INFLUENCE OF AGRICULTURAL WATER TECHNOLOGIES ON FARM INCOME OF SMALLHOLDER FARMERS IN LARE DIVISION NAKURU COUNTY, KENYA

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A Thesis Submitted to Graduate School in Partial Fulfillment of the Requirements for the Award of Degree of Master of Science Degree Community Studies and Extension of Egerton University

EGERTON UNIVERSITY

SEPTEMBER, 2015

DECLARATION AND RECOMMENDATION

DECLARATION

This research proposal is my original work and has not been presented in any university or any other institution of learning for any awards.

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RECOMMENDATION

This proposal has been submitted with our approval as the University Supervisors:

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DEDICATION

This thesis is dedicated to my beloved parents: Boithi and Cheptoo, my wife Wambui and our children: Waruguru, Mureithi and Njambi: the fountain of my inspiration.

ACKNOWLEDGEMENTS

To Almighty, the invisible God, thank you for granting me the grace and forbearance to complete the work. My thanks go to Egerton University for giving me an opportunity to study at the institution. My special thanks go to my supervisors, Dr. Milcah Mulu-Mutuku and Prof. Rodah Birech for their guidance, patience and valuable input throughout the research period. My heartfelt appreciation goes to WATERCAP Project team: Prof. Bebe, Prof. Ogendo, Dr. Ocholla, and Eng. Muchiri, and Egerton University Research Division. Thanks to the Austrian Development Cooperation for funding this study through Austrian Partnership Programme in Higher Education & Research for Development Project. Special thanks to my family for their moral support. To Dr. Lydia Kinuthia and James Gikaba, thank you for technical support. To all whom I may not be able to thank individually including the respondents, am sincerely grateful for your contributions.

ABSTRACT

Rainfall variability affects agricultural output which in turn affects farmers' farm income. Some smallholders farmers in Lare Division have been using agricultural water technologies namely water harvesting, water storage and irrigation in order to boost their farm income. However, it is not clear whether the agricultural water technologies have influenced farm income of smallholder farmers in the Division as scant literature exists. This study sought to investigate the influence of water technologies on smallholder farmers' farm income. *Ex-post facto* correlation research design was used. From a target population of 3,605 households, 114 users of agricultural water technologies were first purposely and then randomly selected for the study. A researcher administered questionnaire was used for data collection. The data collecting tool was pilot tested on 30 farmers in Elementaita Division and yielded Cronbach's alpha reliability coefficient of $\alpha = 0.825$. Statistical Package for Social Science's (SPSS) was used to analyze data. Frequencies, percentages, means and standard deviations of descriptive statistics were used to describe the farmers' demographic characteristics. Multiple regression analysis was used to determine the influence of agricultural water technologies on smallholder farm income. Agricultural water harvesting and storage technologies were found to have statistically significant influence on farm income $p = 0.002$, $R^2 = 0.739$ and $p = 0.030$, $R^2 = 0.595$ respectively, but irrigation technology had statistically insignificant influence on farm income. Inadequate capacities of water storage structures, water loss and insecurity posed by water pans were constraints in use of water storage technologies. Small holder farmers in Lare require empowerment in terms of general education, involvement in farmers' groups, use of water table recharging technology and use of efficient irrigation methods. The farmers also need sensitation on use of water use efficient irrigation methods. Study findings will inform researchers, extension service providers, policy makers and development agencies when designing interventions meant to boost smallholder farmers' water technologies usage hence their farm income.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AfDB	Africa Development Bank
DAO	District Agricultural Officer
EAC	East Africa Community
FAO	Food and Agriculture Organization
GoK	Government of Kenya
HDR	Human Development Report
HCDA	Horticultural Crop Development Authority
IGAD	Intergovernmental Authority on Development
IFPRI	International Food Policy Research Institute
ICID	International Commission on Irrigation and Drainage
ICRAF	International Centre for Research in Agro-forestry
IPCC	Intergovernmental Panel on Climate Change
IWHP	Integrated Water Harvesting Project
KARLO	Kenya Agricultural and Livestock Research Organization
KRHA	Kenya Rainwater Harvesting association
LDCs	Less Developed Countries
MDGs	Millennium Development Goals
MoA	Ministry of Agriculture
NACOSTI	National Commission for Science, Technology and Innovation
NDFF	Njoro District Fact File
SRA	Strategic Research Agenda

SPSS	Statistical Packages for Social Sciences
SSA	Sub-Sahara Africa
UNDP	United Nation Development Program
UNEP	United Nation Environmental Program
UN	United Nation
WB	World Bank
WRI	World Research Institute
WWDR	World Water Day Report
MDGs	Millennium Development Goals

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Rural smallholder farmers mainly depend on income from their farms to cater for households members' needs such as food, clothing, shelter, education and health care among others (Manda, Kimenyi & Mwabu, 2001). Dixon, Tanyeri and Watenbach (2003) define smallholder farmers as those that cultivate less than 2 acres of land in high potential areas which may increase to 44 acres or more in sparsely populated marginal areas. In Asia and sub-Saharan Africa, smallholder farmers produce up to 80% of the food consumed and support up to two billion people (IFAD, 2010). Of the two-thirds of sub-Saharan Africa's population that reside in the rural areas, the majority are smallholder farmers and are among the most disadvantaged and vulnerable as they live in absolute poverty on small farms in rural areas (IFPRI, 2012). Smallholder farmers are faced with several constraints that include land tenure access rights, land management; credit access; access to input and output markets; infrastructure; extension services; institutional problems and more recently climate change among others (FAO, 2010).

Despite their precarious state, smallholder farmers have a key role to play as they are relied upon by most governments of Less Developed Countries (LDCs), to produce food not only for their households, but also for their respective regions and countries (Rauch, 2009). Kenyan, smallholder farmers are regarded as major players in the agricultural sector as they produce, over 75% of agricultural output (Adeleke, Kamara & Zuzana , 2010). They are therefore involved in achieving food security, poverty-reduction and agricultural driven rural development.

Although rain-fed farming predominates, rainfall in many of the drier regions of Africa is erratic and unreliable. Rainy seasons are short and there are often long gaps between rainfall events (AfDB, FAO, IFAD and IWMI, 2007). As a strategy to obtain enhanced steady farm income, smallholder farmers in Africa need to focus more on agricultural water technologies. Case studies done in Zimbabwe, Tanzania and Niger by Ibraimo and Munguambe (2007) showed increased and sustained agricultural yields upon usage of agricultural water technologies resulting in better farm incomes of the rural smallholder farmers.

Agricultural water technologies of interest to this study are water harvesting, water storage and irrigation. They are ancient technologies and still form an integral part of many farming systems worldwide. They were first used over 5000 years ago in Iraq's Fertile Crescent (FAO, 2000). A study carried out in Israel by Zaide (2011) noted that the usage of agricultural water technologies during the 1990s was an important community development step taken by Israel farmers. Due to extended drought in the years 1990-91, the price of water apportioned to agriculture was increased by 47% and the supply reduced by more than 50% to deal with this water shortage. However by using water-saving agricultural water technologies like rain harvesting, storage and irrigation technologies, Israel farmers' farm income was remarkably enhanced. In Africa, rainfall scarcity has led to increased incidences of extreme droughts and reduced agricultural production resulting in reduced food security at household, regional and national levels (IPCC, 2007). In Mpumalanga Province South Africa, rainfall allows for one rain fed cropping season per year only. This prompted local farmers to use agricultural water technologies aiming at improving their farm based income. According to (WHP, 2009), evaluation done on impact of using these agricultural water technologies, to supplement natural rain, revealed increased farm incomes of farmers practicing them.

Water scarcity is one of the rural developmental challenges facing Kenya (WB, 2012). This is because close to 80% of Kenya's population is rural based and resource constrained smallholder farmers. This therefore makes the country highly vulnerable to rainfall variability since 98% of the country's agriculture is rain-fed (Mutai, 2011; UNEP, 2009). The water scarcity problem in Kenya has also been exacerbated by high population leading to high water demand, vulnerability of water resources, human encroachment of marginal areas and decreased rainfall amount and frequency of occurrence due to climate change (UNDP, 2009). Therefore, agricultural water technologies that would improve smallholder farmers' accessibility and efficient usage of the scarcely available water should be fronted. This will lead to high volumes of farm agricultural production resulting in improved communities' food security and enhanced farm incomes.

According to Kenya Rainwater Association (2011), rainwater harvesting potential in Kenya is estimated at over 12,300m^3 per person per year compared to the current rain water availability of just over 600m^3 per person per year. This indicates a significant water availability gap hence water harvesting technologies can be used as a strategy to make more water available particularly for smallholder farmers in marginal areas. Therefore, there is need to focus more on agricultural water technologies such as water harvesting, storage and irrigation in maginal areas such as Lare Division. This will boost food security and reduce poverty of the smallholder farmers hence enhance rural development.

Agricultural water can be harvested using two methods such as surface runoff harvesting and roof top rainwater harvesting (Zhu, 2004). Harvested water can be stored *in situ* or away from the point of harvesting. Water storage systems can be cisterns or ponds. In the former, water is stored in underground or above ground tanks while in the latter, water is stored in dams, pans and trenches. Where soil type permits, pan system can be cost-effective, as has been demonstrated by the farmers of Lare Division Nakuru County, (Tuitoek, Owido, China & Wanjama, 2001).

Lare Division is a water scarce area with only one permanent river Bagaria. The area receives a medium bimodal unreliable rainfall, averaging about 600 - 1000 mm per annum. The long rains fall between March and July while the short rains fall between October and November. This area experiences cyclic droughts every 3-5 years. This scenario has resulted in some smallholder farmers' adopting agricultural water technologies (ICRAF, 1997). However, whether agricultural water technologies have influenced the smallholder farmers' farm income is not documented. In Kenya, incidence of poverty is a major challenge facing rural farming communities especially smallholder farmers settled in marginal areas. According to Manda, *et al*, (2001), the situation is widespread and continues to afflict larger segments of rural population. According to Mati, Maibo and Oduor (2004), Lare Division smallholder farmers were generally poor. There were high food insecurity and low farm income. According to national census, 47.6% of population in Lare Division was below the poverty line higher than the national average of 46% (GoK, 2009). Smallholder farmers in Lare Division practice subsistence farming from which they derive their households' food and farm based economic returns as resources from non- agricultural activities are minimal. In such a scenario, could agricultural water technologies be fronted as an approach to reducing poverty of the smallholder farmers? This strategy is fronted because; agricultural water technologies would enable the farmers to engage their farms all year round, sell food surplus, increase income, improve livelihood and reduce poverty. Therefore, this study investigated the influence of water technologies on farm income of smallholder farmers in Lare Division.

1.2 Statement of the Problem

Rain water scarcity has resulted in low or failed farm yields. This has shown that dependence on rain-fed farming alone is detrimental to food security and farmers' farm income. This is more critical to smallholder farmers in marginal areas. Lare Division is a marginal area and is inhabited by smallholder farmers who are poor, have low education, limited skills and resources endowment. They also have limited resilience capacity to mitigate effects of climate change induced water scarcity and vulnerability. These farmers depend majorly on their small farms for household foodstuffs and income. 1.7% of population in Lare Division living below poverty line is above the national average. Under such situation, could agricultural water technologies be fronted as one approach to reducing poverty engulfing smallholder farmers of this division, through increased farm income? This study therefore endeavored to investigate whether water technologies namely, agricultural water harvesting, storage and storage has influence on farm income of smallholder farmers in Lare Division.

1.3 Purpose of the Study

The purpose of the study was to investigate the influence of water technologies on farm income of smallholder farmers in Lare Division, Nakuru County, Kenya.

1.4 Objectives of the Study

The specific objectives of the study were to:

i. Find out the main sources of smallholder farmer households' income in Lare Division.

ii. Establish the influence of agricultural water harvesting technology on smallholder farmers' farm income in Lare Division.

iii. Establish the influence of agricultural water storage technology on smallholder farmers' farm income in Lare Division.

iv. Determine the influence of irrigation technologies on smallholder farmers' farm income in Lare Division.

1.5 Research Hypotheses

$H_{O1:}$ There is no statistically significant influence of agricultural water harvesting technologies on the farmers' farm income in Lare Division.

$H_{O2:}$ There is no statistically significant influence of water storage technologies on the farmers' farm income in Lare Division.

$H_{O3:}$ There is no statistically significant influence of irrigation technologies on the farmers' farm income in Lare Division.

1.6 Significance of the Study

The findings of this study may enlighten smallholder farmers on the influence of agricultural water technologies on households' farm income. Stakeholders in water and agricultural sectors may find this study useful in understanding farmers' challenges relating to use of agricultural water technologies, hence formulate suitable intervention entry points. Policy makers for example the Ministry of Agriculture (MoA) and Horticultural Crop Development Authority (HCDA) may find the results useful when enacting policies relating to water technologies usage. The findings will also contribute to the existing body of knowledge relating to use of agricultural water technologies for farming in water constrained areas.

1.7 Scope of the Study

The study investigated smallholder farmers who have been using water technologies for farming in Lare Division. It focused on agricultural water technologies namely, water harvesting, water storage and irrigation. The study investigated the influence of using the water technologies on smallholder farmers' farm income.

1.8 Limitation of the Study

Some respondents may not have recalled all information accurately. There was language barrier among some respondents. Questions were repeated and translated into vernacular for respondents to comprehend.

1.9 Assumptions of the Study

Every farmer used at least one of the three water technologies under the study. There were observable changes in farm income. Lare Division remained peaceful hence accessible during the entire period of the study.

1.10 Definition of Terms

Farm Income: According in this study, this refers to money obtained from sales of yields produced in a farm in a given farming season. This was quantified in terms of Kenya shillings.

Farmer's Socio-economic Status: According to Mahmudul (2010), this refers to a farmer's characteristics such as education, gender, access to credit, information and technology among others. In this study this refers to a farmer's age, gender of household head, education level and family size.

Influence: Oxford Dictionary (2011) defines influence as how something has an effect on a situation or on the outcome of certain action. In this study, the term influence refers to the effect of agricultural water technologies on smallholder farmers' farm income.

Smallholder Farmers: Smallholder farmers are those that cultivate less than two acres of land in high potential areas, which may increase to 44 acres or more in sparsely populated areas. They produce crops mainly for family consumption (Dixon, *et al.,* 2003). In this study, smallholder farmers will refer to those farmers owning or leasing pieces of land which is less than five acres and growing crops, keeping livestock or both.

Water Harvesting: This is the process of collecting rainwater from rooftops and land surfaces (Zhu, 2004). In this study, this term refers to collecting water from rooftops, compacted and non-compacted surfaces and river abstraction for agricultural application.

Water Storage: This is storage of rainwater from roof and surface catchments using components such as cisterns and pans (Mati, *et al.,* 2005). This study adopts this definition and expands it to include ground water recharging by directing surface runoff to trenches and farms.

Water Technologies: According to Sundaravadivel (2007), these include all technologies relating to agricultural water uses. In this study, it refers to agricultural water harvesting, storage and irrigation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter reviewed literature include, common characteristics of smallholder farmers role of smallholder farmers in food security and poverty reduction, constraints faced by smallholder farmers in farming, farm income of smallholder farmers, smallholder farmers' and agricultural water technologies, characteristics of smallholder farmers and adoption of technologies, characteristics of technologies and their adoptability by smallholder farmers, various agricultural water technologies, agricultural water harvesting technology and farm income, types of agricultural water storage technologies, agricultural water irrigation technologies and farm income. Theoretical and conceptual frameworks that guide this study conclude the chapter.

2 .2 Common Characteristics of Smallholder Farmers

There are several ways in which smallholder farmers have been defined, but criterion of plot size is widely used. According to Dixon, Tanyeri and Watenbach (2003) smallholder farmers are those that cultivate less than two acres of land in high potential areas which may increase to 44 acres or more in sparsely populated marginal areas. Common characteristics of smallholder farmers include; having only small piece of land to farm (one hectare or less) and few other assets; who lack access to high-quality inputs, credit, services and equipment; who may be cut off from markets due to geographic isolation, poor infrastructure, lack of information or a combination of these; whose rights to land and other resources may be weak; and who have not, as yet, managed to access markets in a way which can increase their productivity and lift them out of poverty (FAO 2010).

Rural smallholder farmers especially those living in water constrained regions are resource constrained. They mainly depend on income from their farms to cater for households members' needs such as food, clothing, shelter, education and health care among others (Manda, *et al.*, 2001). Since these farmers are resources constrained and are dependant on farm incomes, they have low resilience capacity to mitigate negative impact of climate change such reduced or failed farm yields (Parry, Rosenzweig & Livermore, 2005). This situation befalls smallholder farmers in Lare Division. As stated by Mati, *et al.*, (2004), smallholder farmers had generally low farm income before introduction of agricultural water technologies in Lare Division. However, scant literature exists on whether agricultural water technologies has influenced their farm income.

2.2.1 Role of Smallholder Farmers in Food Security and Poverty Reduction

There are an estimated 500 million smallholder farmers in the world. In Asia and sub-Saharan Africa, smallholder farmers produce up to 80% of the food consumed and support up to two billion people (IFAD 2010). Of the two-thirds of sub-Saharan Africa's population that reside in the rural areas, the majority are smallholder farmers (Dixon, *et al.*, 2003). In the developing world, they are among the most disadvantaged and vulnerable as they live in absolute poverty on small farms in rural areas (IFPRI, 2012). Despite their precarious state smallholder farmers have key roles to play. This is because the farmers are relied upon by most LDCs governments to produce food not only for their households, but also for their respective regions and countries (Rauch, 2009). In the Africa continent, food security and poverty are linked (AfDB, FAO, IFAD, IWMI & WB, 2007). Therefore, Africa's smallholder farmers' empowerment in agricultural water technologies could have significant impact on food production, food security and poverty. This is because agriculture has a great impact on poverty reduction due to its strong linkages back to rural economies in LDCs (FAO, 2012). In Rwanda and Kenya, the poverty-reducing impact of agricultural growth has recently been found to be as much as three to four times greater than growth generated in other sectors (IFPRI, 2012). In Kenya, smallholder farmers are regarded as major players in agricultural sector as they produce over 75 percent of agricultural output (Adeleke, *et al*., 2010).They are also drivers in achieving food security, poverty-reduction and agricultural driven rural development. Similarly, smallholder farmers are expected to use agriculture not only to achieve food and economic security, but also as a driver of development in the rural Lare Division. Therefore, there is need to focus more on agricultural water technologies such as water harvesting, storage and irrigation in marginal areas such as Lare Division. This will boost food security and reduce poverty of the smallholders hence enhance rural development.

2.2.2 Farming Constraints Faced by Smallholder Farmers

Agriculture is central to food security as it provides the main source of livelihood for three out of four of the world's poor (Wheeler & Kay, 2011). However, smallholders farmers, especially in marginal areas in LDCs are faced by myriads of constraints. According to (Adeleke, *et al*., 2010), East African smallholders have faced several constraints, including land tenure, access rights, and land management; credit access; access to input and output markets; infrastructure; extension services; institutional problems; climate change and food security; and more recently the global financial, food, and fuel price crises. For instance, unclear land access rights have led to insecurity, underinvestment, small plots, and a high degree of landlessness. Poor road and rail systems have limited market development. Research and extension services in Africa are “disintegrated” and “ineffective”. Smallholders face difficulties in accessing commercial credit due to their lack of collateral and credit history. They face limited access to input and output markets, and consequently value addition, competition and supplies.

A study by Bates, Wu & Palutik, (2008) indicated that climate change will negatively impact on water resources. This in turn will negatively impact on agricultural production and farm based income of smallholder farmers, particularly those in marginal areas which are already water-scarce. In Lare Division, water scarcity problem is compounded by recent destruction of Mau Forest, a crucial water catchment for this area (UNEP, 2009). Therefore, this study focused on whether agricultural water technologies could be a strategy in dealing with water scarcity constraints encountered by smallholder farmers in Lare Division.

2.3 Farm Income of Smallholder Farmers using Agricultural Water Technologies

According to Vyas and Kumaranayake (2006), income refers to the amount of money received during a period of time in exchange for goods, labour or services. In this study, farm income refers to money accrued from sales of farm yields. Studies in Alabama, USA by Hicks (2008) and in India by Kumar and Kumar (2008) indicated sustained farm incomes of farmers involved in use of agricultural water technologies. Although rain-fed farming predominates, rainfall in many of the drier regions of Africa is erratic and unreliable. Rainy seasons are short and there are often long gaps between rainfall events (AfDB, *et al.*, 2007). In order to obtain enhanced steady and sustainable farm income, smallholder farmers in Africa need to focus more on agricultural water technologies.

Case studies done in Zimbabwe, Tanzania and Niger by Ibraimo and Munguambe (2007) showed increased and sustained agricultural yields resulting in better farm incomes of the rural smallholder farmers involved in agricultural water technologies. In Kenya, majority of rural communities are smallholder farmers basically relying on their farm income. The standard of living in Kenya has been generally low with 46% of rural population living below the poverty line. In Lare Division, percentage of population living below poverty line is higher (47.6%) than the national 46% (GoK, 2009). Since they rely mainly on farming, the relationship between farm incomes of smallholder farmers in Lare Division that were involved in agricultural water technologies was investigated.

2.3.1 Smallholder Farmers' Characteristics and Adoption of Technologies

Smallholder farmers vary in their socio-economic characteristics such as age, gender, education, family size and involvement in farmers' groups among others (Kamien and Schwartz, 1982). Some of these socio-economic statuses facilitate while others impede adoption of technologies by smallholder farmers. Hatibu (2003) noted that farmers with higher levels of education were likely to adopt water harvesting technologies more than those of lower education level. A study done in Yatta in Kenya on water harvesting technology by Home and Gathenya (2012) found that low or no education curtailed the chances of smallholder farmers adopting water harvesting technologies. This is because education makes farmers more enlightened on issues pertaining to use of suitable technologies such as agricultural water technologies. Majority of smallholder farmers in Lare Division had low education level (Mati, *et al.*, 2004). In this regard, low education levels would mostly impede adoption of some of agricultural water technologies that would require some level of education and skills in usage. Low resources endowment would impede these farmers from affording technologies that are too costly to purchase and maintain.

On one hand, a farmer's family size may influence a farmer's use of agricultural water technologies. For instance, those farmers with large families are more likely to adopt technologies that would boost their farm income. This would enable them to cater for the needs of their large families. However, the same may impede adoption of the technologies. Farmers with large families may fear experimenting on new technologies that may result in production of insufficient food and farm income to cater for the large families. Farmers' involvement in farming groups may positively influence farmer use of agricultural water technologies. In a study carried out in India, by D' Silva, J.; Shaffril, H.; Uli, J. and Samah, B. (2009) found out that those smallholder farmers that were involved in farmers' groups had adopted irrigation technology twice as much as compared to their counterparts who had not.

2.4 Characteristics of Technologies and their Adoptability

Rogers (1995) identified some common characteristics of technologies as perceived by potential users. These characteristics can be applicable to agricultural water technologies. They include relative advantage of a particular technology over other technologies in performance of similar tasks or the extent to which a technology is perceived, by its users, as being better than the one it supercedes. Compatibility of technologies are the extent to which those technologies are perceived as being consistent with the existing knowledge, skills, and needs of potential users and also other existing technologies and activities. A technology's complexity is the degree to which it is perceived as difficult to understand and apply. Technology try ability is the degree to which a technology may be tried out in piece meal while its outcome is being monitored. Obseverbility is the level and the time it takes for the outcome of use of that technology is visible while affordability refers to initial and maintenance costs the technology user would incur in acquiring and using it. These characteristics may impede or encourage adoption of technologies. According to McCartney and Smakhtin (2010), the 'right' technology must enable users to innovate and adapt the technology to their specific circumstances. It must be simple to construct, reliable to use, easy to maintain, and consider gender specific needs. Therefore, characteristics of technologies such as complexity and affordability would mostly impede agricultural water technology adoption, while try-ability, compatibility and obseverbility would encourage technologies adoption. In Kenya, agricultural water harvesting technologies are affordable and easy to use making them easily adoptable (KRA, 2006).

2.4.1 Various Agricultural Water Technologies

Although water resources are already under stress in many parts of the world, there is increased demand for agricultural water in order to meet the additional requirements for food for growing population. Agricultural water scarcity is therefore one of the most pressing issues facing humanity today (WRI, 2003). For example, several regions such as North Africa, South Asia, and the drier regions of sub-Saharan Africa (SSA) are already facing acute agricultural water scarcity. However, there is adequate water but only if well used in agriculture which is the main water consumer (CA, 2007). According to International Commission on Irrigation and drainage (ICID, 2008), there are various agricultural water saving technologies practised by farmes in different parts of the world. Some of these include; irrigation system modernisation in South Africa for sugarcane farming, water saving rice irrigation in Spain, China, Pakistan, india and Brazil. All these agricultural water technologies had common effects in that, they resulted in lowered cost of agricultural water and increased farm productivity. This translated to increased farm incomes of farmers using these technologies. In this study, agricultural water technologies have been grouped into three main categories. Technologies that harness water such as water harvesting, technologies that conserve water making it available when required such as water storage and those technologies that make use of available water, such as irrigation technologies.

2.4.2 Agricultural Water Harvesting Technology and Farm Income

Agricultural water harvesting is an ancient practice and still forms an integral part of many farming systems worldwide. Water harvesting technology originated in Iraq over 5000 years ago, in the Fertile Crescent, FAO (2000). It is used in many farming communities in various regions all over the world where rainfall is inadequate for farming. For example, as a response to water scarcity and hardship faced by local farming community, the Indian Government empowered local farmers in adopting water harvesting technology. An evaluative study, carried out later, on impact of water harvesting technology indicated that local farmers' households that had used this technology experienced improved farm income (Kumar, J. & Kumar K., 2008). Over 90 % of farmers in sub-Saharan region depend on rain-fed agriculture. However, rain-fed farming faces constraints due to erratic and unreliable rainfall in quantity and distribution. This has made some smallholder farmers, in various regions of Africa, to adopt agricultural water technologies. In Mpumalanga Province South Africa, rainfall pattern only allows for one rain fed cropping season per year, prompting local farmers to harvest rain water aiming at improving their farm income, (IWHP, 2009). According to similar studies carried out in Israel by Zaide (2011), and in Rwanda by Zingiro (2012), both found that use of agricultural rainwater harvesting technologies boosted farm income of the smallholder farmers involved. Therefore use of water harvesting technology to avail water for supplementing rain-fed agriculture can contribute to improving smallholder farmers' farm income (UNEP, 2009).

Runoff harvesting from roads, footpaths and compacted compounds is a practice that is currently not so widely practiced in Kenya. Road runoff harvesting systems vary from simple diversion structures that direct surface water into agricultural fields or water pans, to deep trenches with check-dams to trap eroded soil (Thomas, 1997; Hatibu & Mahoo, 2000). In Lare Division some farmers have developed simple runoff harvesting techniques, where “sheet and rill” runoff generated from compacted surfaces such as roads, footpaths and household compounds is diverted either directly into cropped land or storage structures such as water pans. According to Njoro District Fact File, NDFF (2012), about 60% of Lare Division’s smallholder farmers have been harvesting rain. This translates to about 3600 water pans in Lare Division. However, how the water harvesting technology has influenced smallholder farmers’ farm income in Lare Division has not adequately been empirically documented. Therefore this study endeavors to fill this knowledge gap by investigating the influence of water technologies on farm income of smallholder farmers in Lare Division.

2.4.3 Types of Agricultural Water Storage Technologies

According to Sundaravadivel, Kandasamy and Vigneswaran (2009), there are two types of water storage technologies namely cistern and pond. In the cistern type, water is stored in underground or above ground masonry, galvanized iron or plastic tanks. In the pond type, water is stored in dams, ponds, pans and trenches. Where soil type permits, pond system can be cost-effective, as has been demonstrated by the farmers of Lare Division Nakuru (Tuitoek, *et al.*, 2001). According to McCartney and Smakhtin (2010), storage technology makes water more available by capturing water when it is plentiful and making it available for use in times of scarcity. Storage can also be used to balance supply and demand over much shorter periods such as storing water from river flows during the night and making it available for farmers to use during the day. This makes available water that would have otherwise gone to waste. Therefore, farmers can better schedule their irrigation and reduce water losses. Water can also be stored in the soil directly by directing surface runoff to flood furrow land. Vegetation planted in water harvesting trenches is used in reducing the speed and also blocking surface runoff and therefore allowing it to percolate in the soil. Recharging groundwater is considered cost effective way of storing water. A study carried out in Alabama USA by Hicks (2010), noted that groundwater storage by recharging water table reduced impacts of drought. This is because the raised water table made water availed at plants root zones. This enabled crops to flourish during dry spell by using water already stored in the soil. Therefore, use of ground water recharging storage technology is one approach that can be used to boost Lare farmers’ farm income.

According to (KRA, (2011), underground water tanks have been constructed for agricultural water storage in the semi-arid parts of Laikipia County. The largest concentration of rock catchment water storage dams in East Africa is found in the semi-arid parts of Kitui County in Kenya. In Lare Division, some farmers have installed masonry or plastic water tanks for water storage. A few farmers have also designed innovative ways of cleaning the stored water in pans. Greenish floating mass of azolla plant has been introduced to cover the stored water surfaces thereby minimizing amount of water loss through evaporation. Suspended plant roots turn the once muddy runoff to physically clean water. However, it is not clear whether use of agricultural water storage technology has influenced smallholders' farm income in this area.

2.4.4 Agricultural Water Irrigation Technologies and Farm Income

According to McCartney and Smakhtin (2010), smallholder farmers make up about 80 percent of Africa's population. They practice rain-fed agriculture and also make use of agricultural water irrigation technology in their small farms. Smallholder farmers usually have direct access to surface or groundwater and make their own decisions, at house hold level, about how they use agricultural water irrigation technologies. The farmers also practice mainly subsistence farming with family members providing most of the farm labour. The farm is the principal source of family income. In such situations a household's decision of adopting or not adopting agricultural water irrigation technologies is crucial as it is interlinked with the household farm income. Traditional agricultural water irrigation technologies have been majorly used in kitchen gardening, zero grazing, biogas making, fish and apiculture farming among others. Modern agricultural water irrigation technology encompasses efficient use of water such as drip irrigation and green house farming among others. In India, use of irrigation technology using harvested water, is seen as a major component in curbing rural-urban migration. This is because it enhances farmers' economic stability by boosting farm income and jobs creation at rural farm level (Kumar, J. & Kumar K. 2008). Studies done in Zimbabwe, Tanzania and Niger on irrigation using harvested agricultural water showed increased sustained agricultural yields for smallholder farmers involved (Ibraimo & Munguambe, 2007). In Kenya, farming activities have a projection on improved food security, poverty reduction through creation of on-farm employment, decreased rural urban migration among others (KRA, 2011). Farming using irrigation technologies ensures that a farmer's farming activities are not controlled by rainfall availability. This implies that a farm can be engaged all year round. However, a knowledge gap exists whether the farmers' use of irrigation technology has had an influence their farm income as scant documentation exists on this.

Although smallholder farmers especially those in LDCs are relied upon by their governments to provide food security, poverty reduction and agricultural driven rural development, these farmers are faced with many farming related challenges. The challenges can be grouped into smallholder farmers' socio-economic statuses, institutional based and water scarcity related. These challenges result in low farm income which eventually leads to food insecurity, poverty and reduced rural development. So as to address water scarcity challenges, various agricultural water technologies have been used, in many parts of the world, to harvest, to store and to irrigate smallholder farms as a strategy to boost farm income. However, there is little empirical documentation on influence of agricultural water technology on farm income of smallholder farmers in Lare Division Nakuru County, Kenya.

2.5 Theoretical Framework

The study on influence of use of agricultural water technologies on farm income of smallholder farmers in Lare Division was guided by Sustainable Livelihood Approach. The proponents of this approach are Ashley and Carney (1999). The core principle underlying this approach is people-centredness. This principle implies that, for sustainabily of any technology targeting rural community, the technologies should focus should on issues that are crucial to the people. The concerned people themselves must be the key actors in identifying and addressing livelihood priorities. For sustainability, there should be an inclusive micro and macro levels involvement of stakeholders conducted in partnership in addressing identified needs. Any external support should be flexibile to changes in people's situations.

In this study, use of agricultural water technologies by rural smallholder farmers in Lare Division, in farming, is a way of achieving farm income hence sustainable agriultural based livelihoods. By use of agricultural water technologies of harvesting, storing and using irrigation, the farmers aim at boosting their farm income, producing enough food for consumtion and having extra to sell. External intervention approaches in empowering the farmers in use of agricultural water technologies, should be informed by the farmers' situations. These are education levels, technical skills for managing the technologies and resource endorment for acquiring and maintaining these technologies. There should be all inclusive multi-level invovement of the farmers, local development agents and county government. This would culminate in sustainable adoption of the technologies and farm income of the farmers' households.

2.6 Conceptual Framework

The independent variable is use of agricultural water technologies. These technologies are agricultural water harvesting, agricultural water storage and irrigation. Smallholder farmers' use of these technologies is envisaged to result in increased agricultural farm income. Therefore, it is expected that there will be enough food to adequately feed the households and surplus for selling. The dependent variable is farm income measured in Kenya shillings. Since majority of these resource constrained farmers have minimal other sources of income apart from farming, it is therefore expected that the accrued farm income is prudently used on essential households' needs. Moderating variables include gender, age, farmer's education level and the family size. These are envisaged to have the potential to influence the relationship between the independent variable; use of agricultural water technologies and dependent variable; farm income as indicated in Figure 1.

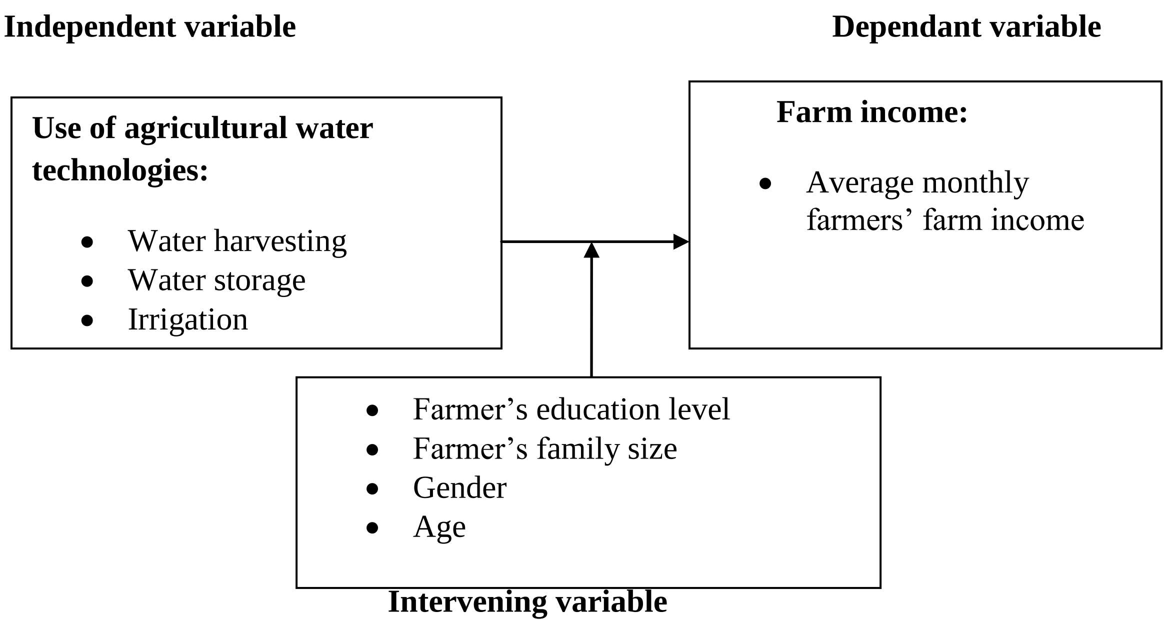

Figure 1: Influence of use of agricultural water technologies on farmers' income in Lare Division

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides discussion on the methods and procedures that were used in achieving the study objectives. It presents research design, population of study, sample size, sampling procedure, instruments used, data collection and analysis.

3.2 Research Design

Ex post facto correlation research design was used to investigate whether use of agricultural water technologies had influenced farm income of smallholder farmers in Lare Division. The design was viewed as appropriate as the variables involved namely, agricultural water technologies and farm incomes were in existence before the research was undertaken and were not manipulated during the study (Kerlinger, 2000).

3.3 Location of the Study

Lare Division is to the west of Lake Nakuru National Park within the geographical co-ordinates 0°30’S 36°0E/0.500°S 36.000°E. It covers about 134 km^2 and has four administrative locations. The four locations are Naishi, Bagaria, Lare and Gichobo. Lare Division is characterized by agro-ecological zones namely LH3, LH2, UM4 and UM5. Lare is dry with only one semi-permanent river and receives highly variable medium bimodal and unreliable average rainfall of about 600 - 1000 mm per annum. According to Migwi, (2006), the long rains normally fall between March to June while the short rains fall between September and October. Temperatures fluctuate averaging around 24-30^0C. In addition, the area experiences a cyclic drought every 3 to 5 years (ICRAF, 1997). In the recent past, rainfall variability has tended towards unexpected long droughts accompanied by high temperatures. Costs for obtaining water are high in terms of distances covered and time taken in fetching it. Although Lare Division is classified as marginal area, increased frequency and severity of droughts has been exacerbated by increased rate of deforestation through charcoal burning and illegal logging in Mau Forest; Kenya’s largest water catchment area (UNEP/GoK, 2008).

3.4 Population of Study

Lare Division had a population of 36,924 and 6008 households in 2009 (GoK, 2009). Smallholder farmers' households were distributed in the four locations of Lare Division, namely Naishi, Bagaria, Lare and Gichobo as shown in Table 1. Assume all are farmers find out

Table 1

Locations and Number of Smallholders' Households

Location	Households
Naishi	1,554
Bagaria	760
Lare	3,156
Gichobo	338
Total	6,008

Source: Ministry of Agriculture Office, Njoro 2012

3.5 Sampling Procedure and Sample Size

The focus of this study was those smallholder farmers who have been using agricultural water technologies. Household head was taken as the unit of study. It was envisaged that household head was the overall decision maker of activities pertaining to use of agricultural water technologies in each household. According to Njoro District Fact File (NDFF) (2012), 60% of smallholder farmers in Lare Division had been using the agricultural water technologies. Therefore 60% of 6008 translated to accessible population of 3,605 smallholder farmers' households. Sample size of the study, n, was determined by use of Kothari (2004) formula, $n = (z^2\ p\ q)/\ e^2$.

Where n = sample size

p = percentage proportion of the population that used agricultural water harvesting technologies.

q = 1-p (1-0.6 = 0.4)

z = standard variant at a given confidence level (= 0.05) = 1.96

e = acceptable error (0.09)

In this case p = 60% =60/100 =0.6, z = 1.96 and e= 0.09.

$n = (1.96)^2(0.6)\ (0.4)/\ (0.09)^2 = 114$

Proportionate sampling was used to select the cases to be studied from each location based on number of households. Lare Division Agriculture Office provided lists of smallholder farmers that were involved in water harvesting in each location. From these lists, each farmer's name was written on a small piece of paper. The papers were each rolled up into a small ball, put in a basket and thoroughly juggled. Using simple random sampling technique, a paper was randomly picked from the basket in turn, farmer's name noted down and put aside. This was repeated until the required sample size, for each location, was obtained as shown in Table 2.

Table 2

Distribution of Study Samples in locations of Lare Division

Locations	Population(Farmers' households)	60% of farmers' households	Proportion percent	Sample size
Naishi	1,554	932	26%	30
Bagaria	760	456	13%	15
Lare	3,156	1,894	53%	60
Gichobo	338	456	09%	09
Total	6,008	3,605	100%	114

3.6 Instrumentation

Data was collected using researcher administered questionnaire. The questionnaire contained open-ended questions based on the study objectives. Open ended questions were preferred because they gave specific information sought and also enlisted respondents' input. Appendix A is the questionnaire used. Section A, consisted of information on demographic characteristics of the respondents. Section B sought information on use of agricultural water technologies, while Section C sought information on farmers' farm income.

3.6.1 Validity of Data Collection Instrument

The instrument was developed guided by the study objectives. Content and construct validity were achieved through the researcher seeking opinion of two supervisors who reviewed the instrument. Their expert opinions were incorporated in the adjusted instrument. The supervisors are from two of the departments of the Egerton University namely; the department of Applied Community Development Studies and the department of Crops, Horticulture and Soils.

3.6.2 Reliability of the Instrument

The researcher pilot-tested the data collection tool for reliability on 30 randomly selected smallholder farmers that were users of agricultural water technologies in Elementaita Division. Mugenda and Mugenda (2003) recommend a pilot-test sample size raging from 10 to 30 as adequate for detecting inadequacies in data collection tool. This was to ensure that there were no deficiencies and ambiguities in the final data collection tool. Elementaita Division was chosen for pilot-testing as it has similar rural settlements and ecological conditions as Lare Division. It is inhabited by resource scarce and water constrained smallholder farmers. A list of smallholder farmers that were using agricultural water technologies was obtained from Elementaita Division Agricultural Office. Data obtained was analyzed using Statistical Package for Social Sciences (SPSS). Multiple regression analysis yielded a reliability coefficient of $\alpha = 0.825$ at a confidence level of 0.05. According to Frankell and Wallen (2000) and Mugenda and Mugenda (2003), this indicated that there was consistency among the items in measuring the concept of interest. However, some questions in the instrument, which were ambiguous, were adjusted appropriately in wording and framing.

3.7 Data Collection Procedure

An introductory letter was obtained from Egerton University Graduate School to facilitate acquisition of research permit from the National Commission for Science, Technology and Innovation (NACOSTI). Prior to data collection, a preliminary study was done to map out those farmers that have been using the water technologies, brief and familiarize with the local administration and obtain permission to collect data. To make data collection process efficient, the area's Division Agricultural Officer (DAO) was requested to assist in identifying location of selected respondents. Actual data collection involved visiting local sub-chiefs who provided a village elder to guide the researcher to each selected respondent's homestead. After greetings and introduction, the questionnaire was administered to the household head. At the end of engagement, the respondent was then appreciated for availing time and information sought.

3.8 Data Analysis

Completed questionnaires were serialized, coded, entered in Statistical Package for Social Sciences (SPSS) data management software and analyzed. Descriptive statistics namely, frequencies, percentages, mean and standard deviations were used to describe the farmers' socio-economic statuses and extent of use of agricultural water technologies. Multiple regression analysis was used in analyzing the influence of use of agricultural water technologies on farm income.

3.8.1 Multiple Regression Model Equation

Multiple regression analysis was used to test whether there was significant influence of usage of water technologies on the farm income at $\alpha = 0.05$ confidence level. Selected parameter of each of the three independent variables was tested against the farm income.

Multiple regression model equation, $\gamma i = \alpha + \beta x_1 (Wh) + \beta x_2(Ws) + \beta x_3(Wi)$ was used

Where,

γi = Farm income after water harvesting technology's use.

α = the multiple regression model equation's constant or the axis y- intercept.

$\beta x_{1,}$ βx_2 and βx_3 are coefficients of each usage of agricultural water technologies.

(Wh) = Use of water harvesting technology.

(Ws) =Use of water storage technology.

(Wi) = Use of Water irrigation technology.

H_{01}

Multiple regression model equation used for influence of use of water harvesting technology on farmers' farm income.

$\gamma i = \alpha + + \beta x_1(YWH) + \beta x_2(CWHS)$, where;

γi = Influence of use of water harvesting technology on the farmers' farm income.

α = Predictor Constant or axis y intercept of the multiple regression model equation.

$\beta x_1$and $\beta x_{2,}$ are coefficients of water harvesting technology selected parameters.

(YWH) = Years of experience in water harvesting.

(CWHS) = Capacity of water harvesting structures.

H_{02}

Multiple regression model equation used for influence of use of water storage technology on the farmers' farm income.

$\gamma i = \alpha + \beta x_1(YWS) + \beta x_2(CWSS)$, where;

γi = Influence of use of water storage technology on the farmers' farm income.

α = Predictor Constant or axis y intercept of the multiple regression model equation.

$\beta x_1$and $\beta x_{2,}$ are coefficients of water storage technology selected parameters.

(YWS) = Years of experience in water storage.

(CWSS) = Capacity of water harvesting structures.

H_{03}

Multiple regression model equation used for influence of use of irrigation technology on the farmers' farm income.

$\gamma i = \alpha + \beta x_1(YIAE) + \beta x_2(IMU)$, where;

γi = Influence of use of irrigation technology on farmers' farm income.

α = Predictor Constant or axis y intercept of the multiple regression model equation,

$\beta x_1$and $\beta x_{2,}$ are coefficients of water storage technology selected parameters,

(YIAE) = Years of irrigation application experience,

(IMU) = Irrigation methods used.

Table 3

Summary of Hypotheses Testing

Hypothesis	Independent variable	Dependent variable	Statistical test
Ho_1: There is no statistically significant influence of use of water harvesting technology on farmers' farm income in Lare Division	**Use of agricultural water harvesting** • Years of water harvesting, • Capacity of harvesting structures'	**Farm income** Kenya shillings	Multiple regression
Ho_2: There is no statistically significant influence of use of water storage technology on farmers' farm income in Lare Division.	**Use of agricultural water storage** • Years of water storage, • Capacity of storage structures	**Farm income** Kenya shillings	Multiple regression
H_{O3}: There is no statistically significant influence of use of irrigation technology on farmers' farm income in Lare Division.	**Use of irrigation technology** • Years of irrigation experience, • Irrigation methods used	**Farm income** Kenya shillings	Multiple regression

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The study investigated the influence of water technologies on farm income of smallholder farmers in Lare Division Nakuru, Kenya. Results and discussions, based on the study objectives, are presented in sections and subsections of this chapter.

4.2 Socio-economic Status of Smallholder Farmers in Lare Division

The study investigated the smallholder farmers' selected socio-economic status such as gender, age, education levels, family size and community groups' participation. Understanding of these farmers' socio-economic status was envisaged to have bearing on subsequent study findings.

4.2.1 Gender of Respondents

The study sought to document gender participation in use of agricultural water technologies of smallholder farmers in Lare Division. Out of 114 household heads studied, 53.9 % and 46.1% were male and female respectively. This finding implies that both genders were involved in usage of water technologies. It also implies that some females in Lare Division are also household heads hence decision makers on usage of water technologies as shown in Table 4. A study done by Mutuku, M., Odero, W., Olubandwa, A., Maling'a, J., and Nyakeyo, A. (2013) indicated that female contributed 66% of all the hours worked on farms throughout the world. Therefore, the 46.1% participation of female smallholder farmers in Lare Division, in use of agricultural water technology is consistent with female participation in farm activities world over.

Table 4

Gender of Farmers' Household Heads in Lare Division

Gender	Number	Percentage
Male	61	53.9
Female	53	46.1
Total	114	100

4.2.2 Age of Smallholder Farmers in Lare Division

As shown on Figure 2, 51.7% of the respondents were aged 51 years and above. This age categories consisted of those farmers that first acquired land and settled in Lare Division. They therefore hold the view that they are the original land owners, hence the ultimate decision makers on issues touching on usage of agricultural water technologies on their land. A study by Mulu-Mutuku, *et al.,* (2013) found that age influences a farmer's usage of technologies. However, the direction of the influence is in contention. Some researchers find age positively influencing usage of technologies and others find a negative correlation or no significant influence at all. This implies that their rather advanced age may have influenced usage of water technologies in their farm and even in those pieces of land occupied by their offspring. How age influences technologies adoption can be investigated further.

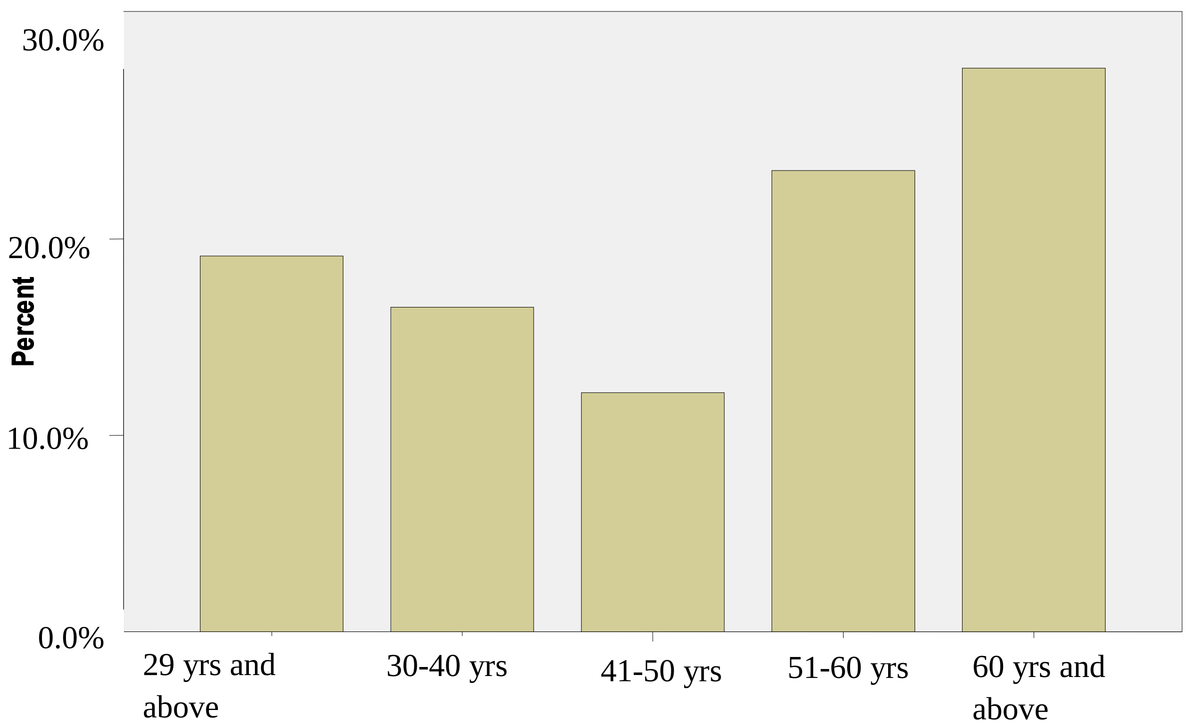

Figure 2: Age of Smallholder Farmers in Lare Division

4.2.3 Education Levels of Farmers in Lare Division

On general farmers' education, findings indicated that the respondents had low level, by Kenyan standards, with more than 76% of them having primary or no formal education as shown in Figure 3. According to Mulu-Mutuku, *et al.,* (2013), education has been found to influence adoption of agricultural related technologies such as water technology usage in farming. This is because education is believed to create a favorable mental attitude for the uptake of new practices. However, a study done in Machakos Kenya, on water harvesting technology, by Home and Gathenya (2012) found that low education levels of the farmers curtailed their chances of adopting the water harvesting technologies, particularly those technologies that required high education levels. Majority of smallholder farmers in Lare Division have low education levels.

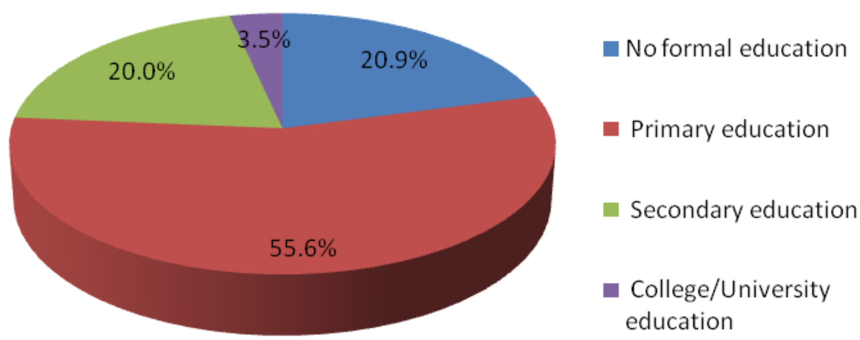

Figure 3**:** Education levels of Farmers in Lare Division

4.2.4 Family Sizes of Smallholder Farmers in Lare Division

In order to understand the trend of the farmers' family sizes, the respondents were requested to indicate the number of members' dependant on household heads. The highest percentage of family size, (60.9%) was in the range of 6-10 members as shown in Figure 4. This finding is in line with rural traditional African communities that tend to have large families. Having a large family may encourage or discourage a household head in embracing farming related technologies such as agricultural water technologies. On one hand, agricultural water technologies may not be embraced if they are perceived as having inherent risks leading to reduced farm income.

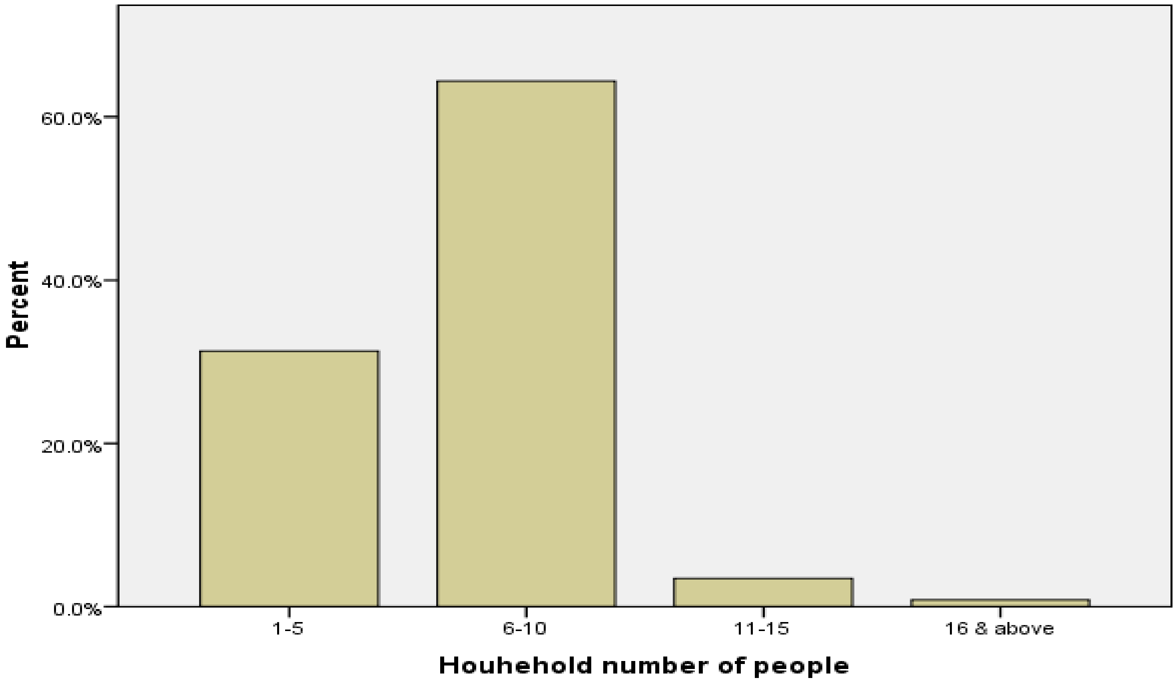

Figure 4: Number of members of smallholder farmers' households in Lare Division

4.2.5 Groups within Farming Community in Lare Division

So as to understand how farmers in Lare Division interacted among themselves, respondents were requested to indicate groups they belonged and were active in. As indicated in Table 5, 71%, 20.0% and 9 % of them belonged to social, farmers and no groups respectively. Only minority of the farmers, (20%) belong to farmers' groups. According to Rogers (2005), farmers' group an avenue for disseminating information on farming to farmers such as agricultural water technologies. A study in India by D' Silva, *et al.,* (2009) found that smallholder farmers active in farmers' groups had adopted farming related technologies, such as water technologies, twice as much as compared to their counterparts who did not. In Lare Division, there is low percentage of smallholder farmers involved in farmers' groups. Whether involvement in farmers' group in Lare Division has relationship with extent of usage of agricultural water technology can be studied.

Table 5

Lare Farmers' Involvement in Community Groups

Groups	Frequency	Percentage
Social group	82	71
Farmer groups No	23	20
group	09	9
Total	114	100

4.3 Sources of Farmers Income' in Lare Division

The study investigated the sources of income of farmers in Lare Division. Based on responses of the 114 respondents, the main source of farmers' income was farming. All the respondents, at least, depend on farming a source of income as shown on Table 6. However, 29.6% of them indicated that they had other sources of income besides farming such as business and employment. A study by Mulu-Mutuku, *et al.,* (2013) found that relying on farming alone or partly, as a source of income, may have an influence on a farmer's effort and dedication in usage of farming-related technologies such as agricultural water technologies. Resources farmers commit to these technologies such as time and labour may influence amount of benefits farmers accrue such as enhanced farm income. Therefore, fulltime farmers would be expected to be more committed to farming given that farming is the only source of their income. However, an extra occupation may mean an extra source of finance that could possibly be ploughed into usage of agricultural water technologies. In Lare Division, a few farmers indicated that they had abandoned other businesses to fully concentrate on farming but not the other way round. They felt that income from farming was more reliable and stable than income from other activities.

Table 6:

Sources of Income of Farmers in Lare Division

Income Source	Frequency	Percentage
Farming only	81	71.1
Farming/business/employment	33	28.9
Total	114	100.0

4.3.1 Average Farmers' Farm Income in Lare Division

The study sought to find out the average farmer's farm income in Lare Division. Majority of the farmers, (96.5%) earned averagely between 1,000-20,000 Kenya shillings per month from their farms as shown in Table 7. The amount of money obtained by majority of the farmers is modest by Kenya standard. This implies that these farmers are financially constrained. According to Manda, *et al.*, (2001), poverty situation is widespread and continues to afflict larger segments of rural population in Kenya. This is the case among the smallholder farmers of Lare Division.

Table 7:

Average Farm Income of Farmers in Lare Division

Monthly Income (Ksh)	Frequency	Percent
1000-10000	81	71.1
10001-20000	29	25.4
20001-30000	4	3.5
Total	114	100.0

4. 4 Extent of Use of Agricultural Water Technologies by Farmers in Lare Division

The study sought to understand the extent of usage of each of the three agricultural water technologies by smallholder farmers in Lare Division. Responses indicated that 100% of the 114 respondents interviewed harvested water, 93.9% harvested and stored water and only 37.4% harvested, stored and used it for irrigation. This finding is in agreement with purposive sampling procedure used in selecting only those farmers that have been using agricultural water harvesting technology. There was low percentage of the farmers that were using irrigation technology compared with the other two technologies as shown in Table 8. According to Home and Gathenya (2012) the low usage of irrigation technology, in Yatta, could be attributable to farmers' inadequate education and skills. In case of smallholder farmers in Lare Division, the low percentage of the farmers involved could be indicative of challenges in usage of irrigation technology.

Table 8:

Usage of water technologies by the Farmers in Lare Division

Agricultural Water Technology	Frequency	Percentage
Harvesting	114	100.0
Storing	108	93.9
Irrigation	43	37.4

4.4.1 Experience of Usage of Water Harvesting Technology by Farmers in Lare Division

The study sought to document years of experiences of use of water harvesting technology by farmers in Lare Division. All the farmers interviewed had experience in agricultural water harvesting technology of over five and most farmers (68%) had adopted the water harvesting technologies in the last 10 years as shown in Table 9. In Lare Division, one calendar year is equivalent to one cropping season. This means that these farmers had at least used the agricultural water harvesting technology for five cropping seasons. This time duration was envisaged as adequate for the farmers to have noted any changes in their farm income arising from their use of agricultural water harvesting technology.

Table 9:

Duration in Years of Water Harvesting by Farmers in Lare Division

Duration	Frequency	Percent
5-10 years	77	67.8
11-15 years	20	17.4
16 and more	17	14.8

4.4.2 Water Harvesting Structures used by Farmers in Lare Division

This study documented water harvesting structures used by the farmers in Lare Division. Out of the 114 respondents interviewed, 95.6 % of them used gutters for harvesting rain water, and 63.5% used runoff trenches for surface runoff harvesting as indicated in Figure 5. However, 59.1% of the respondents used both structures. Gutter and runoff trenches were popular water harvesting structures as were affordable, maintainable and require no specialized skills in their management.

This is in line with socio-economic status of the smallholder farmers in Lare Division such as low level of education and resource constraints (Mati, *et al.*, 2004). According to Rogers (1995), people tend to adopt technologies that are consistent with their skills and within their economic reach. Simple low cost water harvesting technology structures, such as gutters and runoff trenches, fit well within Lare Division smallholders' farmers' socio-economic status.

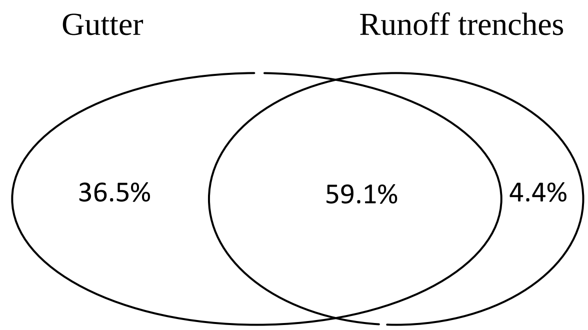

Figure 5: Water Harvesting Structures used by Farmers in Lare Division

4.4.3 Relationship between Water Harvesting Technology and Smallholder Farmers' Farm Income in Lare Division

Multiple regression analysis was used to investigate the hypothesis that there was no statistically significant influence of use of water harvesting technology on the farmers' farm income in Lare Division, at 95.0% confidence level. Parameters of independent variable measured were, years of water harvesting experience and capacity of water harvesting structures. These parameters were simultaneously tested for their influence on farmers' farm income, as indicated in Table 10. The coefficient R square for the predictor variables was .739. This implied that 73.9% of the variance was accounted for by the two predictor variables. Their respective R square values were .487 and .252 respectively implying each predictor variable parameter accounted for 48.7% and 25.2% respectively. Years of farmers' experience in water harvesting was a significant at 0.05 significant level ($p = 0.03$). Therefore the study null hypothesis that there was no statistically significant influence of use of water harvesting technology on the farmers' farm income in Lare Division was rejected. This implies that the use of agricultural water harvesting technology had statistically significant influence on the farmers' farm income in Lare Division. This finding agrees with findings of similar studies carried out in Israel, by Zaide (2011) and in Rwanda by Zingiro (2012).

Both studies found that use of agricultural rainwater harvesting technologies boosted farm income on smallholder farmers involved.

Table 10:

Water Harvesting Technology use on Lare Farmers' Farm Income

Predictor	Beta	T	Sig.	Std. Error	R Square
Constant α	1.569	4.09	.000	.384	.739
Years of experience in water harvesting βx_1(YWH)	.142	2.20	.030	.065	.487
Capacity of water harvesting structures βx_2(CWHS)	-.235	-1.23	.221	.191	.252

Dependent variable: Farmers' farm income

Number of observations = 114, R^2 = .739, Std. Err =.384, t = 4.09, Sig. at $p \leq 0.05$

Multiple regression model equation used for influence of use of harvesting technology on Lare Farmers' Farm income.

$\gamma i = 1.569 + 0.142(YWH) - 0.235(CWHS)$.

4.5 Use of Water Storage Technology by Farmers in Lare Division

This study investigated issues pertaining to water storage technology. Based on114 respondents interviewed, findings indicated that the water storage technology was practiced by 93.9% of the farmers. Water storage structures commonly used by the smallholder farmers in Lare Division were tanks (plastic and concrete) as indicated by 98.30% of the respondents. A few farmers had used trenches as water storage structures as indicated in Table 11. The popularity of plastic tanks as water storage structures could be attributed to their affordable initial and maintenance costs. Water stored in plastic tanks is clean hence suitable for domestic use, unlike the case of water pans.

A project carried out by Egerton University and Kenya Agricultural and Livestock Research Organization (KARLO) Njoro, and funded by ICRAF (Tuitoek, *et al.*, 2001), sensitized and facilitated majority of these farmers in constructing water pans in late 1990s. According to Njoro

District Fact File, NDFF (2012), about 60% smallholder farmers in Lare had water pans. However, study findings indicated that only 49.3% of the farmers were actually using water pans as water storage structure. This drop, of 10.7% in the number of farmers using water pans, may be attributed to water storage associated challenges. In their comments, some farmers cited these challenges such as water loss through seepage and evaporation and collapsing of water pan walls. Drowning of livestock and children was cited as a serious challenge that had led some farmers to abandon and cove their water pans. Only 1.7% of the respondents used trenches for storing water by recharging ground water table. The small percentage of the farmers using water table recharging technology, for water storage, may be a pointer to possible existence of barriers, such as lack of knowledge, in usage of trenches as water storage technology.

Table 11

Water Storage Structures used by Farmers in Lare Division

Water storage structures	Frequency	Percent
Tanks	113	98.3
Pans	57	49.3
Trenches	2	1.7

4.5.1 Capacity of Water Storage Structures used by Farmers in Lare Division

Based on responses of 108 of the farmers who harvested and stored water, about 99.1% of them felt that capacity of water storage structures was inadequate as shown in Table 12. This implies that the capacities of water storage structures and in extension the amount of stored water was inadequate. Faced by an inadequate water scenario, the farmers preferred to use this inadequate water in feeding livestock as opposed to irrigating crops during droughts.

Table 12

Capacity of Water Storage Structure of Farmers in Lare Division

Adequacy of water Storage Structures	Frequency	Percent
Adequate	1	0.9
Inadequate	107	99.1

4.5.2 Experience in Use of Water Storage Technology by Farmers in Lare Division

From responses obtained, all the farmers in Lare Division, that have been practicing water storage technology have water storage experience for over 5 years, as shown in Table 13. In Lare Division, one farming season is equivalent to one calendar year. This therefore implies that the farmers have been involved in use of storage technology for at least 5 farming seasons. It is envisaged that a time span of at least five farming seasons is adequate for the farmers to have noted any changes in their farm income emanating from usage of water storage technology.

Table 13:

Years of Use of Water Storage Technology by Lare Farmers

Experience of Water Storage Use	Frequency	Percentage
5-10 years	49	45.6
11-15 years	32	29.8
16-30 years	27	24.6
Total	108	100.0

4.5.3 Relationship between Water Storage Technology and Smallholder Farmers' Farm Income in Lare Division

The study hypothesis stated that there was no statistically significant relationship between use of agricultural water storage technology and the farmers' farm income in Lare Division. The influence of independent variable (agricultural water storage technology) was tested for its influence on dependant variable (farmers' farm income) as indicated in Table 14. The coefficient R square for the predictor variables was .595. This implied that 59.5% of the variance was accounted for by multiple regression equation used. The water storage technology' use predictor variables were, years of experience in agricultural water storage and capacity of water storage structures.

Their R values were, .391 and .204 respectively. This means that each predictor parameter accounted for 39.1% and 20.4% of the total influence of the usage of the water storage technology on the farmers' farm income respectively.

Capacity of water storage structures was found as a significant predictor variable influencing the farmers' farm income at 0.05 significant level (p = 0.002). The hypothesis that there was no statistically significant relationship between water storage technology and the farmers' farm income was rejected. Therefore, there was statistically significant relationship between water storage technology and the farmers' farm income in Lare Division. This finding is in agreement with finding of a study conducted in Zimbabwe, Tanzania and Niger by Ibraimo and Munguambe (2007) which showed increased farm income of smallholder farmers involved in agricultural storage water technology.

Table 14:

Influence of Water Storage Technology on Farmers' Farm Income in Lare Division

Predictor	Beta	T	Sig.	Std. Error	R Square
Constant α	3.558	4.66	.000	.764	.595
Years of experience in water storage βx_1(YWS)	.105	1.70	.093	.062	.391
Capacity of water storage structures βx_2(CWSS)	-1.215	-3.173	.002	.383	.204

Dependent variable: Farmers' farm income

Number of observations = 114, R^2 = .595, Std. Err =.764, t = 4.66, Sig. at $p \leq 0.05$

Multiple regression equation used.

Where YWS = Years of Water Storage

CWSS = Capacity of Water Storage

$\gamma i = 3.558 + 0.105(YWS) - 1.215(CWSS)$

4.6 Use of Irrigation Technology by Farmers in Lare Division

The research hypothesis stated that there was no statistically significant influence of irrigation technology on the farmers' farm income in Lare Division. The influence of independent variable (irrigation technology) on dependent variable (farmers' farm income) was tested and findings presented.

4.6.1 Extent of Use of Irrigation Technology by Farmers in Lare Division

Out of 114 farmers interviewed, only 37.4% of them practiced irrigation technology. Out of these, 93.0% watered their livestock, 42% used the water for irrigating crops and 35.0% watered their livestock and irrigated crops as indicated in Figure 6. The rather low percentage of the farmers, using irrigation technology may be a pointer to existence of challenges pertaining to the use of irrigation technology. Some of the challenges mentioned by respondents included initial and maintenance costs of irrigation facilities, inadequate skills in practicing irrigation and inadequate available water for irrigation occasioned by small storage structures.

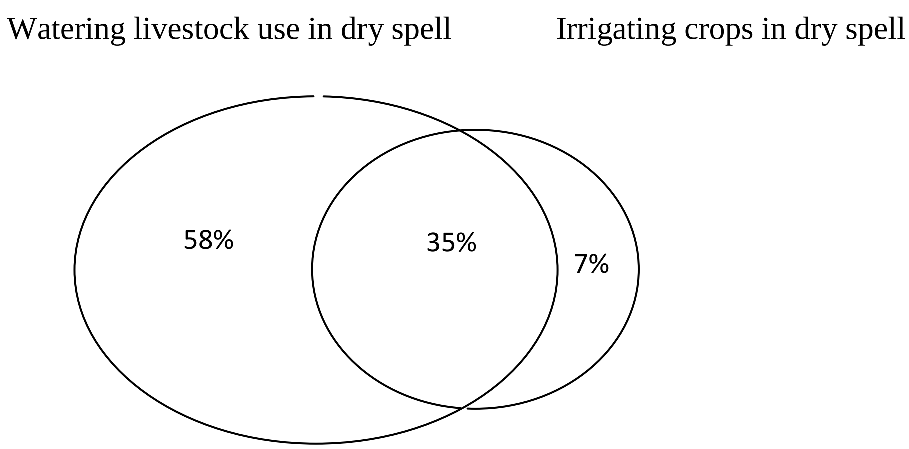

Figure 6**:** Application of stored water by farmers in Lare Division

4.6.2 Irrigation Methods Used by Farmers in Lare Division

Majority of the farmers (86.1%) used bucket irrigation while (9.3%) used drip irrigation methods as shown in Table 15. There is low percentage of farmers that use drip irrigation method, which is more water use efficient, as compared to bucket irrigation method. Initial and maintenance costs besides technical skills required were mentioned as challenges facing smallholder farmers in Lare Division in use of drip irrigation method.

Table 15:

Irrigation Methods Used by Farmers in Lare Division

Irrigation methods	Frequency	Percentage
Bucket	37	86.0
Drip irrigation	4	9.3
Farm flooding	2	4.7
Total	43	100.0

4.6.3 Influence of Use of Irrigation Technology on Smallholder Farmers' Farm Income in Lare Division

Multiple regression analysis was used to study the hypothesis that there was no statistically significant influence of irrigation technology on farmers' farm income at 95.0% confidence level. Parameters of irrigation technology that were analyzed were farmers' experience in using irrigation and irrigation methods used. The coefficient R square for the predictor variables was 0.505. This implied that 50.5% of the variance of influence of irrigation on the farmers' farm income was accounted for by the regression model equation. The R squares for use of irrigation technology predictor variable parameters namely; years of experience in irrigation practice and irrigation methods used were .218 and .287 respectively. This means that the two parameters accounted for 21.8% and 28.7% of the total influence respectively.

Multiple regression analysis found neither of the parameters as significant predictor variable at 0.05 significant level as indicated in Table 16. Therefore, the hypothesis that there was no statistically significant influence of use of irrigation technology on farmers' farm income was accepted. This implied that irrigation technology had no statistically significant influence on the farmers' farm income at 95% confidence level. These findings are not in agreement with findings of similar studies done by Ibraimo and Munguambe (2007) in Zimbabwe, Tanzania and Niger. Their findings showed increased farm income resulting from smallholder farmers' use of irrigation technology using harvested rain water. Reasons why use of irrigation technology has no significant influence on the farmers' farm income, at 95% confidence level needs investigation. However, it is envisaged the bucket irrigation method commonly used (86.1%) and inadequate amount of stored water available for irrigation may have attributed to insignificant influence of irrigation technology on Lare Division farmers' farm income.

Table 16:

Influence of Use of Irrigation Technology on Lare Farmers' Farm Income

Predictor	B	T	Sig.	Std. Error	R. Square
Constant α	.978	2.81	.008	.348	.505
Years of irrigation experience βx_1 (YIAE)	.189	.92	.361	.205	.218
Irrigation methods used βx_2(IMU)	.233	1.69	.091	.138	.287

Dependent Variable: Farmers' farm income

Number of observations = 114, R^2 = .505, Std. Error =.348, t = 2.81, Sig. at $p \leq 0.05$

Multiple regression model equation used.

$\gamma i = .978 + 0.189(YIAE) + (IMU)$.

4.7 Foodstuffs Status after Usage of Water Technologies by Farmers in Lare Division

Adequate foodstuff is that amount that would satisfy household members consumption needs per given duration of time. Households differ in terms of numbers of family members, gender and age. They also differ in terms of the quantity of foodstuff they consider adequate. Therefore no fixed quantity of foodstuff would be rightly described as adequate for each and every household. When requested to comment about household foodstuffs status since they started using the water technologies, 77.4% of the respondents indicated they had observed surplus foodstuffs as shown in Table 17. This observation by the farmers in Lare Division corresponds to findings of a similar study done in Alabama US, by Hicks (2008). The findings indicated that usage of agricultural water technologies boosted farm produce in Alabama, leading to surplus foodstuffs at household level.

Table 17:

Foodstuffs Status after Water Technologies Usage by Farmers in Lare Division

Farm produce status	Frequency	Percentage
Remained the same	26	22.6
Surplus observed	88	77.4
Total	114	100.0

4.7.1 Use of Surplus Farm Produce Farmers in Lare Division

This study investigated what the farmers in Lare Division did with surplus farm produce. Out of 88 respondents who observed surplus farm produce, majority of them (99.0%) indicated that they sold the surplus farm produce in the market it in order to earn an income, as shown in Table 18. Farmers in Lare Division derive both household foodstuff and finances from farming activities. They would therefore be expected to sell their surplus farm produce. This is due to the fact that these farmers basically rely on farm based income as have minimal other income sources (Manda, *et al.,* 2001 & Shimoli, 2005). Farm income is the major source of household income.

Table 18:

Use of Surplus Farm Produce by Lare Farmers

Use of surplus farm produce	Frequency	Percentage
Selling	87	99.0
Donating to others	1	1.0
Total	88	100.0

4.8 Effect of Moderating Variables on Relationship between Independent and Dependent Variables

Moderating variables namely; farmers' education level and household size were tested for their potential moderating influence of the relationship between the independent and dependent variables by use of simple regression analysis. Only the farmers' education level variable had significant influence, at 95% confidence ($p = 0.050$), as shown in Table 19.

Table 19*:*

Effects of Moderating Variables on Relationship between Indepent and Dependent Variables

Variable	B	t	R. Square	Std. Error	Sig.
Education level	.112	.057	.183	1.968	.050
Household size	.020	.075	.025	.273	.790

Dependent Variable: Farm income

This implies that smallholder farmers' education is a crucial component in addressing usage of agricultural water technologies in Lare Division. Home and Gathenya (2012) indicated that farmers' low education level curtailed smallholder farmers' use of agricultural water technologies in Yatta, Machakos County.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Major Findings

This study aimed at investigating influence of agricultural water technologies on farm income of smallholder farmers in Lare Division, Nakuru County Kenya. The study used four objectives namely, listing the main sources of farmer households' income and establishing the influence of agricultural water harvesting, agricultural water storage and irrigation technologies had influence on smallholder farmers' farm income in Lare Division. Three null hypotheses were used in this study. They stated that there was no statistically significant influence of agricultural water harvesting, agricultural water storage and irrigation technologies on smallholder farmers' farm income in Lare Division.

On demographic characteristics of the smallholder farmers in Lare Division, the study revealed that both genders participated almost equally on use of agricultural water technologies. Majority had primary or no education and were aged 51 years and above. Most households had fairy large numbers of dependants comprising between 6-10 members. The main source of farmers' income was farming but only minority of the farmers belonged to farmers' groups. Most of foodstuffs and income were obtained from farms.

Water harvesting technology was practiced by all the respondents. All the farmers interviewed had experience in agricultural water harvesting technology of over five years. Water harvesting structures used were mainly gutter and less of runoff trenches. Multiple regression analysis indicated that agricultural water harvesting technology had significant influence on the farm income of smallholder farmers in Lare Division.

Water storage technology was practiced by majority the respondents. Water storage structures use were plastic tanks and water pans. All the farmers had experience of agricultural water storage technology of over five years. Capacity of water storage structures and the amount of stored water was inadequate. Only a small percentage of the farmers were using water table recharging technology for water storage. Water loss through seepage and evaporation, collapsing of water pan walls and drowning of livestock and children were challenges in use of agricultural storage technology. Multiple regression analysis indicated that agricultural water storage technology had significant influence on the farm income of smallholder farmers in Lare Division.

Irrigation technology was practiced by minority of the farmers. The amount of stored water for irrigation was inadequate. Therefore stored water was prioritized for watering livestock rather than irrigating crops. Common crop irrigation method was by use bucket. Multiple regression analysis indicated that irrigation technology had no significant influence on the farm income of smallholder farmers in Lare Division.

5.2 Conclusions

Majority of smallholder farmers in Lare had low education level and large families. The main source of farmers' income was farming but only minority belonged to farmers' groups. Agricultural water harvesting technology was used by all smallholder farmers in Lare Division. The most preferred water harvesting structures were gutters and runoff trenches. Agricultural water harvesting technology had statistically significant influence on farm income of Lare farmers. Agricultural water storage technology was used by majority of smallholder farmers in Lare Division using storage structures such as plastic tanks and trenches. Only a small percentage of the farmers use water table recharging technology for water storage. However, capacities of water storage structures were inadequate. There were challenges associated with water pans such as loss of water by seepage and evaporation, collapsing of pan walls and loss of livestock and children through drowning. Agricultural water storage technology had statistically significant influence on farm income of Lare farmers. Irrigation technology was practiced by minority of the farmers. The amount of stored water for irrigation was inadequate. Stored water was prioritized for watering livestock rather than irrigating crops. Common crop irrigation method was by use bucket. Irrigation technology had no statistically significant influence on farm income of Lare farmers.

5.3 Recommendations

Small holder farmers in Lare require empowerment in terms of general education, involvement in farmers' groups, use of water table recharging technology and use of efficient irrigation methods. In designing water storage structues, water loss, stability of water pan walls and safety of livestock and childred need to be considered. The farmers need sensitation on use of water use efficient irrigation methods.

5.4 Recommendations for Further Research

Further research is recommended on; use of water table recharging technology, why irrigation technology, in Lare Division has no statistically significant influence on farm income, unlike the cases in other parts of the world and also whether smallholder farmers' involvement in farmers' group has relationship with extent of usage of agricultural water technologies. Similar research can be replicated in marginal areas occupied by smallholder farmers who used agricultural water technologies in farming.

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APPENDIX 1: INTERVIEW SCHEDULE

Questionnaire Serial Number_____

Location _______________ has adopted AWT--------------- has not adopted AWT--------My names are Frederick Boithi. I am an MSc student at Egerton University carrying out research in Lare Division of Nakuru County. The research focus area is: **Influence of use of agricultural water technologies on farm income and living standards of smallholder Farmers in Lare Division Nakuru County Kenya.** You have been selected to participate in this study. Kindly respond to the following questions with the utmost sincerity. Be assured that the information you provide will be used only for the purpose of this study and it will be handled confidentially. Feel free to seek clarification if you do not understand any question(s).

Section A

1. Who is the household head? Husband [ ] Wife [ ] Son [ ] Daughter [ ]

Any other? Specify……………………..

2. What is the age of household head in years?
30 & below [ ] b) 30 -40 [ ] c) 41 – 50 [ ] d) 51- 60 [ ] 61 & above [ ]

3. Highest level of education. None [ ] Primary [ ] Secondary [ ] College/University [ ]

4. How many persons have been living in your household for, at least, the last six months?
1 – 5 [ ] 6 – 10 [ ] 11- 15 [ ] More than 16 [ ]

Section B

5. Have you been using agricultural water harvesting technologies? Yes [ ] No [

6. If the answer to question 6 is "Yes", how long have you been using these technologies? _______years

7. What are the reasons for using water harvesting technologies? [___] [___] [___] (Give at least three.) **Codes: 1=Increases farm yields, 2= Neighbours are practicing it, 3 = I can afford the technology, 4= Technical guidance available for it, 5= I have been trained on this technology** Other (Specify) ______________

8. Which methods do you use to abstract and harvest water in order of priority? **Wells** (borehole, shallow well), **Runoff** (road diversions, surface harvesting), **River abstraction** (free flow, pumping), **Roof water harvesting**

i)………………………… ii)…………………………….. iii)……………

9. Which water harvesting structures have you been using to harvest water? a) Gutter [ ] b) Compact surface [ ] c) Run off diversion trenches d) Farm flooding [ ]

Other? Specify…………………

10. Is the capacity of the water harvesting structures adequate in meeting your agricultural water needs? Yes [ ] No [ ]

11. Have you been using agricultural water storage methods? Yes [ ] No [ ]

12. If the answer to question 10 is "Yes", how long have you been using these methods? _______years

13. What are the reasons for using water storage technologies? [___] [___] [___] (Give at least three). **Codes: 1=Increases farm yields, 2= Neighbours are practicing it, 3 = I can afford the technology, 4= Technical guidance available for it, 5= I have been trained on these technologies.** Other (Specify) ______________

14. Which water storage methods have you been using to store harvest water?

a) Underground [ ] b) Above the ground [ ]

15. Which structure(s) do you use to store the harvested water used for agricultural purposes?

a) Tanks (plastic concrete, GI) [ ] b) Pans/Ponds [ ] c) Dams [ ] d) Trenches with allowance for seepage [ ]

16. Is the capacity of the water storage structures adequate in meeting your agricultural water needs? Yes [ ] No [ ]

17. Have you been using agricultural water application technologies? Yes [ ] No [ ]

18. If the answer to question 18 is "Yes", how long have you been using these technologies? _______years

19. What are the reasons for using water application technologies? [___] [___] [___] (Give at least three.) **Codes: 1=Increases farm yields, 2= Neighbours are practicing it, 3 = I can afford the technology, 4= Technical guidance available for it, 5= I have been trained on this technologies** Other (Specify)______________

20. Which water application methods have you been using? a) Bucket [ ] b) Sprinkling [ ] c) Drip irrigation [ ] d) Farm flooding [ ] e) channel [ ] Other? Specify…………

21 .For what purpose do you apply the harvested water? a) Domestic [ ] b) Livestock [ ] c) Crops [ ] d) Fish farming [ ] e) Tree seedling [ ] Other? (Specify)…………

22. Which structure(s) have you been using in applying the harvested water? a) Bucket [ ] b) Livestock watering troughs [ ] c) Sprinkler [ ] Trenches with allowance for seepage [

23. Is the capacity of the water storage structures adequate in meeting your agricultural water needs? Yes [ ] No [ ]

24. List the best 3 sources of income starting from the leading one. i)………………….

ii)……………………… iii)……………………

Section C: Farm Income

25. Give an estimate of your household's monthly income in Kenya Shillings …................

26. Have you been obtaining adequate farm produce feed your family? Yes [ ] No [ ]

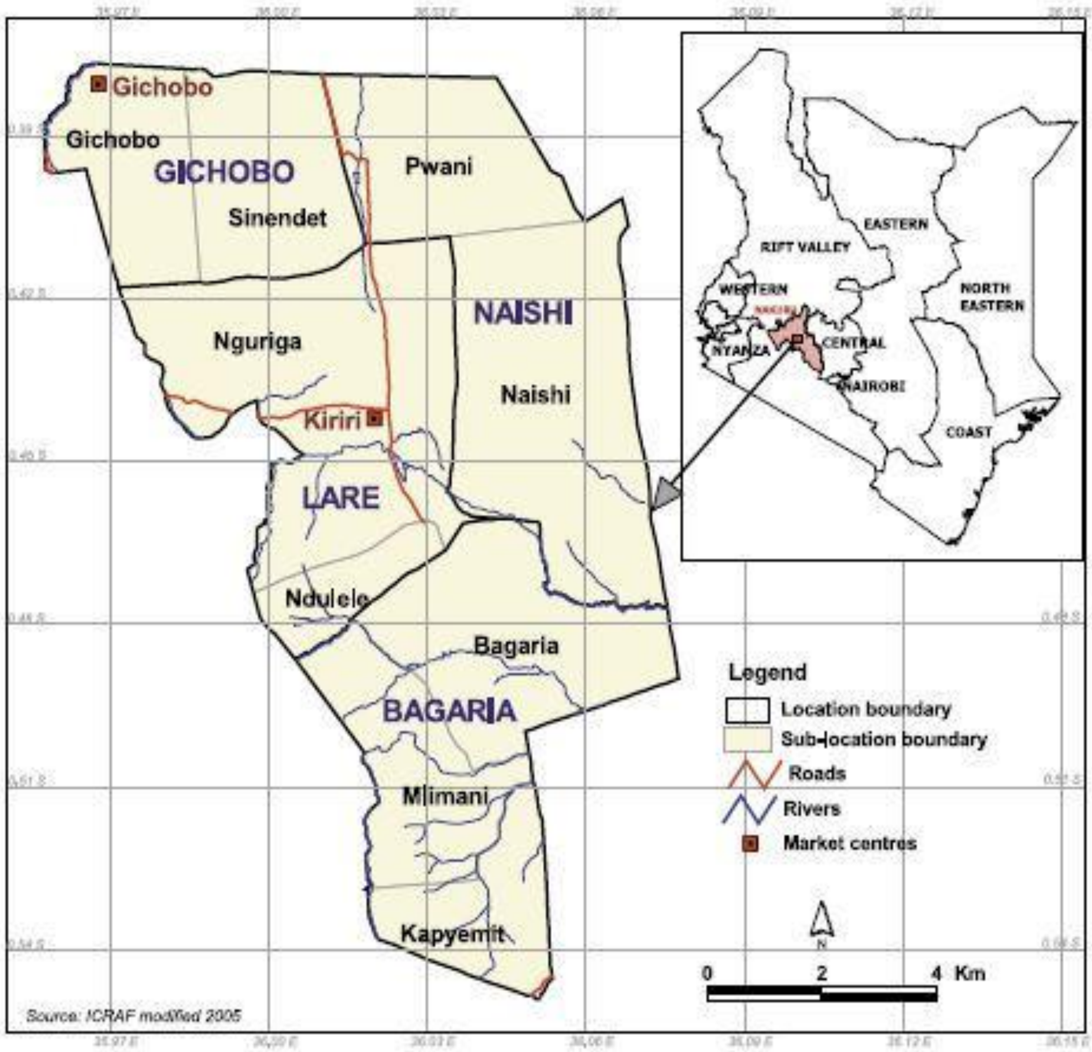
27. Have you been obtaining extra farm produce resulting from use of agricultural water technologies? Yes [ ] No [ ]

28. If your answer to question 27 is "Yes", what do you do with surplus farm produce?

Sell [ ] Donate to others [ ] other? Specify………………………………..

29. Have you been obtaining extra farm income resulting from use of agricultural water technologies? Yes [ ] No [ ]

APPENDIX 2: MAP OF THE STUDY AREA



Locations of Lare Division Nakuru County, Kenya

APPENDIX 3: RESEARCH PERMIT

THIS IS TO CERTIFY THAT:
MR. FREDERICK NJAGI BOITHI
of EGERTON UNIVERSITY, 0-20115
Egerton- Ngondu,has been permitted to
conduct research in *Nakuru County*

on the topic: *INFLUENCE OF AGRICULTURAL WATER USE TECHNOLOGIES ON LIVING STANDARDS OF SMALLHOLDER FARMERS IN LARE DIVISION,NAKURU COUNTY, KENYA*

for the period ending:
31st March,2014

Permit No : NACOSTI/P/13/4099/457
Date Of Issue : 4th February,2014
Fee Recieved :Kshs khs1000.00

....
Applicant's Signature

....
Secretary
National Commission for Science, Technology & Innovation