INVESTIGATION OF RAINWATER HARVESTING TECHNIQUES IN YATTA DISTRICT, KENYA

IBRAHIM AHMED IBRAHIM

ABDELFADEEL

MASTER OF SCIENCE

(Research Methods)

JOMO KENYATTA UNIVERSITY OF

AGRICULTURE AND TECHNOLOGY

2012

Evaluation of Rainwater Harvesting Techniques in Yatta District, Kenya

Ibrahim Ahmed Ibrahim Abdelfadeeel

A dissertation submitted in partial fulfillment of the Degree of Master of Science in Research Methods in the Jomo Kenyatta University of Agriculture and Technology (JKUAT)

2012

DECLARATION

This dissertation is my original work and has not been presented for a degree in this or any other university. The work of others used in this study has been duly acknowledged.

Signature…... Date.……………….....................................

Ibrahim Ahmed Ibrahim

This Dissertation is submitted with Our Knowledge and Evaluated under Our Guidance as Jomo Kenyatta University of Agriculture And Technology And University of Nairobi, Upper Kabete Campus.

We declare that, this dissertation is from the student's own work and effort and where he has used other sources of information, it has been acknowledged.

Signature…..................................... Date.………..................................

Dr. R. N. Onwonga

University of Nairobi, Kenya

Signature….. Date.……………….........................

Dr. David M.Mburu

JKUAT, Kenya

ACKNOWLEDGEMENT

I cannot start without praising God. God, thank you for keeping me inspired and courageous to go through all this work.

And my sincere thanks go to Dr. R. N. Onwonga and Dr. David M. Mburu, my research advisors, who accorded me genuine encouragement and support to complete the study. They spent a lot of time to go through the project and make necessary correction as and when needed.

I am very grateful to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for giving me this opportunity and above all granting me the financial support needed to complete this study.

Oh! Mom and Dad I love you both. I don't have a word to thank you for being there for me in all my needs and helped me out in every aspect of my life. Thanking you is the least I can say.

My special thanks also go to the Dean of the faculty of Agriculture –JKUAT and all the staff in the department of horticulture; for the moral and every support they gave me.

Finally yet importantly, i thank all people including farmers in Yatta district who helped me during the study. Their willingness and cooperation meant a lot for me. To the many people who contributed to the realization of this thesis, lack of mention by name or otherwise does not in any way imply that your deserved contributions is not recognized! I do appreciate your contribution and to all of you, it is a big thank you.

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ACRONYMS

RELMA	Regional Land Management Unit
FAO	Food and Agriculture Organization of the United Nations
IFAD	International Fund for Agricultural Development
MCDF	Marxist Communist Discussion Forum
NACO	National Aids Control Organization
NGOs	Non-governmental Organizations
UNICEF	United Nations Children's Fund
RWHT	Rainwater Harvesting Techniques
RWH	Rainwater harvesting
FWH	Flood water harvesting
GWH	Ground water harvesting

ABSTRACT

Climate change and/or variability are expected to affect water availability as well as the techniques of water harvesting. The main objective of this study was to investigate factors affecting adoption of rainwater harvesting techniques in Yatta district, it involves identifying factors affecting rainwater harvesting techniques, determining factors influencing adoption of rainwater harvesting techniques among households, and investigating the influence of climate change impact on water resources in Yatta district. The data were collected using a semi-structured questionnaires administered to 60 farmers in two divisions in Yatta district of Eastern Province, Kenya. Farmers were randomly selected from each of the two divisions. A logistic regression model was used to determine factors influencing adoption of rainwater harvesting techniques among households. It was found that roof water tanks (45%) as well as sand dams (36.1%) were the most practiced techniques in this area by most farmers. The study also found that most of the farmers were aware about water harvesting techniques and willing to adopt them. Extension officers and NGOs were found to be the most important source of information to the farmers on water harvesting techniques. Logistic model showed that the education level, experience of water shortage, awareness of water harvesting techniques were highly important variables that positively influences adoption of water harvesting techniques. There were positive correlation between the observed changes on water resources and the experiences of water shortages attributed to the effect of climate change. There was also a positive correlation between farmers coping with challenges of the techniques and the source of information. Rainwater harvesting techniques activities required by the farmers include technical knowledge and skills, capital, row material and organization supports. In addition, farmers need to be mobilized and trained in the use of rainwater harvesting techniques and potential benefits of adopting them to their livelihoods.

CHAPTER ONE

1.0 Introduction

The introduction of the study, problem statement, overall and specific objectives of the study, research questions, justification of the problem, and significance of the study are met in this chapter.

1.1 Background

Lack of water of adequate quality and quantity is a major constraint to development in many areas of the world. It affects every aspect of human life: health, agricultural yields, food security, technical development, and the economy of states. Water scarcity and water quality problems are of particular concern in the tropical regions of the world where many countries are less developed Nelly (2010).

Due to variability in rainfall, some rainwater harvesting techniques have been tried in recent years, both in Kenya and in other water-stressed nations, with the aim to abate drought and water shortages. Kenya is classified as a water scarce country with annual water supplies below 1000m^3 /person UNEP (2002). The situation is predicted to worsen drastically within the near future. Rainwater harvesting (RWH) is a method of collecting and storing rainwater for agricultural production in arid and semi-arid areas Hatibu and Mahoo (2000). There are different types of rainwater harvesting techniques, which have been implemented throughout Kenya as a strategy to secure water resources Kenya Rainwater Association (2010). The selling point for rainwater harvesting is that the methods are less complicated and can be easily adopted at individual or community level. According to Rebeka (2006), rainwater harvesting techniques can be applicable in all agro climatic zones. However, it is more suitable in arid and semi-arid areas where the average annual rainfall is from 200 to 800 mm (rarely exceeding 800 mm). In such an environment, rain-fed crop production is usually difficult without using rainwater harvesting techniques.

RWH has been defined as the process of collecting and concentrating water from runoff area into a run-on area where the collected water is either stored or directly applied to the cropping area for immediate use by the crops Prinz and Singh (2000), Critchley and Siegert (1991). RWH has been practiced for thousands of years to irrigate and restore productivity to the land, provide drinking water (to both humans and animals), minimize risk in drought prone areas, increase groundwater recharge, and control flooding Palmbac (2004). Today, RWH is used for irrigation, groundwater recharge and water storage for future use in arid and semi-arid areas.

Hatibu and Mahoo (2000) demonstrated the importance of (RWH) for domestic water supplies, livestock watering and crop. They described effective use of rainwater, noting that 98% of crop production in Tanzania is rain-fed. RWH is particularly necessary as 71% of all disasters in Tanzania are caused by droughts (33%) and floods (38%).

Out of Kenya's population of approximately 38 million, a considerable portion (75 %) is living in rural areas where rain-fed agriculture and livestock keeping are the main livelihoods Nelly (2010). Moreover, the population is increasing at a rate of 2.6 %/year Worldbank (2011).

In developing countries, people living in arid and Semi-Arid Lands (ASALs) are the most vulnerable and likely to be hit hardest by climate change due to their low adaptive capacity IPCC (2007). The risks threaten approximately 70% of rural people living in extreme poverty around the world OECD (2001). Developing countries are experiencing the adverse impacts of climate change despite their low overall contribution to the greenhouse gases. Climate change poses a serious threat to food security of millions of people living in the arid and semi-arid lands United Nations (2000). The agricultural systems and food production in the entire sub-Saharan Africa (SSA) primarily relies on rain-fed agriculture that is climate sensitive IITA (1993).

Analysis of climatic data in the region shows that the coefficient of variation of rainfall in semi-arid tropics can be as high as 50% while most of the annual rainfall often falls in few rainfall events within three to five months of the year. Predictions indicate a more severe crop production decline in many parts of Africa leading to hunger, malnutrition, insecurity and migrations.

1.2 Problem statement

Yatta district, a semi-arid area in Kenya faces serious problems of water scarcity UNEP (2002). The district is predicted to get drier due to climate change, variability and extreme weather condition. Precipitation is one of the variables that continue to be affected by climate change with adverse effect on the populations without access to water.

The district receives inadequate and erratic rainfall Kenya Red Cross (2009) which implies that water harvesting and storage technologies would be vital to ensure water availability during dry periods.

Rainwater harvesting has been identified to have many potential benefits in rural communities Mugerwa (2007), Enfors (2009), and Relma (2007), these include securing and increasing crop production in semi-arid regions where rainfall is insufficient, control of soil erosion and land degradation.

Adoption of various water harvesting techniques needs to be evaluated in Yatta district. This is because climate change and variability are expected to affect water availability as well as the methods of water harvesting which needs to be quantified. This study will therefore try to bridge this information gap.

1.3 Overall objective:

To investigate factors affecting adoption of rainwater harvesting techniques in Yatta district of Kenya.

1.3.1 Specific objectives:

The specific objectives were:

1- To identify factors affecting rainwater harvesting techniques used in Yatta district.
2- To determine factors influencing adoption of rainwater harvesting techniques among households in Yatta District
3- To investigate the influence of climate change impact on water resources in Yatta district.

1.4. Significance of the Study

The study identified problems encountered when implementing rainwater harvesting techniques in the Yatta district, so that possible measures are taken when these interventions are replicated in other parts of Yatta district of Eastern Province or the entire country.

Besides, being an empirical study it will help to add to the empirical literature that uses the combination of both quantitative and qualitative methods in investigating the factors affecting adoption of RWH techniques. Finally, understanding the influence of climate change impact on water resources and availability will assist in decision making regarding appropriate intervention of water harvesting techniques. Therefore, the outcome of this study may serve as a source of additional information that may be of significant use to policy makers and planners during the designing and implementation of RWH technology strategies.

1.5. Research questions:

1. What factors affect the various water harvesting techniques carried out in Yatta district?
2. What factors influence adoption of effective water harvesting techniques among households in Yatta district?
3. What is influence of climate change impact on water resource in Yatta district?

1.6 Justification

Water harvesting techniques in semi-arid areas in Kenya are crucial for both economic and social activities that can improve living standards. The benefits of water harvesting include securing and increasing crop production in semi-arid regions where rainfall is insufficient, control of soil erosion and land degradation. This is in addition to serving as an adaptation strategy to climate change.

Past experiences show that rainwater harvesting is an innovative approach for the integrated water resources management and sustainable development of semi-arid areas. Evaluation of appropriate water harvesting techniques is necessary to identify factors that affecting the techniques most used by the farmers and give recommendations on their improvements**.**

Understanding the effects of climate change on water availability will assist in decision making regarding appropriate intervention of water harvesting techniques.

Water harvesting techniques in Yatta district will eventually contribute to sustainable livelihood and poverty reduction. Farmers' awareness of climate change impact will effectively support and help more to evaluate as well as find out the impact of the climate change and variability on water resource utilization, coping, and adaptation strategies in Yatta district.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of previous research on knowledge sharing and intranets. It introduces background about water harvesting and its techniques, factors influencing adoption of rainwater harvesting techniques, and climate change impact on water resources, which comprises the focus of the research described in this thesis.

2.2 Water harvesting techniques

Different types of rainwater harvesting management systems have been implemented throughout Kenya as a strategy to secure water resources in rural areas Kenya Rainwater Association (2010). The selling point for rainwater harvesting is that the methods are simple enough to orchestrate and maintain at individual or community level with little training from specialists or technicians.

Many reports have been written on the potential benefits of rainwater harvesting for rural communities Gould (1995), Mugerwa (2007), Enfors (2009), Relma (2009). Nevertheless, there are few studies describing the detailed effects of the schemes on water availability, demands, and vulnerability in the case of climatic variations – especially in the light of future climate change. Further studies are a vital part of reviewing the findings from previously conducted water schemes as well as making future rainwater harvesting methods more efficient.

Rainwater harvesting systems can be classified by the runoff generating process, the size of a catchment and the type of storage. Runoff generating processes are rivers, lakes and rainfall. The storage type could be storage within a soil profile, a tank or a reservoir and the size or scale of the system determines whether it is regarded a micro or macro scheme Greater Horn of Africa Rainwater Partnership (2010).

There are three main categories of RWH that have been devised and perfected over the years. Each category has its own methods and techniques that are employed to get the maximum amount of profit from each water source, be it floodwater, rainfall or groundwater. The three main forms of WH include Rainwater Harvesting (RWH), Floodwater Harvesting (FWH) and Groundwater Harvesting (GWH).

2.2.1 Floodwater Harvesting

Often referred to as water spreading or spate irrigation, FWH is involved in the collection and storage of creek flow for irrigation use Prinz and Singh (2000). The main characteristics of FWH are turbulent channels of water flow harvested either by diversion or by spreading within a channel bed/valley floor where the runoff is stored in soil profile Critchley and Siegert (1991). Two categories in FWH include macro catchments and large catchments.

Macro-Catchments sometimes called medium sized catchments are characterized by large flood zones that are situated outside of the cropping area. Often farmers must use structures such as dams or bunds to divert, transfer, collect and store the runoff. Such systems are often difficult to differentiate from conventional irrigation systems and are considered FWH as long as the harvested water is available year round. Mbilinyi *et al.* (2005). Examples of macro catchments include stone dams, large semi-circular hoops, trapezoidal bunds, hillside conduit systems, and cultivated reservoirs, all of which have a scale of between 0.1 ha to 200 ha Prinz (1996).

Large catchments water harvesting comprises systems with catchments many square kilometres in size, from which runoff water flows through a large streambed, necessitating more complex structures of dams and distribution networks. There are two major forms of large catchments i.e., floodwater harvesting within a streambed and floodwater diversion Prinz (1996).

Floodwater harvesting within a streambed involves blocking the water flow to flood the valley of an entire flood plane and force the water to infiltrate the ground and use the wetted area for crop production or pasture improvement Prinz (1996). Floodwater diversion is a method in which water in a river; stream or creek bed is diverted from its natural course and used to flood nearby cropping areas as an irrigation method Prinz (1996).

2.2.2 Groundwater Harvesting

GRH encompasses all methods, traditional and contemporary, of harvesting water from the ground for productive use. It has also been used as a storage method for the other forms of water harvesting outlined above, with many of these techniques requiring a certain type of terrain so that the water diverted from its original source can seep into the ground for crop use. Traditional methods of groundwater harvesting include the use of dams, wells, terraces and ditches, cisterns and aquifers.

(i) Dams

Groundwater harvesting dams pertain to the blockage of groundwater sources for the use in agricultural practices. The subsurface dam and the sand storage dam are used to obstruct the flow of ephemeral streams in a river bed. The water is stored in the sediment below ground surface and can be used for aquifer recharge" Prinz and Singh (2000). There are several advantages to this as evaporation losses are reduced, there is no reduction in storage volume due to siltation, the stored water is less susceptible to pollution, and health hazards due to mosquito breeding are avoided Prinz and Singh (2000). Earth dams are perhaps the most widespread method of water harvesting, especially from river valleys. A dam can be constructed to collect water from less than 20 km^2 for a steep catchment and 70 km^2 for a flat one. In Tanzania, low earth dams called 'malambo' have been built, especially in Dodoma, Shinyanga and Pwani regions Hatibu and Mahoo (2000). Some of these are medium-sized reservoirs for urban or irrigation water supply. Sometimes a regulating reservoir is designed to store flash floods from a single day's rainfall. The water is then slowly released so that it does not endanger bunds constructed on farmlands on lower land. The stored water drains away continuously until the reservoir is dry in a day or two, ready to receive the next flash floods. Due to the high costs of construction, earthen dams are usually built with support from donor-funded projects. For instance, in Laikipia District, Kenya, the excavation of an earth dam 15,000 m^3 cost about US$5,000 Mati (2002).

A. **Photo2: Dam constructed at Ikombe** B. **Photo2: Dam constructed at Katangi, (April 2012)**

(ii) Wells

Probably the most common of GWH techniques, they tap into the water table from a hole excavated on the surface. Wells have been employed as a source of water for thousands of years, with one of the oldest wells found dating back to 8100 – 7500 BC. Like other forms of water harvesting, wells have been adapted to meet the needs of individuals living in specific regions. Technology has also increased the returns from wells, making water easier to obtain. The Dug wells commonly used in Ethiopia, range from 3 to 15m deep and are major sources of water for both agricultural and domestic water uses Alem (2003). Elias, are generally deeper than dug wells and are often used to supply drinking water to livestock. The water of these wells is manually transported to the trough where the livestock drink from. Elias is generally found in Southern Ethiopia.

(iii) Cisterns

These are man-made caves or underground constructions to store water. Often the walls of these cisterns are plastered to prevent water loss, deep percolation and/or evaporation" Prinz and Singh (2000). The underground cistern (China Type), found in Ethiopia, is employed to supply water for domestic for irrigation purposes to drought prone areas. There are two variants to this cistern, one being shaped like a bottle, the other in a circular formation. Both are constructed in a similar fashion with the ground excavated to form the shape of the cistern. The surface is covered with polyethylene or concrete plastering to avoid seepage loss. Both cisterns are expensive and difficult to build, often too complex for individual farmers to construct themselves. The capacity of each is 60,000L Alem (2003).

(iv) Aquifers

Ground water generally occupies in large areas under the earth's surface and will often supply other water sources such as streams, rivers, and springs. Often, aquifers are on the receiving end of water harvesting, in that regards, they are often be used as a way to store harvested rainwater. Recently, awareness of depleting aquifers has spurred an increase in RWH techniques that aim at directly recharging these rapidly depleting resources. Many forms of rainwater harvesting collect water and store it underground for future use. Not only does this recharge depleting groundwater sources, it also raises the declining water table and can help augment water supply Edugreen (2007).

(v) Terraces and ditches

Moisture retention terraces and ditches are other techniques promoted through-out Eastern and Southern Africa. In Kenya the famous *Fanya Juu* terraces, which are made by digging a trench, normally along the contour, and throwing the soil upslope to form an embankment, has had a very significant effect on reducing soil erosion in semi-arid areas with relatively steep slopes (< 20 %) Thomas (1997). Tiffen et al. (1994) present evidence from Machakos district in Kenya suggesting that the adoption of *Fanya Juu* terraces played an important role in reducing land degradation over a period from the 1930s – 1990s when population increased more than fivefold. Similar widely spread techniques are the *Fanya chini* developed in the Arusha region, Tanzania (soil thrown down slope instead of upslope), stone bunds, and trash lines (successfully promoted through extension in dry areas of South-eastern Kenya). In Ethiopia annual mobilization campaigns are used to rehabilitate degraded lands by constructing retention ditches and stone terraces Lundgren (1993). In the northern province of Tigray, micro-basins (roughly 1 m long and < 50 cm deep) are often constructed along these retention ditches for tree planting. In the Axum area in northern Tigray these retention ditches, which prevent large volumes of surface runoff from flowing down the steep escarpments, have contributed to the revival of natural springs which according to the local communities had dried out (probably due to severe upstream deforestation, authors comment) Rockstrom et al. (1999).

2.2.3 Rainwater harvesting

Rainwater Harvesting uses a wide range of techniques for concentrating, collecting and storing rainwater and surface runoff for different uses by linking a runoff producing area with a separate runoff-receiving area Mbilinyi *et al.* (2005). In this sense, RWH collects rainwater runoff and stores it for future use, be it for agricultural, domestic or drinking purposes. As such, RWH encompasses all RWH techniques that collect and harvest runoff from roofs or ground surfaces Critchley and Siegert (1991).The three main forms of water collection that make up RWH are water collection, rooftop harvesting and micro-catchments.

(i) In- situ rainwater harvesting

Also known as, water conservation, this method of RWH is essentially the prevention of net runoff from a given area by retaining rainwater and prolonging the time for infiltration Mbilinyi *et al.* (2005). This practice employs a number of different techniques to catch the water where it falls Mbilinyi *et al.* (2005). The methods for this form of RWH are diverse and are often a product of local ingenuity and varying cultural practices. Examples of water collection include deep tillage, dry seeding, mixed cropping, ridges, borders, trash lines, ponds, fog harvesting Mbilinyi *et al.* (2005). For the most part, these practices are mainly used for irrigation. Soil water for evapotranspiration, sometimes referred to as 'green water' is important for plant growth. The design of run-on facility – such as a semi-circular bund, negarim or zai pit – depends on many factors. These include the catchment area, volume of runoff expected, type of crop, soil depth, and availability of labour. Hatibu and Mahoo (2000) describe the role of RWH in agriculture and natural resource management, from mitigating drought to preventing floods. They give examples illustrated examples of popular techniques such as semi-circular bunds, bench terraces, flood water harvesting, streambed systems, and ephemeral stream diversions. The authors also cover the role of RWH in horticulture, livestock and wildlife, forestry, rangelands and ground water recharge.

(ii) Roof catchment

Roof catchment, is generally practiced as a way to obtain relatively clean drinking water as well as water for domestic purposes. This method involves a relatively small catchment area, the size of the individual's roof of their house, with gutters and pipes to guide the water into a tank on the ground. Often a tap is attached to the tank for individuals to access this water Mbilinyi *et al.* (2005). There is concern over whether or not the water is clean enough for drinking, as pollutants in the atmosphere have been known to be present in rainfall. Today water harvesters must be wary of pesticide contamination, high mineral levels, bacteria and other impurities in their runoff water" Palmback (2004). Most roof catchment systems have screens and purification systems built into the infrastructure to remove leaves and twigs from the water as well as to purify the water prior to use Palmback (2004).

The amount and quality of rainwater collected from roof catchment depends on the area and type of roofing material. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminum or cement sheets, tiles and slates, although thatched roofs tied with bamboo gutters and laid in proper slopes can produce almost the same amount of runoff less expensively Gould (1992). Harvesting roof runoff and storage in above ground tanks proved to be one of the most popular technologies Gould and Peterssen (1999). Galvanized corrugated iron sheets, corrugated plastic and tiles all make good roof catchment surfaces and are now widely available in much of the ESA region. Tanks are built from a wide range of materials including metal, plastic, fiber glass, bricks, interlocking blocks, compressed-soil or rubble-stone blocks, Ferro cement, and concrete. Regardless of the material used to make them, good tanks share common key features: They should be should be watertight, durable and affordable – cost is a key influence on tank choice – and should not contaminate the water. Surface tanks vary in size from 1 m^3 to more than 40 m^3 for households and 100 m^3 or bigger for schools, hospitals and other institutions. Tank size is also dependent on the rainfall pattern and demand for water. Areas with seasonal rainfall will require larger 3 tanks of 25 m^3 – 35 m^2 and a roof exceeding 100 m^2 to satisfy the demand in an average household in the dry season. There is another benefit of surface tanks over sub-surface ones, in that water can be easily extracted through a tap just above the tank's base. This has made surface tanks popular in rural households for drinking water. This popularity was demonstrated in the Kusa area of Nyando District, Kenya, where RELMA was involved in a project to promote rainwater harvesting. In six months, 113 above ground tanks with capacities ranging from 3 m^3 to 23 m^3 for homes and 23 m^3 to 30 m^3 for institutions were constructed Mati (2001).

A. Photo1: Roof plastic tank at Katangi **B. Photo2: Roof cement tank at Ikombe (April,2012)**

(iii) Micro-catchment

Involves a distinct division of a runoff-generating catchment area, and a cultivated basin where runoff is concentrated and stored in the root zone and productively used by plants Mbilinyi et al. (2005). There are multiple advantages to this RWH system than the others in that the design is simple and cheap, there is higher runoff efficiency than larger scale WH systems. They often prevent or reduce soil erosion and, finally, can be implemented on almost any slope and many level planes Prinz (1996). Micro-catchments vary in size, method and technique from region to region. A micro catchment system in Ethiopia, for example, may be completely different in style and operation from a micro-catchment system found in Western Asia. Although there are little variations, there is a basic principle used within the micro-catchment category, they include; pitting, contour ridges, negarin, semi-circular hoops, meskat-type, vallerani type, contour bench terraces, and eye brow terraces or hill slope micro-catchments Prinz (1996).

2.3 Factors influencing adoption of rainwater harvesting techniques

It is evident that there is enough freshwater available every year to fulfill the needs of the present population of this planet. However, in certain regions and countries the annual renewable supply of water is less than 500m^3 Qadir et al. (2007). This need for RWH, as mentioned above, arises from many factors such as low rainfall and uneven distribution, high losses due to evaporation and runoff, and an increased demand on water due to population growth Abu-Awwad and Shatanawi (1997). With a large portion of the human race living in arid to semi-arid regions of the globe, it is necessary to look to RWH to increase water access in these areas.

As RWH becomes an important strategy to deal with water scarcity or water stress, it is important to consider the factors that go into selecting the appropriate RWH techniques to maximize hydrological returns. It is tempting to assume that a system, which works in one area, will also work in another, superficially similar, zone. However, there may be technical variations such as availability of stone or intensity of rainfall, and distinct socio-economic differences Critchley and Siegert (1991).

There are a number of critical factors that need to be taken into consideration when selecting the appropriate RWH method Prinz and Singh (2000).These will be outlined below:

2.3.1 Rainfall and land use

RWH depends on limited and uncertain rainfall, and thus understanding the dynamics of precipitation within the environment can influence the method of RWH that would fit best in each context Qadir et al. (2007). According to Prinz and Singh (2000), the various factors which should be taken into account include: The number of days in which the rain exceeds the threshold rainfall of the catchment, on a weekly or monthly basis, probability and occurrence (in years) for the mean monthly rainfall, probability and reoccurrence for the minimum and maximum monthly rainfall, and frequency distribution of storms of different specific intensities.

Factor of land use, working to reduce erosion and redirect runoff into appropriate catchments can lead to high labour inputs resulting from the necessity to keep the catchment area free from vegetation, to ensure that it is as efficient as possible. The vegetation of the selected area will heavily influence runoff, infiltration and retention levels and must be taken into account prior to implementation, to reduce high labour costs in the future Qadir et al. (2007).

The Maintenance of the catchment system must also be understood when selecting the size of catchment. The system may be damaged during heavy rainstorms or require regular maintenance which could prove problematic in the future Qadir et al. (2007).

2.3.2 Topography, Soil type and soil depth, Hydrology and water resources

Topography is an important aspect of RWH as the slope will greatly impact the size and type of catchment area of the RWH system Prinz and Singh (2000). In addition to the factors of topography and terrain profile, there is an important factor such as soil type and depth that can help judge the potential for runoff and storage potential of water within the soil itself Prinz and Singh (2000). Hydrology monitors the available water sources that are involved in storage, production and runoff of the RWH system, which will aid in the informed selection of the appropriate RWH technique for the proposed site Prinz and Singh (2000).

2.3.3 Socio-economic and infrastructure conditions

Several social, cultural and economic factors are important to consider when selecting the appropriate RWH techniques such as peoples priorities. These factors need to be taken into account when opting to introduce RWH methods to a specific area. RWH aims to increase the availability of water resources for productive use, and it is therefore important that the RWH infrastructure meet the needs of individuals who are using it Critchley and Siegert (1991).

Participation is another factor when implementing RWH projects, for example development projects implemented by governments or NGO's, require high community participation from beginning to end. This helps create a sense of ownership of the project within the community. Knowledge plays an important role here for individuals involved in the RWH scheme as they need to fully understand how it operates. One potential negative effect of implementing complex RWH technologies is that those who are left to use it are unfamiliar with the technology and thus unable to properly maintain it Oweis and Hachum (2005).

There is also the factor of adoption of systems, which indicates the importance of selecting the appropriate RWH method for each site. Widespread adoption of water harvesting techniques by the local population is the only way that significant areas of land can be treated at a reasonable cost on a sustainable basis. Critchley and Siegert (1991). Area differences also be considered to be factor that affect adoption of RWH techniques; it is not always possible to implement the same RWH system in different areas. This is due to differences in site characteristics that can cause a RWH system to be successful in one region and failure in another Critchley and Siegert (1991). In addition to these factors, there is also factor of land tenure to influence adoption of RWH, not having full ownership of the land on which one lives can cause an individual to be reluctant to invest in a RWH scheme that would only benefit the user in the short term Critchley and Siegert (1991).

Land use management is also considered to be a factor of influencing adoption of RWH systems or techniques. How land, both communal and private, is managed and used can determine the effectiveness of the RWH techniques being proposed or implemented. Effective land management is important as conflicts and disputes over water rights, land ownership and use can arise Oweis and Hachum (2005).

2.3.4 Climate, land and ecology

Many researches confirm that one of the greatest risks to rain-fed crop productivity is high rainfall variability. The ability to reduce the reliance on stochastic rainfall is the key to the suitability of any technology aimed at increasing productivity Rockstrm et al. (2002) and in some semi-arid and arid areas the variability of rainfall may be too great for certain types of RWH to provide sufficient benefits. Moreover, RWH must enable crop water demand to be met both in the short- and long-term future, maintaining a lowered level of risk in arable farming even in the context of long-term climate variability. However, water is only one of the many barriers to crop production Barron (2009); Rockstrm et al. (2002) and climatic factors need to be considered closely with wider ecological issues, as these can also have a marked influence on yields. For example, areas with unfavorable soil characteristics, such as low moisture holding capacity, or low fertility may not be suitable for RWH Rockstm et al. (2002) and data collection in Botswana reiterated the importance of combining RWH with soil conservation measures if crop production is to be most successful AfDB (2007), Rockstrm et al. (2002). Other ecological issues such as sufficient availability of water to maintain wider ecosystems in any region despite presence of RWH systems also need consideration Falkenmark (2007).

2.3.5 Availability of assets

In many cases marginally productive and subsistence farming practices in Botswana were linked to a lack of knowledge among individuals (Respondents B, C and N). This was attributed to the unavailability of adequate training and support at both an individual and group level within the farming sector. Similarly, poor performance of agriculture in other developing countries associated with the loss of traditional knowledge regarding optimal farming practice has led to a reduction in adoption and use of RWH Boyd and Turton (2000) due to the reluctance of farmers to invest in activities where returns are unreliable.

A lack of resources, including finances, skills, labour and land, was acknowledged within the literature to be a key constraint to the adoption of RWH by the poorest farmers Pachpute et al. (2009) and although government schemes in Botswana were unsuccessful, the provision of grants and assistance from governments or NGOs has been shown to reduce the barriers to technology uptake Tumbo et al. (2011).

2.3.6 Livelihood strategies

The competition for land, water and labour resources between crops and cattle was a re-occurring theme in the interviews and evidence indicated that the needs of cattle are generally prioritized over those of crops at both household and community level due to the higher value attributed to cattle through greater potential income CAR (2005). The conflict between pastoral and arable farming poses perhaps the greatest barrier to the use of RWH in countries where livestock make a large contribution to livelihoods and competition for land, water and vegetation may lead to the failure of RWH systems unless an appropriate system that allows the co-existence of cattle and crops can be implemented Pacey and Cullis (1991).

2.3.7 Environmental and ecological impacts

Ecosystems are often fragile and can be adversely affected if the water table is tampered with. Thus it is important to pay attention to these factors, understanding where the water flows and how it affects the surrounding ecology, before implementing any kind of water harvesting system. Some negative impacts that water harvesting can potentially have on the existing environment are the reduction of valuable cropland that would be occupied by the catchment area. The catchment often requires a large area and thus occupies valuable cropland Qadir et al. (2007). However, today the technology exists to allow for RWH to occur on a larger scale, allowing for various commercial uses such as plant nurseries, garden centers, and agricultural uses and for use in washrooms and urinal flushing in public buildings Rain harvesting Systems (2006).

2.4 Climate change and Rainwater

Climate change is a reality. Climate change, population growth, increasing water demand, overexploitation of natural resources and environmental degradation has significantly degraded the worlds freshwater resources Ngigi (2009). Climate models predict that by 2050, sub-Saharan Africa will be warmer by 0.50C^{o} - 20C^{o} and drier, a 10% reduction in rainfall is anticipated NAPA (2006). This will be associated with more frequent extreme events, with great influence on water supplies, food production and peoples’ livelihoods among others. The impacts of climate change are already being felt, mostly by the world’s poorest people. According to Tanzania NAPA (2006), agriculture has been identified to be the most vulnerable sector to the impacts of climate change. A study on vulnerability and adaptation to climate change impacts on other sectors in Tanzania clearly indicated that forestry, water, coastal resources, livestock and human health are also likely to be vulnerable to climate change. These sectors are closely linked to agriculture and therefore effects of climate change and variability on such sectors will further negatively affect both crops and livestock production systems.

The impacts of climate variability are manifested by floods, droughts, erratic rains and extreme events. URT (1997) revealed that famine resulting from either floods or drought has become increasingly common since the mid-1990s and is undermining food security. CC & V are likely to intensify drought and increase potential vulnerability of the communities to future climate change especially in the semi-arid regions Hillel and Rosenzweig (1989), where crop production and livestock keeping are critically important to food security and rural livelihoods.

Over 80% of Kenya’s landmass is classified as ASALs, Ministry of Agriculture (2007) and prone to drought and other natural disasters. A sustainable livelihood in the region is threatened by climate change (drought). The region is home to approximately 70% of Kenya’s livestock population estimated at 60 million kept under extensive production systems. The Livestock sub-sector is the major enterprise in the ASALs and contributes 40% of the agricultural Gross Domestic Product (GDP) and 10% of Kenya’s total GDP KARI (2004).The vulnerability of pastoralists in this area is escalating due to recurrent natural disasters coupled with the increasing population growth and declining carrying capacity of the land. Production of pastures/fodder grasses is very low as a result of erratic and low rainfall regimes. Generally, Napier grasses do not grow in ASALs unless supplemented with water and other water conservation structures. Drought resistant grass species such as *Eragrostis superba* and *Cenchrus ciliaris* usually have high chances of survival during establishment in ASALs even when planted under conventional tillage methods Ramathan et al. (2008). In the ASALs, the livestock subsector employs 90% of the 7 million people and contributes 95% of the family income GoK (2003). Therefore, the government under Vision 2030 GoK (2008) recognizes the potential of arid lands and the livestock sub-sector as important drivers for economic growth.

2.4.1 Climate Change and Water Resources for Agriculture

Agriculture and climate change are inextricably linked. Ngigi (2009), stated that Agriculture is part of the climate change problem, contributing about 13.5 percent of annual greenhouse gas emissions (with forestry contributing an additional 19 percent), compared with 13.1 percent from transportation. Agriculture is, however, also part of the solution, offering promising opportunities for mitigating emissions through carbon sequestration, soil and land use management, and biomass production.

Climate change threatens agricultural production through higher and more variable temperatures, changes in precipitation patterns and increased occurrences of extreme events like droughts and floods Ngigi (2009).

The challenges of water resources development in SSA will be aggravated by ensuing climate change, with serious implications on socio-economic development. IPCC (2001) noted that these challenges include population pressure, problems associated with land use such as erosion/siltation and possible ecological consequences of land use change on the hydrological cycle. Climate change especially changes in climate variability through droughts and flooding will make addressing these problems more complex. The greatest impact will continue to be felt by the poor, who have the most limited access to water resources Ngigi (2009). Southern Africa has experienced more recurrent drought and flood episodes in recent times. The frequent droughts and floods in most parts of SSA – leading to severe food shortages, food insecurity, water scarcity, hunger/famine and acute shortage of hydropower signify the regions vulnerability to climate change. Reduced hydropower also affects energy supply for pumping water Ngigi (2009). The IPCC Fourth Assessment Report noted that, since the 1960s, the African continent has experienced a general warming trend with certain regions experiencing more warming than others Boko et al. (2007). Since 1900, warming has occurred in Africa at approximately 0.5°C per century Ngigi (2009). Precipitation is also highly variable across the continent, although much of the continent has experienced decreases in annual precipitation. An increase in inter-annual variability has been noted with the indication that extreme precipitation events (floods, droughts) are on the rise Boko et al. (2007).

Notwithstanding the inconsistency of predictions about climate change, the effects of the phenomenon are being experienced throughout SSA, especially in areas typified by variable rainfall shifting growing seasons IPCC (2001). Most African farmers, particularly those working in rainfed agriculture, have been affected in one way or another. In total, about a quarter of the continents entire population lives in water-stressed regions UNEP (1999).

2.4.2 Anticipated impacts of climate change on agricultural water resources

Water scarcity will be aggravated by the looming climate change. By 2020, yields from rainfed agriculture could be reduced by as much as 50 percent in some countries IPCC (2007). This will adversely affect food security and further exacerbate malnutrition and poverty, especially in SSA. The vulnerabilities and anticipated impacts of climate change will be observed at different scales in different countries IPCC (2001). These heterogeneous and inconsistent data impose serious limitations in constructing scenarios of water resources in response to climate change. Where consistent long-term climatic data are available, they indicate a trend towards reduced precipitation in semi-arid to arid regions IPCC (2001). Instrumental data and climate model simulations indicate an imminent water crisis in large parts of Africa IPCC (2007). Climate change will have a major impact on the baseline environmental characteristics and hydrological cycle World Bank (2009) on which ecosystems and livelihoods are based. A common feature in rainfall patterns as impacted by climate change is greater variability in cycles IPCC (2001). In SSA, most areas are characterized by low and erratic rainfall, concentrated in one or two short rainy seasons. This results in high risk of droughts, intra- and off-seasonal dry spells, and frequent food insecurity. The IPCC (2001) indicates that extreme events, including floods and droughts13, are becoming increasingly frequent and severe. Even countries that previously did not experience floods, such as Burkina Faso, have recently reported severe flooding, notably in 2007.

Drought-prone zones of Africa are already water-limited, further increasing their vulnerability IPCC (2007). Therefore, upgrading rain-fed agriculture, mainly through rainwater harvesting and irrigation, is one of the climate change adaptation strategies.

2.4.3 Conflicts over water resources

When water is scarce, conflicts are common. Increasing water scarcity and demand is a recipe for conflict, even among smallholder farmers sharing the same resources.

Growing water scarcity, increasing population, degradation of shared freshwater ecosystems, and competing demands for shrinking natural resources have the potential to create bilateral and multilateral conflicts Gleick (1992). These conflicts lead to social and political instability with negative impacts on socio-economic development.

For instance, the ongoing conflict in the Tana Delta in Kenya among pastoralists, environmentalists and a private investor has temporarily stopped a huge irrigated sugarcane project. Many conflicts related to water resources have been documented, both at community and at national levels Ngigi et al. (2008); (Gichuki 2002).

In addition, gender issues are expected to intensify in some societies where women are traditionally prohibited from owning land or water resources. Use of water for small-scale businesses, especially those run by women, could be at risk where there are competing users. Women and children are the most affected by water-related conflicts, be it over domestic or agricultural water, due to their roles as the main users and managers of water, especially at household levels. For instance, in northern Tanzania, conflicts over water have led to a mass exodus of pastoralists, drastically reducing school attendance.

The evolving trend for water-related conflict and tension across Africa is such that riparian water projects are implemented within country borders to avoid cross-border politics. However, at some point, various externalities – population increase, climate change, limited resources – force a country to expand operations, affecting other downstream users Wolf (2001). Shared river basins such as the Nile, Niger and Zambezi, already experience tensions over water use. In West Africa, where water withdrawal is expected to increase six fold by 2025, there is potential for conflict since all 17 countries in that region share at least one of the region's 25 trans boundary rivers Niasse (2005). Recent conflict involved Mauritania with Senegal and Burkina Faso with Ghana. In southern Africa, where climate change is expected to significantly reduce precipitation, risk for conflict over water resources is higher than most other regions Ashton (2002).

Conflicts over water are not only associated with shared river basins, but also other shared inland basins like Lake Chad and the Okavango Delta. Precise boundaries on Lake Chad have been established between Chad, Nigeria, Cameroon and Niger. IPCC (2007) noted that “sectors of the boundaries that are located in the rivers that drain into the lake have never been determined, and several complications have been caused by flooding and the appearance or submergence of islands.

2.4.4 Adaptation Strategies

Adaptation to climate change and variability necessitates the adjustment of a system to moderate the impacts of climate change, to take advantage of new opportunities, and to cope with the consequences IPCC (2001). Adaptation involves the action that people take in response to, or in anticipation of, projected or actual changes in climate to reduce adverse impacts or take advantage of the opportunities posed by climate change Parry *et al.* (2005). In terms of climate change, this latter part of the definition is significant since climate change also presents certain opportunities and advantages in Africa, particularly for increased rainfall in certain areas of the continent (parts of the Democratic Republic of the Congo for example). Thus, it reduces communities’ vulnerability or increases their resilience to climate shocks. It also enables ecosystems to coexist with the changing climate, thereby enhancing their capacity for providing the ecosystem services critical for human well-being Parry et al. (2005).

In many cases, adaptation activities are local ‑ district, regional or national ‑ issues rather than international Paavola and Adger (2005). Because communities possess different vulnerabilities and adaptive capabilities, they tend to be impacted differently, thereby exhibiting different adaptation needs. As a result, adaptation largely consists of uncoordinated action at household, company and organization levels. But it may also involve collective action at the local, national, regional and international levels and cross-scale interaction where these levels meet Paavola and Adger (2005).

The vulnerabilities of climate change occur at various scales Adger et al. (2005), and hence successful adaptation will depend on actions taken at different levels as outlined by Paavola and Adger (2005).

At the national level:

- Formulation of climate change policy geared toward vulnerable sectors, with emphasis on poverty reduction and food security
- Establishment of an integrated drought monitoring and information system, including an early warning system and farmers' coping mechanisms
- Development of policies and institutions that support adaptation at community levels and encourage private sector participation, allowing for greater dedication of resources to development of adaptive technologies and innovations
- Resource allocation to development of adaptive technologies and innovations to enhance sustainable economic growth

At the community level:

- Establishment of appropriate social institutions and arrangements that discourage marginalization of vulnerable population and enhance collective/participatory decision-making process
- Diversification of income sources and livelihood systems that reduce vulnerability and risks, especially for the poor
- Introduction of collective security arrangements such as farmers' cooperatives and community-based organizations (CBOs)
- Provision of knowledge, technology, policy, institutional and financial support (e.g. credit facilities) for the vulnerable communities
- Prioritization of local adaptation measures and provision of feedback to stakeholders

One of the important characteristics of an adaptation strategy is that it should reflect the needs and aspirations of the society or community it is meant to benefit. Thus, the most effective mechanisms are flexible and relatively independent of scale. Adaptation efforts must be coordinated across sectors and between agencies, which is a challenge in practice. Without proper coordination, disparate actions may diminish overall effectiveness Adger et al. (2005).

The effectiveness of collective action in reducing climate vulnerability is a prerequisite. Thomas et al. (2005) found that projects utilizing local knowledge and based on market principles were most successful. Capacity building must be an integral component of any climate change adaptation strategy due to existing uncertainty within the climate models, particularly at local and national levels. The capacity of smallholder farmers to adapt to climate change is perhaps the most vital area for development.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter discusses the study area, population of the study, sample size determination, sample size, sampling procedures, data collection, and the methods used in order to achieve the planned objectives of the study.

3.2 Study area

Yatta District is located in Eastern province. The district has three divisions namely; Ikombe, Yatta and Katangi. The district is mainly under agro-climatic zones IV and V, which, is classified as semi-arid to arid lands, respectively Jaetzold and Schmidt (2006). The soils in Yatta district are a combination of Ferralo-Chromic/Orthic/Ferric Acrisols and Luvisols with Ferralsols according to the USDA criteria. These soils are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storage capacity and low nutrient availability Kibunja et al (2010). In most places, they have topsoil of loamy sand to sandy loam.

The District has a semi-arid climate with mean annual temperature varying from 17ºC to 24ºC and experiences bimodal rainfall with long rains (LR) commencing end of March to May (about 400 mm) and short rains (SR) from end of October to December (500 mm).

The major sources of surface water are seasonal rivers during the rainy season, which dry up immediately after the rains. Most of the areas are generally hot and dry leading to high rates of evaporation.

The majority of the farmers in the District are small-scale mixed farmers with low investment for agricultural production. Most crops grown by the farmers are maize, beans and cowpea Macharia (2004).

3.3 Study approach

3.3.1 Research Design

This study used both quantitative and qualitative methods of data analyses. The collected data was coded, entered and checked for consistency before keying into the SPSS software for further processing, and was analyzed using SPSS to obtain information on household characteristics such as age, education and awareness levels, household incomes, household size.

3.3.2 Identification of the targeted population

The population of this study was composed of smallholder farmers in the rural areas of Katangi and Ikombe divisions of Yatta district, Eastern province, Kenya. The study targeted households that were practicing various rainwater harvesting techniques and the factors influencing their choice.

3.3.3 Sample size determination

The sample size was determined using proportional probability to population formula Chirwa (2003) stated below:

$$n = \frac{z^2(1-p)p}{e^2}$$

Where n is the sample size, Z is the desired Z-value yielding the desired degree of Confidence, p is an estimate of the population proportion and e is the absolute size of the error in estimating p that the researcher is willing to permit. In this study a p-value of 0.04 was used. The study used 95 percent level of confidence (Z= 1.96 for a two tailed test), with an allowable error of 0.05. Using the above stated formula the sample size was 60 respondents. The sample size was representative of the study population because the roles and responsibilities are similar within the same category, hence variations in data within the study population was minimal.

3.3.4 Sample size

The study involved collecting data from a total sample of 60 respondents. A sample size of 60 farmers was regarded as adequate for inferences to be made about entire population considering the time available and the costs involved in the survey. Thus, 30 household heads were interviewed in Katangi out of a sampling frame of 306 households and 30 household heads from Ikombe out of a sampling frame of 350 households.

3.3.5 Sampling procedure

A farmers list in the divisional agricultural office was used to select farmers to be used in the study. The selected farmers were visited to ascertain their socioeconomic status and willingness to participate. A representative sample of households by income status and geographical distribution was taken out of the entire population. In both Katangi and Ikombe, the samples were selected through probability sampling methods and the technique was simple random sampling. Simple random sampling is a procedure that provides equal opportunity of selection for each element in the population. The lottery techniques were used where a symbol of each unit of the population was placed in a container, mixed and lucky numbers were drawn to constitute the sample. Although simple random sampling is laborious and is not usually the most convenient sampling method Babbie (1973), it was the most convenient method because every element or number of the population had equal chances of being selected. This eliminates the bias inherent in non-probability sampling procedures because the probability sampling process is random; every farmer had an equal opportunity of selection in the population.

3.3.6 Data collection instruments

This study involved collecting data using a semi-structured questionnaire. Data was collected on factors affecting water harvesting techniques used by households as well as factors influencing their wide adoption e.g. age, education level, farm sizes, and income source. Data on the influence of climate change on water resources was also collected. A face-to-face interview was conducted on the household head for all selected households. Key elements of the questionnaire were factors affecting rainwater harvesting techniques, factors influencing adoption of rainwater harvesting techniques, and the influence of climate change on water resources.

3.3.7 Pilot testing

A pilot testing of survey was conducted for thirty respondents in April 2011 in the Yatta District to look into the possible content of the questionnaires for the full run of the survey. The questions in the pilot survey for the respondents included:

i. Are you aware about any water harvesting techniques?
ii. What are the sources of water in your area?
iii. What are the types of water harvesting techniques do you have?
iv. What is the size of your farm?
v. Is farming your main source of income?
vi. Have you ever experienced water shortage?
vii. Have you observed any changes on the water resources?

3.4 Data analysis and presentation

Data was analyzed and presented quantitatively and qualitatively using different statistical methods to investigate the factors affecting adoption of water harvesting techniques. Descriptive statistics; means as well as percentages were calculated. Logistic regression model with an entry selection process was used to analyze and estimate the dependent variable as adoption of a particular technique and independent variables as educational levels, age of farmers, and farming as source of income, farm size, awareness, and experiences of water shortage. Correlation analysis was also used to correlate the relationship between the influence of climate change on water resource and information source, experiences on water shortage, awareness about water harvesting techniques, coping with the challenges, and the anticipation of further changes in the near future.

3.4.1 Logit model

Adoption of water harvesting techniques, the phenomenon we seek to model, is considered discrete rather than continuous in nature. In this case, the dependent variable is binary.

These are cases where the dependent variable can be characterized as binary, taking the value of 0 or 1. The dependent variable thus takes the value of 1 if the technique is adopted and 0 if the technique not adopted. The regressor in this model is adoption of the techniques (whether a technique is adopted or not).

The logit model was chosen because the properties of estimation procedures are more desirable than those associated with the choice of a uniform distribution Pindyck and Rubinfeld (1991). In the logit regression model, parameters are determined through maximum likelihood estimation (MLE) procedure. The probability that a technique is adopted can be specified as:

$$P_i = F(\alpha + \beta x_i) = \frac{1}{1 + e^{-(\alpha + \beta x_i)}} \qquad (1)$$

Where P_i is the probability that the technique will be adopted given x_i, where x is a vector of explanatory variable and e is the natural logarithm. Equation (1) can be rewritten as:

$$P_i = \left[1 + e^{-(\alpha + \beta x_i)}\right] = 1 \qquad (2)$$

Where $\alpha + \beta x_i = \log\left[\frac{P_1}{1 - P_1}\right]$ and $\frac{P_1}{1 - P_1}$ is the likelihood ratio, whose log gives the odds that a technique is adopted.

Where:

α is the constant of the equation

β is the intercept term

The regression can be expressed as

$$Log\ (p_i/\ (1\text{-}p_i)) = \alpha + \beta_0 + \beta_1 {*} \boldsymbol{x_1} + \ldots + \beta_n {*} \boldsymbol{x_n}$$

Where, i denotes i^{th} farmer, (1……60); P_i the probability of adoption by the farmers, and $(1- P_i)$ is the probability of non-adoption. Where β_0 is the intercept term, and $\beta_1, \beta_2, \beta_3 \ldots \beta_n$ are the coefficients associated with each explanatory variable $X_1, X_2, X_3 \ldots X_n$ the estimation form of logistic transformation of the probability of farmers' decision to adopt the technique.

Table 1: Description of the variables specified in the empirical binary logistic model

Acronym	Description	Type of measure
Dependent variable		
ADOP	Weather a farmer has adopted or not	Dummy (1 if yes, 0 if no)
Explanatory variables		
EDUC	Education background of the household heads	Number of years of formal education
EXPWS	Experiences of water shortage	Dummy (I if yes experienced, 0 if not experienced)
FMZ	Farm size	Acres
AWR	Awareness of water harvesting techniques	Dummy (1 if aware, 0 if not aware)
FSOINC	Farming as source of income	Dummy (1 if yes, 0 if no)
AGE	Household head's age	Years

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and its interpretation of data gathered out of the instrument used in the study, and is presented according to the specific problem sited in chapter1.

4.2 Response rate

Seventy two questionnaires were sent to the farmers in Yatta district who were randomly selected from the list in the Extension Officers. Sixty questionnaires were returned, resulting in 83% response rate. The sixty respondents were considered to be valid for this research.

4.3 Characterization of water harvesting techniques in Yatta district

4.3.1 Water harvesting techniques practiced by households

Table 4.1 show that the majority (45%) of farmers in Yatta district practiced roof water harvesting techniques followed by sand dams (36.1%). Minority of farmers (1.6%) adopted water pans.

Table 4.1: Type of water harvesting techniques practiced by households

	Frequency	Percent
Roof water tanks	27	45
Sand dams	22	36.1
Runoff from terraces	2	3.3
Water pans	1	1.6
Boreholes	8	14
Total	60	100.0

The considerable application of roof water tanks by most farmers in this area was attributed to the fact that most of them were supported to buy the tanks by organizations and Non-governmental organizations (NGOs). This is in addition to the ease of its implementation by rural farmers. Nelly (2010) found that, many roof water tanks have been implemented by NGOs in rural areas of Kenya such as Tseikuru , these tanks is regarded to be of the best quality and increasing water quantity and availability at the implemented sites.

The second most widely practiced water harvesting technique was the sand dams. This was attributed to easy of its construction and suitability of the natural landscape of the area in construction of sand dams. This is in addition to its provision of a large amount of water for people, livestock and plants during the dry season. Similar studies have found that sand dams indirectly benefit up to thousands of people, as the use of the stored water is never restricted to the people who built the technique. Moreover, the sand dam has potential to provide a large amount of water for up to 1,200 people, animals, tree nurseries and vegetable gardens Jacob (2001). This is also shared by UNFCCC (2002) who found that in Sakai and other parts of Kenya, constructed sand dams have proved to be reliable sources of water for people, livestock and plants during the dry season. The dams also trap sand that prevent evaporation and cause water to percolate underground, where it remains available for future use.

Adoption of other techniques such as terracing (3.3%), water pans (1.6%) and boreholes (14%) were found to be inappropriate in this area. Technique of water pans was appropriate and adopted by many farmers in Lare division of Kenya rather than other techniques KARI (2000). However, minority of farmers in Yatta district collect water using terraces which is different from farmers in Lare division who collect runoff water using pans which is more reliable than using terrace. This was due to the relatively flat topography and soil characteristics that are highly sandy. While the technique of borehole adopted by a very few farmers in Yatta district due to high cost of construction and need technical knowledge. ICRC (2010) found that, the technology needed to construct boreholes can be quite complex in its construction, requiring engineering skills.

4.3.2 Preference and rating of adopted water harvesting techniques

Table 4.2 reveals farmer preference and ranking of adopted techniques, the boreholes were found to be the lowest preferred technique as reported by 50% of farmers, this was followed by shallow wells as well as terracing. Furthermore, roof water tanks (41.2%) were ranked as moderately preferred techniques, whereas, only sand dam was highly preferred technique (39.5%).

Table 4.2: Farmer preference and ranks of adopted techniques

	Highest	High	Moderate	Low	Lowest
Boreholes	0	0	30	20	50
Roof water tanks	7.8	15.7	41.2	11.8	23.5
Sand dams	14	39.5	30.2	11.6	4.7
Shallow wells	11.1	2.2	10	22.2	44.4
Runoff terracing	9.8	4.9	19.5	24.4	41.5

The high preference for sand dams (39.5%) was attributed to its simple construction and affordability compared to other techniques', it also harvests a large amount of water to satisfy most of the farmers in their main needs such as domestic, livestock and cultivation consumptions. These results are similar to those of Mati (2006) who reported that the technique of sand dams' was simple and cost effective hence it was gaining popularity as more and more stakeholders adopt it.

The roof water tank was ranked as moderate techniques (41.2%). This was due to its accessibility and provision of clean water within the homestead. Worm (2006), indicated that rooftop rainwater harvesting at the household level is most commonly used for domestic purposes. It is popular as a household option as the water source is close to people and thus requires a minimum of energy to collect it. In that regards, the harvested water from rooftop can be realistic as well as clean and save a walk of many kilometres to the nearest clean water source. An added advantage is that users own maintain and control their system without the need to rely on other community members Worm (2006).

Farmers in this area ranked the technique of terracing lower (41.5%) in terms of preferences. This was because the topography is relatively flat and not appropriate to implement such technique in this area. However, Mitiku (2002) found that in Northern Darfur of Sudan, terracing was used to control soil erosion resulting from surface runoff both in agricultural and grazing land and was used for both water conservation and soil erosion control, found. These differences can most likely be due to the nature of the soil, topography, the sample size of study area.

Boreholes and shallow wells were ranked as the lower techniques by most of the farmers. This is because these techniques are more complex in their implementation and need funds as well as the inadequate technical knowledge and skills that the community have about such the techniques.

Among other factors that influence adoption of the techniques, the study found that most farmers (46.7%) lacked technical knowledge and skills to implement and subsequent adoption of the water harvesting techniques (Annex T). According to the related studies of those ICRC (2010) who demonstrated that, the technology needed to construct boreholes and shallow wells and can be quite complex, requiring engineering skills.

4.4. Proportion and use of harvested water

4.4.1. Proportion of harvested water

Table 4.3 shows the harvested water through the various techniques used for different purposes. Water harvested using sand dam technique was used for domestic (39%), livestock (38%), and crop cultivation (23%). The roof water tank used for domestic (42%), livestock (30%), and crop production (28%).Whereas, harvested water from runoff terracing used for livestock (51%) and crop production (49%). Harvested water through borehole used for domestic (28%), livestock (24%), and crop production (47%).

Table 4.3: Proportions of harvested water used for different purposes from the specified techniques

	Sand Dams		Roof top Tanks		Terracing		Boreholes	
	Average	Share %	Average	Share %	Average	Share %	Average	Share %
Domestic use	472.27	39	435.89	42	0	0	210	28
Livestock use	457.81	38	313.57	30	400.95	51	180.5	24
Crop	280.62	23	292.92	28	380.53	49	353.12	47
Total	1210.7	100	1042.38	100	781.48	100	743.62	100

The high proportion of water from sand dams can be explained by the accessibility and large amount of harvested water that is used for domestic, livestock and crop production purposes. The considerable proportion of harvested water from roof catchments was due to collection of clean water for domestic use. The proportion of harvested water from terracing was used for livestock and crop production. These results are in agreement with those of ADB (2009) indicated that the roof catchment systems were used for domestic consumption, (personal hygiene, cooking, cloths washing). Runoff harvesting from surface catchment such as rock, concrete, plastic sheets, treated ground or other suitable surfaces was used for domestic and livestock consumption, nurseries, as well as small-scale irrigation. Small scale dams such as sand dams, sub-surface dam, water pans, ponds or pits (charco), were also used for domestic ,livestock and agricultural purposes, in addition, External catchment such as Run-off diverted into field (contour stone bunds, terraces etc.) were used for agricultural purposes and food security, water and soil conservation and was relatively used for domestic purposes.

4.4.2. Reasons of applying the different techniques

Table 4.4 reveals that most farmers (20%) adopted sand dams because they store a large amount of water, followed by lower cost of construction compared to other technologies. Roof water tanks were adopted by (21.7%) of farmers because of provision of clean water, 16.7% related to ease of access and 11.7% to cost of production. Terracing was adopted by

10% of farmers with the reason of easy access, while shallow wells were adopted due to provision of clean water and easy access.

Table 4.4: Reasons of adopting different water harvesting techniques

Techniques	Clean	Easy access	Cheap	Collect lots of water	Clean, access, cheap	Less cost	Cheap & easy access	NA
Sand Dam	0	8.3	10	20	0	0	0	61.7
Roof Tanks	21.7	16.7	11.7	1.7	6.7	3.3	3.3	35
Shallow wells	6.7	6.7	0	0	0	0	0	86.7
Terracing	0	10	6.7	5	0	0	0	78.3

The reason of high adoption of sand dams was due to storage of large quantity of water. There was high participation of local community and most of the construction material was locally available thus making it cheaper to construct. These results are similar to those of Arjen (2002) who indicated that sand dams are simple technology that can store large amounts of clean water right through the dry season. In Kitui district, more than 3000 sand dams have now been built, which storing thousands of litres of water during the rainy months. This reduces walking distance to water source where women would typically walk more than 10 km every day to fetch drinking water. In the dry season, these distances can be much longer, making water collection a huge drain on their time and energy Arjen (2002).

Roof water harvesting was mostly adopted by the community due to its design considerations and provision of relatively clean water and easily accessible. Norma (2009) reported that, compared with most unprotected traditional water resources, rainwater from well-maintained roof catchments is usually safe for drinking and often meets the WHO drinking water standards.

Farmers (6.7%) adopted the technique of terrace due to easy access. This result was attributed to its ease of understanding and farmers can promote it even if without any technical knowhow in its construction. Prinz (1996) reported that runoff from terraces had proved to be a valuable, easier and cheaper tool especially in the dry marginal areas to increase crop yields and reduce cropping risk as well as improve pasture growth, fight soil erosion, make best use of available water resources, recharge groundwater and allow a higher degree of food production.

4.2 Factors affecting adoption of water harvesting techniques among households in Yatta District

4.2.1 Farmers awareness

Table 4.5 reveals that a large number of farmers (56.7%) were aware of the water harvesting techniques

Table 4.5: Farmers awareness levels of water harvesting techniques

	Frequency	Percent
Aware	34	56.7
Not aware	26	43.3
Total	60	100.0

This result reflects the high knowledge that the community has about water harvesting techniques. In order to increase adoption of the techniques, more efforts in capacity building and awareness are required. From the study, among the factors affecting adoption and awareness of water harvesting techniques, education level of respondents did not exceed primary school, i.e. male (66.7%) and female (46.4%), respectively (Annex T2). In addition to that, the farmers had more than five years' experience in water harvesting techniques and they seemed to understand the advantages and disadvantages of these techniques. Most of the farmers (60%) have experienced water shortage that underscored the need to adopt the harvesting techniques (Annex T3). These levels of education and experiences of water shortage enabled the farmers to adopt the new technologies. Hatibu (2003) noted that farmers with a higher level of education are likely to adopt water-harvesting systems earlier, therefore shortening the adoption of the techniques. Education exposes someone to information and therefore creates awareness, which is a very important stage in the adoption of water systems Hatibu (2003).

4.2.2 Source of information

Results of Table 4.6 shows that most farmers reported getting information about water harvesting techniques from Extension Officers (53.3%) followed by Radio programmes (23.3%)**,** while minority of the farmers (8.3%) relied on their indigenous knowledge.

Table 4.6: Sources of information regarding the various water harvesting techniques

Sources	Frequency	Percent
Radio	14	23.3
Friends	9	15
Extension officers	32	53.3
Indigenous knowledge	5	8.3
Total	60	100.0

This result reflects that farmers are more receptive to information passed on Extension Officers and are ready to adopt the technologies, compared to other sources of information. NSIAH (2003) stated that the Extension Officers were the most preferred source of information to the respondents. Moreover, the respondents when asked to indicate one choice of how they would like to receive agricultural information, they overwhelmingly indicated that the Extension Officers were their most preferred source of information NSIAH (2003). This is because in most cases the Extension officers' operate as facilitators and communicators, helping farmers in decision making and ensuring that appropriate knowledge is implemented to obtain the best results.

4.2.3 Difference of ages and the use of water harvesting techniques

Table 4.7 shows that people who are aged between 50-60 years prefer to use roof water tanks (33.3%), sand dams (40.9%), and water pans (100%). Terraces are popular for people who are aged between 30-40 years (50%) as well as 40-50 years (50%), while, people who are aged above 60 years prefer to use boreholes (62.5%).

Table 4.7: Age categories and the use of water harvesting techniques

	Age category									
Techniques	30 - 40		40 - 50		50 - 60		Above 60		Chi-square	P-value
	Count	%	Count	%	Count	%	Count	%	15.31	0.225
Roof tanks	7	25.9	6	22.2	9	33.3	5	18.5		
Sand dams	5	22.7	6	27.2	9	40.9	2	9.09		
Terraces	1	50	1	50	0	0	0	0		
Water pans	0	0	0	0	1	100	0	0		
Boreholes	1	12.5	1	12.5	1	12.5	5	62.5		

People within the age of 50-60 years are more selective in the use of the various water harvesting technologies compared to other age groups. Farmers in this age group are assumed to have a good understanding of problems of the techniques due to access to information. As a result, farmers who are aged between 50-60 years usually more interested in water harvesting practices. Babbie (1973), as the farmer gets older he/she tends to intensify adoption of the technologies in his/her farm. This can be attributed to the experience of the farmer in farming activities, which other studies have found to be important in adoption of technologies.

Chi-square suggesting that there is no strong relationship between age groups of farmers and the use of water harvesting techniques.

4.2.4 Organizational involvement

Figure 1 reveals that the majority of (66.7%) farmers reported that various organizations had helped the water harvesting structures. Minority of respondents (33.3%) indicated that there was no assistance from organizations in the construction of water harvesting structures.

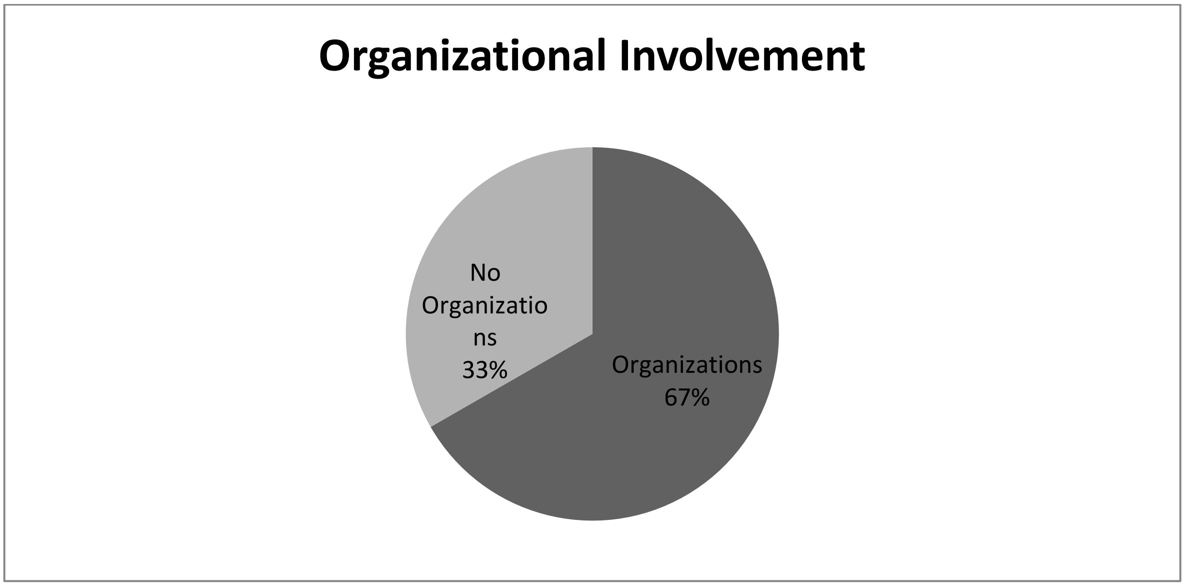

Figure 1: Farmers' perception about organization that helping the community in the setting up of water harvesting techniques.

Results of Table 4.8 shows that majority (30%) of the farmers reported that sand dams were promoted by NGOs followed by RELMA and MCDF respectively. About 28% of the farmers reported that the roof water tanks were promoted by IFAD followed by (20%) of the farmers who reported that roof water tanks were promoted by UNICEF and RELMA.

Table 4.8: Names of water harvesting technique being promoted by the specified organizations

	UNICEF	RELMA	Naco Dep	IFAD	NGOs	MCDF	FAO
Boreholes	15.5	0	6.7	10.6	5.0	5.0	10
Water pans	0	0	3.3	0	0	0	3.3
Wells	15.5	0	1.7	1.7	10	0	1.7
Sand Dam	0	25.5	0	0	30	24	7.5
Roof tanks	20	20	1.7	28	15	10	0
NA	30	17	63.2	7.7	0	44.3	41.6
Community reception of the techniques that brought by the specified organizations							
Well received	25	51	13	28	63.5	34	14
Adopted	19	10.6	14.3	21.6	33.1	19.4	13.6
No technique	56	38.4	72.7	50.4	3.4	46.6	72.4

The considerable role played by the NGOs, Marxist Communist Discussion Forum (MCDF) and Regional Land Management Unit (RELMA) in the construction of sand dams was due to their suitability for the area. This was also due to the extension messages extended by extension officers to the farmers to integrate water harvesting technologies in their agricultural production activities. Such arrangement increased the rate of adoption of the technology by many farmers. Barghouti and Le Moigne (1990) reported that NGOs, with few private sectors, played the most significant roles in supporting farmers in adopting water harvesting techniques all over Kenya, and these organizations were well appreciated by farmers and were considered to be most effective compared to government driven programs.

In another similar study, ABD (2009) reported that there were several water harvesting techniques in northern Kenya that had been promoted by many international organizations and institutions (e.g. FAO, IFAD and RELMA) to augment water availability for many purposes such as food production.

4.2.5 Conflicts on water use

Figure 2 indicates that majority (53.3%) confirmed that conflicts occurred among water users, while minority of farmers (6.7%) reported that conflicts were very few.

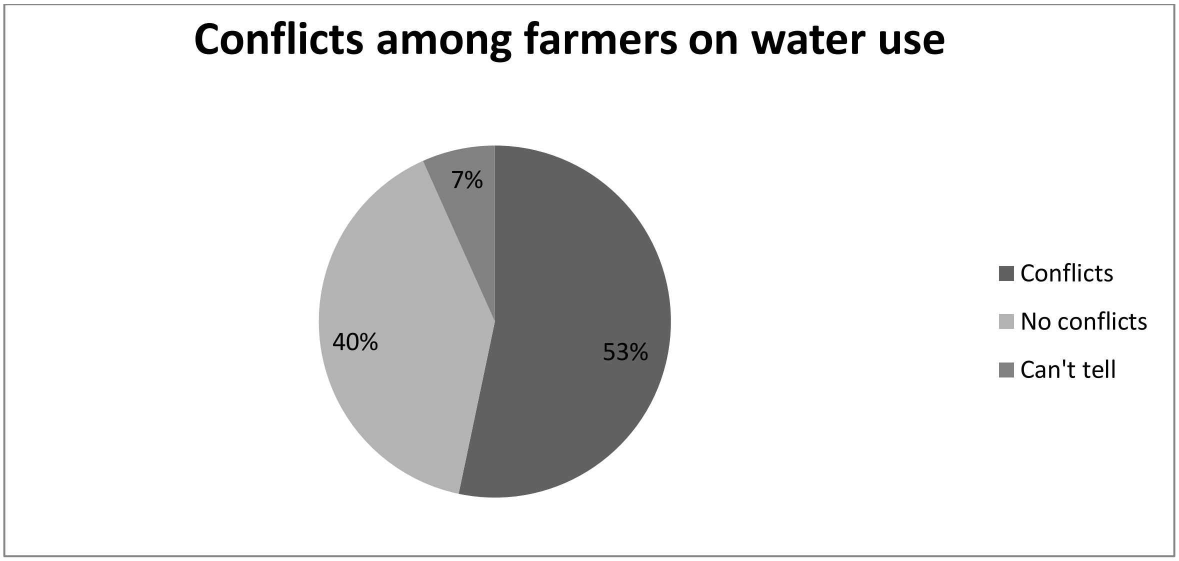

Figure 2: Conflicts among farmers on water use

Table 4.8 shows that most farmers (31.7%) stated the nature of the conflicts to involve animals watering. About 23.3% of the respondents reported that the conflicts were not serious cases.

Table 4.8: The nature of the conflicts

	Frequencies	Percent
Cases of land tenure especially conflicts in dams	2	3.3
Few cases/water containers being stolen	8	13.3
Not serious cases	14	23.3
Animals conflicts	19	31.7
Not common	17	28.3

Conflicts that occurred in the area were mainly over water during the prolonged drought periods, and distribution of water sources in the area due to inadequate water sources.

UNFCCC (2002) reported that a number of people and livestock were attracted to sand dams thereby leading to greater competition and conflict between water users. Drought has contributed to growing conflicts within and between households over reduced quantities of grazing land, water and other natural resources.

4.2.6 Evaluation of factors that influence adoption of water harvesting techniques

Table 4.9 presents the results of a logistic regression analysis for the adoption of water harvesting techniques. In this model the adoption condition used as a regressor. The significance of individual variables was tested by the Wald statistic. The column, exp(β), 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. The model used nine variables: Education level, experience of water shortage, farm size, and awareness of water harvesting techniques, farming as source of income, age of farmers, income Kenyan shillings, organizations and distances of water source, in explaining farmers' adoption of water harvesting techniques. The result showed that six variables such as education level, experience of water shortage, farm size, awareness of water harvesting techniques, age of farmers, and income source were significantly related to adoption of water harvesting techniques. The model showed that the education level had the highest positive influence on adoption of water harvesting techniques. Experience of water shortage was the second effect on the adoption of the techniques. Thirdly were farm size and lastly the awareness of water harvesting techniques. The lowest influence was age of farmers that had positive effect on adoption of the techniques followed by farming as source of income that was significant and negatively related to adoption of water harvesting techniques. Organizations, distance to water sources, and income Kenyan shillings from farm had no influence on the adoption rate of water harvesting techniques.

Table 4.9 Regression model: factors influencing adoption of rainwater harvesting techniques

Model	B	S.E.	Wald	Sig.	Exp(β)
Constant	-18.119	5.578	10.550	0.001	.000
Education	3.860	1.342	8.272**	0.004	47.48
Experiences of water shortage	3.518	1.242	8.022**	0.005	33.71
Farm Size	-0.225	.091	6.077**	0.014	.798
Awareness	3.205	1.313	5.955**	0.015	24.65
Farming as source of income	-2.400	1.218	3.882**	0.049	.091
Age of Farmer	0.076	.039	3.721**	0.05	1.08
Organization	-1.740	1.161	2.246	0.134	.175
Distances	-0.287	.484	.351	0.553	.751
Income KShs	0.952	.515	3.420**	0.064	2.59

Significant at 5%; Chi-square = 50.242; -2 Log likelihood = 32.869; N= 60, Cox & Snell $R2$=.567; Nagelkerke $R2$=.756.

Education level was significant and positively related to adoption of the techniques. The exp(β) value associated with education level attained by the head of a household is 47.48. The exp(β) implies that, in every additional year increase in education level of household head, we expect 47.48 times increase in log-odds of adoption of rainwater harvesting techniques. This suggests that more educated farmers' are more likely to adopt rainwater harvesting techniques than less educated farmers. In most adoption studies, farmers with higher levels of education attainment are more likely to adopt or to practices rainwater harvesting techniques compared to less educated farmers (Chianu and Tsujii, 2004).

Farmers' experiences of water shortage had a positive effect on adoption of the water harvesting techniques. The exp(β) also shows that, for 1-unit increase in farmers experiences of water shortage, log-odds of adoption (the probability of adoption) would increase by a factor of 33.7. Farmers who had experienced water shortage had a greater possibility to adopt water harvesting techniques than those who had not experienced water shortage. UNFCC (2002) reported that smallholder farmers who live in arid and semi-arid lands of Kenya such as Sakai had adopted rainwater harvesting techniques due to long period of water shortages and drought.

Farm size was found to be significant (5% α) with negative impact on adoption of rainwater harvesting techniques. The exp(β) value associated with farm size is 0.798. Therefore when farm size increase by 1-unit, the odds for adoption of rainwater harvesting techniques decreases by 0.798. This means that farmers whose farms were larger were less likely to adopt the techniques. This contradicts research findings by Buyinza et al. (2008) who reported that farmers' who had bigger farms were more likely to adopt rainwater harvesting techniques.

Farmers' awareness of water harvesting techniques had a positive impact on adoption of the techniques. The exp(β) shows that the odds of a farmer who was aware of RWHT was 24.65 times likely to adopt compared to those who were not aware. Similar empirical studies had found that farmers with a positive attitude were keen on implementing agricultural technologies that incorporated an element of water harvesting technologies (Herath and Takeya, 2003; Somda et al., 2002).

Farming as the main source of income had negative impact on adoption of rainwater harvesting techniques. The exp(β) value associated with farming as the main source of income was 0.091. Hence, with 1-unit increase in income from farming, the odds for adoption decrease by 0.091. However, among the factors that affected the adoption of rainwater harvesting techniques the majority (58.3%) of farmers had reported that the farm was the main source of their incomes (Annex T9). This implies that farmers who mainly relied on income from farms had the likelihood not to adopt the water harvesting techniques than those who had other sources of income apart from farms. However, Herath and Takeya (2003) noted that the role of farm income on the decision to adopt is unclear. Hence, it is difficult to predict the sign of farming as source of income.

Related studies have also found that farmers' income level was an important factor affecting adoption of water harvesting techniques AWM (2007). Other empirical findings among smallholder farmers in arid and semi-arid areas have also underscored the importance of diversified farm income sources as a strategy to enhanced adoption of water harvesting techniques (Rutten, 1992).

The farmers' age was found to be significant and positively related to adoption of water harvesting techniques. The exp(β) implies that for each year increase in farmers' age, log-odds of adoption of rainwater harvesting techniques increase by 1.08. This indicates that the probability of adoption of rainwater harvesting techniques is higher among older farmers than among younger farmers. The average age of farmer was found to be 51.78 (Annex T8). According to Babbie (1973), as the farmer gets older he/she tends to intensify adoption of the technologies in his/her farm. This can be attributed to the experience of the farmer in farming activities, which other studies have found to be important in adoption of technologies.

4.3 Effect of climate change on water resources and mitigation measures in Yatta district

4.3.1 Awareness of changes on water resources

Table 4.10 indicates that most of the farmers (96.7%) observed changes on water resources. About 58.3% of farmers demonstrated that the observed change on water resource was due to climate change and/ or variability, while a minority (3.3%) indicated change was due to lowering of the water table. About 33.3% of the farmers reported the impact of climate change in terms of the prolonged drought of 1980's, with 23.3% indicating reduced rainfall and drought during the 1970's.

Table 4.10: Farmers perception to changes on water resource

Changes experienced on water resources	Frequency	Percent
Experienced changes	58	96.7
Not experienced any change	2	3.3
The observed changes on water resources		
Increased	33	55
Decreased	23	38.3
can't tell	3	5.0
completed drying	1	1.7
Farmers attribution of the changes mentioned in the observation of changes above		
climate change	35	58.3
water abstraction	8	13.3
lowering of the water table	4	6.6
human activities	2	3.3
Climate change+ Human activities	9	15
Farmers identification of climate change periods in the study area		
1970's,Drought and low rains	14	23.3
1990's,Drought	7	11.7
1980's,Drought	20	33.3
1990's,drought+increased temperatures	2	3.3
1980's,drought+increased temperatures	2	3.3
1970's,drought+increased temperatures	1	1.7
1980's+1990's,drought+low rains	3	5.0
1990's+2000's,drought+increased temperatures	6	10.0
1980,s+1990's,drought+increased temperatures	2	3.3
1970's,1990's,drought+increased temperatures	3	5.0

According to UNFCCC (2002), the rains have become more unpredictable since the 1980's. This pattern is consistent with projections that Kenya's vulnerable arid and semiarid lands will experience an increase in the frequency and severity of droughts and significant declines in rainfall and river flows due to climate change.

The changes on water resources were due to climate change and its negative impacts, which have become more pronounced in the whole world particularly in the arid and semi-arid areas Ngigi (2009). These changes in water resources can also be explained by the exacerbated existing issues in various sectors such as low water supply, experiences of water shortages, deforestation and conflicts between users on water resources. There was a positive correlation between the observed changes on water resources and the experiences of water shortages (Annex T5). UNFCCC (2002) indicated that climate change and climate variability had become more pronounced in many part of Kenya in recent years, adversely affecting the lives and livelihoods of smallholders' farmers as well as creating conflicts between most of the farmers on water use in ASALs. Moreover, climate change have posed multiple challenges on water resources, water supply and demand, on water quality, on human activities and livelihoods, on societies, health and have impacted land use and ecosystems in multiple ways IPCC (2007). Further, UNFCCC (2002); reported that smallholders' farmers who live in the arid and semi-arid lands that cover approximately 80 per cent of Kenya have long experienced water shortages and drought due to unreliable and poorly distributed rains, which damaged crops and livestock.

4.3.2 Coping with water unavailability due to the effect of climate change

Table 4.11 reveals that about 33.3% of farmers walk long distances to collect or buy water, whereas 26.6% of farmers were coping by using water from pans as well as sand dams.

About 40% of the farmers considered sand dams to be vital techniques to combat water scarcity while 8.3% of farmers indicated that pans to be new technique to combat water scarcity due to effect of climate change. Most (40%) farmers reported that incomes had decreased as well as health risks increased due to the potential impacts of climate change on water resources in the society. About 25% of farmers reported that their economic viability had decreased as well. Nearly 23.3% of farmers demonstrated that climate change had led to decreased construction of water harvesting structures. About 88.3% of farmers anticipated further changes on water resources in the near future.

Table 4.11: Farmers coping with the water scarcity due to the effects of climate change

Farmers coping	Frequency	Percent
Accessing from wells	6	10
Runoff water	8	13.3
Walk to long distances to collect and buy water	20	33.3
Water from ponds	10	16.6
Using water pans and sand dams' water.	16	26.6
The new techniques, approaches applied for combating water scarcity		
Water Pans	5	8.3
Considering new dams	24	40
Runoff terracing	15	33.3
Wells	11	18.3
The potential impacts of climate change on water resources in the society		
Decrease incomes from farmers	4	6.7
Decrease Incomes+ Health risks increased	24	40
Low infrastructure	14	23.3
conflict between water users	3	5.0
Decreased economic viability	15	25.0
Farmers anticipation of further changes in the near future		
Anticipated	53	88.3
Not anticipated	1	1.7
Don't know	6	10.0

Climate change events in semi-arid areas leads to long term droughts which make people suffer and spend a lot of energies and time as well as walk long distances to collect water during water scarcity and unavailability. In that regards, there is a positive correlation between the farmers coping strategies with challenges of the techniques as well as the source of farm information (Annex T5). According to UNFCCC (2002) in dry periods, the water resources, water supply and demand are greatly challenged by climate change and as a result women and children have to travel an average of approximately four kilometres to collect water for their livelihoods purposes.

Adoption of sand dam as the best alternative water harvesting technique could be due to the high water storage capacity and durability to combat water scarcity due to climate change effects. These technologies coupled with water saving techniques may supplement the other sources of water and help to secure future water scarcity. In that regard, rainwater harvesting systems can constitute great potential as alternative source of water UNFCCC (2002).

The farmer's anticipation of further change on water resources can be attributed to the nature of the area which is semi-arid and expected to be threatened by future climate change senarios. There was positive correlation between the anticipation of farmers about the further changes in the near future and the number of years that farmers had been experiencing water shortage (Annex T5). These findings are in line with those of SEI (2009) who demonstrated that Kenya was particularly sensitive to future changes in climate because a large part of the population lives in the highlands, arid and semi-arid lands (ASALs) where drought has already affected the supply and demand of water and vulnerable rains, increased temperature and led to sensitive diseases.

4.3.3 Expected changes from rainfall, floods, temperature and droughts

Table 4.12 shows the expected changes in rainfall, temperature patterns, majority of farmers (76.7%) noted that the drought had greatly increased. Whereas, (55%) of the farmers reported that the temperature had increased. Furthermore, (78.3%) of majority of farmers reported that there were no floods with 63.3% of farmers reporting that the amount of rainfall had reduced.

The majority (71.7%) of farmers stated that the period of decreasing rainfall amount was from 0 to 5 years with minority (1.9%) reporting from 10 to 20 years. Most farmers (78.3) noted that temperature levels would increase in 0 to 5 years. Only the droughts periods were from 5 to 10 years as reported by 51.7% of the farmers Table. About 35% of the farmers reported that deforestation contributed to reduce the amount of rainfall while 1.7% of farmers reported that air pollution reduced the amount of rainfall. Furthermore, 40% of the farmers reported that the reason of temperature increase was due to low rainfall with 28.3% alluding to deforestation. About, 40% of the farmers reported that deforestation was the reason of and course of droughts (Table 4.12).

Table 4.12: Expected changes in Rainfall, floods, temperature and droughts

	Rainfall	Floods	Temperature	Droughts
Increased	21.7	1.7	55.0	76.7
Reduced	63.3	0	30.0	13.3
Low rainfall	3.3	0	0	0
No ideas	11.7	20	15	10
No floods	0	78.3	0	0
Amount of rainfall, floods, temperature and droughts time scales				
0-5 years	71.7	0	78.3	48.3
5-10 years	26.4	1.7	16.7	51.7
10-20 years	1.9	0	5.0	0
Reason for timescales of rainfall, floods, temperature, and droughts				
Poor rainfall	5.0	0	40	6.7
Increased planting of trees	15.0	0	21.7	3.3
Fair rain	1.7	0	6.7	20.0
Deforestation	35.0	1.7	28.3	40.0
No mitigation done	20.0	0	3.3	3.3
Increase air pollution	1.7	0	0	0
No replanting	16.7	0	0	0
Drought	5.0	0	0	0
No idea	0	98.3	0	0
Increased temperature	0	0	0	8.3
Trees are being cutting	0	0	0	18.3

Climate change disasters can thus negatively affect water resources which are the most important for sustainable development in the semiarid areas throughout Kenya. Eugene (2009) demonstrated that increasing climate variability and climate changes have had a large impact on water resources availability and demand. Many water resources have been threatened by climate change events in Kenya SEI (2009).

4.3.4 The severe periods of water shortage

Table 4.13 reveals that majority of farmers (51.7%) reported that the months of July, August, September and October were the most severe months in water shortage. This situation force farmers to use less water leading to a reduction in agricultural production and the other purposes during these serve months.

Table 4.13: The severe months of the water shortage in this area

	Frequency	Percent
Aug+ Sep+ Oct	7	11.7
Jul+ Aug +Sept +Oct +Nov +Dec	2	3.3
Jul+ Aug +Sept +Oct	31	51.7
Jun +Jul +Aug +Sept	3	5.0
May +Jan +Jul +Aug +Sept	2	3.3
Jun+ Jul +Aug +Sept +Oct +Nov	8	13.3
Jun +Jul +Aug +Sept +Oct	6	10.0
May +Jun +Jul +Aug +Sept +Oct	1	1.7
Total	60	100.0

The farmers assertion is agree with the recorded rainfall during the period of study in 2010 and 2011,where there were no rains in June, July, and August in 2010 and 2011 with the months of October and September registering very little rainfall (1.2mm, 3.6 mm) respectively (Annex T6). Rainfall averages of April, May and June were found to be (8.3, 4.1 and 0) mm respectively in year of 2011. These findings are in agreement with those of World Bank (2009) who stated that the rainfalls is driven by the migration of the inter-tropical convergence zone and occurs in two distinct wet periods, the short rains (October to December) and the long rains (March to May) in the arid and semi-arid lands of Kenya. During these seasons the rainfall received is generally 50 - 200 mm per month, exceeding 300 mm in some locations. The onset, duration and intensity vary considerably each year World Bank (2009).

5.0 CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATION

5.2 Conclusions

This study has dealt with rainwater harvesting and its impact on rural communities in arid-semiarid regions of Yatta, a region of water scarcity in Kenya.

The results of descriptive studies show that roof tanks and sand dams were practiced by the most of the communities in this area. However, rooftop tanks were considered to be ranked as moderate preferred techniques. Only sand dam techniques were ranked as high preferred technique by most of the farmers while the borehole as well as shallow wells was ranked as the lowest techniques in terms of their preferences to the communities.

The harvested water from sand dams' were greatly used for domestic, livestock, and crop production respectively in terms its distribution. Moreover, water from roof catchment was used for three purposes; domestic use, livestock, and crop production. Runoff terracing and boreholes water, were used for crop production as well as livestock activities.

The reason of adopting roof tanks was the provision of relatively clean water and easily accessible. While the reason of applying sand dams was the large storage of water. Terraces applied by few farmers to collect water from runoff and they have considered it as easy access.

Education level did not exceed primary school. Majority of farmers were aware of the water harvesting techniques that exist within their local context. Majority of farmers had experienced water shortage.

People who are aged between 50-60 years prefer to use roof water tanks, sand dams and water pans.

Most farmers reported getting information about RWHT from Extension Officers followed by Radio Programmes. Organizations of NGOs, RELMA, IFAD, and MCDF promoted a numbers of techniques such as sand dams, roof tanks, wells and boreholes. Techniques that promoted by NGOs and RELMA were most adopted and received well by the communities.

Knowledge and skills affected adoption of water harvesting techniques. Majority of farmers confirmed that conflicts occurred among water users.

Education level, experience of water shortage, farm size, awareness of RWHT, farming as source of income, and age of farmers have affected adoption of RWHT. Education level has the highest positive influence on adoption of RWHT. Experience of water shortage was the second effect on the adoption of the techniques. Thirdly were farm size and lastly the awareness of water harvesting techniques. The lowest influence was age of farmers that had positive effect on adoption of the techniques followed by farming as source of income that was significant and negatively related to adoption of water harvesting techniques.

Majority of farmers have observed that the water resources have increasingly changed by effect of climate change.

Due to effect of climate change, prolonged droughts events during the years of 1980's were the most factor affected their region. During water unavailability, 33.3% of farmers walked long distances to collect or buy water, whereas 26.6% of farmers were coping by using water from pans as well as sand dams during dry seasons.

Most of farmers considered sand dams to be vital techniques to combat water scarcity while the minority of farmers indicated that pans to be as new techniques to combat water scarcity due to effect of climate change.

Due to the impacts of climate change, the income levels decreased and health risks increased. In addition, majority of the farmers have anticipated further changes on water resources in the near future.

Months of July, August, September and October were the most severe months in water shortage due to effect of climate change and variability.

5.3 Recommendations

Provide more simple materials either at lower cost in the market or on long-term credit basis for those who have not applied the of roof water tanks.

Construction of more sand dams closed to the community to minimize wasting time and energy.

The borehole technique and shallow wells ranked as lowest techniques in terms of preferences because it requires engineering skills to cite them. Farmers have to be trained to adopt such techniques as well as the provision of engineering skills and funds are required.

Ministry of agricultural Extension should add more Extension staff to provide the necessary information.

Relevant agencies should put more emphases on education and awareness creation to increase the adoption of reliable water harvesting technique.

There is an urgent need for government and organizations to come in to hold the community big sizes of land to increase the dependence on their farm incomes as well as increase adoption of the techniques.

There is a need to build future climate change risk screening into development and planning, at sectoral, regional and local levels.

Information on climate, resources and adaptation strategies and options should be mainstreamed into all sectoral plans in this area.

Additional research need to be established to improve the effective traditional techniques and integrate them with the modern techniques that will help farmers and livestock keepers cope with the impact of climate change and climate variability in different ecosystems in Yatta district.

The research on climate and water cycle should also be further enhanced in Yatta district.

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Appendixes

Appendix 1: Tables and figures

(Annex T1) Quantity of water from the various water harvesting techniques and the averages of family for their needs to supply all their household needs

	Sand Dams Average	Cv %	Roof top tanks Average	Cv %	Runoff terracing Average	Cv %	Boreholes Average	Cv%
Domestic use	57.2826	43	85.8333	23	0	0	62.3529	49
Livestock use	51.0000	37	46.6667	61	83.6842	30	59.0000	25
Crop	35.0000	46	41.2500	65	86.1905	26	93.7500	19

(Annex T2) the highest education level of male and female

	Percent (Male)	Percent (Female)
Never went to school	0	14.3
Lower primary school	66.7	10.7
Upper primary school	33.3	46.4
Secondary school	0	25.0
Certificate	0	3.6
Total	100.0	100.0

(Annex T3) farmer's perception about experience water shortage

	Frequency	Percent
Experienced water shortage	36	60
Not experienced water shortage	24	40
Total	60	100.0

(Annex T4): factors affecting adoption of water harvesting techniques

Factors	Frequency	Percent
Lack of technical knowledge and skills	28	46.7
lack of funds+ land tenure	7	11.7
lack of funds+ technical knowledge	7	11.7
lack of funds+ topography + climate change	3	5.0
High costs + Soil types	15	25
Total	60	100.0

(Annex T5): Correlation

		information to your farm	Experienced water shortage	NOFYRs	awareness of water harvesting techniques	coping with the challenges	conflicts among farmers	observed changes on water resource	Anticipation of further changes in the near future
information to your farm	Pearson Correlation	1	-.029	.059	-.103	.258*	-.092	-.153	.051
	Sig. (2-tailed)		.824	.653	.435	.046	.486	.244	.701
	N	60	60	60	60	60	60	60	60
experienced water shortage	Pearson Correlation	-.029	1	-.407**	.138	-.118	.066	.227	-.067
	Sig. (2-tailed)	.824		.001	.293	.371	.616	.081	.610
	N	60	60	60	60	60	60	60	60
NOFYRs	Pearson Correlation	.059	-.407**	1	-.611**	.096	-.091	.106	.382**
	Sig. (2-tailed)	.653	.001		.000	.465	.492	.421	.003
	N	60	60	60	60	60	60	60	60
awareness of water harvesting techniques	Pearson Correlation	-.103	.138	-.611**	1	-.107	.073	-.220	-.088
	Sig. (2-tailed)	.435	.293	.000		.415	.580	.092	.504
	N	60	60	60	60	60	60	60	60
coping with the challenges	Pearson Correlation	.258*	-.118	.096	-.107	1	.089	-.053	-.150
	Sig. (2-tailed)	.046	.371	.465	.415		.497	.685	.253
	N	60	60	60	60	60	60	60	60
conflicts among farmers	Pearson Correlation	-.092	.066	-.091	.073	.089	1	.290*	-.130
	Sig. (2-tailed)	.486	.616	.492	.580	.497		.024	.322
	N	60	60	60	60	60	60	60	60
observed changes on water resource	Pearson Correlation	-.153	.227	.106	-.220	-.053	.290*	1	-.066
	Sig. (2-tailed)	.244	.081	.421	.092	.685	.024		.615
	N	60	60	60	60	60	60	60	60
Anticipation of further changes in the near future	Pearson Correlation	.051	-.067	.382**	-.088	-.150	-.130	-.066	1
	Sig. (2-tailed)	.701	.610	.003	.504	.253	.322	.615	
	N	60	60	60	60	60	60	60	60

(Annex T6): Explanation of rainfall data for 2010-2011

	MAX TEMP (0C)	MIN TEMP (0C)	RAIN (mm)	AVER TEMP (0C)
January	**30.0**	19.0	11.8	24.5
February	**31.2**	19.5	127	25.3
March	29.5	19.3	**157.1**	24.4
April	29.7	19.1	63.6	24.4
May	29.9	18.0	13.5	24.0
June	28.6	16.5	**0**	22.5
July	28.0	**14.4**	**0**	21.2
August	27.7	**14.7**	**0**	21.2
September	28.8	15.3	**1.2**	**22.1**
October	**31.0**	17.5	**3.6**	24.2
November	29.2	18.4	**109**	23.8
December	**34.1**	**21.4**	52.8	**27.7**
January	**31.2**	17.7	13.5	24.5
February	30.8	17.7	49.8	24.3
March	31.9	18.7	**104.2**	25.3
April	31.3	19.0	8.3	25.1
May	30.7	17.8	4.1	24.3
June	30.9	17.2	0	24.1

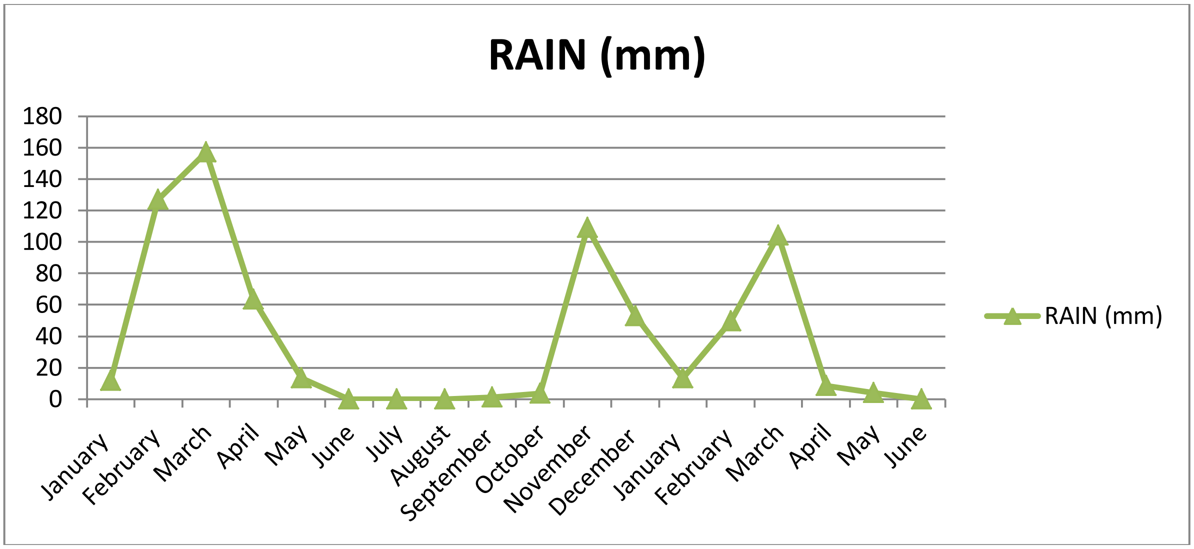
(AnnexT7): Means and Std. deviation of farmers' age and income KSHs per annum from farm

	Mean	Std. Deviation
Age of farmer	51.7833	14.71318
Income (Kshs) per annum from farming	4.3833	1.09066

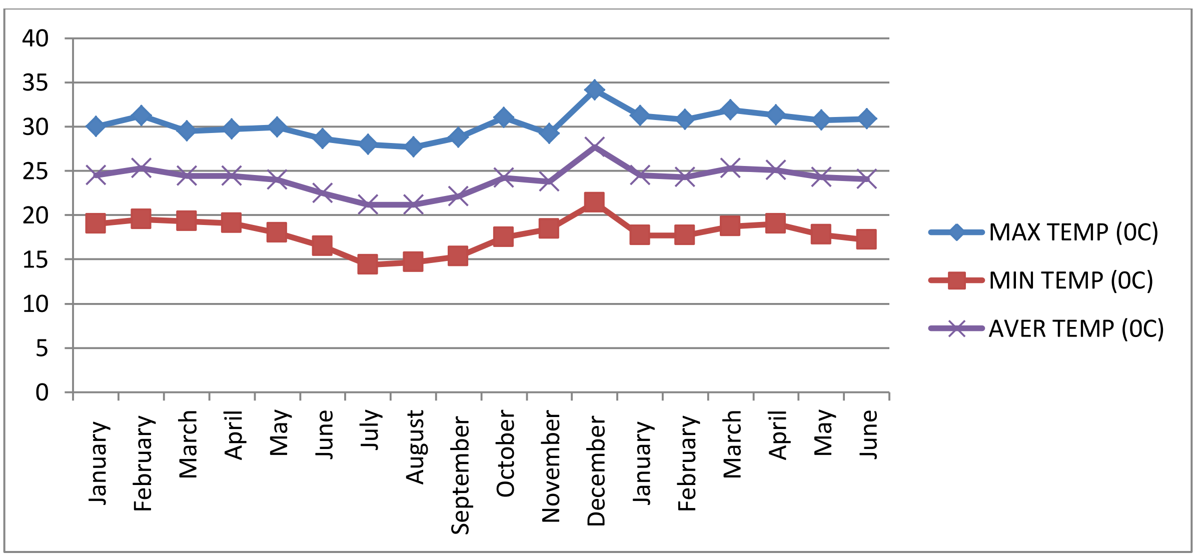
(Annex T8): Source of income from farm

	Frequency	Percent
From farm	35	58.3
Not from farm	25	41.7
Total	60	100.0

(Annex Figure1): Shows the rain level of two seasons (2010, 2011)



(Annex Figure2): Shows the averages of temperature for the two seasons (2010, 2011)



Appendix2: The Questionnaires

Section A: basic information's

Location ………………………………

Age …………………………………….

Sex; Male [ ] Female [ ]

How many household members? ....

What is the highest education level completed? (Parents F [ ] M [ ] children [ ]

	F	M	C		F	M	C
a) Never went to school [ ]				e)Certificate[ ]			
b)Lower primary school[ ]				f)Polytechnic[ ]			
c)Upper primary school[ ]				g)Diploma[ ]			
d)Secondary school[ ]				h)University[ ]			
i) Others (specify)………							

What is the size of your farm (specify units)? ....

What proportion of your farm is used for:

Crop production ……………. (iii) Livestock production………………………….

Homestead………………….. (iv) others (specify)………………………………….

Where do you get information to assist in the management of your farm?

(i) Radio [ ] (ii) Newspapers [ ] (iii) Friends [ ] (iv) Extension Officers [ ]

(v) Internet [ ] (vi) Television [ ] (vii) Others (Specify)………………….

Is farming your main source of income?

Yes [ ] (b) No [ ]

If No (in 9 above), what are your other sources of income?

(i) Business [ ] (ii) Remittance from family members [ ]

(iii)Pension/retirement benefits [ ] (iv) Others (Specify)…………………...

What is your income (Kshs) per annum?

From farming:

[0-500]   b)[500-2000]   c)[2000-4000] d)[4000-10000]

e) [Over 10000]   f) others (specify)…………….

From other sources

[0-500]   b)[500-2000]   c)[2000-4000] d)[4000-10000]

e) [Over 10000]   f) others (specify)…………….

SECTION B: Water harvesting

(a) What are the sources of water in your area?

Rivers ( )   rainwater ( )   earth dams ( )   wells ( ) boreholes ( )

Runoff ( ) others (specify)……………

(b) How far is the nearest community watering point from your homestead?

(c) What means do you or other community members use to access water from the community watering point?

Oxen drawn carts [ ], pickups [ ], Lorries [ ], household labour [ ], others (specify) [ ]

2. (a) Have you ever experienced water shortage

Yes [ ]   NO [ ]

(b) If the answer to question 2 (a) above is yes, *when and for how long* did you experience the water shortage

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(c) Which month(s) of the year is water shortage usually severe in this area (please tick the month or months reported)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dev

3. How do you cope with periods of water shortage? Please explain with respect to water for domestic use, livestock needs and Agricultural activities

4. What, in your opinion, is the cause of water scarcity in your area?

5 (a) Are you aware of any water harvesting techniques? Yes ( ) No ( )

(b) If the answer to 5(a) above is yes, which water harvesting techniques are you aware of?

Water dams [ ], Water tanks [ ], roof water harvesting [ ], earth dams [ ],

Runoff water harvesting [ ], others (Please specify) [ ],

(c) Of the techniques mentioned in 5 (b) above, which one are you practicing on your farm and why?

Technique	Why practiced

(d) (i) Is the water harvested enough for your household need? Yes ( ) No ( )

(ii) If the water harvested is not enough, what amount do you need in order to sufficiently meet your household needs ……………………………………….

(iii) Is the water harvested clean enough for drinking? Yes ( ) No ( )

(iv) If No, what kind of treatment do you use to improve water to be cleaned for drinking?

6 (a). Briefly describe the identified water harvesting techniques in question 5(b) above in terms of their viability and/or durability, resource requirements, order of preference and ability to store enough water during critical periods

Techniques	Viability/durability	Resources required "Labour, cost" (1. Low 2. Moderate 3. high)	Ranks the techniques in order of preference on a scale of 1 (lowest) to 5 (highest)	Is the water harvested sufficient for use during critical periods? Yes (1) or No (2)
Water dams				
Water tanks				
roof water harvesting				
earth dams				
runoff water harvesting				
other (specify)				

(b) What quantity of water (*estimate using 20 litter containers*), from the various water harvesting techniques, could an average family of 4 need to supply all their household needs including livestock*?*

Techniques	Quantity of water stored	Quantity used in (20 litters containers)			
		Domestic	Livestock	Farming	Other specify (…..)
Water dams					
Water tanks					
roof water harvesting					
earth dams					
runoff water harvesting					
other (specify)					

(c) What is the harvested water, using the various water harvesting techniques, used for and in what proportions?

Techniques	Purpose	Proportion (5)	Remakes
Water dams			
Water tanks			
roof water harvesting			
earth dams			
runoff water harvesting			
other (specify)			

(d) At what stage is the water harvesting technique and what are the challenges in its implementation?

Techniques	Stage of technique (1 = Pipeline; 2= Uptake, 3 = adopted	Challenges/ Constraints	How are you addressing/coping with the challenge
Water dams			
Water tanks			
roof water			
earth dams			
runoff			
other (specify)			

7. In general, what are the factors influencing and/or affecting adoption of water harvesting techniques among households in this region

____

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____

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8. Where do you get information regarding the various water harvesting techniques?

Radio [ ] Newspaper [ ] Friends [ ] Extension Officers [ ] Internet [ ] Television [ ] Others (Specify) …………………….

9(a). Are there organizations/institutions helping your community in the setting up of water harvesting techniques? Yes [] No [] Have no idea [ ]

(b) If the answer to question 9 (a) is yes, name the organizations and the water harvesting techniques being promoted

Organization/Institution	Water harvesting technique being promoted	How received by the community

10 (a). Are there any conflicts among farmers on water use?

Yes………………….. No……………………Can't tell …………………

(b) If yes specify the nature of the conflicts?

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SECTION C: Climate Change

1(a). Have you observed any changes on the water resource (e.g. rivers, streams, dams, wells, boreholes) in the past 10 to 15 years?

Yes [ ]   No [ ]

If yes what changes have you observed? …………………………………………………

Increase []   Decrease [ ]   No change []   can't tell [ ] complete drying []

(c)What do you attribute the changes mentioned in 5b above to?

Climate change [], water abstraction [] lowering of the water table [],

Human activities [], others (please specify)

(d) If, among the answers to question 1c above is climate change, when did you start realizing the effects of climate change on the water resources and in what form does it (climate change) manifest (i.e. drought, flooding, increased temperatures etc) itself?

2. How are you coping with the water unavailability and/or insufficient water due to the effects of climate change?

3. What new techniques, approaches, measures or methods have you or the community put in place to combat water scarcity/unavailability arising from the effects of climate change.

What are the potential impacts of climate change on water resources in society (e.g. economic indicators, decreasing economic viability of an activity, conflicts between water users, damage to property/infrastructure, damage to health and loss of life).

4. Do you anticipate further change in climate in the near future?

Yes [ ] b) No [ ]

5. If the answer to 4 above is yes, what aspect of climate change do you anticipate to notice profound changes on, expected timescale and why?

Aspect/Change	Explain the change expected and why	Time scale 1)0-5yrs 2)5-10yrs 3)10-20yrs 4)over 30yrs	Reason for timescale
Rainfall			
Floods			
Temperatures			
Prolonged droughts			
Others (specify) ………………..			

6. Which of the practices listed below are used in your locality in response to climate change?

Strategy	Approximate % of farmers using
Agro forestry [ ]	
Drought tolerant crops [ ]	
Rain water harvesting [ ]	
Irrigation [ ]	
Soil and water conservation [ ]	
Application of fertilizers and organic inputs [ ]	
Planning appropriate crop varieties [ ]	
Use of different cropping systems [ ]	
Others (specify)……………………..	