WATER IRRIGATION COSTS AND FARM OUTPUTS: A CASE OF SELECTED CROPS IN LIMPOPO PROVINCE

by

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DISSERTATION

Submitted in the fulfilment of the requirements for the degree of

MASTER OF COMMERCE

In

ACCOUNTING

In the

FACULTY OF MANAGEMENT AND LAW

(School of Accountancy)

At the

UNIVERSITY OF LIMPOPO

SUPERVISOR: Prof M.B Fakoya

2022

DEDICATION

I dedicate this dissertation to both my parents Mr PG Dandane and Mrs ML Dandane and my supervisor, the late Professor MB Fakoya, this is for you.

DECLARATION

I declare that **WATER IRRIGATION COSTS AND FARM OUTPUTS: A CASE OF SELECTED CROPS IN LIMPOPO PROVINCE** is my work and all sources that were used or quoted have been indicated and acknowledged through reference and this work has not been submitted before at any other institution.

K.Danelane.

22 NOVERMBER 2021

Full names

Date

ACKNOWLEDGEMENTS

I wish to thank the Almighty God, through his Son, the Lord Jesus Christ for the amazing grace he bestowed upon me.

I also wish to thank the following people and institutions for their assistance:

The School of Accountancy of the University of Limpopo for allowing me the opportunity to do this study.

The Africa Centre for Sustainability Accounting and Management of the University of Limpopo.

The Risk and Vulnerability Science Centre of the University of Limpopo for the support, motivation and mentorship

The Kagiso Trust for their financial support and motivation.

I would like to express my appreciation to the following individuals for the roles they played during the duration of the study:

- My parents, Mr PG Dandane and Mrs ML Dandane, for their unconditional love, support and words of encouragement.
- My late professor, MB Fakoya, who guided me till the last days of his life. For his patience, motivation and always believing in my ideas and me.
- Professor Collins Ngwakwe for his unbelievable support, words of encouragement and helping me steer the ship to its destination.
- Mr G Nyrenda for his continuous guidance, motivation and mentorship.
- Prof O Ayaya for his words of encouragement and support.
- Mr T Chirecka for his support, guidance, motivation and mentorship.
- Mr Sono MB for his motivation and support.
- Ms Ledwaba NA for her support, motivation and encouragement.
- Ms Nakeng MV, for her words of encouragement and support.
- Ms Koza T, for her never-ending support, guidance and motivation.

ABSTRACT

Water scarcity is a problem for many countries across the world. Limpopo Province is no exception, as the province has regions that are arid and/or semi-arid. The accessibility of water and the management of water is amongst the critical issues faced by some of the rural farmers in the Limpopo Province. The challenge of inappropriate and inefficient use of modern irrigation technologies is associated with the exorbitant investment and operation costs, resulting in poor irrigation practices by smallholder farmers in the province, mainly affecting the production of citrus, avocado, nuts, potatoes and tomato production resulting in reduced yields and revenues. The study conducted a case study on the selected crop in the Limpopo Province, which included crops such as citrus, nuts, avocados, potatoes and tomatoes. The objectives of the study are to examine the influence that investments in water irrigation infrastructure has on the volume of farm yield, as well as to examine the influence of the cost of water irrigation systems on the volume of farm yield on the selected crops. The study used a survey research design, together with a mixed-method approach, whereby 50 farmers were purposively sampled in the Limpopo province. Primary data were collected from a focus group discussion and the administration of a questionnaire. A multivariate analysis was used to analyse the data. Out of 50 farmers, only 48 responded, which is a 96% response rate. From the analysis, the study found that investment in water irrigation has a positive and significant influence on the farm yield at a 0.01 confidence level. Furthermore, the OLS regression shows that a positive and significant relationship exists between the total cost index for Citrus and the farm yield. The total cost index has a varying effect on the distribution of farm yield. It is expected that an increase in the level of education will increase revenue. Overall, the industry may also need to look at the introduction of hybrid systems that are more cost-effective, that take advantage of solar and wind energy. Future research can look at the different crops in different provinces of South Africa.

Keywords: *Irrigation, Investment, irrigation infrastructure, irrigation cost, smallholders, farmers and yield*.

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 INTRODUCTION

Water scarcity does not only affect the Limpopo Province but the whole of South Africa and the world. The accessibility of water and the management of water are amongst the critical issues faced by societies around the world affecting economic, social and environmental development (Christ, 2014). Karuaihe, Mosimane, Nhemachena and Matundu (2014) state that South Africa is a "water-stressed" country. The insufficient supply of water to farmers and households increases the burden that already exists in communities because water is a scarce resource. Water is known to be a limiting factor for development in many economies around the world (Singh, 2014). Koehler, Thomson and Hope (2015) state that the lack of proper infrastructure and maintenance of these facilities will strain the supply of water to agricultural areas that depend on river and groundwater. Depleted and unmaintained water infrastructures will result in inadequate access to water by farmers and households (Domínguez, Torres-López, Restrepo-Tarquino, Paterson & Gowing, 2016). Mutambara, Darkoh, Atlhopheng (2016) found that unsustainable and insufficient access to water supply resulted in an adverse impact on economies. Kiendrebeogo (2012) further found that insufficient access to water affects crop production levels, as water sources are not easily accessible and are limited in the countryside. According to Rodda, Stenstrom, Schmidt, Dent, Bux, Hanke, Buckley, and Fennemore (2016), the three levels of government in South Africa are failing to create and maintain proper water policies and they aver that bulk water infrastructures are not prioritised. Butterworth, Sutton, and Mekonta (2013) state that most of the rural households and farmers are still faced with the unavailability of water. Furthermore, the gender imbalance in agriculture and the lack of promotion of gender equality in agricultural development often contributes to decreased productivity and loss of revenue (Peterman, Behrman & Quisumbing, 2014). Johr (2012) states that to enable rural farmers to expand production at the farm level, they need to have access to financial management education and financial resources with the aim to increase revenue and make farming sustainable. Weligamage, Shumway and Blatner (2014) state that the type of irrigation system used by the farmer will contribute to the decrease in water pumping costs and will increase the output level as well as increase the revenue of farmers. Gadanakis, Bennett, Park and Areal (2015) argue that although the quantity of water largely influences crop output level, other agricultural input costs influence the production level, such as seeds and fertiliser costs to mention a few. Weligamage *et al*. (2014) further maintain that the volumes of water used on crops and the duration of watering the crops will substantially increase the farm's yield. However, farmers incur additional irrigation costs to maintain sufficient and adequate water to water the crops.

1.2 PROBLEM STATEMENT

The challenge of inappropriate and inefficient use of modern irrigation technologies may be associated with the exorbitant investment and operation costs, which often lead to poor irrigation practices by smallholder farmers resulting in their inability to increase farm yield and revenue. Doulgeris, Georgiou, Papadimos and Papamichail (2015) argue that inadequate water availability for irrigation will affect crop output, as different crops need different amounts of water. Crops such avocados, nuts, citrus, potatoes and tomatoes are more likely to have different water requirements. Furthermore, the challenges of inadequate and insufficient irrigation infrastructure and excessive energy costs because of such inappropriate and inefficient use of modern irrigation technologies by rural farmers can be attributed to poor irrigation practices and an inadequate level of education (Wiebe and Gollenhon (2007). This is more likely to result in a relatively low level of farm yield. As such, there seems to be an indication that issues such as poor maintenance of irrigation infrastructure, the continuous increase in energy costs and the lack of institutional support may affect the production of citrus, avocado, nuts, potatoes and tomato production in the province resulting in reduced farm yields and revenues for the farmers.

The most crucial socio-economic issues that affect farm yield and the income of farmers are usually the farmer's level of education, and the know-how knowledge of the farmers (Mondal, 2011). This will likely affect rural indigenous farmers' ability to earn a sustained income in the semi-arid regions of the Limpopo Province in South Africa, resulting in unsustainable farm output and income. According to Karuaihe *et al.* (2014), the lack of necessary infrastructure to ensure access to water has dire consequences, especially to households and farmers. Karuaihe *et al.* (2014) state that the majority of the households that reside in rural areas mostly depend on crop and livestock farming to earn their income and therefore insufficient access to water places constraints on their ability to generate income. Gadanakis *et al.* (2015) aver that the changing climate, which results in more extended dry periods, changing climate requires farmers to irrigate their crops more regularly, thus increasing the cost of pumping water. Most rural farmers use boreholes to pump water. According to Gadanakis (2015), farmers often need to use large volumes of water for irrigation to produce quality farm produce. Therefore, it is more likely that rural farmers in the selected Province of Limpopo are located in semi-arid and arid regions and are likely to depend on ground water for irrigation. Hence, infrastructure plays an essential role in making water available to irrigate the crops. Weligamage *et al.* (2014) observe that water availability will affect the crop output level and consequently lead to differences in the revenue of farmers. Langarita, Choliz, Sarasa, Duarte and Jimenez (2017) attest that in the past years energy costs have continuously been on the rise and this has caused a significant barrier in the sustainability of farmers' income.

According to De Fraiture and Giordano (2014), investment in modern irrigation technologies has a positive correlation with smallholders' incomes and is often seen as a mechanism for poverty eradication. However, Wichelns (2014) argues that infrastructure investment in irrigation systems comes with both challenges and opportunities. Though the adoption of water irrigation has positive impacts on farm yield, it comes with more significant challenges and risks of inefficiency, capital funding and external factors such as waterlogging and rust of the irrigation systems (Giordano & De Fraiture, 2014). Inefficiencies and declining production levels are because of the use of small pumps, lack of information and the high cost of operation which lead to diminishing and or stagnant farm yields (Wichelns, 2014). The challenges of poor irrigation practices by rural farmers and the resultant high costs may have led to poor farm yield. The study aims to investigate this phenomenon, as no previous studies have been conducted about water irrigation costs and farm output within the Limpopo Province and mainly on the selected crops of avocado, nuts, citrus, potatoes and tomatoes.

1.3 RESEARCH QUESTIONS

This study's research questions are as follows:

- How do investments in water irrigation infrastructure influence the volume of farm yield?
- How does the cost of water irrigation systems influence the volume of farm yield?
- What effects does climate change (measured by water availability for irrigation) have on the volume of farm yield?
- How does the farmers' level of education affect the volume of farm yield?

1.4 OBJECTIVES OF THE STUDY

Based on the research questions, the objectives of the study are:

- To examine the influence that investments in water irrigation infrastructure has on the volume of farm yield.
- To examine the influence of the cost of water irrigation systems on the volume of farm yield.
- To examine the effects of climate change (measured by water availability for irrigation) on the volume of farm yield.
- To examine the influence of the farmers' level of education on the volume of farm yield.

1.5 SIGNIFICANCE OF THE STUDY

The growth and development of rural farmers who irrigate crops play a critical role in job creation and poverty eradication in rural communities within South Africa (Bunce, 2020). Rural farmers in South Africa mostly undertake to farm for household consumption, and only the remaining portions are sold for income (Cousins, 2010). The research study seeks to provide information on how farmers can maximise their production level by understanding the relevant input costs related to irrigation. This study will be beneficial to the farmer as it will provide information on how farmers can manage their production costs.

1.6 DEFINITION OF TERMS

Rural Economy – Spielman, Malik, Dorosh and Ahmad (2017) state that a rural economy is the study of farming and non-farming activities in the rural areas that produce a household income, which includes agricultural production, small village shops and local jobs.

Irrigation – Elzubeir (2018) defines irrigation as a human made way to apply water to the ground to ensure that the soil is sufficiently moist to allow crop cultivation.

Inadequate water infrastructure – Akinwale (2010) refers to inadequate water infrastructure as the shortage or the insufficient supply of resources to provide water.

Sustainable rural economy: According to Kaygusuz (2011), it is the principle of humans utilising the available resources and at the same time not undermining the resources for future generations.

Financial literacy of farmers: - financial literacy comprises the skill and knowledge that enables personnel to make informed decisions about their finances (Kiliyanni & Sivaraman, 2016).

Climate change – Ferguson and Maxwell (2012) contend that climate change is the change in weather patterns, because of the increasing atmospheric temperature.

Irrigation cost – According to Wichelns (2014), irrigation costs include the drilling of wells, the installation of water pumps, the acquisition of the equipment and the construction of dams and ponds to harvest precipitation. Giordano and De Fraiture (2014) state that other costs that relate to irrigation relate to the direct and indirect costs of ownership and operation.

Systems costs – Zebardast, Khoob, Fatahi and Rahimi (2015) state that these are the costs incurred to manage, operate and maintain a system, component or device. Zebardast *et al.* (2015) further add that annual irrigation systems cost includes energy, labour, operation, and maintenance costs.

1.7 SUMMARY OF THE CHAPTER

This chapter outlined the background of the study as well as the research questions and objectives that are to be answered through conducting the study. It further provides the significance of the study together with the definition of terms used in the study. The next chapter presents a review of the literature related to water irrigation costs and farm output.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

Chapter one outlined the background and objectives of this research. The research questions were constructed as well as carrying out a brief analysis of literature on water irrigation costs and farm output. This chapter reviews extant literature relating to factors that influence farm output, namely, water irrigation costs, level of education, and other factors influencing farm output. Section 2.2 discusses the conceptual review that was largely used to understand how water irrigation costs affect farm output. Section 2.3 provides a discussion of the theoretical review employed in the study. Section 2.4 discusses the theoretical framework that is cost-benefit analysis theory to understand the relationship between irrigation cost and associated benefits. Section 2.5 provides a discussion of the empirical literature, which is divided into the following sub-topics; section 2.5.1 Climate change and farm yield, section 2.5.2 Water infrastructure investment and volume of farm output. Section 2.5.3 cost of energy usage (systems costs) and farm yield. Section 2.5.4 outlines the socio-economic issues (level of education and financial literacy) of farmers and the volume of farm output. Section 2.6 presents a conceptual framework of the study. Lastly, section 2.7 concludes the chapter with a summary of the main issues that were discussed in the chapter

2.2 CONCEPTUAL REVIEW

Smallholder’s commonly known as rural farmers are found in the countryside and mostly in villages. Huang, Rozelle, Zhu, Zhao and Sheng (2020) state that the rural economy cannot be ignored as it plays a vital role in poverty alleviation and job creation in rural areas. Furthermore, farming-related activities are a major source of livelihood for rural communities; however, the lack of financial resources to the rural economy to boost smallholder’s production has been a serious setback for the rural farmers (Dharmawan, Mardiyaningsih, Komarudin, Ghazoul, Pacheco & Rahmadian, 2020). Hence, there has been observed that inadequate water infrastructure is one of the reasons smallholders are not realising their full potential (Mghase, Shiwachi, Nakasone and Takahashi, 2009). Plunkett, Chaddad and Cook (2010) have shown that inadequate investment into irrigation infrastructure will often lead to smallholders not having the adequate irrigation resources to use in their agricultural businesses. For rural farmers, the concept of irrigation is very important as this is considered a major contributor to the agricultural process (Darshna, Sangavi, Mohan, Soundharya & Desikan, 2015).

The utilisation of irrigation has enabled reliable water supply throughout the season for farmers (Rosa, Chiarelli, Sangiorgio, Beltran-Peña, Rulli, D’Odorico & Fung, 2020). As such, the use of irrigation has improved agricultural production for the rural farmers and most importantly, irrigation provided rural farmers with relatively higher yields as compared to rain-fed crops (Darshna *et al.,* 2020). With the use of irrigation improving farm yields, rural farmers are more likely faced with challenges of increasing operations and running costs, hence, the concept of irrigation and systems costs that rural farmers need to plan and budget for. Wichelns (2014) is of the view that like any process of production, farmers also incur costs related to their type of business and those costs are mainly split into two categories namely direct and indirect costs. Hence, some knowledge about cost management in the farming business will more likely play role in understanding the system's costs. Therefore, it is essential for the farmers to be financially literate (Abubakar, 2015). Financial literacy will equip the rural farmers with the necessary skills that will improve their financial acumen (Kiliyanni & Sivaraman, 2016).

The concept of climate change was introduced to the study as climate change is closely linked to the agricultural sector and may in one way or the other affect crop yield. Pradhan, Sijapati and Bajracharya (2015) contend that the effects of climate change cannot be ignored as climate change significantly affects farm yield. To maintain adequate levels of farm yield, farmers need to make a substantial investment into irrigation infrastructure and have an understanding of cost management (Wichelns, 2014).

2.3 THEORETICAL REVIEW

This section contains the theoretical review of the input-output model and the theory of cost

2.3.1 The input-output model

The input-output model considers the relationship between usage and outcome (Duchin, Levine & Stromman, 2016). It is considered a set of variables used to achieve a specific outcome, that is, to determine a set of input variables that will produce the best output (Sedlmair, Heinzl, Bruckner, Piringer & Moller, 2014). In this vein, water used for irrigation is one of the inputs required by rural farmers to enable farm productivity, which will subsequently result in crop output. The input-output model is essential in determining the input variables required to produce sustainable crop output. Atan and Arslanturk (2012) state that the input-output model is the applicable approach in measuring the correlation between input and output. An increase in input costs will, in return, increase the projected yield levels (Atan & Arslanturk, 2012). As such, the input-output model is relevant for this study in determining how rural farmers apportion their inputs, especially water used for irrigation, to obtain a clearer understanding of the relationship between irrigation input and farm output. The input-output model depicts the interactions between both the direct and indirect costs incurred in the production of a product and shows how a change in either one of the inputs affects the expected output (Hallegatte, 2008). In support, Hatirli, Ozkan and Fert (2005) contend that input constraint has a significant effect on the level of output. Thus, farmers are required to manage water effectively and efficiently as an input to maximise the farm yield per water volume used for irrigation. In a study conducted by Hamedani, Shabani and Rafiee (2011), they used the input-output model to determine the energy inputs used to achieve a desired output of the potato production. Hamedani *et al*. (2011) calculated the input-output ratio to depict the relationship between energy inputs and the yield achieved by farmers within the Kaboud Rahang region in Hamadan province, in Iran. Therefore, the input-output model can assist farmers to come up with an estimate of either how their production inputs, mainly water irrigation costs, may have affected their farm output, which can positively or negatively affect farm revenue.

2.3.2 The Theory of cost

Duchin *et al.* (2016) assert that the theory of cost is the behaviour of costs regarding one or more production factors or the level of output and is concerned with the relationship between input costs and output levels. According to Sedlmair *et al*. (2014), most firms measure the value of their input variables against the output. Levi, Latruffe and Ridier (2016) argue that for the theory of cost to be workable, farmers need to assume an expected input cost and expected maximum output levels. Cost components play a critical role in industrial production processes, including the agricultural sector. Hence, the theory of cost is relevant for this study as it looks to consider the composition of water irrigation costs of farmers by measuring those costs against farm output value.

According to Pfouts (1961), distinguishing between the different types of costs (fixed and variable costs) incurred in the process of production is essential in decision-making. Variable cost is the cost that varies with the level of output, where the total cost in the short run can be manipulated by the firm (Pfouts, 1961). Pfouts (1961) describes the fixed cost as the cost that remains constant regardless of the level of output, and the total cost unchanged in the short run. The above-mentioned study clearly outlines the types of costs that can be incurred by the firm. Because farming is a business both the smallholder and the emerging commercial farmer will incur either one of the costs (variable or fixed). However, an understanding of the cost theory will assist farmers in classifying costs about water irrigation accurately. Moreover, being able to accurately classify costs that are variable as variable and those that are fixed as fixed will assist farmers to maximise their profit. Silva and Stefanou (2003) state that to minimise cost, a careful and well-planned production schedule is necessary when making decisions about the inputs required for production. Therefore, smallholders and emerging commercial farmers should have the ability to plan for their cultivation season. This planning includes identifying their water irrigation needs and associated cost drivers by classifying the cost as either variable or fixed.

2.4 THEORETICAL FRAMEWORK

This section provides a discussion on the theoretical framework used in the study.

2.4.1 The Cost-Benefit theory

Almansa and Martinez-Paz (2011) state that cost-benefit is a process used to evaluate a decision to know whether to undertake a project or not. Individuals face the task of deciding on assist in the decision whether to decline or accept a project, and this takes into consideration the aggregate benefits and costs, where the benefits outweigh the cost (Singer, 2011). Moreover, rural farmers are facing the challenge of making investment decisions on water irrigation infrastructure where the initial cost of new investments may be higher but eventually yields a higher benefit to the farmers in the long-run. Hence, the cost-benefit theory is appropriate for this study that examines the benefit for rural farmers of investing in irrigation infrastructure.

Upon the use of the cost-benefit analysis (CBA), the farmer can determine which project to undertake, and which one is most profitable or not (Koester & Tangermann, 1977). In the decision-making process, the CBA will be ingrained to augment the entire benefits of an investment, which considers the benefits less the cost in totality and the impact on the environment (Haruvy, 1997). Within the cost-benefit analysis, the total benefit is the total gain of a product at a given price (Koester & Tangermann, 1977). According to Dickinson, Balduccio, Buysse, Ronsse, Huylenbroeck and Prins (2015), after adopting a new strategy, farmers will either in the present or future expect to either be in a position where they gain significantly or suffer potential losses from the associated investment. The cost-benefit analysis proves to be an essential decision-making tool that will assist farmers in making a beneficial decision at a farm level. Furthermore, farmers will be able to calculate the benefit from the associated investment in irrigation to assess whether the water irrigation benefits outweigh the water irrigation costs because of increased farm yield.

2.5 EMPIRICAL REVIEW

This section reviews the different extant literature, to further understand the phenomenon surrounding water irrigation costs and the volume of output for farmers.

2.5.1 Climate change and farm yield

Wada, Wisser, Eisner, Florke, Gerteen, Haddeland, Hanasaki, Masakie, Portmann, Stacke, Tessler and Schewe (2013) state that in the coming years water to irrigate crops will become unreliable as a result of uncertainties associated with climate change, for instance, the change in rainfall patterns and more extended drought periods. Fischer, Tubiello, Velthuizen and Wiberg (2007) state that climate change is directly affecting cultivation, and this has dire consequences on agricultural water demands and its availability. Projected climate change will most likely increase the burden of water scarcity around the world, mostly in the semi-arid and arid regions such as the Middle East and most parts of Africa (Fischer *et al*., 2007). Pradhan *et al,* (2015) indicate that agriculture is one industry that is highly prone to the effects of climate change. Its variations in weather temperatures, rainfall, wind speed and changes to the ozone layer can significantly impact crop production and farm revenue. Pradhan *et al*. (2015) point out that there is a wide range of adaptive strategies that farmers can implement to cope with climate change; these include financial assistance, modernisation of irrigation systems, implementation of new management practices and public-private partnerships specifically tailored to respond to specific farmers' location and the circumstances surrounding it. Thus, farmers are faced with the inevitable, that is climate change, and to remain sustainable, farmers have to adopt measures that suit their individual needs regarding their farming conditions and which will ensure production remains economically sustainable. According to Mushtaq, Maraseni and Rearden-Smith (2013), the changing weather patterns caused by greenhouse gases (GHG) emissions will result in more extended drought periods and change in precipitation in many regions across the continent resulting in the reduction of accessible water available for irrigation. Hence, sustainable water availability for agriculture is closely linked to rainfall and longer dry periods will affect water availability for irrigation. Gohari, Eslamian, Koupaei, Bavani, Wang and Madani (2013) submit that climate change is a limiting factor to sustainable crop production; yet at the same time in other regions, climate change positively influences farm produce (crop output levels).

Kuster and Wangdi (2013) conducted a study in Bhutan to understand the impact of water availability on crop production and the farmers' related costs of applying adaptive measures towards climate change. Most of the participants (91%) in the study area contend that water availability in irrigation channels and rivers has significantly changed over the past decades (Kuster & Wangdi, 2013). However, Pradhan *et al*. (2015) argue that the use of streamflow to approximate water availability in basins resulted in inadequate data in the research area; it was impractical to precisely examine the trend in the streamflow. Furthermore, respondents in the study area are of the view that there has been a decline in water availability for cultivation purposes and within the agricultural sector in recent years. Eighty-four per cent attest to a diminishing water supply in the past decade (Pradhan *et al*., 2015). Nevertheless, farmers tend to associate water availability with the depth level of the aquifer (groundwater). In contrast, the truth behind water availability is influenced mainly by the extraction and recharge rates, weather patterns and the nature of the well (Varghese, Buysse, Frija, Speelman & Van Huylenbroek, 2013). Although water availability trends cannot be accurately analysed, water available for agricultural irrigation is gradually declining and consequently, farmers may have inadequate water supplies to irrigate their crops. These inadequate water supplies might lead to declining production levels, thus adversely affecting farm revenue and the sustainability thereof of smallholders and emerging commercial farmers. Relevant studies in the past years show that climate change is a force to consider. For example, a study conducted by Ju, Van der Velden, Lin, Xiong and Li (2013) found that climate change will significantly affect the soil moisture content and as such can reduce farm yields.

Furthermore, climate change will have adverse effects on water irrigation supply to farms (Shahid, 2011). It is more likely that climate change will affect the irrigation industry, and farmers who are reluctant to apply adaptive measures will suffer a decrease in production and generate insignificant farm revenue. In support of the claim that climate change will have negative impacts on the agricultural industry, Ju *et al*. (2013) argue that achieving positive results from climate change is possible. Given the inevitability of climate change, the agricultural industry is most likely to be affected by climate change because future climate change will change localised water resources and soil-moisture content (Calzadilla, Rehdanz, Betts, Falloon, Wiltshire & Tol, 2013).

Extant literature suggests that climate change has both indirect and direct impacts on irrigation agriculture. Often, it is because of the increasing temperatures and the reduction in soil moisture that farmers are forced to irrigate more to produce crops and to generate revenue. Multiple measures that affect water availability under irrigation agriculture studied in river streams, and aquifers indicated that an increase in temperature, infrequent rainfall, coupled with over withdrawal of water might lead to a reduction in water availability (Xiong, Holman, Lin, Conway, Jiang, Xu & Li, 2010). Subsequently, water availability and the overall water balance can significantly alter with variations in temperature (Kusangaya, Warburton, van Garderen & Jewitt, 2014). Furthermore, the increase in temperature and the variations in rainfall patterns that come with climate change creates a dilemma for irrigation water demand (Wada, Wisser, Eisner, Florke, Gerten, Haddeland, Hqnasaki, Masaki, Portmann, Stacke, Tessler & Schewe. 2013). On account of increasing temperatures, the soil is most likely to lose moisture rapidly and this may lead to smallholders and emerging commercial farmers having to irrigate the crop to ensure continuous high crop yield levels. However, this may come with extra costs related to irrigation, thus hindering farm profits.

Global warming will affect local and regional water sources and most certainly lead to an increase in irrigation-related energy costs (Ferguson & Maxwell, 2012). A large body of literature identifies high temperature, evaporation, changes in precipitation, and the loss of soil moisture as some of the indicators of climate change and as such, they have a direct impact on crop productivity (Calzadilla *et al*., 2013). In addition, factors such as precipitation, temperature and evaporation are proxies to detecting how climate has changed over time (Kusangaya *et al*., 2014). Similarly, variations in rainfall and fluctuations in temperature will alter the soil-moisture content through evapotranspiration (Ferguson & Maxwell, 2012). Furthermore, researchers from China have investigated the impact of temperature on farm productivity by collecting data about the temperature and rainfall pattern from the Tongwei Meteorological station. The results show that there has been an average increase in the mean temperature and a decrease in annual rainfall patterns (Xiao, Zhang, Li, Wang, Yao, Zhao & Bai, 2010). This indicates that increasing air temperature and lower rainfall patterns are most likely to be unambiguous evidence of climate change, and as a result, the farmer's yield is under potential threats of reduction.

Studies conducted in South Africa analysed temperature changes. For example, Tshiala, Olwoch and Engelbrecht (2011), in a study conducted in the Limpopo province catchment area in South Africa, saw a 0.12˚C increase in average temperature in the past decades. Furthermore, Collins (2011) revealed that temperature trends show a significant increase in temperature in the southern parts of Africa. In addition, Mideksa (2010) reports that a percentage increase in the atmospheric temperature will for the time being improve crop productivity in regions of lower atmospheric temperature and vice-versa. However, climate change is not entirely bad for all regions of the world, as some parts of a country will benefit, while others will suffer greatly, especially the arid and semi-arid regions. According to Xiao *et al*. (2010), there is no proof that climate change will decrease farm productivity by 5 to 10 per cent and that specific crops like wheat and maize will be significantly affected. Shahid (2011) studied how climate change will affect irrigation water. The study showed that climate change increases the demand for water irrigation by a significant amount.

This will thus lead to increased irrigation expenditure because of the continuous irrigation required to keep soil moisture (Shahid, 2011). It is likely that climate change will change the rural and emerging commercial farmers cost structure, and hence their understanding of the cost function will help farmers in classifying these added cost dilemmas. As such, they will appropriately manage their irrigation costs with the adoption of relevant irrigation technologies and practices that will help against climate change. Mushtaq *et al*. (2013) found that an improvement in water irrigation infrastructure will help farmers in coping with climate change effects, even though the improvement also correlates with an increase in GHG emissions, but the improvement is financially rewarding, and the benefits outweigh the environmental costs. Schlenker and Lobell (2010) suggest that although climate change may negatively impact agriculture in arid and semi-arid regions across the world, agriculture in Africa would feel the most significant pinch. Moreover, with climate change, not much can be said about the different outcomes of farm outputs in different fields, villages, and countries (Schlenker & Lobell, 2010). Therefore, this could mean that climate change effects will have a different impact on various places and crop types, ultimately resulting in lower crop yields.

2.3.1.1 Type of water source

According to Siebert, Burke, Faures, Frenken, Hoogeveen, Doll and Portmann (2010), three viable water sources may be considered to supply water for irrigation. Siebert *et al*. (2010), distinguishes these water sources to be (a) groundwater which is found underground in aquifers (b) surface water which is located above the earth surface either in river, lakes and dams (c) Non-conventional water which is water that has been recycled.

2.3.1.2 Groundwater

According to Zahid and Ahmed (2006), productivity in semi-arid and arid regions has increased significantly using aquifers to access water for irrigation to cultivate crops. For instance, groundwater was used to cultivate an estimated sixty-two per cent of the arable land in Bangladesh. Yang, Chen, Pacenka, Gao, Ma, Wang, Yan, Sui and Steenhuis (2015) found that most of the water used for irrigation in wheat production is obtained from aquifers and has substantially increased the crop productivity (output) of wheat. Therefore, groundwater supplies an alternative water source for farmers, and if water levels are not depleted, satisfactory crop yield is obtained by farmers. However, Zhang, Hu, Tian, Yao and Sivapalan (2014) found that a shallow aquifer has a high concentration of saline which erodes the soil quality and results in loss of agricultural productivity.

In contrast, distant aquifers cause the natural vegetation to deteriorate as the water contains saline. This negatively hampers the growth of the agricultural industry (Zhang *et al.,* 2014). Soil salinization results in low farm outputs, and this may significantly influence the farmer's ability to generate a higher income. Hence, farmers can reduce the saline content in the soil by diluting the water source using chemicals or by laying underground irrigation pipes which leads to further costs being incurred. The World Bank encouraged the use of groundwater (boreholes) to access water for irrigation, and this method of water use accounts for more than 114 000 Ha for borehole irrigation in Nigeria (Woodhouse, Veldwisch, Venot, Brockington, Komakech & Manjichi, 2017). Here farmers are inclined to draw/pump water from shallow wells or from deep aquifers to access water for irrigation purposes (Woodhouse *et al*., 2017). Besides, this source of water available for use by farmers enables smallholders as well as emerging commercial farmers to access water for irrigation throughout the year and ensure that productivity increases. Shallow and deep aquifers are the practical solution for both rural households and farmers to meet their water demand for both household consumption and irrigation need in arid and semi-arid regions (Calow, MacDonald, Nicol & Robins, 2010). No doubt, groundwater is a crucial resource for crop production; unfortunately, the valuable input is slowly under stress due to over-extraction for irrigation (Hu, Moiwo, Yang, Han & Yang, 2010). In addition, aquifer levels are gradually declining at an average of 1.5 metres annually (Moiwo, Yang, Li, Han & Yang, 2010). Groundwater is a significant input for irrigation agriculture. Yet, because crop production significantly relies on groundwater for irrigation in the arid and semi-arid region this may lead to declining groundwater levels. Consequently, water as an input to irrigation agriculture will be inadequate and insufficient thus reducing crop production levels and farm revenue. Karimi, Qureshi, Bahramloo and Molden (2012) also confirm that the ease of water accessibility and availability of water are benefits associated with the use of groundwater (tube-wells). Furthermore, this affords farmers the ability to cultivate year-round even during the dry seasons and that increases the overall production rate and income (Karimi *et al*., 2012). The declining levels of groundwater are however a challenge.

2.3.1.3 Surface water

Molden, Oweis, Steduto, Bindraban, Hanjra and Kijne (2010) state that the volume of the water available for irrigation in streams is gradually reducing because of the increasing demand for water by households, cities and industries. In enabling continuous sustainable farm production, farmers often resort to precipitation harvest to maximise the benefits of rainfall. Individuals who pump water upstream may, in return, reduce the water available for downstream agriculturalists (Molden *et al.,* 2010). As such, the harvesting of rainwater will increase the availability of water for irrigation and ensure that crops get a sufficient allocation of water and so improve crop yield at a lower marginal cost. The furrow irrigation system diverts water from a permanent mountain stream and makes it available for irrigation purposes. Beekman, Veldwisch and Bolding (2014)claim that the Southern African region has witnessed over 100 000 Ha of land irrigated by means of the furrow system. The majority of the farmers make use of this system to cultivate crops and most notably during the dry season to augment the lack of water during the dry spell (Woodhouse *et al*., 2017). Karimi *et al*. (2012) found that in most cases, surface water users must wait their turn to irrigate their crops because some farmers are upstream and others downstream. As a result of this turn-taking, a farmer’s crops are likely to suffer from water stress and may lead to lower yields. For example, in a survey conducted in Iran, surface water yields of 2.8 tonnes per hectare of wheat, which was found to be significantly lower than the 4.1 tonnes per hectare of wheat produced through groundwater irrigation.

2.3.1.4. Non-conventional water

Cassaniti, Romano, Hop and Flowers (2013) contend that the ever-growing population and the food required to feed the society puts pressure on agriculture as there is a scarcity of water to irrigate crops to ensure food security. Researchers and farmers alike are considering the use of wastewater or desalinated water for the cultivation of crops. The non-conventional water sources for irrigation are becoming a significant resource to assist farmers in ensuring sustainable crop production (Pedrero, Kalavrouziotis, Alarcon, Koukoulakis & Asano, 2010). Moreover, wastewater and desalinated water resources are becoming a reliable source of water that can be used for irrigation to fill the already existing gap posed by freshwater scarcity. According to Pedrero *et al.* (2010), the increase in saline in non-conventional water resources for cultivation also poses a threat as the saline causes the crops not to grow adequately.

It also causes soil and yield challenges, and specific mineral compounds are stored in excessive volumes that hinder and diminish farm harvest. Therefore, the toxicity found in non-conventional water builds up over time and often farm productivity is reduced and then a reduction in economic benefit accruable to farmers ensues.

2.5.2 Water infrastructure investment and volume of farm output

The majority of the irrigated croplands around the world are faced with challenges of ageing and dilapidated infrastructure and thus experience a decline in production. The decline in production affects the farmer’s ability to maintain and repair the irrigation infrastructure (Ward, 2010). This sounds an alarm to farmers, both smallholders and emerging commercial farmers, to see the need of investing in irrigation infrastructure. While distinguishing between expenses required for operation and maintenance of irrigation infrastructure from the capital costs, Turral, Svendsen and Faures (2010) see investment as the expenditure incurred to create an environment suitable for the production of economic outputs. According to Weligamage *et al.* (2014), having proper irrigation infrastructure will lead to increased production levels per hectare, thus increasing the revenue of farmers. Water is essential for the agricultural sector with uses ranging from irrigation, cleaning of crops, and for livestock (Gadanakis *et al*., 2015). However, several studies point out that inadequate infrastructural investment into water irrigation maintenance, water application and the water conveyance structure, can lead to wasteful water uses and leakages (Farmani, Abadia, & Savic (2007). In support of the claims, Ward (2010) found that water conveyance systems account for up to 25% of water losses, while on-farm structures (pipelines) account for as much as twenty per cent and due to the inefficient and improper water irrigation technologies a further 10 to 15% of water is lost. This is clear evidence that due to the bulk of the water being wasted (lost) through inadequate irrigation infrastructure and improper water application practices, the bulk of water wasted might lead to the incurrence of further pumping costs and in some cases reduce productivity, which, in turn, leads to declining farm revenue. Previous studies have recently investigated the fruition of water irrigation infrastructure investment. For example, a study in Pakistan shows that accessibility of irrigation infrastructure helps to eradicate poverty; it also suggests that adequate and improved watercourse lines improve water use and saves water, leading to higher cultivation intensity and an increase in production levels and ultimately improved farm revenue (Ward, 2010). Thus, farmers may be assured that the adoption of irrigation technologies might put them in a better position to increase crop yields and income.

Tarjuelo, Rodriguez-Diaz, Abadía, Camacho, Rocamora and Moreno (2015) argue that installing a proper irrigation system will save electricity costs as well as improve water use efficiency and in return lead to increased productivity and income of farmers. It is more likely that for smallholder farmers, initiatives on water irrigation infrastructure investment will increase productivity and make them economically sustainable. According to Weligamage *et al.* (2014), the revenue generated by farmers is linked to the availability of water as an input resource to crop production. Nakawuka, Langan, Schmittera and Barron (2018) found that through irrigation farmers can manipulate cropping seasons because water is available throughout the year. This means they can cultivate their land with cash crops and take advantage of the high market (commodities) price of certain agricultural products in the food market. Within the context of this study, a semi-arid region with deficient rainfall, the issue of water availability throughout the year through irrigation may not apply. The assertion by Nakawuka *et al. (*2018) may not be valid for the semi-arid region under consideration. The reason for this is that more energy (with concomitant extra costs) is required to pump water from available sources to the farming area.

Moreover, Weligamage *et al*. (2014) argue that if increased water volumes are pumped to water the crops this will result in increased crop output levels leading to increased revenue for the farmers. Trajuelo *et al*. (2015) found that the use of irrigation infrastructure increases productivity up to six times and generates profit margins that are better than those of rain-fed crops. Therefore, the installation of appropriate irrigation infrastructure will assist farmers in reducing the energy costs related to irrigation and may maintain or even increase their crop yield. Investment into proper irrigation infrastructure has proven to be cost-effective (Levi *et al*., 2016). Nakawuka *et al.* (2018) found that investment into irrigation is a driving force that could enable subsistence farmers to become emerging commercial farmers and later also develop into commercial farmers. Additionally, Tarjuelo *et al*. (2015) note that water usage for irrigation can be significantly reduced when the appropriate irrigation system is used and at the same time productivity remains constant and at the same time result in an increased output yield. Mghase *et al.* (2009) attest that inadequate water irrigation infrastructure hinders farm yield. Water is a significant input along with the other inputs, namely, labour, fertilizer and pest control.

Plunkett *et al.* (2010) state that as shown by literature, funding constraints within the agricultural businesses exists because of high-risk bearing costs associated with the investment. Additionally, modern irrigation technologies cost more than traditional practices of irrigation (Monteiro, Kalungu & Coelho, 2010). According to Plunkett *et al*. (2010), the lack of investment funding by private irrigation owners is due to the incapability to source adequate risk capital to finance infrastructure. However, on-farm investments mostly have to do with the individual farmer's resources, which leads us to what is known as private irrigation investment (Wichelns, 2014). Nevertheless, farmers receive significant help from such investments. Such help may, for instance, be used to acquire motor pumps. The investment and the use of motor pumps lessen the amount of labour required to lift and convey water to the crops (Monteiro *et al*., 2010). According to Wichelns (2014), the benefits associated with private investment of irrigation infrastructure include increases in production levels and improvements in farm revenue. This is due to the timely and sterling accessibility to surface and groundwater that has been long stored in an aquifer or harvested through precipitation. Denison, Dube, Masiya, Moyo, Murata, Mpyana, Van Averbeke, and Van Averbeke (2016)concur that significant infrastructural investments need to take place to allow for effective and efficient irrigation farming. The literature suggests that although the individual farmers themselves invest more and more in irrigation, they are at times faced with capital constraints due to higher risk-bearing financing models. However, smallholders and emerging commercial farmers will be able to significantly benefit from their investment efforts in water irrigation infrastructure. Namara, Hope, Sarpong, De Fraiture and Owusu’s (2014) findings show that in Ghana the imports information shows that over the past years since 2003 more than 65 000 pumps and implements have been imported with an estimated total value of $ 8 million. Subsequent to this, the majority of the systems used for irrigation would roughly cost the farmer between

R40 000 and R150 000 per ha taking into consideration water conveyance infrastructure and leaving out storage facilities (Denison *et al*., 2016).

Additionally, farmers may incur storage costs (storage tank installed) that could cost R1000 per cubic metre. Considering the above, access to the import market and the efforts made by farmers to undertake private investment of these infrastructure improvements can be seen to be a progressive step towards sustainable irrigation development. Furthermore, the farmer should invest in fixed assets that make water accessible. However, the associated investments in these fixed assets place a financial strain on the farmers as it increases the cost to pump water through aquifer extraction (Varghese *et al*., 2013). Perez-Perez, Garcia, Robles and Botia (2010) separate irrigation costs for citrus orchards into overhead costs, running fixed costs and variable costs. Tayel, Ebtisam, Shaaban, and Sabreen (2010) point out that included in the irrigation system costs are both fixed and variable costs. Variable costs include labour costs, energy costs, repairs and maintenance. Fixed costs, amongst others, include interest and acquisition costs. Hence, a crucial fixture within the irrigation cost phenomenon would be that the farmer should understand that in all cases he/she is more likely to incur both fixed and variable costs in the process of irrigation. Furthermore, they must view these costs as mixed total irrigation costs which give them a production advantage and improve farm yield and income.

Subsequently, Boyer, Larson, Roberts, McClure and Tyler (2014) suggest that farm-specific irrigation costs cannot be readily determined because the cost is affected by different factors such as the size of the field, depth of the well, energy source, irrigation system and the like. Amongst other things, irrigation costs can be split into two main costs, namely, capital costs and systems costs. Additional capital costs include the acquisition of a pump, drilling of the well, centre-pivot, and installation; while the systems costs are the costs associated with energy usage, maintenance and the cost of labour (Boyer *et al*., 2014). Therefore, at any given stage the farmer must consider multiple factors before committing to an investment decision as this decision is influenced by field size and the energy used to operate the irrigation system. This is crucial, as the farmer needs to operate a cost-effective system that will minimize irrigation costs and maximize profitability from the yield output.

Chandel, Naik and Chandel (2015) argue that optimal functionality can be achieved through the introduction of solar water pumps that are relatively cost-effective and are environmentally friendly. Levi *et al*. (2016) state that capital investment is influenced by the type of land and the desired crop. Forming cooperatives can help smallholder farmers reduce capital investment costs as they will only contribute a part of these costs towards the acquisition of the infrastructure (Levi *et al*., 2016). Woodhouse *et al, (*2017) state that in recent years, the purchase of pumps for irrigation by rural farmers has increased. Smallholder farmers are most likely to own their pumps, while others might prefer to either borrow, lease or even co-own the pump with other farmers (Woodhouse *et al*., 2017). According to MacCarthy, Annis and Mihelcic (2013), other costs related to irrigation (the use of a pump) include repairs and maintenance costs. Pumps can go for a year or more without system maintenance, and the pump will continue to pump adequate water all year-round (Butterworth *et al*., 2013). Butterworth *et al*. (2013) explain that due to the infrequent maintenance of the pumps, maintenance and repairs costs do not affect the overall supply and use of water. Butterworth *et al*. (2013) aver that irrigation systems (pumps) once broken may take at least a month or more to fix, and this may affect the volumes of water needed at that time for crops. However, though energy costs and capital investments largely influence irrigation, minimal costs such as those of repairs and maintenance are required from time to time to ensure a smooth running of the irrigation equipment throughout its life span. Factors such as the purchase price of the irrigation system, repairs and maintenance will influence the overall cost of irrigation (Levi *et al*., 2016). Hence, it is likely that farmers with inappropriate water irrigation pumps may incur added repair and maintenance costs that could affect the farmer’s income.

Tayel *et al,* (2010) suggest that the most crucial part of an irrigation system design is to determine the expected yearly cost of leasing or owning and the operations and maintenance costs of each alternative design. In a study by Woodhouse *et al*., (2017), irrigation is defined to be the ability to manipulate water control techniques used in the cultivation process and methods of water application to the crop. Elzubeir (2018) states that a sprinkler system is a human-made process that mimics the precipitation of rain to water the planted crops. According to Elzubeir (2018), the process forces pumped water out from the water source. Tagar, Chandio, Mari and Wagan (2012) consider the adoption of modern irrigation technologies and strategies such as drip and centre-pivot irrigation by farmers as being more efficient than the traditional method of furrow/flood irrigation. Irrigation practices that promote water saving and cost efficiency are often linked to the modernisation of irrigation technologies such as sprinkler irrigation (SI) and drip irrigation (DI), and they are the solution to improve irrigation practices and farm yield (Van der Kooij, Zwartevee, Boesveld & Kuper, 2013). Irrigation systems costs can range between 1000 USD to 3000 USD per hectare (Monteiro *et al*., 2010), which may make it unaffordable for the farmers. Tagar *et al.,* (2012) confirm that benefits associated with these methods include increased farm yield, uniformity in water application to the crop area and exceptionally saving much water. Senol (2012) believes that a combination of a solar pump with drip irrigation as the method of irrigation supplies the most efficient and effective way to practice irrigation farming. Nevertheless, farmers are inclined to adopt measures that will reduce costs and assist them to attain higher levels of production.

Moreover, this combination helps the farmer to attain up to 90 per cent of water use efficiency coupled with negligible operations and maintenance costs (Senol, 2012). Burney, Woltering, Burke, Naylor and Pasternak (2010) concur that the drip irrigation system is an excellent way to irrigate crops. Additionally, the water and other crop needs like fertilisers are transported directly to the root of the plant through this system, and this has resulted in increases of up to 100 per cent in yields for a farmer and water saving of up to 80 per cent. Tayel *et al,* (2010) reported that farmers could reach maximum net profits with the use of a drip irrigation system. Burnham, Ma and Zhu (2015) posit that drip irrigation (DI) more often than not tends to increase farm yields and reduces the labour needs to less than required by traditional irrigation systems. Furthermore, the increases were seen to be 11 per cent and 14.8 per cent, for the furrow and sprinkler systems, respectively (Tayel *et al*., 2010). Hence, farmers are more likely to invest and adopt a system that would achieve the highest production levels and ultimately increase farm profits. When irrigation water is fed directly to the plant root using a drip, it is most likely to result in low pumping costs and an improvement in water use efficiency.

However, Vanani, Todeshki, Askari and Shayannejad, (2015) argue that flood irrigation does provide uniformity of water application to the crop area; it is just that farmers need to consider land preparation to level the soil surface for irrigation. Furthermore, tillage plays a major role when it comes to water retention. Proper compaction of the soil bed and the stabilization thereof will reduce the irrigation time as well as augment the efficiency of the irrigation method without significantly affecting the farm yield (Vanani *et al.,* 2015). Although the farmer may invest in the appropriate irrigation techniques, attention has to be given to soil preparation. Soil preparation entails the depth of tillage and the water retention rate, which could quickly affect the irrigation period and, thus also extend to the cost of irrigation. A notion supported by Rouphael, Cardarelli, Rea, Battistelli and Colla (2006) is that the desired method of irrigation becomes of prime importance when irrigating in arid or semi-arid regions where the water quality is considerably low. A discovery made by Reise, Musshoff, Granoszewski and Spiller (2012) is that the decision to invest in new technology and make adaptations for climate change may vary from farmer to farmer, and this is because of the associated on-farm benefits versus the cost effects that comes with investing in new technologies. Investment in modern technologies differs from one farm to the other. In most cases, the investment decision is capital intensive and is found to be rare amongst farmers due to constraints on financial resources (Gardebroek & Lansink, 2008).

Musshoff and Hirschauer (2011) in their study of on-farm finance decision making, found that often farmers misjudge the financing costs (the simple and compound interest) of investments and they contend that this under-estimation can lead to overutilization of financial resources. In support of this view, the misjudgement of the cost of capital is because of the farmer’s inadequate skills to consider simple and compounded interest implications when in the process of making an investment decision (Reise *et al*., 2012). Hence, the inability of the smallholder and emerging commercial farmer to consider interest implications when making water irrigation investments may lead to under or over-investment in irrigation machinery and equipment. A contentious issue is that investment in water irrigation was found to have mixed records. Some farmers can attest to successful results from the investments; while, others have proved unsuccessful with their investment initiatives (Wichelns, 2014). According to Closas and Rap (2017), the initial retail investment cost for a solar pump is generally high when compared with electric and diesel pumps.

2.3.2.1 Investing in Solar

Initial investment costs in solar energy may vary from one country to the other, and this system offers reliability in terms of usage regarding their low operation and maintenance costs (Closas & Rap, 2017). In addition, the total initial investment cost for a solar system ranges between $2500 and $3000 per kilowatt compared to the capital cost of a diesel pumps that is between $500 and $800 per kilowatt (Closas & Rap, 2017). Consequently, the production costs of solar systems have recently dropped with a margin of about 30 to 60 per cent in ten years and with that in mind, there was a global plummet of 76 USD per kW in 1977 to just 0.30 USD per kW in 2015. This, together with the continuous escalating fuel prices, means that solar technology has become more appealing to decision-makers (Nederstigt and Bom, 2014). According to Ullah, Ullah, Ali and Junaid (2016), most farmers prefer the use of diesel motor-operated wells over the use of electric pump-operated wells as they offer the advantage of low installation costs and most importantly, a continuous power supply that does not hinder the supply of water, which does not hamper crop yield levels. Hence, farmers are most likely to invest in the diesel system due to its low initial capital costs. The farmers as the sole decision-makers for their projects should consider the use of a solar system as these are becoming more available and becoming cheaper due to the increase in their production and the need to reduce emissions. Bassi (2015) has found that in India at present the cost of a solar pump is Rs 37 65 000 and a diesel pump costs Rs 25 000. On the other hand, Gebregziabher, Giordano, Langan and Namara, (2014) using data collected from a survey in four districts, found that the capital costs of diesel pumps are considerably higher, and those prices are continually increasing. Government taxes are also amongst the costs that are incurred by the farmers and as such taxes are said to approximate 37 per cent of the motor pump prices (Gebregziabher *et al.,* 2014). Hence, these additional costs are likely to be an indication of the high capital costs associated with water irrigation; however, with the use of solar pumps these costs are most likely to decrease and farmers may soon be able to purchase these pumps.

According to Burney *et al*. (2010), a vast majority of PV powered drip systems cost an estimated 18 000 USD to install. Using modest estimates the solar-powered drip system-generated revenues be about 10 000 USD in the first year of use and 16 000 USD after that. The payback period of such irrigation systems is estimated at 2.3 years (Burney, 2010). Furthermore, Bassi (2015) is certain that irrigation systems that use solar pumps have lower CO_2 emissions and incur insignificant operation and maintenance costs. It is more likely that soon the initial investment costs for solar pumps will be reduced to an affordable price for farmers. Furthermore, the clear advantage that solar energy has compared to electricity or diesel pumps when it comes to operation and maintenance (O&M) costs, solar pumps will be considered the most suitable form of investment for farmers. Most farmers out rightly dismiss the solar pump systems due to their high initial cost; however, they have a longer lifespan and cost far less than a fuel-operated system (Burney *et al*., 2010). Therefore, this means that having a system that costs less to run, a farmer is mostly likely to diversify their factors of production and increase their revenue sources. Tayel *et al*. (2010) believe that the system to be chosen or invested in by the farmer should be the system that is expected to produce the maximum net income of the farm or the highest benefit-cost ratio. As Lambrecht, Vanlauwe, Merckx and Maerten (2014) point out, in the process of any adoption phase, a farmer tends to assess the cost versus the benefits of new technologies based on their own experiences whether it is worth being used or not. Moreover, these cost and benefit analyses are likely to differ from one farmer to the next (Lambrecht *et al*., 2014). Hence, when taking into consideration the cost and benefit of an irrigation system, the smallholder and emerging farmers are most likely to be conflicted and choose to use a less adequate system because from their experience it worked and would not work currently. They, therefore, shy away from investing in irrigation infrastructure that will enable increased yields and income.

2.5.3 Cost of energy usage (systems costs) and farm yield

A study conducted by Foster, Brozovic and Butler (2015) produced findings that showed that there is a significant relationship between water irrigation costs and farm profits. Foster *et al*. (2015) cited that the significance in the relationship is associated with declining aquifer water capacity for irrigation production, which further increases the water pumping costs. According to Ahmed, Zander and Garnett (2011), exorbitant running (production) costs in most cases hinder the adoption of improved farming techniques. Tabatabaie, Rafiee, Keyhani and Heidari (2013) state that it is of great importance in agricultural production to minimise costs and to maximise crop yield. In addition, Tabatabaie *et al*. (2013) assert that modern agricultural practices, such as crop production, rely more on energy sources such as electricity and fuel. López-Gunn, Mayor and Dumont (2012) found that in Spain, the adoption of new irrigation technologies came with a whole added cost dimension for farmers. Lopez-Gunn *et al.* (2012) further add that in Spain energy costs ranged from about 200€ to 300€ per Ha, and this meant that farmers are now paying three times the cost of water indirectly as the energy cost. In addition, Gadanakis *et al.* (2015) believe that the use of water to maximise production output is linked to inputs such as labour and fertilisers; which indicates that farmers should balance the inputs all together to maximise crop yield. In support, Pfeiffer and Lin (2014) state that energy (electricity) is an essential input that is needed to pump groundwater for irrigation. Although energy plays an essential role in the crop irrigation process, factors such as the soil type and control of pests may also influence crop yield levels. Increasing the costs of energy will reduce the volumes of water pumped, thereby influencing the type of crops to be planted and the allocation of crops to hectares to be used for cultivation by farmers. This reduces productivity and ultimately makes smallholder farmers economically unsustainable (Pfeiffer & Lin 2014). Similar to the above findings, Tarjuelo *et al*. (2015) found that the volume of water pumped is strongly linked to electricity usage, and a reduction in water volumes may result in decreased productivity as well as farm revenue. Stambouli, Faci and Zapata (2014) state that the improvement in irrigation methods has resulted in the escalation of power utilisation by farmers, thus resulting in an increased cost of energy for irrigating crops. The cost of energy associated with pumping water will gradually increase with the depth of water that needs to be pumped (Pfeiffer & Lin 2014). Zebardast *et al.* (2015) opine that an irrigation system must be designed in a way that it would be able to deliver the proper pumping pressure at the lowest possible cost. Zebardast *et al.* (2015) further add that pumping pressure has a considerable influence on the energy cost. Lopez-Gunn *et al.* (2012) concur and thus argue that farmers now must be more efficient with the use of water for irrigation due to the high cost of energy.

Therefore, energy costs play an integral role in the success of a farm and as a result, the use of these sources of energy come at a price that in most cases may restrain smallholder output, making them economically unsustainable.

Foster *et al.* (2014) believe that due to the low aquifer water yield, farmers may in return, be compelled to reduce their irrigated area under cultivation to limit the cost implications associated with the constraints of groundwater availability. Hamedani *et al.* (2011) suggest that energy consumption patterns and the contribution thereof to production inputs vary from farmer to farmer as the energy use is largely influenced by the farming technology, farming landscape, and cultivation seasons. Mohammadi, Rafiee, Mohtasebi and Rafiee (2010) investigated the energy consumption of kiwifruit in Iran and proved that human capital and water irrigation are amongst the significant influencers of crop yield. This implies that human labour and water irrigation plays a pivotal role in high crop yields and as such smallholder farmers and emerging commercial farmers are inclined to spend most of their money on these factors to increase production and ensure their sustainability. The information, which was collected from the farmers by the use questionnaires, showed that different energy source is required in the production of potatoes (Zangeneh, Omid & Akram, 2010). It goes without question that energy irrigation farming is an energy-intensive business and the increasing energy consumption coupled with forever increasing energy prices is a recipe for monetary loss. García, Montesinos, Poyato and Díaz (2016) support the notion that irrigation farming has undergone major transformations with the widespread adoption of agricultural technology of pressurised water irrigation systems to improve water use efficiency. This is a high energy demand system and leads to soaring energy costs. Thus, farmers are now faced with the challenge to figure out a course of action that will assist in the reduction of energy-related costs and at the same time ensure that the farm remains profitable (García *et al*., 2016). Furthermore, excessive and unrestricted pumping not only increases the energy cost, but the misuse of energy has a direct impact on the increase in carbon emissions (Karimi *et al.,* 2012). It is more likely that some energy sources, if not managed effectively and efficiently by farmers through their irrigation practices, will not only have a devastating impact on the cost of irrigation but will directly contribute to the increase in carbon emissions which help fuel climate change.

2.3.3.1 Energy costs about Fuel vs Electric vs solar

According to Langarita *et al*. (2017), recent years have seen farmers modernise their irrigation systems to be more efficient with water allocation per crop, and as a result, the energy demand for pumping water has skyrocketed. As mentioned by Hendricks and Peterson (2012), energy prices were found to have a significant influence on the price of the crops. In addition, water extraction costs vary from time to time due to the fluctuations in energy prices (Hendricks & Peterson, 2012). Purohit (2007) posits that farmers depend on either electricity or diesel as a source of energy to pump water for irrigation. Senol (2012) reckons that the water extraction methods (electricity, diesel, or solar) are a significant cost driver to the overall cost of the irrigation practice. In support of this notion Shouman, Shenawy and Badr (2016) point out that the energy sources that are usually used by farmers to pump water to various locations around the farm and to irrigate crops include solar power that usually makes use of the photovoltaic pump and fuel-driven pumps, which usually consume diesel. According to Shouman *et al*. (2016), the two sources of energy vary significantly in reliability and cost. Nevertheless, as the asking price of energy increases, the cost to extract groundwater increases and the increase is even greater in arid and semi-arid regions where the depth of water is even greater (Hendricks & Peterson, 2012).

Furthermore, in most cases, the source of energy used to pump water usually dictates the type of pump to be used by the farmer (Diaba & Felix, 2015). A comparison of the cost-effectiveness of using a diesel engine (motor) or a solar panel to pump water for irrigation in a water pumping system has been done in Chile (Chueco-Fernandez & Bayod-Rujula, 2010). Mahmoud and Nather (2003) in a different study also looked at the feasibility of using either solar panels or a diesel motor for water irrigation systems. In their study, the researchers looked at the practicality of both energy sources (diesel and solar power) while also considering all other factors that could affect the associated costs of the two systems and how they might affect the present value. However, in both their studies, they found that it was clear that one of the systems, a diesel-powered system incurred higher water pumping costs for irrigation compared to the photovoltaic (solar) system. One of the significant factors affecting smallholders and emerging commercial farmers' revenue may be the reason that either the farmer uses an inappropriate irrigation system or the source of energy used by the farmer is associated with exorbitant costs that have adverse effects on the farmer’s revenue.

Shouman *et al*. (2016) conducted a study on diesel and solar pumping and as such the study looked at the following factors affecting irrigation systems: cost of capital of infrastructure and implements, installation costs, energy costs as well as running and maintenance costs. The study by Shouman *et al.* (2016) showed that diesel operated systems are characterised by their low investment cost and exorbitant operation and maintenance expenses. On the other hand, the solar-powered irrigation system was the complete opposite. Extremely high investment costs typically characterised the solar system but it incurred inexpensive maintenance and operations costs. Diesel as fossil fuel is generally a limited resource, and because of this the prices of diesel are continuously on the rise and as a result, production costs will be high, which, in turn, influences farm revenue (Biswas & Hossain, 2013). As a result, variable costs, fuel expenses and the cost of replacement make the diesel motor pump the most expensive system to run when compared to solar systems (Senol, 2012).

However, conversely, during operations of the system, the farmer incurs high running costs which they might not be aware of, and this leads to high productivity and because of the high running costs a reduction in income is experienced. Tarjuelo *et al*. (2015) state that the irrigation process has an adverse relationship with the electricity cost led by increased electricity usage and increasing electricity tariffs in recent years. An average increase in the cost of electricity by 8.9% will cause an average decrease of 1.3% in the volume of water pumped for crop production, according to Pfeiffer and Lin (2014). Langarita *et al*. (2017) further suggest that there is a direct relationship between structural modernisation and the increase in energy costs. Pfeiffer and Lin (2014) found that electricity costs of pumping water for irrigation amounts to approximately 10% of the costs incurred by corn farmers. Bassi (2015) points out that smallholder farmers in India have difficulties accessing electricity at reasonable prices for groundwater extraction, and this has an economic disadvantage. Therefore, it is more likely that access to electricity by rural farmers to extract water will not be economically feasible because of the high energy cost. There has been a decline in agricultural production as most smallholders are dependent on electricity to pump water for irrigation and the unscheduled load shedding hinders their ability to increase production (Mongat, Arshad, Bakhsh, Shakoor, Anjum, Hameed, Kalsoom & Shamim, 2015).

This, therefore urges the farmer to look for alternative energy sources that can augment the loss of electricity through load shedding that results in an extra cost to the farmer (Mongat *et al*., 2015). Because of this, crop yields have significantly declined on an annual basis due to the lack of sustainable electricity supply (Mongat *et al.*, 2015) Daiba and Felix (2015) believe that the exorbitant cost of electricity has a significant impact on the number of volumes of water which can be pumped. However, on the other hand, electricity consumption and demand are increasing rapidly in the agricultural sector.

Bassi (2015) states that India is amongst the top countries on the continent that emit carbon dioxide into the atmosphere from the use of fuel to extract water for irrigation. Al-Smairan (2012) argues that one of the factors that influence the diesel (fuel) cost is the transportation of these fuels to the rural areas. In addition, these fuel pumps are exorbitant to both operate and maintain, and most often cause noise pollution. Furthermore, Al-Smairian (2012) supports the claim that less attention is paid to the photovoltaic (solar) pump; a pump that would significantly reduce the greenhouse gas (GHG) emissions contributed by using engine pumps. Solar energy should not only be an answer to the energy catastrophe, but environmentally, solar power has little/no effects on climate change (Harishankar, Kumar, Vignesh & Viveknath, 2014). Empirical literature shows that solar energy is totally cost-effective towards farm operation combined with insignificant operation and maintenance costs. Harishankar *et al.* (2014) add that although solar power irrigation systems require elevated levels of investment, future benefits are plausible as the system mainly incurs insignificant operation and maintenance costs (O&M). According to Biswas and Hossian (2013), the benefit of using solar power, although seen to have high capital costs initially, has insignificant operation and maintenance costs, and ideally, this will be the most cost-effective system to operate in the long run. Mongat *et al*. (2015) found that the operational costs of a solar unit were significantly low, coupled with that is that the system is more efficient, dependable, energy-saving, and economically sustainable. A closer look at the use of solar pumps may find that they are an alternative solution to the exorbitant running costs of conventional energy sources. As revealed by Ullah *et al*. (2016) electric and diesel operated pumps should be replaced by solar power systems as these are environmentally friendly, and they are seen to be cost-effective to the farmer's operations. Diesel motors are expensive to run, and they make a significant contribution to the carbon footprint. Despite the above, smallholder farmers and emerging commercial farmers may still choose to invest in diesel-powered systems as the diesel system is generally associated with low capital costs, which the farmers can afford to buy.

2.5.4 Socio-economic issues (level of education and financial literacy) of rural farmers and the volume of farm output

Smallholder farmers are often insufficiently educated and have inadequate access to financial resources; this means rural farmers are poorly resourced and this thus results in smallholder farmers operating below expectations (Kalunda, 2014). Obiero (2013) says that undefined socio-economic issues are not noticeable in relation to farm yield. Obiero (2013) notes that socio-economic issues include the level of education, access to funding (credit facilities) and age, to mention a few. Education plays a pivotal role for individuals as this enables farmers to obtain knowledge through their ability to read and listen (Kilonzi, 2011). According to Wiebe and Gollenhon (2007), education has proven to provide farmers with a skill that helps them with their problem-solving techniques. They noted that the decision-making process and the behaviour of individuals tend to hinge on their level of education. The level of education also has a significant role to play in ethical decision-making that will result in sound farm production practices resulting in improved farm yields. Mghase *et al.* (2009) link low productivity in Tanzania’s crop fields to the fact that the majority of the crops are being produced by small scale farmers who often engage in deficient farming practices as a result of their lack of knowledge about the timing, the appropriate fertilizer to use and the necessity of small scale irrigation. The most crucial socio-economic issues that affect farm yield and the income of farmers are usually the farmer’s level of education, household sizes, networking with other farmers, and the know-how knowledge of the farmer (Mondal, 2011). Hence, education and knowledge play a huge role in the farmer's ability not only to manage the farm practices but to also understand the principles of the cost associated with farm yields.

Mondal (2011) attests that improved yield can be achieved through adequate knowledge and education levels that enable the farmer to understand information about the benefits of the adoption and use of new technologies that improve productivity. Through training and practical demonstrations, farmers can improve the expertise skills that will help them improve productivity which leads to increased revenue (Mondal, 2011). Furthermore, Dadzie and Dasmani (2010) found that despite any gender differences, adequately educated farmers with a reasonable education level are more receptive to technology adoption than their uneducated counterparts, and this helps them improve productivity. Ahmed *et al.* (2011) found that there are farming techniques in Bangladesh that improve productivity, such as rice-fish farming; however, these techniques are poorly practised due to socio-economic factors such as technical knowledge. Therefore, it is evident that having some level of education enhances the farmers' ability to comprehend information and correctly apply appropriate techniques to help them solve problems and improve on the use of technology to get the highest level of productivity with limited resources.

The farmers' perception and ability to adapt will significantly make the climate change effect tolerable and put them in a better position to produce crops compared to redundant farmers (Acquah & Onumah, 2011). Fakayode, Ogunlade, Ayinde and Olabode (2010) investigated factors that affect the farmer's willingness to pay for water irrigation equipment in Nigeria. They found that the farmer's household size, the age of the farmer, farm income/farmer's household income and, most importantly, the educational level obtained by the farmer are amongst the crucial factors that affect the farmer's ability to pay for these costs relating to irrigation. Additionally, farmers with some form of education are more prone to adopt initiatives that maximize production by getting new information through different sources that include the Internet (Abdullah & Samah, 2013). Furthermore, educated farmers are more likely to better understand the benefits associated with adopting modern irrigation practices (Gebregziabher *et al*., 2014). By using the logit model of analysis, the study highlighted the link between the level of education and adaption of irrigation technology (Kamwamba-Mtethiwa, Namara, De Fraiture, Mangisoni & Owusu, 2012). Subsequently, educated farmers tend to adopt irrigation technologies sooner than their reluctant uneducated counterparts. (Kamwamba-Mtethiwa *et al*., 2012). Hence, education is proving to be a driving tool to a farmer's ability to comprehend information and assess whether the adaptive measure is suitable for their irrigation needs and as such would result in an improvement in their crop yield and farm revenue.

Moreover, the educated farmer can extract and carefully analyse information concerning irrigation practices and technologies (Gebregziabher *et al.,* 2014). Yet, conversely, Panda, Sharma, Ninan and Patt (2013) found that there is no significant correlation between education and farm yield but rather the farmers' experience in farming proved to be active and their know-how to minimize their costs. However, Dantsis, Douma, Giourga, Loumou and Polychronaki (2010) argue that the farmers' level of education fuels effective management practices that have a positive impact on farm profitability driven by the adoption of environmentally friendly methods. Hence, the ability to create prosperous smallholder farmers affects their ability to access financial resources, and their level of financial literacy will significantly contribute to the sustainability of the rural farming community. According to Johr (2012), to enable rural farmers to expand production at the farm level, they need to have access to financial management education and financial resources with the aim of increasing revenue and making farming sustainable. Hence, the ability to create prosperous smallholder farmers affect their ability to access financial resources, and their level of financial literacy will significantly contribute to the sustainability of the rural farming community. Hence, experience plays a vital role in the success of a farm, but coupled with some level of education the farmer is most likely to be in the best position to maximize production and farm income.

2.5.4.1 Financial literacy

Scholars such as Bongomin, Ntayi, Munene and Malinga (2017) suggest that financial literacy is an essential tool that will assist small businesses to access financial resources or reinvest funds in the business to ensure growth for those businesses. Besides, financial literacy skills obtained through training and workshops are necessary to improve financial know-how skills and overall business acumen that are necessary for the business to grow (De Mel, McKenzie & Woodruff, 2014). Data relating to the significance of financial literacy as a critical component to acquire funding and foster growth in small businesses were collected from 169 small-medium enterprises through the administering of adapted questionnaires (Bongomin *et al*., 2017). From its tests, the study revealed there is a significant relationship between access to funding and growth, driven by financial literacy. Therefore, financial literacy may help smallholders and emerging commercial farmers to improve their financial management skills; this will improve their ability to establish whether the benefits outweigh the costs of water irrigation and therefore enable them to make financially sound decisions for their farms. A noteworthy point is that raw data was collected through interviews and questionnaires and the analysis thereof indicated that financial literacy is a crucial component to the financial success of small businesses (Bongomin *et al*., 2017). Financial literacy is seen as the process of getting knowledge through formal schooling, training and practical everyday acts to manage one's financial resources and needs (Sivakumar, Jawaharlal, Palanichamy & Sureshkumar, 2013). A study conducted in Gujarat considered 600 smallholders in an attempt to examine the factors that influence financial literacy (Gaurav, Sarthak, Cole & Tobacman, 2010). The results show that elderly individuals in the study were exceptionally financially literate. Seemingly, farmers are most likely to acquire this skill throughout their farming years and as such farmers who are financially literate are more likely to make an appropriate financial decision that suits their risk appetite.

Financial literacy can influence households’ financial behaviours and especially individuals in business (the entrepreneurs) (Abubakar, 2015). Hence, this concept of financial literacy proves to be an essential factor that could positively improve the smallholders and emerging commercial farmers’ finances because then these farmers may have a better understanding of the finances around their businesses (farms). The study of Abubakar, (2015) showed a positive correlation between financially literate individuals and the need for financial resources and services. Okello Candiya Bongomin, Ntayi, Munene and Nkote (2016) state that financial literacy will significantly improve the decision-making process of individuals, which will, in turn, improve and use financial services. Fatoki (2014) believes that financially literate small business owners gravitate more towards making decisions that are financially savvy for the business and often they have good management practices as compared to other entrepreneurs that are financially illiterate. Therefore, without financial literacy, rural and emerging commercial farmers are inclined to make financial decisions that are not suitable for the farm and most importantly, inappropriate financial decisions that will affect water irrigation costs negatively. Furthermore, MasterCard (2014) also noticed that financial literacy assisted small business entrepreneurs to assess funding options and products, thus making knowledgeable decisions that would ease the financial risk associated with small businesses.

2.5.4.2 Gender

According to Lal and Khurana (2011), female farmers in agriculture are often not considered when developing policies and strategies in irrigation agriculture. Both male and female farmers have constrained access to resources. Furthermore, female farmers are more constrained because of other socio-economic issues, such as traditional and cultural factors (Lal & Khurana, 2011). Kamwamba-Mtethiwa *et al*., (2012) state that through the logit analysis model numerous studies show that gender (disparities) is one of the major contributors to the low adoption level of modern irrigation technologies. The limited access to agricultural technologies that improve irrigation practices poses a severe constraint to female irrigation productivity (Theis, Lefore, Meinzen-Dick & Bryan, 2018).

Furthermore, Njuki, Waithanji, Sakwa, Karuiki, Mukewa and Ngige (2014) found that women who can afford motorised pumps for irrigation are marginally represented as the results show that only six per cent and eighteen per cent of women in Tanzania and Kenya, respectively, can afford to buy these pumps. Nonetheless, women are more likely to be at a disadvantage than men to access irrigation facilities and technologies. Theis *et al*. (2018) state that modern technologies can aid woman farmers, especially smallholders and emerging farmers. These improvements in agricultural technologies can enable female farmers to maximise their returns on investments (Theis *et al.,* 2018). As Peterman *et al.* (2014) point out that if women and men are presented with equal access, both women and men are most likely to acquire these technologies and increase yields and income. Considering the above, women are more likely to be as productive as their male counterparts and to witness this they should be afforded equal access to resources that will enable them to improve their crop yield and investment returns.

2.6 CONCEPTUAL FRAMEWORK

Figure 2.1 below presents the conceptual framework of water irrigation costs and the volume of farm output. The researcher believes that holding everything constant the combination of investment in water irrigation infrastructure, water irrigation systems cost, water availability and the farmers level of education, which these four put together should enhance the volume of farm yield.

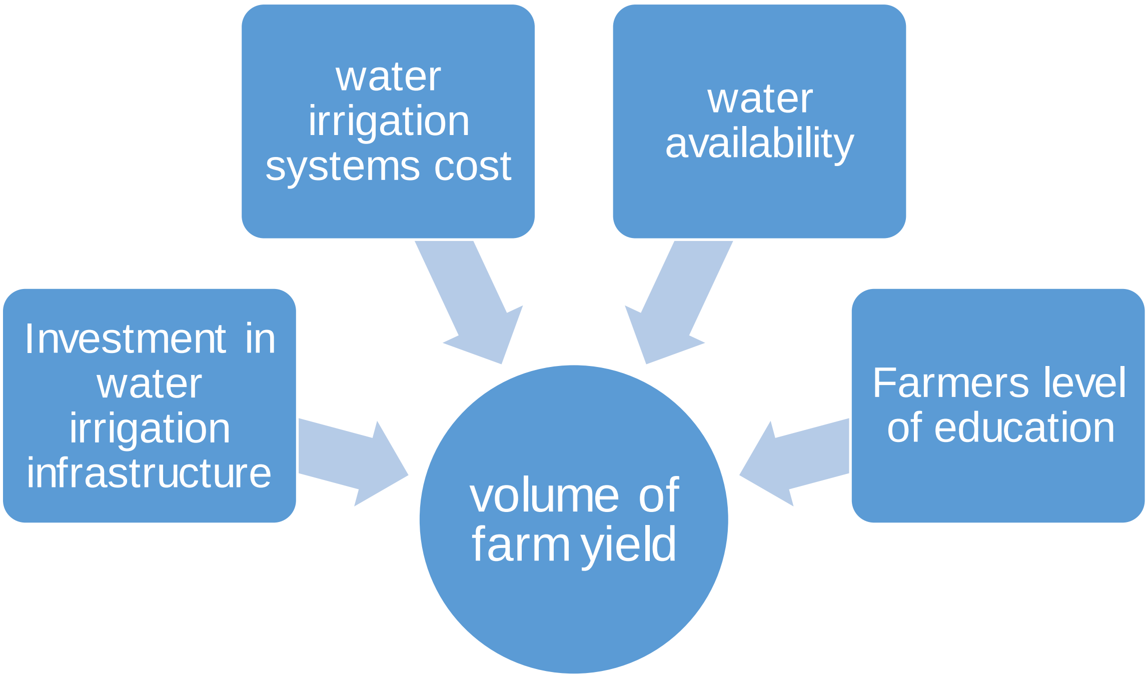


Figure 2. 1: A conceptual framework of water irrigation costs and farm outputs.

2.7 SUMMARY OF THE CHAPTER

This chapter has reviewed the key conceptual theories that were used in studying how to farm irrigation can influence farm output and affect farm revenues. These theories are the Input-output model, the theory of cost, and the cost-benefit theory. The input-output model posits that farming, like any other type of business, must consider production inputs to produce the desired output and as such take into account the quantity and quality of the production inputs. The theory of cost, however, looks at the behaviour of the cost of one or more factors of production that influence farm output. In this case, farmers have to manage water as their factor of production. Lastly, the cost-benefit theory assumes that for any given project farmers must match cost against benefits to be able to choose the best irrigation investment. Likewise, the cost-benefit theory revealed how farmers could minimise the cost to be able to maximise their benefits. The motives that drive farmers to invest in water irrigation infrastructure were explored, and amongst others, these motives include the need to improve farm yields, climate change adaptability, reduction of irrigation costs, and becoming financially sustainable. Socio-economic issues surrounding irrigation practices, costs and farm yields were discussed. The questions raised in the study related to irrigation were discussed as well as empirical findings from earlier studies that focused on irrigation costs and farm output. The next section outlines the research design and methods used to investigate the determinants of irrigation costs and farm outputs for selected crops within the Limpopo province. The source of data employed was discussed together with the sample that was chosen.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this section, the overall research method used in the study is described. Thus, this section specifies the ethical considerations, the data collection, the population sample selected, the method of research and the data analysis, as well as the research limitations of the study. Research methodology considers the question posed by the researcher. Research methodology refers to the key strategy and rationale of the research project (Scotland, 2012). It involves studying the methods used in the field and the theories or principles behind them, in order to develop an approach that matches the objectives.

3.2 CHOICE AND RATIONALE OF RESEARCH DESIGN

The study used the survey research design because it enabled the researcher to obtain information about on-farm energy costs and production output level. According to Garcia, Gorriz, Bastida, Alcon, and Alvares (2013), surveying farmers will give the researcher an idea of the on-farm activities involving energy costs, water use and the farmers' level of production output.

3.3 RESEARCH METHOD AND JUSTIFICATION

A paradigm is considered to be the fundamental set of beliefs and views about the world that directs investigations or research actions (Kivunja & Kuyini, 2017). Additionally, Morgan (2007) states that a paradigm describes the researchers' philosophical traits. As such, this study followed a pragmatist view. A pragmatic approach affords the researcher the flexibility of adopting the most practical way of answering the research questions (Brierley, 2017). Moreover, what is required is a worldview that would provide research methods that are perceived to be most suitable for studying the research phenomenon (Alise & Teddlie, 2010). Kivunja and Kuyini (2017) called for a merger of research methods that when used in conjunction would give an in-depth understanding of the behaviour of the participants. Where for this study the participants are the farmers. The pragmatic approach advocates the use of the mixed-method research approach. Therefore, the current study used the mixed-method approach. The mixed-method is the use of more than one method, mainly qualitative and quantitative in the same study to increase the credibility and the validity of the findings (Hussein, 2009). This method is appropriate because the study requires different sets of data using the mixed-methods sequentially for both the qualitative and quantitative data.

This study used a structured ordinal-scaled questionnaire. The questionnaire was distributed to participants to gather information about on-farm activities including investment and operational costs, as well as other challenges related to the irrigation practices and to quantify the opinions and behaviours of the farmers concerning their on-farm activities. This is done to generalise them and explain the phenomenon. The study used farm records to form a link and ensure that the information corroborates the data collected from the administered questionnaire.

The study used the qualitative approach, and this approach was used to gain an understanding of the underlying reasons, behaviours and opinions of the farmers. This approach has allowed the researcher to understand the on-farm activities relating to irrigation practices, investment and operational costs of irrigation from the participants' perspective. The study has adopted a semi-structured technique to conduct individual interviews with selected participants to uncover these challenges and to dive deeper into the research problem. The researcher has engaged with the selected participants in their preferred space and conditions to allow for a smooth and transparent session.

3.4 Study population and justification

The research population consisted of crop farmers in South Africa's semi-arid region of the Limpopo Province because these farmers have faced challenges of drought in recent years that resulted in most of the farmers installing modernised irrigation systems to boost their water usage in cultivation. There are approximately 386 660 agricultural households in the Limpopo province (Statistics South Africa, 2016). Hence the study population was made up of the entire agricultural households found within the Limpopo province. Coale, Demeny and Vaughan (2013) define a population as the entire group, objects and elements that make up a sample in a field of study.

3.4.1 Study location

This study was conducted in two district municipalities, namely, the Capricorn and Vhembe districts of the Limpopo Province of South Africa, among farmers that produce the following crops: avocadoes, citrus, nuts, potatoes and tomatoes. These farmers are formally engaged in some form of irrigation. The Limpopo Province consists of five district municipalities: the Capricorn, Mopane, Vhembe, Waterberg, and Sekhukhune municipalities. The Vhembe district is located in the northernmost part of South Africa close to the border of Botswana and Zimbabwe. The Capricorn District Municipality (DC35) is situated in the centre of the Limpopo Province, sharing its borders with four district municipalities, namely, Mopani (east), Sekhukhune (south), Vhembe (north) and Waterberg (west). Maps 1, 2 and 3 indicate the areas where the study was conducted.

Figure 3. 1: Map of Limpopo province (GoogleMaps)

Source: Google maps

3.5 The sample, sampling methods and sample size

The study used a purposive sampling method because it allowed the researcher to focus on selected crops that are of interest. Flick (2014) states that sampling allows the researcher to choose from the entire population, which at times is too large to be studied, and allows the researcher to generalise the research findings to the whole population, not the selected participants. Various sampling methods may be used, such as stratified sampling, purposive or judgemental sampling. Purposive sampling was adopted because the sample being investigated consisted of a concentrated small number of farmers. Thus, the study investigated the characteristics of these selected farmers to reach the target sample quickly. According to O'Keeffe *et al.* (2016), purposive sampling enables the sampling units to be chosen based on their characteristics. O'Keeffe *et al.* (2016) further deem that this method of sampling allows the researcher to only focus on the sample population and so is more likely to provide relevant information to answer the research questions of the study. The study sampled the following crops due to their economic importance within the province and the country. The sample of these five (5) crops were purposively selected.

1. Avocados
2. Citrus
3. Potatoes
4. Nuts
5. Tomatoes

Avocados

According to the Marketing Director (2017), the avocado industry in South Africa has a huge export market, while the production of avocados is highly concentrated in the province of Limpopo. The Marketing Director (2017) stated that the avocado industry plays a crucial role in the employment of individuals within the rural outskirts. Mbabazi, Migliaccio, Crane, Fraisse, Zotarelli, Morgan and Kiggundu (2017) in their study used the avocado crop to test how it would perform under modern irrigation technologies and whether the investment into these technologies could benefit farmers in the long term.

Citrus

The Citrus Growers Association of South Africa (2018) states that the growers of the crop play the most crucial role in the citrus industry. According to the Marketing Director (2017), Limpopo is the largest producer of citrus. The Marketing Director (2017) stated that the citrus industry creates many jobs with an estimated one (1) million households living in this industry. Ballester, Castel, Abd El-Mageed, Castel and Intrigliolo (2014) opted to use the citrus crops to assess the returns of irrigation during the summer period under regulated conditions and see whether this will translate to yield increases or decreases. Shirgure (2012) also preferred the use of citrus as a crop to test different irrigations methods and to ascertain whether this irrigation method results in positive or negative yield volumes.

Potatoes

According to the Marketing Director (2017), seventy-five per cent of the potato plantation is irrigated throughout the year to ensure crop availability, with Limpopo being the largest producer of potatoes. The Marketing Director (2017) stated that the country's export market of potatoes is still experiencing growth. Muchara, Ortmann, Mudhara and Wale (2016), in a study conducted in Kwa-Zulu Natal, South Africa, used the potato as a crop variable to look at irrigation water value for smallholders.

Nuts

The South African Macadamia Growers Association, (2018) states that South Africa is the leading producer of Macadamia nuts and the market for the nuts is mostly export-orientated. Limpopo is the second-largest producer of nuts in South Africa with a twenty-one per cent production. According to the South African Macadamia Growers Association (2018), there is an opportunity to grow the industry in the country, as the nut also contributes to the food industry. Perdoná and Soratto (2015) selected the use of nuts to determine whether irrigation and intercropping will be able to improve the farmer's yield and revenues.

Tomatoes

Limpopo is the largest producer of tomatoes, and an estimated 22500 individuals are employed by this industry (Marketing Director, 2017). Kuşçu, Turhan and Demir (2014) in their study, used the tomato crop to evaluate the yield response and financial benefits of deficit irrigation in sub-humid regions.

The total population of Limpopo farmers is too large to be considered. Because of the complexity in the location of the farmers, a sample size of 50 farmers was used for the study. The sample size is made up of 50 smallholder farmers situated in both the Capricorn district and the Vhembe district of the Limpopo province. O'Keeffe, Buytaert, Mijic, Brozovic and Sinha (2016), define purposive sampling as a non-probability sampling that does not take into consideration the random selection of participants. Instead, Etikan, Musa, and Alkassim (2016) explain that participants are chosen deliberately based on their qualities. Furthermore, based on the nature of the study, the researcher identified participants who are able and willing to furnish essential information about their knowledge and experience. Moreover, because of time and financial constraints, the study only sampled the selected group of crop farmers. According to Button, Ioannidis, Mokrysz, Nosek, Flint, Robinson, Munafo (2013), a sample is a portion or segment that illustrates the population.

Figure 3. 2: Map of Capricorn District municipality

Source: Google maps

Figure 3. 3 Map of Vhembe District municipality

Source: Google maps

Agricultural zones

The Limpopo Department of Agriculture and Rural Development identified agricultural zones within the Limpopo Province. These agricultural zones identify the major crops found in the province and showed how the farmers are distributed. The following agricultural zones were used to identify the location that is the most concentrated with farmers that produce avocados, potatoes, tomatoes, citrus and nuts.

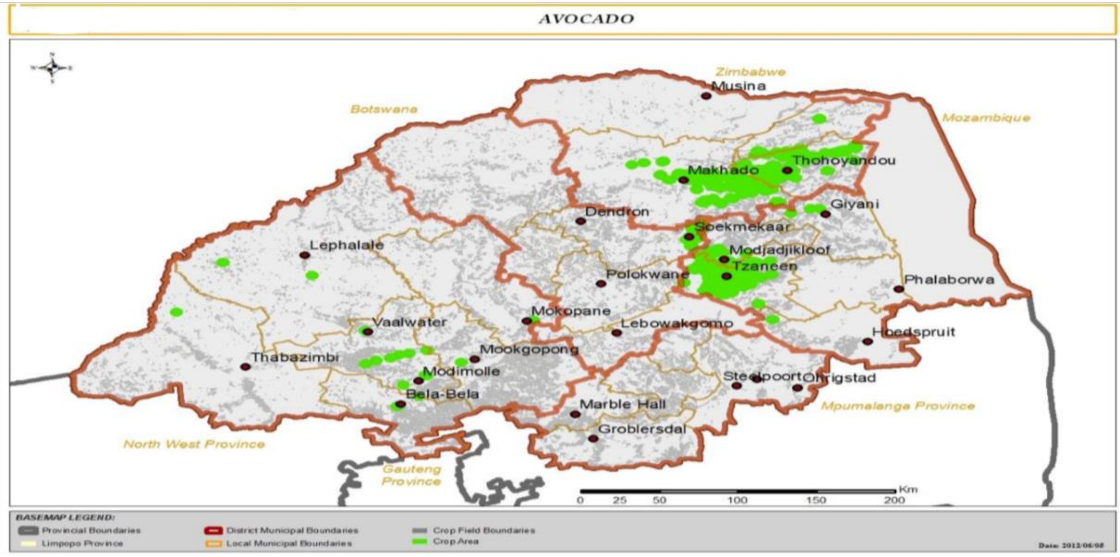


Figure 3. 4 Map of Geographical depiction of Avocado production in Limpopo

Source: Limpopo Department of Agriculture and Rural Development

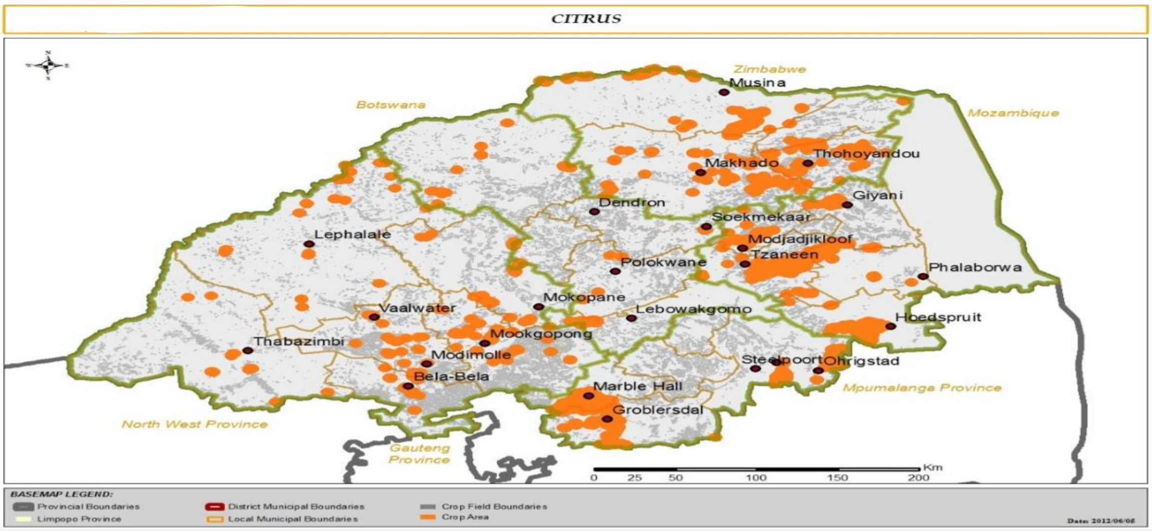


Figure 3. 5 Map of Geographical depiction of Citrus production in Limpopo

Source: Limpopo Department of Agriculture and Rural Development

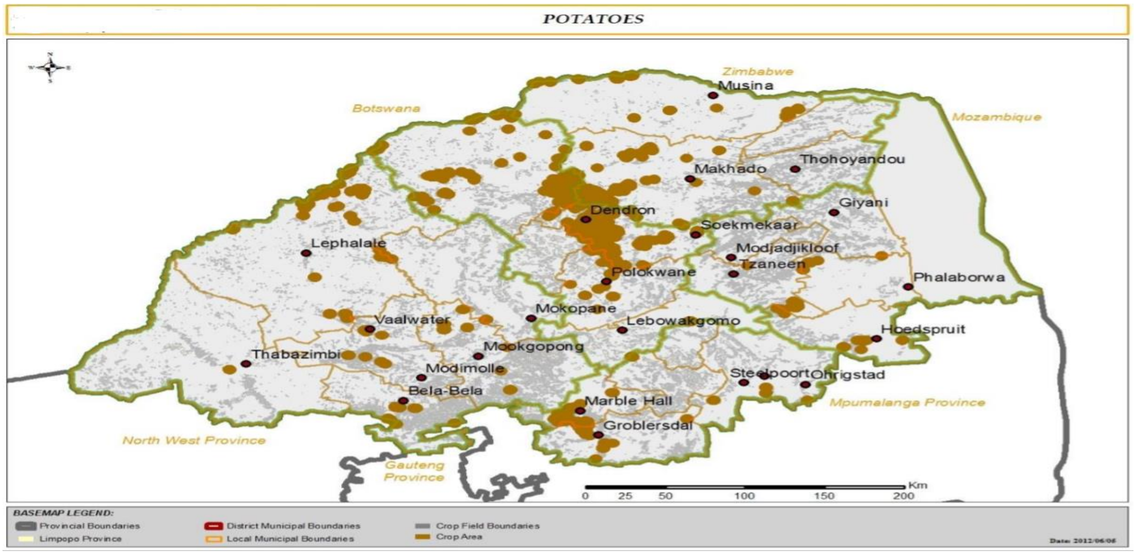


Figure 3. 6 Map of Geographical depiction of potato production in Limpopo

Source: Limpopo Department of Agriculture and Rural Development

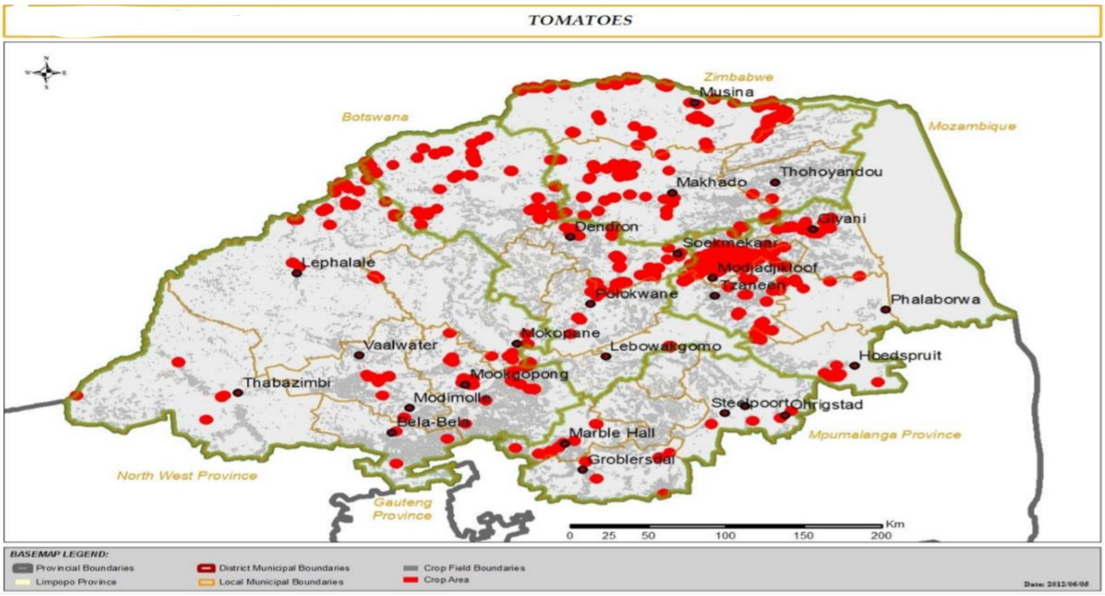


Figure 3. 7 Map of Geographical depiction of tomato production in Limpopo

Source: Limpopo Department of Agriculture and Rural Development

3.6 Data collection approach and justification

Kozlowski (2015) states that data collection is a process of obtaining and gathering relevant information that is connected to the objectives and which responds to the research questions. Firstly, the study collected primary data through the administration of questionnaires adapted from the Department for International Development (DFID), Irrigation Global (IG) and the International Network on Financial Education. This form of data collection gave a general understanding of the typical irrigation costs, practices and farm yields that are obtained by the respondents. The primary data was collected through observation and interviews with the smallholder and emerging commercial farmers in the Capricorn and Vhembe districts. According to Ullah *et al*. (2016), the farmers have to be interviewed in their native language for the researcher to obtain accurate information about the research phenomenon. In support of the above, O’Keeffe *et al,* (2016) recommend that in some instances to gain useful information, translator(s) were used to administer the questions. Moreover, the study made use of secondary data collection methods, where the secondary data collection is referred to as a method whereby the data was previously collected by other researchers or individuals for purposes other than the current study (Han, Powell, Slater & Quinn, 2012). Furthermore, common sources of secondary data include, amongst others, governmental departmental reports, organisational annual reports and records, and also, data that was collected for other research purposes.

In this study, weather information was obtained from the South African Weather Services (SAWS) website, that is, information that pertains to the rainfall and temperature patterns for the two districts (Capricorn and Vhembe districts). Specific crop production quantities and revenue data were obtained from the Department of Agricultural and Land Reform website within the database. The information was collected from the weather stations located within the districts from 2005 to 2019. Xiao *et al*. (2010) in their study that assessed the impact of the rise in temperature on crop yields, collected temperature and rainfall data from the years 2003 to 2008 from the Tongwei Meteorological station. The weather period ranges from 2003 to 2019. The researcher chose this range because the data is recent, and this allowed the researcher to explore the current factors surrounding irrigation costs and farm output.

Secondly, a semi-structured single focus group discussion was held with some of the farmers to gain an in-depth understanding of their farming activities that mainly had to do with irrigation practices, costs and farm yields. The study collected data from a group of 50 farmers who cultivate the different crops highlighted above. In light of the current coronavirus pandemic, the study purposefully distributed the questionnaire to 50 farmers, as this would not expose the participants to the virus and this was in line with the regulations that were set out by the government. The individual interviews were used when the participants were asked questions to gain more understanding of the participants' responses.

3.7 Data analysis and justification

Data analysis refers to how the information gathered from the data collected can be inspected and scrutinized. The useful and relevant information will be used for the study to reach a conclusion (Fetters, Curry & Creswell, 2013). The study employed the use of descriptive statistics to enable the provision of a summary of the data. The mean and the standard deviation were obtained using descriptive statistics. Diaba and Felix (2015) used descriptive statistics in their study to give a summary of their data and were able to calculate and present the data. The study used a multivariate analysis to analyse the variables in the study. According to Spicer (2005), multivariate analysis enables the researcher to detect and inspect the patterns found within the data. The study employed the use of multivariate analysis as the study sought to understand the relationship between multiple variables that can influence farm yield. Spicer (2005) further states that multivariate analysis is appropriate to use where there are more than one or multiple dependant variables in a study.

The study employed the use of a multivariate analysis technique because this analysis tool allowed the researcher to analyse the different variables in the study. Furthermore, Bwambok, Siraj, Macchi, Larm, Baker, Pérez, RL, Ayala, Walgama, Pollard, Rodriguez and Banerjee (2020) contend that the use of multivariate technique allows analysis of multiple data variables and simultaneous investigations into a phenomenon. In a study that is mixed-method or qualitative, the multivariate analysis technique has the ability to interpret a qualitative data set (de Souza Fraga, Reis, da Silva, Guedes & Elesbon, 2020). Due to the nature of the study has both quantitative and qualitative data sets, the multivariate analysis proved to be the superior tool to analyse the data, taking into account the number of variables found within the study that influence water irrigation costs and farm output.

3.7.1 Model specifications

The study has a number of model specifications according to the objectives of the study. Following Wooldridge, (2010), the linear model for the effect of the independent variable on the dependent variable is:

$$Y_i = \alpha_0 + \alpha_1 IW_i + \alpha_2 X_i + \varepsilon_i \qquad (1)$$

Where Y_i refers to the farm yield tonnes per kilogram of each crop (such as nuts, Avocado, Citrus, potatoes, tomatoes) for the individual farmer, it is a function of the vector of the endogenous variable. IW_i denotes the investment in water irrigation infrastructure. Then, α_0 is constant or the intercept, $\alpha_1$is the parameter of investment in the water irrigation infrastructure variable, and α_2 is the coefficient of other covariates.

The study creates an index of capital investment in water using multiple correspondence analysis (MCA). MCA is a method for investigating the associations among the categorical variables (Le Roux, & Rouanet, 2010). The study may not discuss the application of MCA in detail in this study because our study is not central in the data restructuring tools. However, the application of MCA is not cumbersome when using Stata. The study has categorically ordered variables, where 0 = Strongly disagree, 1 = Disagree, Neutral = 2, Agree = 3, and Strongly agree = 4. And they consists of variables such as pumping water from a borehole increases electricity or diesel costs, pumping water from a reservoir increases electricity/diesel costs, using an electric motor to pump water saves costs, using a diesel engine to pump water saves costs, drip irrigation increases pumping costs, centre-pivot irrigation increases pumping costs, flood irrigation increases pumping costs, pumping costs for furrow, pumping costs using pivot, and costs of pumping using the bucket. However, the researcher created indexes for the aforementioned using multiple correspondence analysis following Greenacre, and Blasius, (2006), see Appendix 1 for the output. The inertia is 27.68 per cent in dimension, while 40 per cent in dimension 2. The study predicted the index and multiple -1 with the predicted value because during the restructuring the first coordinate is not properly fixed.

The study introduced a quantile regression approach following Coad, and Rao, (2008), expressed as:

$$Y_i = IW_i\beta_0 + u_{\theta i} \quad \text{with} \quad Quant_\theta(Y_i|IW_i) = IW_i\beta_0 \qquad (2)$$

Where β_0 is the vector of parameters to be estimated for investment in water irrigation, $u_{\theta i}$ is a vector of residual, and $Q_\theta(Y_i|IW_i)$ represent the Q^{th} conditional quantile of Y_i given IW_i. The quantile regression is thus 0< Q^{th}<1. For the sake of simplicity, it is about 100 per cent or 1 quantile, with a range from the lower quantile (0.05) to the upper quantile (0.90). Finally, the analysis increases our understanding of what the crop yield is for the farmer on different quantiles or distribution with bootstrap.

The second objective investigates what the influence of water irrigation system costs (IWS_i) have on the volume of farm yield. The empirical analysis follows a corollary of the model (1) and even the application of quantile. The study expresses the effect of the water irrigation system cost on the farm yield:

$$Y_i = \alpha_0 + \alpha_1 IWS_i + \alpha_2 X_i + \varepsilon_i \qquad (3)$$

The water irrigation system cost consists of approximate diesel cost for irrigation per annum, approximate electricity costs for irrigation per annum, approximate maintenance cost per annum and the approximate cost of labour associated with irrigation. The study created the index of cost using principal correspondence analysis (PCA) following Greenacre and Blasius (2006). The study uses PCA because the cost is a continuous variable, unlike MCA which is suitable for categorical (ordered or dummy) variables (see Appendix II for output of PCA for irrigation cost).

Objective three follows a corollary of the equation (1) to examine the effects of climate change (measured by water availability for irrigation) (WI_i) on the volume of output farm yield. The study examines two different regression specifications. First is the objective mentioned above as:

$$Y_i = \alpha_0 + \alpha_1 WI_i + \alpha_2 X_i + \varepsilon_i \tag{4}$$

Further, the study investigated the effects of climate change (measured by water availability for irrigation) (WI_i) on the log of revenue and the model is specified as:

$$logincome_i = \alpha_0 + \alpha_1 WI_i + \alpha_2 X_i + \varepsilon_i \tag{5}$$

Furthermore, the study applied the variance inflation factor (VIF) to quantify the multicollinearity in equation (5). The VIF could be expressed as:

$$VIF = \frac{1}{1 - R_i^2}$$

Where R_i^2 is the R square value got by regressing the regressor on the covariates. The VIF reveals the degree of standard error square that inflates each coefficient. The criteria to decide the VIF cut-off is when the value is greater than 10, it is assumed collinearity.

The study repeats the same estimation for objective four to examine the influence of the farmers' level of education with the volume of farm yield. The corollary model specification (4) and (5) thus:

$$Y_i = \alpha_0 + \alpha_1 Edu_i + \alpha_2 X_i + \varepsilon_i \tag{6}$$

The study also investigated the effects of climate change (measured by water availability for irrigation) (Edu_i) on the log of revenue and the model is specified as:

$$logincome_i = \alpha_0 + \alpha_1 Edu_i + \alpha_2 X_i + \varepsilon_i \tag{7}$$

3.8 RELIABILITY AND VALIDITY OF THE METHOD

Having different information sources increases and ensures the reliability of the data collected, where one source validates the other (Golafshani, 2003). The study allowed the different approaches for data collection to converge, thus ensuring that the responses given on water irrigation costs and farm output reinforce each other throughout the process. This was done through cross verification of the farm records, questionnaires, and interviews with smallholders about on-farm activities. Hence, Hahn and Kuhnen (2013) believe that reliability and validity when the results or findings of the study can be duplicated with the use of a similar methodological approach and whether the study honestly measures and captures what it was set out to achieve truthfully. The application of these methods allowed the researcher to compare the data collected from the farmers and to make inferences to see whether the data collected from these different sources corroborate. Part of the study required fieldwork or visitation where the researcher used the questionnaires and semi-structured interviews to collect the data; the field notes taken were documented (recorded) in a way that would be easy to compare and share. The use of pre-existing questionnaires means that the questions had already been extensively tested before their first use and are considered reliable. To ensure consistency, the findings of this study about irrigation costs, farm yields and profit were compared to other results that have adopted this questionnaire. The participant's confidentiality and anonymity were ensured to solicit and encourage the farmers to be precise and open during the interviews. The study was conducted in the environment and under conditions that were accepted by the participant, thus making the process trustworthy and unthreatening.

The idea of a pilot study was not feasible because the questionnaire was adapted from an international body such as the Department for International Development, International on Financial Education and Irrigation Global and was carefully adapted to suit the study.

3.9 Pilot Investigation

According to Hazzi and Maldaon (2015), a pilot study is one of the important steps to be undertaken before conducting the study. Furthermore, this will assist the researcher to undercover issues surrounding the study and be able to make modifications where needed(Hazzi & Maldaon, 2015). A focus group investigation was conducted in Leeukraal village, situated within the Sekhukhune District Municipality, in the Limpopo Province. Pothier, Monteiro, Mooktiar and Shaw (2005) in a study looking at the importance of the loss of data, conducted a pilot study and grouped the participants, the groups included volunteer nurses, sister nurses and other staff members in the hospital. Generally, a small number of participants or groups can be looked at into when conducting a pilot study. The focus group discussion involved various participants including agricultural experts from the University of Limpopo's Faculty of Agriculture, members of the Risk and Vulnerability Science Centre (RVSC) that specialise in conservation agriculture (CA). Leon, Davis and Kraemer (2011) the intended purpose of a pilot study is to test the feasibility of the research approach of the study. Others involved in the discussions included representatives from the Local Economic Development known as (LED), the Limpopo Department of Agriculture and Rural Development (LDARD) and a representative from Smart Inputs that provides irrigation and fertiliser solution and techniques for farmers, and then most importantly the farmers themselves. The farmers were classified as smallholder farmers, small-medium farmers, and emerging commercial farmers.

Pratt and Yezierski (2018) and Pellegrino (2014) conducted their pilot study as part of their research approach, however, Gudmundsdottir and Brock-Utne's (2010) originally used the pilot study as the first phase of the action study. Hence, the researcher opted to use the pilot study as the first phase to enable the researcher to modify the research approach. During the discussion, it was noted that because of the changing climate conditions farmers now face numerous challenges relating to farm yields such as in crop production and livestock farming. Due to climate change, farming practices are changing, as productivity is becoming more capital intensive to remain sustainable. The majority of the participants in the groups agreed that for the farmers to keep up with the climate change impact, they would need to improve on their farming techniques, including the practice of conservation agriculture. However, the farmers argued that these new farming techniques require vast amounts of capital outlay to which they have limited access. Moreover, this completely new dimension of farming techniques comes with new cost elements that have a greater effect on their cost structure.

The group then discussed the possible cost elements that significantly influence the farm output cost and identified energy, fertiliser and labour as significant cost components. Smart Inputs (the company that supplies irrigation and fertiliser products) indicated that irrigation and fertiliser usage play a huge role in maximising farm productivity. It was debated that irrigation systems must be able to apply water adequately and sufficiently to the soil to maximise water use and to not just irrigate for the sake of irrigation. Smart Inputs explained that systems cost would increase as productivity increases. Additionally, it was agreed that different crops need specialised irrigation systems designed to meet the water requirements for that specific crop to ensure maximum productivity.

Furthermore, when the annual equipment and operations costs were discussed, it was clear that most of the farmers did not have a sound understanding of cost management and how to minimise production costs. Moreover, most of the farmers present had challenges with costs classification and identification and being able to differentiate among variable, fixed, semi-fixed and capital costs. In addition, the technical know-how was also not sufficient and was an indication that lower farm productivity may be as a result of inappropriate cost combination and the use of inadequate equipment and other inputs used in crop production. Some participants in the focus group opined that with this new farming technique, that is, conservation agriculture, if practised, farmers may notice improved farm productivity, which will result in greater income for the farmers.

3.10 Ethical considerations

Gajjar (2013) is of the view that ethics can be seen as a procedure, approach, or a way of deciding on how to act, conduct and analyse problems and issues. An ethics review body has to grant the researcher approval before conducting the study

(Roberts, 2015). As such the study involved human contact and the ethical clearance was obtained from the Turfloop Research Ethics Committee (TREC). This measure was put in place to protect the interests of human research participants. The respondents participated based on informed consent. The researcher had provided sufficient information and assurance regarding this study about irrigation costs, farm output and being economically sustainable. Furthermore, Jefford and Moore, (2008) state that for individuals to make informed consent, the researcher needs to provide the participants with full information regarding the study and that include; the purpose of the study, the risks and benefits associated with the study in or for the participants to decide whether to take part in the study. This information was provided to allow individuals to understand the implications of participating in such a study. In reaching a fully informed decision, participants needed to decide whether or not to participate in the study.

Privacy and anonymity of the participants are of paramount importance, and so the study made use of pseudonyms instead of the full participants' names. The study assured the participants that their details and the information provided would not be revealed and that the data collected would be used only for this study. As the study involved written and verbal communication, these invoked emotions; however, the questions that were asked were not intended to cause any harm whatsoever to the selected participants. Moreover, participants had the right to withdraw at any point during the interview from participating or responding to questions they did not feel comfortable with and when responding to the questionnaires. In addition, participants were not bound to disclose the reason(s) for the discontinuation. The participants were not pressured or coerced in any way; neither was an attempt made to persuade them from withdrawing or continuing with the study. According to Sultan (2013), one of the most essential features in academic writing is to ensure referencing of the work of other authors. As such, the study acknowledged the work of other authors by way of referencing.

3.11 SUMMARY OF THE CHAPTER

In this chapter, the research methodology was outlined, and this included the discussion of the research design and the methods that were used by the researcher to assist him in answering the research objectives.

The researcher adopted a survey research design and a mixed-method approach for the study which in turn assisted the researcher to analyse and further understand how water irrigation costs can influence farm output/yields levels. The population of the study were farmers in the Limpopo Province and the sample size was 50 farmers that produced the crop of interest to the study – these were either nuts, avocado, citrus, potatoes, and tomatoes. The researcher chose these specific crops as they are considered most important in the Limpopo Province and they account for more jobs and business opportunities for the surrounding communities within the province.

The chapter also discussed the data collection process and the multivariate analysis used to analyse the data on the influence of water irrigation costs on-farm yields. Parts of the data that were used in the study was collected from the South African Weather Services (SAWS) and the other data was obtained through the administration of a questionnaire to the farmers that cultivated the crops. The researcher believes that through the adoption of the methods and techniques mentioned above, the research questions and objectives of this study will be appropriately responded to. The next chapter of the study discusses the results obtained from the study and gives a presentation, interpretation, and discussion of the results based on the methodology outlined above.

CHAPTER FOUR: PRESENTATION, INTERPRETATION AND DISCUSSION

4.1 INTRODUCTION

The previous chapter discussed the overall methodology used in the study. This chapter presents the analysis and discussion of the results of the study.

4.2 Descriptive statistics

This section of the study focuses on descriptive statistics of the entire sample. This study uses primary data collected from the selected farmers and was completed in Limpopo province in 2020 (August to October). Out of 50 farmers, only 48 responded, which is a 96% response. The study used the dummy type of crops to distinguish five selected crops that are the focus of this study. Farmer gender is a binary categorical variable. While variables such as age, education attainment, field identification, field size, field distance, and number of years that the farmer has been in operation, among other variables, are categorically ordered variables. Table 4.1 presents the study sample. Among the crops, tomatoes have the highest mean, followed by potatoes, nuts, Citrus and Avocado. The summary statistics also show that the average number of farmers that are males are 67% and females 33%. This is consistent with Gebregziabher's (2014) finding that the farming business is dominated by male farmers.

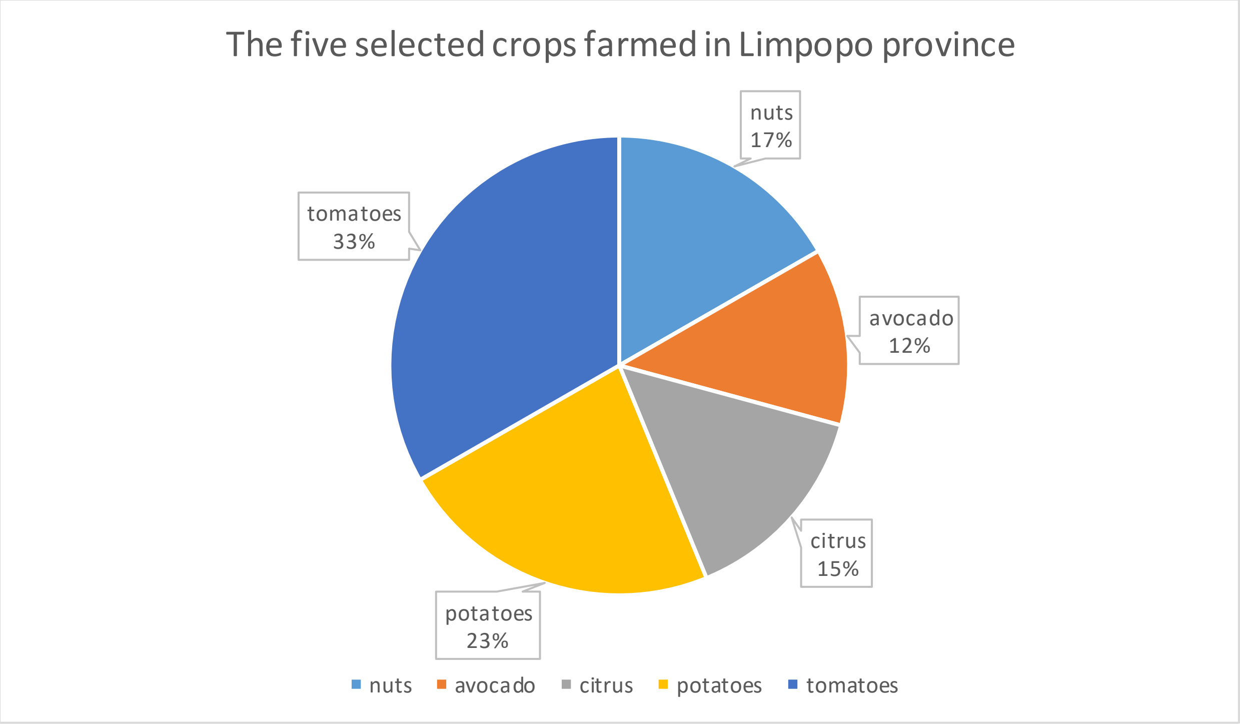
Table 4. 1: Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Nuts	48	0.167	0.377	0	1
Avocado	48	0.125	0.334	0	1
Citrus	48	0.146	0.357	0	1
Potatoes	48	0.229	0.425	0	1
Tomatoes	48	0.333	0.476	0	1
Gender	48	1.313	0.468	1	2
Age	48	4.646	1.896	0	6
Education Attainment	48	1.458	1.725	0	6
Field Identification	48	0.208	0.504	0	2
Field size (ordered)	48	0.708	1.501	0	4
Field distance (ordered)	48	0.167	0.63	0	4
Operation_ year	48	0.625	0.981	0	4
Irrigation period (ordered)	48	0.583	0.986	0	4
Temperature	48	32.896	4.728	22	40
Water pump Type	48	0.208	0.41	0	1
Irrigation Method	48	1.938	1.08	0	4
Irrigation (day)	48	3.021	1.631	1	5
Irrigation (hour)	48	3.854	1.238	2	5
Diesel Energy	48	137.5	540.931	0	2500
Electric Energy (lpm)	48	127.354	622.77	0	4080
Water for plantation	48	3.563	0.796	0	4
Water not enough	48	3.771	0.425	3	4
Water reduces hectares	48	3.813	0.445	2	4
Irrigation improves crop in the night	48	3.25	0.957	1	4
Irrigation improves crop in the morning	48	2.792	1.166	0	4
Irrigation improves crop in the afternoon	48	1.771	1.403	0	4
Sprinkler Irrigation	48	2	0.744	0	4
Drip Irrigation	48	1.792	0.824	0	4
Sprinkler Irrigation saves water	48	3.063	1.019	1	4
Drip Irrigation saves water	48	3.271	0.893	2	4
Furrow irrigation increases crop	48	1.646	1.391	0	4
Furrow irrigation save water	48	1.125	1.142	0	4
Crop yield	48	2.125	0.981	0	4
Centre Pivot saves matererial	48	1.792	0.898	0	4
Bucket irrigation increases crop	48	1.708	1.031	0	4
Bucket irrigation saves water	48	2.5	0.989	0	4
Machine type (Diesel = 0, Electric =1)	48	0.25	0.438	0	1
Pumping by borehole – costs	48	3.083	1.2	0	4
Pumping by a reservoir – cost	48	2.604	1.333	0	4
Pump using electric – cost	48	2.146	1.353	0	4
Pump using fuel - cost	48	1.583	1.381	0	4
Drip irrigation increase – cost	48	1.792	1.414	0	4
Sprinkler irrigation increase – cost	48	2.917	1.028	0	4
Furrow irrigation – cost	48	1.917	1.471	0	4
Centre Pivot – cost	48	2.438	0.965	0	4
Bucket irrigation – cost	48	1.146	1.111	0	4
Financial literacy (on) budgets	48	2.833	1.404	0	4
Financial literacy advisor	48	3.188	1.283	0	4
Financial literacy workshops	48	2.979	1.451	0	4
Financial literacy inputs	48	3.417	1.217	0	4
Financial literacy credit	48	2.667	1.492	0	4
Financial literacy purchase	48	3.604	0.917	0	4
Financial literacy facilities	48	1.542	1.57	0	4
Financial literacy profit	48	2.521	1.53	0	4
Tones (kilogram)	48	11.271	9.699	4	30
Water index (Saline)	48	0	1.011	-1.466	1.912
Index of irrigation pump	48	0	1.011	-1.319	1.759
Index of total cost	48	0	1	-0.69	2.042

Financial literacy index	48	0	1.011	-2.003	1.881
Log of fuel irrigation cost	48	9.581	0.632	9.21	10.82
Log of electric irrigation cost	48	9.636	0.778	9.21	12.766
Log of maintenance of irrigation	48	9.545	0.692	9.21	12.429
Log of labour on irrigation cost	48	9.685	0.645	9.21	10.82
Log of installation	48	10.436	1.063	9.21	12.429
Log of revenue	48	11.912	0.662	11.513	13.305
Capital index	48	0	1.011	-1.759	1.319

There is no business without its own risk; challenges in the business may be numerous. However, an sufficient water supply that has led to water irrigation is vital in the farm business. The lower quantile farms yields a minimum of 4 kilograms and 30 kilograms per tonnes. The field identification consists of communal, private and lease land. The private and lease land takes an average of 21% of the land used by smallholders, while communal land takes 79%. The farmer cultivates approximately 71% of 0-9 hectares of land. The type of irrigation method includes sprinkler (centre-pivot), drip, furrow, flood, bucket, and hosepipe. However, the use of drip and furrow take the lead. When it comes to the type of water pump, displacement and borehole pumps are commonly used. Irrigation is done daily for a maximum of 5 hours and above. As mentioned earlier, the study has categorically ordered variables for water information and an index of water variables was created. Similarly, the researcher created an index of financial literacy from categorically ordered variables using MCA. Relevant cost variables are logged.

The study looked at smallholder farmers that cultivated the following crops: nuts, avocados, citrus, potatoes and tomatoes.



Source: Author

Figure 4. 1: A display of the selected crops

Figure 4.1 presents the five selected crops and amongst the crops, the tomato has the highest mean, which shows that it is the most cultivated crop in the study followed by potatoes, nuts, citrus, and avocado. This is consistent with the discussion held with the farmers as they mentioned that they find it easier to plant the crop than the other crops due to its relatively low cost to plant. More so, some of the farmers emphasized that the tomato crop grows well in different soil series around the Limpopo province. Diaba and Felix (2015), in their study on farmers' comparative use assessment of wind and electric pump irrigation, found tomato to be among the leading cultivated crop as the crop provided the farmers with good amounts of yield and that tomato responded well to different soil types.

4.3 Multivariate analysis

The study presents the multivariate analysis of the influence that investments in the water irrigation infrastructure have on the volume of farm yield.

Table 4. 2: Effect of investments in water irrigation infrastructure on the farm yield (standard error).

	(1)	(2)	(3)	(4)	(5)
Variables	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield
Fixed capital index	4.207***	4.198***	4.267***	3.302***	4.353***
	(1.491)	(1.166)	(1.244)	(1.184)	(1.353)
Field Identification	3.309	3.255	3.616	4.662**	3.494
	(2.604)	(2.375)	(2.371)	(2.228)	(2.654)
Field size	1.939	2.014	1.928	0.742	1.721
	(2.081)	(2.053)	(2.042)	(1.978)	(2.360)
Field distance	5.066***	5.304***	5.013***	4.863***	4.801***
	(0.960)	(1.030)	(0.922)	(0.878)	(1.369)
Temperature	-0.0107	-0.161	0.00172	0.133	0.0376
	(0.378)	(0.389)	(0.347)	(0.315)	(0.438)
Gender	-2.551	-2.870	-2.746	-5.010**	-2.421
	(2.600)	(2.366)	(2.018)	(2.455)	(2.227)
Age	0.698	0.777	0.693	0.691	0.721
	(0.599)	(0.606)	(0.627)	(0.568)	(0.626)
Education Attainment	-0.943	-1.219	-0.905	-0.621	-0.927
	(1.618)	(1.625)	(1.489)	(1.457)	(1.603)
Irrigation Method	3.195*	4.051**	3.126	2.616	3.200*
	(1.849)	(1.550)	(1.869)	(1.598)	(1.811)
Diesel Energy	0.00527**	0.00527**	0.00517*	0.00403	0.00535*
	(0.00259)	(0.00253)	(0.00263)	(0.00320)	(0.00269)
Electric Energy	-0.000710	-0.00130	-0.000891	-0.00184	-0.000754
	(0.00255)	(0.00248)	(0.00270)	(0.00242)	(0.00247)
Nuts	-0.117				
	(2.056)				
Avocado		-6.679**			
		(3.005)			
Citrus			-1.216		
			(5.678)		
Potatoes				7.566**	

				(3.105)	
Tomatoes					-1.382
					(3.129)
Constant	3.393	7.939	3.485	1.728	2.088
	(15.42)	(15.29)	(15.54)	(12.67)	(16.55)
Observations	48	48	48	48	48
R-squared	0.570	0.600	0.571	0.628	0.573

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.2 column (1) presents the effect of capital investment in water irrigation on the farm yield for nuts. The investment in water irrigation has a positive and significant influence on the farm yield at a 0.01 confidence level. This implies that an investment in water irrigation tends to increase farm output. However, investment is not in favour of nuts as a crop. The distance from home to the farm is not a barrier; instead, it is an advantage to increasing the farm yield. The researcher is surprised that the method of irrigation and diesel energy contribute positively to the farm yield. In other words, the method of irrigation has a positive contribution to the increase in farm output, yet the irrigation method may not be an issue for future investment in nuts.

Similarly, column (2) shows that capital investment in water irrigation has a positive and significant effect on the farm yield at the 0.01 confidence level. Notwithstanding this, avocado as a crop performs poorly out of all five crops examined. Investment in water irrigation does not seem to be a problem; instead, there is a possibility of an unobserved specific effect that might have affected the avocado crop. The researcher does not have any justification for speculation, but it is likely to be pest-infested avocado.

Column (3) presents that the water irrigation investment contribution to the farm yield is negative for the citrus crop. One thing the researcher can think of is pest infestation in the absence of constant rainfall. However, column (4) displays that potatoes have a positive and a significant contribution to the farm yield at a 0.05 confidence level.

Although the irrigation method does not seem to be have an effect, this tells us that there is a possibility that potato cultivation does well naturally in the soil of this province. On the other hand, column (5) shows that tomatoes have a negative contribution to the farm yield. The reason for this low yield is because of pest infestation as most of the farmers do not regularly spray the fields to control the pests.

Table 4. 3: Bootstrapped quantile regression for the effect of fixed capital of water irrigation on the farm yield for Nuts

	(1)	(2)	(3)	(4)	(5)
	0.05	0.25	0.50	0.75	0.90
Variables	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield
Fixed capital index	1.74	2.30**	2.17	4.52**	5.05*
	(2.09)	(1.12)	(2.11)	(2.13)	(2.61)
Field Identification	4.27	3.90	2.41	7.99	6.56
	(12.00)	(14.05)	(8.59)	(9.67)	(11.11)
Field size	1.04	1.17	4.59	2.29	2.18
	(3.74)	(3.77)	(3.34)	(3.98)	(4.94)
Field distance	2.87	5.49**	5.55***	4.04	4.36*
	(3.08)	(2.12)	(1.47)	(3.17)	(2.50)
Temperature	-0.23	0.01	-0.05	0.09	-0.19
	(0.34)	(0.42)	(0.52)	(0.76)	(0.76)
Gender	-0.29	-1.50	-1.14	-3.32	-3.05
	(3.03)	(2.50)	(2.51)	(4.77)	(5.55)
Age	-0.15	0.31	0.06	1.06	1.10
	(0.86)	(0.64)	(1.23)	(0.99)	(1.31)
Education Attainment	-1.67	-1.21	-0.63	0.11	-0.36
	(1.43)	(1.36)	(2.59)	(2.11)	(2.74)
Irrigation Method	0.45	0.70	0.75	2.57	3.33
	(1.95)	(2.32)	(2.74)	(3.37)	(3.17)
Diesel Energy	-0.00	-0.00	0.00	0.01	0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)

Electric Energy	0.00	0.00	-0.00	-0.00	-0.00
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Nuts	2.36	1.72	-1.22	-2.86	-3.19
	(3.86)	(1.91)	(3.02)	(2.58)	(4.84)
Constant	12.51	4.25	9.82	3.65	12.73
	(12.01)	(18.12)	(23.47)	(28.51)	(30.96)
Observations	48	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The results show that water irrigation for those farms at the lower quantile does not have any effect on the farm yield. These are likely to be farmers that are struggling to find funds for water irrigation purposes. At 0.25 quantile, investment in water irrigation has a positive and significant influence on the farm yield. The result in column (4), the 0.75 quantile shows no difference when the researcher focuses on the water irrigation effect, while the distance from the field has no effect. There is a probability that some of those at the upper quantile live some distance from the field. Column (3) shows that investment in water irrigation has no effect for the farmers at 0.50 quantile. Column (5) presents the effect of investment in water irrigation on the farm yield at the upper quantile (0.9). This suggests that water irrigation contributes to the farm yield at the upper quantile.

Table 4. 4: Bootstrapped quantile regression for the effect of fixed capital of water irrigation on the farm yield for Avocadoes

Variables	(1) 0.05 Farm yield	(2) 0.25 Farm yield	(3) 0.50 Farm yield	(4) 0.75 Farm yield	(5) 0.90 Farm yield
Fixed capital index	1.68	2.15	4.05**	4.88	5.33**
	(1.11)	(1.33)	(1.96)	(2.96)	(2.10)

Field Identification	4.21	3.01	3.46	2.49	8.85
	(12.96)	(12.25)	(8.09)	(7.83)	(8.59)
Field size	1.19	3.00	4.54*	4.81	2.40
	(3.99)	(3.41)	(2.27)	(3.46)	(3.38)
Field distance	6.99	6.29	6.31**	4.69**	2.92
	(4.64)	(4.59)	(2.85)	(2.05)	(7.58)
Temperature	-0.26	-0.20	-0.45	-0.12	0.29
	(0.25)	(0.54)	(0.54)	(0.89)	(1.12)
Gender	-2.38	-1.52	-0.62	-0.61	-2.76
	(2.25)	(3.69)	(2.80)	(5.69)	(7.09)
Age	0.33	0.13	-0.08	0.52	1.15
	(0.61)	(0.63)	(0.63)	(1.29)	(1.20)
Education Attainment	-1.67	-2.06	-3.26*	-1.53	0.36
	(1.34)	(1.49)	(1.64)	(2.85)	(3.70)
Irrigation Method	2.53	2.14	3.05	3.24	3.37
	(1.56)	(2.50)	(2.24)	(4.34)	(4.41)
Diesel Energy	-0.00	-0.00	0.00	0.01*	0.01
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Electric Energy	0.00	0.00	-0.00	-0.00	-0.00
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Avocado	-6.64	-6.81	-8.92**	-6.77	5.31
	(4.53)	(5.06)	(3.58)	(9.13)	(13.09)
Constant	10.66	11.89	20.91	7.93	-5.66
	(10.39)	(17.39)	(21.16)	(34.47)	(38.41)
Observations	48	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.4 presents a bootstrap quantile regression (QR) analysis of the effect of water irrigation on the farm yield for avocadoes. The evidence indicates that fixed capital expenditure influences the farm yield for those at the 0.50 quantile and the 0.90 quantile. This suggests that farmers at the lower distribution might be struggling financially to acquire infrastructure for water irrigation purposes. The finding shows that farmers at the 0.50 and 0.75 quantiles are doing well when the researcher considered the distance to the farm and the yield. In column (4), a diesel engine seems to be cost-effective, and it influences that farm yield at 0.75 quantiles.

Table 4. 5: Bootstrapped quantile regression for the effect of fixed capital of water irrigation on the farm yield for Citrus

Variables	(1) 0.05 Farm yield	(2) 0.25 Farm yield	(3) 0.50 Farm yield	(4) 0.75 Farm yield	(5) 0.90 Farm yield
Fixed capital index	1.01	1.66	3.48	4.25***	5.19
	(2.09)	(2.77)	(2.85)	(1.44)	(3.53)
Field Identification	3.53	3.36	3.32	2.16	2.09
	(5.52)	(14.70)	(13.53)	(13.17)	(31.78)
Field size	5.34	5.66	4.74	4.91	2.89
	(3.19)	(3.51)	(3.27)	(4.34)	(6.94)
Field distance	7.20	5.58	5.83	4.62	3.42
	(5.28)	(4.90)	(4.09)	(6.36)	(5.22)
Temperature	-0.48	0.10	-0.33	-0.05	-0.33
	(0.29)	(0.42)	(0.57)	(0.43)	(0.83)
Gender	1.08	-2.51	-0.56	-0.83	-3.98
	(1.74)	(4.03)	(2.58)	(3.53)	(3.79)
Age	0.92	0.24	0.04	0.52	1.37
	(0.67)	(0.70)	(0.89)	(1.21)	(0.89)
Education Attainment	-1.67*	-1.29	-2.30	-1.34	-1.04
	(0.97)	(1.12)	(1.37)	(2.10)	(2.32)
Irrigation Method	-0.99	0.13	1.31	2.71	2.93
	(1.69)	(3.21)	(3.20)	(2.59)	(2.27)
Diesel Energy	0.00	0.00	0.00	0.01	0.01

	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Electric Energy	0.00	-0.00	-0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Citrus	-14.79	-22.38*	-3.35	6.72	15.63
	(14.20)	(13.15)	(10.82)	(11.49)	(15.92)
Constant	15.52	4.40	18.30	6.31	19.01
	(11.50)	(19.51)	(22.54)	(19.95)	(32.64)
Observations	48	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Since the sample size is small, Table 4.5 presents a bootstrap quantile regression for the influence of water irrigation on the farm yield at varying distribution. At 0.05, 0.25, 0.50 and 0.90 quantiles, investment in water irrigation has no effect on farm yield. The result in column (4), the 0.75 quantile, shows that water irrigation has a significant effect o farm yield.

Table 4. 6: Bootstrapped quantile regression for the effect of fixed capital of water irrigation on the farm yield for Potatoes.

Variables	(1) 0.05 Farm yield	(2) 0.25 Farm yield	(3) 0.50 Farm yield	(4) 0.75 Farm yield	(5) 0.90 Farm yield
Fixed capital index	0.49	1.66	2.35*	1.97	5.32
	(2.28)	(1.83)	(1.36)	(1.55)	(3.47)
Field Identification	4.87	4.18	4.49	8.31	5.87
	(10.46)	(12.28)	(7.48)	(6.69)	(10.69)
Field size	1.23	0.80	3.14	1.16	2.35

	(3.50)	(4.39)	(3.06)	(3.02)	(3.35)
Field distance	7.15***	5.87	5.18**	3.86***	3.14
	(1.40)	(4.00)	(2.19)	(1.37)	(5.26)
Temperature	-0.35	-0.10	0.08	0.43	-0.14
	(0.37)	(0.44)	(0.55)	(0.51)	(0.98)
Gender	-2.88	-3.12	-5.01	-6.25	-4.87
	(2.43)	(3.19)	(3.94)	(3.92)	(6.97)
Age	0.19	0.03	0.06	0.54	1.42
	(0.91)	(0.79)	(0.83)	(1.02)	(2.05)
Education Attainment	-1.67	-1.29	-0.85	0.63	-0.81
	(2.36)	(1.76)	(1.60)	(2.04)	(2.83)
Irrigation Method	-0.83	-0.39	0.81	1.42	3.84
	(2.39)	(2.15)	(2.38)	(2.87)	(4.50)
Diesel Energy	-0.00	-0.01	0.00	0.01*	0.01
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
Electric Energy	0.00	0.00	-0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Potatoes	8.81**	6.68*	7.03	8.68*	-0.45
	(3.40)	(3.45)	(4.95)	(4.60)	(9.99)
Constant	19.33	13.89	8.77	-3.38	12.08
	(16.58)	(18.91)	(20.01)	(22.65)	(35.19)
Observations	48	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The study applied the bootstrap quantile regression (QR) technique because it allows the investigation of conditional dependence of specific quantiles of farm yield for conditioning variables. Table 4.6 provides the results for the potatoes. The effect of water irrigation on the farm yield is positive and significant at the 0.5 quantile. On the track of the distribution, there is a positive relationship, but insignificant aside from the 0.50 quantile. This indicates that farmers at the lower quantile are likely to face challenges when investing in water irrigation. Nonetheless, at 0.05, 0.25 and 0.75 quantiles potatoes still have a positive and significant correlation with the farm yield. This implies that there is a varying contribution of the potato crop to the farm yield.

Table 4. 7: Bootstrapped quantile regression for the effect of fixed capital of water irrigation on the farm yield for Tomatoes.

Variables	(1) 0.05 Farm yield	(2) 0.25 Farm yield	(3) 0.50 Farm yield	(4) 0.75 Farm yield	(5) 0.90 Farm yield
Fixed capital index	0.98	1.73	3.48**	4.45**	5.45
	(1.98)	(2.00)	(1.33)	(2.17)	(3.29)
Field Identification	3.49	3.28	4.43	5.00	2.07
	(11.29)	(12.11)	(5.54)	(3.76)	(6.80)
Field size	1.26	2.31	4.14	3.74	2.26
	(3.07)	(3.09)	(3.70)	(3.36)	(4.19)
Field distance	6.70*	5.94**	5.15	3.55	2.08
	(3.48)	(2.87)	(4.50)	(2.60)	(4.80)
Temperature	-0.31	-0.02	-0.13	0.18	-0.10
	(0.43)	(0.51)	(0.45)	(0.55)	(0.69)
Gender	0.95	-1.82	-1.56	-2.63	-2.19
	(3.34)	(2.90)	(2.24)	(3.66)	(5.91)
Age	0.86	-0.05	-0.13	0.12	1.40
	(1.24)	(0.74)	(1.55)	(1.25)	(1.09)
Education Attainment	-1.67	-2.19	-1.38	-0.65	-0.71
	(1.78)	(1.96)	(2.27)	(2.27)	(2.38)
Irrigation Method	-0.87	-0.20	1.13	1.92	1.58
	(2.25)	(2.51)	(2.88)	(2.87)	(4.08)
Diesel Energy	-0.00	-0.00	0.00	0.01**	0.01
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
Electric Energy	0.00	0.00	-0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

Tomatoes	-1.53	0.11	-2.21	-5.24	-4.09
	(3.69)	(3.62)	(2.35)	(3.82)	(7.29)
Constant	11.40	10.34	14.29	5.61	14.10
	(19.74)	(20.01)	(23.06)	(23.00)	(23.88)
Observations	48	48	48	48	48

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.7 presents a bootstrap quantile regression (QR) analysis of the effect of water irrigation on the farm yield for tomatoes. There is a positive and significant relationship between the 0.5 and 0.75 quantiles. Similar to the other crops, the results suggest that a heterogeneous effect exists in the distribution along with the farm yield. Evidence indicates that farmers at the lower quantile are likely to experience challenges when investing in water irrigation. However, diesel energy has a positive and significant relationship with farm yield. Tomatoes have a negative association with farm yield in all the quantiles.

Table 4. 8: Effect of water irrigation systems cost on the farm yield using OLS and Quantile regression: Nuts

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	(0.05)	0.25	0.50	0.75	0.90
Variables	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield
Total cost index	5.945**	1.612	1.370	1.232	7.822**	8.695*
	(2.409)	(3.494)	(4.785)	(3.933)	(3.033)	(4.656)
Saline	1.261	2.087	-3.088	-2.292	0.643	-1.761
	(2.721)	(2.759)	(3.884)	(3.742)	(3.730)	(4.270)
Pumping borehole	-0.275	-2.541	-2.186	-1.971	0.662	-3.698
	(1.533)	(2.298)	(2.263)	(2.416)	(3.937)	(4.789)
Pumping reservoir	1.792	3.210	3.176	3.750	1.513	2.951
	(1.836)	(2.620)	(3.246)	(3.085)	(3.104)	(3.011)

Pumping electric	-0.642	-0.551	0.973	0.943	-0.591	-0.0563
	(0.986)	(1.332)	(1.627)	(1.686)	(2.130)	(2.782)
Pumping fuel engine	-0.577	-1.247	0.335	-0.862	-0.411	1.740
	(1.109)	(1.445)	(2.110)	(1.624)	(2.051)	(2.230)
Pumping drip	-2.336*	-4.003	-2.803	-3.282	-1.552	-0.570
	(1.226)	(2.455)	(2.370)	(2.828)	(2.062)	(2.691)
Pumping sprinkler	1.391	3.129	0.758	0.372	-0.0882	3.434
	(1.583)	(2.572)	(2.944)	(2.074)	(3.216)	(4.350)
Pumping furrow	2.080**	0.781	1.402	1.768*	0.998	1.201
	(0.828)	(1.080)	(1.489)	(0.965)	(1.874)	(2.699)
Pumping pivot	-0.0712	0.706	-0.340	-1.237	2.228	0.432
	(1.630)	(1.815)	(2.605)	(2.811)	(2.712)	(3.041)
Pumping Bucket	-1.557	-0.0672	-0.530	-0.899	-0.779	-2.432
	(0.957)	(0.993)	(1.742)	(1.220)	(1.780)	(3.045)
Nuts	0.0738	-1.790	-1.485	0.203	-3.178	-3.583
	(2.816)	(2.070)	(4.176)	(3.221)	(4.330)	(8.413)
Constant	7.831*	2.947	8.150	10.37	8.731	11.83
	(4.051)	(10.15)	(8.214)	(8.898)	(6.685)	(9.852)
Observations	48	48	48	48	48	48
R-squared	0.582					

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.8 presents OLS and quantile regression of the effect of investment in water irrigation infrastructure on the farm yield for nuts. The result shows that there is a varying effect. Water irrigation for farming nuts has a positive and significant effect on the farm yield, as presented in column (1). In column (1), pumping using furrows has a positive and significant contribution to the farm yield. The result suggests that the total cost index has a positive and significant relationship at the 0.75 and 0.90 quantiles. Farmers at the lower quantiles may not be able to finance the fixed cost of the investment that is likely to be a farm asset.

Table 4. 9: Water irrigation systems cost and farm yield using OLS and Quantile regression: Avocados

Variables	(1) OLS Farm yield	(2) (0.05) Farm yield	(3) 0.25 Farm yield	(4) 0.50 Farm yield	(5) 0.75 Farm yield	(6) 0.90 Farm yield
Total cost index	6.062**	2.966	4.622	0.909	9.118	8.113**
	(2.373)	(3.821)	(3.014)	(4.149)	(5.540)	(3.214)
Saline	2.072	2.625	2.043	-1.272	2.180	0.176
	(3.177)	(3.595)	(2.607)	(4.546)	(6.283)	(8.258)
Pumping borehole	-0.456	-3.633	-2.344	-1.772	0.618	1.170
	(1.407)	(2.570)	(2.240)	(3.530)	(2.264)	(3.080)
Pumping reservoir	1.859	3.595	2.641	3.341	1.155	-0.0838
	(1.814)	(3.172)	(2.081)	(4.537)	(3.093)	(2.819)
Pumping electric	-0.555	0.123	0.191	0.754	-0.356	1.002
	(1.034)	(1.248)	(1.106)	(1.770)	(1.594)	(2.117)
Pumping fuel engine	-0.722	-1.752	-1.347	-0.698	-0.807	-0.0843
	(1.130)	(1.937)	(1.347)	(1.593)	(2.147)	(2.571)
Pumping drip	-2.390*	-4.905**	-3.000*	-3.150	-1.549	0.0570
	(1.238)	(2.352)	(1.613)	(2.152)	(2.335)	(2.772)
Pumping sprinkler	1.565	3.467*	1.997	0.792	-0.299	-2.960
	(1.536)	(1.829)	(3.087)	(4.113)	(2.298)	(4.281)
Pumping furrow	2.211**	1.633	2.211**	1.757	2.189	3.810
	(0.835)	(1.932)	(1.052)	(1.777)	(1.458)	(2.269)
Pumping pivot	0.302	0.985	0.506	0.391	3.256	5.056
	(1.745)	(3.475)	(2.378)	(4.130)	(3.673)	(5.664)
Pumping Bucket	-1.593*	-0.589	-1.651	-0.946	-2.616	-4.907*
	(0.913)	(1.919)	(1.197)	(1.673)	(2.696)	(2.475)
Avocado	-2.648	-0.322	-2.718	-1.489	-3.660	-6.020
	(2.972)	(3.192)	(4.951)	(4.720)	(5.663)	(9.259)
Constant	7.072	3.323	5.069	5.947	8.030	9.416
	(4.313)	(7.233)	(7.323)	(8.184)	(7.059)	(14.73)

Observations	48	48	48	48	48	48
R-squared	0.588					

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.9 presents OLS and quantile regression of the effect of investment in water irrigation infrastructure on the farm yield for avocado. First, the OLS regression shows that there is a positive and significant relationship between the total cost index for avocado and the farm yield. The rest of the column displays a heterogeneous effect of the total cost index on the farm yield. Column (6) shows that the total cost index has a positive and significant effect on the farm yield at the 0.90 quantiles. Nonetheless, the avocado crop has a negative but insignificant result with the farm yield. Interestingly, farmers in the lower quantiles might have been struggling with the total cost of operation, but not only that, they struggled with the farm asset.

Table 4. 10: Effect of the water irrigation systems cost on the farm yield using OLS and Quantile regression: Citrus

Variables	(1) OLS Farm yield	(2) (0.05) Farm yield	(3) 0.25 Farm yield	(4) 0.50 Farm yield	(5) 0.75 Farm yield	(6) 0.90 Farm yield
Total cost index	5.937**	5.266	4.665	1.059	8.798	8.658**
	(2.318)	(4.378)	(4.344)	(4.561)	(5.304)	(4.014)
Saline	0.994	1.066	0.523	-2.903	0.264	-2.492
	(2.682)	(2.133)	(2.531)	(5.033)	(5.366)	(6.007)
Pumping borehole	-0.426	-2.076	-2.447	-1.655	1.657	1.801
	(1.351)	(2.295)	(2.508)	(2.315)	(3.452)	(4.875)
Pumping reservoir	1.945	3.155	2.121	3.137	-0.126	-0.911
	(1.732)	(2.725)	(2.877)	(2.943)	(4.458)	(4.149)
Pumping electric	-0.588	-0.415	0.310	0.681	-0.662	0.850
	(1.019)	(1.091)	(1.314)	(2.142)	(1.447)	(2.216)

Pumping fuel engine	-0.364	-1.452	-1.561	-0.308	-0.494	-0.132
	(1.184)	(1.715)	(1.328)	(2.071)	(2.690)	(2.558)
Pumping drip	-2.319*	-2.799	-2.687	-2.999	-0.228	0.962
	(1.257)	(2.554)	(2.138)	(2.517)	(2.834)	(4.013)
Pumping sprinkler	1.231	2.334	1.951	0.483	-0.0362	-3.196
	(1.497)	(1.873)	(2.735)	(3.830)	(5.054)	(5.933)
Pumping furrow	1.807*	1.987	2.311**	1.497	1.544	3.939**
	(0.932)	(1.203)	(1.024)	(2.028)	(1.546)	(1.829)
Pumping pivot	0.515	-0.996	-0.0943	-0.120	0.831	2.301
	(2.048)	(2.708)	(1.910)	(3.871)	(3.848)	(4.133)
Pumping Bucket	-1.635	-1.987*	-1.073	-0.484	-1.634	-3.497*
	(1.005)	(1.085)	(1.258)	(1.380)	(1.219)	(1.986)
Citrus	-3.033	-4.548	-0.675	-3.259	5.478	3.929
	(6.071)	(11.45)	(7.324)	(13.82)	(7.030)	(12.93)
Constant	7.517*	6.528	6.677	7.745	9.798	12.56
	(3.965)	(6.982)	(5.821)	(11.30)	(10.08)	(13.17)
Observations	48	48	48	48	48	48
R-squared	0.590					

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.10 presents OLS and quantile regression of the effect of investment in water irrigation infrastructure on the farm yield for citrus. The OLS regression shows a positive and significant relationship between the total cost index for Citrus and the farm yield. The total cost index has a varying effect on the distribution of the farm yield. Column (6) shows that the total cost index has a positive and significant effect on the farm yield at 0.90 quantiles for citrus. Whereas all quantiles do not affect the farm yield, the evidence indicates similar findings with other crops that the farmers at the lower quantiles might have been struggling with the total cost of operation.

Table 4. 11: Effect of water irrigation systems cost on the farm yield using OLS and Quantile regression: Potatoes

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	(0.05)	0.25	0.50	0.75	0.90
Variables	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield
Total cost index	5.456**	3.093	1.988	2.088	8.603**	8.744**
	(2.084)	(2.952)	(3.637)	(4.057)	(3.403)	(3.945)
Saline	1.556	2.466	-0.727	0	4.400	-0.801
	(2.390)	(3.791)	(3.241)	(5.543)	(4.456)	(5.484)
Pumping borehole	-0.886	-3.766**	-1.439	-1.810	-0.0764	-3.662
	(1.274)	(1.643)	(2.149)	(1.880)	(3.792)	(5.200)
Pumping reservoir	0.756	3.644	2.098	1.024	0.879	3.771
	(1.790)	(3.389)	(2.415)	(2.773)	(3.299)	(4.848)
Pumping electric	-0.793	0.0566	0.0142	0.524	-0.636	0.126
	(1.001)	(1.614)	(1.272)	(0.928)	(1.819)	(2.128)
Pumping fuel engine	-0.770	-1.745	-0.866	-1.397	-1.051	-0.136
	(1.085)	(1.266)	(0.921)	(1.787)	(2.595)	(3.014)
Pumping drip	-1.542	-4.945*	-2.309	-1.601	-2.527	0.261
	(1.266)	(2.769)	(2.157)	(2.221)	(1.592)	(2.827)
Pumping sprinkler	2.883*	3.581	1.140	2.290	1.775	4.095
	(1.577)	(3.280)	(3.758)	(2.343)	(5.106)	(6.365)
Pumping furrow	1.670*	1.633	0.990	0.990	2.536	1.808
	(0.844)	(1.160)	(1.331)	(1.466)	(1.532)	(1.781)
Pumping pivot	0.292	0.934	0.552	-0.0193	3.015	-1.065
	(1.511)	(4.155)	(2.491)	(2.249)	(2.894)	(4.794)
Pumping Bucket	-1.136	-0.655	-1.407	0	-2.229**	-2.435
	(1.022)	(1.328)	(1.021)	(1.679)	(0.952)	(1.612)
Potatoes	6.396*	0.302	5.828	9.541	4.758	-0.520
	(3.664)	(7.062)	(4.111)	(6.241)	(7.076)	(8.382)
Constant	5.232	3.575	6.126	5.441	5.371	10.87**
	(3.798)	(12.61)	(13.60)	(7.694)	(7.731)	(4.769)
Observations	48	48	48	48	48	48

R-squared	0.624

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.11 presents OLS and quantile regression of the effect of investment in water irrigation infrastructure on the farm yield for potatoes. Column (1) shows that there is a positive and significant total cost on the farm yield using OLS. The quantile result shows that there is a varying effect of the total cost on the farm yield for potatoes. The evidence in the findings suggests that the total cost index has a positive and significant relationship at the 0.75 and 0.90 quantiles. This implies that farmers that have access to funds are likely to break even in potato farming. The farmers at the lower quantiles are likely to struggle with finance such as the operating costs, and they are likely not to do well.

Table 4. 12: Effect of water irrigation systems cost on the farm yield using OLS and Quantile regression: Tomatoes

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	(0.05)	0.25	0.50	0.75	0.90
Variables	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield	Farm yield
Total cost index	5.694**	1.884	3.899	0.735	8.777**	8.799**
	(2.411)	(3.890)	(3.324)	(3.807)	(3.892)	(4.177)
Saline	0.881	2.449	0.493	-2.570	-0.147	0.293
	(2.741)	(3.779)	(3.864)	(5.318)	(4.375)	(5.031)
Pumping borehole	-0.0832	-1.105	-2.607	-2.122	0.626	-3.015
	(1.436)	(2.714)	(2.426)	(2.850)	(2.928)	(3.612)
Pumping reservoir	1.369	2.757	2.774	3.650	1.082	4.616
	(1.839)	(1.944)	(2.149)	(3.405)	(5.193)	(4.244)
Pumping electric	-0.659	-0.395	0.189	1.032	-0.142	-0.263
	(1.049)	(0.919)	(1.371)	(2.109)	(2.211)	(2.674)
Pumping fuel engine	-0.685	-1.174	-1.567	-0.986	-0.214	-0.140
	(1.112)	(1.403)	(1.427)	(1.622)	(1.952)	(2.685)
Pumping drip	-2.182*	-2.915*	-2.935*	-3.290*	-1.346	0.0948

	(1.243)	(1.670)	(1.618)	(1.898)	(3.384)	(3.219)
Pumping sprinkler	1.608	1.997	1.978	0.675	-0.632	3.274
	(1.593)	(3.662)	(1.770)	(3.397)	(2.825)	(4.205)
Pumping furrow	2.018**	0.988	1.971	1.706	1.635	1.650
	(0.827)	(0.943)	(1.464)	(1.490)	(1.503)	(2.428)
Pumping pivot	-0.557	0.120	0.402	-1.159	3.059	0.404
	(1.729)	(3.520)	(2.158)	(2.614)	(3.918)	(4.503)
Pumping Bucket	-1.434	-0.226	-1.522	-0.682	-1.673	-3.285
	(0.970)	(1.356)	(1.216)	(1.394)	(1.660)	(2.245)
Tomatoes	-1.851	1.756	0.591	-0.651	1.305	3.386
	(2.340)	(4.347)	(4.004)	(3.983)	(7.434)	(9.251)
Constant	9.429**	1.002	5.588	10.19	7.092	6.383
	(4.474)	(10.31)	(7.637)	(7.078)	(8.831)	(14.99)
Observations	48	48	48	48	48	48
R-squared	0.586					

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.12 presents OLS and quantile regression of the effect of investment in water irrigation infrastructure on the farm yield for tomatoes. Column (1) displays that the total cost has a positive and significant contribution to the farm yield for tomatoes. The result is similar to that of potatoes. The result suggests that the total cost index has a positive and significant relationship at the 0.75 and 0.90 quantiles. Farmers at the lower quantiles may not be able to finance the fixed cost of the investment that could be farm assets. The OLS shows the correlation between climate changes (measured by water availability for irrigation) and output farm yield with option robust standard error.

Table 4. 13: Effects of climate change (measured by water availability for irrigation) on output farm yield.

	(1)	(2)	(3)	(4)
	1	2	3	4

Variables	Farm yield	Farm yield	Log of revenue	Log of revenue
Water availability for irrigation index	-4.608	-4.219	-0.232*	-0.233**
	(3.134)	(2.730)	(0.116)	(0.110)
Temperature	-0.215	-0.0596	-0.00319	0.00246
	(0.293)	(0.262)	(0.0133)	(0.0147)
Total cost index	2.646	2.348	0.258*	0.236*
	(2.538)	(2.529)	(0.134)	(0.139)
Fixed capital index	-1.019	-1.270	-0.0573	-0.106
	(1.683)	(1.648)	(0.0665)	(0.0671)
Financial literacy index	1.322	0.736	0.0854*	0.0308
	(0.868)	(0.766)	(0.0492)	(0.0496)
Land index	6.867	4.888	0.950***	0.819**
	(5.789)	(5.037)	(0.337)	(0.332)
Nuts	-2.818		-0.0951	
	(2.595)		(0.136)	
Avocado	-5.415		-0.425**	
	(4.370)		(0.182)	
Citrus	-6.933		-0.568**	
	(5.558)		(0.226)	
Potatoes		7.403**		0.452***
		(2.784)		(0.142)
Tomatoes		2.068		0.213
		(3.057)		(0.165)
Constant	24.17**	13.46*	12.68***	12.09***
	(9.554)	(7.947)	(0.477)	(0.507)
Observations	48	48	48	48
R-squared	0.546	0.563	0.777	0.756

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The index of water availability for irrigation is a continuous variable restructured by using MCA. Table 4.13 presents column (1) as regression of the effect of the water availability for irrigation on the farm yield (output in Tonnes per kilogram). The general results reveal that water availability for the irrigation index has a negative relationship with farm yield, even from column (2) to column (4). Column (2) indicates that potatoes have a positive and significant association with the farm yield at the 0.05 confidence level. Column (3) presents the relationship between financial literacy and log of revenue at 0.1 confidence level. An increase in the land (size of the field and distance the house to the field) will also increase revenue. In contrast, avocado and citrus have a negative and significant relationship with the log of revenue. Column (4) shows a similar result as that of column (3). Potatoes have an influence on the log of revenue at the 0.01 confidence level.

The findings, as mentioned above, have policy implications; however, this study focuses on providing a plausible explanation that may attract further investigation into whether the presence of saline in the soil is harmful to a good farm yield.

Table 4. 14: ***Summary of VIF; evidence with the model in column (2)***

```
    Variable |       VIF       1/VIF

-------------+----------------------

 water_index |      4.99    0.200561

capital_in~x |      3.43    0.291239

totalcost_~x |      2.72    0.367709

    Tomatoes |      1.81    0.551339

 temperature |      1.70    0.588418

        land |      1.52    0.659944

    Potatoes |      1.31    0.761246

finlit_index |      1.27    0.785973

-------------+----------------------
```

```
Mean VIF |       2.34
```

Table 4.14 presents evidence of the absence of multicollinearity in the regression; all the covariates are less than 5. There is no redundancy in the inclusion of the variables, the researcher investigated all the equations, and there is no collinearity.

*Table 4. 15: **Effect of the farmers' level of education on the farm yield.***

Variables	(1) Farm yield	(2) Farm yield	(3) Log of revenue	(4) Log of revenue
Matric	4.244	3.306	0.425**	0.398**
	(3.385)	(3.057)	(0.190)	(0.169)
Diploma	-3.771	-3.407	0.248	0.290
	(5.162)	(4.833)	(0.290)	(0.268)
Higher Certificate	-3.073	-1.584	0.0927	0.169
	(3.947)	(3.650)	(0.222)	(0.202)
Bachelor's Degree	5.526	5.542	0.923**	0.963**
	(7.332)	(6.475)	(0.412)	(0.358)
Master's Degree	-10.44*	-9.909*	-0.0710	-0.0637
	(5.455)	(5.062)	(0.306)	(0.280)
Financial literacy index	1.626	1.115	0.102	0.0715
	(1.387)	(1.168)	(0.0779)	(0.0646)
Water index	-6.828**	-5.125*	-0.327**	-0.221
	(2.631)	(2.636)	(0.148)	(0.146)
Temperature	-0.349	-0.00921	0.0158	0.0352
	(0.430)	(0.418)	(0.0241)	(0.0231)
Gender	-1.921	-3.295	-0.282	-0.380**
	(3.242)	(3.079)	(0.182)	(0.170)
Age	-0.0848	0.140	0.0253	0.0395
	(0.717)	(0.682)	(0.0403)	(0.0377)
Total cost index	3.978**	3.689**	0.385***	0.366***
	(1.829)	(1.728)	(0.103)	(0.0957)

Fixed capital index	-3.770	-2.897	-0.319**	-0.294**
	(2.335)	(2.005)	(0.131)	(0.111)
Nuts	-5.412		-0.349*	
	(3.524)		(0.198)	
Avocado	-5.684		-0.361	
	(4.956)		(0.278)	
citrus	-3.647		-0.394*	
	(3.675)		(0.206)	
Potatoes		7.858**		0.569***
		(2.916)		(0.161)
Tomatoes		1.560		0.175
		(2.900)		(0.161)
Constant	28.27*	13.25	11.64***	10.70***
	(14.85)	(14.20)	(0.834)	(0.786)
Observations	48	48	48	48
R-squared	0.628	0.660	0.748	0.777

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Column (1) of Table 4.15 presents the regression of the effect of the farmers' level of education on the farm yield (output in Tonnes per kilogram). The education attainment level is a categorically ordered variable. The base of the factor of the level of education is no education, which includes a good number of farmers. Farmers with a matric level of education have a positive but insignificant correlation to the farm yield. An increase in the total cost tends to increase the farm yield significantly at the 0.05 confidence level. The water index, which measures saline in the soil has a negative and significant correlation with the farm yield. Column (2) presents a similar result to that of column (1); but shows that potatoes have a positive and significant association with the farm yield at a 0.05 confidence level.

Column (3) presents the relationship between education and log of revenue. It is expected that an increase in the level of education will increase revenue. The outcome of this study is compatible with the literature. Citrus has a negative and significant relationship with the log of revenue. This suggests that this result is similar to the previous outcome result in this study. In comparison, the matric level has a positive and significant relationship with the log of revenue. The water index may be a proxy of saline, and it is unrelated to the log of revenue. At the same time, the total cost influences the log of revenue significantly at the 0.01 confidence level. Column (4) shows a similar result to that of column (3). Potatoes have an influence on the log of revenue at the 0.01 confidence level. Evidence indicates that fixed capital does not increase the log of revenue. Perhaps, different pumping systems may have different effects on the amount of revenue generated and thus the various pumping infrastructure might have been depreciating.

4.4 OVERVIEW AND DISCUSSION OF THE FINDINGS

This study aims to examine the challenges of poor irrigation practices by rural farmers and the resultant high costs that may have led to poor farm yield. These challenges need to be understood to assist smallholder farmers in managing their irrigation costs and increasing farm yield to improve the farmers' income. The following discussion is based on the statistical model that was conducted and includes the information that was gathered from the farmers themselves during the discussion with them.

4.5 DISCUSSION OF THE FINDINGS

The first question of the study seeks to understand the influence of investment in water irrigation infrastructure on farm yield. From the results presented in Table 4.2 above, the capital investment into water irrigation infrastructure has a positive influence on crop yield. Surprisingly, for some of the crops, including citrus and tomato, was found to have a negative influence on crop yield. The farmers have indicated that they experience fruit dropping because of the increasing heat and as a result, more investment is required for infrastructure such as nets that will reduce the direct heat contact with the citrus trees. One of the most controversial issues is that regardless of the investment made into the borehole, farmers themselves and other businesses like the mine in the surrounding areas compete for the underground water. Moreover, farmers are left with the option to drill deeper boreholes to access adequate water, only for the borehole to collapse or not have an adequate water supply. Similarly, more and more borehole failures have been reported due to the borehole running dry (Brand, 2018).

Figure 4. 2: Above ground borehole structure of the farmer

Source: Author

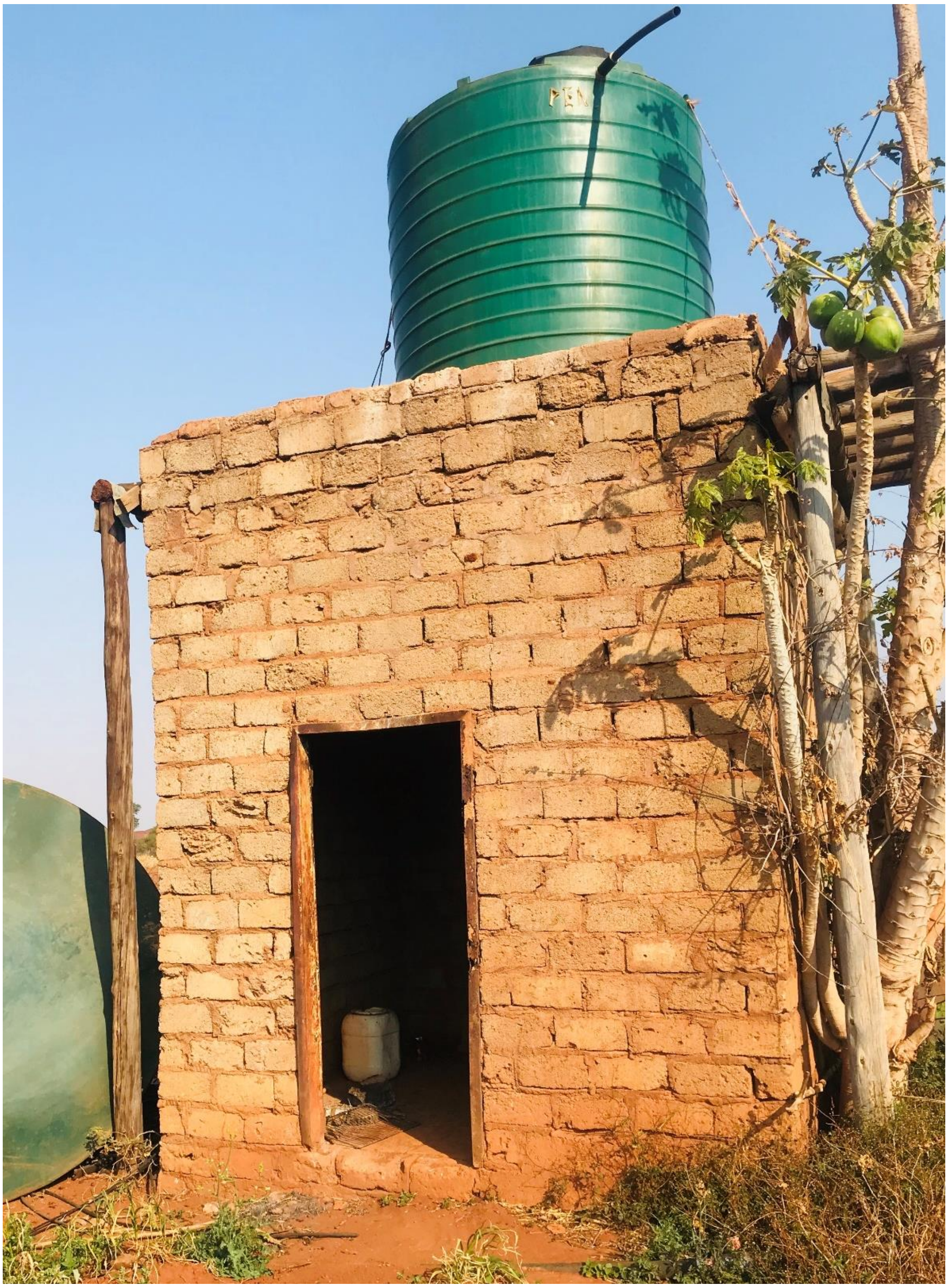


Figure 4. 3: Water storage structure used by the farmer

Source: Author

From the discussion with some of the farmers, they noted that they are farming in a region located within the semi-arid region of the Limpopo province and thus they mostly rely on groundwater as a source of water for irrigation. Suo and Cao (2021) found that in China most farmers that use ground water are located in arid and semi-arid regions. That being the case accessing the underground water is mostly a costly exercise and this requires farmers to make large investments to access the precious resource and have adequate water available for irrigation. Similarly, Varghese *et al*. (2012) analysed how groundwater irrigation can impact farm profits. The results show that according to the declining groundwater levels, additional investment and at times exorbitantly high investments makes farmers use up all the profitable. Figures 4.2 and 4.3 above display a typical borehole structure and water storage structure in the form of a tank that is used by most of the smallholders around the region. Farmers are of the view that the costs of drilling and constructing a borehole system are on the rise and that government needs to subsidise the costs of investment to finance the cost of accessing groundwater. The cost of drilling and constructing a borehole depends on several factors, processes and components that are used to gain access to the water.

The farmers believe the following to be some of the factors that can greatly influence the cost of investment in accessing groundwater and this includes the type of the ground, the depth of the borehole, and the purpose of the borehole, the machinery to be used by the borehole and other equipment and material such as pumps, valves, and pipes. Hughes, Donoghoe and Whittle (2020) observed that with an increase in on-farm investments they found that the benefit associated with the high costs are increased productivity and profits for the farmers. The investment costs in the borehole system can range from R16 200.00 to R150 000.00 depending on the various factors listed above. Farmers also mentioned that the costs sometimes skyrocket and can reach amounts above R200 000.00 to drill and construct a borehole structure. Some of the farmers provided the following account, regarding the use of borehole water:

"We have no choice but to drill and use borehole water because no one will provide water for us and without water, I can't work"

"Water from the borehole is the only solution for us because if you can see there are no rivers or dams here".

Figure 4.4 below is a dam infrastructure that was constructed by one of the farmers. The farmers contend that saline from groundwater is one of the substances that negatively affects the yield and to counter this negative impact, the farmer had to construct the dam. Some of the farmers, however, say that water that comes directly from the borehole contains substantial amounts of saline and this compels them to put other additional investments in place to construct a miniature dam where the water quality can be improved. Ali, Xia, Jia, and Faisal (2020) found that farmers prefer to invest in groundwater for irrigation purposes, even in the presence of increased costs and other externalities. Farmers contend that in doing so they seek to protect themselves against price, yield and income uncertainties surrounding inadequate water supplies. Hence, it is more likely that with increased investments the cost-benefit ratio will continually decline leaving the farmers with little benefit. Nazir, Abdalla, Wang, Chu, Jie, Tian, Jiang, Khan, Sanjeevikumar and Tang (2020) found that as costs increase the margin of benefit will decrease, resulting in a lower cost-benefit ratio for the farmers. However, the inevitable high water irrigation investment costs, mean that farm yield/returns should match the relatively high costs to certify a significant and positive cost-benefit ratio.

Figure 4. 4: Dam structure constructed by the farmer

Source: Author

The dam is used as a secondary water storage facility where the saline water is cleaned before the water is used for irrigation purposes. The farmer is of the view that this has improved yield significantly regarding both the quality and quantity of the yield. The construction of the dam came as an added investment cost and this turned out to yield positive results for the farmer. Sandhu, Scialabba, Warner, Behzadnejad, Keohane, Houston, and Fujiwara (2020) observed an increase in corn production (farm yield) when substantial capital investments were done at the farm level. Furthermore, noting an increased cost-benefit ratio for the farmers (Sandhu et al., 2020). This is in support of the cost-benefit theory, where the benefits of the dam construction outweighed the costs of the dam and as such, the farmer has seen improvement in both quality and quantity of farm yield. According to the farmers, there are different irrigation systems for different crop types. Farmers indicated that to get the best possible results for the potato crop it is better to use the centre-pivot, and the tomato generally does well under drip irrigation. A study conducted by Ali *et al.* (2020) found that drip irrigation systems provided positive results for tomatoes and indicated that production increased by at least 45 %. For the tree crops, such as citrus, nuts and avocadoes, farmers prefer the use of drip or jet sprinkler irrigation systems.

The financing of investment costs is one thing and financing operating costs is another thing. Based on the discussion, farmers say that their systems costs vary depending on the type of irrigation equipment put in place and the number of hectares that are cultivated. Ciliberti, Frascarelli, and Martino (2020) identified costs such as transaction costs, labour, fuel as some of the cost items that farmers can incur in their farming business. Furthermore, Suo and Cao (2021) in China found that these farming costs vary in relation to the farmers' geographical location and the type of crop they produce.

Figure 4. 5: Centre-pivot irrigation system for the potato crop

Source: Author

Farmers rely mostly on electricity and/ fuel as the preferred energy source.

Now to understand the influence of water irrigation systems costs on the volume of farm yield. Tables 4.8 to 4.12 show varying results. The results show that operation costs have a positive and significant influence on farm yield. Operation costs vary from farmer to farmer and mostly depend on the infrastructure that has been put in place by the farmer. Though most of the farmers use electricity to pump water, they have noted that the cost of electricity has spiked, and this increases their water irrigations costs. Subsequently, Heinrichs, Kuhn, Pahmeyer, and Britz (2021) found that crop production costs have increased as a result of inputs such as diesel, machinery maintenance and labour.

However, some farmers that use diesel are of the view that pumping using a diesel machine is more reliable than an electric machine that often succumbs to load shedding that is currently affecting the country. Furthermore, smallholders are unhappy/displeased that load-shedding leads to no pumping as it results in yield losses due to the unavailability of water during the load-shedding; especially because the temperatures are very high on most of the days. Furthermore, farmers that use diesel engines say that during rainy days they have the option not to buy diesel to pump water, whereas farmers that use electricity incur both a fixed charge and a variable fee on the monthly electricity bill, regardless of whether they pumped water or not. The theory of costs comes into play here as the farmers need to understand how to manage the fixed cost element that is associated with using electricity. In this way, the production costs can be managed efficiently thereby ensuring profitability for the farmers. Furthermore, the farmer's operation costs increase with the depth of the borehole and pumping lift. This is supported by Varghese *et al*. (2012) who found that water irrigation cost increases as the water table declines, thus resulting in increased pumping costs.

Other farmers have indicated that they incur insignificant operation costs depending on the type of irrigation system that is being utilised. These farmers use the furrow irrigation system. Farmers are aware that the furrow irrigation system does not save water and more often than not leads to soil erosion; however, they preferred using it as it does not involve huge investment and/or operational costs. During the study, farmers indicated that farmers themselves and family members usually do most of the labour. This is done to save on operation costs. The study found that most of the avocado farmers use the bucket system of irrigation, due to their inability to invest in a suitable irrigation system. The farmers fill their water containers and drums with water then return to their plots where the water is then applied to the trees using buckets. This has proven to be detrimental to the farmers because the farmers in the area using the bucket system are forced to incur further costs (fuel costs) to mitigate the risk of an inadequate water supply in their area. Additionally, Vogt, de Melo, Daher, S, Schmuelling, Antunes, dos Santos and Albiero (2021) in a study on family farming found that fuels take up the largest percentage of the operations costs. The farmers say they can spend up to R1000 a month on fuel costs, to travel to and from where they get access to water and their plots. The farmers say they do all this labour themselves because of the high labour costs that in return affect their profitability.

Figure 4. 6: Tomato crop planted under furrow irrigation.

Source: Author

Thirdly, the effect of climate change on farm yield was investigated. The results in table 4.13 indicate that the water availability index has a negative relationship with farm yield. Farmers have noted that lack of water availability does affect their farm yield. Vico, Tamburino and Rigby (2020) in a study on farm irrigation found that lack of water has decreased the average yield of farmers. The study found that in most cases, the land used for cultivation is reduced because of the lack of water. Farmers over the years have noticed an increase in the maximum temperature followed by delayed rain seasons and sometimes short rainy seasons. Farmers believe this has affected the timing of cultivation which has a direct impact on farm yield. Farmers say they do not have an adequate water supply as they are situated on dry land. The farmers say that one of the challenges that comes with this is they must drive to other places where they can access water. This mitigation strategy is seen as a suitable option as they cannot afford the costly irrigation infrastructure. This, however, exposes the farmers to incurring more fuel costs because of the frequent travelling to fetch water. For the farmers, this is a labour-intensive task that limits the area under cultivation and results in decreased farm yield. Wahyudi (2021) found that during planting and harvesting seasons this process is labour intensive. Farmers mentioned that the lack of water in the area has affected them negatively in the form of fruit droppings and sometimes insufficient fruiting of the trees due to inadequate water applied to the trees. The following recorded statement from the farmers illustrates this:

“There is no enough rainfall so the rivers doesn’t run, it doesn’t fill the underground water and farmers are extracting a lot of water and eventually there is no water”

“Not having water makes us to not plant and because it’s too hot here the avocados sometimes fall down from the trees”

The study considered the effects of the influence of the farmer’s level of education on farm yield. The study found that most of the farmers had not attained any form of education. However, those that had attained some form of education, such as a matric level of education were found to have a positive but insignificant correlation to farm yield. The study further revealed that farmers with a master’s degree or higher qualification have a negative relationship with farm yield and with the log of revenue. In support of this, Kalunda (2014) revealed that a high level of educational attainment will not necessarily translate into knowledge application by the farmer or to lead to increased revenues. These findings inform the researcher that some level of education is sufficient to enable the farmer to benefit through farm yield. Furthermore, the study found that the matric level of education has a positive and significant relationship with the log of revenue. However, this was not the case in a study conducted by Obiero (2013) on socio-economic factors affecting farm yield in Kenya. A negative association between farmer’s education and farm yield with a correlation of -0.075 was found. This implies that the farmer’s level of education has a negative relationship with farm yield, leading to lower revenues. The results in Table 1 show that women are still underrepresented as farmers. Furthermore, results indicate that male farmers are represented with an average of 67% and female with 33%; thus males are dominating the farming platform.

The study also found that some of the farmers lacked an appropriate business attitude concerning irrigation farming. It was revealed that farmers did not keep proper records; nor do they have an accurate record of their production costs. Though most of the farmers had an idea of what income and expenditure are, they indicated that they would rather spend their time on the field planting than reconcile their books and keep a proper record of their financials. Jiyane and Simalenga (2019) also found that in farmers that did not keep a record of their costs, they were not aware if they made a profit or a loss at a particular date. One of the farmers made the following statement:

“I can waste my time writing numbers on paper when I have to work, I already know the budget in my head”.

Therefore, as long as these farmers do not change their attitude toward income and expenditure their production levels will be relatively low, and their farming business will not be sustainable. The study further found that farmers are prone to market risk and price risk. The farmers say one of the biggest challenges that they face in farming is that the market is difficult to deal with, and prices fluctuate at any time. This sometimes leads to the farmers receiving less money for their yield. This is so since most farmers transport their produce to the Johannesburg fresh produce market, which is coupled with further costs such as transportation, agent fees, and storage costs. Fudjaja, Viantika, Tenriawaru and Aulia (2021) found that many farmers manage their costs and improve revenues by selling their produce to village level collectors rather than taking the product to the fresh produce market. Farmers are of the view that these extra costs negatively affect their profitability. As a mitigation strategy farmers resort to selling to the local market; however, the drawback with this is that local customers often buy in small quantities and their buying pattern is inconsistent. The farmers say because of the nature of the local market they are forced to accept this relatively low price rather than take back their products and suffer a complete loss.

4.6 SUMMARY OF THE CHAPTER

This chapter presents the interpretation and presentation of the findings of this study through a statistical analysis to address the research questions and objectives of the study. The study revealed that to some degree water irrigation costs have a positive and significant influence on-farm yield, and it is established that climate change adaption because of investment into water irrigation infrastructure and attainment of some form of training will have a positive influence on the on-farm yield and thus improve farm income and make the farm more sustainable. The next chapter of the study highlights the summary of the study, makes recommendations and presents the conclusions of the study.

CHAPTER FIVE: SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

The previous chapter presented the findings, the interpretation and discussion of the results of the study. This chapter presents the summary, conclusion and recommendations. Section 5.2 provides a summary of the findings concerning the research objectives. Section 5.3 provides the study's contributions to the body of knowledge. Section 5.4 reveals the research limitations experienced. Section 5.5 provides the recommendations made. Finally, Section 5.6 sums the study by providing the conclusion.

5.2 SUMMARY OF THE FINDINGS ON THE RESEARCH OBJECTIVES

This section provides a brief overview of the research findings. The study achieved its objectives through the discussion of different aspects of the existing literature including the analysis and theoretical frameworks and the empirical aspect of the research.

5.2.1 Summary of findings on research objective 1

To examine the influence that investments in water irrigation infrastructure have on the volume of farm yield.

The review of existing literature helped to address the objectives. From the discussion of the cost-benefit analysis theory, the study noted that smallholder farmers must be able to strike a balance between the cost of investment in water irrigation infrastructure and the associated benefits; this will lead smallholders to make informed investment decisions that would benefit their farming business.

Furthermore, the literature discussed the influence that investment in water irrigation infrastructure would have on the volume of output. From the discussion, it is clear that having the proper infrastructure in place will boost the rural farmers' chances of improving their farm yield as well as their income.

In addressing the influence of investment in water irrigation infrastructure on the volume of farm yield, the study adopted a survey research design utilising a mixed-method approach. The study was able to achieve this objective. From the analysis, the evidence indicates that fixed capital expenditure influences the farm yield for those farmers at the 0.50 quantile and 0.90 quantiles. This suggests that farmers at the lower distribution might be struggling financially to acquire infrastructure for water irrigation purposes. Furthermore, the findings of the study indicate that the investment in water irrigation has a positive and significant influence on the farm yield at a 0.01 confidence level. This implies that an investment in water irrigation infrastructure tends to improve the rural farmers' crop output. The findings of this study are consistent with those of Tarjuelo *et al*. (2015). Therefore, research objective one of this study was achieved since the analysis has proven that investment into water irrigation infrastructure does cause an increase in the volume of farm output (within the boundaries of the sample of data used in this research).

5.2.2 Summary of findings on research objective 2

To examine the influence of the cost of water irrigation systems on the volume of farm yield.

The literature review assisted to address this objective. The theory of cost revealed that for any type of business, including the farming business, costs would be incurred. These costs need to be differentiated and understood as to how they will affect the overall farming business. The theory of cost assisted in distinguishing between the fixed and variable costs that are incurred by farmers and how farmers should plan for these costs to maximise their profits. Furthermore, the discussion from the extant literature revealed that the water irrigation system costs are closely linked to the type of water infrastructure that is put in place by the farmer. These could either increase or decrease a farmer’s system costs. In addition, Stambbouli *et al.* (2014) state that the improvement in irrigation methods has resulted in the escalation of power utilisation by smallholders, thus resulting in increased costs of energy for irrigating crops. This implies that smallholders need to adapt to these new technologies in a way that the costs of the system would not escalate and ultimately halting production as the farmer will not be able to maintain these high costs.

The results reveal that the total cost index has a varying effect on the distribution of farm yield. The evidence indicates small findings with other crops that the rural farmer at the lower quantiles might have been struggling with the total cost of operation. These current findings are similar to the findings of Bassi (2015). Moreover, the system cost varies from one farmer to the other, depending on the type of water irrigation infrastructure a smallholder has and whether or not a farmer can finance the system costs. Therefore, research objective two for this study was realised, since the analysis proves that systems cost does affect farm yield. Additionally, the system cost is directly influenced by the water infrastructure put in place for irrigation (within the radius of the sampled data used in this research).

5.2.3 Summary of findings on research objective 3

To examine the effects of climate change (measured by water availability for irrigation) on the volume of on-farm yield.

The effect of climate change on farm yield was discussed here, specifically looking at the water availability for irrigation purposes. The literature revealed that rural farmers are more prone to the effects of climate change as this directly affects their cultivation programmes. Additionally, projected climate change will most likely increase the burden of water scarcity around the world, mostly in the semi-arid and arid regions such as the Middle East and most parts of Africa (Fischer *et al*., 2007). Furthermore, the burden will cost smallholders substantial amounts of money in an attempt to mitigate these effects of climate change. The study showed that climate change increases the demand for water irrigation by a significant amount leading to increased irrigation expenditures because of the continuous need for irrigation (Shahid, 2011). This means that if there is not enough water available for cultivation, it is conceivable for smallholders to incur losses and sometimes not even be able to cultivate due to the inadequate supply of water. The general findings of the study indicate that water availability for the irrigation index has a negative relationship with farm yield. The findings of this study are similar to the findings of Ju *et al,* (2013); but contrary to the findings of Gohari *et al*, (2013). The results prove the objective has been fulfilled, that indeed climate change does affect the volume of farm yield. Therefore, research objective three for this study was achieved, since the analysis has proven that climate change (water availability) has the potential to influence the volume of farm output (within the boundaries of the sampled data used in this research).

5.2.4 Summary of findings on research objective 4

To examine the influence of the farmers' level of education on the volume of farm yield.

In tackling this objective, the extant literature was reviewed and the importance of the rural farmers having some form of education was emphasised, with the belief that education instils in the smallholder farmers a problem-solving skill that is much needed in a farming business. Furthermore, the discussion revealed the need for financial management education for smallholder farmers for them to ascertain the benefit of financial planning and improved financial management practices. Additionally, small businesses that are owned or managed by financially literate individuals tend to have a higher degree of success when compared to those that are run by financially illiterate entrepreneurs (Njoroge, 2013). The outcome of this study is compatible with the literature, but the researcher was surprised that much higher levels of education have a negative relationship with the log of revenue. The findings are similar to the findings of Gaurav *et al,* (2010). Therefore, research objective four for this study was achieved, since the analysis has proven that socio-economic issues such as education do play a role in increasing the volume of farm output and farm income(within the ranges of the sampled data used in the research).

5.3 CONTRIBUTION TO THE BODY OF KNOWLEDGE

This research has contributed to the body of accounting knowledge by linking accounting with agriculture in the sense that it has shown that investment in water irrigation infrastructure can increase farm yields such as citrus, avocado, nuts, potatoes and tomatoes. The study contributes by adding empirical evidence about the water irrigation costs in arid and semi-arid regions of the Limpopo province as no previous study has looked at the effects of water irrigation costs and farm output in the arid and semi-arid regions of the Limpopo province.

5.4 RESEARCH LIMITATIONS

The farmers in South Africa incur different types of costs that contribute to producing their crops. The findings of the study are limited within the range of the crops that were studied (Avocadoes, citrus, nuts, potatoes and tomatoes). Moreover, the findings of the study cannot necessarily be generalised beyond the five crops that were studied. The study was limited to the challenges of water irrigation costs and farm output that are faced by smallholder farmers. Furthermore, the regulations imposed by the government through the introduction of the curfews restricted mobility and this meant that fewer farmers could be visited in a day.

5.5 RECOMMENDATIONS

The findings, as mentioned above, have policy implications;

5.4.1 Industry and Economy

The findings, as mentioned above, have policy implications. This means that the relevant stakeholders in the agricultural sector need to come together to draft policies that will make funding affordable and accessible to farmers. The sector should collaborate with educational institutions to consider designing curriculums for workshops and training in the native languages of different farmers to improve and fast track the understanding of the cost and management of a business. The study opens a platform for the communities to understand how to manage their production costs and what they should do to mitigate the effects of climate change and increasing production costs of farming. The farming communities need an adequate balance of public-private partnerships that promotes investments into water irrigation infrastructure and the management of these systems. A strategic partner relationship can be adopted, whereby successful/ commercial farmers can partner with a smallholder and they share their experiences and sometimes their assets with smallholders. A funding model that is farm-specific, which suits the individual farmers is essential. The industry may also need to look at the introduction of hybrid systems that are more cost-effective, and that take advantage of solar and wind energy.

5.5.1. Future research

Future studies can look at similar crops in other provinces of South Africa. Future studies can also be conducted using different crops from those investigated in the study and include other cost variables that may influence farm yield. Furthermore, future studies can be conducted in line with how to educate farmers about cost management in their native languages to deepen their understanding of production costs and management. However, this study focuses on providing a plausible explanation that may attract further investigation into whether salt present in the soil is harmful to good farm yield.

5.6 CONCLUSION

This research set out to examine the influence of water irrigation systems costs and farm outputs. After reviewing the relevant literature, the study followed a mixed-method approach, whereby it went ahead to collect primary data by means of a questionnaire and farm records from the farmers within the Limpopo province. It also collected data from the South African Weather Services (SAWS). The data were analysed using the multivariate method as well as quantile regression (QR). The findings of the study provided answers to the research objectives, which indicate that investments into the water irrigation infrastructure coupled with an appropriate level of education, can lead to an increased crop output for farmers as well as improve their income. Furthermore, the results show that some form of educational level is essential for farm management and can lead to better decision-making and improve revenue for smallholders. Thus adequate infrastructure investments need to be put in place for rural farmers to produce significant yields and incur low system costs. Overall, the study provides recommendations for increased use of hybrid systems that are cost effective and to take advantage of renewable resources. Future research should scrutinise different crops in other provinces of South Africa.

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APPENDICES

APPENDIX A: MULTIPLE CORRESPONDENCE ANALYSIS OUTPUT

Multiple correspondence analysis output

```
Multiple/Joint correspondence analysis         Number of obs     =         48

                                               Total inertia     =  0.44284215

    Method: Burt/adjusted inertias             Number of axes    =          2



            |   principal               cumul

  Dimension |    inertia     percent   percent

------------+----------------------------------

      dim 1 |    0.1225903     27.68      27.68

      dim 2 |    0.0558298     12.61      40.29

      dim 3 |    0.0387531      8.75      49.04

      dim 4 |    0.0350719      7.92      56.96
```

```
      dim 5 |    0.0292381      6.60      63.56
      dim 6 |    0.0219979      4.97      68.53
      dim 7 |    0.0182949      4.13      72.66
      dim 8 |    0.0097306      2.20      74.86
      dim 9 |    0.0086311      1.95      76.81
     dim 10 |    0.0059436      1.34      78.15
     dim 11 |    0.0037837      0.85      79.00
     dim 12 |    0.0023537      0.53      79.54
     dim 13 |    0.0014166      0.32      79.86
     dim 14 |    0.0010979      0.25      80.10
     dim 15 |    0.0007512      0.17      80.27
     dim 16 |    0.0004637      0.10      80.38
     dim 17 |    0.0002213      0.05      80.43
     dim 18 |    0.0000895      0.02      80.45
------------+--------------------------------------
```

```
       Total |    .4428421    100.00

Statistics for column categories in standard normalization

             |         overall          |       dimension_1        |       dimension_2
  Categories |    mass  quality   %inert |   coord   sqcorr  contrib |   coord   sqcorr  contrib
-------------+--------------------------+--------------------------+--------------------------
water_plan~d |                          |                          |
           0 |   0.001    0.036    0.019 |   0.503    0.005    0.000 |   1.928    0.032    0.005
           1 |   0.001    0.050    0.005 |   0.063    0.000    0.000 |   1.260    0.049    0.002
           3 |   0.018    0.538    0.015 |  -1.248    0.522    0.028 |  -0.323    0.016    0.002
           4 |   0.042    0.453    0.007 |   0.528    0.452    0.012 |   0.042    0.001    0.000
-------------+--------------------------+--------------------------+--------------------------
water_crop   |                          |                          |
           3 |   0.014    0.204    0.013 |   0.195    0.011    0.001 |   1.198    0.193    0.021
```

```
           4 |    0.048    0.204    0.004 |   -0.058    0.011    0.000 |   -0.356    0.193    0.006

-------------+--------------------------+--------------------------+--------------------------

water_hect~s |                          |                          |

           2 |    0.001    0.103    0.011 |    0.550    0.010    0.000 |    2.447    0.093    0.008

           3 |    0.009    0.069    0.013 |    0.406    0.033    0.002 |    0.624    0.036    0.004

           4 |    0.052    0.091    0.003 |   -0.085    0.032    0.000 |   -0.170    0.059    0.002

-------------+--------------------------+--------------------------+--------------------------

water_yield  |                          |                          |

           1 |    0.001    0.284    0.016 |   -3.059    0.216    0.012 |   -2.553    0.068    0.008

           2 |    0.018    0.678    0.017 |    0.777    0.178    0.011 |   -1.931    0.500    0.068

           3 |    0.007    0.190    0.015 |    0.904    0.101    0.005 |    1.260    0.089    0.010

           4 |    0.036    0.538    0.010 |   -0.441    0.205    0.007 |    0.832    0.333    0.025

-------------+--------------------------+--------------------------+--------------------------

water_yiel~t |                          |                          |

           0 |    0.003    0.363    0.018 |   -3.051    0.363    0.024 |    0.066    0.000    0.000
```

```
           1 |   0.008    0.249    0.019 |  -1.466    0.247    0.017 |  -0.180    0.002    0.000

           2 |   0.010    0.401    0.015 |  -0.332    0.022    0.001 |  -2.063    0.380    0.044

           3 |   0.021    0.381    0.012 |   0.897    0.376    0.017 |   0.151    0.005    0.000

           4 |   0.021    0.269    0.009 |   0.200    0.024    0.001 |   0.940    0.245    0.018

-------------+---------------------------+---------------------------+---------------------------

water_afte~n |                           |                           |

           0 |   0.014    0.553    0.013 |   1.222    0.472    0.021 |  -0.750    0.081    0.008

           1 |   0.018    0.109    0.010 |   0.300    0.047    0.002 |   0.508    0.062    0.005

           2 |   0.005    0.531    0.022 |  -1.738    0.194    0.016 |  -3.389    0.337    0.060

           3 |   0.017    0.234    0.013 |  -0.662    0.153    0.007 |   0.718    0.082    0.009

           4 |   0.008    0.124    0.008 |  -0.347    0.031    0.001 |   0.893    0.093    0.006

-------------+---------------------------+---------------------------+---------------------------

water_spri~r |                           |                           |

           0 |   0.003    0.200    0.025 |  -2.614    0.197    0.018 |  -0.482    0.003    0.001

           1 |   0.005    0.331    0.017 |  -1.887    0.305    0.019 |   0.812    0.026    0.003
```

```
           2 |   0.048    0.381    0.006 |   0.361    0.296    0.006 |  -0.287    0.085    0.004
           3 |   0.003    0.051    0.011 |   0.213    0.003    0.000 |  -1.275    0.048    0.004
           4 |   0.004    0.320    0.021 |  -0.334    0.006    0.000 |   3.625    0.314    0.051
-------------+--------------------------+--------------------------+--------------------------
water_save   |                          |                          |
           0 |   0.003    0.200    0.025 |  -2.614    0.197    0.018 |  -0.482    0.003    0.001
           1 |   0.017    0.477    0.016 |  -1.186    0.409    0.024 |   0.721    0.069    0.009
           2 |   0.038    0.761    0.012 |   0.783    0.544    0.023 |  -0.732    0.217    0.020
           3 |   0.001    0.036    0.019 |   0.503    0.005    0.000 |   1.928    0.032    0.005
           4 |   0.004    0.406    0.018 |  -0.854    0.044    0.003 |   3.629    0.362    0.051
-------------+--------------------------+--------------------------+--------------------------
water_drip   |                          |                          |
           1 |   0.003    0.197    0.019 |  -2.307    0.197    0.014 |   0.039    0.000    0.000
           2 |   0.022    0.818    0.021 |   1.595    0.726    0.056 |  -0.839    0.092    0.016
           3 |   0.007    0.046    0.015 |   0.400    0.019    0.001 |   0.710    0.027    0.003
```

```
           4 |   0.031    0.652    0.015 |  -1.021    0.601    0.033 |   0.443    0.052    0.006

-------------+--------------------------+--------------------------+--------------------------

water_drip~s |                          |                          |

           2 |   0.018    0.787    0.021 |   1.730    0.710    0.055 |  -0.846    0.077    0.013

           3 |   0.009    0.010    0.018 |   0.133    0.003    0.000 |   0.333    0.007    0.001

           4 |   0.035    0.704    0.013 |  -0.931    0.661    0.031 |   0.353    0.043    0.004

-------------+--------------------------+--------------------------+--------------------------

water_irri~d |                          |                          |

           0 |   0.017    0.794    0.018 |  -1.516    0.594    0.039 |  -1.300    0.199    0.029

           1 |   0.016    0.629    0.011 |  -0.446    0.077    0.003 |   1.771    0.552    0.049

           2 |   0.010    0.530    0.020 |   1.874    0.495    0.037 |  -0.739    0.035    0.006

           3 |   0.012    0.070    0.010 |   0.464    0.067    0.003 |  -0.157    0.004    0.000

           4 |   0.008    0.288    0.008 |   0.981    0.258    0.008 |   0.496    0.030    0.002

-------------+--------------------------+--------------------------+--------------------------

water_irri~s |                          |                          |
```

```
           0 |   0.023    0.696    0.015 |  -1.113    0.542    0.029 |  -0.880    0.154    0.018
           1 |   0.018    0.497    0.014 |  -0.319    0.037    0.002 |   1.661    0.459    0.050
           2 |   0.013    0.588    0.021 |   1.770    0.535    0.041 |  -0.824    0.053    0.009
           3 |   0.005    0.250    0.010 |   1.342    0.248    0.009 |  -0.158    0.002    0.000
           4 |   0.003    0.094    0.006 |   0.724    0.064    0.001 |   0.728    0.030    0.001
-------------+--------------------------+--------------------------+--------------------------
Centre_pivot |                          |                          |
           0 |   0.005    0.692    0.026 |  -2.388    0.320    0.030 |  -3.816    0.372    0.076
           1 |   0.001    0.374    0.015 |  -1.095    0.029    0.002 |   5.641    0.345    0.041
           2 |   0.046    0.745    0.009 |   0.715    0.731    0.023 |   0.147    0.014    0.001
           3 |   0.001    0.254    0.015 |  -2.881    0.202    0.011 |  -2.182    0.053    0.006
           4 |   0.009    0.479    0.016 |  -1.645    0.415    0.025 |   0.953    0.064    0.008
-------------+--------------------------+--------------------------+--------------------------
centre_piv~s |                          |                          |
           0 |   0.009    0.841    0.029 |  -2.648    0.602    0.064 |  -2.473    0.239    0.056
```

```
           1 |   0.003    0.418    0.016 |  -1.325    0.077    0.005 |   4.136    0.341    0.045
           2 |   0.046    0.745    0.009 |   0.715    0.731    0.023 |   0.147    0.014    0.001
           3 |   0.003    0.201    0.009 |  -1.492    0.182    0.006 |   0.726    0.020    0.001
           4 |   0.003    0.048    0.013 |  -0.435    0.010    0.000 |   1.229    0.038    0.004
-------------+--------------------------+--------------------------+--------------------------
Bucket_irr~d |                          |                          |
           0 |   0.004    0.415    0.021 |  -2.817    0.410    0.031 |   0.450    0.005    0.001
           1 |   0.027    0.556    0.009 |   0.699    0.401    0.013 |   0.642    0.154    0.011
           2 |   0.020    0.572    0.015 |  -1.027    0.386    0.021 |  -1.053    0.185    0.022
           3 |   0.007    0.089    0.008 |   0.517    0.057    0.002 |   0.576    0.032    0.002
           4 |   0.005    0.419    0.010 |   1.652    0.404    0.014 |  -0.476    0.015    0.001
-------------+--------------------------+--------------------------+--------------------------
Bucket_irr~r |                          |                          |
           0 |   0.001    0.139    0.016 |  -2.348    0.124    0.007 |   1.218    0.015    0.002
           1 |   0.010    0.447    0.014 |  -1.018    0.217    0.011 |   1.553    0.230    0.025
```

```
           2 |   0.014    0.569    0.018 |  -1.345    0.404    0.026 |  -1.274    0.165    0.023

           3 |   0.029    0.657    0.009 |   0.846    0.641    0.020 |   0.198    0.016    0.001

           4 |   0.008    0.379    0.008 |   1.112    0.326    0.010 |  -0.662    0.053    0.003

--------------------------------------------------------------------------------------------------
```

APPENDIX B: PRINCIPAL COMPONENT ANALYSIS FOR IRRIGATION COST INDEX

Principal Component Analysis for Irrigation Cost Index

```
Principal components/correlation                 Number of obs    =         48

                                                 Number of comp.  =          5

                                                 Trace            =          5

    Rotation: (unrotated = principal)            Rho              =     1.0000


    --------------------------------------------------------------------------

       Component |   Eigenvalue   Difference         Proportion   Cumulative

    -------------+------------------------------------------------------------

           Comp1 |      2.75931       1.7041             0.5519       0.5519

           Comp2 |       1.0552      .422547             0.2110       0.7629
```

```
           Comp3 |      .632656      .298562             0.1265       0.8894

           Comp4 |      .334094      .115354             0.0668       0.9563

           Comp5 |       .21874            .             0.0437       1.0000

    --------------------------------------------------------------------------
```

```
Principal components (eigenvectors)
```

```
    ------------------------------------------------------------------------------

        Variable |    Comp1     Comp2     Comp3     Comp4     Comp5 | Unexplained

    -------------+--------------------------------------------------+-------------

      costs_fuel |   0.5236   -0.2227   -0.2792   -0.3088    0.7092 |           0

    cost_elect~y |   0.2313    0.8502    0.2928    0.2131    0.3042 |           0

    cost_maint~e |   0.3805   -0.4357    0.7720    0.2635    0.0009 |           0

     cost_labour |   0.5279    0.1918    0.0528   -0.5982   -0.5692 |           0

    cost_insta~n |   0.4989   -0.0311   -0.4874    0.6573   -0.2838 |           0
```

```
    ---------------------------------------------------------------------------

. rotate

Principal components/correlation                 Number of obs    =         48

                                                 Number of comp.  =          5

                                                 Trace            =          5

    Rotation: orthogonal varimax (Kaiser off)    Rho              =     1.0000

    --------------------------------------------------------------------------

       Component |     Variance   Difference         Proportion   Cumulative

    -------------+------------------------------------------------------------

           Comp1 |            1   2.20066e-06             0.2000       0.2000

           Comp2 |            1   8.34289e-07             0.2000       0.4000

           Comp3 |            1   1.11754e-06             0.2000       0.6000
```

```
       Comp4 |            1   6.83709e-06            0.2000       0.8000
       Comp5 |      .999993            .             0.2000       1.0000
    --------------------------------------------------------------------------
```

```
Rotated components
```

```
    ------------------------------------------------------------------------------
        Variable |    Comp1     Comp2     Comp3     Comp4     Comp5 | Unexplained
    -------------+--------------------------------------------------+-------------
      costs_fuel |   0.0000    0.0000    0.0000    0.0000    1.0000 |           0
    cost_elect~y |  -0.0000   -0.0000    1.0000   -0.0000   -0.0000 |           0
    cost_maint~e |  -0.0000    1.0000    0.0000   -0.0000   -0.0000 |           0
     cost_labour |   1.0000    0.0000    0.0000    0.0000   -0.0000 |           0
    cost_insta~n |  -0.0000    0.0000    0.0000    1.0000   -0.0000 |           0
    ------------------------------------------------------------------------------
```

```
Component rotation matrix

    -----------------------------------------------------------------
                 |    Comp1     Comp2     Comp3     Comp4     Comp5
    -------------+---------------------------------------------------
           Comp1 |   0.5279    0.3805    0.2313    0.4989    0.5236
           Comp2 |   0.1918   -0.4357    0.8502   -0.0311   -0.2227
           Comp3 |   0.0528    0.7720    0.2928   -0.4874   -0.2792
           Comp4 |  -0.5982    0.2635    0.2131    0.6573   -0.3088
           Comp5 |  -0.5692    0.0009    0.3042   -0.2838    0.7092
    -----------------------------------------------------------------
```

APPENDIX C: INFORMED CONSENT FORM

INFORMED CONSENT FORM

Dear Respondents,

I am a Masters of commerce student of the School of Accountancy, Faculty of Management and Law at the University of Limpopo. I am conducting a research study titled:

Water irrigation costs and farm outputs: Case of selected crops in Limpopo Province

This study aims to provide information on how farmers can maximise their production level by understanding the relevant input costs related to irrigation as well as increase their crop yield through a better understanding of the operations and investment costs, and to make them economically sustainable. This study will be beneficial to the farmer as it will provide information on how farmers can manage their production costs in order to achieve the highest possible yield. In order to accomplish this research objective, an interview is required with you to gather information. Your response and name will however be treated as confidential and you are also allowed to withdraw from the process anytime. If you have any question(s) concerning the research study, please call me on **078 335 445** or email me at **kdandane@yahoo.com**. You are however expected to sign this letter as consent to have this interview.

Thanks

Sincerely

Khutso D. Dandane

Name of Respondent ……………………………………………………………………………………

Signature of Respondent ....

Respondents are required to mark (X) in the appropriate box.

Section 1: General information

Type of crop	**Nuts**	**Avocados**	**Citrus**	**Potatoes**	**Tomatoes**

1. Gender

Male	Female

2. Age

18 - 22 years	23 -27 years	28 - 32 years	33 - 37 years	38 – 42 years	43 – 47 years	48 years and above

3. Educational level

No matric	Matric	Higher certificate	Diploma	Bachelor's Degree	Honours Degree	Master's degree and above

Section 2: Land information

1	Field identification	Communal land		Private land	Leased land	
2	Approximate size of the field	0-10 Ha	11-20 Ha	21-30 Ha	31-40 Ha	41 Ha and above
3	Distance from the house to the field(km)	1-10 km	11-20 km	21-30 km	31-40 km	41 km and above
4	How many years have you farmed the field	1-10 years	11 - 20 years	21-30 years	31- 40 years	41 years and above
5	How long has the field been cultivated under irrigation	1-10 years	11-20 years	21-30 years	31-40 years	41 years and above
6	Maximum daily temperature	20˚- 24˚	25˚-29˚	30˚-34˚	35˚-39˚	40˚ and above
7	Type of water pump	Centrifugal pump	Borehole pump	Turbine pump	Jet pump	Displacement pump

8	Type of irrigation method	Sprinkler	Drip	Flood	Centre pivot	Subsurface
9	Maximum available weekly days for irrigation	1 day	2 days	3 days	4 days	5 days
10	Maximum available hours per day for irrigation	1 hours	2 hours	3 hours	4 hours	5 hours
11	Name of pump		Existing pumping pressure		Pressure (rpm)	Discharge (lpm)

Section 3: Water information

	Variables	1 Strongly agree	2 Agree	3 Neutral	4 Disagree	5 Strongly disagree
1	Water quality influences the type of crop to be planted					
2	The crop yield is reduced because there is not enough water applied to the crops					
3	Access to water limits/reduces the hectares cultivated					
4	Irrigating the crops at night improves crop yield					
5	Irrigating the crops in the morning improves crop yield					
6	Irrigating the crops in afternoon improves crop yield					
7	Sprinkler irrigation increases crop yield					
8	Sprinkler irrigation saves water					
9	Drip irrigation increases crop yield					
10	Drip irrigation saves water					

11	Flood irrigation increases crop yield					
12	Flood irrigation saves water					
13	Centre pivot increases crop yield					
14	Centre pivot saves water					
15	Subsurface increases crop yield					
16	Subsurface saves water					

Section 4: Irrigation costs

Type of pumping machine energy source	Diesel Engine	Electric motor	Solar power

	Variables	1 Strongly agree	2 Agree	3 Neutral	4 Disagree	5 Strongly disagree
1	Pumping water from a borehole increases electricity/ diesel costs					
2	Pumping water from a reservoir increases electricity/diesel costs					
3	Using an electric motor to pump water saves costs					
4	Using a diesel engine to pump water saves costs					
5	Drip irrigation increases pumping costs					
6	Sprinkler irrigation increases pumping costs					
7	Flood irrigation increases pumping costs					
8	Centre pivot increases pumping costs					
9	Subsurface increases pumping costs					
Select appropriate cost range for items listed below:						

Cost range		R0-R20 000	R20 001-R30 000	R30 001-R40 000	R40 001-R50 000	R50 001 and above
8	Approximate diesel cost for irrigation per annum					
9	Approximate electricity cost for irrigation per annum					
10	Approximate maintenance cost per annum					
11	Approximate cost of labour associated with irrigation					
Select appropriate cost range for items listed below						
Cost range		R0 - R50 000	R50 001-R100 000	R100 001-R150 000	R150 001-R200 000	R200 001 and above
12	Approximate cost of pump and irrigation equipment					
13	Approximate cost of installation					

Section 5: Financial literacy

S/N	Variables	1 Strongly agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree
1	Farmers prepare monthly and yearly budgets					
2	Contacting a financial advisor is important before making any major financial decisions					
3	Farmers have attended management/ financial literacy workshops					
4	Farmers consider affordability of farm inputs before buying					
5	Farmers have a good understanding of the implication of interest rates when buying on credit					
6	Farmers do price comparisons before purchase farm input					
7	Farmers have access to financial facilities					
8	Farmers can prepare a profit/ loss statement					

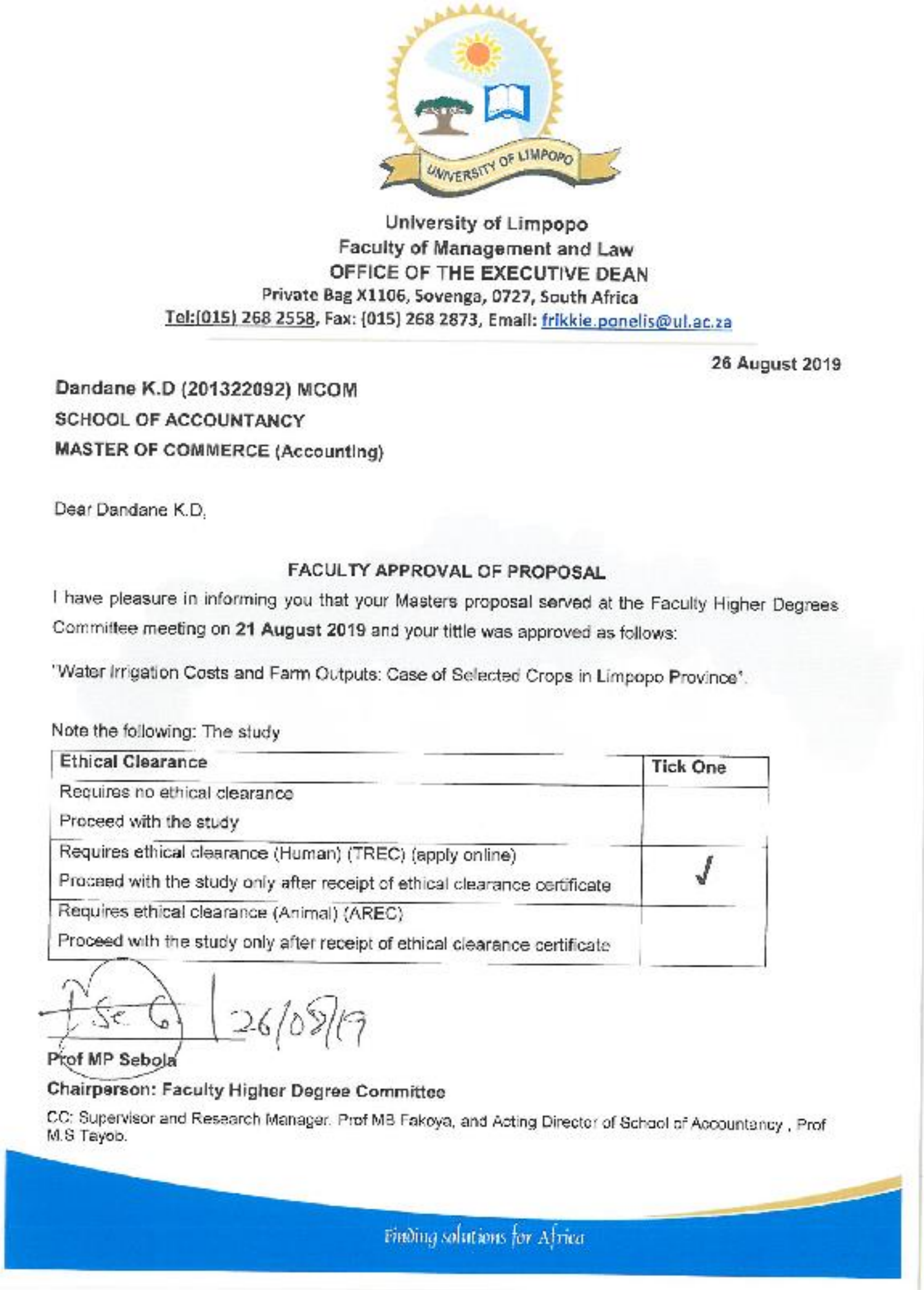
Section 6: Yield information

1. **Crop output**

Variable	**0 – 4 tons**	**5 – 9 tons**	**10 -14 tons**	**15 – 19 tons**	**20 - 24 tons**	**25 tons and above**
Approximate number of tons (kg)						

2. **Revenue**

Variable	**R 1 - R 100 000**	**R100 001 - R 200000**	**R200 001 - R300 000**	**R 300 001- R400 000**	**R400 001- R500 000**	**R 500 001 and above**
Approximate revenue per annum						



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26 August 2019

Dandane K.D (201322092) MCOM
SCHOOL OF ACCOUNTANCY
MASTER OF COMMERCE (Accounting)

Dear Dandane K.D,

FACULTY APPROVAL OF PROPOSAL

I have pleasure in informing you that your Masters proposal served at the Faculty Higher Degrees Committee meeting on **21 August 2019** and your tittle was approved as follows:

'Water Irrigation Costs and Farm Outputs: Case of Selected Crops in Limpopo Province'.

Note the following: The study

Ethical Clearance	**Tick One**
Requires no ethical clearance Proceed with the study	
Requires ethical clearance (Human) (TREC) (apply online) Proceed with the study only after receipt of ethical clearance certificate	✓
Requires ethical clearance (Animal) (AREC) Proceed with the study only after receipt of ethical clearance certificate	

26/08/19

Prof MP Sebola
Chairperson: Faculty Higher Degree Committee

CC: Supervisor and Research Manager. Prof MB Fakoya, and Acting Director of School of Accountancy , Prof M.S Tayob.

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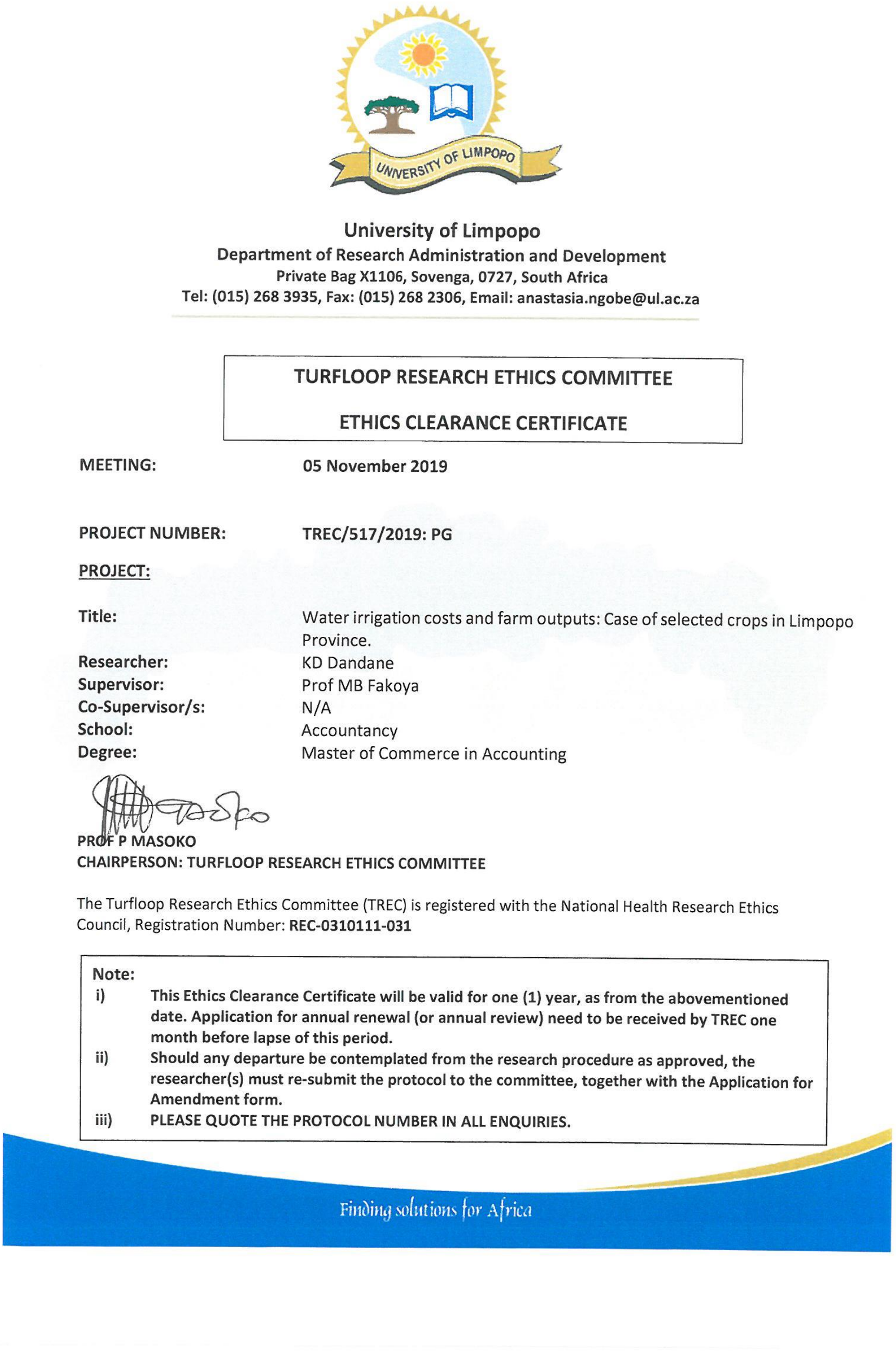

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Tel: (015) 268 3935, Fax: (015) 268 2306, Email: anastasia.ngobe@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING:	**05 November 2019**
PROJECT NUMBER:	**TREC/517/2019: PG**

PROJECT:

Title:	Water irrigation costs and farm outputs: Case of selected crops in Limpopo Province.
Researcher:	KD Dandane
Supervisor:	Prof MB Fakoya
Co-Supervisor/s:	N/A
School:	Accountancy
Degree:	Master of Commerce in Accounting

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

- **i) This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**
- **ii) Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**
- **iii) PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

Finding solutions for Africa

RMC LANGUAGE PRACTITIONER
117 OOSTVALLEI VILLAGE
657 COLEY STREET
GARSFONTEIN
PRETORIA 0081

TO WHOM IT MAY CONCERN

This is to certify that I have proofread and edited the master's dissertation (MCom) entitled *Water Irrigation Costs and Farm Outputs: A Case of Selected Crops in Limpopo Province* by KD Dandane.

I applied Microsoft Office Word track changes to the document and have suggested certain changes and corrections to language usage and style which I trust will be effected to make it suitable for examination.

signed:

R.McCabe

Date:
18 July 2021

Dr RV McCabe
MA in Applied Linguistics (NWU)
MPPS - Masters in Public Policy Studies (UP)
PhD in English Language Studies (NWU)

- **CELLPHONE:** 0827730282
- **EMAIL:** rvmcccabe@oostvallei.co.za