Socio-economic factors influencing the adoption of in-field rainwater harvesting technololgy for enhancing household food security by smallholder farmers in the Nkonkobe Municipality, Eastern Cape Province

By

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Together in Excellence

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DECLARATION

I, the undersigned, hereby declare that the work contained in this research is my own work and that this study is my original work which has not previously, in its entirety or in part been submitted at any university for a degree. Information extracted from other sources is acknowledged accordingly.

This dissertation is submitted in fulfillment of the requirements for the degree Master of Science in Agriculture (Agricultural Economics) at the University of Fort Hare.

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Nomfundo Shange Date

DEDICATION

I dedicate this work to my mother Mrs L.A. Mncwango and my son Xolisa Ndara

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ABSTRACT

In-field rainwater harvesting (IRWH) technology has been used in arid and semi-arid parts of the world and promising results have been achieved in terms of increasing yield. The main aim of this study was to identify socio-economic factors determining the adoption of IRWH technology for enhancing household food security by smallholder farmers. The specific objectives were to assess the level of adoption of IRWH technology using descriptive statistics (mean, frequency and percentages). To determine socio-economic factors influencing adoption of IRWH technology, the binary logistic regression model was used. To determine whether adopters of IRWH technology are more food secure than non-adopters, the Household Dietary Diversity Score (HDDS) was used as a measure for household food security. For the same objective, to determine socio-economic factors that influence household food security, the binary logistic regression model was also used and adoption of IRWH technology became an independent variable.

The study was conducted in Khayalethu, Guquka and Krwakrwa villages in Nkonkobe Municipality in the Eastern Cape Province (EC). The unit of analysis was the individual smallholder farmers practicing agriculture. The availability (accidental) and snowball sampling techniques were used to select 34, 23, 63 respondents from Khayalethu, Guquka and Krwakrwa villages respectively. Since they are non-random, these sampling methods are problematic because of sampling errors. Overall, a sample size of 120 smallholder farmers was targeted for the interviews. Primary and secondary data collected was coded and analysed using statistical package for social sciences (SPSS) version 21. Results were presented using graphs, pie charts and tables (including cross-tables).

The descriptive results showed that adoption status of IRWH technology was low in these areas, with 79% not adopting the technology. Food insecurity was high amongst the non-adopters with 86%. On the basis of descriptive analysis it can be concluded that any change in each one of the significant variables can significantly influence the probability of adopting IRWH technology and household food security.

The results from the logistic regression model for the incidence of adoption revealed that 6 out of 16 variables were significant, three at 1% (access to extension services, access to *information and farmers' perception towards the IRWH technology); one at 5% (access to market) and two at 10% (access to hired labour and farm income). For the incidence of household food security, out of 17 variables, 6 were significant, three at 1% (adoption of the IRWH technology, access to extension services and farmers' perception towards the IRWH technology); two at 5% (access to hired labour and household income) and one at 10% (household size). The empirical findings of this study indicate that there are socio-economic factors influencing adoption of IRWH technology and household food security amongst smallholder farmers.*

This study recommends that the government should provide extension officers and research stations with the capacity, support and physical means to expose smallholder farmers to the IRWH technology through demonstrations and trainings. The government can also introduce agricultural finance institutions in rural areas to assist the rural smallholder farmers to increase their access to credit. Further, it is recommended that smallholder farmers can expand to the communal croplands in order to gain more land size and work as a co-operative or as an association to ease labour constraints.

Keywords: smallholder farmers, adoption, in-field rainwater harvesting technology, increased yield, household dietary diversity score, household food security, adopters, non-adopters, binary logistic model

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LIST OF ACRONYMS

ARC: Agricultural Research Council

ARDRI: Agricultural and Rural Development Research Institute

CARE: Caregivers

CASP: Comprehensive Agricultural Support Programme

Cf: Cartref

CON: Normal conventional tillage

CSI: Coping Strategy Index

DWA: Department of Water Affairs

DRWH: Domestic rainwater harvesting

EC: Eastern Cape Province

FAO: Food and Agriculture Organisation

Ha: Hectares

IDDS: Individual Dietary Diversity Score

IDP: Integrated Development Plan

IRWH: In-field rainwater harvesting

ISCW: Institute for Soil, Climate and Water

$IWRH_{bare}$: In-field rainwater harvesting with bare run-off area and bare basin area

$IWRH_{GLDM}$: In-field rainwater harvesting with green leaf desmodium as a cover crop on the run-off area

$IWRH_{lucerne}$: In-field rainwater harvesting with lucerne as a cover crop on the run-off area

$IWRH_{mulch}$: In-field rainwater harvesting with organic mulch run-off area and bare basin area

$IWRH_{vetiver}$: In-field rainwater harvesting with vetiver as a cover crop on the run-off area

Lo: Longlands

LRAD: Land Redistribution for Agriculture Development

NDA: National Department of Agriculture

NDP: National Development Plan

Oa: Oakleaf

ObBr: Organic mulch in the basin with bare run-off area

ObOr: Organic mulch in the basin with organic mulch on the run-off area

ObSr: Organic mulch in the basin with stones on the run-off area

OECD: Organisation For Economic and Development

PPBP: Provide Project Background Paper

RWH: Rainwater harvesting

RWP: Rainwater productivity

SbOr: Stones in the basin with organic mulch on the run-off area

SDFR: Spatial Development Framework Review

Se: Sepane

SPSS: Statistical Package for Social Sciences

STRIP: Strip cropping

Sw: Swartland

TLC: Traditional Local Council

TRC:	Transition Rural Council
UFH:	University of Fort Hare
Va:	Valsrivier
Vf:	Vilafontes
Wa:	Wasbank
We:	Westleigh
WFP:	World Food Program
WRC:	Water Research Commission
XRWH	Ex-field rainwater harvesting

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CHAPTER 1

INTRODUCTION

1.0 Introduction to the chapter

This research is a survey of the socio-economic factors influencing adoption of in-field rainwater harvesting technology for enhancing household food security by smallholder farmers in the Nkonkobe Municipality, Eastern Cape Province. This chapter provides a background to the study, problem statement, the main objectives as well as the research questions. The justification and delimitation of this study are also highlighted. The outline of this study is lastly presented in this chapter.

1.1 Background to the study

The shortage of water for domestic and agricultural purposes has become a significant challenge in the contemporary South African environment in which an ever increasing water demand now far exceeds its natural availability (Badisa, 2011). It is in this regard that the South African Department of Water Affairs (DWA) (2013) has classified the country as water-stressed for domestic and agricultural purposes, with a low average annual rainfall of 500mm being recorded. The DWA (2013) further pointed out that, only a narrow region along the south–eastern coastline receives good rainfall, while the greater part of the interior and western part of the country is arid or semi-arid. Badisa (2011) has observed that, 65% of the country receives less than 500mm per year, which is usually regarded as the minimum for dry-land farming and 21% receives less than 200mm per year. This study will focus on water for agricultural purposes.

The water shortage for agricultural purposes as suggested by the Food and Agriculture Organisation (FAO) (2008) is increasingly recognised as a major constraint to improving the lives of the rural poor. It has been highlighted by van Averbeke *et al*. (2011) that, water shortage caused by irregular, unreliable rainfall and high evaporative demand limits rain-fed agriculture production in South Africa. As a result, most of the smallholder farmers are found in areas that are marginal and not suitable for crop production (Baiphethi *et al.,* 2009). These areas range from semi-arid to arid and receive very low rainfall (Hatibu *et al.*, 2006). Similarly, Botha (2005) noted that in South Africa 72% of smallholder farmers live in semi-arid to arid areas and mainly rely on rain-fed smallholder agriculture.

As most of the poor rural households are practicing smallholder agriculture, some scholars conclude that smallholder agriculture is not achieving its pivotal role of attaining food security in developing countries like South Africa (Vengayi, 2009; Hosu *et al.,* 2013). This means that in rural areas, smallholder farmers' efficiencies have always been hindered mostly by some factors beyond their control such as agro-ecological factors (Hosu *et al.,* 2013*)*. In contrast, Obi *et al.* (2011) have argued that smallholder agriculture is the main source of food for the rural population as well as an income generating occupation because it is the main activity for many rural parts of developing countries. This implies that smallholder agricultural productivity is very crucial in alleviating poverty and hunger (Kirkland *et al.*, 2011). Furthermore, it has been stated that each 1% increase in agricultural productivity in South Africa reduces poverty by 0.6% (Chisasa and Makina, 2012). A census conducted in 2011, found that the highest proportion of smallholder agriculture was recorded by the Eastern Cape Province (EC) at 35.4% followed by the Limpopo Province (33%) and KwaZulu-Natal Province at 28.2% (Statistics South Africa, 2013).

Van Averbeke *et al*. (2011) have reported that smallholder agricultural productivity in South Africa is regarded as being very low even though it has to support most of the rural poor. As a result, the majority of the rural population in South Africa is food insecure. The basic definition of food security is that it refers to the ability of individuals to obtain sufficient food on a day-to-day basis (Backeberg, 2009; Baiphethi *et al*., 2010; Monde *et al.*, 2012). It was estimated by Statistics South Africa (2013) that 19 million people in South Africa are rural survivalists with traditional agrarian lifestyles. Of these at least 15 million individuals are food insecure. Food security and livelihood studies carried out over the years suggest that the food insecurity rates may be higher in the EC than elsewhere in the country (Provide Project Background Paper (PPBP), 2005; Obi *et al.,* 2011; National Development Plan (NDP), 2013). It showed that 70.7% of its 6.2 million inhabitants are poor and the unemployment rate is as high as 48.5% (NDP, 2013).

Significant effort is being made to alleviate food insecurity in South Africa. It is therefore not surprising to realise that one of the longstanding and key objectives of the South African government is to ensure that all South Africans have enough to eat (National Department of

Agriculture (NDA), 2007). The South African government has continuously sought to implement policy initiatives aimed at creating employment opportunities through food security programmes (Hlanganise, 2010). Another notable effort being made by the South African government is to reach a wider population of the country through social grants. The majority of households in the EC rely on these grants for survival (Monde, 2003). Further, there have been attempts to improve access to water for agricultural purposes, a resource that has been identified as the most important to achieve food security at household level (Hlanganise, 2010).

To address the issue of water scarcity for agriculture, crop failures and food insecurity in South Africa, water harvesting and water conservation techniques were developed in 2001 by the Agricultural Research Council (ARC) (Botha *et al.*, 2007; Hlanganise, 2010). Botha *et al.* (2007) explained water harvesting as a term that describes a number of different practices that have been used for centuries in dry areas to collect and utilise rainfall more efficiently. Methods of water harvesting are categorised as ex-field (outside the farm boundary), in-field (within the farm) and non-field (such as rooftops) (Monde and Aliber, 2007; Botha *et al.*, 2007). This study will focus more on in-field rainwater harvesting (IRWH) technology.

In IRWH technology the term 'in-field' refers to the transportation of water over a short distance of 2m and delivering it to the 1m wide basin (Hatibu *et al.*, 2006). Joseph and Botha (2012) also explained IRWH as a technique that combines the advantages of no-till, basin tillage and mulching. According to Monde and Aliber (2007) and Hlanganise (2010) in the EC, IRWH project is a collaborative effort between the ARC Institute for Soil Climate and Water and the University of Fort Hare (UFH). The project received funding from the Water Research Commission (WRC). Rural communities of Khayalethu and Guquka villages were first trained in 2004 on IRWH techniques followed by Krwakrwa village in 2008. This technique is mostly practiced in backyard food gardens with an aim to improve production hence improved food security (Backeberg, 2009).

IRWH technology is classified as a sustainable technology because it contributes to climate change adaptation (Botha, 2005). It does this, by increasing plant available water and buffering during dry spells. Therefore, better rainwater productivity leads to increased yields (ARC, 2001). Monde and Aliber (2007) also argued that this technique is a sustainable production technique that increases agronomic productivity, decreases production risk, conserves the natural resources and is economically viable and socially acceptable.

However, many water conservation projects have failed despite good techniques and design (Badisa, 2011). For example, He *et al.* (2007) in China found that adoption of IRWH technology was low because of technical, environmental, climatic, socio-economic and policy factors. This study seeks to find out if socio-economic factors affect adoption of IRWH technology in Nkonkobe Municipality particularly in Krwakrwa, Khayalethu and Guquka villages. It has been emphasised by Bunclark and Lankford (2010) that the successful adoption of IRWH technology has the potential to alleviate problems faced by resource-poor smallholder farmers. Adoption was defined by the Orgainisation for Economic Co-operation and Development (OECD) (2001) as the use or non-use of a new technology by a farmer at a given period of time. Adoption of rainwater harvesting technologies require a bottom-up approach rather than the usual top-down approach employed in most water resources development projects. A bottom-up approach that regards beneficiaries as partners, utilises local experience and empowers target beneficiaries has been promoted in the past few decades (Badisa, 2011).

1.2 Problem statement

There is a constant increase in the worlds' population which translates to a high demand for food and water for domestic and agricultural purposes (DWA, 2013). Further, there is competition between humans and agriculture on the use of water resources (Unganai, 2005). Climate change which causes rainfall not to be adequate to sustain crop production has resulted in increased food insecurity in the smallholder farming sector in Africa, including the EC (Aliber *et al.*, 2009). NDP (2013) described the EC as a rural Province whose majority of the population is characterised by food insecurities. According to Monde *et al.* (2012) about 80% of the households in the Khayalethu, Guquka and Krwakrwa villages earned incomes that hardly constitute the main rural livelihood activity to secure households food needs. Buying food from the urban markets was an important food security strategy for these households.

In the EC like in many other African Provinces smallholder agriculture has a long tradition. Dry-land agricultural activities are rain-fed based; therefore planting is predominantly done during summer period (October to April) (Monde *at al*., 2012). Smallholder farmers primarily depended on rainfall in order to use rivers and streams as a source of water to irrigate small plots for cultivation of grain crops and vegetables for home consumption (Aliber *et al.,* 2009). However, farmers have difficulties in practicing farming due to the lack of irrigation water. According to FAO (2008) water scarcity for agricultural purposes is increasing at a faster rate. This scarcity is caused by low, unpredictable rainfall and high evaporative demand which limits dry-land crop production (van Averbeke *et al*., 2011). Therefore, available rain water should be used more efficiently and productively to help to improve dry-land crop production, especially in rural areas where the majority of people depend on rain-fed agriculture for their livelihood (Backeberg, 2009). Improving water sourcing for agriculture is one of the strategies that South African government has employed in its efforts to alleviate food insecurity. This has resulted in the development of IRWH technology.

Previous studies (ARC, 2001 and Baiphethi *et al.* (2010)) showed that IRWH technique is suitable for application in semi-arid to arid areas of South Africa. It conserves water, reduces soil erosion and rehabilitates degraded land. Consequently, IRWH technology contributes to household food security and poverty alleviation. However, its level of adoption remains low (Baiphethi *et al.,* 2010). Tesfay (2008) also pointed out that regardless of the potential of IRWH technology in improving agricultural productivity and general welfare of smallholder farmers, its adoption is not sufficient. The results from assessing rainwater harvesting (RWH) technologies case studies from Ethiopia, Kenya, Uganda and Tanzania by Ngigi (2003) do not explain the reasons for a low adoption of the RWH technologies including IRWH among smallholder farmers, considering all the advantages of practicing RWH technologies. Other studies have been done on technical, environmental, policy and climatic factors that influence the adoption of this technique in South Africa (Botha *et al*., 2007; Mwenge, 2011; Joseph and Botha, 2012). Therefore, this raises the need to investigate the socio-economic factors that influence the adoption of IRWH technique owing to its many advantages to smallholder farmers.

This will contribute to the formulation of policies that enhance crop productivity through the use of IRWH technology thereby enhancing household food security in the rural areas of the EC. Any efforts to promote this technology by the government or any other players need to be directed by the results of this study. This information could then be used as a basis for formulating realistic situations of future expansion of the IRWH technology to other areas in the

EC. In addition, this study will also add to the available literature on IRWH technology.

1.3 Objectives of the research

The main objective of this study is to identify the socio-economic factors determining the adoption of IRWH technology for enhancing household food security by smallholder farmers in selected areas of the EC.

1.3.1 The specific objectives are to:

(i) Assess the level of adoption of IRWH technology by smallholder farmers in Krwakrwa, Khayalethu and Guquka villages in the EC.

(ii) Determine socio-economic factors influencing the adoption of IRWH technology by smallholder farmers in the study areas in the EC.

(iii) Determine whether adopters of IRWH technology are more food secure than non-adopters in the study areas in the EC.

1.4 Research questions

(i) What is the level of adoption of IRWH technology by smallholder farmers in Krwakrwa, Khayalethu and Guquka villages in the EC?

(ii) What are socio-economic factors that influence adoption of the IRWH technology by smallholder farmers in the study areas in the EC?

(iii) Does adopters of IRWH technology more food secure than non-adopters in the study areas in the EC?

1.5 Delimitation

This study only looked at social and economic factors that influence adoption of the IRWH technology for enhancing household food security by smallholder farmers in the EC. It did not cover the environmental, policy and technical factors affecting the adoption of IRWH technology in the EC. Due to financial constraints this study only covered three villages in one municipality in the EC. It only focused on smallholder farmers and not on commercial farmers. This will place a limitation on the extent to which the findings of the study could be generalised.

1.6 Outline of the study

This study consists of seven chapters. Chapter 1 presented an introduction to the problem, the background to the study and objectives of the study. Chapter 2 presents literature review. An overview of a smallholder farmer is outlined and key terms that include adoption and water harvesting techniques are explained in this chapter. IRWH technology is also explained in detail in this chapter. Factors that influence adoption of this technique for enhancing household food security by smallholder famers are also discussed. Chapter 3 explains why the study areas were selected and further presents their description. Chapter 4 is the methodology. The overall plan of how the research was carried out and data analysis techniques are explained in this chapter. Descriptive results are presented in Chapter 5 while empirical results are presented in Chapter 6. The conclusion and recommendations of the study as well as areas of further studies are set out in Chapter 7.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter provides a description on the adoption process of new agricultural technologies, an overview of a smallholder farmer and different types of rainwater harvesting technologies employed by smallholder farmers. For the purposes of this study, IRWH technology is discussed in detail including the benefits associated with the adoption of this technique, implementation of the technology in Nkonkobe Municipality, participants as well as the requirements for the technology. The chapter also provided the literature on factors influencing the adoption of IRWH technology for enhancing household food security by smallholder farmers. The next section discuses the adoption of new agricultural technology.

2.1 Adoption of new agricultural technology

According to Abera (2008) adoption decision is a dynamic process. It involves changes in farmers' perceptions and attitudes, also involves the progression in the acquisition of better information and farmers ability as well as skill improvement in applying new technology. Furthermore, technology adoption has been defined by Baumüller (2012) as an act by which an individual begins using a new practice to replace an old one. White (2012) has highlighted that adoption is taken to be the final outcome of exposure to some practice or innovation and a variety of sources are used to communicate the message. Featherstone *et al.* (1997) defined adoption as the extent to which a new technology is utilised, balanced with other activities, over a long period of time when the farmer has full information on the technology and its potential. The agricultural technology adoption definition adopted in this study falls in the last category**.**

In line with the above, Badisa (2011) has pointed out in the study of socio-economic factors determining IRWH technology adoption for cropland productivity in the Limpopo Province, that quite often, farmers will try a technology when it is first introduced, i.e. in the project phase, only to drop out when it is time for them to stand alone without the donor or government support. Badisa (2011) has further highlighted that usually, those farmers have made an economic decision after weighing the costs and benefits from the continued involvement with the technology. This means, adoption of innovations in general is not a once-off decision rather, it is a stepwise decision made after carefully weighing opportunity costs at each point (Abera, 2008; Yengoh *et al.,* 2010). Understandably, smallholder farmers always sought to avoid unnecessary risks and will, therefore, abandon a technology once their perceived benefits diminish significantly or do not seem to offset the costs involved (Yengoh *et al.,* 2010).

Adoption studies also identify and describe five categories of adopters in a social system. The study by Murgor *et al.* (2013) where factors influencing farmers' decision to adopt RWH techniques in Kenya were reviewed, confirmed that categories of adopting RWH technologies include innovators, early adopters, early majority, late majority and laggards as shown in Figure 2.1. Murgor *et al.* (2013) have further established that the rate of adoption of RWH technologies follows a standard bell curve as shown in Figure 2.1. Similarly Sibanda (2009) showed that the potential adoption of Open Pollinated Varieties of maize at Zanyokwe and Kieskamahoek in the EC follows a standard bell curve.

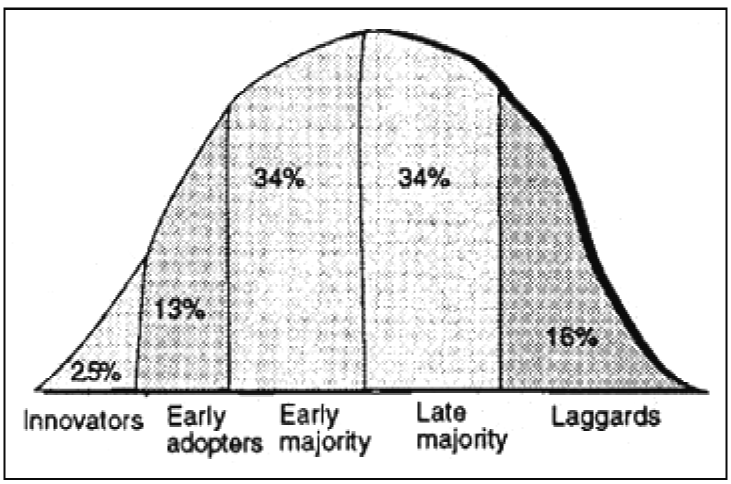

Figure 2.1: Adoption/innovation cycle showing the distribution of different categories of adopters of a new technology over time
Source: Murgor *et al.* (2013)

In describing the characteristics of these groups a study by Rogers (1995) revealed that, the majority of the innovators are risk takers who have the resources and desire to try new things even if they fail. Early adopters are selective about which technologies they start using. They are considered as the "one to check in with" for new information and reduce others' uncertainty about new technology by adopting it (Baumüller, 2012). Early majority take their time before adopting a new idea. They are willing to embrace new technology as long as they understand how it fits in with their lives (Sunding and Zilberman, 2000). According to White (2012) late majority adopt in relation to peer pressure, emerging norms or economic necessity. This means that most of uncertainty around an idea must be resolved before they adopt. Laggards are traditional and make decisions based on past experience (Sunding and Zilberman, 2000). They are often economically unable to take risks on new ideas (Shikur and Beshah, 2012). In Uganda, Mugerwa (2007) studied and divided smallholder farmers in three groups of banana growers, where smallholder farmers who do not use RWH technologies as non-adopters, smallholder farmers who have used RWH technologies for at most four years as late adopters and farmers who have used RWH technologies for at least five years as early adopters. The study revealed that early adopters knew more about RWH technologies in order to improve their banana production as compared to late adopters and non-adopters. This has led to early adopters to have higher production yield than late adopters and non-adopters. This study confirms that early adopters are the ones who know more about the technologies and carefully adopt the technologies that will give higher returns.

Furthermore, farmers will invest in and implement sustainable technologies and farm practices if they expect the investment will be profitable, given the right education, information, motivation and also if government policies set clear goals (Abera, 2008). This study by Mugerwa (2007) also confirms that smallholder farmers adopted RWH technologies because they had more information about the technologies in order to get more profit. However, higher input prices and no markets for the benefits will negatively influence smallholder farmers' decisions on investment and can lead to unsustainable farming practices (Yengoh *et al.*, 2010). Characteristics of a technology, such as simplicity, visibility of results, usefulness towards meeting an existing need and low capital investment promote its adoption and should be considered when transferring any technology (Baumüller, 2012).

For a new technology to be sustainable there is a need for greater follow-up in tracking the adoption of technologies (OECD, 2001). This will help in the accountability of research efforts and policies for technology dissemination and adoption (White, 2012). Thorough ex-post assessments of results could help to ensure that corrections are made before too much is invested in the wrong technology (Yengoh *et al.*, 2010). Identifying possible future trends can help the policy making process in moving towards sustainable agriculture.

Furthermore, the adoption of technologies for sustainable farming systems will be facilitated by a wider participatory approach involving a wide range of stakeholders (Shikur and Beshah, 2012).These stakeholders should include farmers, the agri-food industry, consumer groups and non-government organisations with an interest in sustainable farming. OECD (2001) also stated that sustainable technologies are implemented at the farm level, thus a key requirement is to engage smallholder farmers in the dialogue on technology adoption. A description of a smallholder farmer in a South African context is given below.

2.2 Overview of a smallholder farmer in South Africa

Wenhold *et al*. (2007) explained that smallholder farmers in South Africa are often equated with backward, non-productive, non-commercial and smallholder agriculture that is found in rural areas. As put forward by Vengayi (2009) smallholder farmers are farm households with access to means of livelihoods in land relying primarily on family labour for farm production to produce for self-subsistence and often for market sale, this view is to be used in this study. Kirsten and van Zyl (1998) concluded by defining a smallholder farmer as one whose scale of operation is too small to attract the provision of the services he/she needs to be able to significantly increase his/her productivity. The study by Herman *et al*. (2012) has confirmed that the livelihoods of the majority smallholder farmers in Nkonkobe Municipality in the EC are characterised by poverty, food insecurities, hunger, resource-poor, risk-sensitive, inadequate market access, infrastructure and support services.

In the context of irrigation schemes, van Averbeke (2008) evaluated best management practices for smallholder farming on selected irrigation schemes and surrounding areas through participatory adaptive research in the Limpopo Province and reported that smallholder irrigation schemes are irrigation projects on 5-10 hectares (ha). According to Wenhold *et al*. (2007) smallholder farmers practice mixed farming, which involves the production of both crops and animals on three types of land, namely residential, arable and commonage. In the study of Wenhold *et al*. (2007) it was noted that in the EC residential land which is used for home gardening is normally 0.4ha but where traditional tenure still applies; residential sites can be several hectares in size. Arable allotments range in size between 1ha and 5ha and are used to produce staple food crops. The commonage is used for the production of small and large livestock, mainly cattle, goats and sheep and also for the collection of plant materials for various uses including food in the form of fruit and edible herbs. For the purpose of this study smallholder famers are households practicing crop production in plot size from 0.1 to 10 ha.

Kirsten and van Zyl (1998) observed that smallholder agriculture is ineffective in alleviating food insecurities and causing agricultural development. This was supported by the study of Vengayi (2009) in the EC where institutional constraints to smallholder agriculture were reviewed and the results showed that most smallholder farmers lacked an entrepreneurial spirit, are generally risk averse and do not regard farming as a business. On the other hand Jari (2009) on the study of institutional and technical factors influencing agricultural marketing channel choices amongst smallholder famers in the EC reported that food insecurities can be alleviated through smallholder agriculture due to food price reduction and employment creation. This is the case because small farms are labour intensive thus more people are employed as presented by the results of Obi *et al.* (2011) in the EC. Also Pote (2008) in Nkonkobe Municipality in the EC found that more smallholder farmers have access to land for own food production. This resulted in more food being produced and sold thereby a fall in food prices hence improved food security. It was further highlighted by Jari (2009) that these contributions of smallholder agriculture have been recognised by the South African government and reflected in the Agricultural Policy (Ministry of Agriculture and Land Affairs, 1998). Shikur and Beshah (2012) pointed out that another way to improve smallholder agriculture is through RWH technologies. These technologies are discussed in the following section.

2.3 Rainwater harvesting (RWH) technologies employed by smallholder farmers

According to Alem (2001) RWH in its broadest sense is defined as the collection of run-off for its productive use where run-off may be harvested from roofs and ground surfaces. It could also be described as an act of maximising utilisation of the available rainfall by making use of different techniques (Badisa, 2011). It was explained by Botha *et al.* (2007) as a term that describes a number of different practices that have been used for centuries in dry areas to collect and utilise rainfall more efficiently.

2.3.1 Types of rainwater harvesting technologies

There are different classifications of RWH technologies. Murgor *et al.* (2013) has identified the following water harvesting classes (for agriculture): in-situ water conservation, flood irrigation and storage for supplemental irrigation. FAO (1990) used the following RWH classes: rooftop water harvesting, micro catchment, macro catchment and flood water harvesting. Prinz (2002) gave the following types of water harvesting: fog- dew, rainwater, flood water and ground water harvesting. Mwenge (2011) who investigated decision to support system for sustainable rainwater harvesting in South Africa has categorised RWH technologies according to the catchment area, into: domestic RWH (DRWH), ex-field RWH (XRWH) and in-field RWH (IRWH). Mwenge (2011) further pointed out that IRWH technology is also known as in-situ, within the field and micro catchment RWH while XRWH technology is also known as external or macro catchment RWH. For this study the latter was adapted in categorising RWH techniques used by smallholder farmers. Also this study focused more on the IRWH technology but DRWH technology would be described first.

2.3.1.1 Domestic rainwater harvesting (DRWH) technology

Water is collected from rooftops, courtyards and similar compacted or treated surfaces (Mwenge, 2011). Other RWH technology studies reviewed that roofs made of corrugated iron sheet, asbestos sheet or tiles can be utilised for harvesting the rainwater (FAO, 1990) and according to Botha *et al.* (2007) that water will be diverted to a storage tank. Monde and Aliber (2007) highlighted that, it is done to obtain relatively clean drinking water as well as water for domestic purposes or garden crop. The results of Backeberg (2009) in the study of increasing food security through RWH technologies showed that in the EC, DRWH technology is constructed in such a way that if the tank that harvests water from the roof is full, water will go to the underground tank through the connected pipe. There are some similarities between DRWH and XRWH technologies in-terms of their uses (Mwenge, 2011).

2.3.1.2 Ex-field rainwater harvesting (XRWH) technology

There is a noticeable distance between the catchment area (usually not cultivable) and the target area (Mwenge, 2011). Alem (2001) revealed that ponds are used to harvest rainwater for both humans and livestock, particularly in the arid and semi-arid rural areas. They are major sources of water in the Rift Valley where ground water is deep and other sources of water are not feasible (Botha *et al.*, 2007). The implementation structure of XRWH is a little bit different from that of IRWH technology.

2.3.1.3 In-field rainwater harvesting (IRWH) technology

Hatibu *et al.* (2006) explained IRWH technology as a technique that combines the advantages of no-till, basin tillage and mulching. The basic structure of IRWH technology in South Africa especially in Limpopo, Free State and EC Provinces include the case where rainfall run-off is promoted on a 2m wide strip between alternate crop rows and stored in 1m basins as shown in Figure 2.2 (Baiphethi *et al.*, 2006). According to Monde *et al*. (2012) water collected in the basins infiltrates deep into the soil beyond the surface evaporation zone. After the basins have been constructed no-till is applied to the land as a whole. Due to the absence of cultivation a crust soon develops on the run-off strip. This technique is called *Amadanyana* in IsiXhosa in the EC. The practice is mostly used in homestead gardens while communal croplands are used at a very low rate (Monde and Aliber, 2007).

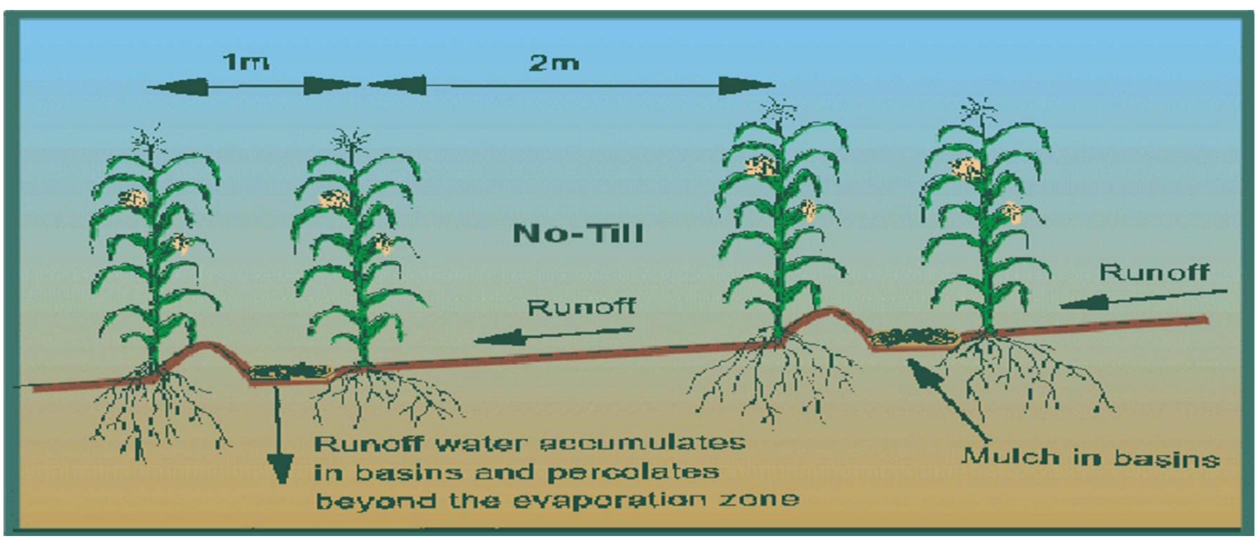

Figure 2.2: In-field rainwater harvesting technique
Source: Botha *et al. (*2007)

IRWH experiments have been conducted at several locations in Zimbabwe and Mozambique. All experiments included treatments with 'Planting Basins' (Mutekwa and Kusangaya 2006; Joseph and Botha, 2012). Crops were planted in the basins, often with small amounts of organic and/or inorganic fertilisers. The objectives were to reduce run-off, increase infiltration through breaking the surface crust by creating a depression/pit/hole and to increase soil fertility through reduction in erosion (Joseph and Botha, 2012).

In Glen, Botha *et al.* (2005) compared four different IRWH techniques and normal conventional tillage (CON) in field experiments over three growing seasons on four ecotopes with maize, sunflower, sorghum and wheat. The four IRWH treatments were: organic mulch in the basins with a bare run-off area (ObBr); organic mulch in the basins with organic mulch on the run-off area (ObOr); organic mulch in the basins with stones on the run-off area (ObSr); stones in the basins with organic mulch on the run-off area (SbOr). According to Monde *et al.* (2012) the other kinds of IRWH technology include: IRWH with a bare run-off area and bare basin area ($IRWH_{Bare}$); IRWH with organic mulch both on the run-off area and basin area ($IRWH_{Mulch}$); IRWH with lucerne as a cover crop on the run-off area ($IRWH_{Lucerne}$); IRWH with green leaf desmodium as a cover crop on the run-off area ($IRWH_{GLDM}$) and IRWH with vetiver as a cover crop on the run-off area ($IRWH_{Vet}$). Monde *et al.* (2012) experimented with these kinds of IRWH techniques in Alice in the EC where they were experimented against CON and strip cropping (STRIP) over four growing seasons. The results are going to be discussed in the next section.

This study focuses on IRWH technology where there is organic mulch both on the run-off area and in the basin area ($IRWH_{Mulch}$) as the one of the treatment conducted in Nkonkobe Municipality.

2.4 Implementation of IRWH technology in the Nkonkobe Municipality

According to Hlanganise (2010) in 2004, WRC funded IRWH project where University of Fort Hare (Agricultural and Rural Development Research Institute (ARDRI) and ARC Institute for Soil Climate and Water worked together in Khayalethu and Guquka villages in the Nkonkobe Municipality, in the EC. The objective of the project was stated by Monde *et al.* (2012, p.2) as a need to help: *"Farmers in the study areas to create a sustainable livelihood through farming so as to alleviate poverty and enhance food security in rural areas"*.

The project was a five year programme that took place between 2004 and 2009. The IRWH technique was formally introduced to the communities of Guquka and Khayaletu in November 2004 (Ngwenya, 2013). As put forward by Monde *et al.* (2012) during the first year, the technique was demonstrated in two households in each village (total=4). The implementation of the first IRWH plots began in mid-December 2004 in both villages. At the demonstration plots, village members were taught how to construct the basins and plant maize. They then duplicated the technique in their own homestead gardens. Only maize was planted at the demonstration plots, but later planting methods for a variety of vegetable crops were also demonstrated. During the first year of implementation, participants were provided with maize and vegetable seeds, fertilisers, herbicides, pesticides, tools (spades, rakes, knapsack sprayers). Thereafter, free inputs were gradually reduced by 25% per year in order to encourage farmers to be self reliant (van der Horst, 2013). During the fourth growing season village members did not receive any free inputs and they had to buy them. The research team also provided support and assistance on all aspects related to crop production within the IRWH system (Monde *et al.*, 2012). At an information day held in January 2005, roof and road water harvesting were introduced. Rainwater harvesting tanks funded by the Department of Agriculture were installed at seven homesteads in each village (van der Horst, 2013).

In 2007 the technique was introduced to six schools. "*The purpose of involving the schools in the IRWH project was to introduce scholars to the benefits of the technology and the conservation of the natural resources, as well as encourage them to develop a love for agriculture, and its potential to address poverty and food insecurity, and improve their eating habits"* (Monde *et al.*, 2012, p.138).

The extension officers in Alice received theoretical and practical training in the implementation of the IRWH technique in the selected villages before they assisted the households (Hlanganise, 2010).

According to Monde *et al*. (2012) besides demonstrations at the two villages, the on-station field experiments were conducted at the Research Farm at the University of Fort Hare over a period of four seasons (2004/05-2007/08). An additional on-station field experiment, funded by the ARC–Institute for Soil, Climate and Water (ISCW), was conducted at Phandulwazi Agricultural school next to the village of Guquka during two seasons (2006/07 and 2007/08). CON was compared with the STRIP and various IRWH treatments on three ecotopes, Fort Hare/Oakleaf; Phandulwazi/Westleigh and Guquka/Cartref. The treatments were CON; STRIP;

IRWH with a bare run-off area and bare basin area ($IRWH_{Bare}$); IRWH with organic mulch both on the run-off area and basin area ($IRWH_{Mulch}$); IRWH with lucerne as a cover crop on the run-off area ($IRWH_{Lucerne}$); IRWH with green leaf desmodium as a cover crop on the run-off area ($IRWH_{GLDM}$) and IRWH with vetiver as a cover crop on the run-off area ($IRWH_{Vet}$) (Monde *et al.,* 2012).The indicators used to show crop response to the different treatments were grain yield, dry matter production, transpiration, run-off and rainwater productivity (RWP). Detailed measurements were conducted on the Fort Hare/Oakleaf and Phandulwazi/Westleigh ecotopes while mainly grain and biomass yield were monitored on the Guquka/Cartref ecotope (Monde *et al*., 2012).

The results indicated clearly that $IRWH_{Mulch}$ and $IRWH_{Bare}$ are far more efficient than CON and STRIP at converting rainwater into grain yield. They gave an average of 20 to 37% higher grain yield than CON and STRIP and their RWP values were on average between 20% and 33% higher. The trend was $IRWH_{Mulch} > IRWH_{Bare} > IRWH_{Vet} > IRWH_{Lucerne} > IRWH_{GLDM}$ (Monde *et al*., 2012; Ngwenya, 2013; van der Horst, 2013). These results motivated more households to participate in the implementation of the IRWH technique in Nkonkobe Municipality.

2.4.1 Participants of IRWH technology in the Nkonkobe Municipality

The difference between the CON and IRWH techniques was clearly visible right from the beginning of these demonstrations (Monde *et al.,* 2012).Other village members in Gilton, Mpundo and Sompondo were also encouraged by the remarkable improvement in crop yield and started to implement the IRWH technique in their homestead gardens with the assistance from other village members, technical assistants and extension officers (Hlanganise, 2010; Monde *et al*., 2012). The implementation of IRWH technique in these three neighbouring villages was initially funded by the Eastern Cape Department of Agriculture in 2004/05.The ARC-ISCW funded the support during the period 2006-2008 (Hlanganise, 2010; Monde *et al*., 2012). In 2008/2009, the implementation continued to Krwakrwa village. It was also ruled out as a five year programme. The ARC-ISCW performed the demonstrations and the project was funded by WRC during the period 2008-2012 (Botha *et al.*, 2013).

The number of households that were practicing IRWH technology at the end of 2008 is presented in Figure 2.3 below.

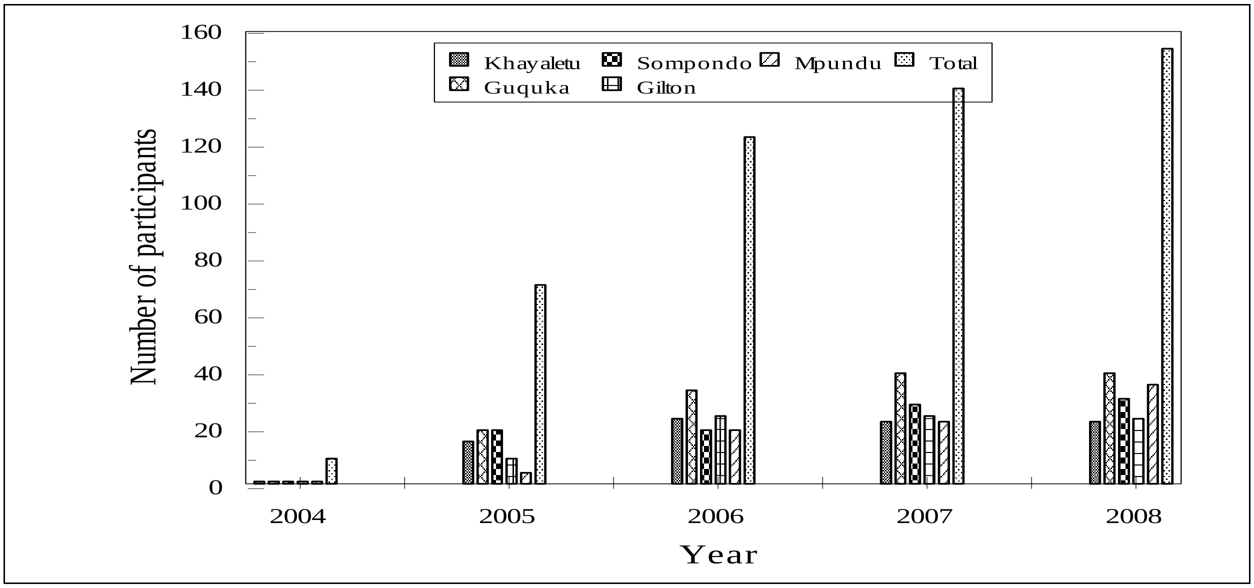

Figure 2.3: Number of households in five targeted villages where IRWH is used
Source: Monde *et al.* (2012)

Monde *et al*. (2012) pointed out that in Khayalethu, the use of the technique expanded to 23 households and 40 in Guquka (total of = 63) during the 2007/2008 summer growing season. By the 2008/09 season the total number had increased further to more than 154 households including households in three villages (refer to Figure 2.3). By 2012, 30 households in Krwakrwa village used the technology (Botha *et al.,* 2013).The impact of this technology to the households is highlighted in the next section.

2.4.2 The impact of IRWH technology in the Nkonkobe Municipality

According to Hlanganise (2010) good yields were recorded during the summer growing seasons, but during the winters only a few village members planted due to the cold and dry weather conditions. Only a few rainfall events were recorded during the winter months and the water collected in the storage tanks was used to give supplementary irrigation. After the farmers harvested their winter crops, they immediately started to maintain the basins for the next summer growing season. In most cases the farmers worked hard to keep the homestead gardens weed-free in order to ensure good yields. During the very wet seasons farmers were kept from weeding and maintaining their gardens in preparation for the next growing season.

Most of the farmers were able to keep accurate records of the produce they harvested, household consumption and the amount of money they made from selling surplus produce, as they were taught how to take records during harvesting. After discussions with the head of the local market in Alice it was agreed that the IRWH farmers could sell their produce at the local market, paying 5% of their earnings to the market management. A food processing unit was built at the University of Fort Hare and IRWH members were invited to have their produce processed there for value addition (Hlanganise, 2010; Monde *et al.*, 2012). There are conditions for this technology to have a greater positive impact to the households. Such conditions are discussed in the next section.

2.5 Requirements for the IRWH technology

In the study of Amha (2006) in Ethiopia it was highlighted that IRWH technology can be applicable in all agro-climatic zones. However, it is more suitable in arid and semi-arid areas. These are areas of average annual rainfall of 200-800mm (rarely exceeding 800mm) where the average temperature is above 18^{o}c. The rainfall may come in one or two season. In such an environment, rain-fed crop production is usually difficult without some form of IRWH practices (Amha, 2006).

Soil depth is a very important attribute for IRWH technique since depth is needed for adequate water holding capacity (WRC, 2007). According to Alem (2001) a soil survey is used as an aid for decision-making and it is therefore used in land planning and management. The soils differ and soil survey results facilitate the matching of the land use requirements with the soil resource (WRC, 2007). Joseph and Botha (2012) revealed that the range of soil forms suitable for IRWH technology includes soils generally considered to be of marginal potential for crop production in semi-arid areas, e.g. vertic, margalitic and duplex soils (excluding Estcourt form).To ensure minimal losses from deep drainage, soils with a low water-holding capacity in the root zone should be avoided, like sandy soils with a coarse texture (Ahmed *et al*., 2013). The minimum rooting depth should be at least 500mm (Joseph and Botha, 2012; Ahmed *et al.,* 2013). It was also pointed out by Monde *et al.* (2012) that in the EC the slope were also important for run-off collection therefore this technique is suitable for gentle slopes of less than 5%.

Smallholder farmers must dedicate their time and labour to implementing the technology since it is time and labour intensive. The study of Bunclark and Lankford (2010) found that an important factor affecting the adoption of IRWH technology in Botswana was the reluctance of farmers to dedicate their time and labour to implementing the systems.

The results of Joseph and Botha (2012) showed that one of the conditions for the success of IRWH technique is the willingness by resource users (farmers) to accept it. Among other issues, chances of acceptance of new technologies are much greater if new production techniques are developed with adequate involvement of resource users (Baumüller, 2012). Furthermore, when a context is created in which the level of skills of community members and the organisational capacity of communities can be improved to allow their effective management of the techniques (Joseph and Botha, 2012). It should be recognised that success in the promotion of IRWH technique requires an understanding of priorities and concerns of smallholder farmers (Badisa, 2011).

Botha *et al.* (2007) also indicated that for the successful adoption and implementation of IRWH technology, local institutions and organisations need to be in place. These institutions may not give attention to natural resources. Some of these may not be functioning up to the required standard for the sustainability of agricultural development, more specifically in the rural context. These local institutions may include land access and land management, market access and flow of marketing information, risks of possibility of failure (insurance), agricultural extension services and training for capacity building, credit facilities for resource users, associations, co-operatives and extensive participation and networking with other decision makers and institutions (Botha *et al.*, 2007). If these conditions are to be followed there is a likelihood of receiving greater benefits from this technology.

2.6 Benefits associated with the adoption of IRWH technology

Some studies have not found significant benefits emanating from some of the IRWH practices. Hatibu *et al*. (2006) investigated the effects of modified cropping system for maize, which aims to reduce drought risk through IRWH technology. $IRWH_{Mulch}$ technology resulted in more benefits compared to cultivation without rainwater conservation techniques. The study, however, only considered the effects of IRWH on maize and therefore, it is difficult to tell if it will give similar results if applied to other crops.

Van der Horst (2013) who attempted to assess a socio-technical feasibility study for an irrigation system in Guquka village in the EC maintained that there is more economic benefit in retaining run-off upstream by implementing IRWH technology than to let it flow downstream, then store it and use it for irrigation.

Botha *et al.* (2005) examined bio-physical requirements and socio-economic acceptance of IRWH and conservation in the semi-arid central region of South Africa. It was concluded that IRWH technique is socially acceptable because it increases income, promotes education, improves social well-being, improves health status, reduces crime and increases crop diversity. Baiphethi *et al.* (2009) evaluated rural women and IRWH technology and conservation; anecdotal evidence from the Free State and EC Provinces. It was reported that benefits such as an increase in production yield, generation of income, improving food security can be achieved through IRWH technique. These are the benefits that this section focuses on.

2.6.1 Increased production yield

Pretty *et al*. (2003) examined the extent to which farmers have improved food production with low cost, locally available and environmentally sound practices. In the study, 208 projects in 52 developing countries selected from Africa, Asia and Latin America were analysed. It was reported that, for the projects with reliable data, over 90% increase in yields per ha were detected owing to improvements in water productivity and improvements in soil conditions which included IRWH technique.

Fox and Rockstrom (2000) investigated the effect of IRWH technology for supplementary irrigation of cereal crops to overcome intra-seasonal dry-spells in the Sahel. The on-farm study demonstrated that supplementary irrigation during dry-spells increased sorghum harvests by 14%. The study by Hatibu *et al.* (2006) in East Africa concluded that IRWH technology increases yields on high drought risk soils by reducing run-off to zero and increasing infiltration rate of rainfall. Woyessa *et al.* (2006) highlighted that this technology was developed to reduce the risk of crop failures in order to increase agricultural production by using water efficiently.

It has been proven in Zimbabwe that farmers practicing IRWH technology enjoy increased yields of 2 to 3 harvests in a planting season (Unganai, 2005). In turn, maize yield increased from 0.55 t/ha to 1.1t/ha and that of sorghum increased from 0.56t/ha to 5 t/ha (Unganai, 2005). Botha *et al.* (2005) evaluated the agronomic sustainability of the IRWH technique in South Africa. It was concluded that IRWH technique contributed to higher crop yields than CON because it stops run-off and minimises soil evaporation losses. Also a research that was conducted by ARC and its partners at ThabaNchu in 2001 has shown that practice of IRWH technique led to maize yields increasing by up to 50%, compared with conventional production techniques. It was explained that yield advantages could be attributed to the total stoppage of run-off and reduction of evaporation from the soil, supplying more water for transpiration (ARC, 2001). The enhancement of in-field run-off towards the basin induces water availability to the crops thereby increasing rainwater productivity significantly (Baiphethi *et al*., 2006).

Several studies have been carried out with an aim of determining the potential of IRWH technology to improve land productivity (Bunclark and Lankford, 2010; Mwenge, 2011). Reports based on smallholder farmers' opinions show that application of water and soil conservation in Ethiopia, Zimbabwe, Kwa-Zulu Natal and EC has rehabilitated degraded land and increased cereal (i.e. sorghum and millet and maize) yields, thus improving household wealth (Mwenge, 2011).

According to Hlanganise (2010) in the EC, the use of mulch in the basins significantly reduced evaporation, contributing to the increase in yield by 30 to 50% on average, compared to production under CON. It was also revealed by Monde and Aliber (2007) that in the EC, run-off and soil loss from the cropland were reduced to zero when using IRWH technique thus, production yield increased.

2.6.2 Generation of income

Mutekwa and Kusangaya (2006) investigated the contribution of IRWH technology to rural livelihoods in Zimbabwe. The on-farm study confirmed that about 75.8% of the IRWH adopters indicated that they depend on farming as the main source of income. For example, 89% of the IRWH adopters indicated that they were now able to grow at least two crops on a rotational basis in one calendar year, which is evidence that the smallholder farmers were intensively utilising their land. Further, farm productivity increased to the extent that some smallholder farmers were able to sell some of the main food crops they used to produce in quantities that could not even meet family requirements in the past. The basic food crops like maize and ground-nuts were produced in quantities that met not only household food requirements, but produced a surplus that could be sold. The IRWH adopters can afford to sell an average of about 2 061 kg and keep an average about 891 kg for household consumption of the maize produced. Furthermore, and related to the same matter, Moyo and Nyimo (2006) confirmed that smallholder farmers in Zimbabwe were selling their surplus of agricultural produce to well-paid markets in Zvishavane and other surrounding places. This led to their levels of income to substantially increase.

A study by Botha *et al.* (2005) on IRWH technology for homestead backyard gardens in South Africa demonstrated that profitability analysis using enterprise budgets revealed that a significant increase in farm income is realised when farmers adopt the IRWH technology compared to the income levels achieved under conventional crop cultivation. By adopting the simplest form of IRWH technology without the use of mulches in the basins and run-off area, farmers can increase their income by about R800.00 per ha in the case of maize production. An analysis of on-station production data suggested that farm income could be increased further with the use of organic or stone mulches.

Phahlane (2007) evaluated market constraints and opportunities for the sustainable adoption of IRWH in ThabaNchu. The results showed that its application in home gardens could produce significant surpluses above household consumption needs. As a result, such surpluses would be commonly marketed in the villages (to other villagers) and through street vending in ThabaNchu town. Through practice of the IRWH technique, home garden producers in the EC produced enough to meet family financial needs such as school fees, medical bills and household expenses (Backeberg, 2009). Hlanganise (2010) and Botha *et al.* (2013) also reported that, the money received by farmers in Khayalethu, Guquka and Krwakrwa villages was used to buy meat, pay school fees and even buy furniture.

2.6.3 Improving food security

Food security has been defined by a number of scholars throughout the years. Household food security has been defined as "access by all people at all times to enough food for an active, healthy and productive life" (World bank, 1986; FAO, 1990; Hoddinott, 1999; von Braun, 2007; Monde *et al.*, 2012). FAO (2008) adds that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". FAO's (2008) contribution to the World Bank's definition is that food security does not only include the ready availability of enough food, but also nutritionally adequate and safe foods, and an assured ability to acquire acceptable foods in socially acceptable ways. According to Monde (2003) in the past, the assessment of household food security was based on food supply. As a result, a decrease in food supply was regarded as the only cause of household food insecurity. More recent views state that, food insecurity should not be seen as a problem of inadequate food supply only, but also as a problem of inadequate purchasing power (Mensah *et al*., 2013). In the context of this study, the definition of food security by FAO (2008) was adapted. IRWH technology is said to improve household food security (Mutekwa and Kusangaya, 2006; Hlanganise, 2010; Botha *et al.*, 2013).

It was evidenced by Woyessa *et al.* (2006) that it would be a wise catchment management decision to allow maize production using the IRWH technique to be developed in the Upper and Middle Modder River Basin in South Africa. This was the case because among the communal farmers, a family of five needs about 1ton of maize per annum to supply their staple food. Therefore, the estimated maize production on the approximately 15 000ha of the IRWH suitable land in the communal farming area within the Upper and Middle Modder River Basin would be sufficient to supply the staple food for about 25 500 families or 127 000 people.

According to ARC (2001) this technique enhances the ability of the household to produce its own food on backyard gardens, resulting in a stable food supply. Baiphethi and Jacobs (2009) concluded on their study that IRWH technology increases household food security and reduces reliance on cash to feed the household thus releasing cash for other household uses. Baiphethi *et al.* (2010) also reported that, increased production under IRWH technology reduces households' dependence on market sourced vegetables. This is because they produce more vegetables in their home gardens.

Since IRWH technology has had considerable success in ThabaNchu, it contributed to the increased agricultural productivity, hence food was available and accessible all year round

(Baiphethi *et al.*, 2009). Agro-hydrological studies of IRWH technique in the same area, suggest that it is an agronomic sustainable crop production tool that can be used to improve rural livelihood by reducing the level of food insecurity (Botha *et al*., 2003; Botha *et al*., 2005).

Also the results from Hlanganise (2010) research project conducted in the EC showed that 96% of project members felt that they were better off since the introduction of the IRWH technology in 2004. This has enabled them to afford three to four meals a day which was not the case in the past. Botha (2005) also argued that the practice of IRWH technology in some villages in the EC has resulted in an increased level of household food security. This has been done by means of maize and vegetable production in homestead backyard gardens.

2.6.4 Improving nutritional status

At a smallholder farm level, IRWH technique improves productivity growth hence, increases rural income and food availability, which enables improvements in diet as concluded by the study of Amha (2006) on impacting assessment of rainwater harvesting ponds in Ethiopia. A study conducted by Baiphethi *et al.* (2006) revealed that, the intake of essential nutrients (iron, energy, protein, vitamin A and C) by project members was much better compared to that of the non-project members in the Free State Province. In addition, from the findings of Hlanganise (2010) it was concluded that the IRWH technology has a potential to address nutritional problems in the Eastern Cape's rural areas. Hlanganise (2010) also reported that, project members indicated that their quality of diet has improved since the introduction of the IRWH project. This was so, because they managed to produce maize, beans, cabbage, carrot, tomatoes, beetroot and spinach as well as new vegetables such as cauliflower, broccoli, turnips and green pepper. Similarly, Monde (2003) on the study of household food security in rural areas of the central EC highlighted that increased agricultural productivity through IRWH technology improved nutrition. This could be done by generating more income to buy more nutritious food, obtain healthcare and by increasing consumption from ones' own production.

The above-mentioned benefits may be influenced by a number of factors which are explained in the following section.

2.7 Factors influencing the adoption of IRWH technology in enhancing household food security

Many IRWH technology adoption studies have been carried out in South Africa (Botha *et al.*, 2007; Monde and Aliber, 2007; Baiphethi *et al.*, 2009; Badisa, 2011; Monde *et al.*, 2012). They concluded that the importance of factors affecting the IRWH technology differs across regions due to differences in natural resources, cultural and political ideologies, socio-economic, technical, policy and institutional factors.

Shikur and Beshah (2012) have pointed out that the factors that significantly influence the adoption of RWH technologies positively were labour availability in man equivalent, indigenous RWH experience of the household, farm size of the household head, total tropical livestock unit owned, sex of the household head, off-farm income of the household head, training in areas of RWH, perception of farmers towards security of land ownership and extension service in areas of RWH. On the other hand, they observed that distance to market from the residence negatively influenced adoption.

Ahmed *et al*. (2013) have found that the education level, experience of water shortage, awareness of RWH techniques and the age of farmers had a positive bearing on the adoption of RWH techniques whereas farm size and source of income had negative significance.

Tesfay (2008) pointed out that despite the potentials of the IRWH technology for improving agricultural productivity and livelihoods, its adoption by the smallholder farmers is not satisfactory. The results indicated that poor capital and human endowment, lack of access to credit, involvement in off-farm activities, negative perception, gender issues, inaccessibility of construction materials, lack of technical know-how, poor water extraction and application methodologies are among the factors that negatively influenced the adoption of IRWH technology. It was concluded by suggesting that, creating awareness, providing technical and institutional support, promoting only technology with higher financial feasibility, timely supply of construction material, empowering female headed households and design as well as development of alternative policy instruments that are accountable to the farmers would help to improve the adoption of the technology.

Ngigi (2003) evaluated six rainwater harvesting case studies selected from Ethiopia, Kenya, Uganda and Tanzania. It was reported that despite success of RWH systems, their impacts remain little owing to low levels of adoption. The report, however, does not provide reasons as to why the rate of adoption of on-farm RWH technologies is low among smallholder farmers. Babatunde *et al*. (2007) pointed out that in most rural communities in South Africa major household decisions like whether or not to participate in community activities are made by the household head often with the input of the spouse. Babatunde *et al.* (2007) further noted that household head attributes such as age, gender and occupation are important factors in analysing the adoption decisions of agricultural technologies. This research seeks to take the same approach; it will analyse and investigate the demographics, economic as well as institutional factors with a view to establishing how they impact on IRWH technology for the purpose of enhancing household food security.

2.7.1 Age of the household head

Age is a factor that is often taken into account when determining adoption willingness of agricultural technologies in many studies**.** Literature puts forward contrasting arguments on how age impacts on the adoption of agricultural technologies. A study by Murgor *et al.* (2013) on factors influencing farmers' decision to adapt RWH techniques in Kenya has found that young farmers are always ready to take risks and adopt expensive, but effective agricultural technologies in order to enhance their food security status. On the other hand, older famers are more traditionalist and not keen to take risks hence a likelihood of being food insecure. Monde (2005) evaluated the sustainable techniques and practices for RWH technologies in Khayalethu and Guquka villages in the EC concluded that age has a negative effect on the willingness to adopt technology or innovations. However, Kai (2011) revealed that age is not a significant factor in the adoption decision.

Since adoption of RWH technologies pay-offs occur over a long period of time, while costs occur in the earlier phases, age of the farmer can have a deep effect on technology adoption. Monde *et al.* (2012) revealed that the probability of adoption of the IRWH technology increased with age among smallholder farmers in the EC. Similarly Ngwenya (2013) focusing on factors affecting rural farming households' willingness to participate in a proposed irrigation scheme in

Guquka in the EC established that 30% of the adopters were over 60 years of age. This can reduce their interest in the IRWH technology because of the smallholder farmers' advanced age and the possibility of not living long enough to enjoy it. For example in the EC, Baiphethi *et al*. (2009) found that elderly farmers often have different goals other than income maximisation, in which case, they did not adopt an income enhancing technology which in this case is IRWH technology.

2.7.2 Gender of the household head

There are several empirical studies that have been conducted on the effect of gender to RWH technologies adoption. Hatibu *et al*. (2006) found no significant association between gender and the adoption of RWH technologies for crop enterprises among rural farmers in East Africa. Shikur and Beshah (2012) revealed that the adoption of IRWH technology among poor households in Ethiopia is gender-neutral. Gebregziabher *et al.* (2013) have indicated that male headed households have a comparative advantage in the adoption of rainwater management technologies in the Blue Nile River Basin. The results of Joseph and Botha (2012) also disclosed that male headed households are more likely to adopt IRWH technology compared to female headed households. While this is in agreement with the findings of Botha (2005), Kalineza *et al.* (2008) reported that female headed households are more likely to adopt sustainable agricultural technologies in Tanzania. Although the impact of gender on technology adoption is likely to be technology-specific and generalisation is not possible (Kalineza *et al.*, 2008). Also Monde *et al.* (2012) in Nkonkobe Municipality in the EC found that the majority (60%) of smallholder farmers who adopted IRWH technology were women.

Baiphethi *et al.* (2009) in the EC established that male farmers tend to adopt IRWH technology than female farmers. The main reason advanced was that IRWH technology is very time consuming. The other argument is that, constraints to women adopting technology include socially conditioned inequalities in the access, use and control of resources and credit. Also women do not access technical training because they are busy with house chores (Baiphethi *et al*., 2009). According to Gebregziabher *et al.* (2013) most of the agricultural work is typically undertaken by men, while women are usually restricted to household and backyard activities. This suggests that men are more likely to have better farming experience than women.

2.7.3 Education level of the household head

According to Murgor *et al.* (2013) education can change the behaviour of smallholder farmers regarding their attitude and awareness towards a new agriculture technique. Thus, the more educated the smallholder farmer, the higher the chances of adopting the IRWH technology which increases the likelihood of being food secure (He *et al.*, 2007). In that sense, one's educational level influences the adoption of IRWH technology in enhancing such individual's food security status positively.

As put forward by ARC (2001) education is associated with adoption because it is believed to increase smallholder farmers' ability to obtain and analyse information that helps him/her to make appropriate decisions. Similarly, Moyo and Nyimo (2006) as well as Ngwenya (2013) indicated positive relationship between education and adoption of RWH technologies. Mutekwa and Kusangaya (2006) also indicated that education enhances the adoption of IRWH technology positively. On the contrary, a study conducted by Monde and Aliber (2007) in the EC, revealed that education had no significant effect on the adoption of IRWH technique. Households with more educated members are likely to have better access to information and are more aware about the merits and demerits of the technologies. They are also able to interpret new information to make knowledge-based decisions in favour of the appropriate/suitable technologies (Amha, 2006). On the other hand, households with more educated members may be less likely to invest in labour intensive technologies and practices because they are more likely to earn higher returns from their labour and capital investment through other activities (ARC, 2001). For instance, van der Horst (2013) has found that more educated farmers did not adopt any irrigation system in Guquka in the EC.

2.7.4 Household size

Household size can influence adoption of technologies negatively or positively because household size is associated with availability of household labour supply (Kai, 2011). IRWH technology is labour intensive. Therefore, family labour availability in elderly equivalent positively influenced the adoption of IRWH technology and the likelihood of being food secure as it relieved the labour constraint faced by most smallholder farmers in the Limpopo Province (Badisa, 2011). Kalineza *et al*. (2008) reported that large households have the capacity to relax the labour constraints required during technology adoption. According to Gebregziabher *et al*. (2013) it is expected that a larger household size will affect positively the decision of adopting RWH technologies. The experience in the EC (Monde, 2003; Monde and Aliber 2007; Baiphethi *et al*., 2009; Monde *et al*., 2012) shows that family size in adult equivalent has a positive and significant effect on the adoption of IRWH technology.

According to Backeberg (2009) construction and maintenance of the IRWH technology normally requires lot of labour. The reasons for this are that, the structure needs to be constructed on an annual basis (Alem, 2001). Also the catchment area has to be maintained to free vegetation (Woyessa *et al.,* 2006). In addition, Bunclark and Lankford (2010) noted that the structure of IRWH technique needs to be repaired after heavy storms because it involves earth ridges which are easily disturbed. Therefore, families with a few numbers of their members working in farm are likely to be non-adopters of this technology and may not expand to larger areas (Botha *et al.*, 2007).

2.7.5 Farmers' perception towards the IRWH technology

Farmer perception on the preferences for certain technology may influence his/her decision to adopt that technology. According to Amha (2006) perception for certain technology based on real experience or perceived characteristics influences the adoption of that technology. In the study of Gebregziabher *et al.* (2013) farmers' positive attitude towards RWH techniques had a positive effect on the adoption of the techniques. A majority of the smallholder farmers who adopted the technologies revealed that the IRWH technology is essential for altering their livelihood. Those smallholder farmers who did not adopt the technology had a negative attitude about the technology. The results imply that respondent responsiveness to IRWH technology depends highly on the strength of this technology related attitude. Abera (2008) reported similar findings on compost adoption in Ethiopia. The findings of some empirical studies show that smallholder farmers with a generally positive attitude are eager to adopt IRWH technology (Botha, 2005; Kalineza *et al*., 2008; Shikur and Beshah, 2012).

In a study conducted by Monde *et al.* (2012) farmers' perceptions were described as a continuous variable and referred to the superiority of the technology in terms of its advantage and compatibility with smallholder farmers circumstances. According Monde *et al*. (2005) there are perceived benefits associated with the adoption of a technology that can translate into more resources being devoted to the technology. Farmer perception on increased production may increase the probability of the adoption of new technologies. This will lead to a higher demand of IRWH technology and a probability of being food secure (Kalineza *et al.,* 2008).

2.7.6 Farm income

Income earned through participation in agricultural activities improves farmers' financial capacity and increases the ability to adopt new technology (Baiphethi *et al*., 2010). IRWH technique improves soil fertility through the use of mulching and reduces production risk significantly (Backeberg, 2009). Therefore, higher yields will be obtained and sold as a result farmers' income is highly likely to increase. Most empirical studies have established that the effect of farm income on households' adoption of agricultural technologies decision is positive and significant. For example, in Ethiopia Shikur and Beshah (2012) found a positive significant relationship between farm income and adoption of the RWH technologies. A study by Ahmed *et al.* (2013) in Kenya has established that the level of household farm income has a positive and significant effect on the decision to adopt the RWH ponds. The finding suggested that farmers with financial endowment had a higher probability of adopting the RWH ponds because the financial resources enabled such farmers to meet the costs related to constructing the ponds.

According to Joseph and Botha (2012) both the rate and extent of the adoption of the IRWH technology are positively related to changes in the income from the technology in the Limpopo Province. This is the case because the existence of agricultural income sources could allow farmers to better manage the costs of some technologies such as fertiliser costs, labour and equipment. In KwaZulu-Natal, Baiyegunhi (2014) on the study of determinants of RWH technologies adoption for home gardening in Msinga, hypothesised farmers with more farm income to be innovators because they have more funds to acquire resources and invest in the technology. The study further found that the source of income for majority of farmers was the farm and about 53% of the farmers entirely depended on farming activities for survival and generation of income and/or depended on farming activities to supplement their main sources of income.

However Ngwenya (2013) highlighted that farm income may affect adoption positively or negatively depending on its' relative contribution to household income and/or farm profitability.

2.7.7 Household income

Total household incomes' effect on innovation adoption has been analysed by multiple studies as well (Amha, 2006; Bunclark and Lankford, 2010; Shikur and Beshah, 2012; Murgor *et al.*, 2013; Gebregziabher *et al*., 2013). Shikur and Beshah (2012) found that having household income that is low had a negative effect on the IRWH technology adoption. While Amha (2006) reported that, greater total household income had a positive effect on the adoption of IRWH technology. The study by Gebregziabher *et al*. (2013) showed that rich farmers and middle income households are more enthusiastic in adopting the RWH technologies than poor households. This is due to the fact that the financial inheritance of the rich and middle income households motivates them to take credit and invest in the RWH technologies. However, the poor households preferred either not to adopt the RWH techniques or adopt the less expensive category. Monde *et al*. (2012) found that household income had a positive effect on IRWH technology. According to Bunclark and Lankford (2010) households' access to alternative sources of income are likely to influence the adoption of rainwater management technologies in different ways. For example, those who have alternative sources of income are better in adopting and investing in IRWH technology. On the other hand, participation on other income-generating activities is likely to divert labour from on-farm activities and working on rainwater management technologies.

Past studies also suggests that household with higher incomes would be more likely to adopt IRWH technology and have a probability of being food secure than those with lower incomes, since the former would even hire labour if they were constrained in that direction (Gebregziabher *et al*., 2013).

2.7.8 Land tenure security

According to Baumüller (2012) a central factor affecting investment, production and conservation decisions is the smallholder farmer's level of control over his land. A smallholder farmer with secure tenure is much more likely to think of long term production and conservation activities than are sharecroppers or migrant labourers. For smallholder farmers to be able to carry out long or medium term investment, they require security of tenure (Pote, 2008). Thus, smallholder farmers who are land secure are willing to learn and take the essential measures which enhance production and productivity (White, 2012). In addition, they are likely to adopt RWH technologies to enhance their food security status.

Land ownership is a factor that has been analysed by various studies (Pote, 2008; Woyessa *et al.,* 2006; Woyessa *et al.,* 2007; Nhundu, 2010).The results have shown contradiction in its effects on the rate of adoption. These contradictions are thought to be due to the nature of the innovation being tied to the land, in the instance of switchgrass, it does not require land tied investments, as is the case for IRWH technology (Unganai, 2005). A study by Pote (2008) suggested that lack of tenure security discouraged smallholder farmers from making long-term, ecologically beneficial investments on their land in the EC.

2.7.9 Land size

According to Murgor *et al*. (2013) farm size can have different effects on the probability of adoption, depending on the characteristics of the technology and the institutional setting. Smallholder farmers with large farm sizes are likely to be able to take the risk of adopting new technology compared to smallholder farmers with small farm sizes (Woyessa *et al.,* 2007). On contrary, the study of Yengoh *et al*. (2010) in Ghana revealed that households with relatively large landholdings were able to diversify their crops and income sources, they were less susceptible to risks and shocks; as such, they were less interested in investing in rainwater management technologies as a coping mechanism. Interestingly, it was also found by van der Horst (2013) that smallholder farmers with small land size utilise the limited resources more efficiently and adopt new technologies at a faster rate.

The impact of land size on adoption of the IRWH technology as shown in a case study by Baiphethi *et al.* (2009) indicated that land size positively influences adoption, as smallholder farmers with a large land size generate more income. This provides a better capital base and enhances risk bearing ability and that smaller farms have little incentive to adopt new technologies compared to larger farmers who benefit from economies of scale. Badisa (2011) in the Limpopo Province found that the adoption of IRWH technology was higher on relatively large farms. As a result, smallholder farmers with larger plots were able to sell more produce and made more use of the technology. It was concluded that larger farms reduce transaction costs, which increases the economic advantage and incentives of new technologies as well as the possibility of being food secure.

2.7.10 Access to credit

Chisasa and Makina (2012) stated that, given the fact that a majority of smallholder farmers are resource-poor and unable to access credit, there will be a limitation to smallholder farmers' ability to adopt modern technologies because the costs of hiring labour, transportation of agricultural products and construction material are too high. According to the study of Gebregziabher *et al*. (2013) access to credit improved options to address liquidity constraints associated with investments in rainwater management technologies. Other studies also found that the lack of credit access limited the adoption of IRWH technology (Mutekwa and Kusangaya 2006; Baiphethi and Jacobs, 2009). Further, the lack of sufficient accumulated savings by smallholder farmers could prevent them from having the necessary capital for investing in new technologies which may limit their food security status (Kai, 2011).

2.7.11 Access to infrastructure

Most scholars pointed out that access to infrastructure is an important factor on deciding whether or not to adopt new agricultural technologies (Baiyegunhi, 2014). However rural communities often lack access to storage facilities and markets because of poor roads. This invariably leads to low rates of the adoption of IRWH technology and the likelihood of being food insecure (Woyessa *et al.,* 2007).

Gebregziabher *et al*. (2013) used the walking distance (in minutes) as a proxy of access to markets. Therefore, the study hypothesised that the longer the walking distance to markets the less likely it is that households will adopt a particular RWH technology. The empirical results proved this hypothesis to be correct as it was found that improved access to markets have the potential to increase farmers' adoption of rainwater management technologies. Alem (2001) reported that a commonly cited challenge for IRWH technology by smallholder farmers in Ethiopia is the unavailability of markets to dispose their surplus produce. Baiphethi *et al*. (2006) concluded that in the Free State Province informal markets were easily over supplied, mainly by similar products being produced and marketed at the same time, thus leading to a fall in prices and profits. Furthermore, it was also noted by WRC (2007) that in the EC the main challenge identified by smallholder farmers was the poor market access for their produce after a good harvest. WRC (2007) further stated that this was compounded by the fact that the community market was too small to absorb all the surplus produce from IRWH farmers. Therefore, Hlanganise (2010) suggested that there is need to identify the market before the choice of produce for IRWH technique. As put forward by Murgor *et al.* (2013) distance to market as the determinant for adoption of IRWH technology indicates that the adoption process does not depend only on smallholder farmers' willingness but also on an overall sustainable rural development. Therefore there is a great need to emphasise the importance of infrastructure particularly road networks and communication services.

According to Phahlane (2007) a lack of financial resources was also found to lead to an inability to purchase fencing material to protect crops from being damaged by livestock. As a result, not having a fence around croplands to prevent animals from entering the fields is an important challenge for smallholder farmers (Botha *et al.*, 2007). Moreover, lack of fence reduced the adoption of IRWH technology by smallholder farmers in Limpopo Province, as the risk of crop damage remained too great (Badisa, 2011). Smallholder farmers in the EC also encountered crop theft as a result of lack of fencing (Hlanganise, 2010).

2.7.12 Access to extension services and information

According to Badisa (2011) access to information on IRWH technology is important for smallholder farmers to adopt the technology. The more the information smallholder farmers get the higher the probability of adopting the IRWH technology. This means that the smallholder farmers' education alone might not have a great influence on the smallholder farmers' decision in deciding whether or not to establish IRWH technology. Therefore smallholder farmers must rely more on the extension officer for information on such technologies. Such contacts are helpful in the early stages of technology experimentation. Access to information positively influenced the adoption of IRWH technology in the study of Badisa (2011).

Contact with extension officers allows smallholder farmers to have a greater access to information on technology, through increased opportunities to participate in demonstration tests and thus increase smallholder farmers' ability to get, process and use the IRWH technology (Shikur and Beshah, 2012). Farmers who are knowledgeable in the IRWH technology are expected to adopt the technique compared to those that are not knowledgeable (Monde *et al.*, 2012). For example in the EC, smallholder farmers cited poor access to information and understanding of the IRWH technology as the problem which leads to a lesser likelihood of the adoption of the technology which may translate to food insecurity (Botha *et al.*, 2007). Botha *et al.* (2007) further emphasised the need for smallholder farmers to be trained more on the operation of the system as they had just recently started using the technique.

According to Backeberg (2009) farmers lack skills and knowledge on how to effectively utilise the IRWH production technique. Monde and Aliber (2007) also stated that, some of the smallholder farmers practicing IRWH technology in the EC's rural areas lacked the agricultural knowledge and expertise to maximise the benefits from the water that they collected. It has been suggested by Hlanganise (2010) that some of the implementation plans/designs may be too technical for users in the EC. Therefore, access to extension service and information influences the adoption of IRWH technology in improving household food security status.

2.7.13 Distance to other water sources

The IRWH technology is thought to be particularly suited to the application of supplemental irrigation in arid and semi-arid areas where yield losses are high due to moisture stress (Bunclark and Lankford, 2010). This decreases production risk therefore, the further away the other water sources for irrigation purposes the higher the adoption of IRWH technology and a likelihood of being food secure (Woyessa *et al.*, 2007).

2.7.14 Availability / reliability of rainfall

Moyo and Nyimo (2006) noted that the success of the IRWH technology is heavily dependent on the reliable seasonal rainfall. Monde *et al.* (2012) revealed that the mean annual rainfall is 571.01mm in Guquka, Khayalethu and Krwakrwa villages in the EC making rain-fed crop production possible. Although the mean annual rainfall is relatively high, the winter period is generally dry, with June and July as the driest months. One can expect only 7% of the total annual rainfall in these months, compared to roughly 70% in the months of October through

March. The unpredictable conditions of rainfall in these areas necessitate irrigation for successful agricultural production. As a result, during the dry season IRWH technology cannot be employed because of the lack of rainwater (ARC, 2001). On the other hand, if rainfall intensity is high and falls with more force on the soils surface, there will be reduced soil infiltration and more run-offs will be generated in fine textured soils (WRC, 2007). This will lead to lower production yields for smallholder farmers. Furthermore, there will be water logging problems during high rainfall periods which may cause irreversible damage to the structures of IRWH technique (Alem, 2001).Therefore, availability and reliability of rainfall influences the adoption of the IRWH technology in enhancing food security of smallholder farmers.

2.7.15 Steep slopes

Another important requirement to be considered in the implementation of IRWH technology for crop production is the slope of the area (Botha, 2005). This technique is not recommended for areas where the slope gradient is greater than 5 %, due to uneven distribution of run-off and large quantities of earthwork required (Baiphethi *et al*., 2010). Steeper slopes can allow rapid run-off of rainfall which will increase soil erosion. This will limit the benefits that a smallholder farmer can achieve from practicing the IRWH production technique. Gebregziabher *et al.* (2013) reported that slope constrained smallholder farmers from adopting the IRWH technology which in turn posed a threat on the probability of being food secure in the Nile River Basin in Colombo. The steepness or flatness of a plot affects the use of the IRWH technology. The deduction from the result of Gebregziabher *et al.* (2013) is that those users of the IRWH technology with plain (flat) slope have more ease to use the IRWH technology than farmers having steep land slope. This is in line with research the findings of Ngigi (2003) who concluded that, the nature of the slope largely determines the suitability of the run-off generation.

2.8 Summary

The decision to adopt a new agricultural technology involves an interrelated series of demographic, economic, social and institutional factors, such as age of the household head, gender of the household head, education level, household size, farm income, household income, land size, land tenure security, access to infrastructure, access to credit, access to extension services, access to information, distance to other water sources and farmers' perception towards the technology. Also, the decision involves characteristics of a technology, such as simplicity, visibility of results and low capital investment. Therefore technology adoption in general is not a once-off decision rather it is a stepwise decision made after carefully weighing opportunity costs at each point. There are five categories of adopters in a social system: innovators, early adopters, early majority, late majority and laggards.

In this study, smallholder farmers are defined as those farm households with an access to means of livelihoods in land relying primarily on family labour for farm production to produce for self-subsistence and often for market sale and that practice crop production in 0.1-10ha of land. Their main objective is to improve their household food security status. Studies discussed that smallholder farmers are linked to smallholder agriculture. Other studies argued that this smallholder agriculture does not improve household food security while others argued that it does.

Three types of RWH technologies reviewed in this study, includes DRWH, XRWH and IRWH. This study focused more on IRWH technology. This technology was first introduced at Khayalethu and Guquka villages in 2004 which took five years to be introduced and followed by Krwakrwa village in 2008 also took five years. The practice is mostly used in homestead gardens by smallholder farmers. IRWH technology can be explained as a technique that has the potential to reduce total run-off to zero and thus make more water available to plants. Therefore, a number of opportunities were reviewed from the various studies which proved that IRWH technique contributes to household food security. There is an agreement in all studies that the greatest opportunity availed by the IRWH technique is increased production yield, thus increased food and/or income for the household and their nutritional status.

CHAPTER 3

SELECTION AND DESCRIPTION OF THE STUDY AREAS

3.0 Introduction

This chapter outlines why study areas were selected as well as giving a brief description of the study areas. A description of the background information about Nkonkobe Municipality includes issues regarding climate, soils, governance, demographics, income levels, economic activities and infrastructural profile. As much as the description covers the entire geographical area which constitutes the Nkonkobe Municipality, specific reference to the study areas is made where necessary. The selection of the study area is discussed in the following section.

3.1 Selection of the study areas

The study was conducted in Khayalethu, Guquka and Krwakrwa villages in the EC. The EC was purposively selected because it is one of the three Provinces that practice IRWH technique in South Africa (Monde *et al*., 2012). Also Khayalethu, Guquka and Krwakrwa villages were selected for the purposes of this study because IRWH technology was introduced in 2004 and 2008 therefore factors that affect the adoption of this technology in these study areas needed to be investigated. These study areas are described below.

3.2 Description of the study areas

The villages are located close to a small town called Alice. They fall under the Nkonkobe Municipality. According to the Nkonkobe Municipality Spatial Development Framework Review (SDFR) (2010/11-2012/13) the municipality falls under the former Ciskei homeland and is named after the Winterberg mountain range. The municipality comprises of 141 suburbs, which are divided into 21 wards. Nkonkobe Municipality is mainly rural, incorporating the now disestablished Alice Transitional Local Council (TLC), Fort Beaufort TLC, Middledrift TLC, Hogsback Local Council (LC), Seymour TLC, Victoria East Transitional Rural Council (TRC), Fort Beaufort TRC, Mpofu TRC and Middledrift TRC (Vengayi, 2009). Fort Beaufort is the capital for Nkonkobe Municipality. It covers an area of 3 725 km^2 and accounts for 16% of the surface area of the Amathole District (Nkonkobe Municipality Integrated Development Plan (IDP), 2013/14).

These villages are located within the Tyhume Valley. The valley, which is traversed by the Tyhume River, is the home of the AmaKhuze Tribal Authority under Chief Mqalo. The villages lie just below the escarpment of the Amatola Mountains with the upper Tyhume River flowing past them. The Tyhume River acts as a border between Guquka and Khayalethu villages. Figure 3.1 shows the location of Khayalethu, Guquka and Krwakrwa villages in Nkonkobe Municipality.

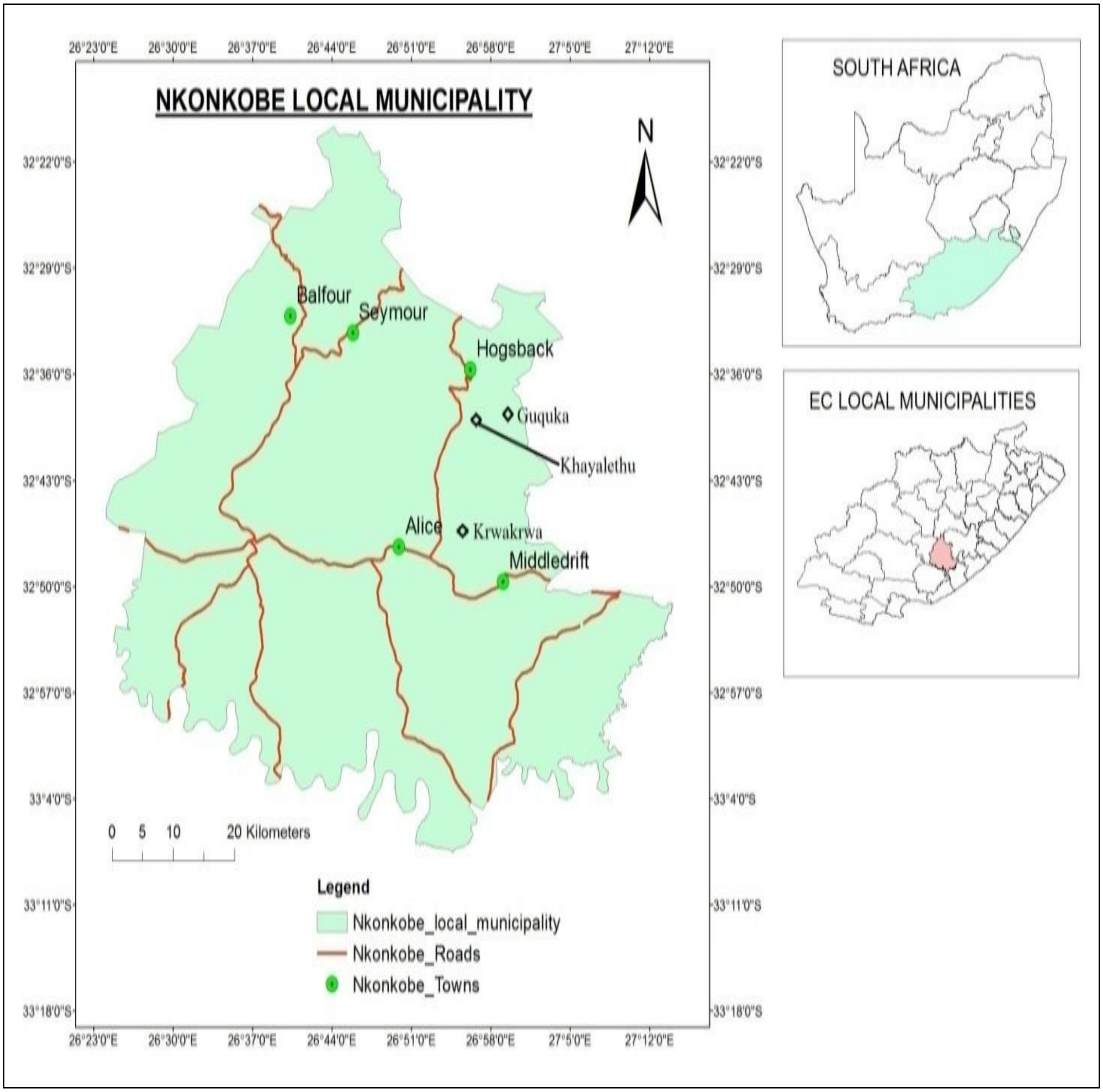

Figure 3.1 Map showing location of Khayalethu, Guquka and Krwakrwa villages in Nkonkobe Municipality
Source: South African explorer (2013)

The study areas were further described in terms of climate and rainfall, soils, governance, demographics, income levels, economic activities and infrastructural profile.

3.2.1 Climate and rainfall

Climate data was obtained from Honey Dale Farm Weather Station. Long-term climate data of Khayalethu, Guquka and Krwakrwa villages indicate that the areas are semi-arid with an aridity index of 0.35 (Monde *et al*., 2012). The mean annual precipitation for the study areas is 571.01mm. The study sites receive 69% of their annual rainfall between October and March. Over this region, the average number of hail events per annum is about two, usually occurring during late spring (November) (Monde *et al*., 2012). The maximum temperature is found in February at 28.58ºC and the minimum falling to 5.05ºC in July. Frost can be expected from 13 May lasting until 15 October (Monde *et al.*, 2012). Table 3.1 illustrates the average rainfall and temperature values for the study sites per month.

Table 3.1: Summarised climatic information 1979 - 2013

Month	Average Max T °C	Average Min T °C	Average Rainfall(mm	Evaporation A pan (mm)	Average Mean T°C
January	28.23	16.24	67.27	189.85	22.24
February	28.58	16.59	66.90	157.72	22.58
March	27.17	14.92	63.57	137.30	21.05
April	25.09	11.61	48.37	106.01	18.38
May	23.20	8.25	20.66	95.75	15.73
June	20.59	5.37	21.40	87.43	12.99
July	20.89	5.05	18.36	101.89	12.97
August	21.78	6.85	31.58	117.27	14.31
September	23.30	8.83	34.23	130.71	16.05
October	24.18	11.30	60.36	147.13	17.73
November	25.46	13.17	80.90	156.32	19.32
December	27.18	14.93	73.52	189.07	21.05
Total	__	__	571.01	1577.65	__

Source: Survey data (2013)

These areas are semi-arid with an average rainfall of 571.01mm and an average temperature that is above 18°C in some months. This makes them suitable for IRWH technology as discussed in

Section 2.5 and if households adopt this technology they will have a likelihood of being food secure.

Soils that were found in the study areas were discussed below.

3.2.2 Soils in the Khayalethu, Guquka and Krwakwra villages

A soil survey conducted by Monde *et al*. (2012) established the following soils to be found in the study areas: Cartref (Cf), Wasbank (Wa), Vilafontes (Vf), Oakleaf (Oa), Westleigh (We), Sepane (Se), Swartland (Sw), Valsrivier (Va) and Longlands (Lo). CF and Wa soils dominate and are not recommended for serious crop production due to their shallow to moderate depth. These soil types Vf, Oa, We, Sw, Se and Va are recommended for crop production especially if the IRWH technology and conservation techniques can be used (Monde *et al*., 2012). According to Monde *et al.* (2012) this is possible because their rooting depth ranges from 300mm to 1200mm and the minimum recommended rooting depth for the implementation of IRWH technology is 500mm as discussed in Section 2.5. This may promote the adoption of IRWH technology and a likelihood of being food secure.

The governance that operates in the study areas is highlighted in the following section.

3.2.3 Governance

In these three villages, chiefs are still leading in terms of governance (NDP, 2013). Whenever there is some activity including agricultural technologies like IRWH that will be implemented in the villages, it is of interest to bring in a chief by informing and explaining the objectives of that activity first. It is good because they will help in mobilising people for programmes related to introducing new agricultural technologies. This is a plausible development as people still listen and respect chiefs. This is the case because there is a general belief amongst traditionally rooted rural communities in South Africa that chiefs always want the livelihood of their people to be improved. This approach has the potential to assist in the adoption of IRWH technology which in turn will improve household food security in these areas.

The following section gives an overview of the demographics of the municipality.

3.2.4 Demographics

Demographics like population, age distribution, gender distribution, education level and unemployment will be discussed in this section.

3.2.4.1 Population

According to the Nkonkobe Municipality IDP (2013/14) the total population in Nkonkobe Municipality is 127 215, which represents 8.7% of the total population of Amathole District Municipality. Nkonkobe Municipality has 21 wards; and it is dominated by large population which is poor. This may serve as the reason why households opt not to adopt IRWH technology because of capital constraints and have a probability of being food insecure. The majority of the population (72%) resides in both villages and farms and 28% are located in urban dwellings. Urbanisation is mainly concentrated in Alice and Fort Beaufort.

The dominant races in Nkonkobe Municipality are Africans with 94.8% followed by the Coloured community with 4%, Whites with 1% and lastly by Indians or Asian with 0.2%, as illustrated in Figure 3.2 below (Nkonkobe Municipality IDP, 2013/14).

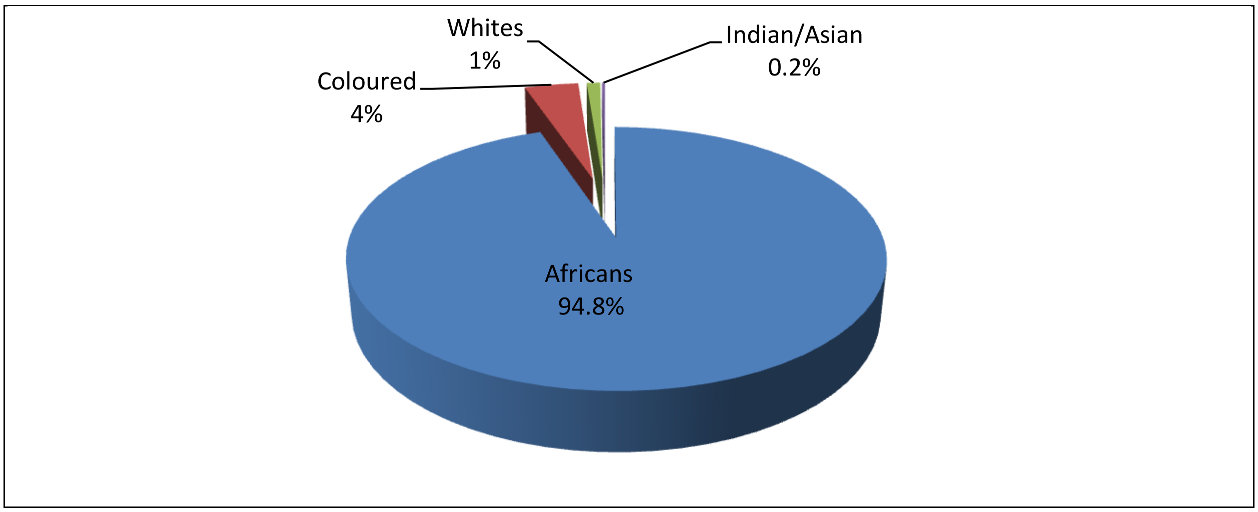

Figure 3.2: Population distributions by race
Source: Nkonkobe Municipality IDP (2013/14)

According to the NDP (2013) this municipality has an average population density of 35 persons per km^2. This suggests that the municipality is densely populated and those smallholder farmers practicing crop production, practice on a small pieces of land (Monde *et al*. 2012).This may lead to the low adoption of IRWH technology and a chance of being food insecure because households might produce for consumption (Murgor *et al,* 2013). The number of populations and households in Khayalethu, Guquka and Krwakrwa villages as well as their distance from Alice town is tabulated in Table 3.2 below.

Table 3.2: Number of population, households and distance from Alice town

Villages	Khayalethu	Guquka	Krwakrwa
Population	1278	1140	2400
Households	233	220	400
Distance from Alice town (Km)	25	30	15

Source: Monde *et al.* (2012)

The distances from Alice town indicate that households have to use some means of transport to get to the input and output markets. This could influence adoption the IRWH technology and household food security status negatively because of higher transaction costs.

3.2.4.1.1 Population growth rate

The population of Nkonkobe has moved from -2.0% in 1997 to -0.5% in 2011 (Nkonkobe Municipality SDFR, 2010/11–2012/13). Population growth slowed in 2001-2002 and the growth rate show signs of population growth at a decreasing rate. This decline in total population can be attributed to a drop in the birth rate coupled with an increase in the death rate, at a younger age (Nkonkobe Municipality IDP, 2013/14). Another factor that may have resulted in population decline is migration and this could result in a reduction in labour supply (Nkonkobe Municipality IDP, 2013/14). As a result this will possibly negatively impact on any attempts to adopt IRWH technology and a possibility of being food insecure because it is labour intensive.

3.2.4.2 Age distribution

The dominant age group consists of people below the age of 19 years by 21% (refer to Figure 3.3). This shows that the youth is dominant in Nkonkobe Municipality, in comparison to older people (Nkonkobe Municipality IDP, 2013/14). The Nkonkobe Municipality SDFR (2010/11–2012/13) noted that, of the current population, 18% consists of the pre-school and school going ages as shown in Figure 3.3 below.

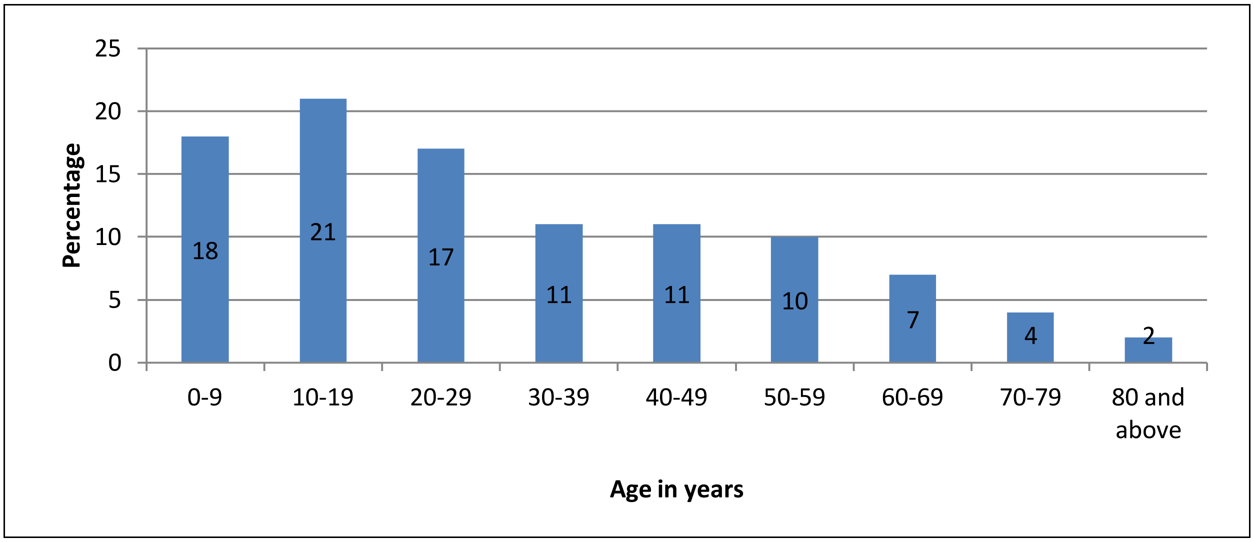

Figure 3.3: Age distribution in the Nkonkobe Municipality
Source: Nkonkobe Municipality IDP (2013/14)

Given that youth is dominant in the Nkonkobe Municipality; this may suggest that the adoption of IRWH technology may be low and the probability of being food insecure is high. This could be because youth of that age is still attending school and have different perception about agriculture such that their participation is low.

3.2.4.3 Gender distribution

According to the Nkonkobe Municipality IDP (2013/14) males constitute 48% and females constitute 52% of the municipality population. The Nkonkobe Municipality SDFR (2010/11–2012/13) noted that the reason for a lower number of males than females is that males tend to migrate to the mining sector as well as other industries in search of better employment opportunities. Therefore, this suggests that the adoption of IRWH technology maybe low with a likelihood of households being food insecure in the study areas. This might be the case because this technology requires lot of time and labour but women are usually constrained to household activities as noted by Gebregziabher *et al.* (2013).

3.2.4.4 Educational level

The educational level of communities in Nkonkobe Municipality has improved since 2008 when there was a low educational level with 19% of the population having no formal education. Only 8% had matriculation and 3% had matriculated with a post-matric qualification. In terms of literacy levels, people over 13 years of age had completed grade 7 (Nkonkobe Municipality SDFR, 2010/11–2012/13).

According to the Nkonkobe Municipality IDP (2013/14) the literacy rate has increased to 61.0% and which makes 39% of the Nkonkobe community illiterate. The high failure rates amongst students due to peer pressure and other environmental factors have influenced the education status of Nkonkobe Municipality. The high rate of literacy may be attributed to tertiary institutions in and around the Nkonkobe Municipality. Nkonkobe Municipality has 258 schools which have grown from 221 since 2008; this excludes tertiary institutions namely: University of Fort Hare, colleges (MSC, Lovedale, Fort Cox as well as Healdtown). The University of Fort Hare and Lovedale College are two institutions famous for being the cradle of South Africa's democracy.

In some areas within this municipality schools are located far from homes meaning that children have to travel long distances before reaching school. This puts the children's lives at risk. Schools lack libraries in order for children to study during breaks should they want to. Proper accommodation for school teachers is also a problem due to the nature of rural areas. Children are migrating to better schools like former Model C schools due to the quality of the education that is offered in rural schools (Nkonkobe Municipality IDP, 2013/14). There are problems that have been identified that influence education, and these are: failure amongst students due to poverty and unemployment, scarcity of teachers of essential subjects (e.g. science subjects), migration of learners to urban schools, shortage of buildings (infrastructure), poor roads that affect the transport of scholars as well as other issues (Nkonkobe Municipality IDP, 2013/14).

The improving of literacy levels in the Nkonkobe Municipality means that more people are becoming educated which makes the understanding of information about agricultural technologies better. This suggests higher chances of adopting IRWH technology and a likelihood of being food secure.

3.2.4.5 Unemployment

Nkonkobe Municipality has the highest unemployment rate in comparison to other municipalities that fall under the Amatole District. The unemployment rate has increased from

35% in 1996 to 57.8% in 2011 (Nkonkobe Municipality IDP, 2013/14). The Nkonkobe Municipality SDFR (2010/11–2012/13) noted that this municipality is faced with high unemployment as well as high poverty levels coupled by factors such as low income. This may lead to the low adoption rates of IRWH technology and a possibility of being food insecure. This might happen because households will not be able to buy inputs like fertilser, seeds or hire labour (Bunclark and Lankford, 2010).

3.2.5 Income levels

According to the Nkonkobe Municipality IDP (2013/14) about 70% of the people in the municipal area go to bed without an income at all. About 6531 people in Nkonkobe Municipality earn an amount between R401 and R800 per month. The income levels are extremely low and people without any income account for 74% of the population. A salary or wage less than R800 per month is of serious concern as it means that the disposable income is low and so is the consumers' spending power. This might contribute to a lesser likelihood of the adoption of agricultural technologies including IRWH and a possibility of being food insecure. This may limit smallholder farmers in buying inputs like fertiliser, seeds or hire labour therefore they could not invest in IRWH technology (Bunclark and Lankford, 2010).

The economic activities practiced in Nkonkobe Municipality were highlighted below.

3.2.6 Economic activities

In this section non-farm and agricultural activities are discussed.

3.2.6.1 Non- farm activities

Figure 3.4 shows the different contributions made by the various sectors to the Nkonkobe Municipality. There are ten different contributors to the Gross Domestic Product of Nkonkobe Municipality (Nkonkobe Municipality IDP, 2013/14). Community services like cleaning of towns, collection of refuse and other contribute more than the other sectors, meaning that the Nkonkobe Municipality is not dependent on government services since these services are characterised by not bringing any growth to the municipality's profit (Nkonkobe Municipality SDFR, 2010/11 –2012/13). There should be a focus on other sectors such as agriculture which will be discussed in the next section and manufacturing sectors which could be encouraged since they have a potential of bringing growth to the economy as well as creating a great deal of jobs (Nkonkobe Municipality IDP, 2013/14).

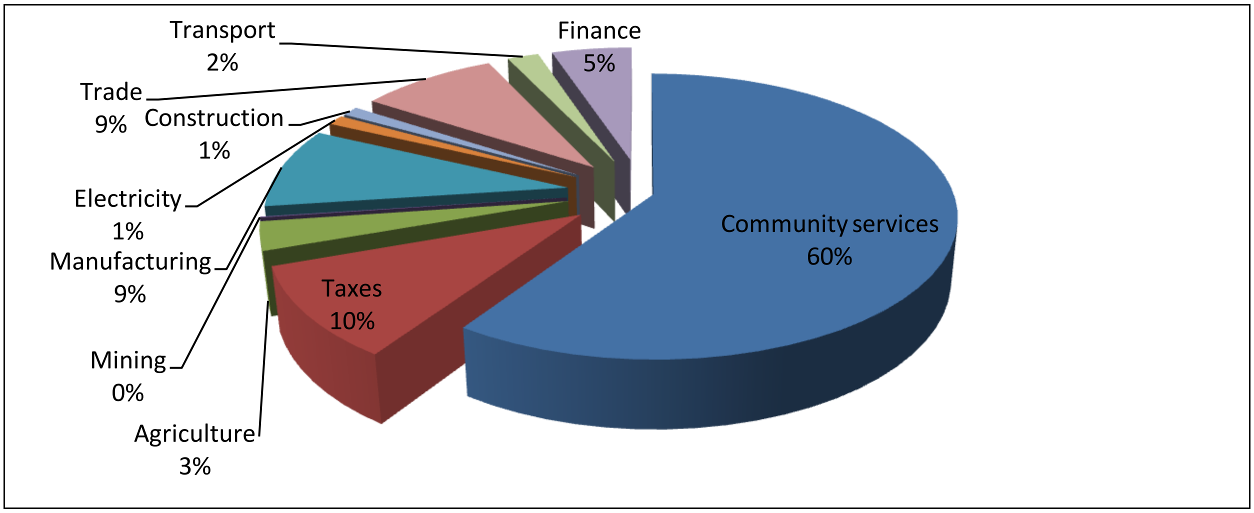

Figure 3.4: Sectors contributing to the Nkonkobe Municipality Gross Domestic Product
Source: Nkonkobe Municipality IDP (2013/14)

Since there is not much growth in the municipality's profit this may mean less formal jobs are created which contributes to low incomes (Nkonkobe Municipality IDP, 2013/14). This could imply that the adoption rates of IRWH technology may be low and a possibility of being food insecure amongst the households because they lack collateral in order to access credit to buy inputs (Badisa, 2011).

3.2.6.2 Agriculture

Nkonkobe Municipality is a place which has diverse climatic conditions that allow various agricultural enterprises to be practiced. The main enterprises within the region are citrus, livestock (cattle, sheep and wool production) and irrigation schemes (Nkonkobe Municipality IDP, 2013/14). There are agricultural projects such as Siyazondla, Comprehensive Agricultural Support Programme (CASP), Citrus production and the King Sandile Development Trust project (KSDT) that have had a significant positive impact on the development of areas of the Nkonkobe Municipality. These projects benefit a large number of communities in various wards of the Municipality who were poverty stricken and have a great deal of unemployment (Nkonkobe Municipality IDP, 2013/14). Siyazondla is a project that allows households to have access to and consume fresh vegetables from their home gardens and to sell the surplus produce to the surrounding communities at low costs. In the 21 wards that Nkonkobe Municipality has, only 16 Municipal wards are beneficiaries with 15 households per ward receiving the funding. There is a CASP project that is under land reform. This project has beneficiaries which causes the CASP project to have an economic impact to the Nkonkobe Municipality (Nkonkobe Municipality IDP, 2013/14).

In the Nkonkobe Municipality, there is a cattle production scheme with five Land Redistribution for Agriculture Development (LRAD) projects. There are a number of communal projects and a number of commonages. These commonages are farms which the beneficiaries get from the LRAD (The Department of Land Affairs) whereby they receive 12 Nguni bulls for livestock improvement. The Katberg river basin is noted for its agricultural potential, with favourable soils and an adequate water supply. It can be suitable for irrigation crop production and the production of high quality citrus. Citrus is a major contributor to economic development in the Nkonkobe Municipality which employs seasonal as well as permanent workers. Paprika, olives and essential oils are some of the crops that have been identified to be grown in some parts of this municipal area (Nkonkobe Municipality IDP, 2013/14).

As agricultural activities like the planting of vegetables are practiced in the municipality, the adoption of IRWH technology is likely to be promoted. It may be promoted because this technology enables crop cultivation during dry seasons, which allows households to have more diverse food all year round. As a result their household food security maybe enhanced.

The description of the infrastructural profile found in Nkonkobe Municipality is given below.

3.2.7 Infrastructural profile

Five types of economic infrastructure are considered below (water, roads, fencing, storage and telecommunications).

3.2.7.1 Water

Water supply is inadequate in most Nkonkobe Municipality areas; especially rural areas lack water more than the urban areas (Nkonkobe Municipality IDP, 2013/14). NDP (2013) reviewed that about 26.27% of people in the Nkonkobe Municipality rely on natural sources and 45.87% rely on public tap water. There is an uneven development and insufficient dams in the region.

This has implications on health and leads to hygiene problems (Nkonkobe Municipality SDFR, 2010/11–2012/13).

The insufficiency of water supply in rural areas of the Nkonkobe Municipality may mean less water for irrigation using sprinkler or drip irrigation and possibly lead to the adoption of IRWH technology and improvements in household food security because households can use the IRWH technique to irrigate their crops.

3.2.7.2 Roads

The Nkonkobe Municipality SDFR (2010/11–2012/13) indicated that the Nkonkobe Municipality has 19282km of paved roads and 1424.63km unpaved roads. The main tarred roads run in a north-south direction through Seymour and Fort Beaufort and an east-west direction through Fort Beaufort, Alice and Middledrift. These routes are of strategic importance because they link places of economic activities. However the existing road network expansion, especially in the rural parts, is in a poor condition. There is 88% of backlog in the Nkonkobe Municipality in terms of roads. Therefore, there is significant reliance on the Department of Roads and Transport for funding in order to address the backlog issue (NDP, 2013).

Given that the road network in rural part of the Nkonkobe Municipality is in a poor condition, this may imply less accessibility to the input and output markets, hence, a low adoption of IRWH technology and a likelihood of being food insecure (Murgor *et al*., 2013).

3.2.7.3 Fencing

In Khayalethu, Guquka and Krwakrwa villages, fencing is a problem as stated by Monde *et al.* (2012). As a result, the adoption of IRWH technology might be limited because of the theft problem and livestock damaging the crops which may lead to food insecurity (Phahlane, 2007).

3.2.7.4 Storage

According to Monde *et al.* (2012) the only form of storage facility some of the households own in Khayalethu, Guquka and Krwakrwa villages is an old rainwater tank. They only store dry maize as a result they produce other perishable vegetables for consumption. This could put a restriction on the adoption of the IRWH technology and household food security (Murgor *et al*., 2013).

3.2.7.5 Telecommunications

Both urban and rural settlements have a wide access to cell phones but there is inadequacy on the part of the municipality with regards to cell phone networks in some rural areas (Nkonkobe Municipality SDFR, 2010/11–2012/13). The wider access to cell phones will enable farmers to contact extension officers, other stakeholders or each other more frequently. This might enable an easy information access about IRWH technology and markets (Botha *et al*., 2007). This may promote the adoption of the technology and a possibility of being food secure.

3.3 Summary

This chapter has given the reasons for choosing the study areas and also offered a brief description of the study areas. It has outlined and explained the physical aspects such as agro-ecological characteristics (climate and soils) as well as governance, demographics, income levels and infrastructural profile. Non-farm activities and agricultural production or economy of the study areas reflected the dominant types of enterprise offered. This is helpful in understanding the characteristics of the study areas that are important in the interpretations of the research outcomes from this study.

CHAPTER 4
RESEARCH METHODOLOGY

4.0 Introduction

This chapter presents the research methodologies employed in this study, where it summarises research methods applied in the identification of factors determining the adoption of IRWH technology for enhancing household food security. It describes the research design as well as the sampling method employed. It also explains how data was collected and analysed. The theoretical and conceptual framework of this study is also outlined. Research design used in this study is described below.

4.1 Research Design

This study employed a cross-sectional design. Data was collected at a single point in time on several variables such as demographics and household socio-economic factors influencing the adoption of IRWH technology in relation to household food security. Only a subset to represent the population therefore was selected. Both qualitative and quantitative data was gathered on demographics and household socio-economic issues. A qualitative analysis examination (non-numerical) was performed, for the purposes of discovering underlying meanings and relationships (Bless *et al*., 2011).Quantitative analysis (numerical representation) was performed for the purposes of describing and explaining the phenomena that are reflected by the data (Babbie and Mouton, 2006).

Information regarding socio-economic factors influencing the adoption of the IRWH technology for enhancing household food security was acquired using a semi-structured questionnaire. In addition to the questionnaire, another source of information was ARC in which the information was gathered using secondary data. The study was carried out in two phases: orientation and a survey in the 2013 farming season.

4.1.1 The orientation stage

The orientation stage involved a visit to the study areas in August 2013. The main aim of this stage was to be introduced to the community leadership and familiarise with the study areas.

The objectives of the study were outlined to the community leadership with the help of an agricultural extension official. The date for the second visit was set during the first visit so that the researcher could be introduced to the community at large and to outline the objectives of the study to them.

4.1.2 The survey stage

The second stage was the actual survey being conducted where data was collected in September 2013 and ethical issues were taken into consideration when collecting data. Permission to enter to the community was obtained from the chief and the ward officer. They were informed about the research. Recruited participants were told about the research objectives. Permission was obtained from the households to participate in the survey.

The households were assured that the information obtained would be treated as confidential, that the results would be used for research purposes and may be used to develop policy guidance that may be used in IRWH technology. The study also took into consideration the culture and the norms of the households because the questionnaire was structured in a way that does not offend the households and no households were forced to participate in answering the questionnaire. There were no unnecessary personal questions asked.

A semi-structured questionnaire was used to interview respondents as a data collection instrument for the study. In order to be able to carry out interviews the unit of analysis was identified which is discussed below.

4.2 Unit of analysis

The unit of analysis is the major entity that is analysed in a study (Bless *et al*., 2011). It could be any of the following: individuals, groups, artifacts (books, photos, newspapers), geographical units (town, census tract, state) and social interactions. In this study, individual smallholder farmers practicing agriculture in the study areas were the units of analysis and hence provided primary data. The respondents were selected from Khayalethu, Guquka and Krwakrwa villages in which a sampling frame was developed.

4.3 Sampling frame

Bless *et al.* (2011) define a sampling frame as a list of all units from which a sample is to be drawn. Not all smallholder farmers in the study areas were selected for the study; but a sample was drawn. For the sample to best represent the total population, a complete frame was employed by selecting smallholder farmers practicing agriculture based on their willingness to participate. A procedure that was used to select respondents will be discussed in the next section.

4.4 Sampling procedure

Possible sampling methods are classified into probability and non-probability. The non-probability sampling methods refer to cases where the probability of including each element of the population in a sample is unknown while the probability sampling methods refer to cases where the probability of including each element of the population in a sample is known (Bless *et al,* 2011). For this research the availability (accidental) sampling which is a non-probability sampling procedure was employed to select respondents. This was done, because of the limited time, the study focused on respondents who were willing to be interviewed. The advantage for using the accidental sampling method was that only those farmers who were conveniently available were interviewed so as to obtain a large number of completed questionnaires quickly and economically as argued by Leedy and Ormrod (2004). Since it is non-random, this sampling method is problematic because of sampling errors.

In each village, smallholder farmers were gathered in the hall to be interviewed. In addition to the accidental sampling method, snowball sampling method was used in cases whereby the available smallholder farmer was referred to by other farmers in the hall. Snowball sampling according to Bless *et al.* (2011) is appropriate for a situation where members of a special population may be difficult to locate. Thus a sample size was raised.

4.5 Sample size

When sampling, it is important to deal with an adequate sample size in order to collect accurate information about a group (Bless *et al.*, 2011). A large sample is more representative but very costly; while a small sample is less accurate but more convenient (Babbie and Mouton, 2006).

The study consisted of three villages in Nkonkobe Municipality where individual smallholder farmers practice agriculture. The secondary data from the Department of Agriculture for smallholder farmers practicing agriculture was used for sampling and a sample from each village was selected as shown in Table 4.1. Khayalethu village had about 71 active smallholder farmers; out of these farmers 34 were interviewed. Guquka village had 67 and 23 were interviewed. Krwakrwa village had 100 and 63 were interviewed. Therefore, the sample size (actual number of respondents) consisted of 120 smallholder farmers practicing agriculture.

Table 4.1: Number of sampled respondents for each study site

Study sites	Population	Number of actual respondents
Khayalethu village	71	34
Guquka village	67	23
Krwakrwa village	100	63
Total	238	120

Source: Survey data (2013)

After a sample size was gathered data was collected from the respondents using a method described below.

4.6 Data collection method

Data was collected from the individuals or respondents who were sampled by using interviewer-administered semi-structured questionnaires. A questionnaire contained written questions that smallholder farmers responded to directly with the aid of an interviewer. This method of data collection is much quicker than formal interviews and it is time saving. The interviewer read questions to respondents and recorded their answers on the questionnaire. The other advantage of this data collection method is that an interviewer was in a position to probe for more information and reduces the instances of misinterpretation or misunderstandings of words or questions by respondents as noted by Bless *et al*. (2011). The questionnaire comprised of closed and open ended questions. Most of the questions were structured as closed ended to extract as much information as possible from the respondents without taking too much of their time. From the data collected from the interviews, it was deduced that there were smallholder farmers who were practicing IRWH technology and some who were not. The following Table 4.2 is going to present the summary of the data collected, data source and how it was analysed against each objective. Data analysis employed in this study will be further discussed later in Section 4.10.

Table 4.2: Summary of data collected, sources and data analysis

Objectives	Data collected	Data source	Data analysis
To assess the level of adoption of IRWH technology by smallholder farmers in Krwakrwa, Khayalethu and Guquka villages in the EC	- Number of households participated during the introduction phase - Number of households currently practicing IRWH technology	-Secondary data from ARC -Primary data from smallholder farmers in the study areas	-Descriptive analysis (mean, frequency and percentages)
To determine socio-economic factors influencing the adoption of IRWH technology by smallholder farmers in the study areas in the EC.	- Demographic information - Farm income - Household income - Land size - Access to hired labour - Access to credit - Access to extension services - Access to market - Access to information - Livestock ownership - Distance to other water sources -Farmers' perception towards the IRWH technology	-Primary data from the smallholder farmers in the study areas - Secondary data from journals, books, internet sources and government documents	-Binary logistic regression model
To determine whether adopters of IRWH technology	- Food security status in the study areas -The same factors that	-Primary data from the smallholder farmers in the study areas	-HDDS as a measure of food security

are more food secure than non-adopters in the study areas in the EC	affect the adoption of IRWH technology were studied in relation to the household food security status in the study areas	-Secondary data from journals, books, internet and government documents	status -Binary logistic regression model

Source: Survey data (2013)

A brief literature review of the data analysis methods employed in similar studies is given in the next section.

4.7 Methods of analysing factors influencing adoption of the agricultural technologies and household food security used in related studies

The models explained in this section are used to determine factors that influence adoption of the agricultural technologies and household food security. This is due to variables that were used (dependent and independent variables). There are many models but binary logistic and binary probit regression models will be discussed.

4.7.1 Binary logistic regression model (Logit model)

Binary logistic regression model is a popular statistical technique in which the probability of a dichotomous outcome (such as adoption or non-adoption) is related to a set of explanatory variables and will be explained more in Section 4.10.1.1. It has been widely applied in adoption studies (He *et al*., 2007). For example, Badisa (2011) used it when analysing the socio-economic factors determining IRWH technology adoption for cropland productivity in the Lambani village at Limpopo Province.

The main objective was to investigate the extent and nature of the adoption of IRWH technology by households. The simple random technique was used to select the sample size of 70 households out of a total of 1398 households in the area. The population was stratified into two groups; those households who have adopted the IRWH technology and those who have not. The first stratum i.e. the adopter group had 405 households, from which 35 households were randomly selected, whilst the non-adopter stratum had 993 households, from which 35 households were selected. The list of households engaged in the IRWH technology was obtained with the assistance of the local extension officer. The heads of the selected households were interviewed using a structured and semi-structured questionnaire. The questionnaires included both open-ended and closed questions.

The statistical package for social sciences (SPSS) for Windows was used to analyse data. Descriptive statistics (means, frequencies and standard deviations) were calculated. The results were presented using percentage, frequency, tabulation and graphs. The results indicated that five out of ten variables were significant in explaining farmers' adoption decision. Land size, access to financial service, access to information and contact with extension officers were some of the variables that had a positive significance on the adoption of IRWH technology, while hired labour had a significantly negative correlation with adoption. Variables such as household size, level of education, age of the household, level of income and the main water source did not influence adoption of the technology.

Shikur and Beshah (2012) also used the binary logistic regression model when identifying socio-economic, physical, psychological and institutional constraints and opportunities that could determine the adoption of RWH technologies. The systematic sampling procedure was used in this study to select the respondents. At the first stage, out of eight districts one district was selected purposively due its better adoption rate of RWH technologies with respect to other districts. In the second stage, out of the total of 25 sub-districts four sub-districts were selected purposively as RWH promotion started earlier than other sub-districts, and the number of RWH technologies users was relatively higher in these sub-districts. At the third stage, to determine the sample households to be selected from each sample sub-district, the sampling frame of each stratum, that is, adopters and non-adopters, was developed. Structured interview schedule was used to generate primary data from 180 farmers.

Data was analysed using SPSS version 16 and presented quantitatively using different statistical methods such as percentage, frequency, tabulation, chi-square test (for dummy/discrete variables) and (t-test for continuous variables). The description was made using mean, minimum as well as maximum values, percentage and standard deviations. Out of 12 explanatory variables used, 10 variables were found to be significant in affecting the adoption of RWH technologies. These were labour availability in man equivalent, indigenous water harvesting experience of the household, farm size of the household head, total tropical livestock unit owned, sex of the household head, off-farm income of the household head, training in areas of RWH, perception of farmers towards security of land ownership and extension service in areas of RWH while distance to market from residence negatively influenced adoption of RWH technologies.

4.7.2 Binary probit regression model (Probit model)

Murgor *et al.* (2013) have argued that the probit model yields the same results as the logit model whereas Kuwornu *et al*. (2013) are of the view that the logit model has better interpretation than the probit model. The dependent variable has also two possible outcomes, 1 or 0. The model is as follows:

$Pr (Yi = 1) = F (Xi \beta)$

Where, Yi = Food security status (1 or 0). In the case of adoption Yi = adoption of IRWH / non-adoption IRWH (1 or 0).

Xi = Independent variables
β = Estimated parameters

The probit model has been used in the study conducted by Sithole *et al.* (2014) to identify factors influencing farmers' participation in smallholder irrigation schemes: The case of Ntfonjeni Rural Development Area in Swaziland. A multiple stage sampling procedure was used to select 96 households in Ntfonjeni Rural Development Area. Households residing close to the irrigation schemes were sampled comprising of 48 households who are participants and 48 non-participating households. A semi-structured questionnaire was used to collect data from selected participants and non-participants on a one to one interview.

SPSS version 21 was used to analyse data. Descriptive statistics (means and standard deviations) were calculated. The results were presented using tabulation. The estimation result of the probit model indicated that age, occupation of household head, farm size and access to credit were positively significant while distance to the scheme and membership in other groups negatively influenced households' decision to participate in smallholder irrigation schemes.

Marital status, gender, education level, household size, extension, market access, non-farm income and livestock ownership were found not to be significant.

From these previous studies discussed above, this study is going to adapt binary logistic regression model and the reasons will be discussed in Section 4.10.1.

Now that methods of analysing factors influencing the adoption of the agricultural technologies and household food security used in related studies have been discussed, the following section outlines food security measures used in related studies.

4.8 Food security measures used in related studies

According to Smith and Ali (2007) food security is the ability of households to access sufficient, safe and culturally suitable food to meet dietary needs in order to lead a healthy and productive life. To assess if the household is food secure or not, different measurements are used. Bickel *et al.* (2000) stated that, the full range of food insecurity and hunger cannot be captured by any single indicator. Instead, a household level of food insecurity or hunger can be determined by obtaining information on a variety of specific conditions, experiences and behaviors that serve as indicators of the varying degrees of severity of the condition. Food security measurements that are discussed in this section are household caloric acquisition, coping strategy and dietary diversity score.

4.8.1 Household Caloric Acquisition (HCA)

Household Caloric Acquisition is the number of calories, or nutrients, available for consumption by household members over a defined period of time (Hoddinott, 1999). The principal person responsible for preparing meals is asked how much food she/he prepared over a period of time (Smith and Ali, 2007). After accounting for processing, this is turned into a measure of the calories available for consumption by the household. The recall period is 7 or14 days.

According to FAO (2007) to convert data into calories, all quantities must be converted into a common unit such as a kilogram and after that, they are converted into edible portions by adjusting for processing; and lastly, convert these quantities into kilograms using the standard caloric conversions. This measure produces a crude estimate of the number of calories available for consumption in the household. However, this method generates a large quantity of numerical data that needs to be carefully checked both in the field and during data entry. It does not capture accurately any food eaten outside of the household (Hoddinott, 1999; Hlanganise, 2010).

4.8.2 Coping strategy index (CSI)

The coping strategy index is based on how households adapt when they cannot access enough food (Maxwell and Caldwell, 2008). Maxwell and Caldwell (2008) further highlighted that, the person who prepares and serves meals within the household is asked a series of questions regarding how households are responding to food shortages. According to Gillespie (2006) CSI was developed by the caregivers (CARE) and field tested by both CARE and the World Food Program (WFP). Eight African countries have used CSI to monitor household food security in emergencies and to assess the impact of various food aid interventions.

Collected data is weighted according to the frequency and perceived severity of behavior. Weighted scores are combined into an index that reflects current and perceived future food security status (Kirkland *et al.*, 2011). Comparison of scores and averages provides a summary of overall household food security. Thus, the higher the sum, the more food insecure is the household (Gillespie, 2006).With CSI, households might perceive that they are more likely to receive assistance when they report greater use of these coping strategies (Hoddinott, 1999).

4.8.3 Dietary Diversity Score

Dietary diversity is measured by using a simple count of food or food groups consumed over a reference period, ranging from 1 to 15 days (Hoddinott and Yohannes, 2002; FAO, 2007; Swindale and Bilinsky, 2006; FAO, 2011). Swindale and Bilinsky (2006) mentioned that dietary diversity questionnaire (Refer to Appendix 2) can be used at the household and individual level, but calculation of the score is slightly different in each case. FAO (2011) further mentioned that, individual dietary diversity scores (IDDS) aim at reflecting nutrient adequacy. Studies in different age groups have shown that an increase in IDDS is related to increased nutrient adequacy of the diet. It was also highlighted by Hoddinott and Yohannes (2002) that, household dietary diversity score (HDDS) is meant to reflect the economic ability of a household to access a variety of foods and its advantage is to reflect a quality of diet better

(Swindale and Bilinsky, 2006). HDDS looks at all people living under the same roof who share meals while IDDS looks at the food eaten by the individual. According to FAO (2008) for HDDS, foods eaten by any member of the household should be included and exclude foods purchased and eaten outside the home. While for IDDS, all foods eaten inside or outside the home by the individual, irrespective of where they were prepared is included. For HDDS, there are 15 groups of food included (cereals, vitamin A rich vegetables and tubers, white tubers and roots, dark green leafy vegetables, other vegetables, vitamin A rich fruits, other fruits, meat, eggs, fish and other seafood, legumes, nuts and seeds, milk and milk products, oils and fats, spices, condiments and beverages) and for IDDS there are 9 groups (starchy vegetables, dark green leafy vegetables, other vitamin A rich fruits and vegetables, other fruits and vegetables, organ meat, meat and fish, eggs, legumes, nuts and seeds, milk and milk products) (Swindale and Bilinsky, 2006).

Both FAO (2007) and FAO (2011) mentioned that if the study is concerned with nutrient adequacy of diet, information should be collected at individual level. Also, if on the regular basis meals/snacks are purchased and consumed by one or more family members outside the home. HDDS cannot be used because it is not possible to capture accurately meals/snacks purchased and eaten outside the home at household level.

When FAO (2007) conducted a study in Mozambique to measure household food security, HDDS was used to assess the household food security status. It was done to differentiate food secure households from those which were food insecure. Respondents were asked to recall all foods consumed by any household member in the previous 24 hours. Then, the score was a simple sum of food groups consumed by any household member from the total of fifteen. Households were classified into terciles: low dietary diversity = 3 or fewer food groups; medium = 4; and high = 5 or more. A dichotomous indicator for poor dietary diversity (< 4 food groups) was also created.

For the context of this study, HDDS was adopted. This food security measure was chosen in order to distinguish households which were food secure from those that were food insecure. It was also chosen because the number of different food groups consumed are calculated and summed, rather than the number of different foods consumed, to better reflect a quality diet. Knowing what households consume, for example, an average of four different food groups implies that their diets offer some diversity in both macro-and micro-nutrients. This is a more meaningful indicator than knowing that households consume four different foods, which might all be cereals (FAO, 2007).

Information on household food consumption was collected using the previous 24-hours as a reference period (24-hour recall). The reason for this was that longer reference periods result in less accurate information due to imperfect recall (FAO, 2011). If the previous 24 hour period was for a special occasion such as a funeral or feast or if most of the household members (e.g.6 out of 10 members) were absent, another day was selected for an interview. This helped to prevent bias in the results. The persons who were responsible for the preparation of meals were the key respondents.

This study was based on the theoretical framework which was discussed in the following section.

4.9 Theoretical and conceptual frameworks

From a theoretical perspective, the decision whether or not to adopt the IRWH technique is based on profit maximisation using scarce resources at the lowest cost (Senkondo *et al.,* 1998). This study borrows such a concept and the decision to adopt the IRWH technology is driven by how much profit smallholder farmers will get from using the technique by using their limited land and water. However smallholder farmers may have non-economic objectives and it may be reasonable to assume that the objective of some famers is utility maximisation. For this study, the utility maximisation theory was adapted from Gebregziabher *et al.* (2013). According to the theory, a new technology will be adopted by a farmer if the utility obtained from the new technology exceeds that of the former one (Gebregziabher *et al.,* 2013).

The underlying utility function depends on household specific attributes X (e.g. age of the household head, gender of the household head, education, access to credit, etc) and a disturbance term having a zero mean:

$U_{i1} (X) = \beta_1 X_i + \varepsilon_{i1}$ for adoption……………………….1

$U_{i0} (X) = \beta_0 X_i + \varepsilon_{i0}$ for non- adoption…………………2

As utility is random the i^{th} smallholder farmer will select the alternative "adoption" if and only if $U_{i1} > U_{i0}$. Thus, for the smallholder farmer i, the probability of adoption is given by:

$P(1) = P(U_{i1} > U_{i0})$

$P(1) = P(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0})$

$P(1) = P(\varepsilon_{i1} - \varepsilon_{i0} < \beta_1 X_i - \beta_0 X_i)$

$P(1) = P(\varepsilon_i < \beta X_i)$

$P(1) = \Phi(\beta X_i)$

Where, U_{i1} = The utility a farmer obtains from the technology

U_{i0} = No utility obtained by a farmer from the technology

P(1) = Probability of adopting IRWH technology

$\beta_{0\ldots}\ \beta_1$= Estimated parameters

X_i = Independent variables

Φ = is the cumulative distribution function of the standard normal distribution.

ε_i = Disturbance term

Based on the above theoretical framework, the conceptual framework of this study was formulated and presented below.

From Figure 4.1, adoption of the IRWH technology is influenced by social, economic, institutional factors, advice from government and other stakeholders as well as from the farmer's perception that production will be increased through IRWH technology. If a smallholder farmer decides to adopt the technology he/she may be more food secure because the farmer will be able to sell surplus and afford to buy more nutritious food and obtain health care. Also food will be accessible all year round. If a smallholder farmer decides not to adopt the technology, the opposite is likely to happen.

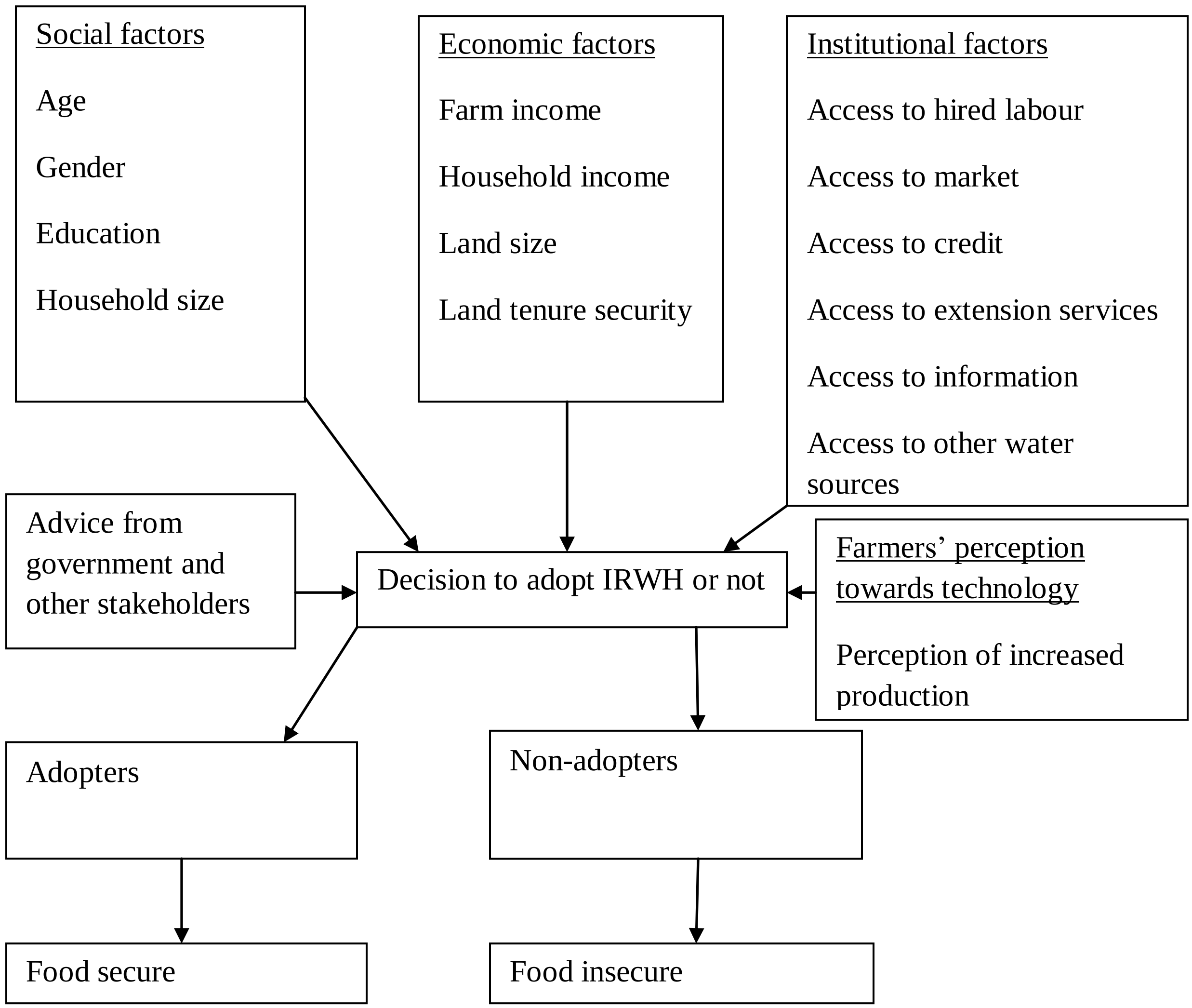

Figure 4.1: Conceptual framework

The next section gives an overview of how data collected to establish whether or not smallholder farmers adopted the IRWH technology was analysed.

4.10 Data analysis

This section describes how the major objectives of the study were answered; whose aim was to determine the socio-economic factors influencing the adoption of the IRWH technology in enhancing household food security by smallholder farmers. According to Bless *et al.* (2011) data analysis allows the researcher to generalise the findings from the sample used in the research to the larger population in which the researcher is interested. The collected survey data was analysed using SPSS version 21. Results were presented using graphs, pie charts and tables (including cross-tables). To assess the level of adoption of the IRWH technology by smallholder farmers, descriptive analysis (mean, frequency and percentages) was used. The binary logistic regression model was used to analyse the socio-economic factors which influence the adoption of IRWH technology. To determine whether adopters of IRWH technology are more food secure than non-adopters in the study areas in the EC, firstly, HDDS as used by FAO (2007) was adopted as a measure of food security (as explained in Section 4.8.3). Then, socio-economic factors influencing household food security were analysed using the binary logistic regression model (as explained in the next section).

4.10.1 Binary logistic regression model (Logit model)

According to Gujarati (2002) the binary logistic model is appropriate when the response takes one of only two possible values representing success and failure, or more generally the presence or absence of an attribute of interest. This model is used when the dependent variable is not continuous but instead has only two possible outcomes, 1 or 0 (Hill *et al.*, 2001). In this research, that is adoption of IRWH technology or not adopting.

The adopters were those smallholder farmers who continued to practice the technology after the introduction period was over. The non-adopters were those smallholder farmers who only practiced the technology during the introduction period and those who never practiced it. This model is based on the probability that Y equals to one (P=P1). The value of Y is assumed to depend on the value of X1…….X16.

The logit model representing the relationship of Y and X is given by:

$\ln(\text{ODDS}) = \ln(\hat{Y}/1 - \hat{Y}) = \beta o + \beta_1 X_1 + \ldots + \beta n Xn + U$………………….1

Where β0 = intercept

β_1….. βn = Estimated parameters

X_1…Xn = Independent variables

U = Error term

In equation 1, $\hat{Y}$ represents the probability of adopting IRWH and $(1-\hat{Y})$ represents the probability of not adopting. Where $\hat{Y}$ is the predicted probability of the event which is coded with 1 (adopt IRWH technique) rather than with 0 (do not adopt IRWH technique), $1-\hat{Y}$ is the predicted probability of the other decision, and X represents predictor variables.

The specific logistic regression model is given as follows:

ADOP/ NADOP= β_0 + β_1 GEN + β_2 AGE + β_3EDUL + β_4HHS+ β_5ACHLBR + β_6HHINCO + β_7FAMINCO + β_8LNDTNRS + β_9LANDSZ + β_{10}ACMKT + β_{11}ACCREDT + β_{12}ACES + β_{13}ACINFO+ β_{14} LIVSTOWN +β_{15}DWRTSOURC + β_{16}FPTRWH +U.........................(2)

Independent variables were chosen based on the theory, assumptions and evidence from past studies. For the third analysis when determining factors affecting household food security the same logistic regression model and potential independent variables were used but the dependent variable was food security status (Food secure =1 or food insecure = 0). Also, the adoption of IRWH technology becomes an independent variable as presented in Table 4.4.

For this study, the binary logistic regression model was adapted because it is an extremely flexible and easily used function. It leads itself to a meaningful interpretation as stated by Gujarati (2002). The disadvantage of this model is that, it does not handle the missing values of continuous variables unless they are divided into classes (Hill *et al.*, 2001).

The description of variables that were used in the binary logistic regression model for the incidence of adoption, how they were measured and their expected outcomes are presented in Table 4.3 below.

Table 4.3: Variables that were used in the binary logistic regression model for incidence of adoption

Variable name	Variable description	Type of measurement	Expected sign
Dependent variable			
ADOP	Adopters of IRWH technology = 1		
NADOP	Non adopters of IRWH technology = 0		
Independent variables			
GEN	Gender of the household heads	Dummy	+/-
AGE	Age of the household heads	Categorical	-
EDUL	Educational level of the household heads	Categorical	+
HHS	Household size	Continuous	+/-
ACLBR	Access to hired labour	Dummy	+
HHINCO	Household income	Categorical	+
FAMINCO	Farm income	Categorical	+
LNDTNRS	Land tenure security	Dummy	+
LNDSZ	Land size	Continuous	+/-
ACMKT	Access to market	Dummy	+
ACCREDT	Access to credit	Dummy	-
ACES	Access to extension services	Dummy	+
ACINFO	Access to information	Dummy	+
LIVSTOWN	Livestock ownership	Continuous	+
DWRTSOURC	Distance to other water sources	Continuous	-
FPIRWH	Farmers' perception towards the IRWH technology	Dummy	+

The variables presented in Table 4.3 and their priori expectations are discussed in Section 4.10.1.1.

Factors which influence the household food security were also analysed using the binary logistic regression model. Table 4.4 shows variables used in the regression model and their expected outcome.

Table 4.4: Variables that were used in the binary logistic regression model for incidence of household food security status

Variable name	Variable description	Type of measurement	Expected sign
Dependent variable			
FS	Food secure = 1		
FI	Food insecure = 0		
Independent variables			
ADOPIRWH	Adoption of the IRWH technology	Dummy	+
GEN	Gender of the household heads	Dummy	+/-
AGE	Age of the household heads	Categorical	-
EDUL	Educational level of the household heads	Categorical	+
HHS	Household size	Continuous	+/-
ACLBR	Access to hired labour	Dummy	+
HHINCO	Household income	Categorical	+
FAMINCO	Farm income	Categorical	+
LNDTNRS	Land tenure security	Dummy	+
LNDSZ	Land size	Continuous	+/-
ACMKT	Access to market	Dummy	+
ACCREDT	Access to credit	Dummy	-
ACES	Access to extension services	Dummy	+
ACINFO	Access to information	Dummy	+
LIVSTOWN	Livestock ownership	Continuous	+
DWRTSOURC	Distance to other water sources	Continuous	-
FPIRWH	Farmers' perception towards the IRWH technology	Dummy	+

The variables presented in Table 4.4 and their priori expectations are discussed below.

4.10.1.1 Explanatory variables and priori expectations

This section explains the variables and the expected outcome direction based on literature. The explanatory variables explained here are thought to have an influence on the adoption of IRWH technology and on household food security status. These include households' demographic variables and socio-economic variables.

4.10.1.1.1 Adoption of the IRWH technology

This variable was measured by asking households if they currently practice IRWH technology and if the household practiced the technology it was represented by "1" and "0" if otherwise. Botha *et al.* (2013) have observed that the adoption of IRWH technology enhances food and nutritional security. For this study, it was hypothesised that the adoption of this technology positively influences the likelihood of being food secure.

4.10.1.1.2 Gender of the household heads

Gender is a dummy variable that indexes the sex of the farmer; it has a value of 1 for male and 0 for female. Both males and females are likely to play different roles in technology adoption, depending on the nature of the technology (He *et al.,* 2007). IRWH technology requires a lot of time and labour and also has a complex structure as noted by Moyo and Nyimo (2006). Therefore, women are not likely to adopt this technology as compared to men. For these reasons, there is a likelihood that women headed households will be less food secure. In this study, it was hypothesised that gender of the household head has a positive or negative influence on the adoption of the IRWH technology and household food security.

4.10.1.1.3 Age of the household heads

In this study age measures the years of household head. Younger farmers are easily attracted by new technologies and are risk loving because they need extra cash while older farmers are more conservative and easily discouraged to adopt new technologies, especially if labour demand is very high (Badisa, 2011). Hence, it may happen that younger people will be more food secure than older people. Therefore, it was hypothesised that the age of the household head negatively influences adoption of the IRWH technology and the household food security status.

4.10.1.1.4 Educational level of the household heads

Educational level refers to the total number years into formal education (Mensah *et al.,* 2013).

Education equips individuals with the necessary knowledge of how to make a living (Kai, 2011). Smallholder farmers with formal education are able to process and use information relevant towards the adoption of new technologies; hence possibilities of being food secure (Murgor *et al*., 2013). Less educated farmers are less likely to adopt new practices than smallholder farmers with higher levels of educational achievement (Kai, 2011). Therefore, it was expected that the level of education has a positive impact on adoption of the IRWH technology in relation to household food security status.

4.10.1.1.5 Household size

This study considered household size as the number of individuals who reside in the respondents' household and related with labour supply. Due to the high labour demands of IRWH technology, the larger the household size in terms of adults the greater the availability of labour, which possibly will enhance adoption of the IRWH technology and a likelihood of being food secure (Kalineza *et al.,* 2008). On the other hand, larger household size with more children is generally associated with a less labour force available (He *et al.* 2007). According to Babatunde *et al.* (2007) larger households may be more likely to be vulnerable to food insecurity. In this study, it was hypothesised that household size has a positive or negative influence on the adoption of IRWH technology and household food security.

4.10.1.1.6 Access to hired labour

The access to hired labour variable was treated as a dummy variable, with 1 representing a farmer having accessed hired labour and 0 otherwise. According to Mensah *et al.* (2013) hired labour may influence the ability of the household to produce. Households with a higher labour supply may be able to devote more labour to the production of crops. These households may be able to produce more, making adoption of IRWH technology easier and also the probability of being food secure. This variable is expected to have a positive impact on the adoption of IRWH technology in enhancing household food security status.

4.10.1.1.7 Household income

The level of household income was measured by capturing the total household income per month. Additional income earned through participation in non-farm activities improves farmers' financial capacity and increases the ability to adopt new technology; hence, possibilities of being food secure (von Braun, 2007). A positive relationship should be expected between household income and the level of the IRWH technology adoption in relation to household food security.

4.10.1.1.8 Farm income

In this study farm income was measured by capturing the total income per month smallholder farmers received after they had sold their produce. According to Baiyegunhi (2014) higher farm income received gives an incentive to adopt RWH technologies and a probability of being food secure. Therefore, it was expected that the farm income has a positive impact on the adoption of IRWH technology and household food security status.

4.10.1.1.9 Land tenure security

Land tenure security was treated as a dummy variable, with 1 implying that a farmer has secure tenure to land and 0 implying otherwise. Smallholder farmers with secure land ownership are more likely to adopt the technology and a possibility of being food secure than smallholder farmers with insecure land ownership (He *et al.,* 2007). In this study it was expected that land tenure security will have a positive influence on the adoption of IRWH technology and household food security.

4.10.1.1.10 Land size

Land size was measured by the actual number of hectares of the land used for planting. Land size may positively or negatively influence the adoption of IRWH technology and household food security status. This might happen because smallholder farmers with small farm sizes are not likely to adopt the technique and may have a chance of being food insecure. Conversely, that small farm size can be used productively such that households could have a likelihood of being food secure, thus promote adoption of the IRWH technology (Woyessa *et al.,* 2007).

4.10.1.1.11 Access to market

Access to market was measured by the actual distance in kilometres to the nearest input and output markets. According to Gebregziabher (2014) the closer a household is to the input and output markets, the greater the likelihood that they will adopt IRWH technology. This may result in the probability of being food secure. In this study it was hypothesised that there will be a positive relationship between access to market and adoption of IRWH technology in relation to household food security. The variable was treated as a dummy variable where 1 implied a farmer having accessed the market and 0 otherwise.

4.10.1.1.12 Access to credit

Lack of access to credit is one of the major stumbling blocks for smallholder farmers in the developing world (Chisasa and Makina, 2012). Therefore, this may prevent them from having the necessary capital for investing in new technologies (Kalineza *et al.,* 2008). It was expected that access to credit will negatively influence the adoption of IRWH technology and household food security. The variable was treated as a dummy variable where 1 implied a farmer having accessed credit and 0 otherwise.

4.10.1.1.13 Access to extension services and information

The access to extension services and information variables were treated as dummy variables, with 1 representing a farmer having accessed extension services like governmental assistance, training workshops as well as information and 0 otherwise. According to Ngwenya (2013) extension officers are the ones who disseminate information about agricultural practices. Smallholder farmers who have a frequent contact with them will have an easy access to information and training; this will upgrade their knowledge on technology. This may result in the higher adoption of IRWH technology and a possibility of being food secure. For this study, access to extension services and information are expected to positively influence adoption of the technology and household food security status.

4.10.1.1.14 Livestock ownership

Livestock ownership was used in this study as a proxy for wealth. The number of livestock was represented as a continuous variable and represents the number of livestock owned by the household. According to Shikur and Beshah (2012) livestock is a source of income which can be liquidated into cash by the smallholder farmers to enable them to adopt IRWH technology, such that households may have a chance of being food secure. This will positively influence the adoption of IRWH technology and household food security status.

4.10.1.1.15 Distance to other water sources

Different types of other water sources include river, stream, tap water and borehole in this research. This variable was measured by the total walking distance in minutes to other water sources. The lesser the walking distance to other water sources, the lesser the likelihood of adopting IRWH technology and this may lead to food insecurity (Murgor *et al*., 2013). A negative relationship is expected between distance to other water sources and the adoption of IRWH technology as well as household food security.

4.10.1.1.16 Farmers' perception towards the IRWH technology

Smallholder farmers' perception towards technology characteristics were said to condition the adoption of that particular technology (Shikur and Beshah, 2012). If smallholder farmers have a positive perception towards the IRWH technology, adoption will be high as well as their likelihood of being food secure (Baiyegunhi, 2014). In this study, famers' perception towards the IRWH technology is expected to positively influence adoption of the technique and household food security. This variable was treated as a dummy variable, with 1 representing positive feelings towards the IRWH technology and 0 otherwise.

4.11 Summary

This chapter outlined the theoretical and conceptual frameworks for the study. Data was collected from three villages in Nkonkobe Municipality in the EC Province from a sample size of 120 smallholder farmers practicing agriculture. The Availability (accidental) and snowball sampling which are non-probability sampling procedures were used to select respondents for interviews. A semi-structured questionnaire was administered to the respondents through face-to-face interviews. The advantages that are associated with face-to-face interviews have been highlighted within the chapter. Also highlighted are previous studies on the adoption of agricultural technologies and household food security as well as food security measures used in related studies. Hypothesis of the study were also highlighted. HDDS was employed to identify which households were food secure or food insecure because it better reflects a quality diet. The binary logistic regression model was used to analyse factors influencing the adoption of IRWH technology and also used for those influencing household food security. The same explanatory variables that were used for the incidence of adoption were also used for household food security where adoption was used as one of the independent variable. This model was used because of the nature of the dependent variable (adoption of IRWH technology/food security), which is dichotomous and for its simplicity.

CHAPTER 5

RESULTS OF THE DESCRIPTIVE ANALYSIS AND DISCUSSION

5.0 Introduction

In this chapter the results and discussions of the descriptive analysis are presented. The first section begins with an analysis and discussion of the overall adoption status of IRWH technology followed by household food security status in the study areas. After that, households' demographic and socio-economic characteristics that influence the adoption of IRWH technology and household food security are also analysed. Full elaboration upon the characteristics was done and literature was also consulted. Within the chapter, descriptive statistics such as mean values, frequencies, percentages are presented in the form of tables, cross-tables, pie charts and bar graphs.

5.1 Adoption status in the study areas

From the study areas it was found that 79% of the households did not adopt the IRWH technology while 21% adopted the technology as shown in Table 5.1. This implies that the adoption status of this technology is low in Krwakrwa, Khayalethu and Guquka villages.

Table 5.1: Adoption status in the study areas

	Frequency	Percentage
Non-adopters of IRWH technology	95	79
Adopters of IRWH technology	25	21
Total	120	100

Source: Survey data (2013)

The study also linked the relationship between adoption of the IRWH technology and household food security, therefore the household food security status in the study areas was measured, analysed and discussed in the next section.

5.2 Household food security status in the study areas

To measure household food security status in the study areas HDDS was adapted as discussed in Section 4.8.3. The questionnaire on the food groups is presented in Appendix 1 and the respondents were expected to answer Yes or No to the questions posed. The dietary diversity scores were obtained from a simple count of foods groups (as listed in the questionnaire, Appendix 1). The number of food groups was calculated by summing the number of food groups consumed in the household in 24 hours as shown in Appendix 2. The value of HDDS variable ranged from 0 to 15.

Since there were no established cut-off points in terms of the number of food groups to indicate adequate or inadequate dietary diversity for the HDDS, the average HDDS indicator was calculated for the sample population as shown in Appendix 2. An average of 5.01 was obtained from the calculation (refer to Appendix 2). A household was food secure if the HDDS score was above 5 and food insecure if the HDDS score was below 5.

Therefore, it was found that 70.8% households were food insecure and 29.2% were food secure in the study areas as shown in Table 5.2. This implies that the majority of the households have a low dietary diversity, hence reduced household food access.

Table 5.2: Household food security status in the study areas

	Frequency	Percentage
Food insecure	85	70.8
Food secure	35	29.2
Total	120	100

Source: Survey data (2013)

In order to know who is food secure or food insecure between the adopters of IRWH technology and non-adopters in the study areas, adoption status was described in relation to household food security status in the next section.

5.3 Adoption and household food security status in the study areas

Table 5.3 indicates that more non-adopters of IRWH technology (86%) were food insecure while 76.5% of adopters were food secure in the study areas. It shows that there are high instances of food insecurity in the study areas hence more households should adopt IRWH technology to improve their food security status.

Table 5.3: Adoption and household food security status in the study areas

Adoption status	Food security status			
	Food insecure		Food secure	
	Frequency	Percentage	Frequency	Percentage
Non-adopters of IRWH	30	86	65	23.5
Adopters of IRWH	5	14	20	76.5
Total	35	100	85	100

Source: Survey data (2013)

The following section gives a description of demographic and socio-economic characteristics in relation to the adoption of IRWH technology and household food security status. Demographic characteristics were analysed in the next section.

5.4.1 Demographic characteristics of the household heads in the study areas

Demographic characteristics such as gender, age, educational level and household size are discussed in this section. Demographic characteristics of households play a pivotal role in determining the behaviour of smallholder farmers (Woyessa *et al*., 2007). It then follows that household demographic attributes are relevant in analysing factors influencing the adoption of IRWH technology and household food security. Gender of the household heads was the first to be described.

5.4.1.1 Gender of the household heads

Figure 5.1 shows the gender distribution of the household heads that were drawn from the sample size of 120. From the data collected, the majority (64.2%) of households were female headed while only 35.8% were male headed. This suggests that females are more dominant in agriculture than men in the study areas as shown by the results. This may be because many men migrate to urban areas to search for better employment opportunities. These results are consistent with Kehler's views (2001) to the effect that, in South African rural areas, women play a vital role in agriculture as food producers, rather than men.

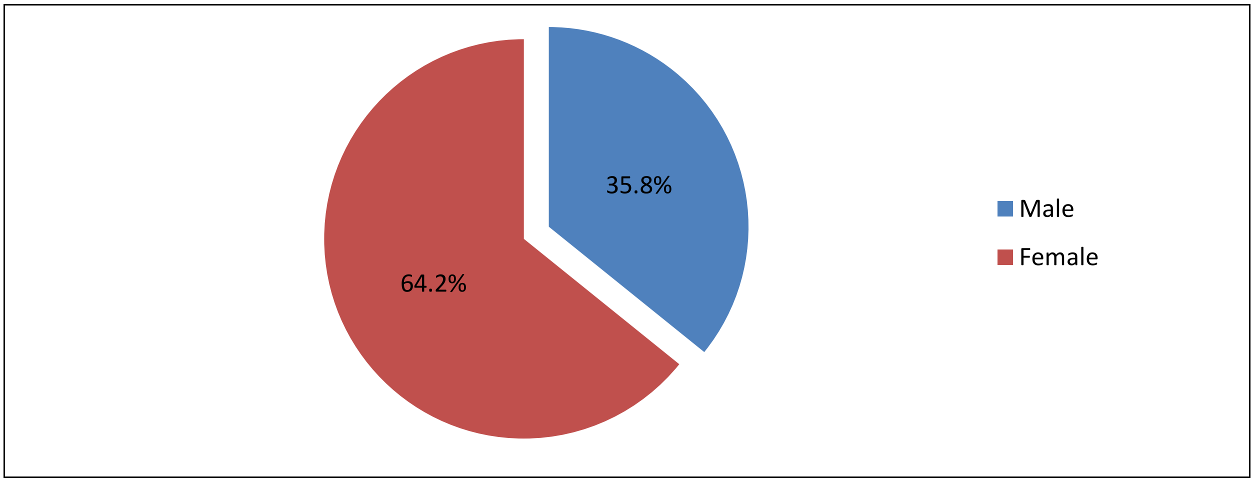

Figure 5.1: Gender distribution of the household heads
Source: Survey data (2013)

Figure 5.2 shows that there was a larger proportion of female non-adopters (72%) as compared to 28% male non-adopters of IRWH technology. The proportion of adopting IRWH technique is high in males (60%) as compared to females (40%). In conclusion, there were more male adopters (60%) and 55% were food secure than female adopters (40%) where their food insecurity status was 74.3%.

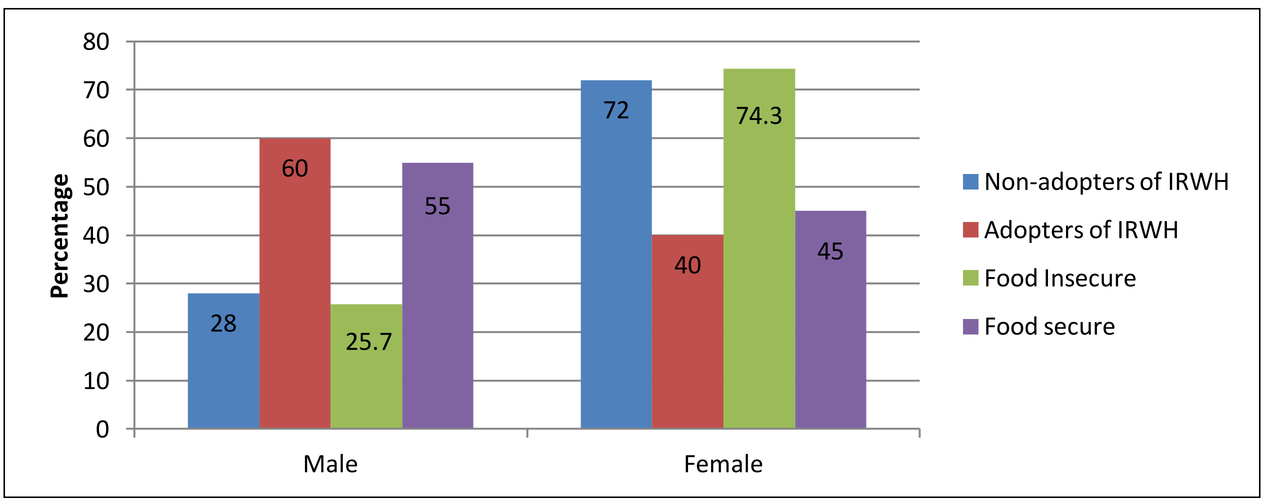

Figure 5.2: Adoption, household food security status and gender distribution
Source: Survey data (2013)

The reasons given by the non-adopters were that this technology requires a lot of time and is resource demanding. This is in line with the findings of Murgor *et al.* (2013) which revealed that female headed households are often more resource constrained particularly with regard to labour and cash than their counterpart male headed households. In addition, Mensah *et al.* (2013) have stated that men have more access and control over vital production resources than women due to many socio-cultural values and norms. This has led to the adoption of IRWH technology by female headed household to be low and likely be food insecure.

The following section gives analysis of age distribution of the household heads in the study areas.

5.4.1.2 Age distribution of the household heads

According to Muchara (2011) the household heads' age is an important aspect because it shows whether the household benefits from the experience of elderly people or has to base its decisions on the risk taking attitude of younger farmers. Findings on the age distribution are presented in Figure 5.3.

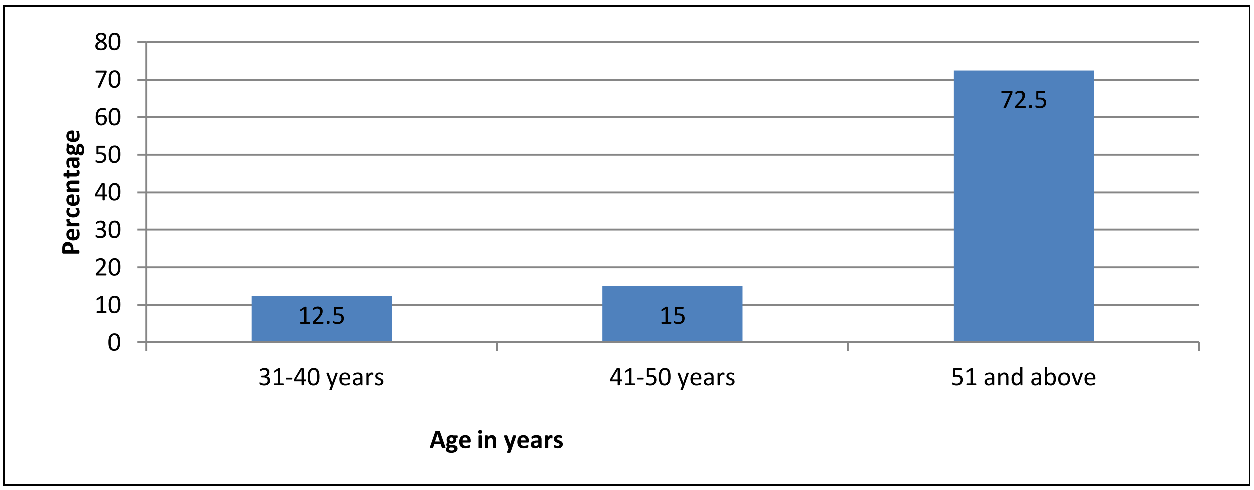

Figure 5.3: Age distribution of the household heads
Source: Survey data (2013)

The age distribution for household heads shown in Figure 5.3 was categorised into age groups of 31-40 years, 41-50 years and 51 years and above. Results show that 72.5% fall under 51 and above category, 41-50 and 31-40 years categories had the percentages of 15%, 12.5% respectively. This shows that the majority of households in the study areas are headed by older people.

As shown in Figure 5.4 in the study areas, it was found that the majority (78%) of non-adopters of the technology falls under age category 51years and above, as a result there is a high percentage (87%) of food insecurity among the group. Age category 41–50 years consists of 13.8% non-adopters and 8.2% fall under age category 31-40 years. About 55% that adopted the technology fall under age category of 41-50 years. Age category 51 and above years is comprised of 26.3% adopters and 18.7% falls under age category 31-40 years. Age category 51 and above have more non-adopters and are food insecure than age category 41-50 years which have more adopters and are food secure.

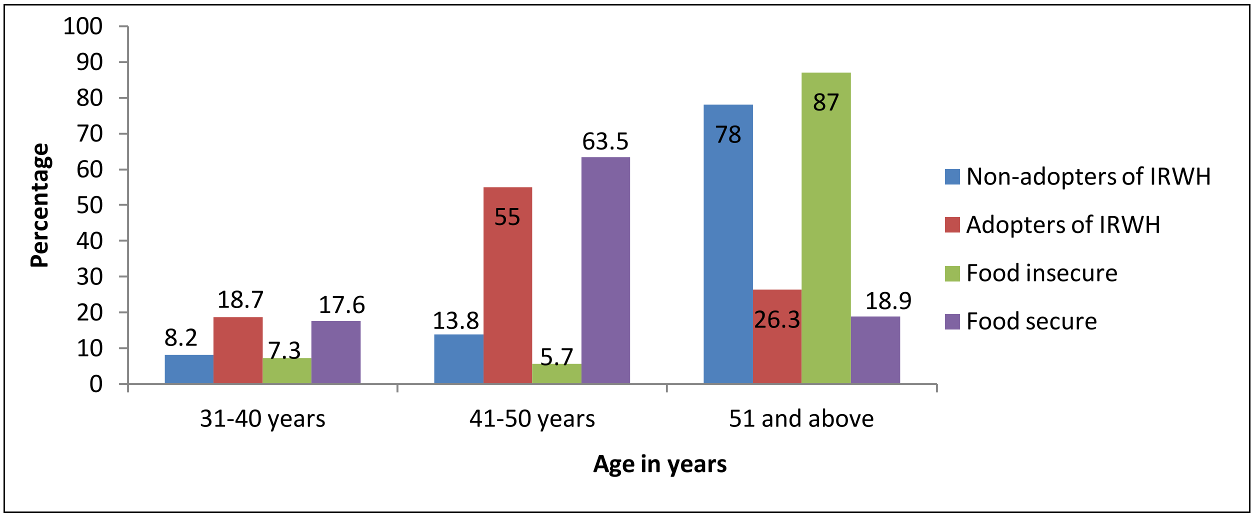

Figure 5.4: Adoption, household food security status and age distribution of the household head
Source: Survey data (2013)

The result implies that the elderly are less fit and therefore cannot carry out the tasks associated with the implementation of the technology. This is supported by Murgor *et al.* (2013) who have observed that elderly farmers are likely to be more risk averse and more resistant to change and therefore be reluctant towards technologies. This has led to low rates of the adoption of the IRWH technology because households in the study areas are headed by elderly people**.**

Educational level of the household heads was described in the next section.

5.4.1.3 Educational level of the household heads

According to He *et al.* (2007) people who have a higher educational level are able to interpret information better. Illiteracy is one of the factors that limit economic, social, physical, technical and educational development in less developed countries (Amha, 2006). In this study, the level of education ranges from those who do not have any formal education to those who attained tertiary education as shown in Figure 5.5 below.

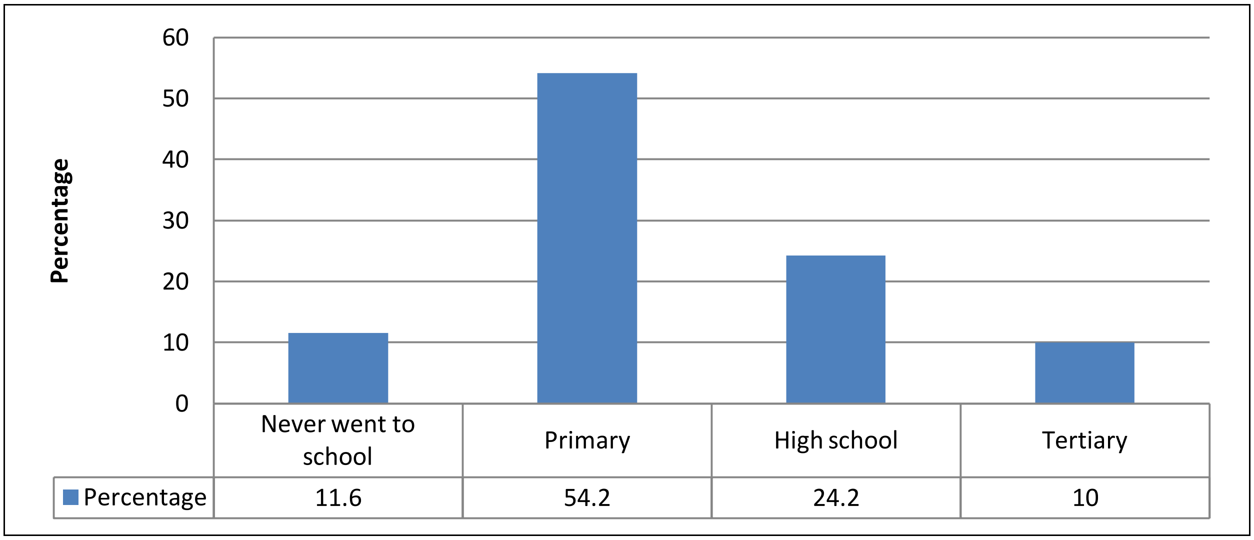

Figure 5.5: Educational level of the household heads
Source: Survey data (2013)

The results in Figure 5.5 reveal that 54.2% of the sampled household heads have a primary education while 24.2% have high school education. The figure also illustrates that 11.6% and 10% had no formal education and had tertiary education, respectively. This implies that the literacy level amongst the sampled household heads is relatively low.

Figure 5.6 shows that more respondents who are non-adopters of the IRWH technology have a primary level in terms of education (63.7%), followed by those who never went to school by 20.8%. Non-adopters respondents that have high school education are 10% and those who went to tertiary level accounted for 5.5%. It was also found that 49% of adopters have attained high school level, followed by those who have a primary level at 20.3%. A proportion of 16.7% of the adopters have a tertiary education while 14% never went to school. The highest percentage of non-adopters (63.7%) has a primary education and in this group there is a huge percentage of food insecurity of 85.7% as compared to adopters (49%) who have high school education, where food security is 45.9%. This relates to the literature which states that, the more the educated the farmer is, the higher the chances of adopting IRWH technology and a likelihood of being food secure (He *et al.,* 2007). This is the case because smallholder farmers who have a higher educational level are able to interpret information better than those with little education (Babatunde *et al*., 2007).

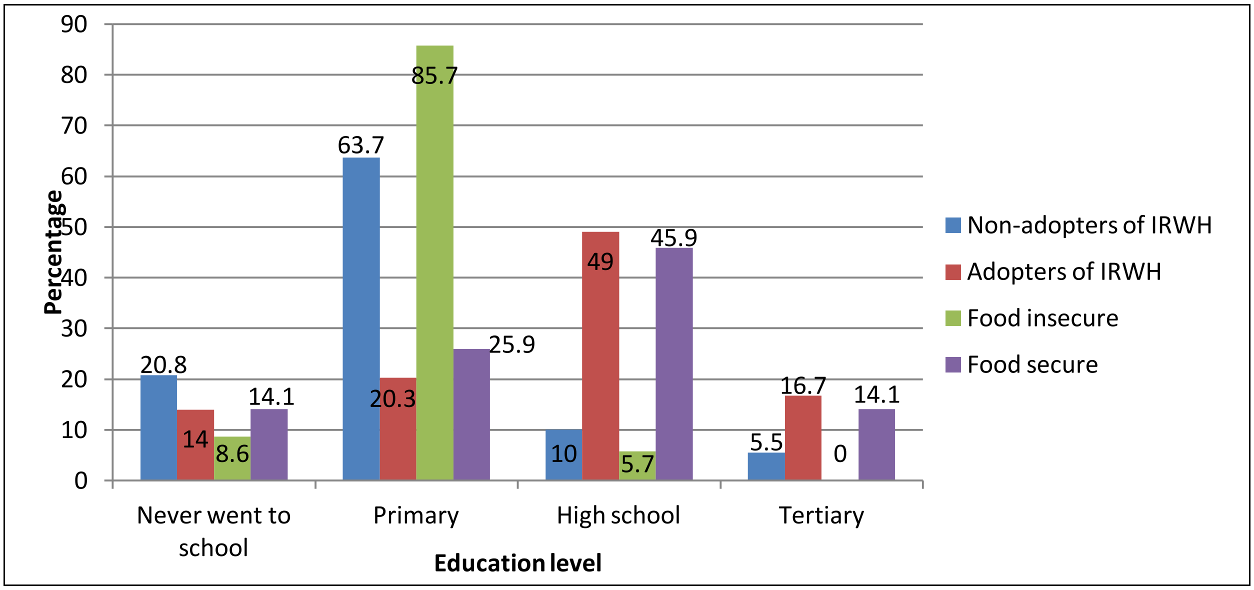

Figure 5.6: Adoption, household food security status and educational level
Source: Survey data (2013)

The size of the households in the study areas was analysed below.

5.4.1.4 Household size

Kai (2011) indicated that a larger family size also means that an increased labour capacity is available in the form of young, middle aged and elderly members. Labour accessibility in adult equivalent increases the adoption of IRWH technology (Ahmed *et al*., 2013). Ngwenya (2013) has outlined that a larger household size discourages the selling of farm produce because the household needs to meet its consumption demand before a decision to sell surplus produce for cash can be arrived at. Similarly, Badisa (2011) stated that household size can give an indication of the extent of the pressure that could be exerted on the household resources. The results are tabulated in Table 5.4 below.

Table 5.4: Household size distribution

Variable	Adopters of IRWH technology	% ge of household size	Non-adopters of IRWH technology	% ge of household size
Average household size	6	-----	5.25	----
Members ≥ 16 years	5.61	75	3.27	68
Members < 16 years	1.20	25	2.49	32

Source: Survey data (2013)

In the study areas, the average households' size for adopters was comparatively higher than for the non-adopters. The mean household size of the adopters and non-adopters was approximately 6 and 5 persons respectively as shown in Table 5.4. This suggests that adoption of the IRWH technology was associated with large household sizes also implying a larger supply of labour for the adopters. Furthermore, on average, more children are residing in the households of non-adopters (32%) compared to adopters' households (25%). The survey results were within the range of what has been found by other studies. For example, Badisa (2011) found an average household size of 7 for adopters of IRWH technology and 6 for non-adopters.

The following section highlights socio-economic characteristics determining the adoption of IRWH technology and household food security in the study areas.

5.4.2 Socio-economic characteristics influencing the adoption of IRWH technology and household food security

This section focused on household socio-economic factors related to farming. These include access to hired labour, household income, farm income, land security of tenure, land size, access to credit, access to extension services and information, livestock ownership, distance to other water sources and farmers' perception towards IRWH technology. Understanding these factors is useful in determining the influences they may have on the adoption of IRWH technology and household food security. Access to hired labour is discussed in the following section.

5.4.2.1 Access to hired labour

Table 5.5 illustrates that only 37.5% of households hired labour while the rest did not hire labour to help with farming activities.

Table 5.5: Access to hired labour distribution of the household heads

Access to hired labour	Percentage	
	Yes	No
	37.5	62.5

Source: Survey data (2013)

It appears that the majority of households use family members for labour provision and it can be assumed that this is attributed to the fact that they do not have money or compensation to pay for hired labour. This result corroborates with the findings of White (2012) on a theoretical framework for understanding factors that contribute to household adoption of rainwater harvesting in South East Queensland. According to Yengoh *et al.* (2010) labour constraints affect a farmer's choice of the technology and can also constrain the adoption of a labour demanding technology.

Figure 5.7 shows that 89.6% non-adopters of the IRWH technology had no access to hired labour and 10.4 % had access. Adopters (55.6%) indicated that they had access to hired labour while 44.4% had no access. The food insecurity was as high as 65.9 % to those who said they did not hire labour. It can be concluded that the unavailability of hired labour gave the incentive not to adopt the IRWH technology because this technique is labour intensive. These results are in line with the study of Badisa (2011) in the Limpopo Province.

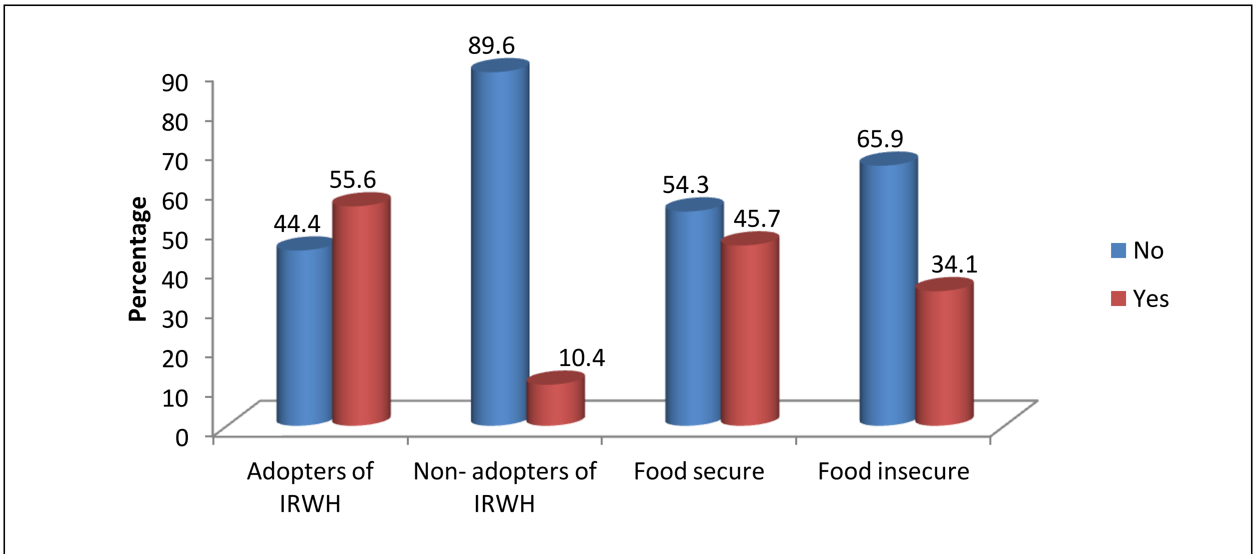

Figure 5.7: Adoption, household food security status and access to hired labour
Source: Survey data (2013)

Household income distribution in the study areas is given below.

5.4.2.2 Household income distribution of the household heads

Most rural households are highly dependent on social grants and wage incomes in addition to own food production. This is also evidenced in the study of Amha (2006) where the researcher indicated that agricultural production is not the only source of monetary income. For monetary income, South African rural households mainly depend on sources including claims against the state, wage earnings and remittances by next of kin that live and work elsewhere. A household can have more than one source of income available to it as shown in Table 5.6.

Table 5.6: Sources of income for the household heads

Source of income	Percentage
Salaries and wages	26.9
Self-employed	5.3
Agriculture	1.5
Child support grant	8.3
Old age pension	9.7
Old age pension and child support grant	12.5
Old age pension and remittances	10.2
Child support and remittances	5.6
Self -employed and remittances	15.0
Child support grant, old age pension and remittances	5.0

Source: Survey data (2013)

The results in Table 5.6 show that the major source of income comes from salaries and wages (26.9%) followed by self-employed and remittances (15%), old age pension and child support grant (12.5%). About 10.2% of the farmers also indicated old age pensions and remittances as their source of income, with 9.7% coming from old age pensions. The smaller percentage of farmers indicated child support grant (8.3%), child support grant and remittances (5.6%) as well as self-employed (5.3%) as their sources of income. Smallholder farmers who receive child support grant, old age pension and remittances accounted for 5%. The much smaller percentage of smallholder farmers received their income from agriculture (1.5%). The reason for the higher source of income emanating from salaries and wages could be that farmers receive lower farm income and that serves as an incentive for people to get paid jobs (Kai, 2011).

Figure 5.8 shows that 41.6% of smallholder farmers earn income between R1500.00–R2999.00 per month, followed by those who earn R500.00–R1499.00 accounting for about 29.2%. Respondents that earned income between R3000.00–R4999.00 accounted for 16.7% and 12.5% earned income between R5000.00–R9999.00. The results postulate that households receive less income per month.

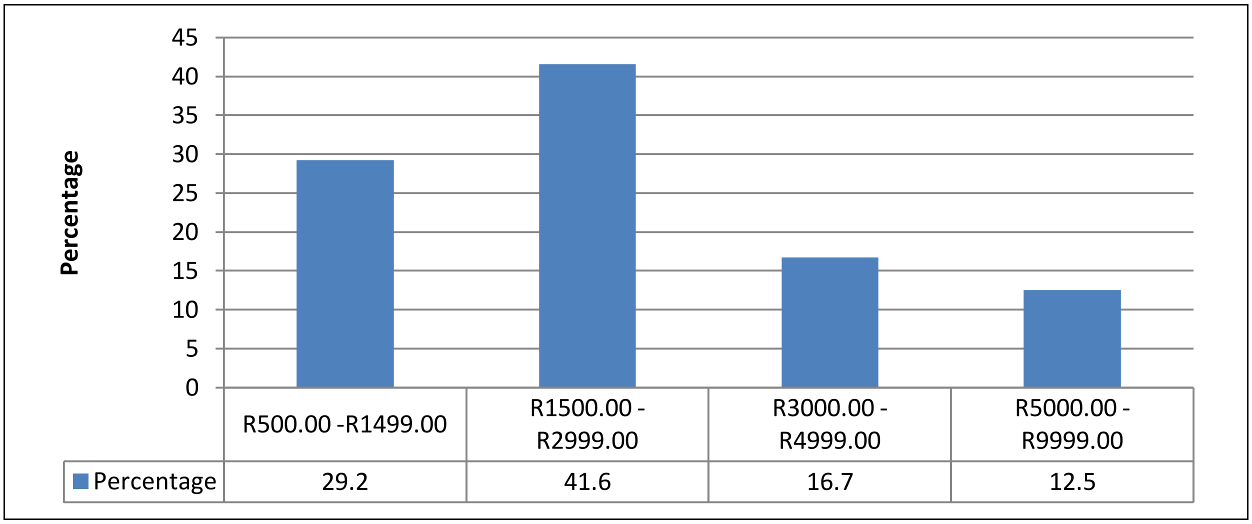

Figure 5.8: Distribution of income earned by farmers (Households)
Source: Survey data (2013)

Smallholder farmers (39.6%) who adopted the IRWH technology earned income between R3000.00–R4999.00 per month and 34.2% were food secure while 43.1% non-adopters earned income between R1500.00–R2999.00 per month with a huge percentage of food insecurity (71.4%) (refer to Figure 5.9). This suggests that, those households with a higher income have the ability to invest in technologies and be able to bear risk associated with its adoption. These results concur with the findings of Kalineza *et al*. (2008) on factors that influence the adoption of soil conservation in Tanzania.

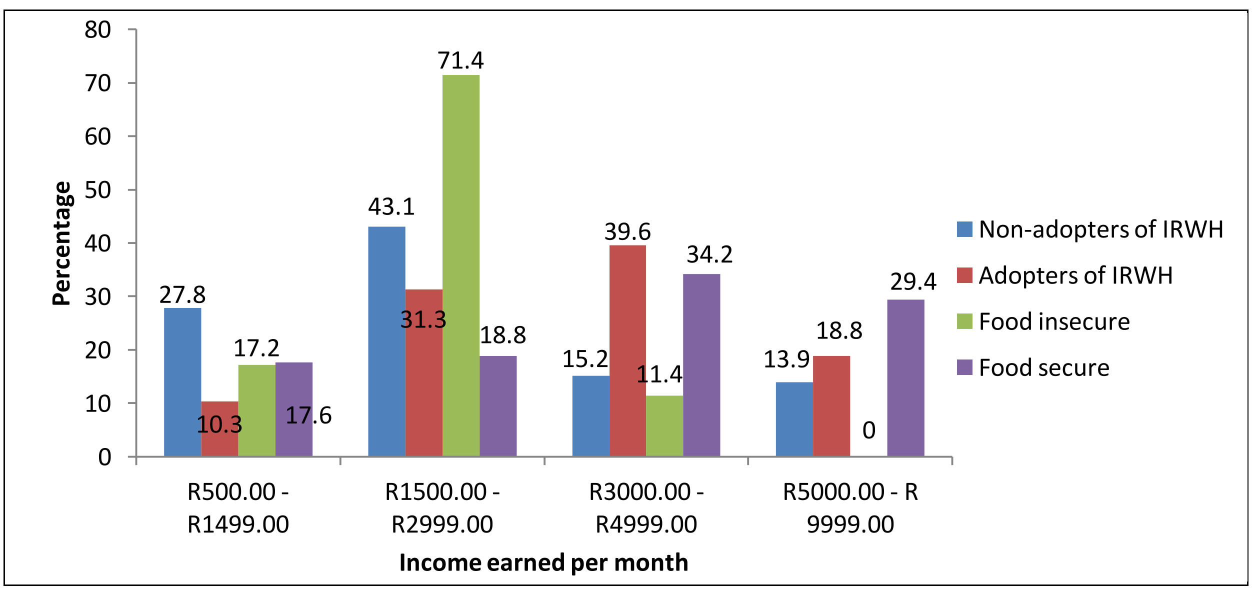

Figure 5.9: Adoption, food security status and distribution of income earned by household head
Source: Data survey (2013)

Now that households' income has been discussed, the following section gives analysis of farm income distribution in the study areas.

5.4.2.3 Farm income distribution of the household heads

Figure 5.10 shows that 54.2% of interviewed farmers received no income from the sale of their produce, 20% received less than R300.00 per month and 25.8% received between R600.00–R1199.00 per month. The reason for the large percentage of respondents not receiving anything is that they do not sell their produce. They only produce for consumption because they have small pieces of land. These results are in line with the findings of Shikur and Beshah (2012).

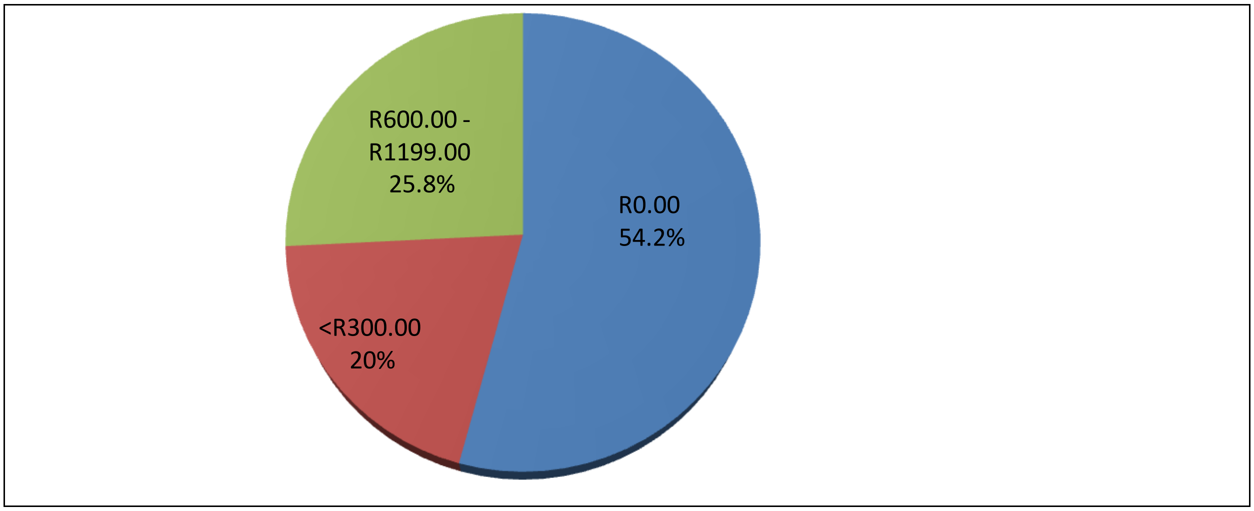

Figure 5.10: Farm income distribution of the household heads
Source: Survey data (2013)

Figure 5.11 shows that the majority of non-adopters (70%) receive no income per month from their produce which led to a food insecurity of 46%. A percentage of non-adopters (24%) received less than R300.00 per month and 6% respondents received R600–R1199.00 per month. About 29% adopters of the IRWH technology do not sell anything therefore do not receive anything per month, 15% received less than R300.00 per month and 56% received between R600.00–R1199.00 per month hence the food secure households were 59%. This shows that no farm income received led to more smallholder farmers not adopting the technology. This is probably because the land they cultivated was small hence they had to produce for consumption. This concurs with literature which points out that if farmers receive low or no income from produce, they will be discouraged from adopting that technology leading to a likelihood of being food insecure (White, 2012).

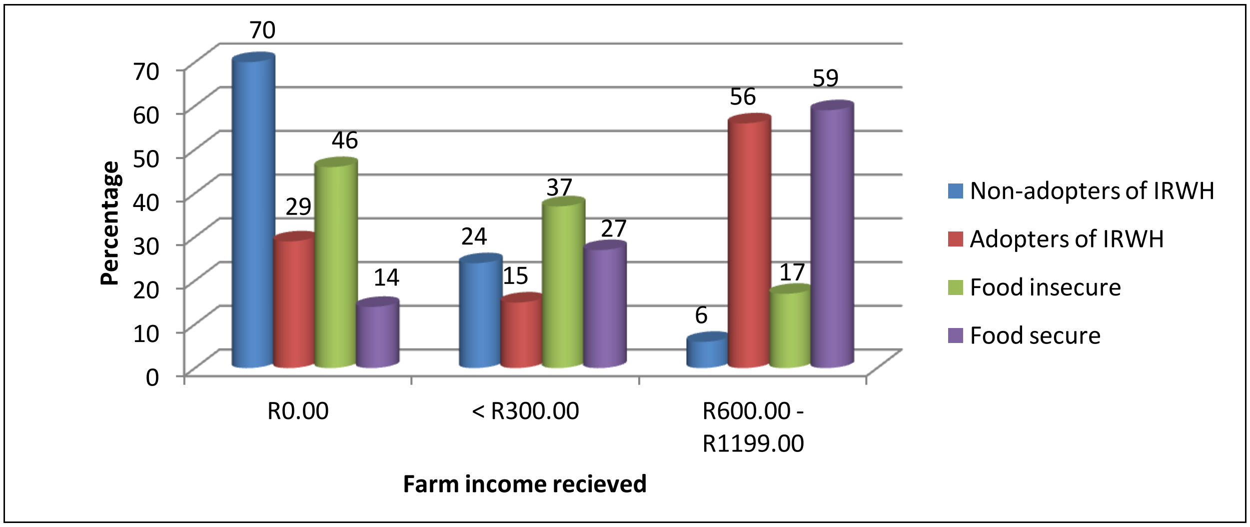

Figure 5.11: Adoption, food security status and farm income distribution of the household heads
Source: Survey data (2013)

Land security of tenure distribution in the study areas was discussed in the following section.

5.4.2.4 Land security of tenure distribution of the household heads

According to Baiyegunhi (2014) there is no doubt that security of tenure is one of the most crucial factors determining farm development. Land tenure implies land ownership. Land can be attained through inheritance, allocation by the chief, buying, leasing and hiring. In the EC, Pote (2008) found that land attained through inheritance had a significant and positive effect on long-term on-farm investments by households as their land is more secure. Land tenure distribution results in the study areas are shown in Table 5.7 below.

Table 5.7: Land tenure distribution of the household heads

Own land through inheritance	Allocated by the chief	Leasing
79%	20%	1%

Source: Survey data (2013)

In the study areas 79% attained land through inheritance, 20% were allocated by the chief and 1% were leasing as shown in Table 5.7. This postulates that the majority of households have more secure tenure of land.

According to Phahlane (2007) land tenure security determines the smallholder farmers' ability to adopt agricultural practices. For this study, results are presented in Figure 5.12.

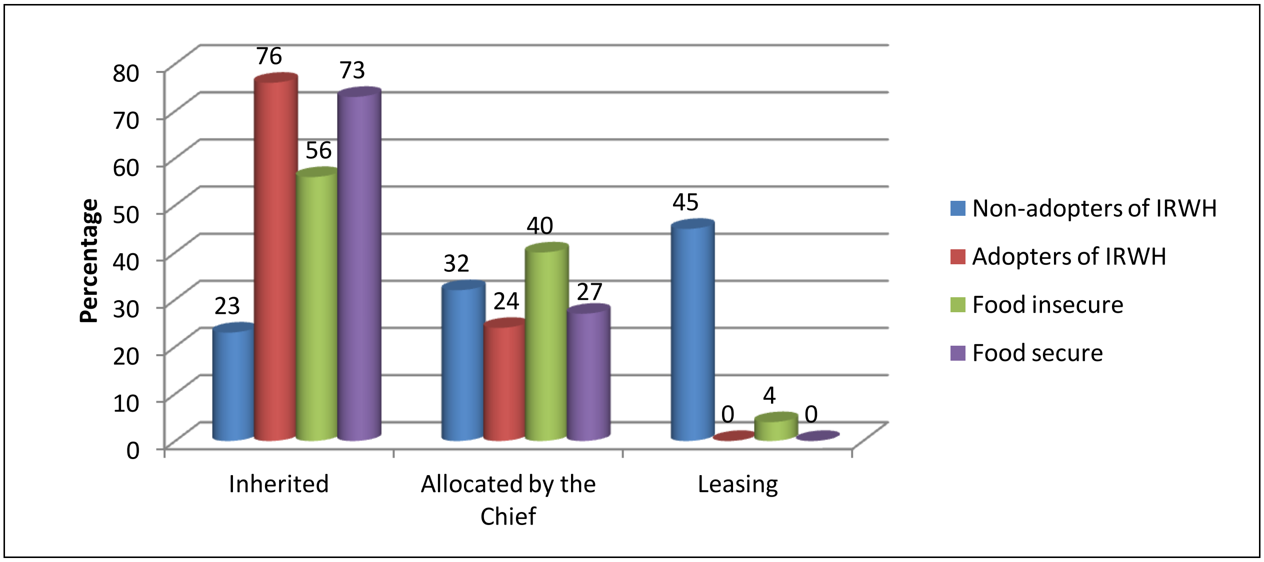

Figure 5.12: Adoption, food security status and land tenure distribution of the household heads
Source: Survey data (2013)

In this study, adopters (76%) of the IRWH technology had access to land through inheritance, 24% allocated by the chief and none were leasing. About 23% non-adopters had access to land through inheritance, 32% allocated by the chief while 45% had access to land through leasing. The findings indicate that most smallholder farmers who had access to land through inheritance adopted the IRWH technology and were food secured (73%) as shown in Figure 5.12. This may be because smallholder farmers feel that they have more security of tenure and do not consider it to be economically viable to produce on leased land. The results corroborate with the findings of Baiyegunhi (2014) on determinants of the RWH technologies adoption for home gardening in KwaZulu-Natal.

Since land tenure security of the household heads had been analysed, the distribution of their land size was discussed below.

5.4.2.5 Land size distribution of the household heads

Land size plays a crucial role in agricultural productivity. In South Africa smallholder farmers have small farm holdings of about 0.5-4ha producing food for household consumption and little for selling (Kalineza *et al*., 2008). For this study the distributions are tabulated in Table 5.8.

Table 5.8: Land size distribution of the household heads

	Adopters of IRWH technology	Non-adopters of IRWH technology
	Mean	Mean
Land size	0.639 ha	0.453 ha

Source: Survey data (2013)

Table 5.8 shows that the mean land size owned by adopters and non-adopters of the IRWH technology in the study areas is 0.639ha and 0.453ha respectively. Adopters possessed more land than non-adopters in terms of the total land size. This is in-line with the literature which provides that having more land is likely to have a positive effect on adoption of most practices (Murgor *et al.,* 2013).

Access to market was described below.

5.4.2.6 Access to market

In this study, access to market was measured by the actual distance in kilometers to the nearest input and output markets. According to ARC (2001) access to markets, enhances farm income but rural areas are characterised by a general lack of this access. This corresponds with what was found in the study areas (refer to Table 5.9).

Table 5.9: Access to market

	Percentage	
Distance to market	Below 30 km	Above 30km
	40	60

Source: Survey data (2013)

Table 5.9 shows that 60% of the respondents indicated that the distance to market they travel is above 30km. This implies that they have a problem with market access while 40% indicated that they travel less than 30km which means they have access to market.

Distance to market is the total time and distance that is required to reach the nearest available input and output markets (Ahmed *et al.,* 2013). The greater the distance to these markets, the greater the transactional costs and time spent. As the market distance increases for smallholder farmers to sell their produce, the adoption of the IRWH technology is expected to decrease (Kai, 2011). For this study results are shown in Figure 5.13 below.

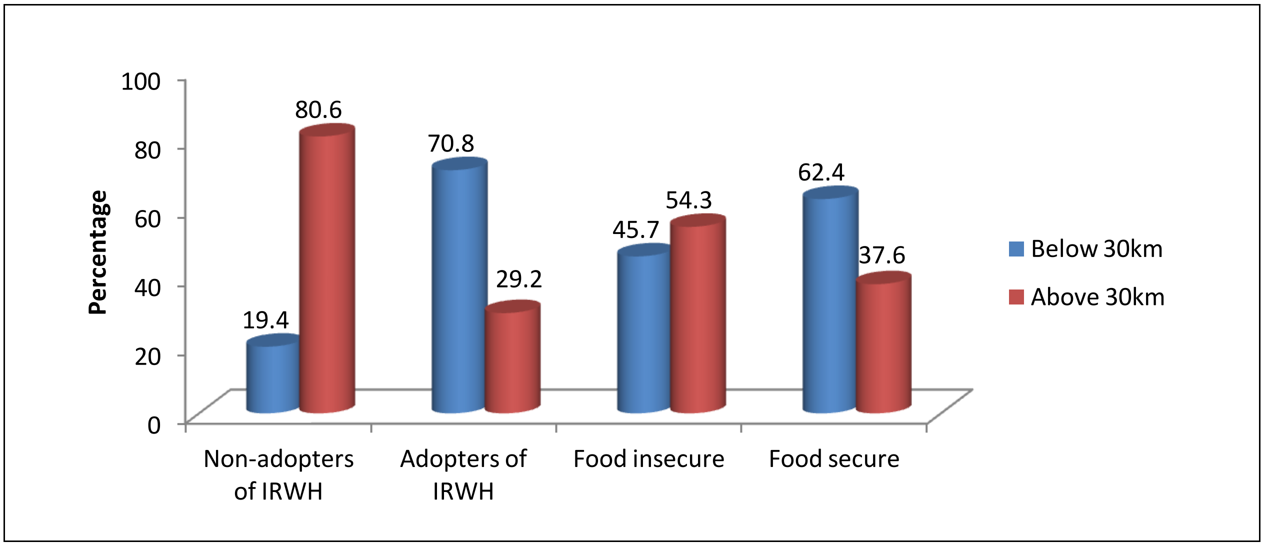

Figure 5.13: Adoption, household food security status and access to market
Source: Survey data (2013)

In the study areas, it was found that 80.6% non-adopters had no access to market and 19.4% non-adopters had an access to market. About 70.8% of adopters of the IRWH technology had access to market while 29.2% had no access to market (refer to Figure 5.13). Food security (62.4%) was high among those who had access to market and food insecurity (54.3%) was high to those who had no access. This is supported by Bunclark and Lankford (2010) who reported that a commonly cited challenge for the IRWH technology by smallholder farmers is the unavailability of markets to dispose their surplus produce leading to a probability of being food insecure.

The following section gives an overview of the access to credit in the study areas.

5.4.2.7 Access to credit

According to Chisasa and Makina (2012) access to credit is important in agriculture in order to help farmers to buy inputs as well as implements but most rural farmers are resource poor. Figure 5.14 shows that about 86.7% of smallholder farmers in the study areas had no access to credit because they were pensioners and lacked collateral. Only 13.3% had access to credit because they had formal jobs therefore they had collateral.

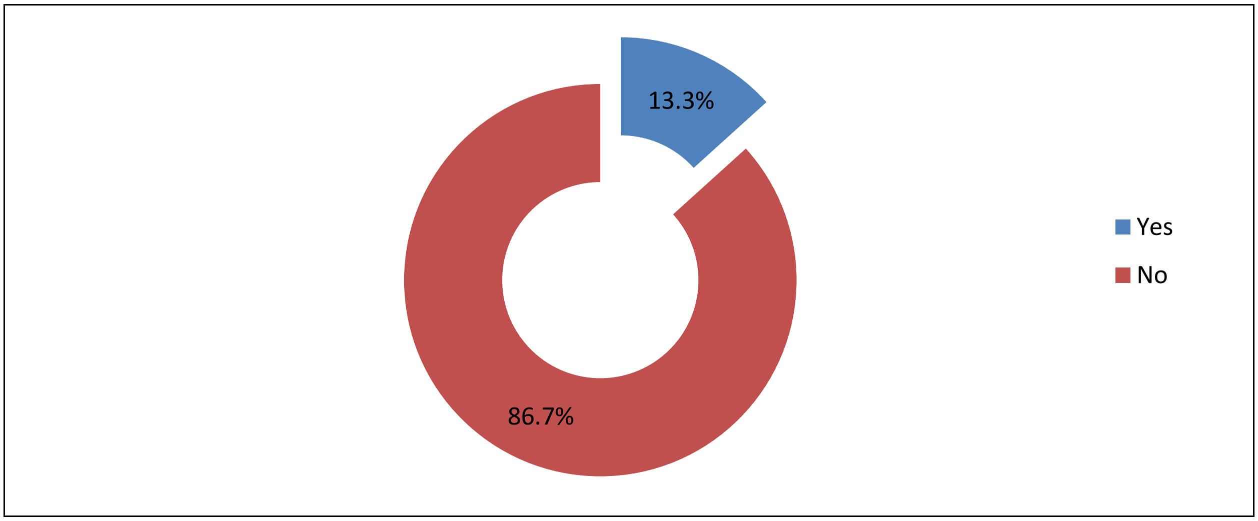

Figure 5.14: Access to credit by the household heads
Source: Survey data (2013)

Table 5.10 shows that most smallholder farmers (85%) did not adopt the IRWH technology and their reason was that they had no access to credit and a smaller proportion (15%) had access to credit. About 76% adopters of the technology had no access to credit and 24% had access. The level of food insecurity (79%) was very high to those non-adopters who had no access to credit while adopters who had access to credit had higher food security status (81%). This indicated that the more smallholder farmers do not get financial support the more they were likely not to adopt the IRWH technology and may be food insecure. This means that financial services are required to enable households to adopt the IRWH technique for the production of agricultural produce (Badisa, 2011).

Table 5.10: Adoption, household food security status and access to credit

Access to credit	Adoption status		Household food security status	
	Non-adopters	Adopters	Food insecure	Food secure
	Percentage	Percentage	Percentage	Percentage
Yes	15	24	21	81
No	85	76	79	19
Total	100	100	100	100

Source: Survey data (2013)

An overview of an access to extension services and information were highlighted in the following section.

5.4.2.8 Access to extension services and information

Shikur and Beshah (2012) mentioned that extension services play a vital role in equipping farmers with the necessary farming knowledge, techniques and skills in order to optimise productivity. The study results are shown in Figure 5.15 below.

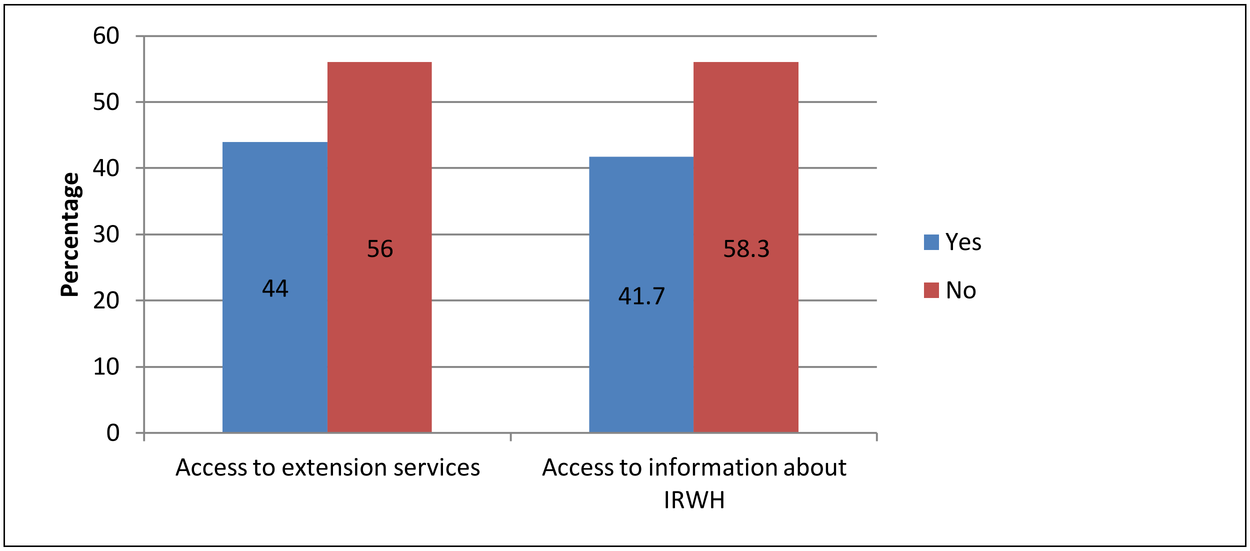

Figure 5.15: Access to extension services and information about IRWH technology
Source: Survey data (2013)

The results presented in Figure 5.15 reveals that about 56% of households indicated that they did not have access to extension services while 44% had access. This indicates that a number of households in the areas do not receive extension services. This has led to 58.3% of smallholder farmers not accessing information about IRWH technology while 41.7% had access to the information.

Access to extension services like training in agriculture improves the capacity of obtaining information that is accurate (Moyo and Nyimo, 2006). Therefore, access to information is essential because it can influence a households' decision on adopting the IRWH technology. According to Tesfay (2008) extension is also known to catalyse awareness, organisation, exchange information and technology adoption among smallholder farmers. The number of extension workers per unit of population influences extension delivery. For this study, results are shown in Table 5.11.

Table 5.11: Adoption, household food security status and access to extension services as well as information

Access to extension services	Adoption status		Food security status	
	Non-adopters	Adopters	Food insecure	Food secure
	Percentage	Percentage	Percentage	Percentage
Yes	13	100	11.4	54
No	87	0	88.6	46
Total	100	100	100	100
Access to information				
Yes	25	100	17	58
No	75	0	83	42
Total	100	100	100	100

Source: Survey data (2013)

About 75% non-adopters of the IRWH technology had no access to information about the technology and 83% were food insecure while 25% had access to information. All adopters (100%) indicated that they had access to information and 58% were food secure (refer to Table 5.11). This indicates that the majority of non-adopters are not informed about IRWH technology and what is needed. This might be because extension officers do not visit the farmers frequently enough. The results are in line with what was found by Hlanganise (2010) on the impact of IRWH technology on household food security at Khayalethu and Guquka villages in the EC.

An overview of how many livestock were kept by the households in the study areas was highlighted below.

5.4.2.9 Livestock ownership

In South African rural areas, livestock keeping is known as a tradition and a source of livelihood (Featherstone, 1997). According to Gebregziabher (2013) the higher the number of livestock owned, the wealthier the household. Therefore households that are wealthier have greater chances of adopting the technology. In this study, livestock ownership was used as a proxy for wealth.

Interestingly, Figure 5.16 presents that on average; non-adopters own a higher number of all the types of livestock under study than adopters. This implies that non-adopters are wealthier than adopters. This could be attributed to the fact that non-adopters are older than adopters and could suggest that they have accumulated the types of livestock over a period of time. This led to low adoption of IRWH technology in the study areas. These results are in contrast with what was found by Shikur and Beshah (2012). It was found that adopters own more livestock than non-adopters because smallholder farmers use their livestock as a source of income.

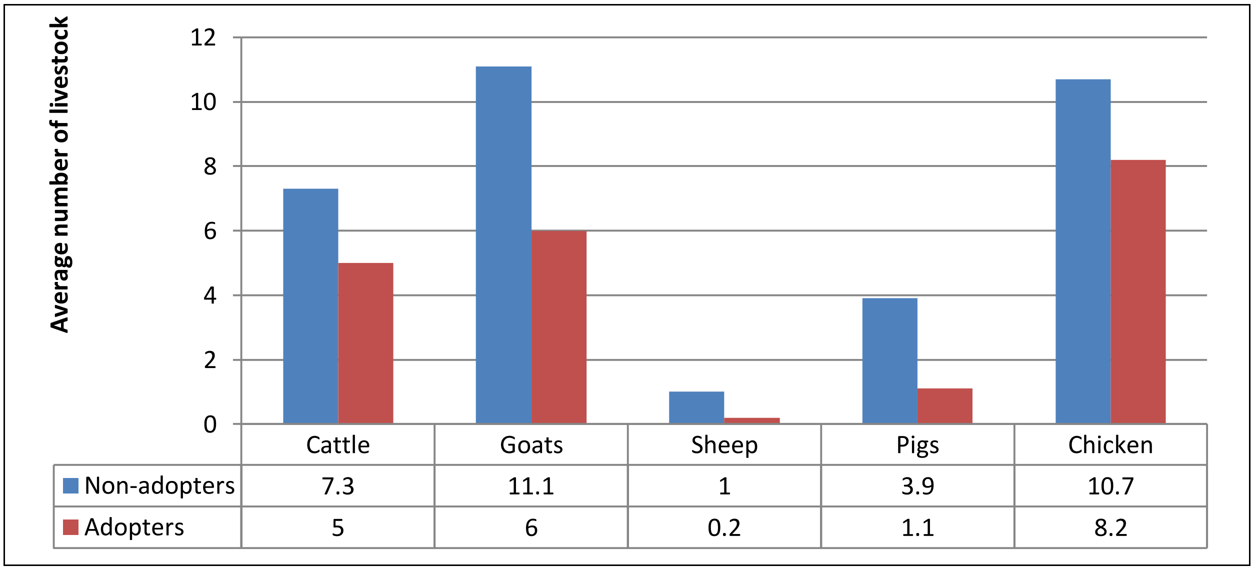

Figure 5.16: Livestock ownership between adopters and non-adopters
Source: Survey data (2013)

Livestock production is identified as an agricultural enterprise with the greatest potential for improving household food security (Babatunde *et al.*, 2007). Therefore, the wealthier the household the higher the likelihood of being food secure than those without livestock (Gebregziabher, 2013).

The findings of this study in Figure 5.17 show that non-adopters had a greater percentage of food insecurity (88.6%) while 69.4% adopters were food secure. The reason for this development could be that livestock was kept to satisfy other needs like social status and could also suggest that they did not see livestock as a source of income to finance household needs to improve household food security status as reviewed by Babatunde *et al.* (2007). These results are in line with the findings of Gebregziabher (2013) who established that non-adopters were food insecure compared to adopters

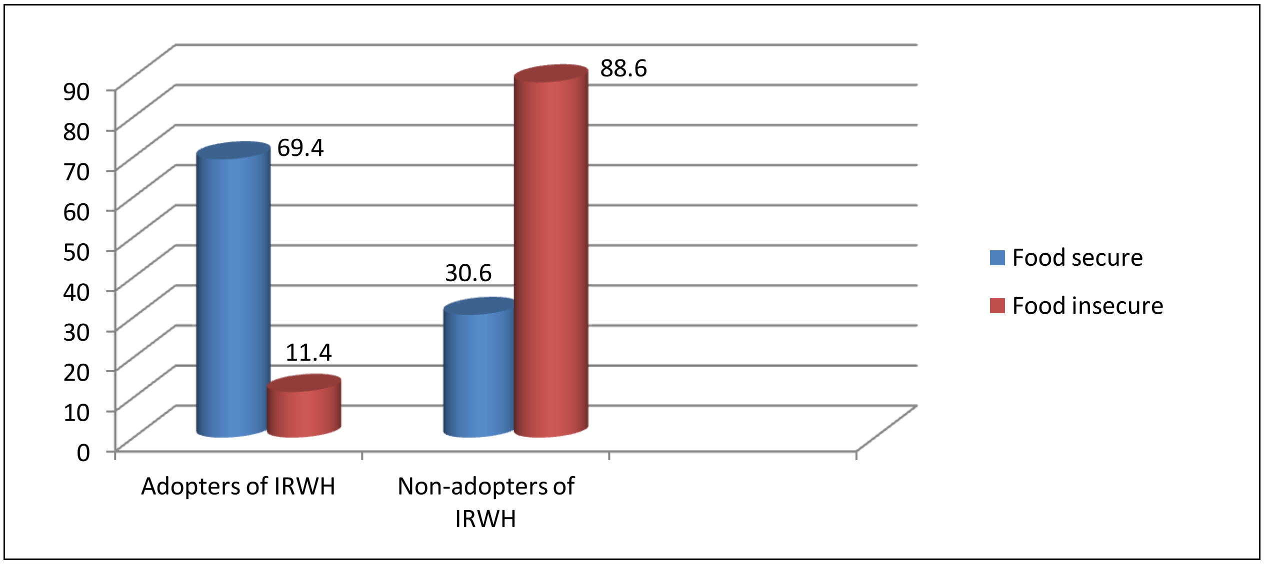

Figure 5.17: Adoption, household food security status and livestock ownership
Source: Survey data (2013)

The next section gives an overview of how many minutes the households walk to other water sources.

5.4.2.10 Distance to other water sources

The distance to other available water sources to irrigate crops is important in the decision whether to adopt IRWH technology or not (Joseph and Botha, 2012). The lesser the walking distance to other water sources the less likely it is that the household will adopt the IRWH technology (Monde and Aliber, 2007). The other sources of water include tap water, borehole, stream and river in the study areas. For this study, results are shown in Table 5.12.

Table 5.12: Total walking distance to other water sources

	Adopters of IRWH technology	Non-adopters of IRWH technology
	Mean	Mean
Minutes	15.64	10.85

Source: Survey data (2013)

The results in Table 5.12 shows that on average the total walking distance to other water sources was 15.64 minutes for adopters of IRWH technology and 10.85 minutes for non-adopters. This postulates that adopters walk a longer distance while non-adopters walk a shorter distance to other water sources. The results are in-line with the findings of Gebregziabher (2013) where adopters walked 11.54 minutes and non-adopters walked 6.43 minutes to other water sources. The closer the water source for irrigation purposes to the household, the less vulnerable to food insecurity because agricultural productivity will be improved (Botha *et al.*, 2013).

In Figure 5.18, the results show no much difference between household food security status of adopters (53%) and of non-adopters (47%) of the IRWH technology with respect to distance to other water sources. Therefore it can be concluded that non-adopters had an access to water for irrigation as much as adopters which enabled them to be food secure. The results concur with the findings of Baiyegunhi (2014) on determinants of RWH technologies adoption for home gardening in KwaZulu-Natal.

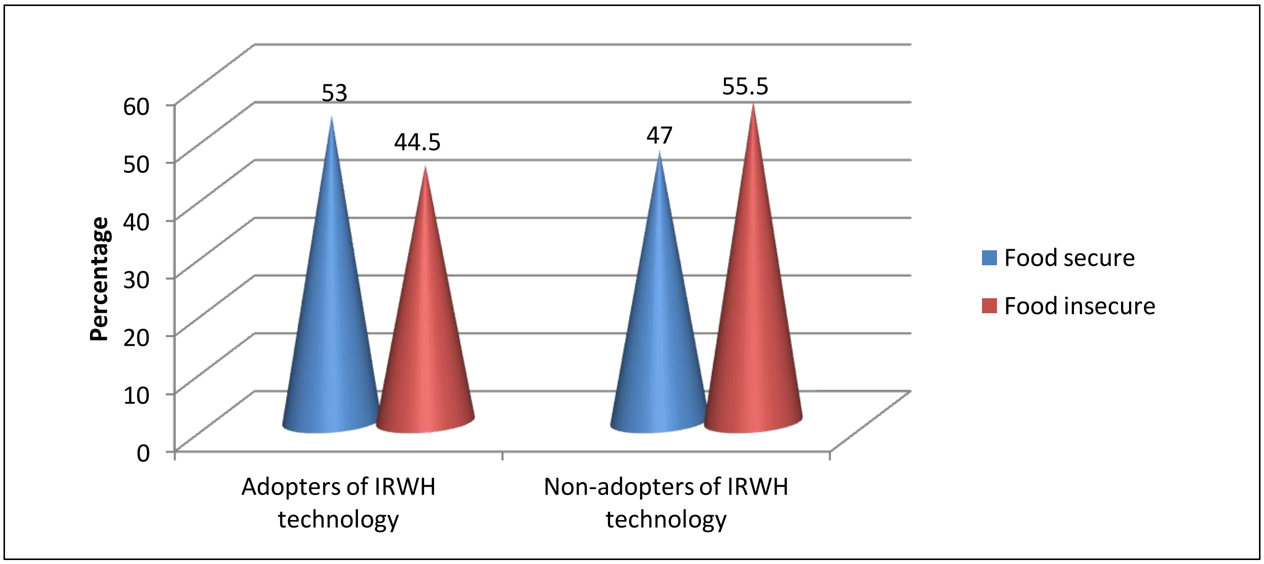

Figure 5.18: Adoption, household food security status and distance to other water sources
Source: Survey data (2013)

The next section discusses how smallholder farmers in the study areas perceived the IRWH technology.

5.4.2.11 Farmers' perception towards the IRWH technology

In order for the IRWH technology to be adopted it depends mainly on how smallholder farmers perceive it (Kalineza *et al.*, 2008). The technology can be perceived positively or negatively. Figure 5.19 shows how the technology was perceived in the study areas.

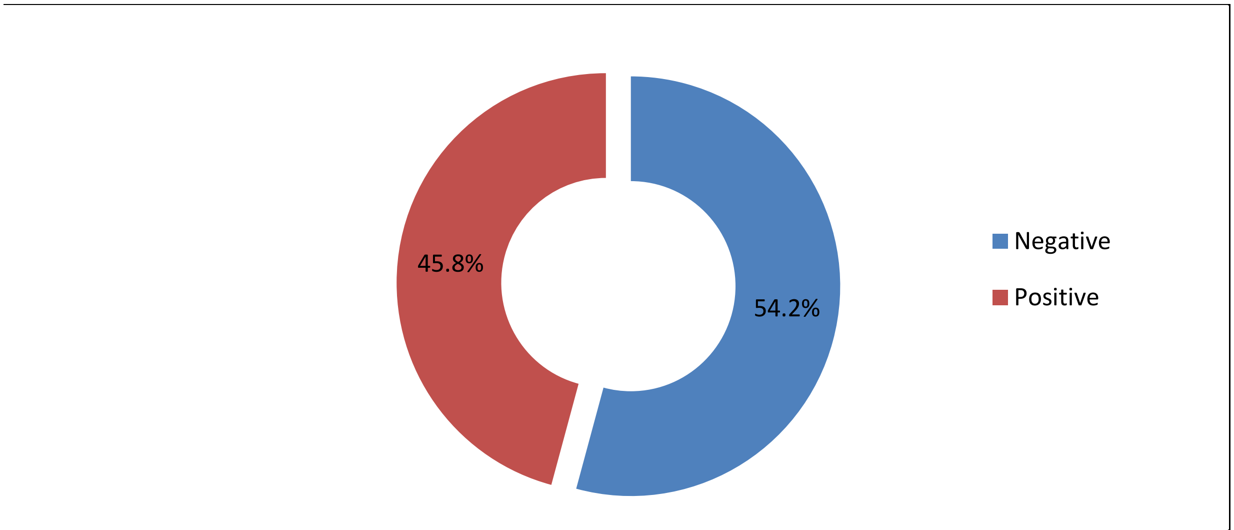

Figure 5.19: Farmers' perception towards the IRWH technology
Source: Survey data (2013)

From Figure 5.19 it shows that about 54.2% of smallholder farmers perceived this technology negatively while 45.8% farmers had a positive perception towards the technology. This indicates that most smallholder farmers had a negative perception towards IRWH technology. The labour-intensive nature of the technology was the reason given for their negative perception. The results are in-contrast with the findings of Baiyegunhi (2014) where the majority of the farmers (70%) had a positive attitude towards the RWH technologies.

With a positive perception towards the IRWH technology, the higher the possibilities of adoption of the technology but a negative perception may lead to a lower adoption and a likelihood of being food insecure (Ahmed *et al*., 2013). The results from the study areas are tabulated in Table 5.13.

Table 5.13: Adoption, food security status and farmers' perception towards IRWH technology

Farmers' perception toward the IRWH technology	Adoption status		Food security status	
	Non-adopters	Adopters	Food insecure	Food secure
	Percentage	Percentage	Percentage	Percentage
Positive	18	100	29	65
Negative	82	0	71	35
Total	100	100	100	100

Source: Survey data (2013)

Table 5.13 shows that larger percentage (82%) had a negative perception and did not adopt the technology leading to higher percentage of food insecurity (71%). Only lesser non-adopters (18%) had a positive perception. All adopters had a positive perception towards the IRWH technology and 65% were food secure. The reason given by the smallholder farmers for not adopting the technology was that, during high rainfall periods there is a water logging problem which causes irreversible damage to the structures of the IRWH technique. The other reason could be that they have steeper slopes which allow rapid run-off which increases soil erosion. Therefore, these problems limit the benefits achieved from practicing the IRWH production technique. The results from the study areas concur with the findings of Kalineza *et al*. (2008) on factors that influence the adoption of soil conservation in Tanzania.

5.5 Summary

This chapter discussed the household demographics as well as socio-economic characteristics of the study population. The results of the survey revealed that the majority was constrained by a general lack of credit, labour since IRWH technology is very labour intensive and access to markets to sell their produce. Lack of cash may suggest that the smallholder farmers have difficulties in purchasing farm inputs. The results also show that the adoption status of the IRWH technology is low in Khayalethu, Guquka and Krwakrwa villages and food insecurity is high among the non-adopters. The most contributing factor was that they own small land which gave them lower or no farm income. This resulted in a negative perception towards the IRWH technology hence low adoption and high food insecurity. Generally, the results of the survey suggest that the household demographics and socio-economic variables may have an influence on the factors that determines the adoption of IRWH technology and their household food security.

CHAPTER 6

RESULTS OF THE EMPIRICAL ANALYSIS AND DISCUSSIONS

6.0 Introduction

This chapter presents the empirical results obtained from the logistic regression model that was formulated and explained in Section 4.10.1. Within the chapter, the independent variables are tested for their significance and conclusions are drawn based on the results. A detailed explanation is provided for the significant variables and this is followed by the summary of the chapter.

6.1 Empirical results

In this section all the variables that were discussed in the previous chapter were considered for the model and tested for their significance. The logistic results are presented in Table 6.1 for demographic and socio-economic factors influencing the adoption of IRWH technology and Table 6.2 for demographic and socio-economic factors influencing household food security. The tables show the estimated coefficients (β values), standard error, significance values and odd ratio of the predictor or independent variables in the model.

According to Gujarati (2002) the coefficient values measure the expected change in the logit for a unit change in each independent variable, all other independent variables being equal. The positive or negative (+/-) sign of the coefficient shows the direction of influence of the variable on the logit. If it follows a positive value, it indicates an increase in the likelihood that a household will adopt IRWH technology or may be food secure. A negative value shows that it is less likely that a household will consider adopting the IRWH technology or may be food insecure.

The significance values (also known as p-values) show whether or not a change in the independent variable significantly influences the logit at a given level. In this study, the variables were tested at 1%, 5% and 10 % significance levels. Thus, if the significance value is greater than 0.01, 0.05 or 0.10 then it shows that there is insufficient evidence to support that the independent variable influences a change from not adopting the IRWH technology or a likelihood of being food insecure. If the significance value is less or equal to 0.01, 0.05 or 0.10, then there is enough evidence to support a claim presented by the coefficient value.

The odds ratio indicates the extent of the effect on the dependent variable caused by the predictor variables. It gives the exponential of expected value of β raised to the value of the logistic regression coefficient, which is the predicted change in odds for a unit increase in the corresponding explanatory variable. According to Hill *et al*. (2001) and Gujarati (2002) a value greater than one implies greater probability of variable influence on the logit and a value less than one indicates that the variable is less likely to influence the logit. The standard error measures the standard deviation of the error in the value of a given variable (Hill *et al,* 2001; Gujarati, 2002).

The goodness-of-fit test for a logistic regression model measures the suitability of the model to a given data set. The -2log likelihood is a test value used to determine whether or not the independent variable has an effect on the dependent variable. It measures the relevance of the model employed in the study. It indicates the difference between the estimated logistic model and the perfect model.

6.1.1 Factors influencing adoption of the IRWH technology

The logistic results for demographic and socio-economic factors influencing the adoption of IRWH technology are presented in this section in Table 6.1. The overall percentage of correct predictions was 77.5% as shown below in Table 6.1. The results for the goodness-of-fit test shown in Table 6.1 indicate that the model fits the data well. Thus, the results for Hosmer & Lemeshow Test show that the binary logistic regression model is well suited to predict the influence of the independent variable on the dependent variable. The Nagelkerke R^2 is 0.51 (refer to Table 6.1) and it lies between 0 and 1, confirming the goodness of fit of the model.

The formula in Section 4.10.1 is briefly described by Gujarati (2002) as the cumulative logistic distribution function for factors influencing the adoption of IRWH technology. The results of the binary logistic regression equation (refer to Table 6.1), expressed in terms of the variables used in this study are given as:

$$\ln(\text{ODDS}) = \ln(\hat{Y} / 1 - \hat{Y}) = \beta o + \beta_1 X_1 + \ldots + \beta n X n + U$$

$$= -1.52 - 1.47\ ACHLBR + 1.10\ FAMINCO + 0.08\ ACMKT + 0.32\ ACES + 1.66\ ACINFO + 0.87\ FPTRWH$$

Table 6.1: Binary logistic results for adoption or non-adoption of IRWH technology

Variable	Coefficient	Standard Error	Significance	Odds ratio
Gender of the household heads	0.61	0.48	0.20	1.85
Age of the household heads	-0.03	0.02	0.19	0.97
Education level of the household heads	0.17	0.09	0.60	1.19
Household size	0.23	0.18	0.21	1.25
Access to hired labour	-1.47	0.69	0.06*	0.23
Household income	-0.83	0.66	0.21	0.43
Farm income	1.10	0.63	0.05*	0.30
Land tenure security	-0.00	0.00	0.78	0.99
Land size	0.05	0.03	0.23	1.05
Access to market	0.08	0.04	0.03**	1.08
Access to credit	-0.00	0.00	0.34	0.99
Access to extension services	0.32	0.15	0.00***	8.37
Access to information	1.66	0.47	0.00***	5.29
Livestock ownership	-1.73	0.70	0.97	0.18
Distance to other water sources	1.18	0.68	0.82	0.44
Farmers' perception towards the IRWH technology	0.87	0.42	0.00***	6.38
Constant	-1.52	1.88	0.42	0.22
-2 Log likelihood		167.65		
Nagelkerke R^2		0.51		
Hosmer & Lemeshow Test		Chi-square	Sig	df
		2.18	0.97	8
Percentage correctly predicted		77.5%		

Significant at 1%***, 5%** and 10%* probability level

Source: Survey data (2013)

The significant explanatory variables included: access to hired labour, farm income, access to market, access to extension services, access to information and farmers' perception towards IRWH technology (refer to Table 6.1). Each of these variables is briefly discussed below.

6.1.1.1 Access to hired labour

In this research access to hired labour was measured by asking smallholder farmers whether they had hired labour for farming. This variable was found to be significant at 10% and related negatively with the farmers' desire to adopt the IRWH technology activity. A -1.47 coefficient was obtained for access to hired labour. This indicates that as access to hired labour increases by 1 unit, the probability to adopt the IRWH technology decreases by 1.47 units, *ceteris paribus.* This was found to be in-contrast with the literature which said more labour availability will positively influence adoption and the extent of adoption as it eases the labour constraint faced by most smallholder farmers towards the implementation of IRWH technology (He *et al.*, 2007; Kai, 2011; Shikur and Beshah, 2012). The contributing factor could be that, the majority of households use family members for labour provision and smallholder farmers cannot hire labour because of the unavailability of funds which led to less adoption.

6.1.1.2 Farm income

According to Sithole *et al*. (2014) farm income shows a positive effect on households' adoption decision of improved technologies. In this study the variable farm income was measured by capturing the total income per month smallholder farmers received after selling their produce. It was significant at 10% and related positively with smallholder farmers' desire to adopt the IRWH technology activity, *ceteris paribus.* The coefficient of 1.10 was obtained for this variable. This implies that as farm income increases by 1 unit, and the probability of adoption of IRWH technology increases by 1.10 units. These results are in line with the *priori* expectations of the probability which provide that if farm income increases, the adoption of IRWH technology will also increase. This is supported by descriptive analysis of this study which indicated that when farm income was less than R300.00 per month only 15% adopted the technology and when income was between R600.00–R1999.00 per month more smallholder farmers adopted (56%) as discussed in Section 5.4.2.3. In Ethiopia the study by Shikur and Beshah (2012) also found that farm income was positively related to the adoption of RWH technologies.

6.1.1.3 Access to market

Access to market was measured by the actual distance in kilometres to the nearest input and output markets. As expected this variable was found to have a significant positive relationship to the adoption of IRWH technology at 5% significant level, *ceteris paribus*. The coefficient 0.08 was found for this variable. This implies that as access to market increases by 1 unit, farmers become motivated to produce hence increasing the probability of them adopting IRWH technology by 0.08 units a development which enhances productivity. This result is consistent with Murgor *et al.* (2013) who have observed that there is a potential for adopting new technology, provided that households produce surplus and that they have an easy access to markets (formal or informal) to sell their produce. Shikur and Beshah (2012) have also concluded that distance to the market from the place of dwelling may matter in adopting RWH technologies. Further in the study areas, it was found that more smallholder farmers adopted (70.8%) the technology because they had access to market as discussed in Section 5.4.2.6.

6.1.1.4 Access to extension services

Access to extension services was measured by asking smallholder farmers whether they had access to extension services like governmental assistance and trainings/workshops with regards to IRWH technology. This variable was found to have a significant positive effect on the IRWH technology adoption as was hypothesised. It is highly significant at 1% level and is positively related to the adoption of IRWH technology, other things held constant. This suggests that the findings of this study indicated that smallholder farmers who adopted the IRWH technology had contacts with extension services more than non-adopters as discussed in Section 5.4.2.8. The coefficient obtained was 0.32. This postulates that if access to extension services increases by 1 unit, the probability of adopting IRWH technology increases by 0.32 units.

In addition, Woyessa *et al*. (2006) highlighted that smallholder farmers who are in contact with research development or extension agencies have a greater likelihood of adopting the IRWH technique. Farmers who have a frequent contact with research extension agencies will have an easy access to information and training workshops; this will upgrade their knowledge on technology (Woyessa *et al*., 2006). Therefore it will help in the implementation of the IRWH technology because it is too technological for the users (Moyo and Nyimo, 2006). This result is consistent with the findings of Yengoh *et al.* (2010) on technology adoption in small-scale agriculture in Cameroon and Ghana.

6.1.1.5 Access to information

The variable access to information was measured by asking smallholder farmers whether they had enough knowledge on the IRWH technology. This variable was found to be highly significant at 1% and related positively with the farmers' desire to adopt the IRWH technology activity, other things held constant, as hypothesised. The coefficient of 1.66 was obtained and this indicates that, if access to information increases by 1 unit, the probability of adoption will increase by 1.66 units. In other words, the greater the access to information, the more smallholder farmers will adopt the IRWH technology. This is so because, according to Baiyegunhi (2014) contact with extension officers allows farmers to have a greater access to information on technology, through increased opportunities to participate in demonstration tests and thus increase farmers' ability to get, process and use IRWH technique. Also, the findings of this study indicated that smallholder farmers adopting the IRWH technology had access to information more than non-adopters as discussed in Section 5.4.2.8. This is in agreement with Sunding and Zilberman (2000) who stated that exposure to information sources is expected to have a positive influence on the adoption of new technologies. Furthermore, these results are consistent with a study conducted in China by He *et al.* (2007) on the econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology.

6.1.1.6 Farmers' perception towards the IRWH technology

Farmers' perception can be defined as the degree of farmers' positive or negative feelings towards the technology (Kalineza *et al*., 2008). In this study smallholder farmers were asked whether they had positive or negative perception towards the IRWH technology. According to Yengoh *et al*. (2010) a smallholder famer who has a positive attitude adopts the RWH technologies at a higher rate than those smallholder farmers who have a negative attitude. For example, in the preliminary findings of this study it was indicated that more smallholder farmers (82%) did not adopt this technology because they had a negative perception towards it as discussed in Section 5.4.2.11. Also Murgor *et al.* (2013) have come to the same conclusion about factors influencing farmers to adapt RWH techniques in Kenya to the effect that household members' who did not adopt the technology had a negative attitude about the technologies. From the regression results, farmers' perception towards the IRWH technology is strongly significant at 1% and related positively with the farmers desire to adopt the IRWH technology activity, *ceteris paribus*, as hypothesised. The coefficient obtained was 0.87. This suggests that if famers' perception towards IRWH technology increases by 1 unit, more people will adopt this technology by 0.87 units. He *et al.* (2007) reported similar findings.

In the next section factors that influence household food security were highlighted.

6.1.2 Factors influencing household food security

This section discusses binary results of demographic and socio-economic factors influencing household food security as shown in Table 6.2.

Table 6.2: Binary logistic results for the incidence of household food security

Variable	Coefficient	Standard error	Significance	Odds ratio
Adoption of the IRWH technology	2.44	1.22	0.00***	8.37
Gender of the household heads	2.30	1.55	0.13	0.99
Age of the household heads	0.05	0.06	0.28	1.06
Education level of the household heads	-0.04	0.21	0.82	0.95
Household size	1.05	0.54	0.05*	2.87
Access to hired labour	1.04	2.09	0.01**	2.82
Household income	1.25	0.51	0.02**	0.28
Farm income	0.81	0.42	0.59	0.44
Land tenure security	1.65	0.85	0.52	2.38
Land size	-1.62	0.98	0.98	2.09
Access to market	0.09	0.46	0.83	1.10
Access to credit	-1.49	0.84	0.77	3.57
Access to extension services	0.43	0.21	0.00***	7.80
Access to information	0.03	0.33	0.30	1.03
Livestock ownership	0.34	0.61	0.57	0.09
Distance to other water sources	-0.39	0.43	0.97	0.67
Farmers' perception towards the IRWH technology	0.92	0.34	0.00***	5.62
Constant	-8.61	3.71	0.02	0.00

Significant at 1%***, 5%** and 10%* probability level
Source: Survey data (2013)

The binary logistic regression model fit was tested using the Hosmer & Lemeshow statistics. The overall percentage of correct predictions was 89.2% as shown in Table 6.3. The p-value of 0.72 shows that there is a significant difference between the observed and predicted values of the dependent variables, indicating that the models' estimates fit the data well, at an acceptable level. The Nagelkerke R^2 is 0.60 (refer to Table 6.3) and it lies between 0 and 1, confirming the goodness of fit of the model.

Table 6.3: Model summary

-2 Log likelihood	96.292		
Nagelkerke R^2	0.60		
Hosmer & Lemeshow Test	Chi-square	Sig	df
	5.33	0.72	8
Percentage correctly predicted	89.2%		

Source: Survey data (2013)

The results of the binary logistic regression equation (refer to Table 6.2), expressed in terms of the variables used in this study are given as:

$$\ln(\text{ODDS}) = \ln(\hat{Y}/1 - \hat{Y}) = \beta o + \beta_1 X_1 + \ldots + \beta n X n + U$$

$$= -8.61 + 2.44\ \text{ADOPIRWH} + 1.05\ \text{HHS} + 1.04\ \text{ACHLBR} + 1.25\ \text{HHINCO} + 0.43\ \text{ACES} + 0.92\ \text{FPTRWH}$$

The significant explanatory variables included: adoption of IRWH technology, household size, access to hired labour, household income, access to extension services and farmer's perception towards IRWH technology (refer to Table 6.2). Each of these variables is briefly discussed below.

6.1.2.1 Adoption of the IRWH technology

The adoption of IRWH technology variable was measured by asking households if they currently practice the technology. The variable adoption of the IRWH technology was positively significant at 1% level as was expected and hypothesised in the study. This shows a positive relationship between adoption of IRWH technology and household food security status, *ceteris paribus*. The coefficient for the adoption of IRWH technology was 2.44. This implies that the higher the probability of adopting the IRWH technique by 1 unit the higher the household food security status by 2.44 units because more crop yields could be obtained. This could further indicate the importance of adoption of IRWH technology to smallholder farmers and the potential to improve household food security and income generation. These results correspond with the literature which states that IRWH technology increases yields in high drought soils because run-off is directed and stored into the basin area improving water availability (Hatibu *et al.,* 2006). Badisa (2011) reported similar findings in Lambani village in the Free State Province.

6.1.2.2 Household size

Household size variable was measured by capturing the actual number of members in a household. From the binary logistic regression model results, household size is significant at 10% and related positively with household food security, other things held constant. The coefficient of this variable was 1.05 which entails that if household size increases by 1 unit, household food security improves by 1.05 units because IRWH technology is labour intensive therefore more household labour will be available (Kai, 2011). As such, more diversified crops will be planted resulting in higher yields. These results are supported by Kuwornu *et al.,* (2013) who have pointed out that smallholder farmers in Ghana have access to family labour, a development which may translate to an increase in the demand for new innovations that are labour intensive. However, the results are in-contrast with the findings of Babatunde *et al.* (2007) who established that household labour is negatively related to household food security.

6.1.2.3 Access to hired labour

The study expected access to hired labour to be positively related to household food security and it was found to be significant at the 5% significant level, *ceteris paribus*. The coefficient obtained for this variable was 1.04. This indicates that with increasing hired labour force by 1 unit, household food security increases by 1.04 units. This might happen because there will be an increased diversity in the production of crops planted leading to higher yields. This also shows the importance of hired labour because the quantity of the harvest depends on the number of labourers for ploughing, weeding and irrigating the crops (Monde, 2003). These results are consistent with the literature which has stated that the more the farmers hired labour for farming the more the yields they would receive which improves household food security (Hlanganise, 2010). Kuwornu *et al.* (2013) have also reported similar results in Ghana.

6.1.2.3 Household income

The household income variable was measured by capturing the total household income per month. As hypothesised in the study, this variable was found to be positive and significant at 5% level. The coefficient of 1.25 was obtained for this variable. This indicates that the higher the household income by 1 unit, the higher the probability that household would be food secure by 1.25 units, other things held constant. This could be expected because the increased income means increased access to healthy and nutritious food all the time (Hlanganise, 2010). These results are supported by the descriptive findings of this study in Section 5.4.2.2 which indicated that smallholder farmers who adopted (39.6%) the technology earned income between R3000.00–R4000.00 per month and were food secure (34.2%) as compared to non-adopters (43.1%) who earned income between R1500.00–R2999.00 per month, who were food insecure (71.4%). These results are in line with the observations of Babatunde *et al*. (2007) who stated that the greater the household income, the more food secure the household is. Similar results were found by Kuwornu *et al.* (2013) who have revealed a positive and significant relationship between household income and food security.

6.1.2.5 Access to extension services

Access to extension services like governmental assistance, information, training as well as workshops helps smallholder famers to better understand the construction of IRWH technique (Hatibu *et al.*, 2006). Also, farmers mostly produce particular crops based on the knowledge that they have on those specific crops (FAO, 1990). This study hypothesised and expected that the variable access to extension services is highly significant at 1% and is positively related to household food security, *ceteris paribus.* The coefficient obtained for this variable was 0.43 and this means that if access to extension services increases by 1 unit, there would be a probability of household food security increasing by 0.43 units. This could be the case because smallholder farmers will harvest more quantities and sell the surplus in order to buy more nutritious food and obtain health care (Hlanganise, 2010). Sithole *et al.* (2014) have reported similar findings.

This is also supported by the descriptive findings of this study in Section 5.4.2.8 which indicated that all adopters (100%) of the technology had access to extension services and were food secure (54%) more than non-adopters.

6.1.2.6 Farmers' perception towards the IRWH technology

Farmers' perception towards the IRWH technology also proved to be a highly significant variable to household food security in the study areas. This variable is statistically significant at 1% significance level and positively related to household food security, as hypothesised. The coefficient obtained for this variable was 0.92. This indicates that if a positive perception towards IRWH technology that more yields will be obtained increases by 1 unit, the probability of adopting IRWH technology will increase. Hence, a likelihood of more households being food secure will in turn increase by 0.92 units, other things held constant. This is consistent with the expectation that smallholder farmers are likely to invest in technologies that enable them to maximise production in order to improve household food security and which are compatible with their farming systems (Kai, 2011). In addition, smallholder production increases household food security and reduces reliance on cash to feed the household thus releasing cash for other household uses (Baiphethi and Jacobs, 2009).

6.2 Summary

This chapter discussed the influence of the significant predictor variables on the dependent variable. The results from the socio-economic analysis for the incidence of adoption showed that access to hired labour and farm income were significant at 10%. This means that these variables appear to play a lesser role in influencing adoption of the IRWH technology as proved by their significance levels. Access to hired labour negatively influences the adoption of IRWH technique while farm income positively influences adoption. If farm income can be improved adoption of the IRWH technology can be enhanced. Access to market was significant at 5% and influences adoption positively meaning the more markets are available the higher the adoption of IRWH technology. Farmers' perception towards the IRWH technology, access to extension services and access to information were found to be highly significant at 1% and positively influences the adoption of IRWH technology. This suggests that improving farmers' perception towards the IRWH technology, access to extension services and access to information will significantly improve the adoption of IRWH technology.

For the incidence of household food security, significant variables were all positively related to household food security. Adoption of the IRWH technology, access to extension services and farmers' perception towards the IRWH technology were highly significant at 1% significance level. This means that these variables appear to play a major role in influencing household food security as proved by their significance levels. If smallholder farmers can improve their adoption status of IRWH technology, more households will be food secure. Also if extension officers which help with extension services like trainings, demonstrations, workshops, information and government assistance can visit households more often, improving their access, more households will adopt IRWH technique leading to improved household food security status. If more smallholder farmers can perceive IRWH technology positively, their household food security status will improve. Variables like household income and access to hired labour were found to be significant at 5% significance level. Household size was significant at 10% meaning it plays a lesser role in influencing household food security as proved by its significance level in the binary logistic regression model.

Generally, the findings of this study suggest that any change in each one of the significant variables can significantly influence the probability of adopting IRWH technology and household food security.

CHAPTER 7

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.0 Introduction

This chapter provides the summary of the research findings and conclusions basing on the results of the study and puts forward some recommendations. Lastly, it also provides areas of further studies.

7.1 Discussion and conclusion

The main objective of this study was to investigate the socio-economic factors influencing the adoption of the IRWH technology for enhancing household food security by smallholder farmers. The major determinants and their prior expectation were explained in Section 4.10.1.1. The specific objectives of this study were to assess the level of adoption of IRWH technology by smallholder farmers, to determine socio-economic factors influencing the adoption of IRWH technology by smallholder farmers and to determine whether adopters of IRWH technology are more food secure than non-adopters in the study areas in the EC.

To assess the level of adoption of IRWH technology by smallholder farmers, descriptive statistics were employed. The main descriptive indicators that were employed were percentages, frequency and mean values. The results were presented in graphs, pie-charts, tables and cross-tables. The binary logistic regression model was used to test the factors that influence the adoption of IRWH technology and household food security. To measure household food security in the study areas, the HDDS was adapted and an average HDDS indicator of 5.01 was obtained. A household was food secure if the HDDS score was above 5 and food insecure if the HDDS score was below 5.

The descriptive results of the study revealed that level of adoption of the technology is low by 21% and the level of food insecurity is high amongst the non-adopters in the study areas by 86%. The contributing factor might that on average non-adopters have smaller land of 0.453ha compared to adopters which have 0.639 ha. This has led to 70% of non-adopters to receive no farm income per month which resulted in food insecurity of 46% because they have to produce for consumption. It can be concluded that any change in each one of the significant variables can significantly influence the probability of adopting IRWH technology and household food security.

The empirical results show 6 out of 16 variables that are used to test the hypothesis are significant in the incidence of adoption. These significant variables are access to hired labour which negatively influences the adoption of IRWH technology. On the other hand farm income, access to market, farmer's perception towards IRWH technology, access to extension services and access to information are found to be positively influencing the adoption of this technology. The influence of farmer's perception towards IRWH, access to extension services and access to information appear to play a major role in influencing incentives for IRWH technology adoption while farm income, access to market and access to hired labour play a lesser role as shown by their level of significance. Based on the empirical results, IRWH technology does contribute to household food security.

From the empirical results, out of 17 variables, only 6 variables affect household food security of the smallholder farmers in the study areas. These variables are adoption of the IRWH technology, household size, household income, access to hired labour, access to extension services and farmer's perception towards IRWH technology. They all positively influence the household food security. As shown by their level of significance, adoption of IRWH technology, access to extension service and farmer's perception towards IRWH technology strongly influences household food security while household size influences it to a lesser degree.

Generally, empirical findings of this study indicate that there are socio-economic factors influencing adoption of IRWH technology and household food security amongst smallholder farmers.

To increase and promote the likelihood of farmers to adopt IRWH technology in order to improve their food security status, this study recommends the measures outlined in the following section.

7.2 Recommendations

The majority of the non-adopters in the study areas indicated that they have no access to extension services and information about the IRWH technology. Access to extension services can be a useful source of information as it can play a crucial role in empowering farmers with farming knowledge, techniques and skills. Therefore, increasing smallholder farmers' knowledge through better access to technical information, extension and training will help them to develop a positive economic assessment of IRWH technology. As a result there is a need for government to provide extension officers and research stations with the capacity, support and physical means to expose smallholder farmers to IRWH technology through demonstrations and trainings. This will help to improve adoption of IRWH technology as well as smallholder farmers' food security status.

On average non-adopters have smaller land size compared to adopters. With expansion to the communal croplands, both adopters and non-adopters will be able to produce large enough surpluses. This could solve the problem of not having enough land to construct the structure of IRWH technology. Enough surpluses will help smallholder farmers to raise their farm incomes and consequently improve their household food security status. This will also help to improve the positive perception towards the technology and gives an incentive to adopt it.

The majority of non-adopters indicated that they have no access to hired labour. Hired labour eases the labour constraints since this technology is labour intensive. Therefore, when smallholder farmers are working as a co-operative or as an association, they will be able to help each other in the construction and maintenance of the structure of IRWH technique. This support service will have a positive influence on adoption and household food security status.

Results of this study reveal that most of smallholder farmers have no access to credit which is one of the major constraints for smallholder farmers not adopting IRWH technology. Smallholder farmers need access to finance to invest in basic inputs, such as improved seeds and fertiliser to raise farm productivity and generate profits but they may not be getting access to it because financial institutes may not be available in their areas. If government can introduce agricultural finance institutions in rural areas mainly to assist the rural smallholder farmers since other financial institutions like banks may have strict requirements in providing loans such as collateral which the smallholder farmers may not have. The Department of Water Affairs could establish a new policy to provide financial assistance to resource-poor irrigation farmers.

This will help to improve adoption and household food security status.

This study highlights and recommends that future research should focus into the following:

7.3 Areas of further studies

- Investigation on socio-economic factors influencing IRWH technology in all communities in the Province that have benefited from the project have to be done because the importance of socio-economic factors affecting technology adoption differs across countries and regions due to differences in natural resources, cultural and political ideologies and socio-economic. Therefore the study urges policy makers, researchers, specialists and others in South Africa to review socio-economic factors in each and every region before they implement new technology so that major socio-economic factors affecting adoption of IRWH technology would come out strongly.

- While the results reported that the use of IRWH technique provides social and economic benefits, these findings come from the assessment of the technique in a short period. There is need for a continued monitoring of the impacts (economic and social) of this technique. In this regards it would be necessary to conduct an impact assessment study in three to four seasons. This could allow researchers and policy makers to have a better understanding of the role that IRWH technology can play in the farming systems in arid and semi-arid areas.

LIST OF REFERENCES

Abera, H.B., 2008. Adoption of improved tef and wheat production technologies in crop livestock mix system in Northern and Western Shwewa zone of Ethiopia. University of Pretoria.

Agricultural Research Council (ARC), 2001. In-Field Rainwater Harvesting: A climate-smart sustainable production practice. Available at: <http://www.iwmi.cgiar.org/News_Room/Archives/Durban_Climate_Change_Conference/PDF/infield.pdf> [Accessed 14/03/2013].

Ahmed, I., Onwanga,R.N., Mburu, D. and Elhadi, Y., 2013. Evaluation of types and factors influencing adoption of Rainwater harvesting techniques in Yatta District Kenya. *International journal of education and research,* 1(6): 1 – 14.

Alem, G., 2001. Rainwater harvesting in Ethiopia: an overview. In: J. Pickford [Ed]; Proceedings of 25th WEDC conference: Integrated development for water supply and sanitation (pp 387-390). Laughborough, UK.: Water Laughborough University, Engineering and development center.

Aliber, M., Baiphethi, M., de Satge, R., Denison, J., Hart, T., Jacobs, P. and van Averbeke,W., with Alcock, R., Antwi, M., Belete, A., Cousins, B., Field, L., Mariga, I., Masika, P., Materechera, S., Mayson, D., Monde, N. and Tapela, B., 2009. Strategies to support South African smallholders as a contribution to government's second economy strategy: Situation analysis, fieldwork findings and main conclusions. Institute for Poverty, Land and Agrarian Studies. University of the Western Cape.

Amha, R., 2006. Impact assessment of Rainwater Harvesting Ponds: The Case of Alaba Woreda, Ethiopia. MSc. Addis Ababa University.

Babatunde, R.O., Omotesho, O.A. and Sholotan, O.S., 2007. Socio-economics characteristics and food security status of farming households in Kwara State, North – Central Nigeria. *Nigeria-Pakistan Journal of Nutrition*, 6 (1): 49 -58.

Babbie, E. and Mouton, J., 2006. The practice of social research. Cape Town: Oxford University Press.

Backeberg, G., 2009. In-field rainwater harvesting on croplands: opportunities and challenges. *Water Wheel*, 8(2): 30-33.

Badisa, K.T., 2011. Socio-economic factors determining in-field rainwater harvesting technology adoption for cropland productivity in Lambani village: A case study of Thulamela Local Municipality of the Vhembe District in Limpopo Province. Msc. University of Limpopo.

Baiphethi, M.N., Viljoen, M.F., Kundhlande, G., Botha,J.J. and van Rensburg, L.D., 2006. Quantifying the impact of in-field rainwater harvesting (IRWH) production techniques on household food security for communal farmers in ThabaNchu, Free State Province. *Agrekon*, 45 (3): 239-45.

Baiphethi, M.N. and Jacobs, P.T., 2009. The contribution of subsistence farming to food security in South Africa. *Agrekon*, 48 (4): 459-82.

Baiphethi, M.N., Viljoen, M.F. and Kundhlande, G., 2009. Rural women and rainwater harvesting and conservation (RWH&C): anecdotal evidence from the Free State and Eastern Cape Provinces. In: Human Sciences Research Council (HSRC), Responding to the global crisis: Contribution of human and social science to social protection, growth and national building, HSRC Social Sciences Research conferences, 16-17 September 2009.

Baiphethi, M. N., Viljoen, M. F., Kundhlande, G., Botha, J. J. and Anderson, J. J., 2009. Reducing poverty and food insecurity by applying infield rainwater harvesting (IRWH): How rural institutions made a difference. *African Journal of Agricultural Research*, 4 (12): 1358-63.

Baiphethi, M.N, Viljoen, M.F, Kundhlande, G. and Ralehlolo, N.G., 2010. Enhancing food and livelihood security in the context of the food and financial crisis: challenges and opportunities for small scale rainwater harvesting and conservation, In: Research in Agriculture and Applied Economics, African Association of Agricultural Economists (AAAE)>2010 AAAE Third Conference/AEASA 48th Conference, 19 -23 September 2010. Cape Town, South Africa.

Baiyegunhi, L., 2014. Determinants of rainwater harvesting technology (RWHT) adoption for home gardening in Msinga, KwaZulu-Natal, South Africa. *Water South Africa,* 41 (1): 33-39.

Baumüller, H., 2012. Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones. ZEF Working Paper Series 93, University of Bonn.

Bickel, G., Nord, M., Price, C., Hamilton, W. and Cook, J., 2000. Guide to measuring food security, Revised 2000. Alexandria VA, USA.

Botha, J.J., van Rensburg, L.D., Anderson , J.J., Hensley, M., Macheli, M.S., van Staden, P.P., Kundhlande, G., Groenewald, D.G. and Baiphethi, M.N., 2003. Water Conservation Techniques on Small Plots in Semiarid Areas to Enhance Rainfall Use Efficiency, Food Security, and Sustainable Crop Production. South Africa: Water Research Commission.

Botha, J.J., 2005. Livelihoods: in-field rainwater harvesting for homestead backyard gardens, South Africa. In: African Association of Agricultural Economists (AAAE)>2010 AAAE Third Conference/AEASA 48th Conference, Cape Town, 19 -23 September 2010. South Africa: AAAE.

Botha, J.J, Kundhlande, G, and Sanewe, A.J., 2005. Bio-Physical Requirements and Socio-Economic Acceptance of Infield Rainwater Harvesting and Conservation in the Semi-Arid Central Region of South Africa. In: Food and Agriculture Organisation (FAO), FAO/Netherlands Conference on Water for Food and Ecosystems: Make it Happen, 31 January-5 February 2005. Netherlands: FAO.

Botha, J.J., Anderson, J.J, Groenwald, D.C., Mdibe, N., Baiphethi, M.N., Nhlabatsi N.N. and Zere, T.B., 2007. On-Farm Application of In-field Rainwater Harvesting Techniques on Small Plots in the Central Region of South Africa: Main Report. Pretoria: Water Research Commission.

Botha, J.J., Anderson, J.J., Joseph, L.F., van Staden, P.P., Smith, K., Beukes, D.J. and Hensley, M., 2013. Increasing water productivity towards food security through rainwater harvesting and conservation. Available at:

<http://www.combinedcongress.org.za/pdf/2013/CC13_Abstracts_ORAL.pdf> [Accessed 08/11/2014].

Bless, C., Higson, S.C. and Kagee, A., 2011. Fundamentals of Social research methods: An African perspective. 4^{th}edition. Cape Town: Juta.

Bunclark, L.A. and Lankford, B.A., 2010. Rainwater harvesting: A suitable poverty reduction strategy for small-scale farmers in developing countries. *Waterlines Journal*, 30 (4):312-27.

Chisasa, J. and Makina, D., 2012. Trends in credit to smallholder farmers in South Africa. *International Business and Economics Research Journal*, 11 (7): 15-21.

Department of water affairs (DWA), 2013. Water Supply and Sanitation Policy. White Paper, water-an individual national asset. Cape Town. Available at: <http://www.dwaf.gov.za/Documents/Policies/WSSP.pdf. > [Accessed 06/06/2013].

Featherstone, A.M., Kaliba, A.R.M. and Norman, D.W., 1997. A stall feeding management for improved cattle in semi-arid central Tanzania: factors influencing adoption. *Agricultural Economics*, 17:133–46.

Food and Agriculture Organisation (FAO), 1990. An international action programme on water and sustainable agricultural development. Rome: FAO.

Food and Agricultural Organisation (FAO), 2007. Guidelines for measuring Household and Individual Dietary Diversity. Available at: <http://www.fantaproject.org/downloads/pdfs/tn4_dd.pdf> [Accessed 07/05/2013].

Food and Agriculture Organisation (FAO), 2008. World food crisis – world food situation. Available at:<http:// www.fao.org> [Accessed 05/04/ 2013].

Food and Agricultural Organisation (FAO), 2011. Guidelines for Measuring Household and Individual Dietary Diversity. Available at:<http://www.FAO_guidelines_dietary_diversity2011.pdf > [Accessed 16/05/2013].

Fox, P. and Rockstrom, J., 2000. Water harvesting for supplementary irrigation of cereal crops to overcome intra-seasonal dry-spells in the Sahel. *Chemistry of the Earth*, 25:289-96.

Gebregziabher, G., Rebelo, L-M., Notenbaert, A., Ergano, K. and Abebe, Y., 2013. Determinants of adoption of rainwater management technologies among farm households in the Nile River Basin. Sri Lanka: International Water Management Institute.

Gillespie, K., 2006. Coping strategy index as a measure of household food security. Washington D.C.: International Food Policy Research Institute.

Gujarati, D., 2002. Basic Econometrics. 5th edition. New York: McGraw-Hill.

Hatibu, N., Mutabazi, K., Sekondo, E.M. and Msangi, A., 2006. Economics of rainwater harvesting for crop enterprises in semi – arid areas of East Africa. *Agricultural Water Management*, (80): 534-36.

He, X., Cao, H. and Li, F., 2007. Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China. *Agricultural Water Management*, (89): 243 – 50.

Herman, D., van Schalkwyk, H., Groenewald, J., Fraser, C., Obi, A. and van Tilburg, A., 2012. Unlocking markets to Smallholders: Lessons from South Africa. Netherlands: Wageningen Academic Publishers.

Hill, R. C., Griffiths, W. E. and Judge, G. G., 2001. Econometrics. 2nd edition. New York: John Wiley & Sons.

Hlanganise, Y.H., 2010. Impact of in-field rainwater harvesting technology on household food security: a case of Guquka and Khayalethu villages in central Eastern Cape Province. Msc. University of Fort Hare.

Hoddinott, J., 1999. Choosing Outcome Indicators of Household Food Security. Washington, D.C.: International Food Policy Research Institute.

Hoddinott, J. and Yohannes, Y., 2002. Dietary Diversity as a Food Security Indicator. Washington D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Hosu, S., Sibanda, M. and Mushunje, A., 2013. Scenario simulation of small farms production efficiencies in the Eastern Cape Province, South Africa. In: African Association of Agricultural Economists (AAAE), 4th International Conference of the AAAE, Hammamet, 22-25 September 2013. Tunisia: AAAE.

Jari, B., 2009. Institutional and Technical factors influencing agricultural marketing channel choices amongst smallholder and emerging farmers in the Kat River Valley. Msc. University of Fort Hare.

Joseph, L.F. and Botha, J. J., 2012. Critical natural resources factors that promote the adoption of new In-Field Rainwater Harvesting *(IRWH)* by extensionist in Lambani, Limpopo Province. *South African Journal, Agriculture*, 1(40): 231 -38.

Kai, O., 2011. Food security status among cocoa growing households in Ondo and Kwara States of Nigeria: A discriminant analysis approach. *African Journal of Food, Agriculture, Nutrition and Development,* 11(7): 201 – 5.

Kalineza, H., Mdoe, N. and Mlozi, M., 2008. Factors influencing adoption of soil conservation technologies in Tanzania: a Case study in Gario. Available at: < http://www.tzonline.org/pdf/factorinfluencingadoptionofsoil.pdf> [Accessed 09/05/2013].

Kehler, J., 2001. Women and Poverty: The South African Experience. *Journal of International Labour Office,* 2 (3): 143-45.

Kirkland, T.M., Kemp, R.S., Hunter, L.M. and Twine, M., 2011. Toward Improved Understanding of Food Security: A Methodological Examination Based in Rural South Africa. *Food, Culture and Society*, 16(1): 65–84.

Kirsten, J.F. and van Zyl, J., 1998. Defining small-scale farmers in the South African context. *Agrekon,* 37(4): 560-71.

Kuwornu, J., Suleyman,D., Ditchfield,P. and Amegashie, P.K., 2013. Analysis of food security status of farming households in the forest belt of the central region of Ghana. *Russian Journal of Agricultural and Socio-economic Science,* 1 (13): 347 -56.

Leedy, P. and Ormrod, J., 2004. Practical Research: Planning and Design. 8th edition. Upper

Saddle River, New Jersey: Prentice –Hall.

Maxwell, D. and Caldwell, R., 2008. Measuring Food Insecurity. *Food Policy*, 33 (6):533-40.

Mensah, O., James, I., Aidoo, R. and Tuffour, T., 2013. Determinants of Household Food Security in the Sekyere-Afram Plains District of Ghana. *European Scientific Journal*, (3):514-21.

Ministry of Agriculture and Land Affairs, 1998. Agricultural policy in South Africa. A discussion document. Pretoria: National Department of Agriculture.

Monde, N., 2003. Household Food Security in Rural Areas of Central Eastern Cape: The Case of Guquka in Victoria East and Koloni in Middledrift Districts. Ph.D. University of Fort Hare.

Monde, N., 2005. Sustainable Techniques and Practices for Water Harvesting and Conservation and their effective Application in Resource-Poor Agricultural Production: A Situation Analysis of Guquka and Khayalethu at Nkonkobe District Municipality, Eastern Cape. Deliverable No.3 for WRC Project Nr K5/1477.

Monde, N., Chiduza, C., Brutsch, M., Mnkeni, P., Mtshali, S., Dladla, R., Modi, A., Mthembu, B., van der Stoep, I. and Stevens, J., 2005. Best management practices for smallholder farming on two irrigation schemes and surrounding areas in the Eastern Cape and KwaZulu-Natal through participatory adaptive research: A Situation Analysis Report on the Zanyokwe and Tugela Ferry Irrigation Schemes. Alice, South Africa: University of Fort Hare.

Monde, N. and Aliber, M., 2007. Multiple uses of water in rural areas of central Eastern Cape: a case of three villages in Nkonkobe Local Municipality, Eastern Cape. Pretoria: Water Research Commission.

Monde, N., Botha, J., Joseph, L., Anderson, J., Dube, S. and Lesoli, M., 2012. Sustainable techniques and practices for water harvesting and conservation and their effective application in-resource-poor agricultural production. Pretoria: Water Research Commission.

Moyo, S. and Nyimo, T., 2006. Regional Annex Rainwater Harvesting in Southern Africa. The WELL resource centre for water, sanitation and environmental health. Available at: <

http://www.lboro.ac.uk/orgs/well/resources/fact-sheets/fact-sheets htm/RSA%20Rainwater%20in%20SA.htm> [Accessed 15/05/2013].

Muchara, B., 2011. Analysis of food value chains in smallholder crop and livestock enterprises in the Eastern Cape Province of South Africa. Msc. University of Fort Hare.

Mugewra, N., 2007. Rainwater harvesting and rural livelihood improvement in banana growing areas of Uganda. Ph.D. Linköping University.

Murgor, F.A, Owino, J.O, Cheserek, G.J. and Saina, C.K., 2013. Factors Influencing Farmers' Decisions to Adapt Rain Water Harvesting Techniques in Keiyo District, Kenya. *Journal of Emerging Trends in Economics and Management Sciences,* 4 (2): 133-39.

Mutekwa, V. and Kusangaya, S., 2006. Contribution of rainwater harvesting technologies to rural livelihoods in Zimbabwe: The case of Ngundu ward in Chivi District. *Water South Africa*, 32 (3):437-44.

Mwenge, K., 2011. Decision support system for sustainable rainwater harvesting in South Africa. Ph.D. University of the Witwatersrand.

National Department of Agriculture (NDA), 2007. Agricultural statistics. Available at:<www.nda.agric.za> [Accessed 17/04/ 2013].

National Development Plan (NDP), 2013. Millennium development goals, country report. Available at: <http://www.za.undp.org/content/dam/south_africa/docs/Reports/The_Report/MDG_October-2013.pdf > [Accessed 08/11/2013].

Ngigi, S.N., 2003. What is the limit of up-scaling rainwater harvesting in a river basin? *Physics and Chemistry of the Earth*, 28: 943–56.

Ngwenya, K., 2013. Factors affecting rural farming households' willingness to participate in a proposed irrigation scheme: A situation analysis of Guquka in Nkonkobe District Municipality, Eastern Cape, South Africa. Msc. University of Fort Hare.

Nhundu, K., 2010. Determinants of Farmer Participation in Irrigation Development Post “Fast Track” Land Reform Programme; A Case Study of Mashonaland East Province, Zimbabwe. Msc. University of Fort Hare.

Nkonkobe Municipality Spatial Development Framework Review (SDFR), 2010/11 -2012/13. Available at:<http://drupal6dev15.econsultant.co.za/sites/psdp.ecprov.gov.za/files/Nkonkobe%20LM%20SDF_pdf> [Accessed 14/04/2014].

Nkonkobe Municipality Intergrated Development Plan (IDP), 2013/2014. Available at: <http://www.nkonkobe.gov.za/?q=system/files/filedepot/2/FINAL%20IDP%202013%2014.pdf > [Accessed 14/04/2014].

Obi, A, Pote, P. and Chianu, J., 2011. Market access: Components Interactions and Implications in Smallholder Agriculture in former homeland area of South Africa. Netherlands: Springer.

Orgainisation for Economic Co-operation and Development (OECD), 2001. Adoption of Technologies for Sustainable Farming Systems: Wageningen Workshop Proceedings: Agriculture and Food, Netherlands: OECD.

Phahlane, H., 2007. Market constraints and opportunities for the sustainable adoption of Infield Rainwater Harvesting in Thaba Nchu: a Principal Component Analysis (PCA) approach. Available at: <http://www.findavenue.co.za/AEASA/Presentations/Market%20Constraints%20and%20Opportunities.pdf> [Accessed 13/06/2013].

Pote, P., 2008. Technical Constraints to Smallholder Agriculture: Case study of Nkonkobe Municipality, Eastern Cape, South Africa. Msc. University of Fort Hare.

Pretty, J.N., Morison, J.I.L. and Hine, R.E. 2003. Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture, Ecosystems and Environment*, 95:217-234.

Prinz, D., 2002. The role of water harvesting in alleviating water scarcity in arid areas. Keynote lecture, proceedings, international conference on water resources management in arid regions. 23-27 March 2002, Kuwait Institute for scientific research. *Kuwait*, 3: 107-22.

Provide Project Background Paper (PPBP), 2005. A profile of the Eastern Cape Province: Demographics, Poverty, Inequality and Unemployment. Cape Town: Elsenburg.

Rogers, E., 1995. Diffusion of innovation. 4th edition. New York: Free Press.

Senkondo, E.M.,Mdoe, N.S., Hatibu, N., Mahoo,H. and Gowing, J., 1998. Factors affecting the adoption of Rain Water Harvesting technologies in Western Pare Lowlands of Tanzania. *J. Agric. S* (1): 81-89.

Sithole, N., Lagat, J. and Masuku, B., 2014. Factors influencing farmers participation in smallholder irrigation schemes: The case of Ntfonjeni Rural Development Area in Swaziland. *Journal of Economics and Sustainable Development*, 5(22): 201-12.

Shikur, A. and Beshah, T., 2012. Analysis of influencing factors in adoption of rainwater harvesting technology to combat the ever changing climate variability in Lanfuro Woreda, Southern region, Ethiopia. *Wudpecker Journal of Agricultural Research*, 2(1):15-27.

Smith, L. C. and Ali, S., 2007. Measuring Food Security Using Household Expenditure Surveys. Food Security in Practice technical guide series. Washington, D.C.: International Food Policy Research Institute.

South African Explorer, 2013. Alice map. Available at<http://www.saexplorer.co.za/south-africa/map/alice_map.asp> [Accessed 05/06/2013].

Sunding, D. and Zilberman, D., 2000. The Agricultural Innovation Process:Research and Technology Adoption in a Changing Agricultural Sector. *Handbook of Agricultural Economics*, 1: 207-61.

Sibanda, M., 2009. Assessment of livelihoods, market size and potential adoption of open pollinated varieties (OPVs) of maize at Zanyokwe and Kieskamahoek in Eastern Cape Province. Msc. University of Fort Hare.

Statistics South Africa., 2013. Census 2011 Agricultural households key highlights. Pretoria: Statistics South Africa.

Swindale, A. and Bilinsky, P., 2006. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide VERSION 2. Washington, D.C.: FHI 360/FANTA.

Tesfay, N.H., 2008. Rainwater Harvesting in Ethiopia: Technical and socio-economic potentials and constraints for adoption in Wukro District resources. Msc. Alemaya University.

Unganai, L. 2005. Coping with drought and climate change. Available at:<http://www.thegef.org/gef/sites/thegef.org/files/documents/document/Zimbabwe%20Drought%20and%20CCA_%20UNDP_SCCF.pdf > [Accessed 13/04/2013].

van Averbeke, W., 2008. Best Management Practices for Sustainable Subsistence Farming on Selected Irrigation Schemes and Surrounding Areas through Participatory Adaptive Research in Limpopo Province. WRC Report No. TT 344/08. *Water Research Commission*, 56 (2): 318.

van Averbeke,W. Denison. J. and Mnkeni, P., 2011. Smallholder irrigation schemes in South Africa: a review of knowledge generated by the water research commission. *Water South Africa*, 5 (37): 356-73.

van der Horst, B., 2013. A socio-technical feasibility study for an irrigation system in Guquka, South Africa. Msc. Wageningen University.

Vengayi, C., 2009. Institutional constraints to smallholder agriculture: A case study of Nkonkobe Municipality, Eastern Cape, South Africa. Msc. University of Fort Hare.

von Braun, J., 2007. Food security and Agriculture. Available at: <www.sasix.co.za/files/sectors/food.pdf> [Access 13/04/2013].

Water Research Commission (WRC), 2007. An improved soil survey technique for delineating land suitable for IRWH. Available at:<http://www.ewisa.co.za/misc/WRC_Facts/InfieldrainwaterharvestingA4.pdf> [Accessed 10/07/2013].

Wenhold, F., Faber, M., van Averbeke, W., Oelofse, A., van Jaarveld, P., Jansen van Rensberg, W., van Heerden, I and Slabbert, R., 2007. Linking smallholder agriculture and water to household food security and nutrition. *Water South Africa*, 33(3):327-36.

White, I., 2012. A theoretical framework for understanding factors that contribute to household adoption of rainwater harvesting in south east Queensland. Available at:<http://www.ctahr.hawaii.edu/hawaiirain/Library/papers/White_Ian.pdf> [Accessed 30/06/2013].

Woyessa, Y.E., Pretorius, E., Hensley, M. L., van Rensburg, D. and van Heerden, P.S., 2006. Up-scaling of rain-water harvesting for crop production in the communal lands of the Modder River basin in South Africa: Comparing upstream and downstream scenarios. *Water South Africa*, 32(2): 223-28.

Woyessa, Y.E., Hensley, M. and van Rensburg, L.D., 2007. Catchment management in the semi-arid area of central South Africa: Implications for River Basin Management. *Water South Africa*, 32 (5): 648-54.

World Bank, 1986. Poverty and Hunger: Issues and Options for Food Security in Developing Countries. A World Bank Policy Study. Washington D.C. :World Bank.

Yengoh, G.T., Ato, A.F. and Svensson, M.G., 2010. Technology Adoption in Small-Scale Agriculture: The Case of Cameroon and Ghana. *Science, Technology and Innovation Studies*, 5 (2): 21–28.

APPENDIX 1

HOUSEHOLD SURVEY QUESTIONNAIRE
UNIVERSITY OF FORT HARE
Masters (Agricultural Economics)

Socio-economic factors influencing the adoption of IRWH technology in enhancing household food security by smallholder farmers in the Nkonkobe Municipality, Eastern Cape Province

KEY HOUSEHOLD QUESTIONNAIRE
NB: The information captured by this instrument will be treated with high level of privacy and confidentiality.

BACKGROUND INFORMATION

Date……………………………………..Interviewer………………………………………..……

Name of village……………………………Name of respondent (optional) …...…………………….…..

Questionnaire number ……………………………………………………………………………..

Fill in the relevant information and where possible mark with an X

A.1 Gender		**A.2 Age (years)**	**A.3 Education**	**A.4 Household size**			
1) M	0)F	1) 31-40 2) 41-50 3) 51 and above	1) Never went to school 2) Primary 3) High school 4) Tertiary	< 16	16-60	60>	Total
				1)	2)	3)	

A.5 What is your employment status, total monthly income and source of income?

Employment status		**Income earned**	**Source of income**	**Amount (R)**
1) Not employed		1) < R 500	1) Salaries and wages	
2) Informally employed		2) R 500 – R 1499	2) Self employed	
3)Formally employed		3) R 1500 – R 2999	3) Child support grant	
4) Pensioner		4) R 3000 –R 4999	4) Old age pension	
5) Other (specify)		5) R 5000 – R 9999	5) Retirement pension	
			6) Remittances	
			7) Agriculture	
			8) Other (specify)	
			Total	

A.6 Do you keep any livestock?

1.Y	0. N

A.7 If Yes, which livestock do your household keep and indicate numbers owned?

Type owned	**Numbers owned**
1) Poultry (Chicken)	
2) Rabbits	
3) Goats	
4) Sheep	
5) Pigs	
6) Cattle	
Other (specify)………………..	

A.8 Do you have access to secure tenure?

1.Y	0. N

A.9 If Yes, what tenure you hold, *please tick*

1) Bought (Title deed)	
2) Leased	
3) Inherited	
4) Allocated by the chief	
5) Renting and /or sharecropping	
6) Other (specify)	

A.10 How many hectares is your arable land? (ha)……………………………………………….

A.11 If No, to A8, state the problem(s)

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

A.12 Do you have enough knowledge about IRWH technology?

1.Y	0.N

A.13 If Yes, who is your source of information

1) ARC	
2) Extension officer	
3) Other farmers	
4) Other (specify) …………………………	

A.14 If No, to A12, state the problem(s)

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

A.15 Do you have access to extension services?

1.Y	0.N

A.16 If Yes, what assistance extension services do you receive with regards to IRWH technology?

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

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

A.17 How often does extension officers visit your farm? *Please tick*

1) Once a week	
2) Once a fortnight	
3) Once a month	
4) Twice a month	
5) Never	

A.18 Do you currently practice IRWH technology?

1.Y	0.N

A.19 If Yes, for how long? ……………………………………………………………………….

A.20 If No, to A15 state the problem (s)
…………………………………………………………………………………………..………

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

A.21 Have you received any training/workshop with regards to IRWH technology?

1.Y	0.N

A.22 If Yes, what training did you received?

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

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

A.23 How do you harvest water? *Please tick*

1) Tank	
2) Through a 2m wide strip and stored in 1m basin	
3) Other: specify …………………………………………..	

A.24 Please indicate which crops were produced by household in 2012/2013 season

Crops	**Quantity produced**
1) Onion	
2) Cabbage	
3) Spinach	
4) Carrot	
5) Tomatoes	
6) Green pepper	
7) Beetroot	
8) Beans	
9) Maize	
10) Cauliflower	
11) Other (specify) ……………………………	

A.25 Do you sell your produce?

1.Y	0.N

A.26 If Yes, where do you sell? …………………………………………………………….

A.27 How far is it to get to your main market? State km

1.Less than 30km	0. Above 30km

A.28 How much quantity sold and consumed in the household? *Fill table below*

Crops	**Quantity produced**	**Quantity sold**	**Quantity consumed**
1) Onion			
2) Cabbage			
3) Spinach			
4) Carrot			
5) Tomatoes			
6) Green pepper			
7) Beetroot			
8) Beans			
9) Maize			
10) Cauliflower			
11) Other (specify) …………………			

A.29 How much do you get per month from selling your produce? *Please tick*

Amount	
1) R0.00	

2) < R300.00	
3) R600.00 – R1199.00	

A.30 If No, to A25 state the problem (s)

……

……

A.31 Do you have access to credit?

1.Y	0.N

A.32 If Yes, where do you acquire loans? *Please tick*

1) Commercial bank	
2) Agric.Co-op	
3) Other (specify) ……………………………………………….	

A.33 If No, to A 31 state the problem (s)

……

……

A.34 Do you hire labour for farming?

1.Y	0. N

A.35 If No, state the problem (s)

……

……

A.36 Is your garden fenced?

1.Y	0. N

A.37 If No, state the problem (s)

……

……

A.38 Do you have any other source of water for irrigation?

1.Y	0. N

A.39 If Yes, what is your source of water for irrigation and their total walking distance in minutes from the household?

Water source	1) River/stream	2) Tap water	3) Bore hole	4) Spring Rainwater	5) Other specify …………………
Total walking distance in minutes					

A.40 What are your general perceptions about IRWH technology?

1.Positive	0.Negative

A.41 If Positive, why?

…………………………………………………………………………………………………

A.42 If Negative, why?

…………………………………………………………………………………………………

A.43 In general, what are the problems and constraints that you encounter with regards to IRHW technology?

………..

Food Security status: Household dietary diversity score

Which of the following items did your household consume as part of a meal or snack, YESTERDAY (24 hour period)?

Question no. and Food group	**Example**	**Yes (1)**	**No (0)**
A. Cereals	bread, noodles, biscuits, cookies or any other foods made from millet, sorghum, maize, rice, wheat + *insert local foods e.g. ugali, nshima, porridge or pastes or other locally available grains*		
B. Vitamin A rich vegetables and tubers	pumpkin, carrots, squash, or sweet potatoes that are yellow or orange inside + *other locally available vitamin-A rich vegetables*		
C. White tubers and roots	White potatoes, white yams, cassava, or foods made from roots.		
D. Dark green leafy vegetables	Sweet pepper, dark green/leafy vegetables, including wild ones + *locally available vitamin-A rich leaves such as cassava leaves etc.*		
E. Other vegetables	including wild vegetables		
F. Vitamin A rich fruits	Ripe mangoes, papayas, *other locally available vitamin A-rich fruits*		

G. The fruits	other fruits, including wild fruits		
H. Meat	beef, pork, lamb, goat, rabbit, wild game, chicken, duck, or other birds, liver, kidney, heart or other organ meats or blood-based foods		
I. Eggs	fresh or dried fish or shellfish		
J. Legumes, nuts and seeds	beans, peas, lentils, nuts, seeds or foods made from these		
K. Milk and milk products	milk, cheese, yogurt or other milk products		
L. Oils and fats	oil, fats or butter added to food or used for cooking		
M. Sweets	sugar, honey, sweetened soda or sugary foods such as chocolates, sweets or candies		
N. Spices and caffeine or alcoholic beverages	spices, coffee, tea, alcoholic beverages or *local examples*		
O. Other			
		Y (1)	N (0)
1. Did you or anyone in your household eat anything (meal or snack) OUTSIDE of the home yesterday?			

Source: FAO, 2011

THANK YOU FOR YOUR COOPERATION

APPENDIX 2

Summation of food groups consumed by members of the household.

HDDS (0-15)	Total number of food groups consumed by members of the household. Values for A through O can be either “0” or “1”. Sum(A + B + C + D + E + F + G + H + I + J + K + L+M+N+O) Sum (1 + 1 + 0 + 1 + 1 + 1 + 0 + 1 + 0 + 0 + 1 + 1+1+0+0)

$$\text{Average HDDS} = \frac{\text{Sum (HDDS)}}{\text{Total number of households}}$$

=8+6+5+4+6+5+7+5+4+3+5+6+5+4+5+5+4+8+5+5+7+3+5+6+5+4+8+6+5+4+
4+5+6+5+6+7+4+5+6+6+7+5+4+8+6+6+4+6+7+5+5+3+5+4+8+5+6+7+4+4+5
+3+4+5+5+4+5+5+5+6+7+4+5+6+5+7+5+4+5+3+3+5+4+3+5+5+6+3+5+5+5+
4+8+5+6+7+4+6+4+3+5+6+5+3+3+5+4+5+5+4+3+3+4+5+3+4+5+5+5+4

120

$$= \frac{601}{120}$$

$$= 5.01$$