

RISK AND BENEFIT ANALYSIS OF INVESTMENTS IN CONSERVATION
TECHNOLOGIES UNDER VARYING CLIMATE IN EASTERN KENYA.

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DECLARATION

I LUCY WANGUI NGUGI declare that this thesis is my original work and has not been presented for the award of a degree in any other University or any other award.

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DEDICATION

This work is dedicated to my parents, Mr. and Mrs. Felix Ngugi, my sisters and brothers, for their commitment, support and sacrifice towards my education.

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ABBREVIATIONS AND ACRONYMS

APSIM	- Agricultural Production Simulation Model
ASARECA	- Association for Strengthening Agricultural Research in Eastern and Central Africa.
BCR	-Benefit Cost Ratio
CALESA	-Climate Change Analogue Locations in Eastern and Southern Africa
CARMASAK	- Collaboration on Agricultural Resource Modelling and Applications in Semi- Arid Kenya.
DAO	- District Agricultural Office
ECA	-Eastern and Central Africa
GDP	- Gross Domestic Product
GOK	- Government of Kenya
HH	- Household
ICRISAT	-International Crops Research Institute for the Semi- Arid Tropics
IPCC	-Intergovernmental Panel on Climate Change
KARI	-Kenya Agricultural Research Institute
KMD	- Kenya Meteorological Department
NGO's	- Non-Governmental Organizations

- ReSAKSS -Regional Strategic Analysis Knowledge Support System
- SIDA -Swedish International Development Co-operation Agency.
- SPSS - Statistical Package for Social Sciences
- SRA - Strategy for Revitalization of Agriculture
- SWC - Soil and Water Conservation
- WH - Water Harvesting
- WOCAT -World Overview of Conservation Approaches and Technologies
- WRUA -Water Resource Users Association

ABSTRACT

Soil degradation and moisture stress remain the major constraints and environmental threat to agricultural productivity in the semi-arids of Kenya, which account for more than 80% of the total land mass. Government development partners and donor institutions have been promoting soil and water conservation technologies aimed at reducing soil erosion and in making more water available for agricultural production. Investments in soil and water conservation technologies can be undertaken when sufficient returns are guaranteed and the risks thereof are known. This study assessed soil and water conservation technology investment by farmers, examined factors that influence investment into soil and water conservation technologies, quantified the costs and the benefits of short term investments in soil and water conservation technologies and finally, it identified the potential opportunities to reduce risks of investments in soil and water conservation technologies under variable climatic conditions. The study was carried out in Mwanja and Kaliu watersheds in Machakos and Makueni Counties of Eastern Kenya. Two stage sampling method was used to obtain the sample size of farmers used for the household surveys. First the watersheds were delineated, and the number of HHs picked from sub locations depending on the sampling frame of that sub location to obtain a sample size of 380 households. Purposive sampling method was later used to obtain total of 120 households based on the SWC technologies invested by the farmers. Descriptive statistics were conducted using Statistical Package for Social Sciences (SPSS). The crop simulation model APSIM was used to generate yield data under irrigation, tied ridges and terraces which were subjected to analysis of variance (ANOVA) using R-statistical software. Results indicated that terraces were the most used SWC technology in both sites while tied ridges and mulching the least invested technology in Mwanja and Kaliu respectively. High cost and input unavailability locally were the key factors constraining investments in SWC technologies. On the other hand, benefit accrued after investing in SWC technologies was the significant factor promoting the investments. Benefit-cost analysis (BCA) during 2010/2011 SR season indicated that irrigation and tied ridges yielded the highest benefit-cost ratio (BCR) of 1.3 and 2.5 in Mwanja and Kaliu respectively in maize production. Terraces gave the highest BCR (1.5) in Kaliu under bean production. ANOVA results indicated that the technology used, fertilizer rate applied and the season type were significant in both maize and bean production. Modeling results indicated that investing during above normal seasons was risky in all technologies but beneficial during normal seasons. Model simulations further indicated that fertilizer application led to up to 73% and 61% yield gains in maize and beans production when up to 30kg N/ha fertilizer was applied. The study recommends development of strategies that will ensure reduction of prices of farm inputs and their availability in the study area, farmers' economic empowerment to enhance investment in irrigation and tied ridges to ensure food security in semi-arid Eastern Kenya.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Agriculture is an important sector of the Kenyan economy, contributing about 28% of the GDP (World Bank, 2011) and is a major income earner to the farmers. It accounts for 60% of national employment, 60% of total export earnings and 45% of government revenue. In the rural areas where much of the Kenyan population resides, about 80% of the people derive their livelihood from agriculture and the majority of farmers are small holders. The smallholder agricultural production accounts for about 70% of total output and a further 50% of the gross marketed output (GOK, 1997-2001).

However, about 82% of the Kenya's agricultural lands are marginal with fragile ecosystems receiving irregular and low amounts of rainfall (GOK, 2010, Mwakubo, 2002). The variability in the amount and distribution of rainfall both during and across the seasons, that these areas experience not only makes the availability of water for crop production erratic, but farming, a risky undertaking. The high risk along with the general risk-averse nature of smallholder farmers is leading to adoption of low input management practices that lead to low productivity and are inadequate to meet the needs of the farmer (Rao, 2011). In addition, these practices contribute to severe physical, chemical and biological degradation. The semi-arid areas face very serious problems of land degradation in

the form of soil loss and nutrient depletion posing a threat to food security and sustainability of agricultural production in these areas (Juma *et al.*, 2009).

In the recent past, the government, development partners and donors working in semi-arid areas have devoted substantial resources to increase agricultural production by addressing the challenge using soil and water conservation (SWC) technologies as the key adaptation strategy in developing countries (Kato *et al.*, 2009). As a result, various SWC technologies have been suggested and emphasized as a possible solution for soil and water conservation (World Bank, 2008, SRA; 2004). Indeed, international and national initiatives have promoted SWC technologies for both poverty alleviation and environmental conservation (Shiferaw *et al.*, 2009). A wide variety of programs that promote SWC technologies have been initiated and are on-going in Kenya (Pretty, 2003).

Before independence in 1962, some of these technologies were implemented through strict regulations, prohibitions and coercive communal work; it became linked to colonialism and was largely abandoned after independence (Tiffen *et al.*, 1994, Gachene and Mureithi, 2004 and Khisa *et al.*, 2002). It is instructive that frustration with farmer indifference led the government and donors to stimulate SWC technologies by offering various inducement aimed at conservation (Nyangena, 2007). Farmers' preferences of these conservation technologies vary depending on the costs of construction and maintenance (Biamah *et al* 2005; Kassie *et al.*, 2011), the risks involved and the benefits expected (Nyangena, 2007).

Besides economic returns or profits, other socio-economic circumstances of individual farm household (HH) and risk considerations, often play a significant role in soil and water conservation decisions (Bekele, 2006). According to Rao *et al* (2010), investments in soil and water conservation has been found to be justified in terms of economic returns. However, various constraints that hamper adoption of these technologies are to be addressed so that potential benefits could be realized by the farmers. Teklewold and Kohlin (2011) found that reducing farmers' risk exposure could promote soil and water conservation practices thus land degradation managed.

1.2 Statement of the Problem

To sustain and increase food production from small holder farms in the semi-arid Eastern Kenya, SWC has been strongly promoted over the past 50 years. As a consequence, many soil and water conservation projects and programmes have been implemented to make farmers invest the improved SWC practices. Despite these efforts, the level of adoption of these practices by smallholder farmers continues to be very slow and water shortages and degradation of soil conditions remain a major threat to agricultural production. One of the major problems is with the lack of immediate tangible benefits from the investments on SWC practices.

In these areas, rainfall is highly variable and very likely that the investments on SWC may not result in increased productivity and income in very

dry years in which additional water conserved is insufficient to meet crop production and in very wet years in which crop requirement for the conserved water is very low. As a result, benefits from SWC technologies tend to vary from year to year depending on the amount and distribution of rainfall during and across the seasons and use of SWC practices can help realize the full potential of conserved water. Existing information is not clear about the costs and benefits of SWC in different season types (depending on the amount of rainfall received thus below normal, normal and above normal seasons), with and without complementary technologies and risks involved and opportunities associated with the investment, which is critical to promotion of these technologies. Thus, there is a need to assess the risks and the benefits accrued in their investments with due consideration to the variability in seasonal weather conditions so that SWC technologies can be promoted by tailoring the needs and expectations of the farmers in Eastern Kenya who are risk averse and can hardly afford to make investments that have high levels of uncertainty.

1.3 Justification of the study

Investment into SWC technologies may be undertaken when sufficient returns are expected in comparison with the situation when no such investments are made and more importantly, when farmers are assured that they will reap the benefits for a considerable period of time (Mwakubo, 2002). Moreover, only economically secure farmers who have enough security against risks will

undertake profitable capital investments and innovations (Dercon and Christiaensen, 2007 and Yesuf and Bluffstone, 2009). Thus, farmers will not be interested in investing in SWC technologies and bearing associated risks unless they perceive a significant threat on productivity due to soil erosion and expect economic gains from conservation technologies (Nyangena, 2007). An understanding of the farmers' economic circumstances and ability of the SWC technologies currently being promoted to match those conditions would thus be essential in determining whether the proposed technologies would be applicable to the existing farm conditions. Hence, an assessment of risks and benefits associated with the investments on these technologies is an essential pre-requisite in the selection and promotion of SWC technologies for adoption by smallholder farmers in the semi-arid areas.

Adoption of SWC technologies is also an important option to adapt to future changes in climate. Current projections of future climatic conditions indicate an increase in temperature and increase in variability associated with rainfall as well increased incidence of extreme events (IPCC, 2007). Though there are uncertainties over the exact magnitude of these changes, there is a high probability for temperatures to increase by up to 3°C by end of this century. This will lead to further increase in crop water requirements due to increased evapotranspiration. SWC technologies can play an important role in mitigating the negative effects of climate change.

1.4 Research questions

The study set out to address the following research questions

- i. Which soil and water conservation technologies have most farmers invested in?
- ii. How do socio-economic characteristics of farmers in Mwanja and Kaliu watersheds affect investment in soil and water conservation technologies?
- iii. How profitable are the soil and water conservation technologies being invested by farmers in Mwanja and Kaliu watersheds?
- iv. What are the potential opportunities to reduce risks of investments in soil and water conservation technologies?

1.5 Study objectives

The main objective of this study was to assess the risks and benefits of investments into soil and water conservation technologies under variable and changing climatic conditions in Eastern Kenya.

The specific objectives were

- i. To assess soil and water conservation technology investment by farmers in Mwanja and Kaliu watersheds.
- ii. To examine factors that influence investment into soil and water conservation technologies in the two watersheds.

- iii. To quantify the costs and benefits of short term investments in soil and water conservation technologies with respect to short-term trends in climate.
- iv. To identify the potential opportunities to reduce risks of investments in soil and water conservation technologies under varying climate.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

The problem of soil erosion and land degradation has become more acute due to population pressure on land, land fragmentation, deforestation and encroachment by farmers on ecologically fragile lands. Soil and water conservation measures (SWC) recommended vary from one area to another depending primarily on rainfall intensity, erosivity, erodibility and stability of soils. Other factors like land tenure and size, land use, grazing management, costs and returns expected, income and marketing, information also significantly influence the choice of appropriate conservation technologies (Biamah and Rockstrom, 2002, Mwakubo 2002, Freeman *et al.*, 1996, Pagiola, 1994).

An evaluation done in Semi-arid environment by Liniger *et al.*, 2006, showed that the present analysis detected knowledge gaps especially quantification of the impacts of SWC and cost-benefits assessments, where most information is based on judgements and not on measurements. Research must therefore aid in addressing the identified knowledge gaps, the achievements and the wealth of knowledge should be tapped and used as a basis for present and future SWC activities to enhance conscious investments to be made.

2.2 Definition of terms

2.2.1 Soil and water conservation- according to WOCAT are measurements, practices, techniques taken by farmers, agricultural offices, NGOs etc., to protect the soil and agricultural land from dangers such as erosion or degradation, and to conserve water resources.

2.2.2 Bench terraces are made by digging a trench about 60 cm wide along the contour, and throwing the soil upslope to form an embankment, which has a significant effect in reducing slope-length, and hence soil erosion from steep croplands

2.2.3 Tied ridging is a type of surface configuration whereby the ridges are “tied” to each other at regular intervals by cross-dams, blocking the furrow and can be used when surface run-off is to be prevented. Crops are planted on ridge tops, along ridge sides, or in the furrow.

2.2.4 Irrigation- the action of applying water to land in order to supply crops and other plants with necessary water. Sometimes nutrients may be applied via irrigation as well.

2.2.5 Climate risk in agriculture represents the probability of a defined hydro-meteorological hazard affecting the livelihood of farmers, livestock herders, fishers and forest dwellers. Risk refers to a probability that can be estimated from prior information.

(Definitions from, Selvaraju, S. 2011, Mati, 2005)

2.3 Soil and water conservation technologies

The desired effect of soil and water conservation technologies is to get rid of or reduce the impacts of land degradation. By applying SWC technologies, an attempt is made to conserve or reinstate the multiple functions of land and water resources (de Graff, 1996). Since soil and water constitute the physical basis of agricultural production, SWC technologies are aimed at increasing agricultural production and decreasing soil loss. (Herweg and Ludi, 1999).

Morgan (2005) defined soil and water conservation as a set of measures intended to control or mitigate soil erosion and achieves the maximum potential agricultural productivity of a land without damaging the environment. SWC technologies/ practices consist of the control measures including managerial, vegetative/ agronomic and structural practices aimed at reducing the loss of soil and water. Such methods seek to encourage water infiltration into the soil, reduce its velocity and check run off losses. Examples of management and agronomic practices are strip cropping, mulching, crop rotation, contour cultivation, planting of grasses for stabilizing bunds, planting of trees and afforestation, minimum tillage, organic and inorganic fertilizers; while examples of structural practices are stone bunding, terracing, gully control and control of stream and river banks. More technical practices will include irrigation and other water harvesting technologies such as tied ridges, planting basins, check dams, ponds, tanks and wells used in many rain-fed systems. (Bekele, 2006, Mgbenka *et al*, 2012).

2.4 Investment into SWC technologies.

According to Kerr and Sanghi 1995, the different perceptions about the costs and benefits of investments in soil and water conservation technologies are reflected in the value placed on soil and water conservation measures. Some groups of experts and farmers argue in favour of major efforts for conservation without questioning their cost effectiveness, while others assert that if conservation were profitable, private farmers would care for it themselves.

Farmers, particularly, those with least resources would expect to see benefits within a cropping season from their investments. However, conservation measures usually involve significant initial and ongoing investment in cash and labour with benefits only realized in the longer term (Ellis-Jones and Tengberg, 2000) and since the circumstances of poor farmers are usually characterized by critical scarcity of assets, the highest priority is usually placed on short term benefits (Kato *et al.*, 2009).

High investment reflects individual and community awareness of the negative impacts of soil and run of losses, reduction in soil fertility, agricultural production and land value and increased rehabilitation costs and positive effects of their investments (Gichuki, 2000). Violet *et al* 2010 argues that technologies should have multiple uses and benefits for the farmers and also effectively control soil and water erosion and replenish soil fertility, provide wood for construction, fuel and high quality fodder for livestock for improved crop and livestock performance.

2.5 Risks and benefits of investments into SWC technologies.

Agricultural production is highly interconnected with weather and climate (Selvaraju *et al*, 2011). Rainfall quantity and distribution are important seasonal determinants of crop distribution. In semi-arid tropics, unreliable rainfall, soils with low water holding capacity and high run off results in a high risk of crop failure (Muchow and Bellany, 1991) and this makes investment in agriculture a risky undertaking.

According to Mwakubo (2002) the construction of soil and water conservation (SWC) structures is complex and demanding in terms of labour requirements and technical skills. Local farmers are poorly equipped to deal with these problems since they have little formal training. Also, more solid structures have substantial establishment and maintenance costs. Usually, some land is taken out of production. The productivity enhancement of the structure has to compensate for this yield loss and also compensate for the incurred costs. Productivity increases will materialize in the longer run but may not be sufficient if the farmers have high time preference (Johan, 2011). Understandingly, to farmers future yields trends when investing into SWC technologies are uncertain and have to be experienced.

Place *et al* 1999 also argues that farmers' investment demand may be constrained by other factors such as unfamiliar technological options, investment may be unprofitable or returns may be risky. A research carried out in Kwa Vonza and Kiomo on the benefits of water harvesting and tied ridging as methods of

SWC during the 2001 short rains and 2002 long rains by Itabari *et al* (2002) showed that there was an increase in net benefits in terms of the grains yields obtained.

2.6 Potential opportunities in risks reduction and increasing benefits

Appropriate SWC technologies and optimal utilization of soil and water resources should be encouraged and enhanced so as to sustain and improve food production. Such an effort calls for resource management strategies and technological options that minimize land degradation reduce soil loss and compaction and limit the movement and depletion of soil nutrients and organic matter. The technologies should be compatible with current land potential and traditional farming systems. These conservation farming strategies and options have to be technically and economically feasible. They should also be socially acceptable to local people (Biamah and Rockstrom, 2002).

Poor farmers may not adopt SWC technologies which have limited short-term benefits. This implies SWC technologies and environmental conservation technologies should show demonstrable/ verifiable benefit in a reasonable short time in order to be accepted to poor farmers (Kajembe, 1994).

Muhammad and Parton (1992) described socio-economic factors such as farmers' innovativeness, age, off-farm income, risk and uncertainty limiting investments into SWC technologies thus low adoption of the technologies. Only components that meet farmers' felt needs were adopted. Ockwell *et al* (1991) also

said that resource poor farmers do not easily adopt SWC technologies that require a substantial cash outlay.

According to Freeman *et al* (1996), farmers in semi-arid areas of Eastern Kenya practice SWC technologies when they have both information and resources. Some farmers cannot invest in SWC technologies irrespective of the availability of information on technological possibilities because they do not have resources to re-allocate to investments in soil productivity. Others, with financial resources will be re-allocated to investments into SWC technologies if there are sufficient incentives given their investment portfolio.

A research carried out by Okwach (2000) around Katumani area for 7 years, results did not confirm the cited benefits of reduced tillage in controlling run off and soil erosion losses. He therefore recommended for more rigorous studies to help determine why minimum tillage works in some circumstances and not in others. He said it is possible that there are critical interactions between soil, equipment and climate that spell such differences in the performance of minimum tillage as conservation tillage. He also said that a good conservation approach must find ways and means of retaining some level of vegetation on the soil. This must be done despite the conflicting or competing needs of such cover material such as the prevalent use of crop residue as animal feed.

According to Mwakubo (2002) formal market credits do not function well in agricultural societies due to high information, monitoring and transitional costs. Lack of credit discourages investments in productive activities like soil and water

conservation. Success of investment into SWC requires co-operation behaviour among farmers. For example, run off causing soil erosion does not respect boundaries. This means even if a farmer adopts SWC technologies, he may still face damage from neighbouring farms where no measures are taken.

2.7 APSIM Model in agricultural research

There is an increasing recognition in agricultural research that a systems approach utilizing dynamic simulation models, can assist in interpretation of field experimentation dealing with crop responses to soil management, genetic or environmental factors. In the search for strategies for more efficient production, improved risk management and more sustainable production systems, such as an approach can increase research efficiency by allowing analysis of systems performance at different locations, for varying season length, where climate is unpredictable and relatively variable (Robertson *et al*, 1996).

Agricultural Production Simulation Model (APSIM) was developed primarily as a research tool to investigate on-farm management practices especially where outcomes are affected by variable climatic conditions (Dean *et al.*, 2007). The initial stimulus came from perceived need for modeling tools that provided accurate predictions for crop production in relation to climate, soil and management factors whilst addressing long-term resource management issues in farming systems. The modeling framework is made up of a set of biophysical modules that simulate biological and physical processes in farming systems, a set

of management modules that allows the user to specify the intended management rules that characterize the scenario being simulated and controls the conduct the simulation, various modules that facilitate data input and output to and from the simulation and a simulation engine that drives the simulation process and controls all messages passing between the independent modules (Wang *et al.*,2003).

According to Robertson *et al* (1996), a key concept of APSIM is that the soil provides a central focus, crops, seasons and managers come and go, finding the soil in the same state and leaving it in another. In this way, it is ideally suited to examine crop production issues where feedbacks between crop and soil are of primary concern.

APSIM is capable of simulating a diverse range of farming systems including dry land and irrigated systems, small holder systems etc. it was developed primarily as a research tool to investigate on-farm management practices especially where outcomes are affected by variable climatic conditions. Its use has been extended to looking at modifying farm practices and to include climate risk studies and climate change scenarios (Verburg *et al.*, 1998).

2.8 Gaps in literature

Despite all the above literature, the risks and benefits of investments into soil and water conservation technologies has not been fully documented. Whereas it is sufficiently documented that farmers are risk averse and therefore cannot invest in any technology if the costs are not justified in terms of the benefits

accrued, farmers have continued to shun from some technologies that would be beneficial in the face of varying climate in the semi-arids. The discussion above therefore presents the background information on key issues involved in investments into soil and water conservation technologies and hence formed the entry point of this study. Any meaningful investment into soil and water conservation technologies requires the understanding of the farmers and farmers' conditions as a basis for understanding reasons for or against investment of SWC technologies. Further, adoption and investment into SWC technologies is site specific and hence this study sought to assess the factors, benefits and the potential opportunities in Mwanja and Kaliu watersheds as a basis for effective investments in SWC technologies.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

This study was conducted at two sites, Mwanja watershed in Machakos County and Kalii watershed in Makueni County, located within the semi-arid Eastern Kenya. In these areas, agriculture is mainly rain fed and crop production is severely constrained by low soil moisture, low levels of soil fertility and widespread practice of low input agriculture. Most of the rivers are seasonal and hence cannot supply water when it is most needed. Groundwater resources are not abundant and in many places, the water produced is saline. On average, there is a crop failure in two out of every five seasons. These sites represent well the prevailing agro-climatic conditions in these two counties. Crop production is mainly constrained by the low and erratic rainfall and use of soil and water conservation technologies to improve water availability and reduce the impact of frequent dry spells is essential to increase productivity of crops. The two sites have similar seasons and rainfall distributions but Kalii is warmer than Mwanja and receives lower rainfall with higher variability than Mwanja. These two sites thereby provide different levels of risks and opportunities for investments in soil and water conservation. The dominant soil groups of Machakos and Makueni are alfisols, ultisols and oxisols soils. These soils are all generally of low fertility, and many are highly erodible. The ultisols and alfisols are also susceptible to hard

setting and crust formation, which increases runoff and makes the clay soils hard to plough by the end of the dry season. A rough estimate of the agricultural quality of the region's soils indicates that less than 20 per cent has well-drained, deep, friable red and brown clays of good fertility; more than 60 per cent has very erodible, relatively shallow, sticky, red, black, and brown clays of variable fertility, on steep slopes; 20 per cent has poorly drained, shallow, stoney soils of low fertility (Jaetzold *et al.*, 2007).

3.2 Site characterization

Mwania watershed in Machakos lies around KARI Katumani research station at a latitude of $1^{\circ}34'60''\text{S}$ and longitude of $37^{\circ}15'10''\text{E}$. It is generally characterized as hot and dry with bimodal distribution of rainfall. Rainfall is subject to pronounced variability year to year and breaks in rain occur often and at any time during the rainy season (Table 1).

Nearly 85% of the average annual rainfall is received during the two cropping seasons, long rains between March and May and short rains between October and December. Average total rainfall received during the two rainy seasons at this location is 576 mm of which 293 mm is received during the short rain season and 283 mm during the long rain season. Though both short rain and long rain seasons receive similar amounts of rainfall, short rain seasons are more reliable than the long rain seasons and therefore more important for crop production (Rao and Okwach, 2005).

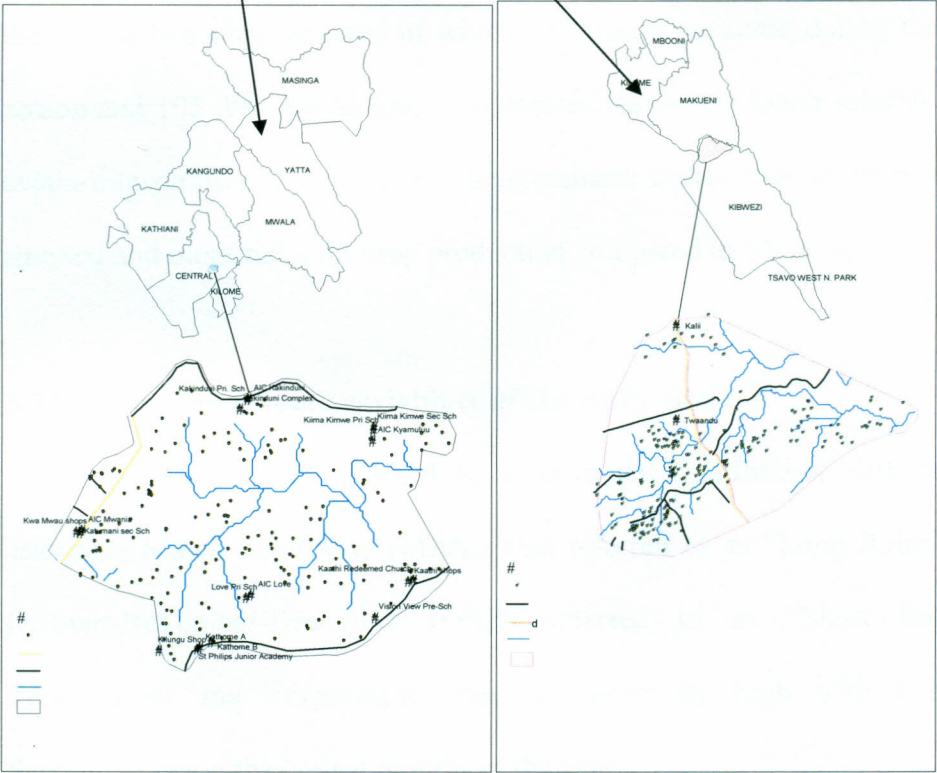


Figure 1: Mwanja and Kalii watersheds in Machakos and Makueni Counties

Annual average temperatures range between 25.0⁰C and 13.1⁰C. However, temperatures during short rain season are slightly lower than those during long rain season. The area has an undulating topography with a hilly terrain and a ground elevation of 1600m above the sea level.

Kalii watershed lies at a latitude of 2⁰11¹ 38S and a longitude of 37⁰44¹04E. The terrain is flat and 970 m above the sea level. Due to lower altitude compared to Mwanja, the temperature regime at this location is warmer. The average annual maximum and minimum temperatures are 28.7⁰C and 17.1⁰C, about 4⁰C higher compared to Mwanja. It receives total mean rainfall of 534 mm during the two rainy seasons of which 337 mm is received during the short rain season and 195 mm during long rain season. Relatively lower rainfall and higher evapo-transpiration due to higher temperatures makes this location more water stressed and more risky for crop production compared to Mwanja.

3.3 Climate and climate variability of the study sites

Rainfall is characterized by a bi-modal distribution with two distinct seasons - March-April-May (MAM) also referred to as “Long Rains” (LR) and October-November-December (OND) referred to as “Short Rains” (SR). Temperature and evaporation rates are generally high with February and September being the hottest months of the year.

Table 1: Climatic conditions at the two locations based on the data from meteorological stations in Katumani Exp. Res. Station and Kiboko Met. Station

	Mwania	Kalii
Annual rainfall (mm)	698	614
Short rain season rainfall (mm)	293	337
CV of short rain season rainfall (%)	48.8	54.2
Long rain season rainfall (mm)	283	195
CV of long rain season rainfall (%)	42.7	51.3
Annual average maximum temperature ($^{\circ}\text{C}$)	25.0	28.7
Annual average minimum temperature ($^{\circ}\text{C}$)	13.1	17.1
Short rain season average maximum temperature ($^{\circ}\text{C}$)	25.2	28.6
Short rain season average minimum temperature ($^{\circ}\text{C}$)	14.0	18.0
Long rain season average maximum temperature ($^{\circ}\text{C}$)	25.9	29.8
Long rain season average minimum temperature ($^{\circ}\text{C}$)	14.4	18.4

Nearly 76 per cent of the Machakos County falls into agro-ecological zones 4 (semi-humid to semi-arid) and about 24 per cent falling in zone 5 (suitable for livestock, sorghum, and millet). Agriculture is mainly through small farmers with most households in agro-ecological zone 4 owning 2-10 ha and in zone 5 owning 2-15 ha. The most common food crops are maize, beans, cowpeas, pigeon peas, pumpkins, sweet potatoes, green gram, and bananas. Farmers intercrop maize, beans, bananas, potatoes, sweet potatoes, and pumpkins. Cabbages, tomatoes, onions, red peppers, and greens are usually limited to river flood plains or poorly drained valley sites.

Analysis of rainfall and temperature records for long periods provides information about rainfall and temperature patterns and their variability. Since the Short Rain (SR) season is the most reliable season in the study sites, 30 years observed rainfall and temperature data (1981-2010) were analyzed to show their variability and are shown below in Figure 2 and 3.

Rainfall amounts during SR season

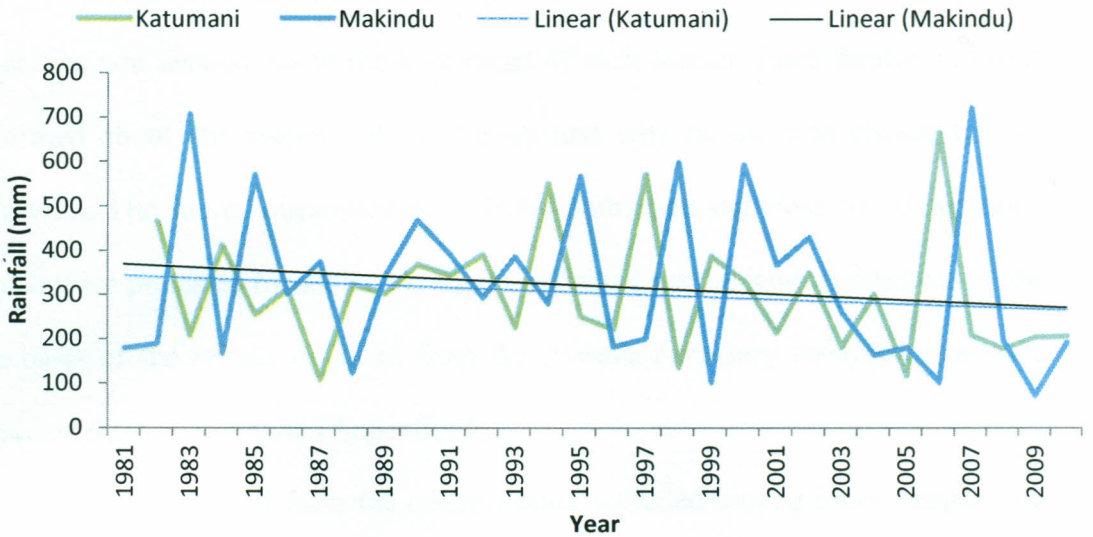


Figure 2: Total rainfall received during SR season in Machakos and Makueni Counties

Average temp during the SR season

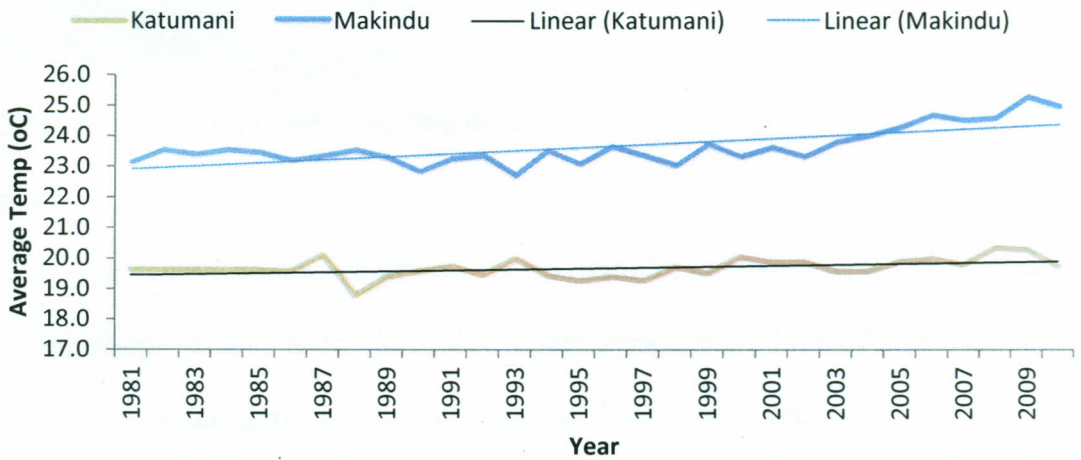


Figure 3: Average temperatures during SR season in Machakos and Makueni Counties

3.4 Data collection methods

A structured questionnaire was used for the field interviews and the interview was carried out in the homestead of each farmer. Each farmer was well informed about the purpose of the survey and why he/she was chosen for the interview. The survey questionnaire included both open and close ended questions which were pretested by administering it to selected respondents. Subsequently, on the basis of the results obtained from the pretest, necessary modifications were made on the questionnaire (Appendix 1).

Data generated from the questionnaire included among other things, type of SWC technologies, cost of production of different crops the farmers planted, size of land used and the length of time the technology has been used. Secondary data was also obtained from literature (scientific reports, proceedings, abstracts) and District meteorological Offices.

3.5 Study population and sampling design

3.5.1 Study population

The sample comprised of households living in the two selected watersheds and members of the Water Resource Users Association (WRUA), which are registered as water users' association under the 2002 Water Act.

3.5.2 Sample size and sampling procedure

Sampling method adopted was two-stage. First the watersheds were delineated, and the number of HHs picked from sub locations depending on the sampling frame of that sub location. A total of 173 households in Mwanja and 207 households in Kaliu, selected randomly from the total households registered with the WRUA were picked for the baseline survey. A structured interview questionnaire was administered as the surveying instrument in the formal survey. The questionnaire covered general household information, household HH assets, availability and use of water resources, important production constraints and use of improved technologies, crop production, and incomes and marketing constraints and opportunities were used. Based on the SWC technologies adopted, purposive sampling method was used to obtain total of 120 households at the two locations. The households were subjected to systematic simple random sampling where every 3rd farmer was selected to achieve the required sample size.

3.6 APSIM model and inputs

APSIM model version 7.3 which was earlier calibrated and validated for the study sites by (Okwach and Simiyu 1999; Okwach, 2002) was used to generate yield data. Long-term yields of maize and bean crops were simulated using the system simulation model APSIM with the long term climate data for the two sites. Available weather data from Katumani meteorological station in Machakos (1958-2009) and Kiboko meteorological station in Makindu (1959-2004) was used for

simulation. Terraces, tied ridges and irrigation were the management practices evaluated. APSIM was configured to simulate sole maize and bean crops.

Table 2: Key soil, crop and management parameters used in APSIM simulations

Parameter	Value			
Soil profile	Luvisol profile with a total depth of 1.5 m divided into six layers (0-0.15, 0.15-0.30, 0.3-0.6, 0.6-0.9, 0.9-1.2, and 1.2-1.5 m)			
Plant available water	Maximum plant available water capacity of 163.5 mm with root depth constrained to 1 m.			
Soil nitrogen organic carbon	Depth (m)	Organic carbon (%)	Initial Nitrate N (kg ha ⁻¹)	Initial Ammonia N (kg ha ⁻¹)
	0-0.15	0.460	2.000	1.000
	0.15-0.30	0.380	1.000	1.000
	0.30-0.60	0.280	1.000	1.000
	0.60-0.90	0.230	1.000	0.500
	0.90-1.20	0.210	1.000	0.500
	1.20-1.50	0.150	1.000	0.500
Management	<p>Tillage: disc</p> <p>Plant population: 4 plants/m² for maize and 15 plants/m² for beans</p> <p>Row spacing and planting depth: 75 cm with 50 cm depth for maize and 45 cm with 30 cm depth for beans.</p> <p>Irrigation criteria: 10 mm at knee length of the crop</p> <p>Fertilizer: NO₃-N</p> <p>Soil water, nitrogen and surface organic matter: Accumulated effects with no resets</p>			

Table 2 above presents the summary of model parameters used for the simulations. In both sites, short rain season (Oct-Dec) was simulated and maize was planted at 4 plants per square meter while beans were 15 plants per square

meter and the sowing window was from mid to end October each year. A crop was simulated to be planted every season and crop residues were removed from the field after harvest. A soil description from Katumani (Chromic Luvisol, Katumani Research Station PAWC=164 mm) was used to simulate soil water and N supply to crops at the two sites.

Scenarios reflecting the soil and water conservation practices were created by adjusting the curve number. For irrigation, 10 mm of water was added when the crop was knee high i.e. one month after planting (Table 2). Yields were simulated under below normal (<250 mm), normal (250- 350 mm) and above normal seasons (>350 mm) using APSIM model to assess the risks and opportunities associated with the investments in soil and water management technologies under the different seasons.

3.7 Climate data analysis

3.7.1 Grouping of seasons into below normal, normal and above normal seasons

This was aimed at determining the number of seasons in each category to establish the number of seasons with adequate rainfall for crop production (assuming fair and uniform distribution). The seasons were categorized into (i) below normal seasons with 250mm of rainfall and below, (ii) normal seasons having between 250 to 350mm and (iii) above normal seasons with over 350mm. A total of 52 years for Mwanja and 45 years for Makindu were used for the analysis.

3.8 Data analysis

3.8.1 Statistical data analysis

The data collected from baseline surveys were entered into electronic forms which were used to generate a database in Microsoft Access. The data were then cleaned for any errors by cross checking with the survey questionnaires. Microsoft Excel was used to enter the data collected from the sub-sample. The questionnaires were examined to ensure they were complete and had been consistently filled in. The data was then coded. Analysis using descriptive techniques, cross tabulation and separation of means using Statistical Package for Social Sciences (SPSS) version 11.5 was then done. In addition, MS- Excel was used to generate tables and graphs. Data generated using APSIM model was subjected to analysis of variance (ANOVA) using R-statistical software. Treatment means were separated by Least Significant differences (LSD).

3.8.2 Economic analysis

Economic analysis was performed on the data obtained for the third objective. The information used for the cost-benefit analysis was collected at specific time for each activity from land preparation to harvesting in the course of the 2010/2011 SR season labour was calculated in terms of man-days using the mean prevalent market wage rates from the study area as opportunity cost for labour provided by household members. To calculate benefits, simple average farm gate prices and mean quantities (kg) of maize and beans were used. All costs

and benefits were calculated per hectare basis in Kenya shillings (Ksh/ha) using the following concepts as defined in economic analysis (CIMMYT, 1988):

$$NB = GF_b - TC$$

$$BCR = NB / TC$$

where,

NB = net benefit

TC = total cost

BCR = benefit-cost ratio

GF_b = gross field benefits which is the product of mean yield and farm gate price.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characteristics of farmers interviewed

4.1.1 Household characteristics

A total of 380 households, 173 from Mwanja and 207 from Kaliu watersheds, were interviewed during the main baseline survey. Most households in the study area were male headed. In both watersheds, results show 89% males and 11% females (Table 3).

Table 3: Household characteristics in Mwanja and Kaliu watersheds in the baseline survey

Household type	Mwanja		Kaliu	
	No. of respondents	Percentage (%)	No. of respondents	Percentage (%)
Male headed	154	89	185	89
Female headed	19	11	22	11
Total	173	100	207	100

Source: survey June 2011.

For a detailed survey on the use of soil and water conservation practices, a sub-set of 120 households using one or more improved soil and water conservation practices was used. Fifty of the households selected for this survey were from

Mwania and seventy from Kalii. In Mwanja, the proportion of women headed households was nearly double (22%) to that involved in the baseline survey while in Kalii was similar to the baseline survey (Table 4). Higher percentage of women in the sub-sample at Mwanja is an indication that more women farmers are using soil and water conservation practices at this location compared to Kalii where no difference in the proportion of men and women using these technologies was found.

Table 4: Household types in Mwanja and Kalii watersheds in the sub sample

Household Type	Mwanja		Kalii	
	No. of respondents	Percentage (%)	No. of respondents	Percentage (%)
Male headed	39	78	62	89
Female headed	11	22	8	11
Total	50	100	70	100

Source: survey March 2012.

Traditionally, male member of the family heads the household and they are the owners of the land and also the decision-makers on matters related to use of land and other related issues (Kajembe, 1994). Males' generally control all household activities including decisions about what crops to grow or what soil and water conservation technologies to invest into. Women on the other hand had user rights to the land and bore the bulk of the agricultural and domestic work. A

woman generally becomes head of the household in the absence male counterpart either from urban migration of her husband, divorce, single-womanhood or by becoming a widow (Fletschner and Kenny, 2011). According to Ashby (1989), in Colombia, women influenced production decisions indirectly, which influenced the type of crops to be planted on the farm. Occasionally, household members make independent decisions on different aspects of the farm activities either directly or indirectly. Lyamchai *et al.*, 1998 observed that presence of higher proportion of women headed, households has a negative effect on investments in soil and water conservation practices because they have limited access to information on SWC and to land and other resources which was the case in the study areas.

4.1.2 Age of the respondents

Majority of the respondents were aged between 25-54 years amounting to 66% in Mwanja watershed and 64% in Kaliu watershed (Table 5). This comprised of the youthful, energetic and economically productive category of the respondents in the area hence an indication of the potential for the success in investment in SWC technologies.

Many researchers agree that the age of the household head may have an ambiguous influence on investments. Young generations as compared to older ones, may be more inclined to adopt new technologies as they learned these in schools and they might have a longer time horizon. However, older people may

have saved money to invest and gained more knowledge through their actual experiences in farming thus they become more knowledgeable in dealing with soil fertility management. Furthermore, older farmers may be motivated to leave something of lasting value for their children, hence invest in long term assets e.g. SWC technologies.

Young generation is involved in agriculture, with a longer planning horizon, more understanding of soil erosion problems and thus more interested in soil conservation. Old farmers on the other hand, may not implement SWC measures due to labour shortage, tend to be conservative thus sticking with their old traditional way of farming (Tenge *et al.*, 2004). In the study areas, thirty five percent (35%) composed of farmers above the age of fifty five.

Table 5: Age of respondents in Mwanja and Kaliu watersheds

Age (years)	Mwanja		Kaliu		Total
	Males	Females	Males	Females	
18-24	0	1	0	0	1
25-34	11	0	11	1	23
35-44	7	2	14	2	25
45-54	8	4	15	2	29
Above 55	13	4	22	3	42
Total	39	11	62	8	120

Source: survey March 2012

4.1.3 Education level of the household head

Majority of the respondents in the study area had education of up to secondary level. In Mwanja, 48% male and 6% female households from the baseline survey and 32% male and 14% female participants in the detailed survey had attained education up to primary level while 35% male and 2% female household heads in the baseline survey and 46% and 4% of male and female household heads in the detailed survey had education up to secondary or higher level. Only 1% and 2% of females had no formal education from both surveys while 2% of females had attained vocational training.

In Kaliu, 1% males in the baseline survey and 3% males and 1% females in the detailed survey had not attained any formal education, 50% and 5% of males and females from the baseline survey and 51% males and 9% females in the sub sample had attained education up to primary level. About 28% males and 3% females in the baseline survey and 29% males and 1% females in the sub sample had attained education up to secondary level while only 5% and 6% males had tertiary education from both surveys.

Pender and Kerr (1996), in their study of villages in India's semi-arid tropics, observed that investments in SWC increased by about 25% of the average investment level for every additional year of education. Also, Tegene (1992) noted that better educated households have more realistic perceptions about soil erosion problems, have more knowledge related to SWC and hence can more easily be involved in conservation activities. Also, educated households are expected to

understand soil erosion problems, have more access to information related to SWC measures (Tenge *et al.*, 2004) and hence can easily invest into different SWC measures. In this study, no major difference was observed in the education profile of men and women households adopting or not adopting soil and water conservation practices. This probably had generally high level of education compared to the areas in the above mentioned studies.

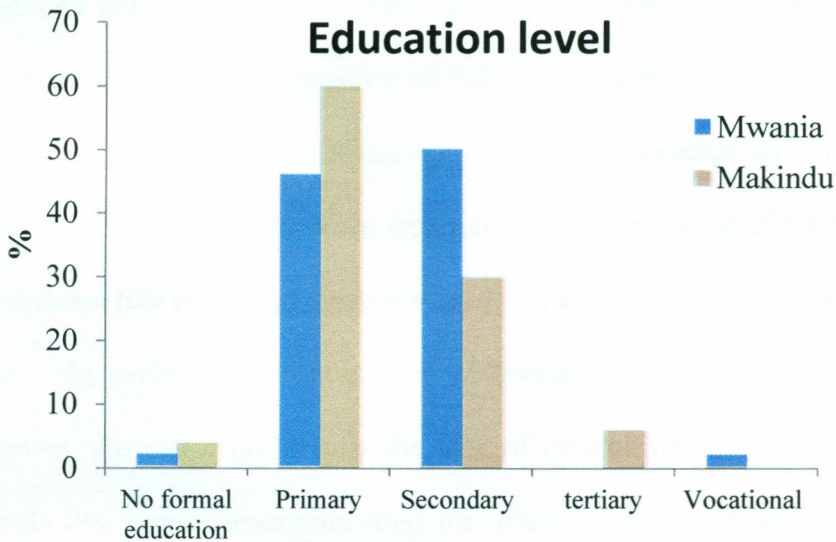


Figure 4: Education level of household head in Mwania and Kalii watersheds

Source: survey March 2012

4.1.4 Employment status of the household head

In the study area, 70% and 69% of respondents in Mwania and Kalii watersheds respectively were full time farmers (these were households whose source of livelihood was entirely from crop production in their farms- implying that such farmers relied entirely on production from their farms to meet all the

food and income needs of their households) as shown in Figure 4. Approximately 28% and 20% of the respondents in Mwanja and Kaliu were employed (mostly civil servants) while 2% and 11% of the respondents were self-employed (had small businesses). Off-farm activities may have a negative effect on the investment into SWC due to reduced labour availability. When the farmer and family members are more involved in off-farm activities, the time spent on their farmland will be limited and hence the family is discouraged from being involved in construction and maintenance of SWC structures. On the other hand, off-farm activities can be a source of income and might encourage investment in farming and SWC. Farmers with more external income sources could afford to purchase equipment like pipes and machines used in a technology e.g. irrigation.

In general, with about 70% of farmers in the study sites being full time farmers, the major problem is the lack of income for the purchase of expensive inputs like pipes, generators used for irrigation and other maintenance of SWC technologies.

Mwania and Kalii

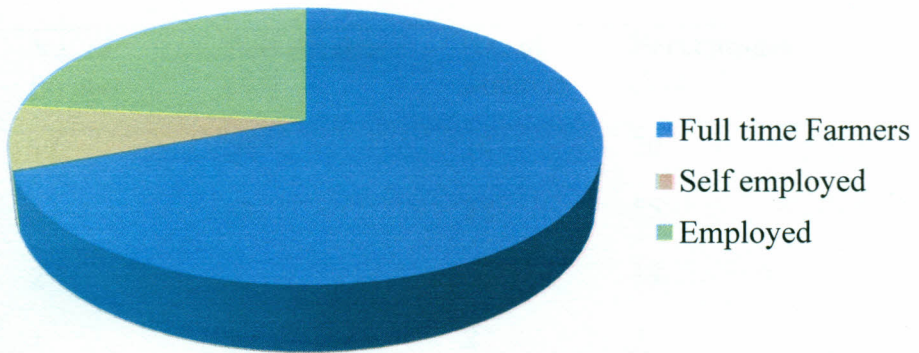


Figure 5: Employment status of the household head in Mwanja and Kalii watersheds

Source: survey March 2012

4.1.5 Land sizes in Mwanja and Kalii watersheds

In the study area, 92 percent and 75 percent of farmers in Mwanja and Kalii respectively had invested in SWC technologies on land sizes between 0.125-5.0 acres. 24 percent of farmers in Mwanja and 20 percent in Kalii had used land sizes between 0.125 acres to 1 acre. 68 percent of the farmers in Mwanja had land sizes ranging from 1 acre to 5 acres with 55 percent in Kalii. 8 percent in Mwanja and 25 percent of farmers in Kalii had invested in land sizes above 5 acres. This clearly shows that investment is an expensive undertaking and unaffordable to many farmers and since 69 percent of the farmers in the study sites were full time farmers with only 31 percent of them with supplementary sources of income which can be used for investment into SWC technologies as shown in Figure 4.

Table 6: Land sizes in Mwanias and Kalii watersheds

Land size (acres)	Mwanias		Kalii	
	No. of farmers	Percentages (%)	No. of farmers	Percentages (%)
<1	12	24	14	20
1-5	34	68	38	55
6-10	2	4	10	14
11-15	1	2	2	3
16-20	1	2	3	4
>20	0	0	3	4
Total	50	100	70	100

Source: survey March 2012

4.2.0 SWC technology investment by farmers

4.2.1 Awareness and use of SWC technologies

During the baseline survey, farmers were asked to indicate the soil water management practices they were aware of and using (Table 7). Results indicate that a high proportion of households who were aware about the soil and water conservation technologies had not really adopted and using them at both locations. For instance, while 81.9% of farmers had knowledge about irrigation only 30.6% were using it. More interestingly, in Mwanias 76.8% and 87% of farmers were knowledgeable about irrigation and tied ridges but only 18% and 16% were practicing the technologies respectively. Overall, awareness and use of terraces

was highest in both sites with 98.9% and 87.1%. The low level of adoption of terraces in Kaliu is mainly due to the relatively flat landscape compared to Mwanja which is hilly and slopes often exceed 25%, making it essential to use structures such as terraces. Except for terraces and Tied ridges, the level of adoption of soil and water conservation practices was higher at Kaliu compared to Mwanja. These findings concur with results obtained by Violet *et al* (2010) who found that terraces were the most adopted SWC technology among other existing technologies in Eastern Kenya.

Table 7: Technology knowhow and use

Technology			Mwanja		Kaliu	
	Knowledge (%) **	Usage (%) **	Knowledge (%)	Usage (%)	Knowledge (%)	Usage (%)
Terraces	98.9	87.1	98.8	98.1	99	76.1
Water harvesting	85.3	53.8	91.6	62.4	80.1	45.1
Irrigation	81.9	30.6	76.8	18	86	43.2
Tied ridges	74.1	41.1	87	16	74.1	66.2
Conservation farming	72.4	44.8	68.9	31.2	75.1	58.3
Mulching	66.1	32.2	75.2	27.3	58.9	37

****Significance at 0.01**

Source: survey June 2011

Technology knowhow and use depend on a number of biophysical and socio-economic factors. Similarly, high level of adoption of irrigation and tied

ridges in Kalii compared to Mwanias is due to availability of water and ease with which it can be applied. The differences within the location are attributed to differences in socio-economic conditions of the farmers. For example irrigation inputs are costly and unaffordable to most farmers since they are full time farmers (70%) as in Figure 4. Tied ridging is labour intensive and this could be the reason behind low usage of this technology in both Mwanias and Kalii locations. Among the technologies, mulching had very low levels of adoption. This probably is due to high value farmers attach to plant residues as livestock feed.

Irrigation gives higher yields and greater intensity of land use. It leads to reduced production variability and greater climate resilience when well designed and maintained. Mulching on the other hand, leads to increased yields due to greater retention in soils. In addition, in drier conditions, it leads to reduced yields variability due to greater moisture retention (Bryan *et al*, 2010). This is well indicated by the adoption of these technologies in Kalii than in Mwanias where rainfall variability is higher.

Adoption of any SWC technologies is related to the awareness of SWC technologies. Farmers with high awareness will invest more and take up the technologies compared to those who have less awareness (Amarasekara *et al*., 2009). There is therefore need for strengthening extension services as this would contribute significantly to increase in adoption and investment in SWC technologies. Generally, awareness and usage of SWC technologies were significant at 1% level of significant in both sites.

4.2.2 Factors affecting investments into SWC technologies

Benefits accrued: This were a significant factor affecting investment in SWC technologies by the famers who had invested into the technologies evaluated as indicated in Table 8. The benefits included yields increase (96%), decreased run off and erosion (81%), increased water infiltration (56%), improved soil moisture conditions (48%) and improved soil physical properties (38%) as shown in Table 10. In Mwanja about 69% of the farmers cited little or no benefit from conservation agriculture for non-investment into conservation agriculture while only 30% at Kaliu (Table 9). The findings indicate that farmers in these two watersheds are more concerned with the product they get in return after putting their money and time in the technologies. Food security is a major concern for many and especially in these areas where rainfall is highly varied. This could explain why yields increase was indicated as the key benefit (highest percentage) compared to other soil benefits which would translate to high yields. These results concur with findings by Kangai *et al* (2003) that analysed the trends in adoption of soil fertility improvement strategies and Liniger *et al* (2006) that explored the impacts of SWC activity on soil productivity and water issues as part of the discussion concerning global change and MDGs. Reducing erosion and run off, increasing soil moisture, and improving soil fertility are basic to increasing crop productivity. Therefore, while many of these practices provide benefits in terms of climate change adaptation, the farmers' main motivations for adopting SWC technologies and practices are their productivity impacts and immediate livelihood

benefits. This finding is supported by (Kiptot *et al.*, 2007). Runoff and erosion causes impairment of the quality and productivity of land, both that are eroded and that are receiving soil material from the upslope. Erosion results in the decline of soil fertility as a result of loss of top soil and nutrients, loss of organic matter and consequent loss of soil's capacity to retain nutrients and water (Danga and Wakindiki, 2009, Mati *et al.*, 2000). This leads to serious impoverishment of land and renders it unusable for crop production. Decreasing runoff and erosion therefore becomes of paramount importance boosting agricultural production especially in semi-arid areas. Farmers' expect that they will obtain returns from their investments within a short time and the benefits thereof should be long term. Most of them will not invest in a technology that do not give returns and that explains why little or no benefit was a significant factor affecting investment into SWC practices by famers who had not invested in the technologies evaluated at both sites (Table 9). This concurs with findings by Gebremedhin and Swinton (2003) who found that soil and water conservation technologies must offer both short term and long term benefits.

Cost of labour: Although labour was not a significant factor, famers who had not invested in mulching and tied ridges cited it as a key constraint in the investment of these practices at both sites with 42% and 28% in Mwanja and 28.2% and 22.7% in Kaliu respectively. Mulching was reported to be labour intensive because of cutting of the mulching materials, drying and applying the

Table 8: Factors promoting investment into SWC technologies

Technology	Mwania				Kaliu			
	Low cost	No additional labour	Benefits accrued**	Input available locally	Low cost	No additional labour	Benefits accrued**	Input available locally
Conservation farming	15.8	10.5	73.7	0	6.4	10.3	80.8	2.6
Irrigation	4.3	0	95.7	0	1.4	0	97.1	1.4
Mulching	3.0	0	93.9	3.0	2.2	2.2	95.6	0
Water harvesting	2.1	4.3	92.6	1.1	1.3	0	98.7	0
Tied ridges	1.6	0.8	95.1	2.5	1.0	1.0	97.9	0
Terraces	1.2	1.8	96.4	0.6	2.0	0	98.0	0

Source: survey June 2011

in the farmland while making of ridges was found labour intensive and time consuming by the farmers.

Labour was not a significant factor affecting investments in SWC technologies by both famers who had invested and not invested in both study sites. This was because labour was supplied by oxen and ox-ploughs which were locally available and owned by most farmers. Famers without oxen reported that they borrowed them from their neighbours or negotiated with their neighbours at a low fee making labour cheap and affordable. In general, the findings indicate that as long as livestock used for cultivation in the semi-arids are available, labour will never be a concern for the famers in the study sites.

High cost of inputs: This was a key constraint to investing in SWC technologies as shown in Table 9 for the farmers who had not invested in the SWC technologies. High cost under irrigation was cited as a major challenge in investment in both study sites with 56.2% and 87.3% of farmers in Mwanja and Kaliu respectively. Most famers in the study sites were full time farmers having their sole livelihood from agriculture production. At the same time, rivers whose water can be used for irrigation are seasonal and if the water was to be utilized for agricultural production through irrigation, farmers are to have reservoirs to preserve the water when the rain falls. This calls for more money which most of them do not have. According to Bryan *et al* (2010), irrigation requires a more significant initial investment by farmers and access to water is crucial which is a

key setback in the semi-arids. Blank *et al* (2002) cited that while the Government of Kenya once provided irrigation facilities to farmers at no cost, this is no longer the case. Farmers now assume a full investment cost to undertake this practice. In order to meet these costs, farmers need to produce crops that can repay this investment and provide a livelihood for their families. Increasingly, farmers need to move from just the production of staple crops to market-oriented crops that can provide the needed cash incomes. In general, farmers adopt and invest into technologies that are beneficial, easy to use and cheap to establish, environmentally friendly and those that are able to increase or maintain sustainable fertility of the soil (Kassie *et al.*, 2011). That is why this was found to be a significant factor for those farmers who had not invested in the SWC technologies.

Completion of a project promoting a technology: Agriculture research and development has been majorly through projects that are normally funded by governments, donors from the developed world or agricultural bodies with different interests, one being farmers' benefiting as the end user of the knowledge that is being generated. Ending of a project was not a significant factor in the investment of SWC technologies. In both sites, it is worth noting that end of a project promoting the use of mulches to conserve moisture had 64.3% and 41.7% of farmers who had not invested in the technologies in Mwanja and Kaliu respectively. This indicates that mulching as a practice cannot be adopted by farmers without external support.

Input availability locally: This was not a significant factor contributing to investments in SWC technologies for the farmers who had invested in the technologies. However, for those who had not invested in the same, unavailability of the inputs locally was very significant. For instance, 74.5% and 41.7% of farmers who had not invested in irrigation in Mwanja and Kaliu respectively mentioned input unavailability a key constraint. Kaliu being close to Mombasa road thus enhanced transport could have attributed to the lower percentage of the farmers in this area although the high percentage of the farmers in Mwanja is a concern since this study site was close to Machakos and therefore very proximal to Nairobi. Investing to technologies like terraces and tied ridges did not need major inputs in both study sites resulting in the low percentage of farmers in this category with as low as 0% in Mwanja. Blank *et al* (2002) found that small holder farmers are constrained by unavailability of agricultural inputs locally which was also reflected in this study. Fertilizers, seeds, irrigation equipment etc. should be within reach and supplied at affordable prices to encourage investment by farmers.

In general, under erratic and apparently deteriorating rainfall conditions in the semi arid areas, major contributions to crop production improvement can be anticipated with SWC technologies. Investment in SWC technologies by farmers is crucial to increasing agricultural productivity hence meeting food and nutrition requirements which is a great challenge in semi-arid Eastern Kenya.

Table 9: Constraints to investment into SWC technologies

Technology	Mwania					Kali				
	High cost **	Labour intensive	Little or no benefit**	Project ended	Input unavailable locally**	High cost **	Labour intensive	Little or no benefit**	Project ended	Input unavailable locally**
Conservation farming	31.8	8	2.1	14.3	9.1	61.9	6.4	7.6	33.3	23.3
Irrigation	56.2	6	2.1	7.1	74.5	87.3	12.7	5	16.7	45.6
Water harvesting	33.5	12	68.8	14.3	1.8	19.6	21.8	29.6	8.3	15.6
Mulching	62.2	42	20.8	64.3	14.5	19.6	28.2	21.8	41.7	13.3
Tied ridges	16.4	28	6.3	0	0	6.7	22.7	15.1	0	1.1
Terraces	0	4	0	0	0	0	5	8.2	23.5	1.1

Source: Survey June 2011

Table 10: Benefits of investments in SWC technologies (%)

Benefits	Mwania	Kalii
Yields increment	98	94
Decreased run off and erosion	78	83
Increased water infiltration	26	86
Improved soil moisture conditions	43	53
Improved soil physical properties	-	75

Source: survey March 2011

4.3.0 Costs and benefits of investments into swc technologies

4.3.1 Production costs for maize and beans without technology in Mwanias and Kalii

Results indicate a significant difference in the land preparation costs in the two study sites (Table 11). The costs were higher in Kalii compared to Mwanias by Ksh 575 and Ksh 885 which was (40%) and (50%) in maize and bean production respectively. This is because of the use of tractors for land preparation by more farmers in Kalii compared to Mwanias where farmers use oxen whose cost was relatively cheaper. Large land sizes and the relatively flat nature of Kalii landscape are the probable reasons for increased use of tractors by farmers at that location compared to Mwanias. Planting costs were generally higher at Mwanias with farmers spending 30% more compared to those in Kalii. Regarding the actual amount spent on seed, no difference was observed between the locations for maize

production but in beans, the investment was 44% higher in Mwanja compared to Kalii which was mainly due to use of higher seed rate and also use of purchased seed. Seed varieties used were mostly local with few exceptions that used Katumani composites which are drought resistant.

Table 11: Maize and beans production costs and returns (Ksh) without SWC technology in Mwanja and Kalii during 2010-2011 SR season

Activities	Maize production		Beans production	
	Mwanja	Kalii	Mwanja	Kalii
Land preparation	850	1425	890	1775
Planting	2110	1430	2930	1760
Seed cost	1095	1175	1580	885
Fertilizer Basal/TD	2075	640	1490	155
Pest control	200	145	65	70
Weeding	3700	2725	4240	2550
Harvesting and threshing	2200	655	1025	440
Total cost	12230	8195	12220	7635
Total costs without labour	6410	4040	5045	3330
Returns	15520	5475	8025	370

Source: survey March 2012

Farmers at Mwanja had also invested significantly in the use of fertilizer and manure than that by farmers in Kalii. While no significant difference was observed on the amount spent on pest control, major differences were observed in case of weeding and harvesting and threshing. In Mwanja, farmers incurred 26%

and 40% higher costs during weeding while on harvesting and threshing, the spending was higher by 79% and 57% for maize and beans respectively. In general, production costs were higher in Mwanja compared to Kaliu. Total costs incurred were 33% and 37.5% higher for maize and beans respectively. Labour constituted the major component of the total investment by accounting for more than 50% of the total investment.

The returns achieved by farmers in Mwanja were much higher than those by farmers in Kaliu mainly due to differences in the potential of these two environments. Mwanja receives higher rainfall than Kaliu and also experiences less variability in its distribution. Hence, the returns on maize and bean at Mwanja were 64.7% and 95.4% higher than at Kaliu for maize and beans. Results further indicate that maize and bean production without SWC technology and with hired labour was only profitable in Mwanja for maize yielding a net profit of Ksh 3290. Production of beans in Mwanja and both maize and beans in Kaliu led to a loss when household labour was accounted for. Farmers in Kaliu suffered a net a loss with the cultivation of beans during this season even after excluding the costs of household labour. The rain received during this season was too low to sustain beans in the fields and thus very few farmers had some harvest and that is why the returns were Ksh 370.

4.3.2 Production costs for maize under different SWC technologies

Results in Table 12 are a summary of the costs and returns involved in maize production under different SWC technologies.

Results indicated that fertilizer use was limited to farmers in Mwanja except for those using irrigation in Kaliu. Additionally, there was a 47.6% and 58.5% higher cost incurred in fertilizer basal in Mwanja under irrigation compared to terracing and tied ridges respectively. Costs incurred during weeding across the technologies in Mwanja were almost equal with only Ksh 400 difference under irrigation. However, in Kaliu irrigation took the highest costs with 48% and 31% higher investments compared to terraces and tied ridges. Irrigation as an expensive undertaking requires that investment made should lead to fruition and that could be the reason why more cash was used in both study locations compared to other technologies to ensure that returns were obtained from their heavy investment.

Pest control was only done under irrigation in Kaliu. Both study sites being prone to high pest manifestation but having very few farmers control them clearly indicated the economic situation of most farmers. These further result in low yields when infestations are high. Farmers therefore need empowerment to improve their economic welfare to minimize yield losses.

Table 12: Maize production costs and returns (Ksh) under irrigation, terraces and tied ridges in Mwanja and Kalii

	Irrigation		Terraces		Tied ridges	
	Mwanja	Kalii	Mwanja	Kalii	Mwanja	Kalii
Land preparation	2700	2755	3050	3530	2010	3235
Seed	855	1565	870	860	355	735
Planting	880	1105	1225	1505	880	1105
Manure	1175	0	1390	0	1030	0
Fertilizer Basal	1240	2510	650	0	515	0
Weeding	4115	7665	4530	3970	4510	5290
Top dressing	585	535	315	0	810	0
Pest control	0	1470	0	0	0	0
Harvesting & threshing	1910	1085	1470	2425	2840	1030
Others(equipment, repair and maintenance, transport etc)	2635	5420	555	1745	1325	2425
T/A cost with other costs	16095	24110	14055	14035	14275	13820
Returns Good Season	36750	47040	26720	37485	22050	48510
Returns Average Season	17700	22080	11125	17640	7350	26460
Returns Poor Season	3970	2645	3610	0	2115	0
P/L Good Season	20655	22930	12665	23450	7775	34690
P/L Average Season	1605	-2030	-2930	3605	-6925	12640
P/L Poor Season	-12125	-21465	-10445	-14035	-12160	-13820

Source: Survey March 2012

T/A – Total Average

P/L – Profit/ Loss

Total cost of production was highest under irrigation compared to terraces and tied ridges at both locations. Between the locations cost of production with irrigation was 33% higher in Kalii compared to Mwanja. When compared with terracing and tied ridges, irrigation required 41.8% and 42.7% higher investment at Kalii and 12.7% and 11.3% higher in Mwanja respectively

Except in poor seasons, gross income from maize was higher in Kalii under all the three technologies with more than Ksh 47000 in good seasons under tied ridges and irrigation. Additionally, tied ridges had 0.3% and 10.3% higher returns compared to irrigation and terraces. In Mwanja, irrigation had 22.7% and 40% higher returns compared to terraces and tied ridges respectively. Lowest gross returns were obtained under tied ridges.

Since the returns vary across years, while collecting the data farmers were asked to indicate how investments and returns on those investments varied from year to year by classifying them into good, average and poor seasons. In general, land preparation and weeding constituted the major part of the investment in terms of the costs involved. There were no significant differences in costs involved with land preparation between the sites and also between the technologies. At Kalii, farmers made higher investment on weeding, fertilizer and pest control when maize was grown under irrigation compared to their counter parts at Mwanja. This was due to the higher temperatures in Kalii and the available moisture from irrigation creating conducive grounds for weed and pest infestation.

During good seasons, irrigation and tied ridges were the most profitable technologies in Mwanja and Kaliu respectively giving Ksh 20665 and Ksh 34960. During poor seasons, investing in any of the technologies would lead to loss. Based on the results, investing in seasons when rainfall falls below normal is risky under all the technologies. In Kaliu where rainfall is very variable, irrigation is the most risky investment while tied ridges the less risky. In Mwanja, irrigation too is the most risky enterprise while terraces least risky. It is therefore important for farmers to have prior knowledge about the expected seasonal rainfall in the locations.

4.3.3 Production costs of beans under different SWC technologies

Land preparation, weeding and harvesting were significant production costs in bean production for all farmers in the study sites (Table 13). Weeding and harvesting were the main production costs accounting to over 30 to 60% of all production costs incurred. Land preparation was done using tractors in Kaliu while in Mwanja oxen and human labour was used. This brought the differences in the land preparation costs in the two sites. Fertilizer use was in Mwanja only with its use in large quantities under irrigation. During planting and harvesting, there was a significant cost difference between the technologies. In Mwanja, irrigation was 35% and 83% higher than terracing and tied ridges respectively. Additionally, there was 57% and 38% higher cost of harvesting during irrigation than terracing and tied ridges.

Other costs involved included purchase of pipes and generators for irrigation, repair and maintenance of the terraces and furrows, buying of fuel (petrol) etc which was different in the various SWC technologies. The costs were highest in Mwanja under irrigation with 87.5% and 77.5% higher compared to terracing and tied ridges respectively. In Kaliu, the costs were 91.8% and 48% higher. Irrigation and terracing had the highest gross returns of Ksh 6395 and Ksh 14150 per hectare in Mwanja and Kaliu respectively. The most profitable technology in both sites, on the other hand was terraces. This could be due to the higher moisture conserved under tied ridges and additional water when irrigation is used compared to terraces affecting the grain yields negatively.

Table 13: Beans production costs and returns (Ksh) under irrigation, terraces and tied ridges in Mwanja and Kaliu

	Irrigation		Terraces		Tied ridges	
	Mwanja	Kaliu	Mwanja	Kaliu	Mwanja	Kaliu
Land preparation	2805	3235	2015	2590	1950	3235
Seed	2940	590	1350	930	480	735
Planting	3530	1295	1285	980	590	1615
Fertilizer FB	2060	0	405	0	130	0
Weeding	4705	7055	4695	3035	5880	3530
Harvesting & threshing	3530	3530	1065	1470	880	940
Others	5460	3000	680	245	1230	1560
T/A costs	25030	18705	14495	9250	11140	11615
Returns Good Season	26460	13230	20890	23400	16080	17275
Returns Average Season	8820	8820	9965	5290	9480	13230
Returns Poor Season	2645	1325	3085	1715	2315	2645
P/L Good Season	1430	-5475	6395	14150	4940	5660
P/L Average Season	-16210	-9885	-4530	-3960	-1660	1615
P/L Poor Season	-22385	-17380	-11410	-7535	-8825	-8970

Source: survey March 2012

T/A – Total Average

P/L – Profit/ Loss

4.3.4 Benefit-cost analysis of maize and beans in the two study sites

Economic analysis was done using average yields (kg/ha) obtained during the 2010/2011 SR season (Table 14). On average, across the different technologies under maize production in both sites evaluated during this season, benefit-cost analysis indicated that irrigation gave the highest net benefit (Ksh 20655) followed by terraces with Ksh 12,665 in Mwanja. In Kaliu on the other hand, the highest net benefits were recorded in tied ridges (Ksh 34690) followed by terraces (Ksh 23450). In both sites, control gave the lowest net benefits. In bean production, terraces gave the highest net benefits in both sites with Ksh 6485 and Ksh 14150 in Mwanja and Kaliu respectively. Control however gave the lowest net benefits.

Benefit-cost analysis (BCA) during the season studied indicated that irrigation and tied ridges yielded the highest benefit-cost ratio (BCR) of 1.3 and 2.5 in Mwanja and Kaliu respectively in maize production. Terraces gave the highest BCR (1.5) in Kaliu under bean production otherwise the BCR was below 1 in the other technologies in both sites. The net benefits accrued were directly related with the BCR. This indicated that considering the net benefit accrued in the technologies evaluated could reflect the cost effectiveness of the technologies invested by the farmers. This therefore implies that going further to do a benefit-cost ratio may not be necessary to determine the most profitable SWC technology to invest in.

Table 14: Benefit-cost ratios of average maize and bean yields under the different soil and water conservation technologies during the 2010/2011 SR season in Mwanika and Kaliu watersheds

	Treatment	Gross benefit (Ksh)	Total cost (Ksh)	Net benefit (Ksh)	Benefit-cost ratio
Mwanika	Maize				
	Control	15520	12230	3290	0.3
	irrigation	36750	16095	20655	1.3
	terraces	26720	14055	12665	0.9
Beans	Control	5495	8195	-2700	-0.3
	irrigation	26460	25030	1430	0.1
	terraces	20980	14495	6495	0.4
	tied ridges	16080	11140	4940	0.4
Kaliu	Maize				
	Control	8025	12220	-4195	-0.3
	irrigation	47040	24110	22930	1.0
	terraces	37485	14035	23450	1.7
Beans	Control	370	7635	-7265	-1.0
	irrigation	13230	18705	-5475	-0.3
	terraces	23400	9250	14150	1.5
	tied ridges	17275	11615	5660	0.5

4.4.0 Potential opportunities towards reducing risk due to varying climate.

Farmers have been found to be risk averse and in semi arids where rainfall is unpredictable and uncertain, reducing risk exposure to farmers can go a long way in ensuring that any investment made in agriculture is worthwhile. A number of different approaches have been suggested as a way to reduce risks of investments in the face of varying climate. Among them are change in crop/ varieties, use of drought/ heat tolerant varieties, fertilizer use, soil and water conservation, seasonal weather forecasts, adjusting planting dates, improved markets and crop insurance (Rao, 2011). Diversifying production, reducing inputs and system flexibility are also some intervention approaches given by Kahan, 2008. The potential benefit achieved include increased soil water availability, improved soil quality, increased income by realizing better prices and reducing vulnerability to price fluctuations among other benefits (Cooper et al, 2008; Rao, 2011). Development of interventions to reducing risk and increasing profitability of investments into SWC technologies in this study evaluated the use of different rates of fertilizers being one of the approaches suggested. Using the system simulation model APSIM, a scenario analysis was conducted to estimate the potential yields based on the seasonal rainfall variations under different fertilizer rates. Fertilizer rates of 0, 20 and 30 kg N per ha for maize production while 10, 20 and 30 kg N per ha for bean production were applied under irrigation, terracing and tied ridges during the seasons under evaluation (below normal <250mm annually, normal between 250mm and 350mm annually and above normal seasons >350mm annually).

Table 15: Simulated maize yields (kg/ha) with different fertilizer rates under the different technologies in Mwanja and Kaliu

Study site	Season type	Fertilizer rate 0kg N/ha			Fertilizer rate 20kg N/ha			Fertilizer rate 30kg N/ha		
		Irrigation	Terracing	Tied ridges	Irrigation	Terracing	Tied ridges	Irrigation	Terracing	Tied ridges
Mwanja	Below normal	738	1108	750	2084	2096	2039	2423	2602	2578
	Normal	791	1163	716	2134	2096	2073	2761	2652	2614
	Above normal	735	1060	647	2043	2070	2004	2699	2637	2545
Kaliu	Below normal	1025	1549	1066	2209	2152	2168	2674	2408	2653
	Normal	1391	2046	1385	2471	2478	2470	2959	2695	2744
	Above normal	1001	1421	910	2052	2139	2064	2718	2548	2652

4.4.1 Effect of fertilizer rates on maize yield

The simulation grain yields shown in Table 15 indicate that investments into SWC technologies with an increased application of fertilizers lead to increased agricultural productivity. In both study sites, when fertilizer rate of 0 kg N/ha was applied highest simulated maize yields were obtained under terracing regardless of the seasonal rainfall received. This shows the ineffectiveness of increased soil moisture without the use of fertilizers. Irrigation on the other hand gave the highest simulated yields with fertilizer rate of 30 kg N/ha. High fertilizer rate with irrigation giving the highest maize yields indicates the efficient utilization of the nutrients facilitated by the available water. This is because water helps in dissolution of nutrients availing them in a form utilizable by the plants. Overall grain yield increase with application of fertilizers was highest when 30 kg N/ha was applied under tied ridges during above normal seasons in both study sites. Grain yield increase was 1898 kg/ha (294%) and 1742 kg/ha (191%) in Mwanja and Kaliu respectively. During normal seasons, the highest grain yields increase in both sites was simulated under irrigation, however, during below normal seasons, tied ridges had grain yield increase of 1828 kg/ha (244%) in Mwanja and 1649 kg/ha (161%) in Kaliu under irrigation. This shows the variation in the nutrition of the soils in the study sites bringing the differences in the water holding capacities which thus translates to the simulated grain yields obtained in response to the fertilizer applied and the water available in the soil. To determine whether application of fertilizers contributed to yield differences, analysis of

variance was carried out on the maize yields. Statistical analysis found out that there were significant differences among the different fertilizer rates applied. These findings are in agreement with Gregory *et al.*, (1997) who found that applying sufficient amounts of N and P fertilizers to soils lacking these nutrients is a very effective way of increasing the efficiency of crop water use in semi-arid areas, so that more dry matter and grain are obtained from the same amount of rainfall.

4.4.2 Effect of seasonal rainfall variations on maize yield

Simulated maize yields obtained were lowest during above normal seasons except when fertilizer rate applied was 30kg N/ha indicating that conserving water during above normal seasons is futile and therefore farmers need to take advantage of the normal seasons unless high fertilizer rate is applied. Maize yields were highest during normal seasons under the different SWC technologies used which could be due to the optimum prevalent conditions promoting growth of the crops. During below normal seasons, moisture is the limiting factor and therefore the yields were lower although higher compared to the yields obtained during above normal seasons. A comparison on the simulated yields obtained during below normal and above normal seasons indicated a yield reduction in both study sites with 103 kg/ha and 156 kg/ha in Mwanja and Makindu respectively under tied ridges when no fertilizer was applied. Upon application of fertilizer to 30kg N/ha, irrigation and terracing had the highest simulated yields increase in the study sites

during above normal seasons. During normal seasons, yield increase was highest under irrigation and terracing in Mwanja and Kaliu respectively. In general, during below normal seasons, highest grain yields were obtained under terracing in both sites. During normal and above normal seasons, highest yields obtained are varied depending on the technology used. This is due to the climate variation in the sites with Kaliu having high rainfall variation compared to Mwanja. This made irrigation give higher yields in Kaliu. Analysis of variance indicated a significant difference at 0.1% between the seasons evaluated (Table 16). This shows that seasonal rainfall received has a great effect on the yields received and therefore farmers' needs to be made aware of the seasonal rainfall expected to avoid the risk of loss in the investments made.

4.4.3 Effect of different fertilizer rates and seasonal rainfall received on maize yield

Maize grain yield varies highly with water availability, soil types as well as with fertilization and relevant agricultural management practices adopted in an area. Comparisons were done under different fertilizer rates and seasons. Under tied ridges, the yield increase was highest with 1357 kg/ha (210%) and 1154kg/ha (127%) when fertilizer was applied from 0 to 20kg N/ha in Mwanja and Kaliu respectively during above normal seasons. There was a further 83% and 64% increase in simulated yields in Mwanja and Kaliu respectively when 10kg N/ha more fertilizer was applied. Lowest yield increase was obtained under terracing in

both study sites. Generally, highest yields were simulated under irrigation during normal seasons with grain yields of 2761 kg/ha and 2959 kg/ha in Mwanja and Kaliu respectively. High yields in Kaliu compared to Mwanja under all technologies and during the different seasons indicate the efficacy of soil and water conservation in this site. Also, rainfall has 46% CV with over cultivated soils and 53% CV with newly opened lands in Katumani and Makindu respectively. Both fertilizer and the seasons in question were very significant when the maize yields were subjected to analysis of variance as indicated in Table 16 in both study sites. This shows that use of soil and water management alone may not be worthwhile and therefore need to integrate fertilizers to achieve better yields and a clear indication that investing in SWC technologies may not be worthwhile without the use of fertilizers and that conservation of water with application of fertilizers is very important as indicated by the results. These results concurs with simulations using APSIM model carried out by Masikati (2011) in Zimbabwe which revealed that grain yield is affected to a great extent by low fertility. She concluded that under low soil fertility conditions in semi-arid areas, maize production is more limited by fertility than soil water.

Table 16: Analysis of variance for simulated maize yields with the different fertilizer rates under the different technologies

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value	Pr (>F)
Fertilizer rate (kg)	2	22915511	11457756	348.072	<2e-16***
Technology	2	237296	118648	3.604	0.03514*
Season type	2	459079	229538	6.973	0.00226**
Study Site	1	709557	709557	21.555	2.88e-05***
Total	46	1514220	32918		

Significant Codes 0 (***) 0.001 (**) 0.01 (*)

4.4.4 Beans responses with different fertilizer rates under the different technologies

In general, simulated beans yields were about 40% higher in Mwanja compared to Kaliu under the different SWC technologies. This is because of the higher temperatures experienced in this region which are hostile to bean production affecting the yields obtained. This indicates that farmers need to seek for an alternative legume that would give higher yields and are drought resistant like pigeon peas and cowpeas. Also, researchers too need to seek for genotypes that resist drought stress to promote bean production. Irrigation simulated the highest average yields under the different fertilizer rates while terracing the lowest average yields (Table 17). Highest yield increase when 20kg N/ha was fertilizer applied was 181 kg/ha (11%) in Mwanja under tied ridges during above normal seasons. In Kaliu, on the other hand, 181 kg/ha (15%) under irrigation during normal seasons were the yield increase. When 30 kg N/ha fertilizer was applied, below normal seasons under irrigation had the highest yield increase in both sites with 383 kg/ha (22%) and 599 kg/ha (34%) in Mwanja and Kaliu respectively. This indicates the need for more water and fertilizers to boost bean yields in these sites especially Kaliu where rainfall is very erratic and varied. Analysis of variance indicated very significant differences in fertilizer use and the technology adopted. This indicates that fertilizer and technology employed are key considerations if bean production in the study sites was to be profitable. Although bean crop

Table 17: Simulated bean yields (kg/ha) with different fertilizer rates under the different technologies in Mwanja and Kaliu

Study site	Season type	Fertilizer rate 10kg N/ha			Fertilizer rate 20kg N/ha			Fertilizer rate 30kg N/ha		
		Irrigation	Terracing	Tied ridges	Irrigation	Terracing	Tied ridges	Irrigation	Terracing	Tied ridges
Mwanja	Below normal	1776	1658	1671	1915	1724	1795	2159	1777	1874
	Normal	1905	1813	1805	2036	1970	1960	2083	2037	2082
	Above normal	1708	1635	1654	1833	1843	1835	1960	1999	1986
Kaliu	Below normal	881	885	895	1025	997	1022	1480	1105	1104
	Normal	1142	988	991	1317	1130	1132	1152	1258	1260
	Above normal	795	826	798	913	970	935	1067	1019	1064

as a legume is known to fix nitrogen on its own, using some fertilizers and conserving water through tied ridging or supplemental irrigation would boost production.

4.4.5 Effect of seasonal variation in bean yields under the different technologies

In both study sites, irrigation had the highest simulated yields during below normal and above normal seasons in both study sites (Table 17). This indicates that beans are efficient in water utilization thus not affected when rains are high and irrigation carried out at the same time. Also, the highest yields obtained during below seasons shows that with fertilizer application and supplemental irrigation, up to 20% increase in bean yields can be achieved. Analysis of variance carried out to determine whether there were significant differences in the bean yields obtained during the different seasons evaluated indicated that seasonal rainfall received and the technology used by the farmers were very significant (Table 18). This indicates that farmers need to do a careful assessment on the technology they invest in and the specific season they grow beans for production to be profitable.

Table 18: Analysis of variance for simulated bean yields with the different fertilizer rates under the different technologies

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value	Pr (>F)
Fertilizer rate (kg)	2	599616	299808	51.766	1.68e-12***
Technology	2	73894	36947	6.379	0.00359**
Season type	2	306729	153365	26.480	2.23e-08***
Study Site	1	9243796	9243796	1596.068	<2e-16***
Total	46	266414	5792		

Significant Codes 0^(***) 0.001^(**) 0.01^(*)

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study revealed that most farmers in the research sites had invested in terracing more than all the technologies evaluated. Almost all farmers had terraces in their farms in Mwanja which was because of the terrain of the landscape in this area. Tied ridges in Mwanja and Mulching in Kaliu were the least used technologies. Generally, all the farmers had invested in one or more of the technologies that were evaluated. Short and long term benefits accrued with investment into SWC technologies was a significant factor for the farmers that invested in the technologies. However, costs for the investments and the unavailability of the agricultural inputs locally have major inference to the farmers who had not invested in the technologies. Under maize production, irrigation and tied ridges were found the most cost effective technologies in Mwanja and Kaliu respectively. Bean production was only cost effective when grown under terraces in Kaliu. Results further indicated application of fertilizers, technology use, season type and study site were significant sources of variation for maize and bean production.

5.2 Recommendations

The following recommendations can be drawn from this research;

- Strategies for reducing farm input prices like fertilizers, fuel prices, pipes etc. need to be sought both from national and county levels in order to make it more affordable to the resource poor farmers in Eastern Kenya. Modalities to bring fertilizers close to the farmers through local shops should be found and packing them in smaller quantities to ensure affordability. This will encourage farmers to uptake and invest in SWC technologies especially irrigation since it has higher returns compared to other technologies.
- Irrigation and tied ridges technologies should be promoted in the study areas for maize production which is the staple food for the farmers. This is because of their cost-effectiveness in maize production. However, since bean production is not cost effective in Mwanja and only under terracing in Kaliu, farmers should seek for an alternative legume and do away with bean production. Researchers too should look for genotypes that resist drought stress if bean production is to be promoted.
- One of the ways towards reducing risk of crop failure even during below normal season is through use of fertilizers and supplemental irrigation. There is therefore need for farmers' empowerment in this study sites to enhance their purchasing power and investment ability to ensure food security in the semi-arid areas studied.

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APPENDICES

Appendix 1: Survey Questionnaire

IDENTIFYING INFORMATION

District	
Location	
Sub-location	
Village	
Household no.	

1. Respondent and general household information

Name of the respondent	
Gender of the respondent	Male/ Female
Age of the respondent	18-24/25-34/35-44/45-54/above 55
Is respondent the household head	Yes/no
If not, relationship to the household head	
Name of the household head	
Gender of the household head	Male/Female
Marital status of the household head	Single/married/separated/divorced/widowed
Level of education of the household head	None/primary/secondary/tertiary/vocational/others (specify)
Employment status of the household head	Employed/self-employed/farmer/others (specify)
Type of wall	Stone/earthen/wood/brick/other(specify)
Type of floor	Cemented/earthen/other(specify)

2. Household composition

	Male	Female
Number of household members aged <18 years		
Number of household members aged >18 years		
Number of household members working full time on farm		
Number of household members working full time off farm		

3. Use of soil and water conservation technologies

Technology/ management practice	Do you know this technology? Yes/No	Are you using this technology? Yes/No	If not, why? <i>See codes</i>	If yes, why? <i>See codes</i>
Water harvesting				
Terraces				
Tied ridges				
Irrigation				
Conservation farming				
Mulching				

If not, (1-High cost, 2-Labour intensive, 3-Little or no benefit, 4-Project ended, 5-Input unavailable locally)

If yes, (1-Low cost, 2-No additional labour, 3-Benefits accrued, 4-Input available locally)

**4. Use of soil and water conservation technology during 2010-2011
Short rain season**

i. Which among the following technologies are you using in your land this season?

1. Water harvesting, 2. Tied ridges, 3. Mulching, 4. Conservation farming 5. Irrigation 6. Other (specify)

ii. On how much piece of land you are using the technology?

1. Less than 1acre 2. 1-5acres 3. 6-10acres 4. 11-15acres 5. 16-20acres 6. More than 20acres

iii. How long have you used the technology?

1.1-5years 2.6-10years 3.11-15years 4.more than 15years

iv. Which crops do you grow using this technology?

Crop 1..... crop 2..... Crop 3..... Crop 4.....

v. How much does it costs to grow these crops?

Item	Unit	Unit cost KSh	Crop 1		Crop 2	
			Units required/ac without technology	Units required/ac with technology	Units required/ac without technology	Units required/ac with technology
<i>Land preparation</i>						
Labor Household						
Labor hired						
Animal						
Tractor						
<i>Planting</i>						
Seed						
Seed treatment						
Labor Household						
Labor hired						

Item	Unit	Unit cost KSh	Crop 1		Crop 2	
			Units required/ac without technology	Units required/ac with technology	Units required/ac without technology	Units required/ac with technology
Fertilizing Basal						
NPK 20:10:10						
DAP						
Urea						
Labor Household						
Labor hired						
Fertilizing top dressing						
DAP						
Urea						
CAN						
Labor Household						
Labor hired						
Pest control						
.....						
.....						
Labor Household						
Labor hired						
Hiring charges for Sprayer						
Weeding 1						
Labor Household						
Labor hired						
Herbicide						
Weeding 2						
Labor Household						
Labor hired						
Herbicide						
Weeding 3						
Labor Household						
Labor hired						

Item	Unit	Unit cost KSh	Crop 1		Crop 2	
			Units required/ac without technology	Units required/ac with technology	Units required/ac without technology	Units required/ac with technology
Herbicide						
Bird scaring						
Labor Household						
Labor hired						
Material						
Guarding						
Labor Household						
Labor hired						
Material						
Harvesting & Threshing						
Labor Household						
Labor hired						
Material						
Investment on technology						
Cost of material						
Cost of labor						
Equipment						
Repairs & maintenance						
Others (specify)						
Others						
Communication						
Transport						
Land Tax						
Lease rent						

vi. What yields do you expect from the use of these technologies?

	Season type	Grain Yield Without technology	Grain Yield With technology	Price grain/bag/kg	Fodder yield without technology	Fodder yield with technology	Value of fodder
Crop 1.....	Good						
	Average						
	Poor						
Crop 2.....	Good						
	Average						
	Poor						
Crop 3.....	Good						
	Average						
	Poor						
Crop 4.....	Good						
	Average						
	Poor						