandini, 2008). This might be because older farmers (>60 years) dominated the schemes. The three extension officers stated that older farmers resist change and do not easily learn new things.

5.1.2. The purpose of crop production and marketing of agricultural produce

Makuleke and Rabali farmers complained of not having a good market for selling their produce. For this reason, the Makuleke irrigation scheme had only 30% of farmers who sell their agricultural products while the rest cultivate only for household consumption. This is mainly due to either remoteness of the scheme to the nearest town and/or a lack of knowledge on marketing since most of them do not read agriculture information on their own but rely primarily on farmers meetings (facilitated by extension officers) for information relating to agriculture. Each scheme had only one extension officer available to assist farmers in all the farming operations (i.e., production to marketing agricultural products). However, one extension officer could not manage all the operations. For example, in the North West Province of South Africa's Mahikeng Local Municipality Matsane and Oyekale (2014) observed socio-economic factors such as (1) unemployment rate, (2) degree of remoteness, (3) lack of marketing information available for farmers, (4) the need for support and training for marketing service personnel, and (5) the need for communication strategies that facilitate the adequate flow of information between government agencies and farming communities to be negatively affecting poor marketing of small-scale farmers' produce.

The ratio of one extension officer is to 112 plot holders in Folovhodwe; 1: 105 in Dzindi; 1: 65 in Rabali, and 1: 90 in Makuleke. This shows the lack of support and training for marketing service personnel because one extension officer can not visit all the plots in a week, but will require a very long period to cater for them all. in the North West Province of South Africa's Mahikeng Local Municipality, Moobi and Oladele (2012) observed that government agencies' inappropriate ratio (1:500) to farmers negatively affects the adequate information exchange between government institutions and agricultural communities. Poor extension service, according to Van den Berg (2013), is one of the key variables impacting small-scale farming production in rural regions.

In the Vhembe District Municipality, the degree of commercialisation of smallholder irrigation systems was linked to the scheme's proximity to local urban centers (Van Averbeke, 2012). The lack of market in the Makuleke irrigation scheme is due to its remoteness to the nearest town (approximately 35 km to Malamulele town). Selling agricultural produce here can be expensive since it will require farmers to hire transportion to move their produce to the market area. On the other hand, the Dzindi irrigation scheme is located not too far from the nearest town (approximately 7 km from Thohoyandou town). This makes selling the agricultural produce easy for Dzindi farmers since the street vendors from Thohoyandou come to buy from the scheme. Van Averbeke (2008) also reported that street vendors are the primary consumers of farmers' produce at the Dzindi irrigation scheme. Nearly all of the 66 sedentary vendors examined who bought fresh produce in Dzindi utilized combi-taxis to transfer their purchases to their booths, and 54 of the 66 had stalls in Thohoyandou's urban center (Van Averbeke, 2012). Although the Folovhodwe irrigation scheme is located far from the nearest town (43 km from Tshilamba town), farmers' profit was higher because the scheme had better marketing information, better support and training from marketing service personnel. In Folovhodwe, a non-profit organisation volunteered to assist farmers in organizing the files and forms to register for selling their vegetables to well-known supermarkets like Spar. In the Rabali irrigation scheme, farmers mentioned that they used to make a very good profit when they were producing tomatoes for a company that would come and collect all the tomatoes and sell them.

5.1.3. The role of small-scale farming on farmers' household income and livelihoods

The majority of farmers did not have any other source of household income except for the unpredictable profit made from their farming activities and a little money from pension and child grants. Although farmers do not consistently profit from their produce, there are times during the peak year when farmers profit and with farming as their primary source of household income, farmers can maintain their families. The income from these agricultural activities is sending many children to school and becoming better individuals, employable to better job opportunities, and reducing poverty.

Even though there are agricultural peak years in other schemes, the poor government's support (not providing irrigating water and fertilizer) in the Makuleke irrigation scheme hinders the scheme's agricultural sustainability, thus compromising farmers' well-being and standard of living. Dryland farming or rainfed crops do not strive well as compared to the crops in irrigation schemes. For this reason, the Makuleke scheme was the least scheme making a profit in addition to the issue of not having a good market for their produce.

Small scale farming, especially in irrigation schemes, plays a vital role in family's income, food security and the development of the rural economy in general. Aseyehegn et al. (2012) found a substantial difference in mean total family income between irrigation scheme farmers and non-irrigation scheme farmers in Laelay Maichew District, Central Tigray, Ethiopia. They found irrigation scheme farmers' income exceeding that of non-irrigation scheme farmers by 37.03%. The irrigation scheme farmer's nutritional status and standard of living have improved by the similar factor as income (Aseyehegn et al. 2012). For Makuleke farmers to be more sustainable, the government should resume providing necessary support such as water and fertilizers. However, farmers should take responsibility for utilising fertilizers wisely and in combination with mulch or crop residuals they currently rely on.

Small-scale farming is essential to most farmers, especially Dzindi, Folovhodwe and Rabali because they spend five to seven days a week in the field. Unlike most Makuleke farmers who spend 3-4 days in the field. The rest of the irrigation schemes farmers consider farming as their full-time job, which is encouraged by seeing their improved livelihoods. By spending almost daily in the field, farmers also get an opportunity to socialise with fellow farmers, reducing stress and depression associated with unemployment. Unfortunately, young people who are the most affected by unemployment in the Vhembe District Municipality and South Africa at large are not significantly participating in small-scale farming.

Although the main household income from current farming activities is bettering farmers standards of living, the household income of the four irrigation schemes' farmers could have been more if sustainable agricultural practices had been adopted. Examples of such practices include Crop rotation, low tillage, and permanent organic cover over soils utilizing crop wastes or live cover crops. Tambo and Mockshell (2018) documented the improved livelihoods of small-scale farmers who fully adopted sustainable agriculture technologies compared to farmers who did not adopt the technology.

5.1.4. Farmers' farming records

Farmers across all schemes did not have full records of the production costs and profits they made and the proportion of the produce they sell and those they take home for consumption. Farmers should be trained in record keeping to be able to track profitable and non-profitable farming activities. Record keeping positively impacts the overall performance and adoption of sustainable farming practices as farmers can track the records of the most productive agricultural practices from the less productive ones (Snapp et al., 2019). Record keeping will allow farmers to make informed decision when choosing specific farming practices. It will also enable farmers to plan better and maximise their profit.

5.1.5. Conclusion

Small-scale irrigation schemes play a vital role to farmers by offering them an opportunity to become self-employed and improve their livelihoods. However, the input money required for the whole crop production process is a lot considering the lack of market and the agricultural droughts that frequently occur in the district due to its aridity (Chauke et al., 2013). Poor marketing of small-scale farmers' produce negatively affects farmers' socio-economic status. Farmers' problem of not having a good market for their produce can only be resolved if the government and private entities or even individuals can step up and try to address these socio-economic issues affecting marketing. Another option that can help farmers is to adopt affordable and effective seeds storage technology like cow dung ash and airtight containers.

5.2. Farmers' knowledge and perception of sustainable agriculture and their adopted agricultural practices

5.2.1 Famers' knowledge and perceptions on sustainable agriculture

The higher percentage (85%) of farmers were not concerned (do not have either a positive or negative point of view) about sustainable agriculture because they do not know what it is. This makes it more difficult to adopt and conduct sustainable agriculture. Agricultural innovation-based adoption choice models (such as the theory of reasoned action and the technology acceptance model) stress the importance of potential technology users' knowledge and attitude toward technology-specific qualities in affecting adoption decisions (Fishbein and Ajzen, 1975; Feder et al., 1985). Farmers' perceptions about adopting the technological acceptance model, according to Bagheri et al. (2016), were the biggest obstacle to the adoption of sustainable agricultural technology.

In this study, most farmers claimed not to receive any sustainable agriculture information from extension officers, but extension officers and few farmers reported the opposite. This shows that farmers might not be interested in sustainable agriculture knowledge shared by extension officers since it is only theoretical and not demonstrated on their farms.

Although there was no significant difference in knowledge and understanding of sustainable agriculture across the four schemes, Makuleke farmers had adopted practising some of the sustainable agriculture practices. The practices include the use of crop recidues or mulch for soil nutrients and minimum soil disturbance as they rely mostly on hand hoes rather than tractors for ploughing. Approximately 30% of these farmers said they got theknowledge of enhancing soil nutrients through mulch from the extension officer. This shows that farmers have adopted certain practices but do not know that they fall under sustainable agriculture. Therefore, extension officers need to unpack what sustainable agriculture is by giving examples of traditional practices that are part of sustainable agriculture, also through demonstrations.

Demonstrations that engage farmers in testing out sustainable agriculture technologies improve the adoption (Kiełbasa et al., 2018; Wang et al., 2019). Farmers participatory research (FPR) was undertaken by Snapp et al. (2019) in Michigan, in the North Central United States, to assure relevance and propose locally tailored solutions for increased adoption of sustainable agriculture technology. Farmers were engaged in testing out sustainable agriculture technologies (conservation tillage systems to enhance the sustainability of soybean production) to see which works best for them. After five years of the initial process of FPR, 90% (19 respondents) of the farmers indicated that their understanding of soybean soil management improved as a result of their involvement in the research; 86 percent (18 respondents) of the farmers said they planned to modify their soil management techniques as a result of what they learned (Snapp et al., 2019).

In contrast with sustainable agriculture technology adoption through FPR, is the implementation of short-term sustainable agricultural projects that do not engage farmers in doing the actual job. Chinseu et al. (2019) observed that conservation agriculture (CA) in Malawi is overly reliant on financial assistance from international donor agencies, subjecting CA to the donor-recommended three-year project term limit. The short project periods are not in line with the gradual impact nature of CA (Pittelkow et al., 2015;

Findlater et al., 2019). As a result, CA is often regarded as failing to meet the aspirations of small-scale farmers (Baudron et al., 2012), because programs terminate before tangible advantages are realized. Given CA's reliance on'short-term' finance from universal donors, expert-led programs are widespread (Wood et al., 2016), diminishing farmers' feeling of ownership and satisfaction. On the other side, Chinseu et al. (2019) found that donor expectations of quick adoption encouraged promoters (NGOs that support CA technology) to compete and bring in unsustainable inducements to recruit farmers. However, promoters' 'push' tactics merely create serial dis-adopters, since 82 percent (246 respondents) of research participants stated that they could not continue practicing CA without obtaining incentives (Chinseu et al., 2019). Donor pressure at the global level results in inadequate methods to CA delivery at the district level, affecting project operations and eventually contributing to local disadoption (Chinseu et al., 2019).

Chinseu et al. (2019) reported the alleged inequitable allocation of funds in CA projects to cause conflicts amongst the farmers. Approximately 44% (132 respondents) of survey respondents quit CA project clubs mainly due to a lack of problem solving skills amongst the group leadership, making it tough to keep project members for the long term. The weak incorporation of CA in agricultural policies and disjointed agricultural strategies put pressure on resource availability and effectiveness of extension delivery, resulting in a poor distribution of financial and technical resources for CA activities (Mwase et al., 2014). Definitely, delivery of technical and consultation services to CA farmers becomes inadequate, characterized by irregular visits of extension officer, even though small-scale farmers'' general view that CA is not user-friendly (Ndah et al., 2014). Lack of regular knowledge support means that farmers have poor 'know-how' to efficiently practice and benefit from CA, thus leading to frustration and disappointment at the same time (Chinseu et al., 2019). In addition, the delivery of varied extension messages, largely due to incoherent agricultural policies (Chinseu, 2018), confuses CA farmers, pushing many farmers to return to conventional tillage practices understood to be less complex.

For sustainable agriculture technologies to be adopted in the Vhembe District Municipality's irrigation schemes, medium-term (at least five years) FPR and sustainable agriculture projects that provide farmers with necessary support (knowledge and

Materials) should be implemented. Resources needed to run the experiment should be distributed equally amongst the farmers to prevent conflicts that discourage other farmers from participating in the project. The project should allow farmers to test out the technology for themselves to identify the technology that works best for them.

5.2.2. Age and educational level's influence on sustainable agriculture practices

All the irrigation schemes are highly populated by pensioners, with relatively low education levels and the lower percentage of farmers who read agricultural information on their own. This makes adopting a different farming practice like sustainable agriculture difficult. The ability of a farmer to absorb professional knowledge increases with farmer's level of education (Bhandari, 2014). Hence, the less-educated farmer lacks knowledge of sustainable agricultural practices such as the standardized application of synthetic fertilizers and pesticides (Elahi et al., 2019). Consequently, with low level of education, there is significantly higher probability that the farmer will utilize pesticides excessively, leading to soil and water contamination due to higher pesticides concentration (Xu, 2004; Huang et al., 2008). Thamaga-Chitja and Morojele (2014) also stated that poor formal education for small-scale farmers in rural areas, in combination with their on-going practice of rain-fed agriculture, reduces their agricultural output. Low agricultural yield endangers farmers' livelihoods and food security since most small-scale farmers depend on agriculture (Sabahelkheir and Hassan, 2015).

5.2.3. Farmers' use of agrochemicals and their contribution to environmental pollution

Safety in agriculture and the resulting environmental and health challenges from pesticide usage are increasingly becoming world's area of concern (Dinham and Malik, 2003; Cooper and Dobson, 2007; Leyk et al., 2009). A higher dependency of farmers on synthetic fertilizer and pesticides coupled with limited knowledge of application including indiscriminate disposal of pesticides containers and fertilizer bags, pose a threat to soil, water bodies, non-target organisms and human health. Various studies reported the overutilization of agrochemical to have an adverse impact on the air, water, soil and non-target organisms and human health (Qi et al., 2002; Hou and Wu, 2010; Al Hattab and Ghaly, 2012; Bhandari, 2014; Elahi et al., 2019;). The biomagnification of some pesticides has resulted in the reproductive failure of some fish species and eggshell thinning of birds such as eagle owls, peregrine falcons andsparrow hawk (Al Hattab and Ghaly, 2012). Health consequence caused by pesticides in people include skin and eye inflammation and skin cancer (Al Hattab and Ghaly, 2012). Even though the effects of pesticides on agricultural goods differ corresponding to the kind of pesticide applied, all pesticide remains alter nutrient balance and diminish the quality of agricultural produce (Bourn and Prescott, 2002). The negative environmental impacts hinder the sustainability of the agricultural sector since healthy soil and water are the essential resources to produce agricultural products which are fit for human consumption. Minimizing the effects of agrochemicals on the environment and human health is a key to agricultural sustainability and safer production (Elahi et al., 2019). Across the four irrigation schemes, very few farmers were not using chemicals or synthetic fertilizers (they did not control pests and were using mulch or crop residual and animal manure for soil nutrients). However, they were not using them because pesticides and synthetic fertilizers were expensive. This supports the statement by Gaffeney et al. (2019) that African countries do not practice organic agriculture by choice, but because they do not afford the external inputs, hence their organic agriculture practices with poor yield cannot be regarded as being sustainable.

Across the four irrigation schemes, most farmers' claimed that their farming activities have no negative or positive impacts on the environment. This response shows that these farmers lack an understanding of practices that contribute to negative and positive environmental impacts. Similarly, in Huong Thuong, Commune, Dong Hy district Thai Nguyen province, Vietnam, Thanh *et al.* (2021) noted that most farmers have partial awareness of the negative effects of using plants pesticides repeatedly and improperly. This is because they were never taught how to use pesticides, including their impacts on the environment and their specific effects. On the other hand, even farmers who know practices that adversely affect the environment disregard such knowledge. For example, in Huong Thuong, 60 farmers were trained on using agrochemicals and were taught about the negative impacts of improper use (Thanh et al., 2021). However, only 56.7% of the farmers showed interest in adopting practices that will protect the environment (Thanh *et al.,* 2021).

5.2.4. Water use and management

All farmers from Dzindi, Folovhodwe and Rabali irrigation schemes are not managing water properly since they were not reducing their dependence on river water by practising water conservation strategies within their plots. Farmers were unwilling to put effort into water conservation strategies since they knew about rainwater harvesting within the field. Dzindi irrigation scheme farmers showed a very good understanding of rainwater harvesting strategies. They got this knowledge through their engagement with the Department of Water and Sanitation's national project on rainwater harvesting strategies. Adopting in-field rainwater harvesting (IRWH) could help conserve water in Dzindi Folovhodwe and Rabali irrigation schemes by reducing water extraction from the river. In-field rainwater harvesting involves the collection of in-field runoff and its storage in the soil profile. Since Makuleke farmers relied only on rainwater for irrigation, the adoption of IRWH could enhance soil moisture conservation for an extended period and enhance their productivity. The farmers used the IRWH technique in Gladstone village, outside Thaba Nchu town in the Free State Province of South Africa, for crop production (Gandure et al., 2013). This technique was proved a good instrument for poverty alleviation through enhancing food security in the area (Gandure et al., 2013). The IRWH technique is suitable for resource-poor farmers such as small-scale farmers in the Vhembe District Municipality since it does not require complex materials (Gandure et al., 2013).

Dzindi and Folovhodwe farmers did not mind cultivating close to water bodies because they cared about getting a plot to cultivate on, irrespective of its proximity to water bodies. However,such practice pollutes water bodies since there were no strategies to control rainwater runoff. Agrochemicals runoff from the agricultural fields situated close to water bodies cause eutrophication of water bodies and bioaccumulation of chemical substances in freshwater organisms (Li et al., 2021). Although there was a significant number of farmers in Dzindi, Rabali and Makuleke who could not cultivate close to water bodies, farmers were mainly concerned about the poor yield that the inundated environment produces than the environmental pollution that the practice causes.

5.2.5. Environmental pollution from agricultural chemical containers

Chemical waste disposal methods (throw, burry and burn) that Dzindi, Folovhodwe, Rabali and Makuleke irrigation scheme's farmers practice can be summarized as toxic to different spheres of the environment. Farmers did not remove pesticide residues from the applicator by rinsing with water, then disposing of the wastewater, but simply buried pesticide containers with pesticide residues. Although microorganisms can break down the pesticide compounds into non-toxic elements (Al Hattab and Ghaly, 2012), burrying such containers is considered toxic. This is because the polyester material of most of the pesticide's containers can't be decomposed by microbes and can cause harm to the environment. Selonen et al. (2020) studied the effects of polyester fibres on enchytraeids (*Enchytraeus crypticus*), springtails (*Folsomia can-dida*), isopods (*Porcellio scaber*) and oribatid mites (*Oppia nitens*), which play a vital role in soil decomposition food webs. The study found that both long and short fibres reduced isopods' energy reserves, and enchytraeids' reproduction decreased down to 30% with increasing long fibre concentration.

Disposing packaging by throwing is an issue that needs more attention, especially in Dzindi because 53.85% of farmers say that they disposed of the packaging in dense bushes close to the river. Thanh *et al.* (2021) considered throwing chemical waste in water bodies or on the ground next to water bodies as a wrong way of treating them and harming the environment. This situation directly affects the aquatic ecosystem, eventually affecting human wellbeing when utilizing water and food sources from the polluted water bodies (Thanh *et al.,* 2021).

Folovhodwe and Rabali farmers piled up empty pesticide containers (paper and plastic containers) and set them on fire. Although this method is cheap and accessible, it is dangerous to farmers, plants and animals (Al Hattab and Ghaly, 2012). This process emits gases, smoke, and smells into the atmosphere, as well as harmful residues in the containers. In open burning experiments on 22.7 kilogram pesticide containers, Adebona et al. (1992) found several incomplete combustion products, polyaromatic hydrocarbons, and low quantities of dioxins. Oberacker et al. (1992) found that after burning phorate bags, 2% of the phorate was released into the air and 0.5 percent remained in the solid leftovers. According to Felsot et al. (2003), bags containing atrazine released 13% of the leftover product into the air, whereas 25% remained residue. These data show that the temperatures required for full combustion were not met in order to obtain 99.99 percent or higher destruction capabilities (Felsot et al., 2003). Findings from these studies show that the burning practice employed by farmers in Folovhodwe and Rabali is harmful to the environment and the people. The agrochemical waste challenge can be addressed by engaging the local department of the environment from the local municipalities to help collect this hazardous waste. Makuleke had no significant practice of either one of the chemical disposal methods because most farmers did not use pesticides and chemical fertilizers since they could not afford such inputs. This renders the schemes' agricultural practices less harmful to the environment.

5.2.6. Biodiversity conservation within the farm

Production in agriculture relies on the function of a variety of regulating and supporting ecosystem services that include cycling of nutrients which maintains soil fertility, water flow and storage, and biological population control (Frison et al., 2011). Biodiversity is the fundamental building block in the provision of ecosystem services (Luck et al., 2003; Reid et al., 2005; Altieri et al., 2017). Nevertheless, Rabali and Dzindi significantly believed that biodiversity conservation benefits are only theoretical. They do not see any of that happening in their farms. Clearing all trees by all irrigation schemes' farmers deprive the schemes of crucial ecosystem services in agricultural production, such as the habitat provision for pollinators and agents of biological control (predators). Frison et al. (2011)

noted the yield increase linked with greater biodiversity due to numerous ecological functions carried out by various plant groups and the use of different niches.

The yield optimizer agricultural practice that almost all farmers from Dzindi, Folovhodwe and Rabali practised threatens biodiversity due to the intensive use of fertilizers. In Austria, Schmitzberger et al. (2005) observed a significant decrease of species numbers of both vascular plants and bryophytes with increasing mowing intensity and increasing fertilizing intensity. Schmitzberger et al. (2005) investigated the effect of farming style (yield optimizer, traditionalist and innovative) on biodiversity and found traditionalist and innovative farming styles to have more species than yield optimizers. Since the yield optimizer farming style reduces biodiversity, the functioning of the agricultural ecosystem deteriorates, resulting in unsustainable agricultural practices. On the other hand, the traditional farming practices (intercropping and fewer fertilizers input), which were practised by a very few farmers in Rabali and Makuleke provide diversity which enhances the resistance to outbreaks of pests and diseases (see Frison et al., 2011; Altieri et al., 2017). Intercropping of maize and groundnuts provide a symbiotic relationship where a leguminous plant (groundnuts) fix nitrogen for the maize, reducing the dependence on synthetic fertilizers. The hostile farmers' perceptions on having trees on the farm are because farmers do not know where the trees can be best planted so that they cannot hinder crop growth. Nordstrom and Hotta (2004) regard planting trees and particular crops (windbreaks) as the best method of controlling sediment loss resulting from farming operations (e.g., ploughing, planting, weeding and burning fields) that increase wind erosion and dust emission.

5.2.7. Conclusion

Generally, Dzindi, Folovhodwe, Rabali and Makuleke irrigation schemes' farmers lack knowledge of sustainable agricultural practices. They are also less interested in matters relating to sustainable agriculture but more interested in maximizing their crop yield. The farming practices that irrigation schemes' farmers are practising can be regarded as unsustainable because they pose threats to human health and the natural environment.

However, adopting sustainable agricultural practices by irrigation schemes farmers can be more profitable since there will be fewer agricultural inputs needed, and the production will not be at the expense of the environment and human health.

5.3. Extension services knowledge on sustainable agriculture

5.3.1. Impact of extension officers' knowledge of sustainable agriculture on farmers' adoption of sustainable agriculture

The study found that two extension officers out of four showed good knowledge of sustainable agriculture by explaining sustainable agriculture content well. Extension officers' knowledge of sustainable agriculture has considerable influence on extension officers' view of sustainable agriculture practice (Wheeler, 2008). As a result, extension officers influence farmers to adopt or disregard such agricultural practices (Wheeler, 2008). Judging from the way the two extension officers from Dzindi and Folovhodwe understood the content of sustainable agriculture, it is more likely that the extension officers from those two irrigation schemes could influence farmers from Dzindi and Folovhodwe to adopt sustainable agriculture. On the other hand, extension officers' lack of understanding of sustainable agriculture can result in farmers not adopting sustainable agriculture practices. For example, in the case of Rabali farmers, we do not expect them to consider the benefits of nutrients cycling when their extension officer regards nutrients cycling as theoretical but not practical in real farming. In Dzindi and Folovhodwe, where the extension officers had good knowledge of sustainable agriculture, there was a considerable number of farmers acknowledged the benefits of conserving biodiversity within the farm. Adnan et al (2018) reported that most of the farmers in underdeveloped regions are not aware of the most recent agricultural innovations geared toward yield increase without harming the environment. In order to increase farmers awareness of the recent inventions, Adnan et al. (2018) mentioned that agricultural extension officers in underdeverloped nations need to transfer the knowledge in a way that farmers of all age groups and levels of education would understand. Since not all agriculture extension officers have adequate knowledge on sustainable agriculture practices, the transfer of innovations such as sustainable agriculture practices to farmers appropriately and understandably will not happen unless the extension officers themselves go through some workshops on sustainable agriculture. This will only mean that sustainable agriculture practices won't be adopted easily in irrigation schemes where the extension officer does not know such practices.

In Selangor granary areas, knowledge sharing, particularly sustainable agriculture knowledge from knowledgeable extension officers, helped Paddy farmers to improve their farming styles and productivity (Kamarudin et al., 2015). As a result of improved productivity, Paddy farmers became even more active in farming activities in general because they received a technology (sustainable agriculture) that helped them reduce their production cost while they make more profit (Kamarudin et al., 2015).

The adoption of sustainable agriculture by farmers is influenced by extension officers' perception of sustainable agriculture, which is determined by extension officers' knowledge of sustainable agriculture. For farmers to understand and adopt sustainable agriculture practices, extension officers should be taught and understand the content of sustainable agriculture so that they can transfer to farmers what they know.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

This chapter concludes the study by summarizing the important research outcomes in accordance with the research aim, objectives and questions and the value and contribution thereof. It also proposes opportunities for future research and gives recommendations to diffent irrigation schemes' stakeholders.

6.2. Conclusion

This research aimed to investigate small-scale farmers' knowledge and the rate of adoption of sustainable agriculture. Results obtained from this study indicate that farmers do not know what sustainable agriculture is and tend to ignore it. They could not differentiate between sustainable and unsustainable agricultural practices. As a result, a lack of knowledge of sustainable agriculture makes it difficult for farmers to adopt sustainable agriculture. Furthermore, without any knowledge and understanding of what sustainable agriculture is and failure to differentiate unsustainable agriculture practices from sustainable agriculture practices means that farmers cannot make informed decisions on the choice of sustainable agricultural practices. Therefore, there is a need to fill the gap between science (sustainable agriculture) and practice.

In this study, the hypothesis that Vhembe irrigation scheme farmes do not have good perception of sustainable agriculture and are not practicing it either is accepted. For agriculture to be regarded as sustainable agriculture, both social, economic, and environmental aspects of sustainability should be met. Although there are other schemes that are thriving economically, their attitude towards the environment (not concerned about activities that compromise the well being of the environment) renders their agricultural practice unsustainable.

Since there was little focus on sustainable agriculture practices and adoption in Vhembe small-scale farmers, this study provides an overview of how small-scale farmers in the

Vhembe District Municipality view sustainable agriculture. Farmer's perception is crucial for successful agricultural practices that ensure high yield without jeopardizing the environment's wellbeing.

6.3 Recommendations

6.3.1 Future studies recommendation

To achieve sustainable agriculture in small-scale farming, future studies should consider transdisciplinary research that involves farmers, hydrology, environmental and agricultural scientists and practitioners to address problems that farmers face.

6.3.2. Recommendation to farmers, extension officers and government

- Farmers should consider harvesting rainwater for irrigation purposes during the dry winter season to reduce the strain on the already diminishing water sources on land (i.e. rivers, dams and reservoirs). Rainwater harvesting in the field can be done by creating artificial ponds between cultivated land and watercourse to reduce the amount of runoff while promoting infiltration. The artificial ponds will also help purify agriculture runoff by filtering excess nutrients and pesticides before the water gets into the river or any other watercourse. Creating vegetated buffer strips within the farm is also one of the strategies that can be used to reduce surface water runoff and increase infiltration that will keep soil wet for a bit longer.
- Farmers' committee should write a proposal seeking support from the government and NGOs to help them market their produce to local and national supermarkets. In other words, farmers should reach out to their potential market assistants.
- The Department of Forestry, Fisheries and Environment joining hands with the Department of Water and Sanitation and the Department of Agriculture, Land Reform and Rural Development should host an awareness campaign (at least

twice a year) where they will teach (with demonstrations) farmers about safe and sustainable agricultural practices and their benefits. This will help equip farmers with the right knowledge and help them make informed decisions regarding their farming methods.

- The local Department of Agriculture, Land Reform and Rural Development should advertise voluntary positions for accounting related graduates to teach farmers the basics of record keeping. This will help graduates to gain practical experience of bookkeeping while enhancing sustainable agriculture adoption when farmers can track the effects that are brought about by sustainable agricultural practices as compared to the unsustainable ones

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Appendix 1.

Small-Scale Farmers' Perceptions on Sustainable Agriculture: The Case of Vhembe District Municipality of Limpopo Province, South Africa

AIM: To investigate the knowledge and the rate of sustainable agricultural practices adoption among small-scale farmers.

SEMI-STRUCTURED INTERVIEW SCHEDULE for:

Dzindi, Rabali, Tshipise and Makuleke Irrigation Schems of Thulamela, Makhado, Musina and Collins Chabane Local Municipality

INSTRUCTIONS:

1. **Kindly respond to all questions**
2. **The interview schedule consists of 5 sections**
3. **Mark with an "X" where relevant**

1. SECTION 1.

BIOGRAPHIC DATA

1.1. Gender

Male

Female

1.2. Age distribution categories (years)

<30

31-40

41-50

51-60

61+

1.3. What is your position in the irrigation scheme?

Extension officer

Irrigation scheme manager

Plot holder

employee

1.4. Educational data

No formal education

Primary level

Secondary level

Degree/ Diploma

Postgraduate degree/ diploma

1.5. How long have you been actively farming? (years)

<5

5-10

11-15

16-20

21+

1.6. Field size

<1 ha

1-2 ha

2-3 ha

>3 ha

1.7. What is the main source of household income?

Pension

Farming

Farming and pension

Farming and employment

Non-agricultural (specify)

1.8. How many days do you spend on the farm in a week?

1-2 days

3-4 days

5-7 days

1.9. What is the distance between the homesteads and fields?

<500 m

500 m -1 km

1 km – 2 km

2 km – 3km

>3km

2- SECTION 2

FARMING PRACTICES

2.1. What type of agriculture do you practice? E.g., traditional farming, mixed farming (crop and animal production), monoculture or polyculture.

2.2. What types of crops do you farm?

2.3. What land preparation technology do you use?

2.4. What is the source of seeds for planting?

2.5. What is the main source of water?

2.6. What irrigation system do you use?

2.7. How do you harvest your crops?

For livestock farmers:

2.8. What kinds of livestock do you farm?

2.9. Where do you keep your animals during summer and winter?

2.10. What does your livestock feed on?

3- SECTION 3

FARM MANAGEMENT

3.1. What do you do to maintain or improve soil nutrients?

3.2. What do you do with crop residues (e.g., maize stalks/stubble)?

3.3. What are the strategies that you implement to minimize the effects caused by both wind and water erosion?

3.4. What strategies do you practice to conserve water as scarce resources?

3.5. What strategies do you use to control pests?

3.6. How do you control weed?

3.7. What do you do with the weed's biomass within the farm?

3.8. What is your view on having tree plants around or within the farm?

3.9. What do you do with the old farm equipment which no longer serves the purpose they were bought for? e.g. the licking water pipes, the bags that contain seed from the shops.

3.10. What is your view on a farmer, who is cultivating upstream, in a very close proximity to the water body?

4. SECTION 4

QUESTIONS ON KNOWLEDGE ABOUT SUSTAINABLE AGRICULTURE

4.1. What is your understanding of sustainable agriculture?

4.2. Where have you gathered the knowledge? E.g., radio, press, farmers meetings, etc

4.3. Have extension officers conveyed the knowledge (theoretical or demonstration) on sustainable agriculture?

4.4. What is your perception of sustainable agriculture?

4.5. Do you have any knowledge of some markets who want fresh produce from farmers who are practicing sustainable agriculture?

4.6. What is your perception of such markets?

4.7. How are the prices of the fresh products from sustainable agriculture compared to conventional agriculture?

4.8. Are there any benefits of preserving biodiversity that you see on the farm?

4.9. What environmental impacts (negative and positive) do you associate with your farming practice?

4.10. How can the negative impacts be avoided?

5. SECTION 5

ECONOMIC PERCEPTION

5.1. Do you cultivate for selling or only for household consumption? If you sell, where do you sell your products to?

5.2. What amount of money do you spend annually for agricultural input?

5.3. What is the amount of money do you generate in a year?

5.4. How many kilograms do you produce per hectare within a year? E.g., kilograms of maize, of cabbage, spinach etc.