Vaalharts: Environmental aspects of agricultural land and water use practices

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ABSTRACT

The world population is rapidly growing and this population growth is placing tremendous strain on food security. Therefore, more food has to be produced to meet the demand of the increasing number of people, which leads to an increase of food production. It is referred to as intensive agriculture. Although this intensification of agriculture will benefit food security, the intensification might negatively affect the environment. South Africa's population is also growing and farmers' intensifying food production may lead to environmental degradation.

For the purpose of this study, the Vaalharts irrigation scheme was used as case study area. The Vaalharts irrigation scheme is a unique agricultural region which is referred to as the breadbasket of the Northern Cape because of the high yield production. Farmers operate in vastly different modes of food production, with differing environmental influences and impacts. Much still needs to be understood of the environmental issues arising from small and large scale farming in Vaalharts. This leads to the question: What are the different environmental aspects associated with agricultural land and water use in the Vaalharts irrigation scheme?

This study examines how the farmers go about farming and what the environmental effects are of these activities. One of the outcomes of the research was to determine if sustainable agriculture could mitigate these environmental issues that derive from agriculture and how implementation thereof can benefit food security.

To answer this question, an analysis of land and water use practices within the irrigation scheme was carried out. One method was using existing information that was gathered through local organizations and authorities in the region. Secondly, a questionnaire was circulated among local small and large scale farmers to investigate the environmental issues that derive from agricultural land and water use in the Vaalharts irrigation scheme. The results show that the main environmental issues farmers experience is a decline in water and soil quality because of high salinization caused by agricultural inputs. The farmers perceive canal water to be polluted and would rather use borehole water for household and livestock consumption. Previously farmers did not have a wide variety of crops and most farmers would farm with pecan nut trees. This was identified as the main crop. Most farmers felt that their farms were sustainable and presented examples like drip irrigation and cover crops to support their statements. The study found that there were farmers that prove that sustainable agriculture can mitigate some environmental issues in the Vaalharts irrigation scheme.

Key words: Agro-environmental issues, Agricultural land & water use, Sustainable agriculture, Agricultural sustainability perceptions.

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CHAPTER 1: BACKGROUND AND INTRODUCTION

1.1 Background and introduction

The world's population has grown rapidly in the last decade and is predicted to grow in the forthcoming future (Gerland *et al.* 2014). This population growth has increased the need and use of resources such as land, water, energy and food production (Godfray *et al.* 2010). Godfray *et al.* (2010) further explained that the competition for these resources has made it difficult for producers to keep up with the food demand. Cresswell (2009:2) predicted that by the year 2030 the world has to produce 50 to 100% more food than what is currently produced in order to feed the people throughout the world. This is of great concern because currently the world is struggling to provide food for the current population and food security along with environmental degradation are becoming distressing issues that need to be addressed (Godfray *et al.* 2010). A decline in productivity has effectively put the world in a food security dilemma, which is caused by droughts, water scarcity and land degradation as identified by United Nations Environmental Program (UNEP, 2009). Such environmental degradation is influenced by natural and human elements. In recent years the concerns are not only to improve food security but also improvement of the quality of food that people consume. The scope of this explanation can be termed as 'sustainable diets'.

In the end food production has to increase in order to provide food for the people that is safe and nutritional without damaging the environment. This is referred to as 'sustainable diets' and the scope of the bigger project is to explore this concept. The Food and Agriculture Organization (FAO) and Biodiversity International defines the concept of sustainable diets as follows:

> "Diets with low environmental impact which contribute to food and nutrition security and to a healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and the eco-system, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy; while optimizing natural and rural resources" (as seen in Burlingame & Dernini, 2012:7).

The objective globally is to produce more food whilst obtaining a well-structured and healthy environment with farmers that have the knowhow and passion for farming (UNEP, 2009). This can be seen in the Millennium Development Goals set out by the United Nations (UN) in the Millennium Project. (2005). A few of these goals can be reached by improving the agricultural sector, which influence food security and the environment.

Agriculture is one of the most important sectors in the world and arguably the largest sector in a developing country such as South Africa (Department of Agriculture, Forestry and Fisheries (DAFF), 2016). There are many elements, factors and role-players involved within agriculture. The industry employs more than one billion people and produces food with an estimated worth of $1.3 trillion dollars annually throughout the world according to the World Wildlife Fund (2015). This is not entirely true for Africa. In Africa, agriculture is a major contributor to a country's economy and labour force, but does not always get the necessary attention (Scotcher, 2009).

During the last few decades there has been a 70% increase of irrigated crop land, which in turn has intensified the global use of fertilizers and pesticides. According to Foley *et al.* (2005) this intensification of agricultural input has increased by 700% in an effort to increase productivity. This intensification within agriculture has produced more food for the people but has also caused extensive environmental damage. One such example could be seen in the degradation of water quality in many regions of the world due to the high amount of fertilisers and pesticides used. Foley *et al.* (2005) further explained that this degradation in water quality has led to agricultural areas becoming heavily salinized causing a loss of 1.5 million hectares of arable land per year worldwide, which amounts to an estimated $11 billion in production loss. Foley *et al.* (2005:507) further stated that "up to 40% of global croplands may also be experiencing some degree of soil erosion, reduced fertility, overgrazing and loss of habitats which is also dampening production. The loss of these native habitats is not only affecting food production but degrading the services of natural pollinators, such as bees". Although it seems that modern food production is providing adequate food products to the people, farmers are also setting themselves up for future or long-term losses and major food security problems (Foley *et al.* 2005). These statements made by Foley *et al.* (2005) are supported by Zalidis *et al.* (2002); and Lal and Stewart, (1990) whereby they refer to rising food and fibre productivity due to the new governmental policies, mechanization, technologies and increased chemical use which all maximised production. They also agree that there are positive effects to this intensification but that it will come at a cost, giving examples of degradation of water and soil resources which play a pivotal role in food production (Zalidis *et al.* 2002; Lal & Stewart, 1990).

It is determined that most of the land in Africa and especially South Africa, is not suitable for crop farming and has a very low percentage of arable land and is more suitable for livestock grazing (Goldblatt, 2010). To bring this into perspective it is estimated that 60% of the people in Sub-Sahara Africa depend on agriculture for their livelihoods (Shiferaw *et al.* 2014). These livelihoods are being threatened by factors such as land degradation, desertification, unequal land-tenure, unsustainable practices, declining soil fertility and poor land management that add to stress on agro-food production and food security throughout (McIntyre *et al.* 2008). This is why people in Africa may have food security and nutritional issues. Africa is also experiencing rapid population

growth but does not have the necessary resources to deal with problems associated with population growth such as providing food for the people (Alexandratos, 2005).

The increased need for food has led to the intensification of farming systems. According to Scotcher (2009:7) this intensification of agriculture can be detrimental to farmers because the "overuse of synthetic fertilisers, pesticides and herbicides reduces long-term soil fertility, causes soil erosion, pollutes water supplies, poisons fragile ecosystems, exposes farmers and farm workers to toxins, and contributes to climate change through greenhouse gas emissions". One of the main reasons for the intensification is the profit farmers could make which rather should have been to provide food to the people (Hassan & Nhemachena, 2008). The intensification of farming systems can be detrimental to the environment, people's welfare and a farmer's ability to adapt to change, if implemented incorrectly (World Wildlife Fund, 2015). According to the African Biosafety Network of Expertise, (2014) and European Environment Agency, (2014) these agricultural intensification activities cause further loss of biodiversity and changes natural habitats in numerous ways which negatively affect them. Such effects derive from macro- and microscale aspects. Macroscale aspects such as different landscape features and climate have wide-ranging effects on a region. Microscale factors, such as the management of land usage and activities on a farm, will negatively affect the water and soil resources in that region (Zalidis et al, 2002). The research focus should be shifted towards environmental issues of agriculture as these issues would get worse rather than better over time according to Weis (2007) and would evidently affect sustainable diets and food security.

This population growth and intensification of farming systems might cause more issues that will have direct and indirect effects on the agricultural sector (Alexandratos, 2005). Such effects include less arable land because people need shelters to stay in and development will therefore increase. With an increase of the number of people comes more pollution such as air, water and soil pollution, which all have an effect on agro-food production (Satterthwaite *et al.* 2010). Agriculture contributes to both indirect and direct environmental effects (issues) of multiple resources on various scales, which affect the quality of soil and water amongst other things (Van der Werf & Petit, 2002). Direct environmental issues are issues where the primary activity is the cause for any occurring issues such as inputs of fertilizer, herbicides, and pesticides that pollute water resources such as ground and surface water. Another example of direct agro-environmental issues can be greenhouse gas emissions into the atmosphere, such as methane (CH_4) through large scale cattle farming. Indirect issues are issues that originate from primary activities, which then cause secondary issues to arise. Such issues include disturbances of nutrient, water and carbon cycles caused by land use activities and excessive land cover changes (Zalidis *et al*, 2002).

A healthy environment will be beneficial to farmers and provide easier agricultural practices and will provide more - and better quality yields (Horrigan *et al.* 2002). In essence, a healthy environment provides quality outputs for the people such as farmers in this case.

The South African population is also increasing at about 2% per year and is projected to reach 82 million by the year 2035 (Goldblatt, 2010). According to Goldblatt (2010) the food security causes mentioned above have left South Africa with a two-third loss of farms since the 1990s because it was not profitable for farmers to continue. This leaves South Africa with a growing population and less production activities to provide for a growing demand. This causes remaining farmers to intensify agricultural activities, which includes using more fertiliser, fuel, mechanisation, and genetically modified seeds. These inputs and intensification of agriculture may even cause more strain on the environment in the not so distant future (Tilman *et al.* 2002).

South Africa is home to the largest irrigation scheme in the Southern hemisphere (Chetty & Adewumi, 2014). This irrigation scheme is known as the Vaalharts irrigation scheme and is situated in the Northern Cape. The Vallharts area is regarded as the breadbasket of the Northern Cape based on its agricultural production (Maisela, 2007). According to Maisela, (2007) the irrigation scheme provides the country with some of the best quality agricultural products, such as cotton and wheat. The area also has high potential for agro-tourism because of its scenery. The country's food production is dependent on the short-term output and long-term stability for food security. This puts a burden on the area in order to maximise production within the already strained agricultural sector trying to do so in a balanced manner to protect land and water resources and ensure sustainably (Altman *et al.* 2009).

The figure below is a map of the Vaalharts irrigation scheme. The function of the map is to get an overview of towns, rivers and dams in the area and where the scheme is situated. The brown circles in the irrigation scheme is used to illustrate how farms are distributed within the scheme.

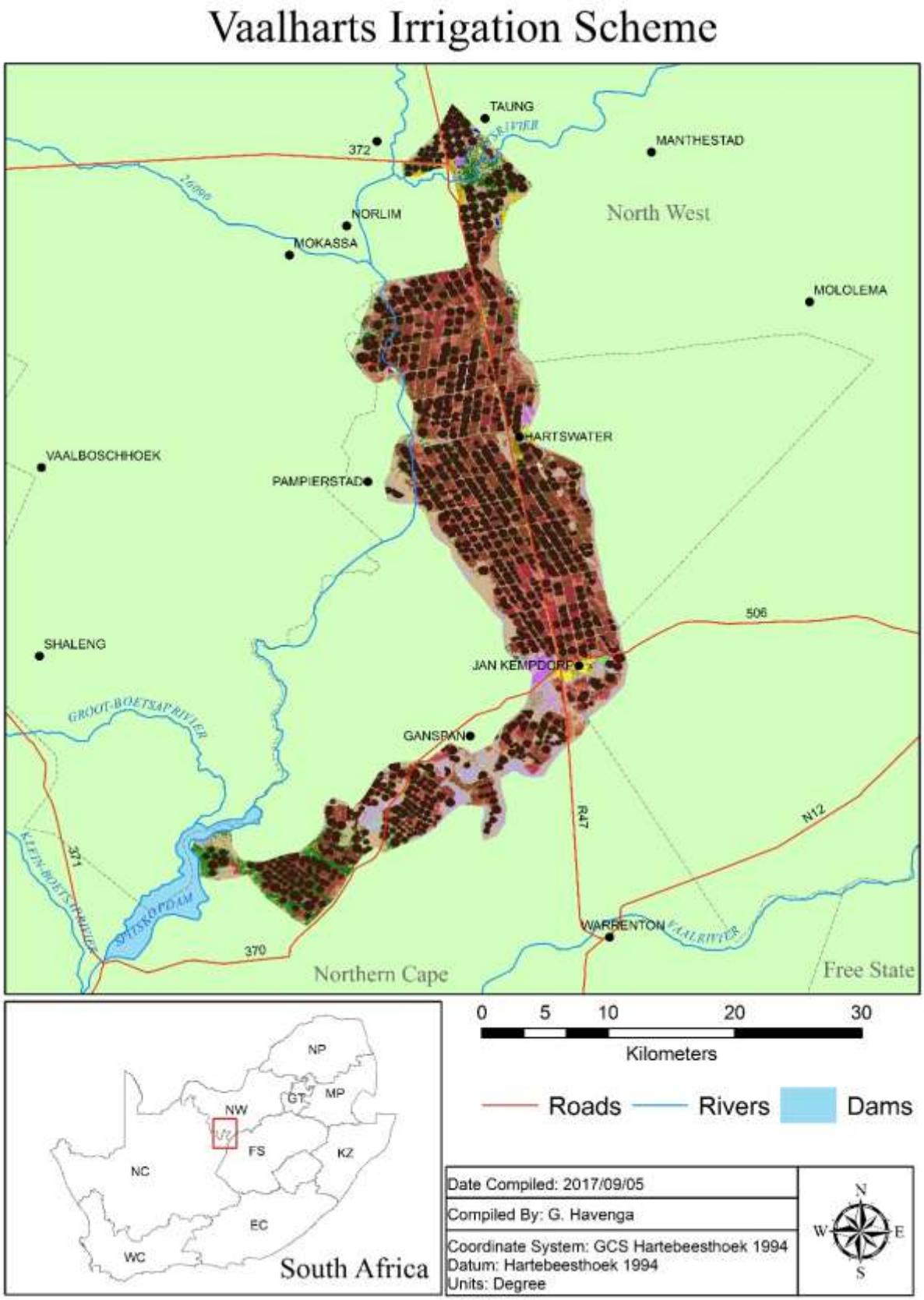

Figure 1: The Vaalharts irrigation scheme and surrounding areas (Havenga, 2017)

In 1934 construction began on a man-made dam (Vaalharts weir) which was to serve as the catchment for water from the Bloemhof dam and as the supply point for a complex channel system for the area (Van Vuuren, 2010). The canal's main source of water comes from the Vaalharts weir. The bulk of water is sourced from the Vaal River and gravitationally fed by canals to the Harts River upstream of the scheme, and then disturbed throughout the scheme. The outflow returns to the Harts River near the Spitskop dam and eventually returns to the Vaal River at its confluence with the Harts in the south (Vaalharts Water, 2010). The irrigation scheme was based on the concept of using gravity feeds from rivers to provide water to farmlands (Van Vuuren, 2010). There are 1,176 km concrete lined canals throughout the irrigation scheme. The Vaalharts Irrigation Scheme measures 75km in length and irrigates 39,820 ha of licensed agricultural land. Drainage canals were also built to transport storm water and subsurface drainage water out of the irrigation scheme (Vaalharts Water, 2010). Today the weir and canals are managed by Vaalharts Water. Vaalharts Water is a government-driven and funded organisation, which is responsible for managing the water resources in the scheme, assigns water quotas and attends to the needs of the local farmers.

This leads to the question:

What are the different environmental aspects associated with agricultural land and water use in the Vaalharts irrigation scheme?

1.2 Problem statement and substantiation

The intensification within the agricultural sector, because of the need for improved food security, has created an increased demand for production in South Africa. It is within this context that the environmental concerns derived from agricultural land and water use activities within the Vaalharts Irrigation Scheme and the role of sustainable agricultural practices in mitigating threats to these resources, need to be defined.

1.3 Aims and objectives

The aim of this study is to investigate the environmental issues of land and water use for agricultural food production in Vaalharts and to assess to what extent sustainable agriculture has contributed to the mitigation of these impacts.

The specific objectives are:

1. To identify the environmental issues of food production in terms of land and water use in the Vaalharts irrigation scheme.

2. To investigate the interrelationship between land and water use in the Vaalharts irrigation scheme.
3. To investigate the link between current agricultural practices and the sustainability of these practices.

The dilemma caused by food security has triggered intensification of agricultural activity which will provide food to people but may also cause environmental degradation. This study has identified the problems associated with the above mentioned issues and will explore in more detail in the following section referring to other researches and findings.

CHAPTER 2: LITERATURE REVIEW

2.1 Agriculture's role in food security and the environment

This section will discuss agriculture in general and describe how population growth is influencing global food security and the role of the environment in an agricultural system. This section will also endeavour to identify which environmental impacts are derived from agriculture and how sustainable agriculture could be the mitigating measure for the environmental and food security issues.

Researchers of several similar studies identified some of the major influences agro-environments have on people and their health (Nugent 2011; Foresight, 2011, and MacDiarmid *et al*. 2011). Such research is similar to the larger project "Exploring the potential of local food systems (LFS) for sustainable rural development – A case study of the Vaalharts Area" which assisted for a better understanding of this study. Such influences not only include the environment but health statuses of people as well, such as rising weight levels, diet-related issues and also non-communicable diseases (NCDs). Studies of such nature lead to a better understanding of agro-environments and systems, which stresses the need to change agro-environments in order to mitigate environmental issues and rise of NCDs. Such research also contributes by illustrating a necessity to conceptualise the different role-players and activities to achieve better sustainable practices. When translating these studies into a South African perceptive it is clear that South African farmers have to cope with numerous struggles. Such struggles include a competitive economic environment, lack of inputs, support structures and training, an inadequate land tenure system, ineffective selection of beneficiaries for government intervention programmes, low land potential and a lack of access to competitive markets (Jacobs *et al.* 2003; Ortmann & Machethe, 2003). These issues affect both small and large scale farmers in the country. In response to these findings, more international and local initiatives are being implemented and explored to promote more sustainable agricultural systems (Food and Agriculture Organization (FAO) (2014).

As explained by World Wildlife Fund (2015) agriculture can be beneficial to the people and environment when managed effectively. Such management activities can be seen in sustainable agriculture practices. When sustainable agricultural practices are implemented, agriculture can help to improve water quality as well as soil health to protect watersheds and preserve and restore critical habitats (Vervey & Vermeulen, 2011). If mismanaged it can have serious impacts on people and the environment (World Wildlife Fund, 2015).

2.2 The aspects of a functioning farming system

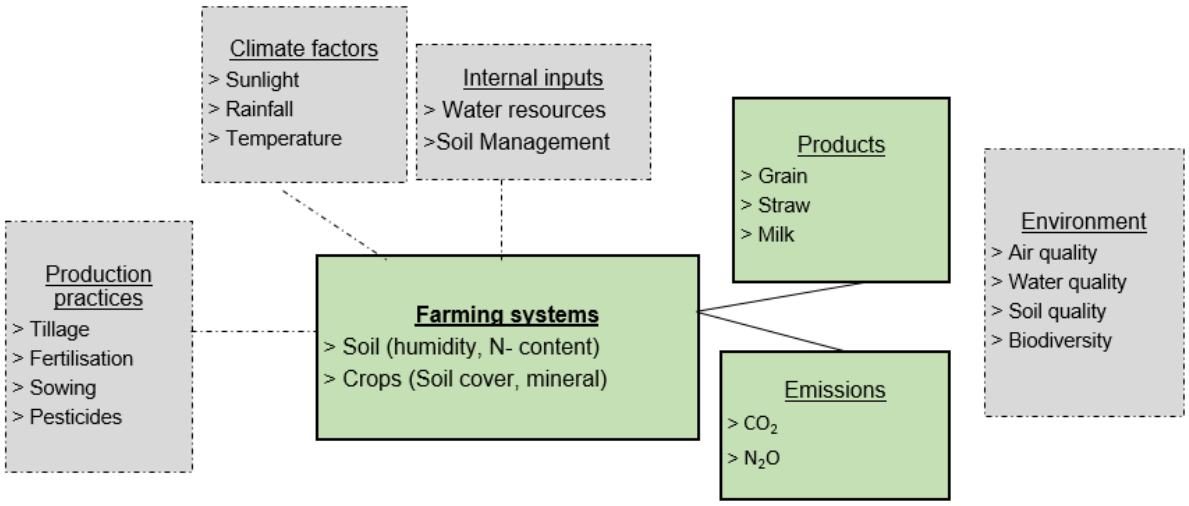

Figure 2: Farming system processes and practices - adapted from Van der Werf and Petit (2002:133)

Figure 2 is a representation of aspects within an agricultural system and of fluxes of emissions and products. This figure was used from a similar figure in Van der Werf and Petit (2002:133), to explain how a farming system functions and which inputs and outputs there are to these systems. In addition, this will also be helpful to understand where environmental issues derive from in a farming system and where sustainable agriculture could be implemented to help mitigate the environmental issues. It can be described as a schematic representative of input and outputs within an agricultural system.

2.2.1 The main aspects of a farming system

Firstly, water and soil (land) are two important elements that are needed for a functioning farming system. Water is a critical resource that agriculture needs to function. Without water agriculture would struggle to produce large crops and the quality of those crops will also be affected (Zalidis *et al.* 2002). Water as a resource in agriculture can take on many forms. There are two specific water resources agriculture use namely surface and ground water (Vörösmarty, 2000). Surface water is mostly concentrated in one area for example the Vaal River in South Africa. Ground water resources can also be used in agriculture but needs to be carefully managed and is extracted through boreholes. Agriculture alone accounts for 85% of global consumptive use, which is water removed from available water supplies or resources without returning the water to the resource system (Goyal, 2014). This activity causes numerous rivers, especially in semi-arid regions like the Vaalharts irrigation scheme to have weaker flows, and even to routinely dry up, especially downstream. In addition, the extraction of groundwater is just as unsustainable and can result in a lowering of water tables in a region. The decline in water quality in agriculture is most often

caused by land usage activities and/or inputs by the intensification of agricultural practices. Intensive agricultural practices increase soil erosion and excess sediment load and also agricultural chemicals and nutrients to leach into rivers, streams and groundwater (Foley *et al.* 2005). Intensive agricultural practices produce significant levels of nutrients, particularly nitrogen, phosphorus, faecal bacteria and sediment that may influence the agricultural system. The transfer of these pollutants to water resources can deteriorate water quality (Monaghan *et al.* 2007).

According to Falkenmark (1989), agriculture uses more of our fresh water resources than any other human activity and most of the time more than half of this water is wasted or lost through processes like evaporation, transpiration and transportation. Furthermore, the quantity of water needed for agriculture is dependent on the type of crop, regional water requirements, rainfall patterns, temperatures, soil quality, and vegetation cover which influence soil moisture levels and evidently yield production (Scotcher, 2009 & Pimentel, *et al.* 1997). In addition to crops, livestock consume less water but livestock need to eat as well. This requires water use for their grazing area and other food needs such as grain and lucerne. Another problem that arises from the water usage and requirements of agriculture is the amount of energy needed to use the available water. Some areas of the world do not receive enough rain annually to produce yields (Such as the Vaalharts region) and water needs to be transported to the farmers in order for them to irrigate their crops. This transportation can be in forms such as pipelines and canals. This may use precious energy needed for transportation that may lead to other environmental issues such as air pollution and using of non-renewable resources. The transportation of water may also cause water loss through transpiration and leakage to name a few (Pimentel, *et al.* 1997). Water can be pumped from boreholes as well which effectively means that it takes more than three times the energy than it would have used from using surface water. This will lead to more expenses such as fuels, generators and municipal bills. As mentioned above lots of water is lost through processes and techniques, for example some farmers use flooding and channelling as irrigation techniques which lead to most of the water not reaching the crops (Goldblatt, 2010).

In South Africa, availability of water is probably the single most important farming aspect. Water is needed for agricultural production and this resource is going to take more strain from other growing sectors in the country such as the industrial and mining sector (Goldblatt, 2010; Horrigan *et al.* 2002 & Scotcher, 2009). This may be detrimental to the Vaalharts irrigation scheme where water resources are limited due to a semi-arid region. Goldblatt, (2010) further states that farmers will have to double their water use by 2050 if they are to produce enough food for a growing demand.

Arable land (soil) is another important component of agriculture because crops get their necessary nutrients and resources from the soil. Soil can also control the amount of water needed to help irrigate the crops. Unfortunately, soil is also the element most under stress because it receives

most of the impacts such as fertilisers and mismanagement of land use. Soil is defined by (Larson & Pierce, 1994:38) “as an open system, with inputs and outputs that are bounded by other systems collectively termed the environment”. Soil is the central part of land use and it is critical to have good quality soil in a farming system to keep the agricultural system and relationships working. Soil quality is defined by Doran and Parkin (1994) as “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health”. Soil is a multidimensional structure with processes taking place within the soil. The soil structure is made up of biological, physical and chemical processes because of the different soil attributes. Agricultural practices change the soil features which may result in a malfunctioning soil and, ultimately, cause degradation of water and soil quality within a region (Zalidis *et al.* 2002). One of the issues that derive from mismanaged soil is the influence of predatory vegetation like weeds. They compete for water, sunlight and soil nutrients to grow stronger than surrounding crops or vegetation. In essence if there are weeds between crops water requirement will rise because there will be competition between the different types of vegetation (Lee, 2005). In modern agriculture people have found ways to make weeds sustainable. They are used to retain the nitrogen content in the soil and help to keep the moisture inside. This is especially helpful in semi-arid regions (Fischer *et al.* 2002). Weeds are then able to form part of an ecosystem.

The largest part of South Africa’s land surface (69%) is suitable for grazing, which has made it easier for livestock farming to increase and evidently becoming the largest agricultural sector in the country (Department of Agriculture, Forestry and Fisheries, 2016). Since the 1970’s the number in the national cattle herds had increased by about 6 million head but also had seen a decline in total grazing land because of expanding developments such settlements and activities such forestry and mining. Overstocking is one issue that can occur within the livestock-farming sector and may cause environmental issues such as trampling, crusting of the soil and the removal of vegetation and decline in biodiversity. These issues have led to reduced productivity within soil, reduced soil fertility and increased soil erosion (Scotcher, 2009 & Goldblatt, 2010).

An ecosystem is a natural system with flora and fauna, animals and climate that is native to that particular area. Ecosystems could offer agricultural practices numerous advantages, “such as the increased provision and purification of water; protection against natural hazards; pollination and grazing; increased soil fertility and regulation of the world’s climate” (Goldblatt, 2010:14). Therefore farming does alter the ecosystem of an area by changing the landscape, removing native flora and fauna, which in turn decrease the population of the local animals and insects (Goldblatt, 2010 & Knauer, 1993). Biodiversity will also be affected as desertification will increase rapidly which in turn would have its own affects. Desertification can be the result of mismanaged

agriculture and has already caused a reduction in agro-food production. One such example is over grazing resulting from livestock farming (Horrigan *et al.* 2002).

The interrelationship between land and water use is important because they are dependent on each other for example additional water resources in an area can influence the type of crop a farmer produces because of the need versus availability factor. The canals and rivers in the Vaalharts irrigation scheme supply enough water annually whereby farmers could pick the type of crop they prefer even if the required crop needs an excessive amount of water. This choice is heavily dependent on the market value for that specific crop especially for commercial farmers. The goal is to gain financial strength and if there is an adequate resource, farmers will plant the most beneficial crop (Hassan & Nhemachena, 2008), whereas small-scale farmers would grow crops that harvest easily, grow fast, can feed the household and have nutritional value.

2.2.2 Climate and agriculture

Another element that is important to agriculture is climate. Climate also plays an integral role in agriculture. The type of climate determines which crops are suitable to grow in a certain area and which resources are needed to assist these climate conditions. Southern Africa has unique climate conditions that affect the way farmers go about farming. This can be seen in the different climate conditions of the Northern and Western Cape for example. The Northern Cape is a semi-arid region which has warm and dry conditions and receives an average seasonal rainfall during the summer time, which is between 150 mm and 200 mm, normally from November to March (Dzikiti *et al.* 2013) whereas the Western Cape is a Mediterranean region and receives winter rainfall and is mostly cold and wet during the winter. Therefore the Northern Cape is more suitable for wheat and maize whereas the Western Cape is perfect for grapes. South Africa has two extreme climate conditions that affect agriculture. These conditions are droughts and floods. Drought is arguably the most feared and most experienced climate condition that farmers experience in South Africa. Droughts typically occur in the winter months when there are no warm moisture sources feeding the high and low pressure systems. South Africa normally gets around 500 mm of rain. Summer is also when flooding (or flash flooding) mostly occurs. This occurrence washes away important top soils with their nutrients as well as crops. The floods also cause crops to decay and farmers can lose their whole harvest. At the time of this study (2016) South Africa was experiencing one of the worst and longest droughts in 50 years (Mukheibir, 2007 & Jordaan, 2012).

Agriculture is highly dependent on the right climate type and weather conditions. As previously mentioned in Van der Werf and Petit (2002) natural capital is a contributor to producing food. Some climate variations play an impelling role on agriculture such as the El Nino Southern Oscillation phenomenon, which is associated with cycles of droughts and flooding events. This

phenomenon explains why there is a variation in wheat, oilseeds and grain production of between 15% and 35% globally. This also explains why a changing climate can and will be associated with an agro-environmental issue both as an internal and external factor. Hence, it has become critical to adapt to climate change by identifying and evaluating new and different farming options for the coming decades. Sustainability could then be implemented effectively (Howden *et al.* 2007).

The situation will not get easier as can be seen in Figure 3 and Figure 4. It is predicted that by the end of the 21st century global precipitation would have changed dramatically. Some regions would get more rain and other regions less. This comes as a major concern for Africa and especially for South Africa. When looking at Figure 3 it can be noted that South Africa (especially the western side) has a decline in precipitation from 5% up to 20% on average. For a region that is already struggling with annual rainfall to lose more rainfall would be catastrophic especially if something should happen the other water resources. Hence, even more attention needs to be given to local water resources if agriculture is to continue in the area and farmers will have to adapt to ensure productivity on their farms. Figure 4 shows predicted water runoff at the end of the 21st century and that figure makes for sombre viewing. It is predicted that South Africa will experience an increase in runoff of between 20% and 40%, meaning that about 40% of the little rain the region will experience, will be lost through runoff and will effectively be lost in an agricultural system. These alarming statistics show how much work needs to be done to ensure that agriculture in the region can survive. The agricultural system should also be used effectively to optimally utilize limited water resources in the area.

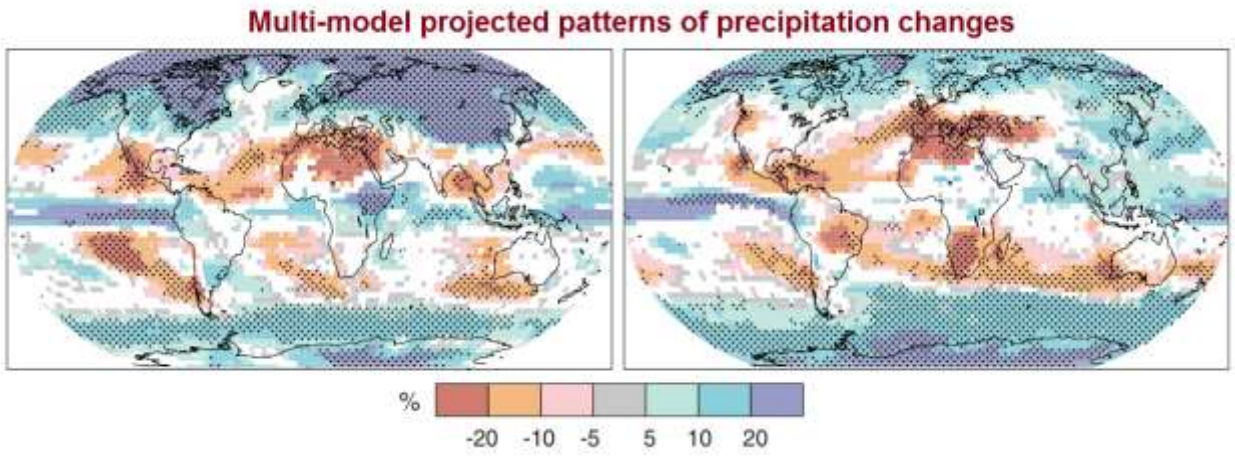

Figure 3: Future predictions of rainfall averages across the globe (IPCC Synthesis Report, 2007)

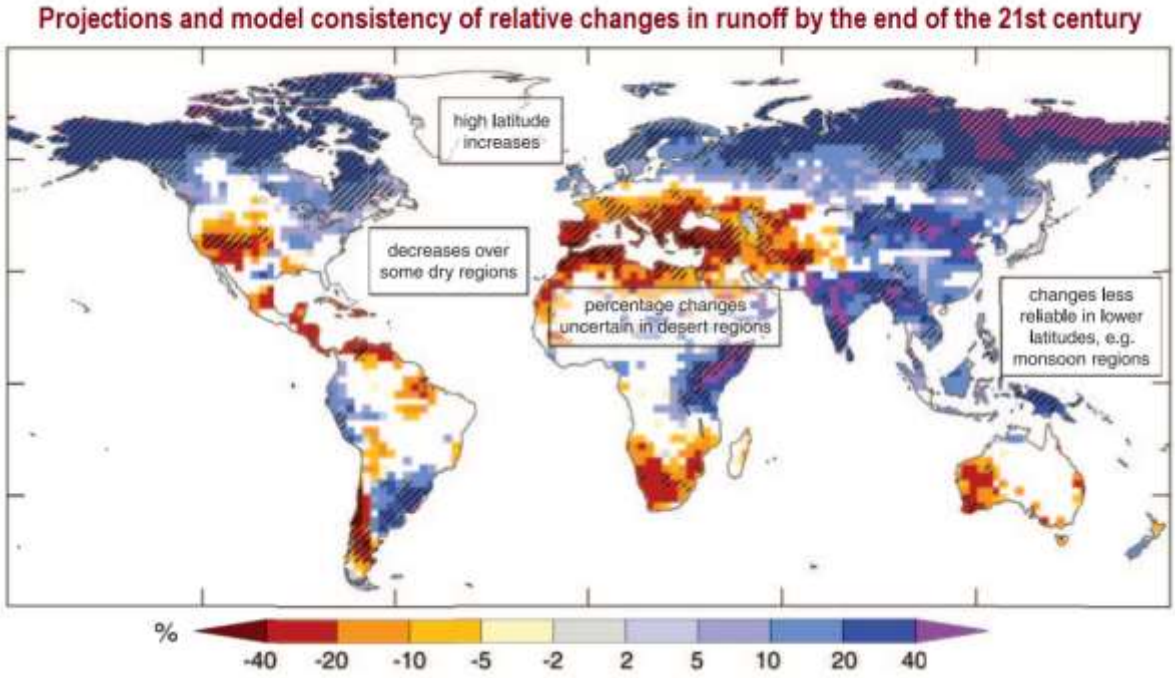

Figure 4: Predicted runoff changes at the end of the 21st century (IPCC Synthesis Report, 2007)

Without sufficient sunlight farmers' crops would not grow or their livestock would not have the necessary grazing. Rainfall is also an important component, too much rainfall would cause the crops to decay and too little rain would cause the crops not to grow or it would grow defectively with numerous imperfections. The amount of rain at any given time is critical to any form of production. The majority of crops need limited amounts of water over time. In recent times weather patterns have changed and it could rain heavily within an hour or two, which would then result in (flash) flooding that would not penetrate the ground and destroy fields and yields (Mukheibir, 2007).

The other natural factor that have a major influence on productivity is temperature. Certain crops are more suitable to colder climates whereas others are more adaptable to warmer climates therefore influencing farmers to plant seasonal crops. Maize is considered a summer crop whereas wheat is more of a winter crop. This has become a difficult process since climate change started influencing seasonal changes. Seasons are starting later or earlier than usual and this is disrupting farming preparation, planting and harvesting. This can lead to failed or low yields or over utilisation of resources such as fertilisers, which may lead to other environmental issues. This will influence the soil quality as well because the soil will contain less moisture and may experience a loss of nitrogen. Runoff will wash away top soil, which is vital for soil quality for it contains natural and human inputs that would help with productivity. As a result, hereof more inputs need to be brought in such as fertilisers and pesticides that will pollute and destroy the environment as mentioned earlier (Horrigan *et al.* 2002).

2.2.3 Agricultural inputs

It has been speculated that herbicides, pesticides and fertilisers are the main culprits which have serious effects on the local environment and on humans. Some research shows that the use of these chemicals has impacted the natural balance in the environment and affects the ecosystems around agricultural activities. Altieri (1998) states that these chemicals can cause birth defects in animals, may be toxic to fish and can cause cancer in humans. The use of pesticides started getting popular in the 1970s when the need for larger crop production arose because of the increase in population and in turn a bigger food demand. Back then farmers and researchers already had to determine how to grow food without using too much resources. The idea then was that the use of pesticides was one method that would assist in larger yields and people later on came to realise that it has caused severe environmental issues (Wauchope, 1978). The author further states that pesticides might influence areas far from the point of origin. These pesticides can be transported by runoff water into rivers or other water resources and then be carried to other environments, destroying the ecosystems in and around an area. Yield reductions could be severely affected by the incorrect use of pesticides due to the presence of lasting herbicides. Water resources are also affected, mainly because leaching and drainage. Pesticides could be seeping into surface and ground water resources (Zalidis *et al.* 2002). These are peoples' first reactions when speaking about agro-environmental issues. They immediately think of polluted surface and ground water resources, caused by fertilisers and pesticides that had been added to the soil during agricultural practices. Such practices do exist and are of prominent importance. (Sequi, 1999). Agriculture would not be able to function without these chemicals but it is rather a case of using it responsibly and when necessary.

Intensive high-yield production is dependent on direct inputs such as fertilizers, especially inputs such as industrially produced ammonium (NH_4) and Nitrate (NO_3). Tilman *et al.* (2002) argues that in some regions of the world crop production needs more fertilizers and that there is a need for more of these processes. Tilman *et al.* (2002:673) states "that without the use of synthetic fertilizers, world food production could not have increased at the rate it did and more natural ecosystems would have been converted to agriculture", which could have triggered more and/or bigger issues. Therefore the need for pesticides and fertilizers are important but these need to be used responsibly (Tilman, *et al.* 2002 & Goldblatt, 2010). If used correctly, fertilizers may actually be beneficial to the environment. These benefits are to keep the environment healthy. This may result in fewer inputs and larger yields. Although fertilizers are there to assist the environment, if used excessively or incorrectly, it can have the opposite affect and have a degrading impact on the environment. One such an effect is the release of nitrous oxide (N_2O) into the atmosphere which is 300 times more potent that carbon dioxide (CO_2) (Scotcher, 2009).

Currently over utilization of pesticides and fertilizers is causing the main environmental issues because these are being used unsustainably (Horrigan *et al.* 2002). These issues affect the soil quality and cause more salinization in the ground and in most water resources. Salinization is common in an area such as the Vaalharts irrigation scheme because salinization is more common in semi-arid regions where evaporation rates are high and rainfall is low and cannot leach salts from the soil. To mitigate this issue is costly (Goldblatt, 2010). More salinization means that more water will be required to keep up soil moisture content, which is already a problem in the region. The quality of the crops will also be affected because the water would not have all the essential nutrients that it needs to supply. These crops may not grow to their full potential and the quality of the crops (nutritional wise) may decrease. The food chains may also be thrown out of balance as the natural food of predators will be driven away or exterminated and they may die or leave the region, which may cause an instability in the environment. It is not just animals and insects that will be affected, as various plant species will be affected in the same way (Scotcher, 2009).

According to Van der Werf and Petit (2002), another concern regarding environmental issues is erosion of top soils on farms, the decrease of organic matter in the soil, and the disappearance of beneficial predatory and parasitic invertebrates in crops that are needed in a natural system. These issues not only affect the surrounding local environment but also the farming environment. Even though people do not realise that even these small organisms play an important role in the environment and if altered, can have significant consequences in the long run (Horrigan *et al.* 2002).

2.3 Sustainable agriculture

It would be much easier to use sustainable agriculture as a mitigation measure for environmental issues should be brought to the fore, as well as the interrelationship of these concepts and which environmental issues need to be addressed (Fischer *et al.* 2002).

This is where sustainable agriculture could intervene. Sustainable agriculture could be a mitigation measure to environmental issues derived from agriculture and even boost the quality and quantity of yields. Vervey and Vermeulen (2011:155) stated that “the sustainability of the scheme is very important; it provides a farming livelihood and job opportunities for many people, contributing significantly to national food security”. One aspect of sustainability is to focus on soil quality as a resource. The relations between management and use of soil and the environmental dimensions are also of importance (Zalidis *et al.* 2002; Larson & Pierce, 1994).

Van der Werf and Petit (2002) explain that many authors acknowledge that the concern of environmental issues should be met with sustainability to mitigate this problem. They explain that environmental issues depend largely on the production practices of farmers and that other factors

like the condition of the environment, rainfall and temperature also play an integral role. This is also applicable to human inputs such as pesticides. Sustainable agriculture does not mean parting ways with these methods, as these play an important role in agriculture, but rather alter the way it is used (Garnett *et al.* 2013).

Herdt and Steiner (1995) state that it is difficult to pinpoint whether or not current agricultural systems are sustainable and would still be productive in the near future. Human made inputs into agriculture is are greater than ever before which has increased productivity of yields, but may be at the expense of the quality of natural capital, such as land degradation, and thus of the underlying productive capacity. Natural capital is the input of natural resources that have none or limited human influence, for example soil, solar energy and rain. On the other hand, stands human capital (resources) which attempts to improve or assist farming productivity, such as fertilisers, seeds and pesticides. Farming is a combination of these capitals and works in conjunction with production practices to ensure that a farmer has adequate yields of good quality (Van der Werf & Petit, 2002).

Sustainability on its own is a very broad and difficult concept to define and utilise as the meaning differs between sectors and in sustainable agriculture there is no clear and accepted definition. In simple terms, “sustainable agriculture is the production of food, fibre, or other plant or animal products, using farming techniques that protect the environment, public health, human community and animal welfare” as defined by GRACE, (2017). Therefore sustainable agriculture will enable farmers to produce healthier food without compromising future generations' ability to do the same (GRACE, 2017).

The definition of ‘sustainability’ is different in meaning but similar in concept to other ‘sustainable’ definitions such as for economics, development and environment. Therefore this study will distinguish between sustainable agriculture and environmental sustainability. As noted above sustainable agriculture is already defined. This definition is different to environmental sustainability as can be seen in the definition of Morelli, (2011:5) which is “a condition of balance, resilience and interconnectedness that allow human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity”.

In sustainable agriculture the focus is on agriculture, whereas with sustainable environment, the focus is on the environment which is the central point of the concept. Hence, more focus will be placed on sustainable agriculture because the environment is in this concept a pillar equal to those influenced by other pillars such as well-being and human influences.

The local environment must be taken into account when defining sustainable agriculture as not all environments are the same. Local knowledge is to be used to better understand the local region and outside knowledge has to be incorporated to fill in the gaps where local knowledge cannot do so (Horrigan *et al.* 2002). Sustainable agriculture does not mean resorting to low-technology, traditional or 'backward' agricultural practices but instead on improved systems that will help farmers and most importantly the environment. This is supported in the following statement of Zalidis *et al.* (2002:138) "The agricultural impacts on the quality of the soil and water resources of a region, should be studied within the context of the characteristics and particularities of the broad area in which these activities take place".

How do farming systems introduce sustainable agriculture? According to Scherr and Sthapit (2009:33) sustainability can be enhanced within agriculture systems by enriching soil carbon through incorporating high carbon-cropping approaches, reduce the impact of livestock intensive production systems and using degraded land to plant trees or any other vegetation to restore the natural balance. They go further stating that there are five main ways of reducing the current issues of agro-food production systems on the environment. These include organic production methods, conservation tillage, crop rotation as well as livestock grazing and replanting of once-cleared lands. Horrigan *et al.* (2002) and Altieri (1998) argue that special attention should be given to organic production methods as these methods have to assist the environmental strains of agriculture as they can benefit in ways such as soil water retention (increasing drought tolerance) and improved soil fertility.

People working with sustainability claim that people need to devote less time arguing about the meaning of sustainability and sustainable agriculture and spend more time implementing the concept. Whilst this is understandable, especially for those directly involved such as farmers, it also entails a contradiction. How could sustainable agriculture be implemented in an agricultural system if it has not yet been clearly conceptualised for a specific region particularly (Allen *et al.* 1991)?

According to Pretty (2008), Every successful farmer has the ability and knowledge to realise that farming needs the best possible combinations of human (e.g. pesticides, seeds, fertilisation, sowing and tillage operations) and natural inputs (water, soil, rain, solar - and fossil energy). Inputs that will evidently help get the best quality and quantity of yields. Without these inputs farming would be difficult and will most likely fail, leaving the world with an ongoing food security problem. Therefore in order to be successful farmers have to incorporate the right combination of human and natural inputs according to their local situations. This crucial part of farming has its negative issues as well. Most human inputs increase the quality of the yields through their methods of farming but it also has the opposite effect on the natural features. This can cause a

decline in quality and in turn will have a long lasting effect on productive capacity on farms (Van der Werf & Petit, 2002 & Herdt & Steiner, 1995).

As previously stated, food production and the ecosystem play a critical role in people's quality of life. Sustainable agricultural systems which increase yields by conserving soil and water quality, use less energy whilst protecting the environment has become a focus point for many researchers, farmers, governments and organisations who have found interest in this concept. This interest in sustainable agriculture has become a very demanding and captivating concept within the mainstream agricultural community (Zalidis *et al.* 2002 & Stamatiadis *et al.* 1996). Intensive agricultural practices which have increased global food supplies over recent years have had unintentional yet detrimental impacts on the environment and surrounding ecosystems, illustrating that sustainable agricultural may be the way forward globally (Tilman *et al.* 2002). Tilman *et al.* (2002) further stated that sustainable agriculture should be culture and region specific because the benefits and costs of the numerous agricultural practices are related in local values and constraints. Some sustainable practices/methods include cover crops and no-tillage that can reduce leaching and erosion losses such as soil and nutrients, which can improve nutrient use efficiency on a farm. The cover crops method uses a crop rotation system where different cover crops are integrated into the system over time or use an intercropping system where two or more crops are grown simultaneously. These methods might improve pest control and increase soil moisture, which will assist in nutrient and water-use efficiency. Another method is agroforestry in which trees are included in a cropping system, which has the same advantages as other sustainable methods and can provide additional firewood and also store much needed carbon in the soil (Zalidis *et al.* 2002 & Tilman *et al.* 2002)

People can get confused when facing sustainable agriculture especially in a region or country where people have minimal knowledge on the concept like the Vaalharts irrigation scheme. Many believe that sustainable agriculture is resorting to low-technology, traditional or "backward" agricultural practices which will affect food production. This is obviously not the case as sustainable agriculture evidently is the incorporation of innovations that were developed by science/research, farmers or the combination of both (Pretty *et al.* 1996). Therefore sustainable agriculture is the future of farming and was conceptualised in a time where the environment is under stress and needs support to relieve some of the environmental issues. This means that if sustainable farming is implemented it will benefit future farming, food security and environmental issues. It is important to know that the success (in terms of sustainability) of one farmer or farm does not necessary mean success for another. There are numerous factors that contribute to sustainable agriculture (Ikerd, 1993:31). According to Rigby and Cáceres (2001), there is a mutual agreement between researchers that farming does cause environmental issues and on the other

hand a disagreement on the type of methods that should be used to improve agricultural sustainability.

The production of food has significant opportunities to be improved upon through sustainable intensification of agriculture if farmers and people accept and implement the necessary changes. It has the ability to shape a completely new environment and may play an integral part in a changing world. There are many examples of farmers using sustainable agriculture, producing more yields in contrast with the techniques they have used before implementing sustainability. This can be seen in Pretty *et al.* (1996) where they examined 1.1 million farmers in rain fed areas who have converted to sustainable agriculture and more than doubled their yields. Furthermore, another 0.79 million rice farmers have substantially cut their use of pesticides and the results were a 10% increase in their yield production. This is proof that sustainable agriculture has the ability to reduce environmental issues and uses of external resources and can increase food production by increasing yields.

According to Goldblatt (2010) South Africa needs more sustainability in the agricultural sector to improve the welfare of current and future generations. Mismanagement of agriculture in South Africa might not only cause food security and environmental dilemmas but also can cause more unemployment. According to Goldblatt (2010) sustainable agriculture in South Africa should aim to:

- Modify the manner in which land and water resources are managed, to improve and sustain productivity
- Support the social and economic well-being of people in South Africa
- To make sure that agricultural products are safe and of high-quality
- Ensure the livelihood and well-being of farmers, farm workers and their families
- Sustain healthy, operational agricultural ecosystems rich in biodiversity
- Mitigate and adjust to climate change.

Goldblatt (2010) further states that if sustainable agriculture is implemented correctly farmers should see the benefits thereof. Some of these benefits may include:

- Lower input costs
- Stabilised yields
- Decreased environmental pollution
- Reduced toxin exposure
- Improved efficiency of water use
- Living soils or improved soil fertility and/or nutrient-holding capacity
- Lowered erosion of soil
- Carbon sequestration (mitigating climate change)

- Improved, vigorous natural systems guarding biodiversity and ecosystem services.

Sustainable agriculture can only flourish when there is collaboration between the different role players within agriculture from governmental level down to even the small-scale farmers.

As mentioned in Figure 3 and Figure 4 water resources would be a major concern in the nearby future. Sustainability would help farmers to use these resources effectively and optimally. Some of the sustainable methods are the use of “surge flow” instead of flooding and channelling which leads to better irrigation management and less energy consumption (Verplaneke *et al.* 2012). According to Dubenok and Nesvat (1992) another sustainable way of irrigating is to do so at night time were the effect of transpiration and evaporation is at its lowest. Another sustainable irrigation method is drip irrigation, which leads to the crop receiving direct water to their roots with minimal evaporation and maximum absorption, which will help with runoff in the future as mentioned above. Drip irrigation would also use less electricity and should push away all the salinization around the crop (Payero *et al.* 2008).

2.3.1 Sustainable practices and methods

Cover crops refer to any type of plant material that is rotated into or within rows with crops in order to introduce a management system that will improve sustainability in the long run. The function of cover crops is to stabilise the soil structure, improve water infiltration, and produce a soil and material layer that has a high moisture concentration. Cover crops also add more nitrogen to the soil which in turn is used by the crops. A high nitrogen concentration in the soil is essential for yield production and lastly to counter the production and growth of weeds and unnecessary plant materials. If correctly used, cover crops can help to minimise the amount of operation needed to improve soil and crop quality. In order for cover crops to function and grow properly the soils’ nutritional status has to be sufficient for that particular situation. On a testing farm (Nietvoorbij farms) that has introduced cover crops into the fields, the land had up to 38% more yield production than those farms that did not make use of cover crops (Schutte, & Kellerman, 2016).

Table 1 below shows examples and functions of cover crops that can be used. The functions of cover crops differ from each other, certain cover crops may mitigate specific environmental needs and others could have the complete opposite effect as can be seen below (Schutte & Kellerman 2016). It should also be noted that there is a wide range of cover crops to choose from. Sometimes regular crops can also be used as a cover crop. The examples below are grass type cover crops that were presented for marketing purposes. Table 1 is a representation of what a cover crop is capable of.

Table 1: Examples of particular cover crops and its most contributing feature/s (Schutte, & Kellerman, 2016).

Cover crops	Best Features
1) Avena strigosa	Soil stability; Erosion prevention; Weed suppression; growth speed
2) Paspalum notatum	Soil stability; Erosion prevention
3) Raphanus sativus	Nitrogen intake; provides livestock feed
4) Sinapus alba	Resistance to drought
5) Trifolium alexandrinum	Source of Nitrogen; Weed suppression;
6) Vicia dasycarpa	Source of Nitrogen; Soil stability; Weed suppression; High tolerance for heat, drought and flooding
7) Vigna unguiculata	Source of Nitrogen; Erosion prevention; Weed suppression; High tolerance for heat and flooding

There is a worldwide debate whether or not sustainable agriculture is the main concept and organic farming part thereof, or is sustainable agriculture part of organic farming or should it be seen as separate entities. In this study organic farming will form a part of sustainable agriculture for the simple reason that organic farming contributes to a more sustainable environment. There seems to be a disagreement between linking sustainable farming to organic farming, with some researchers claiming that the two concepts are synonymous to one another. Other researchers argue that sustainable agriculture is the heart of organic agriculture and that organic agriculture originated from sustainability (Lampkin, 1994; Henning *et al.* 1991; York, 1991).

Lampkin (1994:5) defines organic farming as follows: “to create integrated, humane, environmentally and economically sustainable production systems, which maximise reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human nutrition, protection from pests and disease and an appropriate return to the human and other resources”. Stolze *et al.* (2000:15) explains that organic agriculture is reliant on “crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes and measures of biological pest control”. These factors contribute by improving and maintaining soil productivity and texture, provide plants and crops with the necessary nutrients and finally control weeds, insects and other pests.

Organic farming is categorised from other farming styles through a set of principles and standards (legislated and voluntary) that need to be followed in order for it to be classified as organic (Stolze *et al.* 2000).

The definition of organic farming is based on the 'Basic Standards for Organic Agriculture and Processing' of the International Federation of Organic Agriculture Movements otherwise known as IFOAM (Stolze, 2000:16). The IFOAM principles and standards are set up in such a way that individual countries can adjust the concept to their own local and unique circumstances (IFOAM, 2014). Farmers like the idea of organic farming but struggle to implement the concept in practice because in the first few years of organic farming, the crop yield is mostly low. The transition phase takes a few years to be fully effective and during these years, farmers grow nervous and return to old practices. Many of the farmers make the decision not to switch to organic farming because they are convinced that they will not make any profit in the transition years (Erbentraut, 2016). There are some characteristics of organic farming according to the Soil Association (as cited in Rigby & Cáceres, 2001). Two of the basic characteristics are the avoidance of fertilisers that carry a high concentration of mineral salts and the prevention of using agro-chemical pesticides.

Organic agriculture is mostly associated with crops, yields, soil quality, pesticides and fertilisers, which is how most people experience and conceptualise organic farming. Clearly, this is not the case, as organic farming includes livestock as well. Just as crop farming has certain principles and standards so too has livestock farming. These principles and standards include maximum welfare of animals for example sufficient free movement, fresh air and natural daylight to name but a few of the standards (Stolze *et al.* 2000).

This section identified the aspects of a functional farming system. These aspects included internal and external elements that play an integral role in the irrigation scheme, each element having a unique function. These elements are adjusted by natural as well as human influences. Natural elements included climate and water resources and human elements included fertilizers and pesticides. These natural and human influence can have positive and negative effects and therefore introducing the need for sustainable agriculture. Sustainable agriculture is needed to ensure that agriculture can continue to provide food for a growing population without depleting the resources of future generations.

After having explained more about food security, environmental issues, land and water use and sustainable agriculture, the following section will describe how the study was set out to achieve the objectives in section 1.3.

CHAPTER 3: METHODOLOGY

3.1 Research infrastructure and design

The study was carried out within a larger project, titled “Exploring the potential of local food systems (LFS) for sustainable rural development – A case study of the Vaalharts Area”, funded by the Programme to Support Pro-poor Policy Development (PSPPD II). This is a partnership programme of the Department of Planning, Monitoring and Evaluation (DPME), Republic of South Africa and the European Union (EU). The PSPPD II is a component of the South African National Development Policy Support Programme and its overarching theme is reducing poverty and inequality. This larger project explores local food systems in the context of rural sustainable development, using the Vaalharts irrigation scheme as a case study. The overall aim is to provide empirical evidence on the potential of LFS to contribute to sustainable rural development by investigating six sustainability components (economic, environmental, socio-cultural, quality, governance, and health and nutrition, adapted from Sustainable Development Commission, 2011). The emphasis is on short food supply chains from producer to consumer. The study presented here focuses on the environmental dimension of the bigger projects, which contributes to the larger concept of ‘sustainable food systems’ by identifying environmental issues that derive from agriculture in the region.

Field research was carried out within the infrastructure of the Wellness INnovation (WIN) platform, a Faculty of Health Science project led by Africa Unit of Transdisciplinary Health Research (AUTHeR) at the North-West University, which focuses on community engagement and community-based research to improve rural public health and well-being. The Wellness INnovation (WIN) platform, endeavour to create sustainable livelihoods and promote healthy lifestyles, was initiated by Prof. Annemarie Kruger and continued by Dr. Nicole Claasen. This study titled ‘Vaalharts: Environmental aspects of agricultural land and water use practices’ was the environmental dimension of the project which was undertaken by the subject group Geography and Environmental Management on the Potchefstroom campus of the North-West University, South Africa.

This study has used a quantitative approach whereby the data was analysed to allow the use of graphs, figures and tables. In short, a quantitative study is where research and its findings can be explained by using numerical data that is calculated through mathematically based methods such as statistics (Yilmaz, 2013). It can also be defined as follows;

> “A type of empirical research into a social phenomenon or human problem, testing a theory consisting of variables which are measured with numbers and analysed with

statistics in order to determine if the theory explains or predicts phenomena of interest" (Creswell, 2013; Gay *et al.* 2003:203)

Quantitative research makes use of a pre-constructed standardised instrument or pre-determined response categories. The researcher guides the participants in such a way that the data can be categorised according to what the study needs to evaluate (Yilmaz, 2013). One such an example is a scale-based question whereby the participant can answer by choosing a category that best fits their answers. These scales normally consist of negative, neutral and positive categories that participants can choose from. These scales can also be manipulated to only illustrate one or two of the categories in order to achieve the desired findings.

3.2 Sampling method, size and criteria

The questionnaire that has been used in the interviews included local small and large scale farmers who produce food for human consumption.

The study has made use of Statistical Services on the Potchefstroom campus to determine how many farmers would be required to achieve adequate data for the required study according to the demographical data of the area and the scope of the study. It has been determined that a sample size of between 50 and 60 participants would be adequate for such a study. According to Francis (2010) data saturation is reached when no new themes, findings, concepts or problems are found in the data and the researcher gets the same findings after a certain amount of data collection. This study has set out a predetermined sample size. During the data collection the researcher would follow the trend of the data. After the sample size has been reached the researcher could determine if the data was saturated. If not, the sample size would be adjusted to accommodate more participants until enough data had been collected to continue with the study. It had been decided to be sensitive when contacting farmers because farmers usually are very difficult to recruit for interviews because of their time consuming occupations, especially commercial farmers.

It is difficult to categorise farmers in South Africa because there are many elements to consider. Elements such as region, farm size, type of activity, cultivated land, should be considered when defining farmers (Pienaar, 2013). Hence, the reason for the *classification* of farmers in this study was because of the wide range of farm sizes and their purpose for farming. For the purpose of this study small and large scale farmers are defined as follows: Small scale farmers are referred to as subsistence farmers within the irrigation scheme, people that grow crops or hold livestock for the purpose of feeding their families. Small scale farmers were also classified in this study if their farm size is less than 10 hectares (ha). These farmers were purposefully selected according to their availability in predetermined areas of the irrigation scheme. Most small scale farmers

came from the local informal settlements such as Ganspan, Valspan, Pampierstad and Taung. Large scale farmers on the other hand are farmers with a land size of more than 10 hectares within the Vaalharts irrigation scheme and who produce for local and foreign markets

Snowball sampling was applied to reach a combined sample size of 50 small and large scale farmers. Snowball sampling is a technique researchers use to find research subjects for their studies. In this technique one participant gives the researcher details of another possible participant, who in turn provides details of a third participant, and so on and so forth until the researcher has recruited enough participants (Vogt, 2011). At the end of the data collection 29 large and 21 small scale farmers were interviewed. Throughout the data collection it became apparent that there was a trend in the data from both small and large scale farmers. The trend was the same for both small and large scale farmers in themes such as management, but different in themes such as sustainability. After conducting the interview, the participant was asked if he or she could provide or recommend another participant that would be willing to participate in the study. The reason being that most farmers have busy schedules and are difficult to reach. Other participants would then have a better understanding of the local area and people that can help save resources to get the necessary participants for the study.

The small-scale farmers were closer to the towns and farming was not their only focus whereas the larger farmers had bigger farms. The study identified different types of farming such as livestock farming, cash crops, citrus fruits, arable crops and game farming in order to get an overview of the activities in the irrigation scheme.

Inclusion criteria for participating farmers are:

- Willingness to participate.
- Local producer of food for human consumption.
- Ability to communicate in Afrikaans, SeTswana or English.
- Age 18 or older.

3.3 Questionnaire design

The interview would entail a questionnaire that had structured and open-ended questions. The questionnaire is attached as Appendix 3. The goal of the structured questions was to have set benchmarks that were easy to follow and define when analysing the data. Open-ended questions assisted with extra information if the participant felt that they could elaborate more on a question, which may have helped with further detail. The questionnaire consisted of five sections.

3.3.1 Demographic profile of farmers

The first section was dedicated to the demographic profile of farmers to get a better understanding of the participant, their background and farm structure. This section also assisted in identifying the land use practices of the farmers (part of objective 1) in order to compare it with objective 3 to see how land use practices could be sustainable. The demographic section included 8 questions. Question 1 – 3 enquired farmers about their age and that was divided into categories of 10, starting at 18 years and ending at 70+ years. The 2nd question required the gender. Question number 3 identified their languages which include English, Afrikaans, Nguni, Sotho, Venda, Tswana and other. These three questions were asked to categorise farmers according to their demographic profile because a 50 year old Afrikaans speaking male is expected for example to have a different background and perspective to a 20 year old Tswana female. This information may help the researcher understand the different answers and perceptions of farmers to get a better overview of the data. Question 4 of the questionnaire enquired about the type of knowledge and training the farmers had regarding agriculture because an educated farmer may be more familiar with the concept of sustainable agriculture or more knowledgeable towards environmental issues than an uneducated farmer. The next two questions (5 & 6) identified the location and size of the farmers' land. In this way the researcher could establish if it was a small or large scale farmer and how much of the farm was used for agricultural activities. The last two questions of the demographic section were dedicated to identifying land and water use on the respective farms. Question 7 identified the type of water used on the farm and how much was stored whereas in question 8, farmers had to indicate what type of farming activities took place on the farm. These two questions assisted with structuring objective 3 of the study as indicated in section 1.3.

3.3.2 Environmental issues

The second section was dedicated to environmental issues. This section has identified the perceptions of farmers toward the environmental issues that derive from agriculture and the surrounding areas. It started with question 9 which asked farmers to what extent they felt agricultural practices impact the environment from the categories 'none' to 'definitely'. The next question (10) identified where farmers felt environmental issues came from, inside or outside the irrigation scheme. This question was asked to determine whether or not farmers have been aware of the respective environmental issues. The last question (11) of this section was an open-ended question which asked farmers to identify environmental issues that they struggled with.

3.3.3 Sustainable agriculture

The third section served to establish farmers' perceptions towards sustainable agriculture and its influence on environmental issues. This section consisted of six questions starting with question 12 where the farmers have been asked how familiar they were with the concept of sustainable

agriculture. This question assisted the researcher to determine if the farmers had known of sustainability and how to ask follow-up questions depending on their answers. The following question (13) asked farmers how sustainable they perceive their farms to be which lead to the next question (14) where farmers had to identify sustainable activities if they had any. Question 15 was a follow-up question if farmers answered that they were not sustainable in the previous question. This question wanted to know if the farmer would like to incorporate sustainable activities on their farms. The last two questions (16 & 17) in this section asked farmers whether they could enhance sustainable agriculture on their farms and if sustainable agriculture could assist other farmers in the irrigation scheme as a method that could be implemented to mitigate environmental issues and help reduce excessive agricultural inputs.

3.3.4 Governmental assistance towards agricultural aspects

The fourth section was on governance and was developed to get a better perspective whether or not government representatives were assisting farmers with environmental issues and sustainable agriculture. This section has had two questions (18 & 19). The first question asked farmers whether or not they have received guidance towards environmental issues and sustainability. The follow up question asked whether these government representatives could do more to assist farmers with environmental issues and sustainable agriculture. These questions helped the researcher to determine why there may be issues and lack of assistance in the irrigation scheme. The researcher would possibly be able to formulate policy recommendations with the help of these questions.

3.3.5 Water use and water quality

The final section of the questionnaire was devoted to water use activities and perceptions of water quality. This information would be used in conjunction with information on land use activities to help identify the interrelationship between land and water use in the irrigation scheme as set out in objective 2. This section started with question 20 where farmers were asked to identify water use activities on their farms and what type of water resources these activities use. Through this question the researcher could also determine the interrelationship between land and water use of farmers. The last two questions (21 & 22) were dedicated to perceptions of the water quality. Question 20 asked farmers how they perceive the quality of water coming into the irrigation scheme. The second last question asked whether they think the irrigation scheme has any effect on the water quality. This question was asked to determine if farmers were aware of agricultural inputs such as pesticides into the different water resources.

The questionnaire had a final question where farmers were asked if they had any additional information or comments.

3.4 Data collection and analysis

This study applied a quantitative research approach whereby a questionnaire was designed to use when interviews took place with participants. These interviews set out to investigate environmental issues and sustainable practices that were set out in objective 1 and 3. This resulted in a better understanding of the farmers' perceptions towards environmental issues and sustainable practices. The local famers unions, governmental and non-governmental entities have also assisted with information and statistics (existing data described in the aims) that were relevant to the study. The information included land and water use statistics of the Vaalharts irrigation scheme and other information that may have assisted towards environmental issues and sustainable practices. This information was gathered through informal meetings with stakeholders that were part of the study or knew of the study and agreed to assist the researchers.

The second method of data collection was through observations made when conducting field visits. This method was used to find possible environmental issues that have not been identified through interviews and were used to drive interviews if information was unclear. This has applied to applicable forms of sustainable agriculture as well. The information gathered through interviews was used to follow-up and see how the activity was implemented. Pictures and/or notes were taken when one of these elements were spotted. This method was unstructured because it has assisted the researcher with additional data that may have been used as evidence to prove a finding.

To show the interrelationship between land and water use (objective 2) in the Vaalharts irrigation scheme a map was generated from the information gathered through the interviews and from information obtained from authorities. The map was generated using ArcMap to show all the different activities taking place in the irrigation scheme.

Farmers unions in Vaalharts were approached and asked whether they could establish contact between the researchers and local farmers. Union meetings served to introduce the research team and to describe the objectives and methods. Interested farmers have been approached and contact was made to set up an appointment for an interview. Consent forms and introduction letters (Appendix 2) were handed to farmers possibly taking part in this study, giving them the chance to read information about the study in their own time. Previously established contacts have been followed-up by phone to set appointments at the most convenient time for the farmers.

After having conducted these interviews, the data was incorporated into a software program called Statistical Package for the Social Science (SPSS). Field (2009:113) defines SPSS as "a Windows based program that can be used to perform data entry and analysis and to create tables and graphs". SPSS is capable of handling large amounts of data and can perform all of the analyses

covered in the text and much more (Field, 2009:113). After all the data has been incorporated and the software adapted to suit the study requirements, the data was analysed and represented using simple descriptive statistics such as graphs, figures and tables. This included all the structured questions and excluded the open-ended questions and observations.

The open-ended questions have been identified and classified in dedicated tables. The main perceptions were identified by means of theme frequency (content analysis) and the number of times a certain theme or subject came from a farmer's perception. This was especially applicable to various environmental issues that farmers highlighted. These issues have been incorporated along with other perceptions in categories and stored over multiple tables. These then have been analysed and interpreted and integrated into the study if there has been relevance to any section within the study. A similar method was used to document and incorporate the observations made in the field. If any environmental issues of sustainable method were identified it was noted down and a picture was taken as proof. These have been stored and analysed in the same manner as the open-ended questions. The observations were especially important when farmers failed to mention or indicate any environmental issues and/or sustainable methods.

3.5 Study area

Vaalharts was identified as the project area for a few reasons. Firstly, the area within of the larger project was known to the primary investigator and connections have already been established with local stakeholders. The irrigation scheme also met all the requirements that the project has set out to accomplish, either from number of small and large scale farmers or from unique cultural differences as well as different role players within the irrigation scheme. As the largest irrigation scheme in South Africa the research possibilities have been endless and presented the opportunity to make policy recommendations.

The Vaalharts irrigation scheme can be found is located in the Northern Cape (NC) Province close to the North West province. The irrigation scheme stretches from Warrenton in the South, to Taung in the North. Larger towns within the scheme are Jan Kempdorp, Hartswater and Magogong, however in and around the irrigation scheme there are informal settlements to be found. These settlements include Ganspan, Pampierstad and Valspan (Van Vuuren, 2010).

The irrigation scheme is 75 km in length and irrigates 39,820 ha of licensed agricultural land. There are 1,176 km concrete lined canals throughout the irrigation scheme. All the water available for irrigation is gathered through the Harts and Vaal Rivers, which flow on both sides of the irrigation scheme and confluence south of the scheme. The canals' main source of water is from the Vaalharts weir. The weir is a synthetic dam that is fed by the Bloemhof dam and it supplies the canals with water. Building of the weir started in 1934 and it was opened a few years later.

Today Vaalharts Water manages the weir and canals. Vaalharts Water is a government driven and funded organisation, which is responsible for managing the water resources in the scheme and assigns water quotas and attends to the needs of the local farmers. Drainage canals have also been built to transport storm water and subsurface drainage water out of the irrigation scheme (Vaalharts Water, 2010).

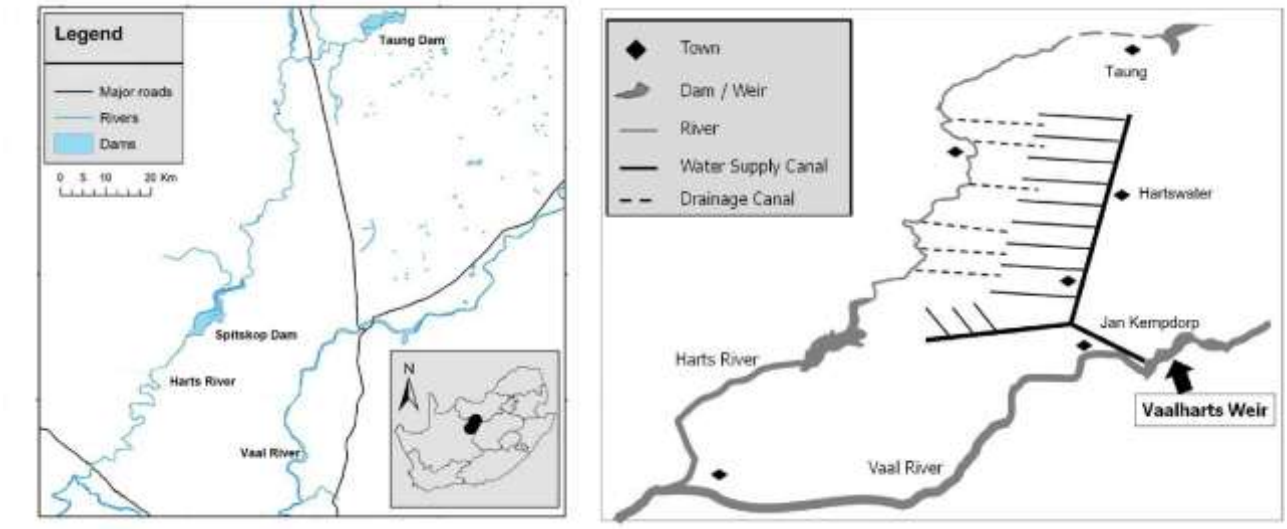

Figure 5: Rivers and canals providing water to the scheme (Malherbe *et al.* 2016).

The Vaalharts irrigation scheme had been proposed as early as 1875, when General Francis HS Orpen, a surveyor, saw that the contour of the land had a gentle downward slope. He had formed an idea that water could be directed from the rivers to certain areas using gravity. The idea was then stopped by war. Orpen's idea paved the way forward. There have been numerous attempts to establish the scheme which mostly were halted by financial restrictions or the occasional war. In 1933 it was decided that the irrigation scheme would be put into place to accommodate poor white people that were affected by the great depression, most of which were people returning from the First World War. These people were given small pieces of land in 1941 to establish farms that would help grow food for the government until the farm was paid off. In the beginning only men were allowed to be on the farms but later on these farms helped families to get to their feet and earn a living (Van Vuuren, 2010).

Most of the current farmers in the irrigation scheme are historically from the area with their fathers and grandfathers having been farmers in Vaalharts irrigation scheme. The current farmers inherited or bought new farms in the irrigation scheme, keeping to the present day most of the original families in the scheme. The farmers explained that to their knowledge the irrigation scheme was believed to have a life span of only 50 years. At the time of this study the scheme was in existence for 76 years. The irrigation scheme has been ideal for farmers because of the flat surface of the area. This has made it easy for farmers to use flood irrigation on their farms, which raised the ground water table from 24 m to 1 m according to Fourie, (2006). The irrigation

scheme was originally developed to assist poor people and improve productivity in the country to ensure food security. This could be seen as a mutualistic relationship between farmers and the Government where both parties benefited from the development.

3.6 Ethical considerations

The larger project, including this study, has gone through an ethical process and was successful in obtaining ethical clearance (NWU-00352-15-A1) as can be seen in Appendix 1. This process was completed through the Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University, Potchefstroom campus. This study has been evaluated to have minimal risk levels and issues according the ethical standards. The main ethical factors that have been kept in mind were the different cultures, time constraints of particular participants, confidentiality of participants' information and lastly storage of and access to data. Before any data was collected an informed consent form and an introduction letter have been given to possible participants to carefully read through the details of the study in their own time to decide if they were willing to participate, before conducting any interviews. Ethical monitoring was conducted yearly to establish that the correct steps have been taken throughout the study and also to determine and ensure that no new or other ethical issues would arise.

The questionnaires were stored in a lockable cupboard in a room on campus that could be locked and where only the researcher had access to the questionnaires. Thereafter, the data was analysed on a computer that was protected with a password in a lockable room where only the researcher had access to the data. The data was also backed-up on an online cloud system that was linked with the researcher's profile and was also protected by a password and could be accessed only by the researcher.

3.7 Limitations

The main constraint has been to find participants, especially large scale farmers, who had limited time because of their time consuming occupation and as farmers had to be identified through already established contacts. Thereafter, they had to be contacted and some would explain that they have not been in the area at that moment or simply have not had time to meet with the researcher. It had also been difficult to get hold of new farmers using the snowball sampling technique because farmers would refer to other farmers that have already been interviewed and thus establishing a new contact had been extremely difficult. It has also been (from various sources) made clear to researchers that they should not drive in and around farms unannounced because farmers are attentive to strange vehicles driving around and would potentially be confrontational because of the unsafe environment on farms in South Africa. Farmers who have agreed to meet were very friendly but sometimes tiringly so. They would talk for long periods and

would even show researchers their whole farm, which took precious time from researchers that could have been used to interview other farmers. A time constraint researchers have had a problem with, was the distance between the study area and the university. Farmers were informed of the time constraint and that other farmers had pre-arranged appointments.

The concept of sustainability within the study was questioned and the researchers were constantly asked the question of what was meant by sustainability and why *sustainability* and not *resilience*? These were valid questions that had to be addressed in this study, firstly sustainable agriculture had to be clearly defined and secondly the researchers had to distinguish between sustainability and resilience.

The Vaalharts irrigation scheme is a very large scheme and driving between farms and farmers had been time consuming and costly. This made it harder to reach the total number of farmers set out in the study. The Vaalharts irrigation scheme is also far away from the North-West University, which has made it difficult travel wise, and most of the time the resources had to be shared between different researchers. Teaming up with another researcher was very supportive in the end as it made the workload easier.

Some farmers have previously had negative experiences with other researchers or University related projects and then would refuse to be part of another study. The researcher would explain how this study would function and that feedback sessions would be scheduled which farmers could attend to see what the findings were and they would be given feedback of their own to help with research in future.

Despite the limitations mentioned here, meaningful results have been obtained which would be discussed in the following chapter.

The methodology was set out to explain the larger project and to indicate where this study has connected with the project. The study design was explained to help the reader understand the way the study was conducted to achieve the objectives that were set out in section 1.3. The explanation also described how the data was collected and analysed before presenting the results in the following section.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Results

The following section will address the analysis of the data which is shown by means of figures and tables. This interpretation of data will allow the researcher to achieve the objectives that were set out in section 1.3.

4.1.1 Demographic profile of farmers

50 farmers were gathered throughout the irrigation scheme to participate in this study. These farmers were categorised into two categories namely; small – and large scale farmers. The small-scale farmers included 21 participants ranging from Valspan, Ganspan, Pampierstad, and Taung. These farmers were predominantly female, Tswana speaking people, who relied on subsistence farming to sustain their families. These farmers had an irrigation area of 1ha or less which included livestock and mostly vegetables.

The other participants were 29 large scale farmers. These farmers were mostly male, Afrikaans speaking people relying on commercial agriculture as their livelihoods. These large scale farmers' irrigation ranged from 10ha to <1000ha which include livestock and cash crops and in some cases both. These farmers were obtained from Bullhill, Jan Kempdorp, Hartswater, Warrenton, Magogong and Taung. The majority of small – and large scale farmers fell in the age range of 30 to 60 years of age.

4.1.2 Agricultural land and water use

The first objective of this study was to identify the land and water use activities of participants in the Vaalharts irrigation scheme. Table 2 and Table 3 identified these activities respectively. Firstly, Table 2 described the type of crop and the livestock farmers kept on their farms. One finding from the table below is that small and large scale farmers differ in the type of crop and livestock they use. There were rare cases where small and large scale farmers had similar crops such as maize and lucerne.

One major finding was that the farmers in the Vaalharts irrigation scheme started favouring farming with pecan nut trees. Pecan nut farming is slowly becoming 'the main' crop in the scheme because of its low input, high market value and the easy water accessibility within the scheme especially with large scale farmers.

During the interviews it became aparrent that numerous farmers have switched to pecan nut farming, which can be very risky according to some other farmers because the pecan nut market can change unexpectedly leaving the farmers without a market or a very uneconomical market.

Some farmers are concerned about the possible negative impact that pecan nut production may have on the country's food security status because most of the crop is exported and not many of these nuts are being consumed in the local communities.

Along with pecan nuts, wheat and maize are also prevalent in the irrigation scheme especially with large scale farmers. These are the more traditional crops in the irrigation scheme, are grown seasonally and are mainly used as cash crops according to the farmers. Lucerne and cotton are also well distributed among large scale farmers but are less popular than wheat and maize. These crops are grown because farmers want a variety on their farms, especially with cotton, or as livestock feed, for example lucerne. The least common crop is citrus fruits. There are a few citrus farmers in the irrigation scheme but these farmers farm on a large scale and citrus trees would normally be their main crop. Livestock farming is increasing in the irrigation scheme and large scale farmers tend to keep cattle as their livestock which they would sell to the local abattoir.

Small-scale farmers would mostly use subsistence crops such as fruits and vegetables that they grow in their backyards to sustain their households. These farmers would grow different crops in each garden and then swop or sell the surplus crops to other community members to improve variety in their diets and/or gain financial income to buy other products. This is the same for their livestock. The bigger variety they have the better.

Table 2: The type of land use activities of both small – and large scale farmers

	Large scale farmers		Small-scale farmers	
Crop production	Maize Wheat Pecan nuts Lucerne	Cotton Ground-beans Barley Citrus fruits	Tomatoes Watermelons Carrots Beetroots Spinach	Cabbages Pumpkins Onions Strawberries Grapes
Livestock	Mostly cattle Sheep Goats		Cattle Sheep Goats Chickens	

Table 3 describes the water use and activities in the Vaalharts irrigation scheme. The red cells refer to high use of a water resource and the green cells a low use. Farmers claimed to have introduced new irrigation methods such as drip and pivot irrigation because of the variety of crops in the scheme. These farmers had also installed drainage systems on their farms that lead to

drainage canals to transport excess water off their farms. The number of livestock farmers had also since increased throughout the scheme, which increased the need for water resources. The community in and around the irrigation scheme had also increased in number and with a growing community the need for water would have increased.

People complained that river and canal water was polluted and municipal water was not always to be trusted or managed well. This statement can be seen in Table 3 where farmers mainly use borehole water as drinking water in their households, as well as for their livestock. They feel that borehole water is safer to consume and easier to manage especially with the water quota they receive on canal water.

Municipal water is mostly used by the small-scale farmers because they are generally located in town and do not have access to canals or boreholes and if they do they do not have the financial capital to buy water. In town it is also easier for them to manage municipal water. According to these farmers the low use of dam water such as natural dams or synthetic dams, is because there are easier ways to obtain water, such as the use of canal and borehole water. The farmers argue that the few smaller synthetic dams are too small for major irrigation. A lot has changed since the inception of the irrigation scheme with farmers using different farming techniques, methods and crops. Drip and pivot irrigation methods were introduced into the irrigation scheme, to replace the flooding, by planting new crops like pecan nuts and citrus fruits.

Table 3: The water activities of participants in the irrigation scheme

Purpose		Source					
		River/Channels	Municipal	Borehole	Dam	Spring	Other
1	Household use	4%	40%	56%	2%	2%	0%
2	Drinking water	4%	31%	56%	4%	2%	0%
3	Livestock water	16%	20%	27%	4%	0%	0%
4	Irrigation	60%	29%	2%	13%	0%	0%
5	Filling dams	49%	7%	13%	4%	0%	0%

When talking to farmers it became apparent that water quality was a major issue in the irrigation scheme as can be seen in section 4.2. This has led to the question to farmers about their perception of water quality. Figure 6 clearly illustrates that farmers feel that the water quality is a problem in the scheme. Nearly 50% of the farmers see the water as polluted, stating that they are very hesitant to use this water in any form or activity. Over 40% of farmers feel that the water is not up to standard, stating that it is still useable to some extent but it is not at an acceptable

standard. Farmers in both categories use the examples of acid mine drainage, salinization and wastewater to describe sources of pollution that negatively influence the water quality. Farmers claim that they see governmental representatives testing the water but they never receive information informing them of the water quality. Governmental representatives claim through informal interviews that they do test the water and that the results are available to the public but also claim that these tests are expensive and must be sent away to specialised laboratories which takes a few months for the results to become available. This could result in a lack of communication or mismanagement that most farmers complain about.

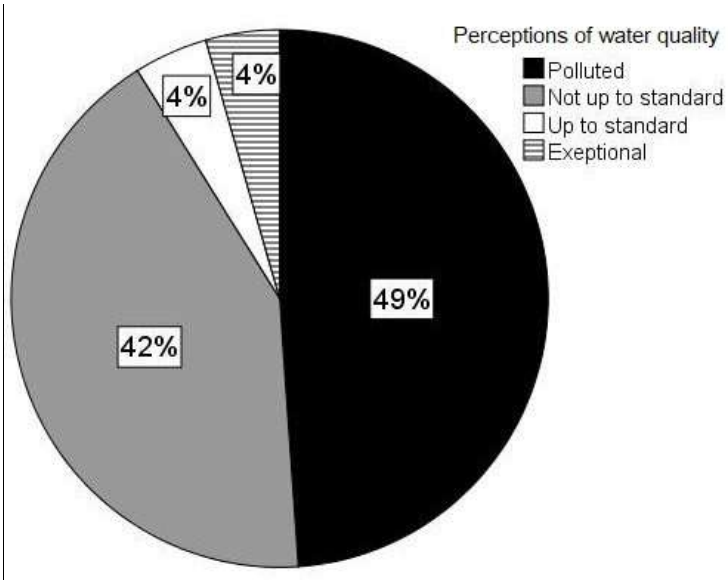

Figure 6: Farmers' perceptions of the water quality

The last question that was asked to the farmers was what effect the irrigation scheme has on the water quality'? In Figure 7 it can be clearly seen that 58% of farmers assume that the agricultural activities in the irrigation scheme have no effect on the water quality. Farmers perceive that the pesticides and fertilisers they use do not have any effect on the water quality. They refer to outside issues such as acid mine drainage to be the problem. Only 36% of farmers admitted that agriculture has a negative impact on water quality.

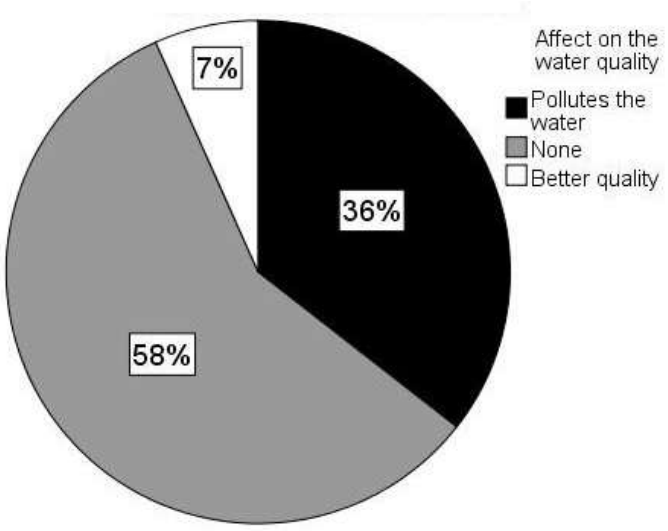

Figure 7: Farmers' perception of the effect the irrigation scheme has on the water quality

4.1.3 Environmental issues associated with agriculture

The next section will explore the environmental issues derived from agriculture. This will include perceptions of farmers according to information gathered in the interviews and observations made on field visits to the irrigation scheme. Environmental issues refer to what impacts (issues) agriculture has on the environment and what issues agriculture experience from external environmental issues. This will include issues that originate inside the scheme and issues from the surrounding areas.

Figure 8 illustrates the analysis of the perceptions of farmers on these issues. In the questionnaire farmers were asked about agricultural issues affecting the environment and where they felt the main environmental issues were derived from. Most farmers (53%) undeniably agreed that agricultural practices have had an influence on the environment and led, or may lead to environmental issues. Other farmers (29%) would argue that they are aware of agricultural impacts on the environment but it is not something to be concerned about at present and/or can easily be dealt with. Another portion (11%) of farmers agreed that agriculture did affect the environment in various ways but disagree on the significance of these issues. The minority (7%) felt that agricultural practices had no influence on the environment. The farmers who had acknowledged the impacts of agriculture were concerned about environmental issues, stating that it should not be under estimated because the consequences might be detrimental and that would be negatively felt in future.

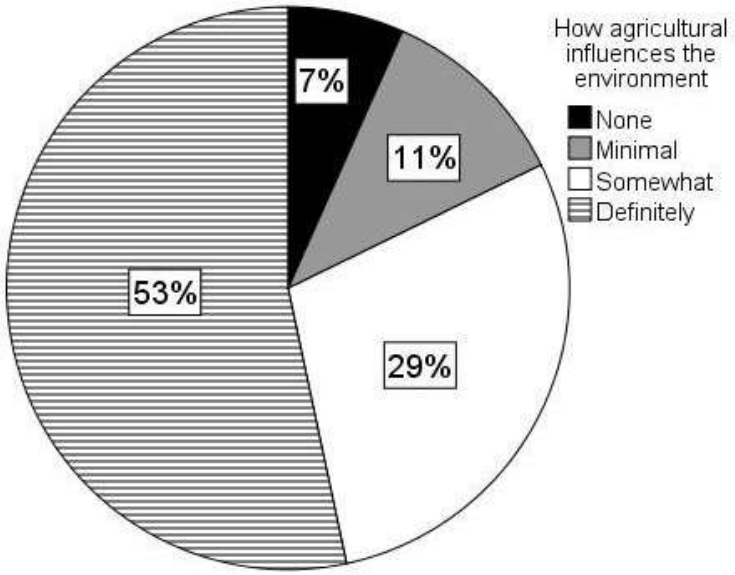

Figure 8: Farmers' perceptions on environmental issues derived from farming

After having established farmers' perceptions concerning environmental issues, they were asked about where the most significant environmental issues derived from. They were asked if these issues that they currently experience came from inside the scheme or if these were external issues from the surrounding area. The majority (60%) of farmers explained that it is a combination of both. They would elaborate by giving examples such as polluted water coming into the irrigation scheme. The water that comes into the system has been used in mining sites upstream and is then diverted back to the river and canals, which they then must use for agricultural purposes. They further explained that when this water was used within the scheme, the quality would deteriorate because farmers in the scheme are overusing herbicides, pesticides and fertilizers that pollute the water even more. A minority (20% each) of farmers would argue that environmental issues arose inside or outside the scheme respectively.

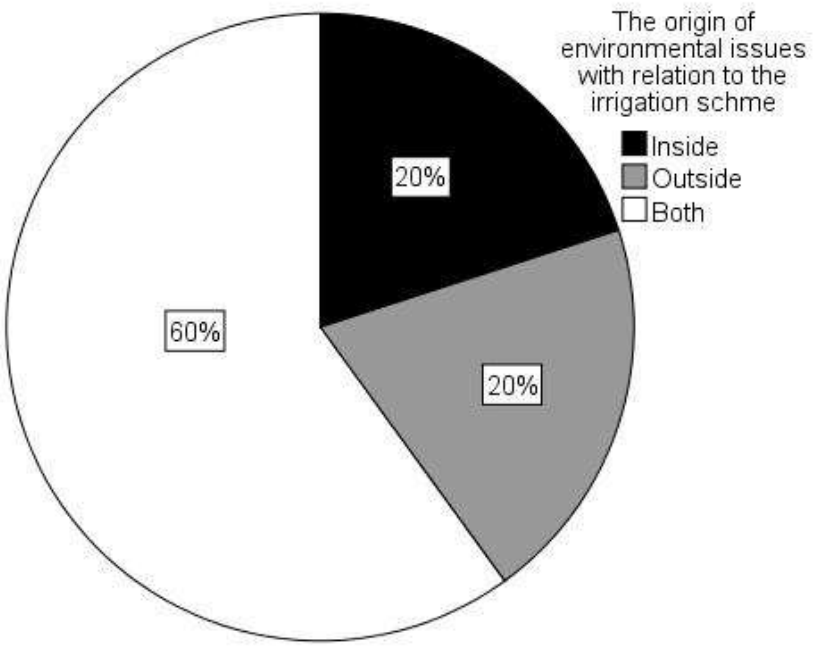

Figure 9: Farmers' perceptions of where environmental issues derive from in relation to the irrigation scheme

Table 4 is a summary of all the main environmental issues farmers identified regarding agriculture and the environment. A wide range of issues were listed. These issues were categorized into different themes that are closely or directly connected with one another in order to get an overview of the issues farmers are currently concerned about.

Table 4: Farmers' main environmental concerns

Participants' environmental issues	Percentage %
Water quality	(49)
Climate issues	(18)
Human influence (including knowledge and management)	(13)
Soil quality (Including erosion)	(7)
Pesticides and Fertilizers	(5)
Awareness (Sustainability & environmental issues)	(2)
Animal welfare (illnesses)	(2)
High salts concentrations (In water and soil)	(2)
None	(2)
Total	**100**

As illustrated by the table there is a clear indication that almost half (49%) of the farmers are concerned about the water quality in the irrigation scheme and also the manner in which it is managed. Firstly, farmers have complained about the water coming into the scheme, stating that the water is polluted from communities and mines upstream. They stated that water contained acid from the mining activities upstream. To prove that the water is polluted is a difficult challenge because farmers have complained that the water management in the scheme is poor and they see governmental representatives testing the water and have never received feedback of the results. The quality of water is a big concern because it is the same water they use to irrigate their crops and to water their livestock with. These may be the same products that communities consume or use afterwards. Farmers have started to use other water resources such as boreholes, as can be seen in Table 3. The use of additional water resources is significant and might influence the stability and quality of the groundwater as a resource, as explained by farmers. They have given examples of boreholes starting to dry up as a result. Small-scale farmers do not have the luxury of access to boreholes and rely on municipal water of which the quality is unknown. The use of boreholes can be beneficial but farmers have to be resourceful when doing so. It might become an environmental issue if there is an overuse of the resource. Another concern these farmers have had is that they may be contributing to polluting the water downstream because the drainage canals flow back to the Harts River. These drainage canals contain runoff water that may contain herbicides, pesticides and fertilizers that travel back into the natural ecosystems.

The second biggest environmental issue farmers have been concerned about are issues related to Climate Change. During the course of this study (2016 – 2017) South Africa had experienced one the worst droughts in the country's history, declared as a natural disaster in 2017. Farmers have argued that predicting and trusting weather forecasts became difficult. They have stated concerns like changing weather patterns, rainfall coming too early or too late, temperatures fluctuating between hot and freezing, hailstorms and drought. Farmers cannot prepare properly anymore because they are unsure of which weather elements they would experience and if they misjudge the weather they might lose a harvest or two.

The next issues farmers have complained about is that of direct human influence. People are the main reason for environmental issues and affect agriculture in numerous ways. There are many complaints concerning the management of agriculture throughout the whole irrigation scheme. There seems to be a distrust toward people in different managerial positions. These include the water management of the irrigation scheme, local and national farming organisations, government, as well as other farmers. One such an example is the perception between farmers that the water in the irrigation scheme is distributed unfairly or is too expensive especially among

small-scale farmers. They have also explained that no feedback from governmental representatives and/or information is given to them on the water situation in the scheme. The second concern they have had was that farming organisations were not as helpful as in previous years especially when it comes to sustainability. Farmer organisations have been accused of being money orientated and not farmer orientated. Examples have been given of past years where the organisations would have gone to the farm to assist the farmers and now the farmers have to go to the organisation when they need assistance and even then there is no guarantee that they would be properly assisted. Another remark was that organisations sell and prescribe agricultural products unnecessarily and that may have major impacts on the farms. The farmer might then have to use counter products to mitigate the issues by buying another product from the same company to restore the balance, resulting in more profit for the company. Regarding sustainability, when both small and large scale farmers have been asked about sustainability they would reply that there was no assistance with regards to sustainability and they were also unsure about how and where to ask about sustainability leaving no room for improvement to become more sustainable.

Another key issue is the use of fertilizers and pesticides that influence the soil and water quality needed for agriculture. The use of fertilizers and pesticides cause high salt concentrations that affect the crops and also the type and amount of farming inputs, according to the farmers.

Livestock farmers have had fewer issues and were mostly concerned about their livestock's health. The issues they have been concerned about were diseases from nearby game reserves that affects their cattle such as Tuberculosis (TB) or Foot-and-mouth disease (FMD) because cattle are susceptible to these type of diseases, especially from buffaloes.

Other issues that have emerged from the questionnaires but were only mentioned by one or two farmers were:

- Burning of crop residues. This is harmful to the nutrients in soil as it burns away all the nutrients that the farmer has put in throughout the season.
- Lack of dumping sites (litter lying everywhere).

The identification of environmental issues in this section causes reason for concern because the issues not only influence the environment but also the local farmers, producers and consumers. Hence there exists a need for an intervention that could mitigate these issues and ensure a more sustainable future.

4.1.4 Sustainable agricultural practices and methods

The following section of the questionnaire, relating to objective 3 has been designed to obtain an understanding of the farmers' perceptions and knowledge towards sustainable agriculture and how they see, understand and implement the concept.

Farmers have been asked whether they were familiar with the concept of sustainable agriculture. Figure 10 illustrates how many farmers were familiar with this concept. 75% of the farmers answered affirmatively that they are aware of the concept of sustainability and some would even elaborate on it. Although 75% of the farmers have acknowledged that they were familiar with the concept, it could be noted in the interviews that people had different perceptions and some even have questionable explanations on how they define or implement sustainability. A farmer has highlighted one such an example where he reverted to traditional farming as sustainable by using tillage as the example. This finding illustrates that there is no single clear understanding of sustainability in the area and farmers administer their own understanding of sustainability on their farms.

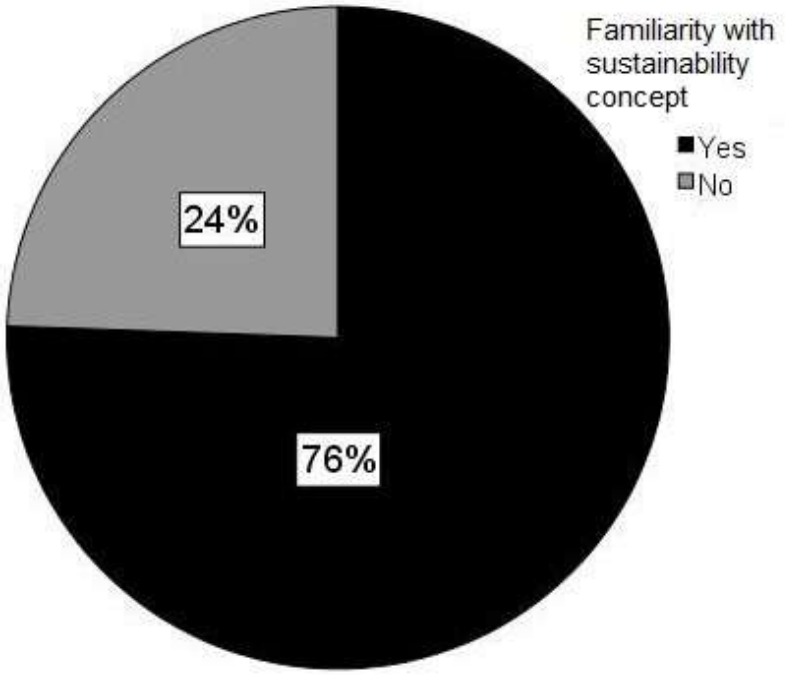

Figure 10: Participants' familiarity with the concept of sustainability

Throughout the interviews small-scale farmers have been less familiar with this concept than large scale farmers which may be because of their background in agriculture. The other observation that was made was that the older generation (in both small and large scale farmers) has been less familiar with the concept or had negative connotations with it. This can be helpful in comprehending the existence of the gap between the different understandings of sustainability and also be beneficial when constructing an acceptable definition.

After having collected information on farmers' perceptions on sustainability, they were asked how sustainable they felt their farms were and they gave applicable examples of how they made use of sustainability in open-ended questions. In Figure 11 it can be noted in the far right-hand corner that a majority (38%) of farmers have felt that their farms were fully sustainable. This shows their perception of the idea that they would be able to farm in the same way for generations to come without any severe environmental, economical and social impact, with consistent quantity and quality of yields. Through observations made during the field visits and interviews, there was no conclusive evidence of any fully sustainable farms. The other proportion of farmers (36%) have perceived that their farms were somewhat sustainable, meaning that they have felt that their farms were reasonably sustainable and a few steps away from being fully sustainable. It was noted through observation that some farms were somewhat sustainable where farmers made efforts by improving sustainability on their farms. Hence, some of these farmers were satisfied with how sustainable their farms have been but were reluctant to improve the sustainability in the irrigation scheme, which may be the effect of limited knowledge and available information. A small percentage (24%) of farmers would argue that they have had limited sustainable practices on their farms and that there is room for improvement to incorporate sustainability. These are mostly the farmers that can be approached to improve sustainable practices in the scheme if they were better informed. Only 2% of farmers have indicated that their methods of farming are not sustainable and that they can do much more to improve their situation.

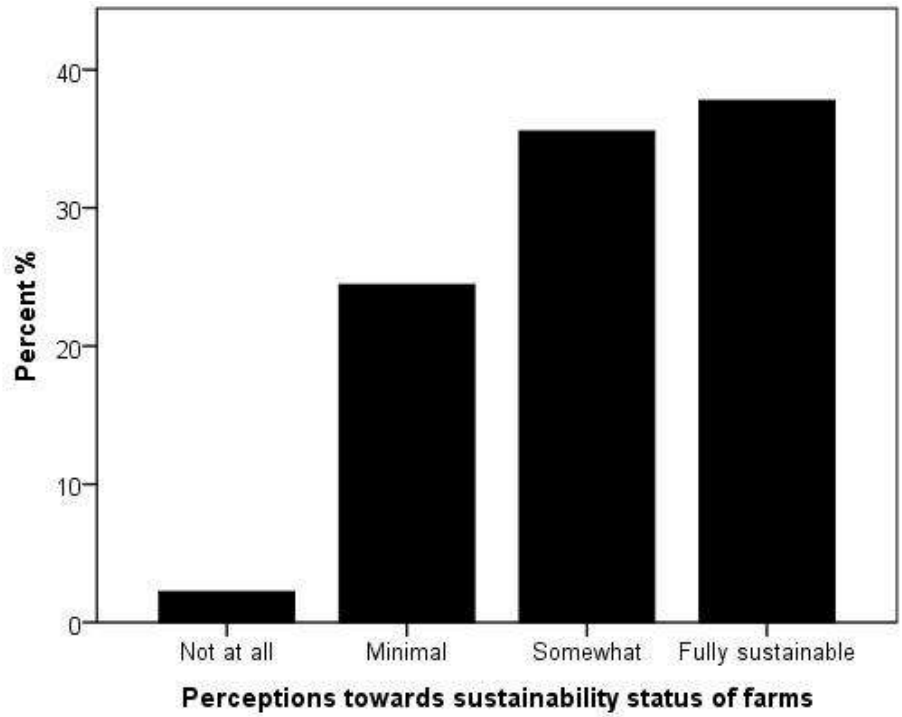

Figure 11: Perceptions of sustainability

The questionnaire was designed to obtain examples of sustainable practices and/or methods that farmers use on their farms. These examples will be listed and explained in the following section.

One of the popular sustainable practices that farmers have listed and which was evident throughout, was **drip irrigation**.

Another popular practice was **cover crops**. Farmers would also make use of cover crops especially between trees as well as in parallel crops.

Some of the large scale farmers have shown researchers the use of **ultra-violet (UV)** lights that were integrated into pump systems to improve the oxygen levels in the water used in irrigation. The farmers have stated that oxygen rich water should improve soil and crop quality and allow the famers to use less farming inputs which may result in savings in time, money and resources.

Some farmers have also claimed that they currently only use **organic farming methods** and have steered away from conventional farming. One farmer has shown that the Total Dissolved Salts (TDS) concentration in his underground water had decreased by up to 80% after converting to organic farming.

Livestock farmers would **rotate** the pasture where their cattle are grazing to let the soil rest and rehabilitate. This would ensure that there will always be grazing ground and the vegetation is managed in this way. Researchers have observed that some farmers would let cattle graze after they had harvested a field.

Some small-scale farmers have explained in the interviews that they would take the **ash residues of fires** and heave it between crops to keep away pests, a natural pesticide of sorts.

The practice of **no-tilling** is now being used more often in the irrigation scheme because in a South African context, tillage is detrimental to the environment.

Maximizing land utilization by using as much land as possible to cultivate: One such an example is where farmers cultivate pecan nut trees at the borders of centre pivots. These trees may benefit from the other farming activities.

Farmers have been asked if they feel sustainability could be enhanced on their farms as seen in Figure 12. In graph A Figure 12 it can be noted that 44% of farmers feel that their farms cannot be enhanced and they are as sustainable as can be or they do not feel the need to further sustainability on their farm. This indicates that sustainability is not a high priority in the irrigation scheme. A few farmers (16%) have indicated that they do not know how to implement sustainable agriculture, which raises concern, for these farmers implement no sustainable agricultural practices probably because they do not know how to. Only 40% of farmers have felt that they

would be able to improve on their sustainability, which is a positive sign if sustainability is to be taken seriously in the scheme. Sustainable farmers can act as role models for other farmers. By seeing and hearing the success stories of these farmers, other farmers might be persuaded to start incorporating sustainable farming practices.

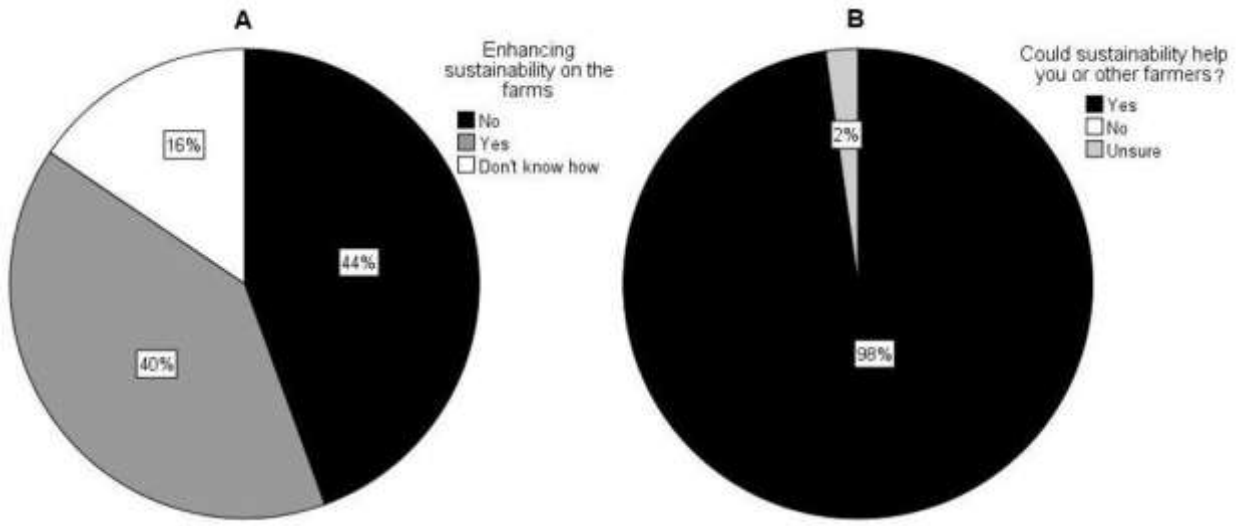

Figure 12: Participants' perceptions on enhancing sustainable farming

Graph B also illustrates the overall perception farmers have had when asked whether sustainability could benefit everyone in the scheme. There has been almost no hesitation from farmers when asked if sustainability could improve farming and the environment. The majority (98%) of the farmers have unquestionably agreed that sustainability would benefit them and the environment. Most of these farmers have said that it is only a case of time, money and knowledge. Younger farmers explained that their fathers have been cautious to incorporate sustainability because they had not wanted to fail and lose a harvest or two. They would rather stick to what they knew and to what worked for them. Farmers that have used sustainability over the last few years and are busy making a success thereof have said that according to their experience it takes around five years to start observing the results of sustainable agriculture. They would further state that certain farmers do convert to sustainable agriculture would but would revert back to original methods because they were not getting the required results they expected. Other notable comments made by younger farmers were that the older generation sees sustainable agriculture as a step backward towards old farming methods and techniques.

4.1.5 Interrelationship between land and water use

Objective 2 of this study was to identify and illustrate the interrelationship of land and water use in the Vaalharts irrigation scheme. Figure 13 shows a map of the Vaalharts irrigation scheme that represents the large scale farmers in the scheme. This map is linked with Table 5 to illustrate the relationships in land and water use on the respective farms and it includes a column on how sustainable farmers perceive their farms to be. This map shows general areas and not the exact farm location or size because of ethical considerations where farmers have the right to be anonymous. This map also illustrates a representative sample of farmers that had been part of this study and their farming activities in an irrigation scheme. It was difficult to plot small-scale farmers because they are closer together in densely populated areas such as Ganspan, Valspan, Pampierstad and Taung. The data required to generate this map and table was gathered through the questionnaire where farmers had to identify land and water use activities as well as their perceptions toward the sustainability status of their farmers. Data was completed with additional existing data that was gathered from famers' unions, governmental and non-governmental entities.

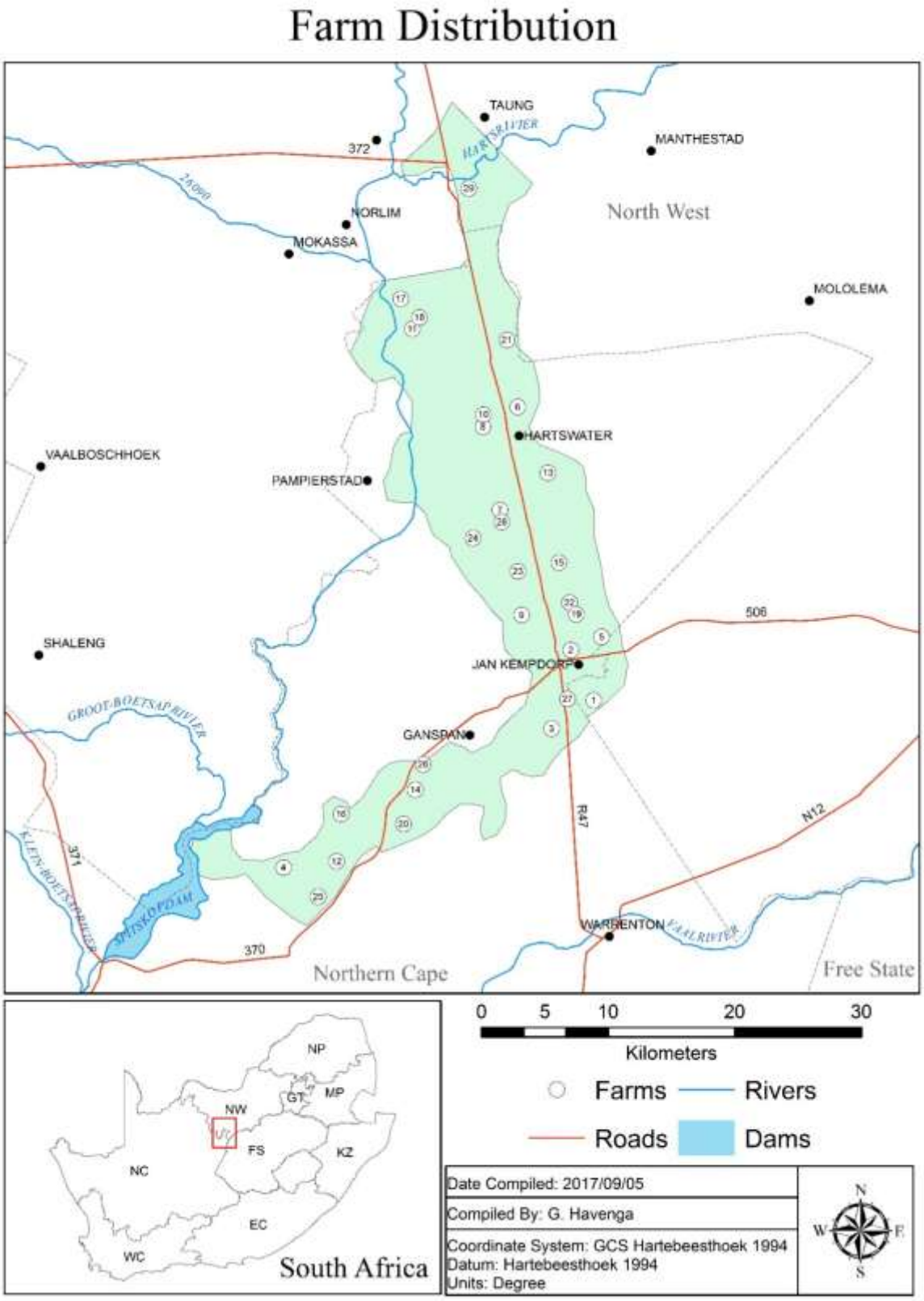

Figure 13: Map and information about the interrelationship of land and water use within the irrigation scheme (Havenga, 2017)

Table 5 illustrates the interrelationship between land and water use. This shows which farming practices and water (resources) are being used in the irrigation scheme. Objective 2 will allow for a better understanding of the different varieties of produce and practices or lack thereof. By understanding the interrelationship one can identify which resources are being over utilized and which have more potential.

Table 5: The interrelationship between land and water use

Farmer perceptions of their farms' environmental sustainability	Farm no.	Land use	Water use
Fully sustainable	1	Game; Pecan nuts; cattle	Boreholes
Fully sustainable	2	Pecan nuts; wheat; maize; beans	Boreholes and canal
Fully sustainable	3	Pecan nuts; wheat; maize; beans; cotton	Boreholes and canal
Fully sustainable	4	Lucerne	Boreholes and canal
Fully sustainable	8	Lucerne and pecan nuts	Boreholes and canal
Fully sustainable	10	Pecan nuts; Lucerne	Boreholes and canal
Fully sustainable	11	Pecan nuts; Lucerne; cattle	Boreholes and canal
Fully sustainable	13	Wheat; maize	Boreholes and municipal
Fully sustainable	15	Wheat; beans; maize	Boreholes and canal
Fully sustainable	16	Beans; pecan nuts	Boreholes and canal
Fully sustainable	19	Cattle	Canal
Fully sustainable	20	Cattle	Boreholes and canal
Fully sustainable	29	Wheat; maize; pecan nuts	Boreholes and municipal
Somewhat sustainable	5	Lucerne and wheat	Boreholes and canal
Somewhat sustainable	6	Wheat; pecan nut; maize; Lucerne; cotton; beans	Boreholes and canal
Somewhat sustainable	7	Wheat; Lucerne; lemons; pecan nuts	Boreholes and canal
Somewhat sustainable	12	Pecan nuts; Lucerne; goats	Boreholes and canal
Somewhat sustainable	14	Maize; wheat; Lucerne	Boreholes and canal
Somewhat sustainable	17	Lucerne; maize; cattle	Boreholes and canal
Somewhat sustainable	18	Wheat; maize	Boreholes and canal
Somewhat sustainable	22	Pecan nuts	Boreholes and canal
Somewhat sustainable	23	Pecan nuts	Boreholes and canal
Somewhat sustainable	24	Pecan nuts; Lucerne	Boreholes and canal
Somewhat sustainable	26	Pecan nuts; wheat; maize	Boreholes and canal
Somewhat sustainable	27	Wheat; maize	Boreholes and municipal

Somewhat sustainable	28	Lucerne; cattle	Boreholes and municipal; spring
Minimally sustainable	9	Beans; pecan nuts; maize; cattle	Boreholes and canal
Minimally sustainable	21	Lucerne; cattle	Boreholes and canal
Not sustainable	25	Lucerne	Boreholes and municipal

It is clear from the table that farmers in the region are reliant on canal (river) fed water, as these rivers are perennial and supply water throughout the year. Farmers cannot depend on dryland irrigation because it is a semi-arid region. This was expected as the study area is an irrigation scheme after all. The water table in the region is near the surface because of all the irrigation throughout the preceding decades and thus provides the farmers with another water resource namely, boreholes. These boreholes can contain canal water that farmers irrigate with and could be perceived as to be of poor quality. Small-scale farmers, as mentioned previously, mainly use municipal water. As mentioned in section 4.1 the main crops in the irrigation scheme are influenced by the type of environment in which it is harvested. Water is not the only factor for land use activities as financial gain, climate and soil type also have their part to play, which could be the reason for the amount of lucerne, wheat, maize and pecan nuts produced by the different farmers. Most of these farmers perceive their farms to be sustainable. Some farmers have stated that the more variety there is on their farms, the more sustainable they are. This may point to financial sustainability and good business practices accompanied with environmental sustainability.

Small-scale farmers were not added because of their close proximity to one another and the relatively small size of their towns / settlements.

4.2 Discussion

The following section will explain the finding above through literature and give additional information of the finding for a better understanding. This section follow the exact structure portrayed in the results section above which includes the objectives named in the results.

4.2.1 Agricultural land and water use

As previously mentioned in Van der Werf and Petit (2002), natural capital is a contributor to producing food in an agricultural system. One natural capital includes climate variations which plays an impelling role on agriculture alongside human capital. Agricultural land and water are influenced by the climate of these regions (Fischer *et al*, 2002). In the case of the Vaalharts irrigation scheme the region is classified as semi-arid (Dzikiti *et al.* 2013). This may influence the type of crop farmers would use in such a region because of the limited water resources available. Careful consideration needs to be done to utilise the best form of crop and the amount of water

needed by such a crop in the region. A good management system of land and water use can increase the benefits of farming production and decrease problems associated with land and water use. Furthermore, the relationship of land and water use in agriculture is dependent on the crop type, regional water requirements, rainfall patterns, temperatures, soil quality and vegetation cover which influence soil moisture levels and evidently yield production (Scotcher, 2009 & Pimentel, *et al*. 1997). Agricultural practices alter the soil attributes that result in soil malfunction and, ultimately in the degradation of soil and water resources within that area (Zalidis *et al*. 2002).

Sustainability is achieved by using the relationship of land and water use in an agricultural system. Sustainability includes both the soil and water resources and incorporates the management of the agricultural practices for a better utilization of the concept (Zalidis *et al*. 2002; Larson & Pierce, 1994). Hence, a better understanding of the land and water relationship will allow for better implementation of sustainable agriculture.

The reason for such a wide variety of crops and livestock in the Vaalharts irrigation scheme is because small-scale farmers grow crops and keep livestock that they themselves can use (subsistence farming) whereas large scale farmers grow crops or use livestock for commercial purposes therefore producing vast quantities of products for financial gain (Hassan and Nhemachena, 2008). Small-scale farmers would rather cultivate crops that have nutritional value, grow faster and is financially cheaper to maintain, with which they can sustain their households (Baiphethi & Jacobs, 2009). On the other hand, large scale farmers need large yields because they sell it in bulk according to the market value and the more they grow the more income they can receive (Hassan and Nhemachena, 2008). These types of crops generally take a bit longer to grow and need substantial input as some farmers would explain. Hence, the popularity of pecan nut trees because they do not need a lot of maintenance and highly are profitable.

There are positive and negative aspects regarding the popularity of these pecan nuts tress. Some of the positive aspects are that most of the pecan nuts are being exported to places like China because of a higher price value internationally and this benefits the local and national economy (Pecans South Africa, 2017). Another positive aspect is that some farmers have seen the financial benefits of pecan nuts but are cautious to devote an entire farm to pecan nut trees so they use the open borders of farmland such as in Figure 10 to cultivate these trees thus leaving the farm with greater crop variety (Krüger, 2016). Some of the negative aspects associated with this type of farming is the downsizing of the workforce leaving more people without work, as well as the export of the best quality products making these products inaccessible to locals (Barrientos & Kritzinger, 2004).

4.2.2 Environmental issues associated with agriculture

Foley *et al*. (2005) and Zalidis *et al*. (2002) stated that current food systems can and do provide enough food to meet the needs of a region or country. They further explain that this increase in production may lead to future problems because of the numerous agricultural inputs that are being implemented on a farm. The balance between the positive and negative aspects are debateable because on the one hand people are provided with food but on the other hand soil and water quality in the farming system may degrade.

As previously mentioned, water resources are critical elements for any successful agricultural system. Water needs to be used optimally and managed according to the needs of that specific region. In order for water resources to be used sustainably, one must first identify major issues and concerns regarding the resource. As seen in the perceptions of farmers in Vaalharts, water quality is a major concern for them. They complain about mines polluting the water upstream as well as the presence of pesticides and fertilisers within the irrigation scheme. When looking at Figure 4, runoff in the region is going to decrease, meaning that all the excess pesticides and fertilisers are going to be transported in all the other water resources, polluting the surface water even more. These agricultural chemicals cause yield reduction as well (Zalidis *et al.* 2002). The need for pesticides and fertilizers in current farming systems are important but it needs to be used responsibly (Tilman, *et al*. 2002 & Goldblatt, 2010). If used properly, these inputs may actually be beneficial to the environment. These benefits include less input and more yield. Although, agricultural inputs are there to assist the agro-environment, when used erroneously it can have the opposite affects and have a degrading effect on the environment (Scotcher, 2009). Farmers mostly make use of borehole water and the only concern regarding the use of borehole water is how sustainable it is and at what rate is the resource is being used. On the other hand, the canal/river water that farmers perceive to be polluted, are mostly used for the purpose of irrigation and filling of irrigation reservoirs. Farmers who irrigate with possibly polluted water may be increasing environmental issues, using ‘polluted’ water on crops that people have to consume and affecting the quality of the soil in the local area (Scotcher, 2009).

Flooding was the primary irrigation technique used by farmers when the irrigation scheme was established. Flood irrigation caused the water table to rise to such an extent that in certain areas of the scheme the water table was just a meter below surface. This has led to weak infiltration, more runoff and stagnant water on farms which is susceptible to pollution (Van Vuuren, 2010).

The Vaalharts irrigation scheme which, is situated in the Northern Cape Province, is one of the driest provinces in the country (Dzikiti *et al.* 2013). Fortunately, the scheme’s main water resources (canals and rivers) are uniquely perennial, meaning that the irrigation scheme was not as severely affected by the drought than other provinces such as the Free State and Western

Cape. Weather patterns are becoming unpredictable which may affect farmers' preparation, irrigation practices and harvesting and that may cost farmers money, time and yields which is worrying for farmers. Section 2.2 highlighted that the western side of South Africa will be affected at the end of this century with less rainfall and more runoff, which means farmers will be struggling with water resources (IPCC, 2007). Better techniques have to be incorporated to ensure adequate water resources for farmers and constant moisture in their soil.

It is important to understand the human aspects because people are the driving force behind agriculture (Aimin, 2010). Human influences can both have positive and negative effects depending on the management of the activities. Human influences in agriculture mostly have negative effects because of the numerous inputs they are using in farming systems. Farmers use agricultural inputs, which they have bought from the agricultural companies, to improve their yield, which in turn affects the environment. Thereafter they have to go back to buy more products to mitigate the issues which allows the company to sell more products (Foley *et al.* 2005. & Zalidis *et al.* 2002). The lack of government input has left the door open for fertiliser companies and agri-businesses to assist farmers and build new relationships with them. The goal of these companies are to promote their products and sell them to make a profit, not always thinking about the health of the environment (Scotcher, 2009). In South Africa there is a call for greater localization of food systems to promote the government's envisaged priority to promote rural development and food security (De Schutter, 2011; Ortmann & King, 2010).

According to Foley *et al*. (2005) the intensive use of agricultural products such as fertilisers and pesticides can negatively influence water quality that may lead to agricultural systems becoming heavily salinized. This salinization of water (and soil also) is caused by leaching of nutrients and agricultural chemicals into groundwater, streams and rivers which affect the local area and areas downstream of the sources.

4.2.3 Sustainable agricultural practices

This interest for sustainable agriculture has become very informative and captivated concept within academia and government organisations. The interest in sustainability is starting to filter through to a local level where farmers are starting to explore the concept more (Zalidis *et al*. 2002 & Stamatiadis *et al*. 1996). Sustainable agricultural can increase food supply, mitigate environment issues and protect ecosystems, which highlight the need for more sustainable agricultural methods in critical area such as the Vaalharts irrigation scheme (Tilman et al. 2002).

Small-scale farmers are more likely to not improve their sustainability status because they feel they have nothing to gain from it whereas large scale farmers are over cautious with sustainable agriculture because of the negative connotation associated with sustainability. According to

Altman *et al.* (2009) these are the realities facing sustainable agriculture which needs to change if any progress is to be made. The major issue regarding sustainable agriculture is farmers' understanding thereof. The first step forward is to identify how farmers understand the concept. This action has positive and negative aspects. The positive aspects were that the study obtained a broad overview of farmers' definitions of sustainability that could be used to further define sustainability for the area as a policy recommendation. One of the negative aspects is when farmers misinterpret sustainability they might implement it incorrectly which may not work effectively or may lead to more issues in and around the environment (Zalidis *et al.* 2002).

When farmers were asked to identify *sustainable activities* most farmers would refer to the following methods:

Drip irrigation *as a sustainable activity*. Drip irrigation uses less electricity than a pump system, there is less evaporation and runoff, water is being fed directly to the roots which in turn uses less water in the long run and it is very easy to manage (Payero *et al.* 2008).

Another activity they refer to is ***cover crops***. Cover crops can improve the ecological system, keep nitrogen (N) and moisture in the soil, which is beneficial to the crops and uses less water resources. Some cover crops can even be used as additional crops to sell or be used in the household. Less water is needed because cover crops retain the moisture and help with minimizing runoff. Farmers will also have optimal land utilization when they use cover crops (Schutte, & Kellerman, 2016).

Organic farming is a big part of sustainable agriculture and more farmers should start to experiment with it to cut out any unnecessary chemicals and pollutants that are used on farms (Stolze *et al.* 2000). After implementing organic farming the transition phase may take a few years to be fully effective and during this time farmers grow restless and return to old practices. Many of the farmers make the decision not to switch to organic farming because they are convinced that they won't make any profit in the transition years (Erbentraut, J. 2016).

In a South African context tillage causes moisture loss in the soil, an increase in erosion and releases carbon dioxide (CO_2) into the atmosphere (Tilman *et al.* 2002). This method can be destructive to the environment and there are more sustainable methods of no-tillage that farmers could implement.

More farmers plant pecan nut trees at the borders of central pivot irrigation, which has a circular shape, to "square off" the circle as they define it, meaning that farmers use the bare edges to cultivate and this maximizes their land use.

In the figure below, image A represents maximized land use by planting trees such as pecan nuts to increase variety and income. Image B shows cultivation that has bare land on the borders, which could have been used for other agricultural activities, which may have benefited the farmer. This method shown in image A is valuable because it uses land that was not being used, it is close to current irrigation infrastructure, helps to absorb excess water, is visually appealing and may even help with wind breaks. These positive aspects can be tremendously beneficial if implemented correctly.

Figure 14: Pivot layout in the Vaalharts irrigation scheme (Google Maps, 2017).

A social issue regarding pecan nuts is a down scaling in manual labour because pecan nut trees do not need a lot of maintenance and the local community loses job opportunities and money (Barrientos & Kritzinger, 2004). Pecan nuts also require lots of water in an area which is not known for its abundance of water resources, unnecessarily using water that could have been used for other farming or agricultural purposes such as cash crop irrigation or livestock watering (Pecans South Africa, 2017). This is another example of lack of knowledge and management because there is no assistance to these farmers (Baiphethi & Jacobs, 2009).

Although the Vaalharts irrigation scheme is a unique place with unique people, the irrigation scheme does not have unique issues. Through literature it is clear that the irrigation scheme experiences that same issues as other farming systems and the reasons for these issues are the same throughout. The mitigation of these issues may differ for this region because sustainable agriculture should be incorporated according to the conditions of the local area (area specific), knowledge and cultures of the people as seen in Tilman *et al.* (2002). Keeping the irrigation totally functional is vital because it has the potential to be the breadbasket of the country.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study formed part of a larger project which was titled “Exploring the potential of local food systems for sustainable rural development.” The larger project contained six dimensions of sustainability which included economic, environmental, socio-cultural, sustainable indicators, governance and health and nutrition dimensions. This study presented the environmental dimension of the project which investigated the environmental issues of land and water use of agricultural food production in the Vaalharts irrigation scheme and assessed to what extent sustainable agriculture contributed to the mitigation of these issues. The Vaalharts irrigation scheme was identified as the study area because of established stakeholders and familiarity of the region and people from previous research projects. The irrigation scheme also had all the relevant dimensions needed to complete this project.

This irrigation scheme is currently providing food for South Africa’s people but with a growing population worldwide as well as in South Africa, the demand for food is increasing which puts pressure on food security (Goldblatt, 2010). An increase in environmental issues such as droughts, water scarcity and land degradation make it difficult for farmers to keep up with the food demand. These issues are both natural and human based influences. These issues and high demand of food production have caused farmers to intensify their agricultural practices which in turn cause more environmental issues (UNEP, 2009). If agriculture is managed in the correct manner it could be beneficial to the environment as well as to farmers. This proper management of agricultural practices can help preserve and restore critical habitats, help protect watersheds, and improve soil health and water quality. This level of good management is referred to as sustainable agriculture and could be a mitigation measure for environmental issues (World Wildlife Fund, 2015).

Agricultural inputs are greater than ever before and increased yields to keep up with the demand of food, but at the expense of natural capital such as soil and water which are essential for agricultural activities (Van der Werf & Petit, 2002). In the end agriculture has to provide food in a sustainable manner for a growing population that is both safe and nutritional without damaging the environment. This results into the question of research:

What were the different environmental aspects associated with agricultural land and water use in the Vaalharts irrigation scheme?

This study has identified the land and water use activities of small and large scale farmers along with environmental issues associated with agriculture through perceptions of farmers. Thereafter,

this study has identified the interrelationship between the land and water use activities. Lastly, ways of sustainable agriculture have also been identified through farmers' perceptions, to explore how these agricultural practices could mitigate environmental issues. The study has found the following:

The type of land and water use activities differed between farmers. Small-scale farmers tend to use more subsistence crops such as vegetables, fruits and livestock that benefited them, whereas large scale farmers implement cash crops which they could harvest in bulk and then sell in order to make as much profit as possible. One such a popular crop, especially with large scale farmers, was pecan nuts, which seems to be engulfing the irrigation scheme because of its low maintenance and high market value. This phenomenon is economically more sustainable but in the context of the Northern Cape it may be environmentally unstainable because of the trees' high water requirements.

Large scale farmers use water from canals for irrigation purposes whereas a majority of small scale farmers make use of municipal water because they do not have access to the canals or the canals they have access to might be mismanaged in their area. Most large scale farmers felt that the canal water was polluted and they made use of boreholes for domestic and livestock consumption. The alternative to pecan nut trees were wheat and maize crops which were grown seasonally according to the weather. Small and large scale farmers stated that they do prefer a variety on their farms and they try to incorporate as big a variety as possible.

This study also found that there is a strong interrelationship between land and water use in the Vaalharts irrigation scheme. The availability of water resources influences the type of crops and farming activities that could be implemented on the respective farmers. The land use activities such as the use of soil determine the water quality and the quantity of water needed for land use activities. One such an example is number pecan nut trees in the Vaalharts irrigation scheme which is classified as a land use activity and is mostly influenced by the availability of water resources within the irrigation scheme.

The results also showed that the majority of farmers were aware of the environmental issues and that these issues were derived from agricultural practices. When asked which environmental issues they experience, 49% of farmers stated that water quality was a problem because of pollutants originating from inside and outside the irrigation scheme. A second major issue farmers were concerned about was that of a changing climate. Farmers stated that climate features such as seasons seem to be changing and it affects their farming preparation. Rainfall appeared to be decreasing and more droughts occur like the major drought that was experienced during the time of this study. These perceptions are in line with the predictions from the Intergovernmental Panel

on Climate Change (IPCC), (2007) which determine that South Africa will have less rainfall and more runoff from the rain by the end of this century.

The third significant issue that was listed was the influence of human impact. This type of impact included the lack of management and information towards environmental issues and sustainable agriculture as well as the large amount of agricultural inputs such as pesticides and fertilisers. Farmers explained that some farmers were less knowledgeable of agriculture practices and are causing more issues because they farm differently. Another issue that was highlighted by farmers was degrading soil quality which resulted from salinization which is in turn caused by high use of agricultural inputs. Livestock farmers complained that diseases such as tuberculosis (TB) and Foot-and-mouth disease from neighbouring farms or game farmers may impact their livestock.

After collecting information of environmental issues farmers were asked about sustainable agricultural practices. From these answers it was determined that 76% of farmers seem to understand sustainability but some farmers struggled to define on the concept. When asked about the sustainability of their farms, a high number (over 60%) stated that their farmers were fully or somewhat sustainable. Farmers were asked to give examples of sustainable activities and these activities included the use of cover crops, drip irrigation, UV-lights and ash from fires that act as a natural pesticide. When asked if sustainability could be enhanced on the farms 40% of farmers said there is room for improvement and 44% said they are satisfied with their sustainability status. When asked if sustainable agriculture could benefit the irrigation scheme and the farmers within the scheme almost all of them (98%) agreed that it would be beneficial to the Vaalharts irrigation scheme.

The last section of the questionnaire was on water quality and in this section the results indicated that more than 90% of farmers perceive the water quality in the irrigation scheme to be polluted or not up to standard. Farmers would elaborate that water is being polluted upstream by mining activities such as acid mine drainage and within the irrigation scheme by overutilization of fertilisers and pesticides. When asked if the irrigation scheme had any effect on the water quality 54% farmers indicated that the irrigation has no effects on the water quality. Some other farmers argued that the irrigation scheme does influence the water quality in a positive or negative manner.

To conclude, environmental issues is a reality in agriculture and these issues are impacting farmers' capability of producing food for a growing population in South Africa and internationally. Farmers have to produce more food meaning more arable land and resources would be used to keep up with the demand for food. This will in turn cause more environmental issues but it is also evident that sustainable agriculture could help mitigate these issues that may help farmers to farm in a smarter manner. Sustainable agriculture may also improve the amount of food produced

without using excessive resources. More has to be done to incorporate these sustainable practices and knowledge into farms and more access has to be given to farmers to educate themselves with the concept.

5.2 Recommendations

Resulting from what is discussed above, a few recommendations are presented:

- More research should be done on the overall impact farming related activities on the agro-environment.
- Sustainable agriculture has to be clearly defined for the Vaalharts irrigation scheme and farmers in the scheme.
- Identifying where resilience fits into sustainability and if it could benefit agriculture
- Both small and large scale farmers need more assistance and education from government and other organisations on environmental issues and sustainable agriculture.
- The gap between different generations has to be filled using intervention studies for better communication and understanding among farmers.
- Female farmers possess the ability to contribute to agriculture and should be empowered in future.
- An in-depth exploration into new sustainable farming methods should be considered. This may result in the mitigation of agro-environmental issues.
- Agriculture training should be made more accessible to upcoming and existing farmers in South Africa.

The Vaalharts irrigation scheme is a unique setting which provides food to a large number of people. This production of food has led to certain environmental issues which could affect production in future. It is clear through findings and literature that most environmental issues could be mitigated through sustainable agriculture but sustainable agriculture is not well defined and implemented in the irrigation scheme to be able to make a difference at this stage.

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ANNEXURES 1

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT

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Institutional Research Ethics Regulatory Committee
Tel: +27 18 299 4849
Email : Ethics@nwu.ac.za

2016-05-23

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by **Health Research Ethics Committee (HREC)** at the meeting held on **21/10/2015**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby **approves** your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Environmental impacts of land and water use for agro-food production in the context of sustainable diets in Vaalharts.

Study Leader/Supervisor: Dr N Claasen

Ethics number: N W U - 0 0 3 5 2 - 1 5 - A 1
(Institution – Project Number – Year – Status)
Status: S = Submission, R = Re-Submission, P = Provisional Authorisation, A = Authorisation

Application Type: Full Single Application
Commencement date: 2016-05-16 **Expiry date:** 2017-05-15 **Risk:** Minimal

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

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

- *The study leader (principle investigator) must report in the prescribed format to the NWU-IRERC via HREC:*
  - *annually (or as otherwise requested) on the monitoring of the study, and upon completion of the study*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
  - *Annually a number of study may be randomly selected for an external audit.*
- *The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these amendments at the HREC, prior to implementation. Would there be deviated from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via HREC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC and HREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the HREC or that information has been false or misrepresented,*
    - *the required amendments, annual (or otherwise stipulated) report and reporting of adverse events or incidents was not done in a timely manner and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *HREC can be contacted for any report templates Ethics-HRECApply@nwu.ac.za or 018 299 1206.*

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or HREC for any further enquiries or requests for assistance.

Yours sincerely

Linda du Plessis

Digitally signed by Linda du Plessis
DN: cn=Linda du Plessis, o=NWU, ou=Vaal Triangle Campus, email=linda.duplessis@nwu.ac.za, c=ZA
Date: 2016.05.23 20:08:17 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

ANNEXURE 2

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

HREC Stamp

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR RESEARCH PARTICIPANTS:

Farmers who participate in a survey on land and water use for food production in Vaalharts

TITLE OF THE RESEARCH PROJECT:
Environmental impacts of land and water use of agro-food production in the context of sustainable diets in Vaalharts

REFERENCE NUMBER: NWU-00052-13-A1

PRINCIPAL INVESTIGATORS:
Prof Luke Sandham, Dr Nicole Claasen, Wihan Pretorius (student)

ADDRESS:
School of Geo and Spatial Sciences / Geography and Environmental Management; and Africa Unit for Transdisciplinary Health Research (AUTHeR)
North-West University, Potchefstroom Campus
11 Hoffman St, Potchefstroom 2531

CONTACT NUMBER:
Prof Luke Sandham, Dr Nicole Claasen: 018 299 2099

You are being invited to take part in this study which is part of the Programme to Support Pro-Poor Policy Development looking into the potential of local food systems on rural sustainable development, led by Prof Annamarie Kruger and Dr Nicole Claasen of the Africa Unit of Transdisciplinary Health Research (AUTHeR) of the North-West University, Potchefstroom Campus. The Programme is funded by the Department of Planning, Monitoring and Evaluation of South Africa in partnership with the EU. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied and that you clearly understand what this research entails, and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00052-13-A1) and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.

What is this research study all about?

- *This study will be conducted in Vaalharts. We will carry out face-to face interviews with farmers who produce food for human consumption. This study will be carried out by Wihan Pretorius, and he will be assisted by local field assistants. Wihan Pretorius and the field assistants have been trained in general research procedures and interviewing skills by their supervisors Prof Luke Sandham and Dr Nicole Claasen. During the period of May 2016 to August 2016, we will interview 40 large- and 20 small-scale farmers in Vaalharts.*
- *In this study we aim to explore the land and water use practices of local food producers. We try to gather applied land and water use practices of different farmers. We then hope to give recommendations on better environmental considerations for policies and programmes that address local food production and food security.*

Why have you been invited to participate?

- *You have been invited to participate because you are a farmer of food for human consumption in Vaalharts.*
- *You have also complied with the following inclusion criteria: You are older than 18 years, and you are able to speak English, Afrikaans or SeTswana.*
- *You will be excluded if you are under the age of 18; or not an active farmer in Vaalharts.*

What will your responsibilities be?

- *You will be expected to take part in a face-to-face interview where we will talk about your land and water use practices. The interview will take approx. 60 to 90 min. I will try to arrange the meeting at your most possible convenience.*
- *We may contact you for follow-up questions if you allow us to.*

Will you benefit from taking part in this research?

- *There are no direct benefits for you as a participant in this study.*
- *Indirect benefits for participants is the opportunity for a reflection of the environmental sustainability in Vaalharts. This research will raise awareness on these issues among the participants and possibly lead to adjustments of existing programmes or practices. This research will formulate recommendations that allow policy makers to better design programmes for better agriculture and food security programmes that link environmental sustainability and local food production to support rural sustainable development.*

Are there risks involved in your taking part in this research?

- *The risks in this study are minimal. It may be that you experience fatigue or boredom during the interview. Further, the time of the interview procedure may cause inconvenience.*
- *The earlier stated benefits of this study outweigh the risk by far due to the low level of anticipated harm and its low level of likeliness of occurrence.*

What will happen in the unlikely event of some form of discomfort occurring as a direct result of your taking part in this research study?

- *We will schedule the interview at a place and time most convenient for you. In case of fatigue or boredom, we will introduce a break and continue when it is convenient for you.*

Who will have access to the data?

- *Your name will never be made known and your data will be handled as confidentially as possible. No individual identifiers will be used in any publications resulting from this study and only the team of researchers will work with the information that you shared. The research team and student will have access to the data.*

What will happen with the data collected?

- *All information of yours will be protected by locking it up and storing it on a password protected computer, and will only be accessed by the research team. Data will be stored for 5 years and afterwards shredded, deleted and destroyed responsibly thereafter.*

Will you be paid to take part in this study and are there any costs involved?

- *No, you will not be paid to take part in the study but refreshments will be served during the interview. Research procedures will be carried out at a place convenient for you, there will thus be no financial costs involved for you.*

Is there anything else that you should know or do?

- *You can contact Prof Luke Sandham or Dr Nicole Claasen (0182992099) if you have any further queries or encounter any problems.*
- *You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.*
- *You will receive a copy of this information and consent form for your own records.*

How will you know about the findings?

- *The findings of the research will be shared with you. You are welcome to contact us regarding the findings of the research. We will invite you to a meeting where we will share the findings with you and will welcome your feedback. No information will be shared at these meetings that might cause you any possible loss and/or harm (physical, emotional and financial).*
- *Please be aware that analysis of the data is time consuming and feedback will only be given end of 2016.*

Declaration by participant

By signing below, I ……..……. agree to take part in a research study entitled: Envi Environmental impacts of land and water use of agro-food production in the context of sustainable diets in Vaalharts

I declare that:

- I have read this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions to both the person obtaining consent, as well as the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) .....…..…….. on (*date*) ……...…….. 2015.

....

Signature of participant **Signature of witness**

Declaration by person obtaining consent

I *(name)* ……..…… declare that:

- I explained the information in this document to ……..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) .....…….. on (*date*) ……...…….. 2015.

....

Signature of person obtaining consent **Signature of witness**

Declaration by researcher

I *(name)* ……..…… declare that:

- I explained the information in this document to ……..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use a interpreter.

Signed at (*place*) .....…….. on (*date*) ……...…….. 2015.

....

Signature of researcher **Signature of witness**

ANNEXURE 3

Programme to support Pro-Poor Policy Development II

Land use and water use questionnaire 2016

Questionnaire for small- and large scale farmers

The survey is administered by:

School of Geo and Spatial Sciences / Geography and Environmental Management, and

Africa Unit for Transdisciplinary Health Research,

North-West University

The following survey assembled to gather information about sustainable farming and any environmental impacts that farming may have or experience

Please answer each of the following questions **by inserting an X** on the corresponding answer or by filling in your answer in the space provided.

We assure you that your responses will be treated confidentially.

SECTION A

GENERAL INFORMATION AND PROFILE

1. What is your age?

1) 18-29	2) 30-39	3) 40-49	4) 50-59	5) 60-69	6) 70 or older

2. What is your gender?

1) Female	2) Male

3. What is your primary home language?

1) English
2) Afrikaans
3) Nguni (Zulu, Xhosa, Swati, Ndebele)
4) Sotho (N.Sotho, S.Sotho, Tswana)
5) Venda/Tsonga
6)Other (please specify):_____

4. What kind of farming/agriculture training do you have?

1. None	2. Informal	3. Secondary	4. Tertiary	5. other

5. Please indicate where your farm is situated in the irrigation scheme.

6.1. What is the size of your farm?

1) 0 – 1ha	5) 21 – 50ha
2) 2 – 5ha	6) 51 – 100ha
3) 6 – 10ha	7) 100 – 1000ha
4) 11 – 20ha	8) > 1000ha

6.2. How much of your farm is covered by arable land?

1) 0 – 1ha	5) 21 – 50ha
2) 2 – 5ha	6) 51 – 100ha
3) 6 – 10ha	7) 100 – 1000ha
4) 11 – 20ha	8) > 1000ha

7. What water storage capacity do you have on your farm?

8. Please indicate the type of activities being carried out on this farm (please specify type and mark all applicable)?

	Type	Area in ha	Production quantity
1) Game farming			
2) Crop farming			
3) Livestock farming			
4) Aquaculture			
5) Horticulture			
6) Recreational			
7) Tourism			

SECTION B

9. Do farming practices have an environmental impact?

1. None	2. Minimal	3. Somewhat	4. Definitely
Explain why do you think so:			

10. Do you think environmental impacts come from inside or outside the irrigation scheme?

1. Inside	2. Outside
Explain:	

11. Which environmental impacts is the most important to you?

12. Are you familiar with the concept sustainable farming?

1. Yes	2. No

13. How environmentally sustainable is your farm?

1. Not at all	2. Minimal	3. Somewhat	4. Fully sustainable
Explain why do you think so:			

14. Do you implement any form of sustainable agriculture on your farm?

1. Yes	2. No
Explain :	

15. Would you implement sustainable farming on your farm? (If answer is No above)

1. Yes	2. No
Explain:	

16. Can you enhance environmentally sustainable farming?

1. No	2. Yes	3. Don't know how
Explain:		

17. Do you think sustainable agriculture could help you or other farmers?

1. Yes	2. No	3. Unsure
Explain:		

18. Do you receive any guidance or assistance from authorities/government on sustainable agriculture?

1. Not at all	2. Minimal	3. Somewhat	4. All the time
Explain from whom and what type:			

19. Do you feel higher authorities can do more to ensure a more safe and sustainable environment?

1. Yes	2. No	Explain:

20. For each of the following purposes please indicate from which sources you obtain water?

Purpose		Source		
		1. River	2. Municipal / Vaalharts water	3. Borehole
1	Household use			
2	Drinking			
3	Livestock watering			
4	Irrigation			
5	Filling of dams			

Purpose		Source			
		4. Dam	5. Spring	6. Other (specify)	7. Not applicable
1	Household use				
2	Drinking				
3	Livestock watering				
4	Irrigation				
5	Filling of dams				

21. What do you think of the water quality coming into the scheme?

1. Polluted	2. Not up to standard	3. Up to standard	4. exceptional
Explain:			

22. What effect do you think the scheme has on water quality?

1. Pollutes the water	2. None	3. Better quality
Explain:		

23. Any additional information or comment?

Thank you for your time and patience in completing the survey and your contribution to my study.