IMPROVING SMALL HOLDER LAND PRODUCTIVITY THROUGH PROMOTION OF SUSTAINABLE SOIL AND WATER CONSERVATION TECHNOLOGIES IN MACHAKOS DISTRICT: A CASE OF VEGETATIVE MACRO CONTOUR LINES

BY

BAARU MARY WAMUYU
A80/80031/09

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN DRYLAND RESOURCE MANAGEMENT, UNIVERSITY OF NAIROBI

MAY 2011

Declaration

This thesis is my original work and has not been presented for a degree in any other University.

Signature ____________ Date 30 May 2011

Baaru Mary Wamuyu

This thesis has been submitted for examination with our approval as university supervisors

Signature ____________ Date 30th May 2011

Prof. C.K.K Gachene, Department of LARMAT

Signature ____________ Date 02.06.2011

Dr. R.N. Onwonga, Department of LARMAT

Signature ____________ Date 30/05/11

Prof. J. P Mbuvi, Department of LARMAT

Dedication

To my family,

My Dear husband Simon N. Mwangi who believed in me and tirelessly stood by my side to the end.

And children, Loise, Rogers, Victor, Ken, Bill and Antony who encouraged and gave me hope to soldier on.

Acknowledgment

I thank the Almighty God who bestowed the grace to successfully go through this study to the finishing line. I express my heartfelt gratitude to my supervisors Prof. Gachene, Dr. Onwonga and Prof. Mbuvi for their guidance, encouragement and support throughout the study to completiont. I acknowledge the Ministry of Agriculture (MOA) for giving me study to pursue this research. Special thanks go to Regional University FORUM (RUFORUM) and National Council for Science and Technology (NCST) for making this study possible through financial, logistic, and moral support. I owe my deepest gratitude to Fendinard Anyika and Martha for their assistance during laboratory analysis and to Francesca for assistance in field work. My sincere appreciation goes to the International Livestock Research Centre (ILRI) librarians for their backing during literature review. It is my pleasure to thank Katheka-kai farmers especially Alphonse, Philomena, Kioko and Nyamai for giving their land and time for this study. I am also grateful to Kathumo for the timely input and assistance during landsat maps analysis. Finally, I feel indebted to thank many of my University of Nairobi (UoN) and Kenya Agricultural Research Institute (KARI) colleagues for their continued encouragement throughout the study.

Abstract

The study was carried out at Kathekakai settlement scheme, Machakos District to evaluate effects of vegetative macro contour line on soil moisture content and crop performance. In addition, the study also looked at land use and land cover changes in the area, farmer perception on soil erosion and, soil and water conservation technologies as well natural resource change. The research methods used in this study included: baseline survey, focus group discussions and farmer interviews, landsat imagery map analyses and establishment of vegetative macro contour line. The latter comprised of three treatments, namely, terraced vegetative macro contour line with maize-dolichos intercrop and ditch (TVMDD), un-terraced vegetative macro contour line with maize-dolichos intercrop and vegetative macro contour line (UVMD) and terraced vegetative macro contour line with maize mono crop and ditch (TVMD), arranged in a Randomised Complete Block Design (RCBD). Observations were made on soil moisture content and crop performance under these treatments. Analysis of Variance (ANOVA) was conducted and means separated at $P \leq 0.05$.

The result confirm that soil erosion is a major challenge at Katheka-kai settlement scheme, and that most farmers rely more on advice from other farmers (65%) than experts (40%) to control runoff. Lack of training (30%) was identified as key constraint to investment in soil and water conservation measures. Farmers also reported that natural resources (e.g. forests and water resources) had declined with time, a situation they associated with increasing population usually leading to land clearing either for agricultural or development activities.

According to landsat imageries, savanna grassland, forest cover, cultivated land and built-up areas increased by 15.8, 2.7, 1.8 and 0.5% whereas rocky areas, bareland and water bodies

decreased by 12.8, 7.4 and 0.5% between 1988 and 2009 respectively. However, rocky and bare land became forested, a situation that was associated to population growth that made people to settle on any available land.

Results on soil moisture content indicated higher soil moisture levels along the ditch than all other slope positions within the bench. Although there were no significant differences between treatments, terraced benches recorded 15% and 13% higher soil moisture in TVMDD and TVMD treatments respectively compared to UVMD treatment. Furthermore, the upper and lower slope positions gave significantly ($P \leq 0.05$) higher soil moisture content compared to middle position. Besides, biomass yield and crop perfomance trend on the bench terrace was similar to that observed for soil moisture. While no significant differences were observed for biomass yield and plant height, TVMDD had plants taller by 60% than those in UVMD treatment. Moreover, TVMDD and TVMD treatments gave 9 and 2% higher biomass yield respectively compared to UVMD treatment. Additionally, upper and lower slope positions tended to have taller plants and higher biomass yield than the middle slope position.

The results show some degree of effective soil moisture conservation associated with the ditch which seems to serve as a water harvesting site. The findings thus, signifies the possibility of enhancing productivity through establishment of terraced vegetative macro contour line. For this reason, the technology ought to be considered when advising on and implementing agricultural activites.

TABLE OF CONTENT

List of Figures

Chapter 3

Chapter 5

Chapter 7

Chapter 8

List of Tables

Chapter 3

Chapter 5

Chapter 6

Chapter 7

Chapter 8

List of Plates

Chapter 3

Chapter 4

Chapter 6

Chapter 7

Chapter 8

CHAPTER 1

INTRODUCTION

1.1 Introduction

Dwindling investments in the agriculture sector, escalating population, degrading land resources and vagaries of climate change and variability has contributed to steady decline of agricultural productivity in recent years and hence a threat to food security. This situation is further aggravated by land degradation resulting from among others soil erosion and runoff, where about 250 million people in the developing world are directly affected by land degradation through loss of soil nutrients and reduced land productivity, and thus potentially affecting 2.5 billion people living in the drylands worldwide (Reynolds et al. 2007). The problems are more severe in semi-arid regions often characterized by low and erratic rainfall, high temperatures and evapotranspiration, long dry periods, and poor vegetation cover (Thomas, 1988).

Population pressure has further forced many farming communities to settle in marginal dry areas, with severe and pronounced soil degradation and this affects natural resource base in different ways. First, it increases demand for basic living needs e.g. food, water, arable land, second, it creates the need for more agricultural land, which encourages encroachment into forests and woodlands and third, the impact of degraded natural resource base affects rural communities more than any other. These further threaten achievements of Millennium Development Goals (Mortimore, 2006), especially goal number one of eradicating extreme poverty and hunger and goal number two of ensuring environmental sustainability. Moreover, increased cultivation of highly steep slopes with annual crops and overgrazing in these fragile areas without effective conservation measures has contributed to soil erosion (Mortimore, 2006).

Currently, soil degradation by erosion affects 1966 million hectares worldwide with estimated soil loss of 200–1000 Mg km^{-2} $year^{-1}$ (Lal, 2007). This contributes to low and declining farm productivity that profoundly affect poor farm households with minimal economic margins. Apart from low food production, soil degradation seriously affects other natural resources essential to community livelihoods and development. For example, increased sediment loads in water due to erosion and runoff degrade the quality of the lake water, which harm the fisheries as well as water supply for both human and livestock consumption and, power generation. These deleterious consequences, in turn lead to health problems (Reynolds et al. 2007). Despite this, many farmers remain largely unconvinced on the value of relatively sophisticated and labour intensive soil and water conservation measures such as water harvesting, construction of trenches and water ways.

In Kenya, about three quarters of the population are engaged in agriculture and this makes land degradation important. However, this industry is threatened by the increasing soil erosion and runoff. Soil and water erosion was first identified in Kenya as a major environmental problem in 1935 and in the 1940's, when the colonial government introduced the first soil and water conservation measures in the country (Gachene and Mureithi, 2004; Khisa et.al. 2004). Although this was a noble idea, the implementation was based on forced communal labour that made farmers resist the move and hence little happened until 1970 when the Kenyan Government initiated the National Soil and Water conservation campaigns under the National Soil Conservation Project (NSCP) (Gachene and Mureithi, 2004; Khisa et.al. 2004). Machakos District was used as a pilot project. However, the approach of this initiative disregarded farmer's knowledge and hence did not achieve its intended objectives. Since soil erosion is a rampant problem in the Kenyan Arid and Semi Arid Lands (ASALs), there is an urgent need to address this setback through a participatory approach, use of environmentally friendly, feasible, and sustainable soil and water conservation methods for increased adoption rate.

There is a consensus that physical soil and water conservation measures are more expensive than biological measures (Thomas, 1988; Gachene et.al. 2002) and potentially dangerous, causing great damage if they fail to contain runoff. This has led to the growing emphasis on the use of indigenous soil and water conservation (ISWC) measures, such as trash lines, terraces, stone bunds (stone lines), wooden barriers (log lines), pits and basins and grass strips as soil and water conservation measures in the semi-arid areas and humid potential areas (Fagerstrom, 1994; Sitek, 1996). However, some of these measures (e.g. grass strips) have been shown to increase nutrient and moisture competition between plant and grass (Thomas, 1993; Belay, 1992) and hence decrease crop yields (Kinama et. al. 2007). Furthermore, most of these measures are cost ineffective and benefits are not realized as fast as the farmers would wish. Effective soil and water conservation measures should therefore largely borrow and build on indigenous soil and water conservation techniques for targeted research and technology development.

This study was carried out at Katheka-kai Location in Machakos District, Kenya. The area was selected by stakeholders from Ministry of Agriculture (MOA), farmer representatives, Kenya Agricultural Research Institute (KARI) and University of Nairobi (UoN). It is a new settlement and has not benefited from previous National Soil Conservation Project or National Agriculture and Livestock Extension Programme. According to the local people, the name "Kathekakai" means land that has harsh environment. The area has witnessed bush clearing for cultivation, cutting down of trees for building materials, firewood and charcoal burning together with frequent dry spells which has continually exposed the land to soil and water erosion (Gachene and Mureithi, 2004; Khisa et.al. 2004). This made the area an appropriate site to study land use changes, current status and measures used to control soil erosion with the view to formulate and develop realistic and appropriate soil and water conservation technologies in a participatory approach.

The underlying rationale of this study was to unlock the agricultural potential of the ASALs through use of vegetative macro contour lines (a technology that potentially offers multiple benefits e.g. high fodder quality, fuel wood, nitrogen fixation and hence improved soil fertility, reduced competition for resources) as a means of overcoming prevailing agriculture production challenges and consequently address the chronic poverty levels, food insecurity, and environmental degradation.

1.2 Problem statement

Soil erosion and runoff are the major limiting factors to crop production and are more severe in semi-arid regions of Kenya, often characterized by extreme weather conditions and poor vegetation cover. Population pressure have further forced many farming communities to settle in marginal dry areas. Effects of climate change have further worsened the condition in the dry lands. In addition, the sizes of land parcels have continued to decrease with time hence the farms are continuously cultivated year round. Since most farmers in the marginal areas are resource poor, use of fertilizer and other soil amendments to replenish soil fertility are not within their reach. This coupled with the need to produce more food for the ever-growing population has led to further land degradation through accelerated soil erosion and runoff.

Soil erosion and runoff strategies advocated by the extension agents have often not taken into account the farmers' knowledge, experiences and views, and are often expensive and labour intensive. This together with lack of appropriate measures has made many farmers to remain largely unconvinced on the value of undertaking appropriate soil and water conservation approaches, which translates to low adoption rates (Tenge, 2005). On the other hand the largest population among the smallholder farmers of the semi-arid areas of Kenya are poor with limited resources to invest in SWC. Furthermore, farmers are often not involved in the development of SWC technologies. The outcome is reduced land productivity that cannot meet the basic needs of the resource poor. This study therefore aimed to determine factors that influence adoption of soil and water conservation measures with the aim of developing and establishing in a participatory way, a soil and water conservation technology that meets most of the farmers needs.

1.3 Justification

A general consensus is that physical soil and water conservation measures are more expensive than biological measures (Okoba and De Graaff, 2005) and thus lead to low adoption due to high cost of labor and capital investment, perceived wastage of land and slow response to soil fertility improvement. The desire of resource poor farmers is to earn a better living for the household and this most often outweighs the need to invest in expensive and labour intensive conservation technologies. Conservation technologies should therefore be easily accessible, locally available, low cost and builds on or blends with the farmers' ISWC techniques. At the same time, conservation technologies that improve crop performance on sustainable basis and have high potential for multiple uses are likely to be highly valued by farmers. Most of the SWC measures and especially the popularized contour hedgerow provide only limited early returns on investment (Bayard et al. 2007). Furthermore, the general feeling of farmers is that improved yield response only comes several years after hedgerow establishment (Kiepe, 1996). Therefore, alternatives, which reduce soil degradation and at the same time meet farmer interests, are required.

Vegetative Macro Contour Line is one technology that provides multiple benefits and is effective for soil erosion and runoff control and, replenishes soil fertility. Other benefits include: minimum competition for resources between food crops and creeping legume and shrubby legume, replenishing soil fertility through nitrogen fixation and nutrient pumping, trapping sediments, high quality fodder, microclimate improvement, fuel wood, timber, erosion reduction and terrace stabilization. This novel approach to soil and water conservation in dry areas will result in a more efficient, cost effective and easily adaptable system for smallholder farmers in dry areas. This will in turn bring about sustained exploitation of the soil for agriculture with resultant increased food production for the growing population and a well-protected environment. Consequently, the majority of the resource poor small-scale farmers will enjoy better standards of living.

1.4 Objectives

Overall objective

The overall objective of this study was to improve small holder land productivity through establishment and promotion of sustainable soil and water conservation technologies in semi-arid areas of Machakos District, Kenya

Specific objectives

- Determine the factors that influence the adoption of soil and water conservation measures in Kathekakai Settlement Scheme
- Evaluate the spatial and temporal land use and land cover changes for the last 21 years
- Assess the effect of vegetative macro contour lines on soil moisture conservation and crop performance

1.5 Hypotheses

The study was based on the following assumptions,

1) Adoption of soil and water conservation technologies is influenced by a range of socio-economic factors
2) Use of new remote sensing and geographic information tools will lead to a better understanding of the spatial and temporal land use changes
3) Vegetative Macro contour lines will conserve soil moisture and hence improve crop performance

CHAPTER 2

LITERATURE REVIEW

2.1. Adoption of Soil and Water Conservation Measures

2.1.1. Technology adoption

Technology has been defined in various ways. Rogers (1995) defines technology as the design for instrumental action that reduces uncertainty in cause effect relationship involved in achieving desired outcomes. Enos and Park (1998) defines technology as the general knowledge of information that enable tasks to be accomplished, services to be rendered or products manufactured. According to Abara and Singh (1993) technology transfer is the actual application of that knowledge that would be termed as technology. Another definition of technology is a "set of new ideas, usually associated with some degree of uncertainty and lack of unpredictability on their outcome." For a technology to have economic impact, blending into normal routine without upsetting the state of affairs is required. Technologies that are usually aimed at making work easier, are described as labour, time, capital and/or energy saving, which according to economists is saving on scarce resources. The idea should therefore entail overcoming rather than eliminating uncertainties and hence, this study aims to establish the social, economic and institutional factors influencing adoption of soil and water conservation technologies with a view to incorporate the findings in order to develop farmer friendly and appropriate technologies.

2.1.2. Determinants of adoption

Adoption is an outcome of a decision to accept a given innovation. It is a mental process an individual passes from when they first hear about the technology to when they finally utilize the technology. Usually a technology being adopted must have an advantage over the convectional practices, and should at least encompass some degree of benefit to the potential users (Rogers, 1995). Charlotte and Slaymaker (2000) demonstrated that investment in SWC was greatly influenced by the degree to which agriculture is a source of livelihood, agricultural land was scarce; and/or the potential to increase yields and especially of high value crops. In Bantieniema, Burkina Faso where agriculture is the main source of income, farmers reclaimed abandoned land (Bandre and Batta, 1999) while those in Pankshin, Nigeria continue to cultivate land which would be considered unsuitable for agricultural farming (Ahmed et al., 2000). In both cases, the importance of agriculture in rural livelihoods and the shortage of agricultural land are the driving forces for investment in SWC.

Several factors have been found to affect adoption and different authors have attempted to classify them. For instance, McNamara et.al. (1991) classified the factors as farmer characteristics, farm structure, institution characteristics and managerial structure. Kebede et.al. (1990) categorized the factors into social, economic and physical characteristics. Others still group them into human capital, production, policy and natural resource characteristics (Wu and Babcock, 1998). Therefore, there seems to be no standard classification and hence categorization is done to suit the current technology being investigated, location and researcher preference or even to suit the needs of the client. In this study, social, economic, and institutional factors were used.

2.1.2.1. Social factors

Most SWC measures are labour intensive and are affected by high population density and off-farm diversification and migration (Hatibu et al. 2000). The ever increasing population has placed a high demand on land. However, the relationship between SWC and population growth is complex (Charlotte and Slaymaker 2000). Population growth has been shown to increase soil and water resources degradation where migrants did not understand the unique local environment (ENDA Pronat, 2000), while reduced availability of land associated with population growth led to an increase in SWC investment (Bandre and Batta 1999). High population density and limited off-farm diversification and migration also influence SWC investment (Hatibu et al. 2000).

2.1.2.2. Economic factors

Economic factors also play a role in determining whether farmers will adopt SWC technologies. For instance, contour hedgerow which is a very common and frequently advocated for use as a SWC measure, provides only limited early returns on investment (Bayard et al. 2007), and the general feeling of farmers is that the benefits are realized several years after hedgerow establishment (Kiepe, 1996). Reduction of 15–25% of the cropping area due to additional hedgerow planting and competition between hedgerows and crops, as well as high labour requirements are other major concerns of farmers when applying SWC (Pansak et al. 2008).

Many authors have reported varied reasons influencing investment in SWC. Significant investment in SWC observed in Senegal, Tanzania and Nigeria, is associated with the potential to improve yields of selected high-value crops (ENDA Pronat, 2000). In Ghana and Burkina Faso, areas identified with low agricultural productivity, investing in agriculture and SWC was found to be of lower interest (Bandre and Batta, 1999). A study in Uganda pointed out continued livelihood insecurity and market collapse as major driving forces to the desire to invest in SWC (Makumbi and Okubal, 2000). This means that investment in SWC measures is not only area specific but also influenced by varied forces .

2.1.2.3. Institutional factors

Awareness removes doubts about a technology and thus, helps farmers make informed decisions and choices (Caswell et al., 2001., Feder and Slade, 1984). It is therefore important to create awareness for increased adoption of technologies. Some of the ways to access information is through informal education e.g. media, extension personnel, visits, meetings, and farm organizations, and through formal education. The greatest challenge is to make this information reliable, regular and accurate. It therefore becomes paramount to understand the people and issues at hand in order to package information that is effective.

The ideal situation is where information on new technologies originates from experts (Government agents, researchers, NGO's). However, other farmers as well farmers' own experience play a big role in information transfer. Exchange of ideas among farmers has been found to be more frequent and efficient with those familiar and similar to them (Murphy, 1993), and hence farmer field schools (FFS) become crucial in extension services. Farmer field schools encourage peer learning and by so doing develop farmer expertise that enables them make their own crop management decisions, and this has been found to increase adoption of technologies. A study by Agwu et. al. (2008) found a positive relationship between farming experience/social participation and adoption of improved technologies while Dinpanah et.al. (2010) reported that

63.9% of farmers who participated in FFS adopted rice production technologies compared to only 13.3% who had not participated in FFS and adopted the technology. This notwithstanding, extension services plays a key role in technology dissemination and adoption. A publication by IFPRI, (1998) stated that "a new technology is only as good as the mechanism of its dissemination" to farmers". Diebel et. al, (1993) indicated that dissemination in the context of agricultural technology positively influenced adoption and reduced the negative effect of lack of years of formal education in the overall decision to adopt some technologies.

It is clear that adoption is influenced by a range of factors, which may vary from place to place. For instance, in Machakos District, Kenya, increased population was found to be important for providing capital, labour and new knowledge etc that promoted use of SWC and hence led to reduced soil erosion (Tiffen et. al. 1994). On the other hand, Ong et.al. (2002) found that the fewer the people utilized the resources, the less erosion. The purpose of this study was to identify factors and challenges that influence adoption of SWC and bring into play the findings in developing and up scaling of farmer driven SWC technology that can be highly adoptable.

2.2. Participatory Resource Mapping

Participatory resource mapping which is referred to as community mapping is used to show the link between local people and landscapes (Cobert et.al, 2006). It involves mental reflection and classification of the surrounding land and location of important resources and sites and putting together the community observations into maps. The ability of individual citizens and communities to share their understanding of the past, present and visions for the future is an important pre-requisite to informed planning and, through this, to building a consensus on complex issues such as sustainable development (Curwell and Hamilton, 2003). Through maps, communities are able to communicate long but invisible history of managing resources.

Participatory maps have widely been used by communities and external facilitators to enable effective land use planning (Chambers, 2006., Rambaldi, 2005). Lasimbang (2009) found that through community made maps, people were able to advocate for indigenous land and resource rights in Malaysia. Further still, the Ogeik, Sengwer and Yaiku indeginous communities in Kenya were able to initiate their own ancestral land rights, cultural rights and natural land resource management projects after a participatory resource mapping exercise carried out in 2006 (Muchemi et.al. 2009). This study aims to use community knowledge to understand changes in natural resources that have taken place in Kathekakai settlement Scheme since the place became a settled area in 1995.

2.3. Land Use Changes

2.3.1. Land use and land cover change

Land use change is used to describe human uses or actions which lead to modification or conversion of land cover. In fact, human beings are increasingly recognized as a dominant force in global environmental change (Moran 2001, Turner 2001, Lambin et al. 2001), associated with exploitation of earth surface leading to landscape alterations. Kamusoko and Aniya (2009) observed deforestation and the encroachment of cultivation in woodland areas as a continuous trend in all the land tenure systems. Further, Drummond and Loveland (2010) identified a transition mode from regional forest-cover gain to one of forest-cover loss caused by timber cutting cycles, urbanization, and other land-use demands. These land use alterations have the potential to affect global cycles, which in turn influence life on planet earth.

The need to understand land-use and land-cover change results from their direct relationship to many of the planet's fundamental characteristics and processes, including the productivity of the land, the diversity of plant and animal species, and the biochemical and hydrological cycles (Sherbinin, 2002). Land-cover change, especially the conversion of forested areas into other uses has been identified as a contributing factor to climate change, accounting for 33 percent of the increase in atmospheric CO_2 since 1850 (Sherbinin, 2002). More-natural landscapes can capture and store carbon in the soil, decreasing the amount of carbon dioxide in the atmosphere. If vegetation and/or the soil is disturbed, stored soil carbon can be released back into the atmosphere. Rai and Sharma (2009) found that forest conversion to other land uses during the thirteen year period resulted into large amounts of carbon (7.78 Mg C ha-1 yr-1) release from vegetation and soil. The converted agriculture and wasteland showed rapid turnover and increased flux relative to stored carbon and further, soil carbon levels drastically declined from forest to cropped area.

Land use by humans lead to changes in land cover that can negatively impact on biodiversity. Conversion of natural wood- and grass-lands to more developed uses decreases the amount of habitat available. However, different species have different habitat requirements. While some plant and animal species do better in patchy, fragmented environments, others need large, uninterrupted areas (CARA, 2006). Land use change can either affect soil and water erosion positively or negatively (Vien, 2009). More developed areas were found to have large areas of impervious surface and this increases rainstorm runoff as water cannot soak into the ground, hence increasing flood and water pollution risks into lakes and streams (CARA, 2006). Further still, human activities disturb natural land cover, increasing the potential for soil erosion into streams and lakes (Lorent et. al., 2009). In land-use system, nutrient losses through soil erosion represent an important nutrient flux, which is influenced by land-use practices through erosion processes and nutrient dynamics in the soil systems (Meng, 2002). On the other hand, opening land to grow cash crops has been shown to increase soil erosion (Ovuka, 2000).

2.3.2. Factors influencing land use and land change

Land use and land cover change is the most ancient phenomenon of all human-induced environmental impacts, and the first to obtain a magnitude to warrant the title "global change" (Sherbinin, 2002). In effect, global environmental change has been associated with humans as a dominant force (Moran, 2001; Turner, 2001; Lambin et al., 2001). This is largely through changes in the way people use and manage land (Millennium Ecosystem Assessment (MEA), 2005a; Gobin et.al. 2001). In essence, land use/cover changes are a product of prevailing interacting natural and human activities and hence detection of change allows for identification of major processes that cause change (Sherbinin, 2002). Some of the factors recognized as drivers of change include: economic, institutional, technological, cultural, demographic and climate change

2.3.2.1. Economic factors

These factors dominate the underlying causes of land use change, accounting for about 81% of cases (Sherbinin, 2002) with both local and international markets playing a key role. Mundia and Murayama (2009) reported change in land use and population dynamics in Masai Mara ecosystem because of increasing tourism activities. Increased tourist arrivals have led to development of tourist facilities within this natural resource and its surrounding, resulting in habitat destruction and fragmentation. On the other hand, viable timber markets as well as market failures are frequently reported to drive land use change through deforestation (Lorent et.al., 2009). The habitat change emanating from these activities lead to bare soil that is usually prone to erosion (Allendrorf, 2007). However, land use has been found to affect runoff and erosion differently, a situation associated to human factor on land management (Nadhomi and Tengwa, 2009), Other economic factors that influence land use change include low costs especially for land, labor, fuel, or timber, price increases for agricultural products that usually lead to expansion of agricultural land.

2.3.2.2. Institutional factors

Policies account for about 78% of the land use change (Sherbinin, 2002). This is because these policies either directly or indirectly promote exploitation of the resources. A study in Masai Mara ecosystem revealed that government policies that continue to discourage nomadic pastroralism led to encroachment of agricultural areas formally used solely for livestock and wildlife (Mundia and Murayama, 2009). The policies have instead favored permanent settlement, changing land ownership policies from communal to individual ownership with huge financial gains compared to pastroralism. Policies which result to access to credit facilities, subsidies and exemptions encourage investment in housing industry and hence lead to land use change (Zondag and Borsboom, 2009).

Studies carried out also indicate that development projects influence land use practices. Mortimore (2006) found an increase in forest cover due to a conservationist attitude towards biodiversity which reduced heavy grazing, cutting of trees for fuel and clearing land for cultivation in Kano plains. The amount of timber growing on farms was greater than that in adjacent woodland and farmers sold wood to make up for crop failures. In the same way, farmers in Machakos District planted *Melia Volkensii* in a tree planting project conducted by International Centre for Research and Agroforestry (ICRAF) in 1996 that embarked on planting exotic trees such as *Grevillea robusta* and reintroducing *Melia volkensii,* a threatened trees species in the area. Such intiative and campaigns finaly lead to increase in area under forest cover.

2.3.2.3. Technological factors

Technological developments which increase productivity in terms of land and employment especially in agriculture are important drivers of land use change. Technological developments in areas of genetic modification, farming technologies and mechanization are important in giving future direction in land use change (Zondong and Borsboom, 2009). Modification of farming systems through intensification (high-input, labour-intensive agriculture) and extensification (low-input, large area cultivation) are other factors that influence land use change. However, Lambin (2001) argues that a lot of caution should be taken with land use modification and conversion as they have been identified as the main source of another positive desertification.

2.3.2.4. Cultural factors

Cultural values influence people's lifestyle and are hence important in almost any type of land use. People's lifestyle affect consumption patterns and housing and hence determine the type and location of economic production and house type and location preference respectively (Zondong and Borsboom, 2009). According to Vien (2009), cultural factors (i.e. attitudes, values, beliefs and even individual perceptions) influence decisions made on land use. Perception towards sacred places will lead to preservation of such areas and hence protect soil from erosion.

Moreover, some communities will leave land untouched for livestock feeds during the dry spell (Mortimore, 2006).

2.3.2.5. Demographic factors

Demographic factors such as natural increase or in-migration are important driving forces of land use change as they affect the size and composition of population and households and hence the behavior of the actors. However, mixed finding have been reported on effects of increasing human population on land use. A study carried out by Mundia and Murayama (2009) reported conversion of grassland into mechanized agriculture, permanent settlements and small holder agriculture as a result of increased population density associated with high rate of in-migration and natural population. Other studies associated expanding human population with negative side effects including habitat destruction for farming activities, human settlement, and pollution (Millennium Ecosystem Assessment (MEA), 2005b; Grime, 1997), usually linked with how people use and manage land (MEA, 2005a; Gobin et.al. 2001). Additionally, Nadhomi and Tengwa (2009), Ovuka, (2000) and Tiffen et.al., (1994) reported that human factor on land use and management greatly reduced runoff and soil loss and thus improving land productivity.

2.3.2.6. Climate change

Climate change influence land use through various ways e.g. rising sea levels, floods, drought, changing temperatures, humidity, all of which affect land production. The effect of these factors changes climate change policies such as mitigation and adaptation. Energy transition from fossil fuels towards more sustainable energy production is driven by mitigation policies addressing climate change that influence the type of land use respectively (Zondong and Borsboom, 2009).

The policy leads to planting of trees for energy production hence increasing forest cover and thus reducing soil erosion.

2.4. Soil and water conservation

2.4.1. Soil and water conservation measures

The different types of soil and water conservation measures have been well documented (Oostendorp and Zaal, 2011., Bezuayehu and Sterk, 2010., Hessel and Tenge, 2008., Bashar and Klaassen, 2005., Li et.al., 2001., Hatibu et.al. 2000). Soil and water conservation measures are predominantly applied to: control runoff and thus prevent loss of soil by soil erosion, reduce soil compaction; maintain or improve soil fertility; conserve or drain water; and harvest (excess) water (Tidemann 1996). Krüger et al. (1997) classified Soil and Water Conservation (SWC) measures based on type as; 1) Physical measures:- stone and earth terraces and bunds, check dams, contour ditches, retention reservoirs 2) Biological measures:- vegetative strips, protective bush land, natural drainage way reforestation and, 3) Agronomic measures:- strip cropping, mix cropping and intercropping, mulching.

These measures are often used in combination with many traditional soil and water conservation techniques (e.g trash lines; grass strips; wooden barriers and stone bunds) and are increasingly considered as most reasonable since technical approaches are often not successful, especially without participation of the local farmers (Ong et.al, 2002). It has also been recognized that under modern circumstances traditional measures alone may often be insufficient to conserve the vital soil and water resources and thus, have to be supplemented by modern practices to achieve sustainable resource management (Förch and Schütt 2004 a, b).

2.4.2. Physical Measures of Soil and Water Conservation

Physical measures aim to; increase the time of concentration of runoff, thereby allowing more of it to infiltrate into the soil; divide a long slope into several short ones and thereby reducing amount and velocity of surface runoff; and protect against damage due to excessive runoff (Tidemann 1996). Although physical measures can be used in most agricultural systems (Heathcote 1998), they are more expensive to build and need to be maintained year after year (Thomas, 1988; Gachene et. al. 2002). Additionally, these measures tend to take up more land and are potentially dangerous, causing great damage if they fail to contain runoff. For example, stone buds take up more land, which become unproductive.

2.4.3. Biological Measures of Soil and Water Conservation

Biological measures of soil and water conservation work by their protective impact by vegetation cover. A dense vegetation cover prevents splash erosion; reduces the velocity of surface runoff; facilitates accumulation of soil particles; increases surface roughness, which reduces runoff and increases infiltration whereby the roots and organic matter stabilize the soil aggregates and increase infiltration (Morgan, 1999; Richter 1998; Hurni et al. 2003).

Reduced soil erosion has been observed in cultivated crops in agricultural areas as they offer better protection against soil loss than uncovered soil (Morgan, 1999). Other positive impacts that have been observed include improved soil moisture condition and protection against wind erosion. Biological measures are thought to be cheap and effective method of soil and water conservation (Heathcote, 1998) that most farmers can afford to invest in. This measure can easily be used together with other soil conservation measures.

2.4.4. Agronomic Measures of Soil and Water Conservation

Agronomic measures reduce soil erosion and run off; and increases infiltration rates by reducing the impact of raindrops through interception (Tidemann, 1996). The measures are cheap (Wimmer, 2002) and can be more effective in many systems than structural measures (Heathcote, 1998). The significance of land use practices as reported by Tidemann (1996) who indicated that differences in erosion rates caused by different land use practices on the same soil are much greater than the corresponding values from different soils under the same land use. Land use practices that reduce soil and water conservation, tend to improve soil condition and hence improve land productivity. Agronomic measures can be applied together with physical measures, though often more difficult to implement compared with structural ones as they require a change in familiar practices (Heathcote, 1998). In this study, vegetative macro contour lines were established, which combined physical, biological and agronomic measures with the aim of improving land productivity through increased soil and water conservation and improved soil properties.

2.4.5. Soil and water conservation measures for increased soil moisture conservation

Concerning resource base utilization in drylands areas, it will no longer be "Business as Usual" and the need to organize and manage resources under uncertain conditions that characterize drylands in order to secure sustainable livelihood is important and urgent. In addition to development of crop varieties for the drylands areas, Georgis et.al. (2001) suggested that improving management practices, that focus on managing all resources associated with land productivity including soil and water is vital. Soil moisture has been identified as critical both in crop growth and vegetation restoration in semiarid environments (Fu et. al. 2004). However, moisture stress is a major problem contributing to low agricultural production in the dryland areas and hence the need to manage this resource cannot be overemphasized.

A range of technologies have been developed for the purpose of soil moisture conservation. Among the most common technologies with the farmers is bench terrace. Though the technology has a high initial capital investment, the fact that it can be used for multiple benefits makes it the most preferred option among the farmers especially in areas characterized by steep slopes. Farmers are able to grow trees for fuel wood, fodder for animal and food crops both for domestic and income generation, consequently get multiple benefits that becomes strong driving force to adoption of this technology. A study carried out by Ong et.al. (2002) found that farmers would accept any form of soil moisture conservation measure when they can combine it with a clear return on their investment and as long as they have multiple benefits.

One of the most important benefits of bench terrace is the potential to reduce soil and water loss and thus increase soil moisture. Work by Miller and Shrader (1973) showed that bench terrace increased the average soil moisture content in 90 cm soil depth by more than 50% than that of unterraced land. Bench terraces were also found to be more efficient in moisture conservation, concluding the importance of bench terrace in soil moisture conservation. Further, Kannam et.al. (2010) reported that contour planting of potatoes associated with terracing reduced runoff by as much as 150 mm of rainfall equivalent, and thereby increased available soil moisture for plant growth. Moreover, soil loss was reduced while terracing also made drainage basin hydrological characteristics less prone to cause ditch and stream flooding. In order to design appropriate crop management practices, it would be imperative to understand moisture distribution along the bench terrace. However, few studies have concentrated on an in-depth analysis of soil moisture distribution along a bench terrace and therefore this study aims to assess how vegetative macro contour will influence soil moisture distribution on a bench.

2.4.6. Soil and water conservation measures and soil nutrients

Population growth has lead to intensified land use to meet population demands. This has further caused land degradation, which has resulted in crop production stagnation or decline in many African countries, hence undermining the foundation for sustainable economic growth in Africa (Kassam et al. 2009). The situation is further worsened by unreliable rainfall, nutrient leaching, and soil erosion that often deplete most soil nutrients. In addition, poor cropping systems, inadequate use of fertilizer and inappropriate soil conservation measures also accelerate the problem.

Soil erosion removes topsoil, which is the richest layer of soil in organic matter, nutrients and microorganisms that are crucial for plant growth. A study carried out by Kannan et.al. (2010) reported 287.32 and 817,439 tons loss of total soil and nutrients respectively due to severe heavy rains that caused floods within one month in 14 districts of India. In effect, nutrient loss has been found to be highest where loss from soil erosion is high. Fagerstrom et al. (2002) observed erosion induced N losses of up to 150 kg ha^{-1} for upland rice over 2 years, on an average slope of 20–28% while Dung et al. (2008) indicated that erosion and leaching lead to loss of 126 kg N ha^{-1} in two unfertilized rice crops in a similar setting. This points out to the importance of controlling soil erosion.

Implementing soil and water conservation measures restricts runoff, minimizes erosion and nutrient losses hence sustains soil productivity. Hedgerow systems were found to play an important role in reducing nitrogen losses from water erosion. A study carried out by Owino et al. (2006) proved the effectiveness of narrow grass barriers in controlling nutrient loss by erosion. The result indicated that Napier grass was able to reduce NO_3^--N and NH_4^+-N losses of upto 45–50%. At the same time, bench terraces were found to conserve moisture (Miller and Shrader, 1973), reduce runoff and flooding (Kannam, 2010). Kiepe (1995) also observed that when sloping land was transformed into a series of terraces, soil physical properties were greatly improved. The importance of managing soil erosion is hence fundamental in land productivity. This study endeavors to develop and implement "vegetative macro-contour lines" as an improved soil and water conservation measure.

2.4.7. Soil and water conservation measures and crop performance

Dry land areas are characterized by food insecurity and dependency on food aid. Although this has been attributed to drought, other factors that come into play include low agricultural productivity and soil degradation. Among the effects of soil degradation are; loss of plant nutrients and reduced water holding capacity, resulting in severe decline in crop yields and environmental quality (Pansak et al. 2008; Mahdi Al-Kaisi, 2008). These challenges together with land scarcity and the need to increase production for improved livelihood causes people to change natural resource management strategies. One of the ways that people respond is by use of soil and conservation measures.

A range of soil and conservation measures are available which offer varying benefits. For example, although contour hedgerows were found to control run off and soil loss (Garrity, 1996), studies have demonstrated that rows adjacent to hedgerows result in decreased yields due to competition for light, water and nutrients (Dercon et al. 2006; Kinama et al. 2007; Pansak et al; 2007). Moreover, Kasenge (1998) indicated that the slow return to investment in contour hedgerows was responsible for the low adoption of this technology. On the other hand, Dercon et al. (2003, 2007) and Morgan (2005) suggested that exposure of infertile subsoil during the process of natural terrace construction may lead to negative effects on crop yields.

To reduce the trade-offs between crop productivity and environmental functions in the semiarid tropics it is crucial to select appropriate trees and to design tree spacing to minimize competition (Ong, et.al. 2002). Kiepe (1995) used a slow-growing tree, *Senna siamea*, to form contour hedgerows in Machakos, Kenya. The trees reduced soil erosion from 58 to 1.4 t ha^{-1} over 3 years and did not reduce crop yield. In this study, a creeping legume that has the ability to improve soil fertility was be planted next to Napier grass on the embankment. The aim is to improve crop performance by use of agroforestry while still reducing plant competition.

Thesis format

This work is presented in paper format as follows:- Chapter one, two and three provides the general introduction, literature review and methodology of the research whereas chapter four gives a summary of results and discussions based on the following papers:

1). Chapter five: farmers' views on soil erosion and soil and water conservation technologies at Katheka-kai location, Machakos District, Kenya

2). Chapter six: farmers perception on changes in natural resource base at Kathekakai settlement scheme, Machakos District, Kenya

3). Chapter seven: trends in land use and land cover over a 21 year period in Kathekakai settlement scheme, Machakos District, Kenya

4). Chapter eight: effects of vegetative macro contour line on soil moisture conservation and crop performance in Kathekakai Settlement Scheme, Machakos District, Kenya

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Study site

The study was carried out in Kathekakai Settlement Scheme, in Machakos District of Kenya (Figure 3.1). The area, which was a ranching enterprise where cattle rearing was the main activity for nearly a hundred years was subdivided in 1995 into individual farm holdings. Individual farmers opened-up the land (cutting trees and shrubs) for crop and livestock farming, and other land developments.

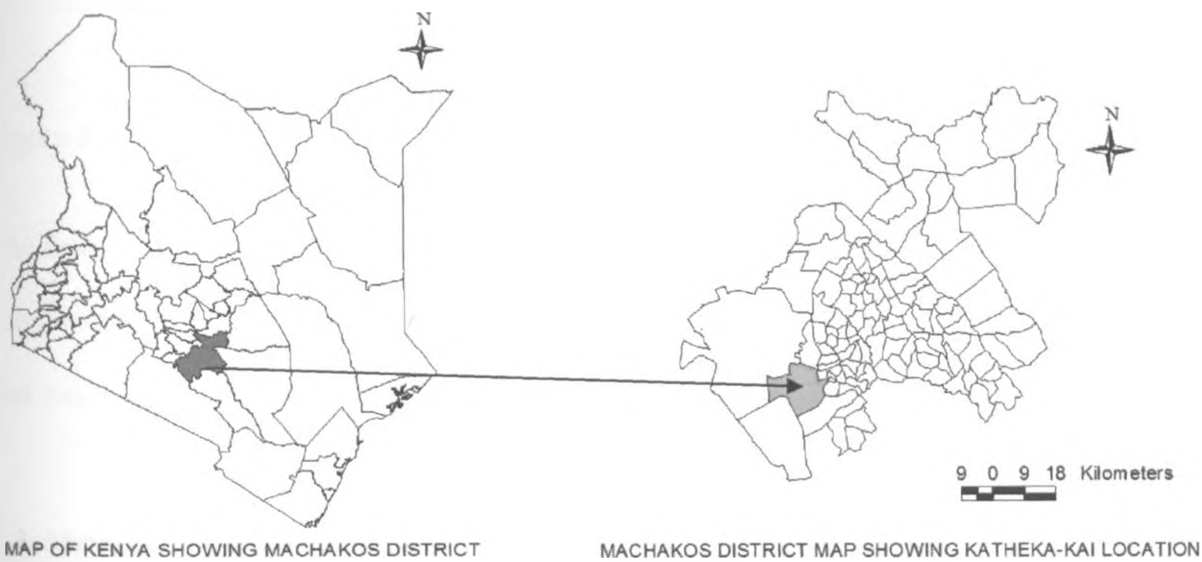

Figure 3.1: Study area

The climate of the district is typically semi-arid with mean annual temperature varying from 15 to 25°C and a total annual rainfall ranging from 400 and 800 mm. Rainfall distribution is bimodal with the long rains starting from March to May and short rains from November/December to early January (Figure 3.2). Short rains are more reliable than the long rains and therefore most important (Gicheru and Ita, 1987).

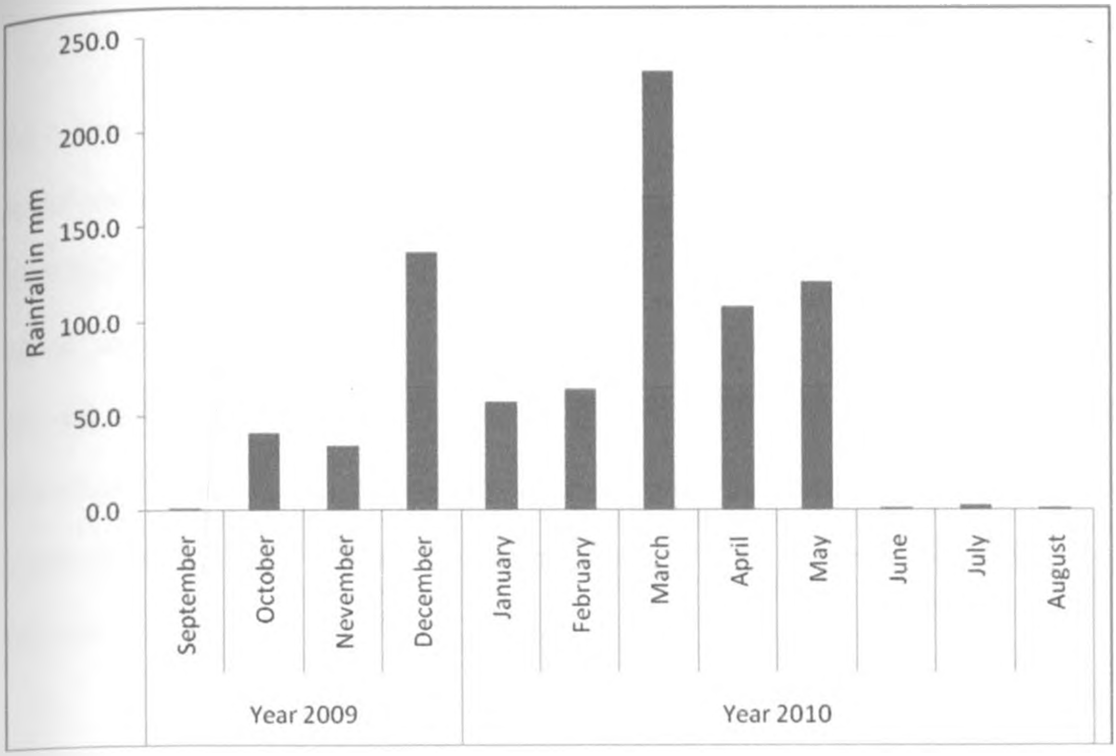

Figure 3.2: Rainfall distribution during the study period

The soils are mainly luvisols and of low inherent fertility (Gicheru and Ita, 1987). The main land use practices are crop and livestock farming. The crops grown include maize, beans, peas, millet, and sorghum, while poultry and cattle rearing are the main activities in livestock production.

3.2. Methods for socio-economic data collection

To determine factors influencing adoption of soil and water conservation measures in Kathekakai settlement scheme, the following activities were carried out:- Project introduction, community sensitization, data collection tools and procedures, and participatory resource mapping.

3.2.1. Project introduction

A stakeholders meeting was held at the District Agriculture office of Machakos District on 5/09/2009. Staffs from the Ministry of Agriculture who were key in this project were sensitized on the purpose and project objectives. The role of each stakeholder and Project work plan was also discussed. To avoid misunderstandings, expectations of the project implementer and farmers plus project benefits were also addressed at this point. This made it possible to involve relevant stakeholders and hence provide a good environment for project implementation, management, and exit.

3.2.2. Community sensitization

A meeting with the area residents was convened on 14/10/09 at Volta Primary School. The purpose of the meeting was to introduce the project and hence justify the presence of the research team in the area. The forum was also used to get information on the area that could enrich the study. Some of the issues addressed in this meeting included:- Purpose of the project, what the project could/could not offer, expectations of both the project implementer and farmers, choosing demonstration farms, project benefits and dissemination of project findings.

3.3. Data collection tools and procedures

3.3.1. Baseline survey

A transect drive was carried out to understand the area in terms of topography, population (size and composition) and farming systems as well as meeting elders and talking to farmers.

3.3.2. Sampling framework

The sampling design was based on the fact that Kathekakai location has five vast villages and that resources were limiting. Six households from each of the village were selected. The interviewers selected household by walking through identified feeder roads and systematically selecting every fifth household on either side of the road. This gave a sample population of 60 households which is greater than the statistical requirement to have a minimum size of 30 sample units (Freund and Williams, 1984).

3.3.3. Questionnaire development

A questionnaire taking into account the objectives of the study was constructed before going to the field. The design was such that it could give out the following information:- Social capital, farming systems, land use and cropping systems, soil and water conservation and household income. The questionnaire consisted of semi structured, open-ended and dichotomous questions (see appendix 1). An effort was made to ensure that each question was simple and could be understood by all involved.

3.3.4. Questionnaire pre-testing

To ensure the questionnaire produced desired results, a pre-test was carried out before embarking on household interviews. Eleven farmers were interviewed and data assessed based on: how the farmer understood the question, kind of response, and objective of the study. Any changes and adjustments were done before the questionnaires were administered. To make sure the questions were asked the same way to each household, three enumerators were taken through the questionnaire, and common way of asking each of the questions was agreed upon.

3.3.5. Household interviews

This was done in total regard of the busy schedule of the farmers. Visits started at around 9.00 am and ended at 3.30 pm local time to give time for morning and evening duties. Market days were also considered and any other, that the community suggested. Generally the meetings were kept to between 45 minutes and one hour as is the rule of thumb (Nyariki, 2008). To avoid becoming bored, questions were kept short and few, and only those relevant to the objectives of the study were asked (Hoinville and Jowell, 1978). Questions that were personal and appeared sensitive (Household income, land ownership, family size) were asked towards the end when a rapport with the interview had been attained (Nyariki, 2008).

3.3.6. Focus group discussions

Focus Group Discussions (FGDs) is a widely used approach for qualitative data collection. In this method, both the researcher and farmer are able to discuss key issues that are important to them. The discussions are conducted in a free environment where the participants comment, ask questions or respond to comments of others (Mulwa and Nguluu, 2003). Most of the studies on social economic dynamics as well as natural resource management use FGDs (Odimegwu, 2000). In this study, FDGs were to establish changes in resources that have taken place since the first people settled in Kathekaka in 1995.

3.4. Participatory resource mapping

Data was collected through focus group discussion (FGDs) during which a mental resource mapping exercise was carried out. The discussions were conducted in a free environment where the participants commented, asked questions or responded to comments of others. Mulwa and Nguluu (2003) have recommended similar approach of collecting information using FGDs. Most of the studies on social economic dynamics as well as natural resource management employ FGDs (Odimegwu, 2000). In this study FDGs were used to establish changes that have taken place since the first people settled in Kathekaka in 1995.

A Participatory Rapid Appraisal exercise involving 30 farmers (13 men and 17 women) from Kathekakai location was conducted through focus group discussion and resource mapping. Based on the objective of the study, two FGDs consisting of 12 members each were formed. The first group consisted of farmers who settled before year 2000 and who drew the map of Kathekakai as they found it when they first settled. The second group had farmers who settled after year 2000 and they drew a map showing the current resource situation of the area. Household interviews were carried out, with 62 farmers (36% men and 64% women) who expressed their views on changes that have taken place and the coping strategies used. A comparison of the two sketch maps drawn in terms of farmers perception on natural resource was made.

3.5. Land use and land cover change

3.5.1. Characteristics of landsat maps

One Thematic Mapper 4 (TM) and two Enhanced Thematic Mapper 7 (ETM+) landsat maps from Kathekakai sub location, with a scale of 1:25000 were studied in order to identify areas with different land use and changes in land use that have take place over the years. The three images were purchased from National Resource Mapping Centre, Kenya. The characteristics of each image are shown in Table 3.1.

Table 3.1: Characteristics of the Satellite images in the study area

Characteristics /sensor	Landstat TM	Landstat ETM+	Landstat ETM+
Date	1988-10-01	2000-09-16	2009-09-25
Path - row	168-61	168-61	168-61
Elevation source	GLS2000	GLS2000	GLS2000
Spatial resolution	30	30	30

The dates of the images were purposively chosen to avoid uncertainties and were acquired within the same season (dry period) in a year. This is to avoid temporary land cover evident in wet season. Cloudiness was also considered especially in the area of study.

3.5.2. Landsat map examination

Using a Geographical Positioning System (GPS), points of areas (training areas) corresponding to each class (forests, savanna grassland, cultivated land, bare land, built-up areas, rocky areas, water bodies) were taken. Analysis of landstat maps was done using ENVI 4.7 software. Bands 4, 3, 2 were used to transform the black and white images to false color images. This helped in identifying areas/classes associated with certain spectral reflectance. Cursor location/value (Geographical position) for identified training areas from defined Regions Of Interest were ascertained and each class was allocated the color that matched that on the landstat map. Maximum Likelihood classification was used. The method assumes that the statistics for each class in each band is evenly distributed and calculates the probability that a given pixel belong to a certain class. The training points were as uniform in color as possible and their location maintained for the three images to ensure that correct pixel identified the correct class. The following classes were identified (Table 3.2):

Table 3.2: Land use classes

Class	Description
Forests	Native trees
Cultivated land	Crop land
Savannah grassland	Grasses, scrubland, pastureland
Water bodies	Lakes, rivers, dams, Streams
Built-up land	Building, roads, warehouse, green houses
Rocky areas	Large areas with visible rocky cover
Bare land	Bare soil, very sparse vegetation

3.5.3. Change detection

Thematic change detection for Landstat TM and Landstat ETM+ was established using ENVI EX. This was done by selecting two images of the same scene, with same number of classes and same names at different times. The software identifies differences between the images, with a resultant classification image. Thematic change vectors created during classification were saved to a shape file; while statistics on image change was saved as thematic change statistics and opened in a Microsoft excel spreadsheet. The results were then examined and analyzed for land use change.

3.6. Establishment of experimental plot

3.6.1. Introduction of technology

Farmer's demonstration on technology layout and training on plot management was carried out during project sensitization (Plate 3.1 and 3.2).

Plate 3.1: Project sensatization meeting

Plate 3.2: Farmers demostration on planting and management of experimental plots

The layout out of vegetative macro contour line is shown below (Figure 3.3)

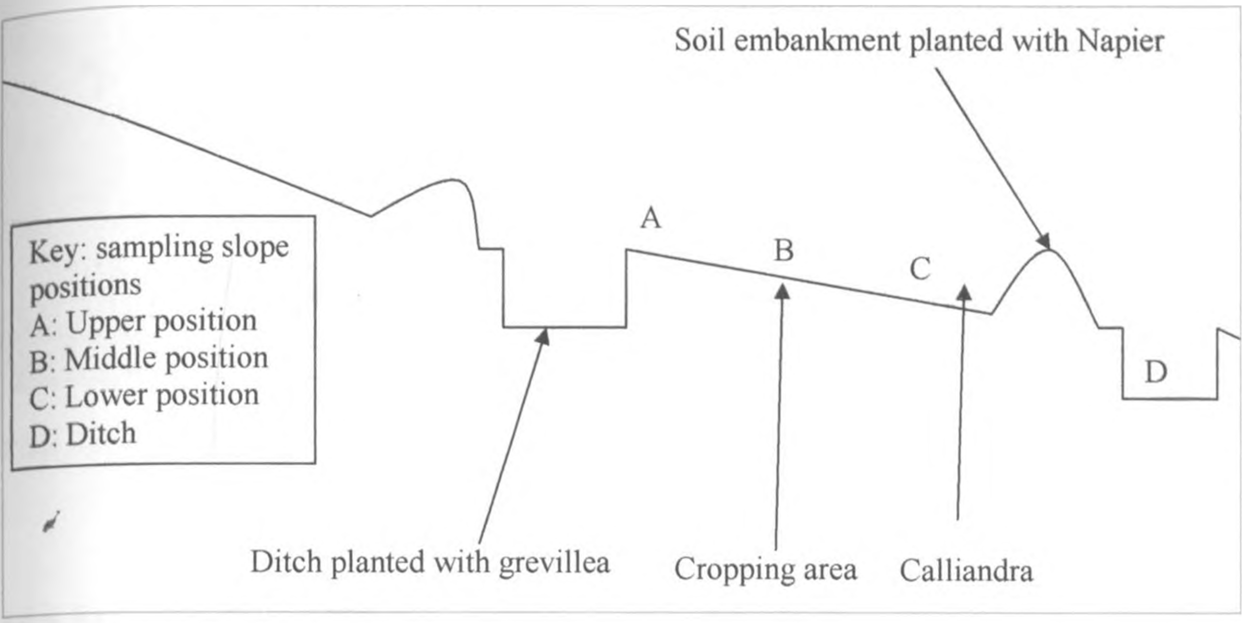

Figure 3.3: Layout of the technology

3.6.2. Selection of experimental farms

The community selected four farms during sensitization meeting. The farms served as blocks in this study. Selection was based on the following characteristics:- Farm must be big enough for three treatments, cooperative farmer, farm open to community and other outsiders especially for learning purpose, ready to provide land and manage the experiment for at least two seasons and easily accessible even in rainy season

3.6.3. Laying of terraces

Terraces were laid with the help of Ministry of Agriculture staff (Plate 3.3), according to the procedures described in Soil and Water Conservation manual for Kenya (1997). A 90 cm wide and 60 cm deep ditch was dug and scooped soil thrown on the upslope (Plate 3.4).

Plate 3.3: Laying terraces

Plate 3.4: Laid out terrace

3.6.4. Experimental treatments

The trial involved three treatments: Terraced Vegetative Macro Montour line with maize mono crop and ditch (TVMD), Un-terraced Vegetative Macro Contour line with maize-dolicos intercrop UVMD) and Terraced Vegetative Macro Contour line with maize-dolicos intercrop and ditch (TVMDD). Each of the four selected farms served as a block and had the three treatments arranged in a Randomized Complete Block Design (RCBD) giving a replica of four for each of the treatments. Each treatment measured 15 m in length while the width was dependent on the slope of the land. Fertilizer was applied during planting using the recommended rate of 60 kg Di-Ammonium Phosphate (DAP) in all plots. Other agronomic practices were carried out according to the local conditions. A laid out vegetative macro contour line plot is shown in Plate 3.5.

Plate 3.5: Experimental plot Layout

3.6.5. Planting materials

Grevillea was planted 3m apart along the ditch. Napier grass was planted at the soil hip and *Calliandra calothyrsus* on the immediate upper side of the embankment. The crop along the bench was either maize mono-crop or maize and dolicos (*Lab lab purpureous*) intercrop.

3.6.6. Land preparation and planting

Tilling of the land was done before planting using hand hoes. Fertilizer was applied to maize (*Zea mays*) at planting. Maize (hybrid, Duma 43) was planted at a spacing of 75 cm by 25 cm between and within rows respectively. In maize-dolicos intercrop, dolicos was planted in between the maize rows.

3.7. Soil and plant data collection

3.7.1. Soil samples

Soil samples for moisture analysis were collected at 0-30 cm, at critical stages (germination and tussling) as well as when the crop showed water stress. The samples were collected at four points along the bench terrace i.e. upper, middle, lower slope positions of terrace and along the ditch (Figure 3.4). The sampled soil was packed in polythene papers and immediately transported to the laboratory at Kabete Campus, University of Nairobi.

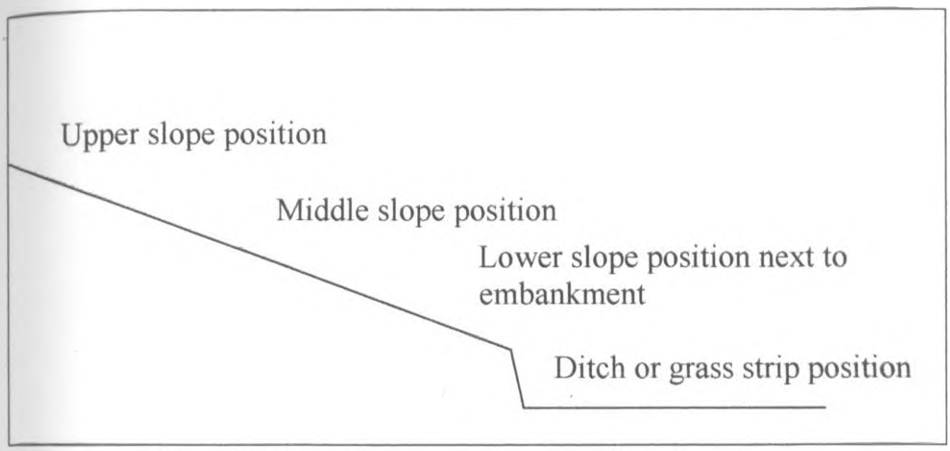

Figure 3.4: Sampling slope positions

3.7.2. Crop parameters

Plant height was measured at tassling stage by taking an average of five randomly selected maize plants from each sampling slope position. Maize was harvested at maturity stage as biomass from an area of 3m X 3m of each plot and oven dried at 60^{0}C until a constant weight was attained after which the dry weight was recorded.

3.7.3. Soil moisture determination

Field soil moisture was determined by oven drying about 200 g sub sample at 105°C for 24 hours. Moisture content was calculated using the following formula:

$$\%\text{Moisture content} = \frac{(\text{Sample wet weight} - \text{Sample dry weight})}{\text{Sample dry weight}} \times 100$$

CHARPTER 4

RESULTS AND DISCUSSIONS

4.1. Summary of results and discussions

In this section, a summary of the study results are presented in the following order, first adoption of soil and water conservation measures followed by participatory resource mapping and land use changes. Lastly, results on effects of vegetative macro contour lines on soil moisture, and crop performance are discussed.

4.2. Soil and water conservation measures: The Socio Aspect

4.2.1. Socio-economic characteristics

Results indicate that most households are male headed with male still as the dominant factor in land ownership. Despite this, most of the respondents were women (chapter 5). This would suggest that men make most of the farm decisions, which could be a threat to adoption of new technologies, because women may have to consult and agree with their husbands first.

Although the area is semi-arid, farming is a major occupation. Sale of farm produce comes third as a source of household income. Farming also is important in household consumption and hence most households rely on agriculture as the main source of livelihood. These results have some implication on the use of SWC measures in the area. Charlotte and slaymaker (2000) demonstrated that investment in SWC was greatly influenced by the degree to which agriculture is a source of livelihood, shortage of agricultural land; and/or the potential to increase yields and especially of high value crops. This may explain the reason why most farmers in this area reported use of SWC measures. To supplement farming income, most farmers engaged in casual labor and business activities. This further could lead to increased adoption of SWC measures, as farmers would be able to pay the usually expensive and labor intensive soil and water conservation technologies. Similarly, Pansak et al. (2008) reported that high labour requirements are concerns of farmers when applying SWCs, and could affect adoption rate of technologies.

4.2.2 Status, adoption and challenges in soil and water conservation

Most of the respondents indicated that soil erosion was a serious issue although majority of them did not know of any soil erosion indicators (Chapter 5). A large number of farmers use SWC measures to control this menace. Other farmers cited water damage, and slope of the land as factors that highly influenced use of SWC measures. A majority of farmers said that they received information on SWC measures from other farmers. This would suggest that farmers trust their counterparts more than outsiders as they believe these farmers have already tried the technologies they advocate for and seen them work. They also seem to understand faster in nonprofessional's demonstration and language used by farmers not to mention that they can always go back for further information and clarification if need be. Similarly, Murphy (1993) found out that exchange of ideas among farmers was more frequent, efficient with those familiar, and similar to them. This makes farmer field schools (FFS) crucial for effective extension services and could be pursued for increased adoption of soil and water conservation technologies.

Lack of training, pests and diseases were also cited as major threats to adoption of SWC measures. With the shrinking extension services, it would be worthwhile to invest in FFS. Proper training of farmer trainers would be crucial to avoid transfer of substandard information among farmers. Lack of trainings result in inappropriate use of the SWC measures (Plate 4.1) while pest and diseases destroy crops (Plate 4.2) and hence lead to reduced land productivity meaning that farmers do not reap maximum benefits from the investment, a situation which reduce adoption rate. Farmers confirmed that terraces laid from own knowledge and other farmers advise could not meet the objectives for which they were meant. Such terraces could not control heavy floods and were expensive to maintain, as they needed to be repaired after rains. This was verified during the base line survey where terraces were found to be straight from one end of the farm to the other without following the contour. In addition, farmer laid terraces were found to intersect with those laid by experts signifying that the farmer laid terraces were not well laid out (Plate 4.3).

Plate 4.1: Farmer laid terraces run straight from one end of farm to the other

Plate 4.2: Napier grass planted along the terrace infested by termites

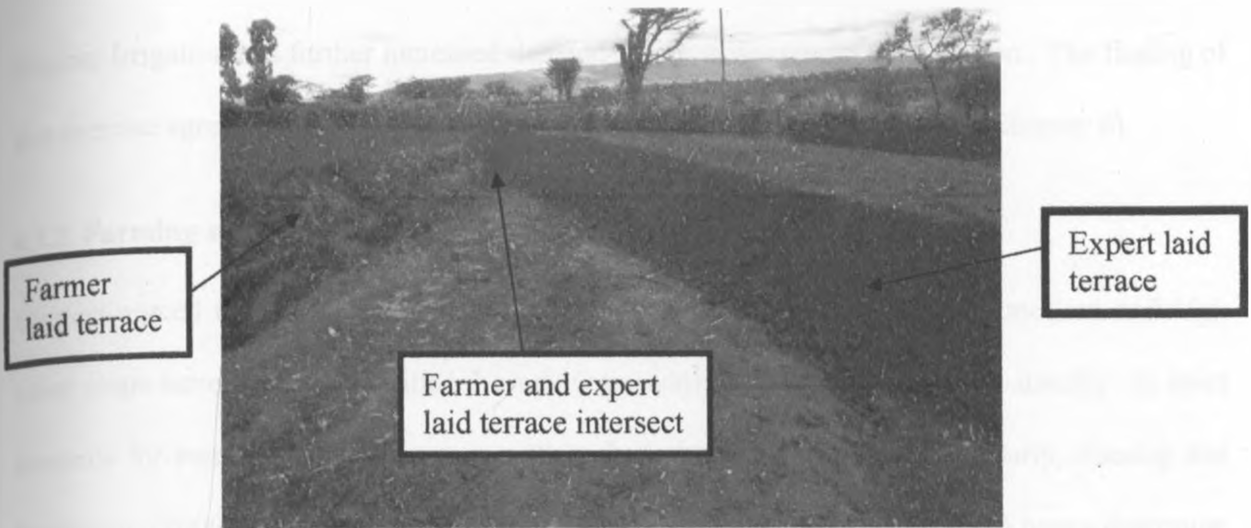

Plate 4.3: Terrace developed through own experience and experts intersects

4.3. Participatory resource mapping

4.3.1 Trend in natural resource change

Kathekakai settlement scheme was a co-operative society until 1995 when it was subdivided to individual share holders, hence now under private ownership. Farmers reported that the land had many different types of indigenous trees and shrubs e.g Acacia varieties (Chapter 6). However, the resources have continued to diminish with time. The area has continued to experience increase in population due to both natural population and in-migration. This has resulted in increased exploitation of the natural resource hence the resource base has decreased with time. In the same way, Laukkonen et. al. (2009) indicated that increased population leads to change of the surroundings, causing significant impacts on the natural resource base mainly through opening of new land for agriculture and other developments and cutting trees for domestic use to cater for the emerging needs. According to farmers, water has become a scarce commodity as most rivers have dried up and the ones flowing are sedimented with soil particles due to increased soil erosion. Irrigation has further increased demand for, thus worsening the situation . The finding of this exercise agrees with the analysis of landsat maps of the area in this study (Chapter 6).

4.3.2. Farming systems

Farmers agreed that farming systems have changed with time. For example modern and high value crops have replaced traditional crops (commonly suitable for the area), usually to meet demands for increased population as well as for commercial purposes. Similarly, Zondag and Borsboom, (2009) found that people's lifestyle affect consumption patterns and hence determine the type and location of production. Further still, Murayama (2009) indicated that conversion of grassland into mechanized agriculture, permanent settlements and small holder agriculture was as a result of increased population density associated with high rate of in-migration and natural population.

Most of the farmers were aware of climate change and its causes. They agreed that climate change was a key causal reason to the changing farming systems in the area. According to the farmers, human activities are a major factor influencing climate change. The activities guide land use alterations that have the potential to affect global cycles, which in turn influence life on planet earth. Sherbinin, (2002) found that conversion of forested areas into other uses increased atmospheric carbon dioxide by 33 percent since 1850 and has therefore been identified as a contributing factor to climate change. Aware that climate change is disastrous and with the government campaigns, farmers in this area have embarked on some coping strategies (e.g. growing drought tolerant and early maturing crops, water harvesting, destocking, irrigation) . According to Zondag and Borsboom (2009), climate change policies are likely to influence land use. Campaigns to plant two trees for every tree cut for a better environment, shifting from use of fossils to sustainable energy (e.g. trees) would lead to increased forest cover hence changing the type of land use.

4.4. Land use and land cover changes

The area which was a rangeland has not been spared from land use change especially after change of land ownership. It was a home to different wildlife animals and until privatisation, wild life and livestock animals lived together in harmony (personal communication during FGDs). After human settlement, competition for resources and conflict between human, wildlife and livestock set in. This was confirmed during the study period when a son of one of the demostration farmers was killed by hyneas. We were also able to witness residents selling game meat.

With the world's population growing at some 75 million a year, humans and wildlife have to squeeze even more tightly together, increasing the risk of conflict between them (FAO, 2010). The result is a growing threat to people's lives and livelihoods and to their health from animal-borne diseases. According to the World Conservation Union (V^{th} World Park Congress, 2003), conflict occurs when wildlife's requirements overlap with those of human populations. If man destroys or disturbs animal's habitat it is obvious that there will be a struggle for the survival from the part of animal. The destruction of their habitat due to human activities compels the wild animals to enter human settlements in search of food and water leading to conflict.

It is evident from the results of this study that land use changes have taken place between 1988 and 2009. Rocky areas (18.7%) and bareland (2.1%) were converted to savanna grassland, and forest land and this led to increase in area under these two land uses. Some of the bareland

(1.8%) was transformed into cultivated land and built-up areas (chapter 7). Since natural resource is diminishing, the increasing population requires that the available resource be utilised and managed in a sustainable way. On the other hand, the decreasing land have forced people to settle in very fragile areas. Restoration of such areas to habitable conditions takes centre stage and this could explain the conversion of rocky areas and bareland to savanna grassland, cultivated areas and forests. Conversion of water bodies to savanna grassland and rocky areas led to decline in area under water bodies. Furthermore, increase in population also increases water requirement. Moreover, more irrigated farms have mushroomed in the area (Chapter 7) hence reducing water bodies. Generally, all the land uses were affected, with most of the land uses losing more area than gained. However, all the land under water bodies was converted to other land uses.

4.5. Development and establishment of vegetative macro contour line

Information gathered from farmers as indicated in Chapter 8 revealed that Kathekakai location is a soil erosion prone and food insecure area. The area has also been left out on most of the agricultural activities that are implemented by government agencies and especially in soil and water conservation. Being a new settlement area, diverse cropping systems, usually based on farmer's original areas of residence have engulfed the area too. These systems, typically inappropriate, have further exacerbated soil erosion warranting an urgent act to salvage the situation. Vegetative macro contour line, an improved soil and water conservation technology, was established with the aim of enhancing soil productivity through soil and water conservation.

The findings point out to the effectiveness of this technology to conserve soil and water as soil moisture content measured on terraced benches (15 and 13% for TVMDD and TVMD respectively) was higher than on the un-terraced bench. The ditch also greatly influenced partitioning of soil moisture along the bench. The upper and lower slope positions had higher soil moisture than the middle positions. Water that could otherwise have been lost was harvested in the ditch (chapter 8), and through lateral seeping, moisture was made available to the crop planted at the upper slope position of the terraced benches. At the lower slope position, soil embankment could have increased water infiltration by reducing soil and water loss. Similarly, Ovuka (2000) reported improved soil properties at the lower slope compared to mid and upper slope, which was associated with transportation of soil nutrients through both natural and accelerated soil erosion, and this explained the higher biomass yield at this position. In this study, the high soil moisture content available at the upper and lower slope positions could as well explain the better performance of crop in terms of height and yield (chapter 8). Likewise, Kannam (2010) reported that bench terraces were more efficient in moisture conservation than un-terraced benches, a phenomenon associated with reduced soil and water flow along the bench terrace, thus allowing more time for water to infiltrate into the soil (Woyessa et. al. 2006).

4.6. Conclusion and recommendations

The study confirms that soil erosion is a major challenge in this area. Results further show that information on soil and water conservation is scanty with most of the farmers relying on their own experience or other farmers' knowledge. Clearing of land and high population growth rate was cited as key contributing factors to soil erosion as well as declining natural resource witnessed in the area.

Land use has greatly changed in this area. Savanna grassland, forest cover, cultivated land and built-up area have all increased with population increase, land ownership and infrastructure are believed to be the main causes of this event. Besides, field observations revealed that most farms have absentee farmers who have fenced off the farms with minimal cultivation, thus allowing time for trees and vegetation growth. The established vegetative macro contour line was found to be effective in conserving soil moisture, which became available for plant growth and hence increased productivity.

Despite soil being very fundamental for sustainable land productivity, it is highly threatened and especially with the current shrinking extension services. The results spell out the need to create awareness on soil erosion and conservation measures. This puts into balance the current advocacy to privatize the extension services. In the present state of events, such a venture would only make the situation worse and hence calls for the government to redesign strategies to manage the problem within the available resources.

On the other hand, the study identifies farmer-farmer extension as a powerful tool in extension services suggesting that training farmers as trainers would be one of the ways to increase technology adoption. Further, involving the farmers in development and up scaling of soil and water conservation measures would also alleviate the adoption rate. Besides, the looming destruction of natural resource base in this area calls for places an urgent need to train the area residents on sustainable natural resource management.

REFERENCES

Abara I.O and Sigh S. (1993). "Ethics and biases in technology adoption: The small farm argument". Technological forecasting and social change, **43 pp 289-300**.

Agwu A.E., Ekwueme J.N., Anyanmu A.C. (2008).Adoption of improved agricultural technologies via radio farmer programme by farmers in Enugu State, Nigeris. African Journal of technology. **Vol. 7 (9), pp 1277-1286**.

Ahmed, B., Longtau, S.R. and Odunze, A.C. (2000) 'Soil and Water Conservation in Nothern Nigeria: Case Study Report' prepared by Eco Systems Development Organisation (EDO), Jos, Nigeria for the Overseas Development Institute.

Allendorf T. (2007). Resident's attitudes towards three protected areas in Southern Nepal. Biodiversity and conservation **16 pp 2087-2102**

Bandre, P. and Batta, F. (1999) 'Conservation des Eaux et des Sols (CES) au Burkina Faso'. Rapport Final. Voisins Mondiaux, Ouagadougou.

Bashar K and Klaassen G.J (2005). Watershed erosion and sediment transport. Nile Basin Capacity Building Network (NBCBN).

Bayard, C., Jolly M. and Shannon D.A. (2007). The economics of adoption and management of alley cropping in Haiti, J. Environ. Manage. **84 pp. 62–70.**

Belay, T. (1992). Effects of erosion on soil properties and productivity of nitisols in Gununo area, southern Ethiopia In: Erosion, conservation and small-scale farming (eds. H Hurni and Tato). Geographical Benmensia, Berne, Switzerland, **pp 229-242**.

Bezuayehu T and Sterk G. (2010). Land management, erosion problems and soil water conservation. In: Finchiaa, watershed, western Ethiopia. **Land use policy Vol. 27(4) pp 1027-1037.**

CARA. (2006). Consortium for Atalantic regional Assessement. Land use premier: drivers of land use change

Chambers R. (2006). Participatory mappings geographic information systems. Whose maps? Who is empowered and disempowered? Who gains and who loses? Electronic Journal on information systems in developing countries **25(2) pp 1-11**.

Charlotte B and Slaymaker T. (2000). Re-examining the 'more people less erosion' hypothesis: Special case or wider trend? Natural resource perceptive, No. 63, Overseas Development Institute

Corbet, J.M., Rambaldi, G., Kyem, P., Weiner, D., Olson, R., Muchemi, J., McCall, M.K. (2006). Overview : mapping for change : the emergence of a new practice. In: Participatory learning and action (2006) 54. Special issue on: Mapping for change: practice, technologies and communication: Proceedings of the international conference on participatory spatial information management and communication PGIS '05 - KCCT, Nairobi, Kenya, 7-10 Sept 2005. IEED, **pp. 13-20.**

Curwell, S. and A. Hamilton (2003): The Intelcity roadmap. Report of the EU Intelcity project **IST-2001-37373.**

Dercon G., Deckers J, Govers G, Poesen J, Sánchez H, Vanegas R, Ramírez M and Loaiza G (2003). Spatial variability in soil properties on slow-forming terraces in the Andes region of Ecuador, Soil Till. Res. **72 pp. 31–34**.

Dercon G., Deckers J, Poesen J, Govers G, Sánchez H, Ramírez M, Vanegas R, Tacuri E and Loaiza G (2006). . Spatial variability in crop response under contour hedgerow systems in the Andes region of Ecuador, Soil Till. Res. **86 pp 15–26.**

Dercon G, Govers G, Poesen J, Sanchez H, Rombaut K, Vandenbroeck E, Loaiza G, Deckers J (2007). Animal-powered tillage erosion assessment in the Southern Andes region of Ecuador, Geomorphology **87 pp. 4–15.**

Diebel P.L., Taylor D.B., Batie S.S. (1993). Barriers to low input agriculture adoption: A case study of Richmond County; Virginia. **American Journal of alternative agriculture. 8(3) Pp 120-127.**

Dinpanah G.,Mirdamadi M., Badragheh A., Sinaki J.M., Aborye F. (2010). Analysis of effect of farmer field school approach of biological control on rice producer'producer, characteristics in Iran. American-Eurasian J. Agric. And Environ.Sci. **7 (3) pp 247-254.**

Drummond M.A. and Loveland T.R. (2010). Land use pressure and transition to forest cover loss in the ecosystem in the Eastern United States. Bioscience **60(4): pp 286-298.**

Dung V.N., Vien D.T., Lam T.N.,Toung M.T. and Cadisch G. (2008). Analysis of the sustainability within the composite swiddening agroecosystem in Northern Vietnam. 1. Nutrient balances of swidden fields with different cropping cycles, Agric. Ecosyst. Environ. **128 pp. 37–51.**

ENDA Pronat (2000) 'Pratiques de la Conservation de L'eau et des sols dans la region des Niayes (Senegal): Cas des villages de Dara, Beer, Mbawane et Keur Abdou Ndoye'. Rapport Final Octobre 1999. ENDA Pronat, Dakar, Senegal

Enos J.L and Park W.H (1988). The adoption of imported technology. The case of Korea. New York: Croom ltd

Fagerstorm, MH. (1994). Grass strips as a soil conservation measure in Kenya suitability and effects. Msc. Thesis, Swedish University of Agricultural Sciences, IRDC, Working Paper 259, Uppsala, Sweden

Fagerstrom, S.I. Nilsson, M. Van Noordwijk, T. Phien, M. Olsson, A. Hansson and C. Svensson (2002).Does Tephrosia candida as fallow species, hedgerow or mulch improve nutrient cycling and prevent nutrient losses by erosion on slopes in northern Viet Nam, Agric. Ecosyst. Environ. 90 (2002), pp. 291–304.

FAO. (2010). Coping with raiding elephants and hippos

Feder G. and slade R. (1984). Aspects of the training and visit system of agricultural extension in India: A comparative analysis. Vol. 659, ISBN-0821303929

Förch, G. and Schütt, B. (2004a). Watershed Management – An Introduction. In: FWU Lake Abaya Research Symposium– Catchment and Lake Research, Proceedings.

Förch, G. and Schütt, B. (2004b). International MSc 'Integrated Watershed Management' (IWM). In: Schütt, B. (ed.) (2004). Watershed Management in the Abaya-Chamo Basin, South Ethiopia. Berlin, pp. 1-14.

Freund J.E. and Williams F.J. (1984). Modern business statistics. London, Pitman.

Fu B. J., Meng Q. H., Qiu Y., Zhao W. W., Zhang Q. J., Davidson D. A. (2004). Effects of Land Use on Soil Erosion and Nitrogen Loss in the Hilly Area of the Loess Plateau, China. Land Degrad. Develop. 15: 87–96

Gachene C.K.K. and Mureithii J.G. (2004). Lost and Reclaimed. A case of study of gully rehabilitation in Central Kenya highlands using low-cost measures proceedings of the 4th International Crop Science Congress on new directions for diverse plant. Brisbane, Australia, 26th Sep-1st Oct. 2004. Ed. Fischer I et.al. ISBN 1 920 843 217.

Gachene, C.K.K., Mureithi, J.G., Anyika, F. and Makau M. (2002). Incorporation of green manure cover crops in maize based cropping system in in Ndome and Ghazi, Taita Taveta, Kenya

Garrity D.P (2004) Agroforestry and the achievement of the millennium development goals. Agroforestry System Vol. 6 Pp: 5–17

Georgis K., Temesgon M and Goda S. (2001). On-farm evaluation of soil moisture conservation techniques using improved germplasm. 7th Eastern and Southern Africa regional maize conference Pp 310-316

Gicheru, P.T. and Ita, B.N. (1987). Detailed soil survey of Katumani National Dryland Farming Research Station Fearms (Machakos District). Report No. D.43. Kenya Soil Survey Ministry of Agriculture, Nairobi, Kenya .

Gobin. A., Campling P.,Feyen J. (2001) Spatial analysis of rural land ownership. Landscape and urban planning 55: 185-194.

Grime, J.P. (1997). Climate change and vegetation. In plant ecology, 2nd edition, Crawley M.J. (ed.) Blackwell Science: Oxford, UK: 582-594.

Hatibu N., Mahoo H.F., Lazaro E., Rwehumbiza F.B. (2000). The contribution of soil and water conservation to sustainable livilhoods in semi-arid areas of Sub-Saharan Africa. AGREN Network paper No. 102.

Heathcote, I.W. (1998): Integrated Watershed Management. Principles and practice. New York

Hessel. R and Tenge A. (2008). A pragmatic approach to modeling soil and water conservation measures with a catchment scale erosion model. Catena 74(2) pp119-126

Hoinville G. and Jowell R. 1978. Survey research practices. Hants: Gower, England

Hurni, H.; Herweg, K., Liniger, H.; Maselli, D. and Kläy, A. (2003): Nachhaltige Ressourcennutzung I: Integrale Betrachtung von einzelnen natürlichen Ressourcen, sowie Forschungsmethoden und Möglichkeiten zu deren nachhaltigerNutzung.

http:/www.cde.unibe.ch/University/pdf/NRN%20I%20WS%2003 04 neu.pdf. Accessed :02.02.2011.

ICRAF, (1996). Farmer to farmer extension workshop held at Machakos Distict, Kenya

IFPRI. (1998). Pest management and food production: Lookin into the future. Vol. 20. No.52

Kamusoko C. and Aniya M. (2009). Hybrid classification of landsat data and GIS for land use/cover change analysis of the Bindura District, Zimbambwe. International Journal of Remote Sensing. Vol. 30: 97-115.

Kannan N., Senthivel T., Rayar A.J., Mutesa F. (2010). Investigating water availability for introducing an additional crop yield in dry season on hill land ar Rubirizi, Rwanda. **Journal, Agricultural Water Management, Vol. 97, Issue 5, Pp. 623-634.**

Kasenge V. (1998). Socio economic factors influyencing the level of soil management practices on fragile land. Soil Science Society of East Africa. Tanga, Tanzania **Pp. 102-112.**

Kassam, A., Fredrich T., Shaxson F., Pretty J. (2009). The spread conservation agriculture: Justification, sustainability and uptake. International Journal of Agriculture sustainability 7 (4) 292-320.

Kebede Y., Gunjal K., Coffin G. (1990). Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-bulga District, Shoa Province. Journal of Agricultural Economics. 83(1): 35-51.

Khisa P., Gachene C.K.K., Karanja N.K. and Mureithi J.G. (2004). The effects of post harvest crop cover on soil erosion in a maize-legume based cropping system in Gtege, Kenya. Journal of agriculture in the tropics and sub tropic Vol. 103. pp 17-28

Kiepe P. (1996). Cover and barrier effect of *Cassia siamea* hedgerows on soil conservation in semi-arid Kenya, Soil Technol. 9 pp 161–171.

Kinama J. M., Stigter C. J., Ong C. K., Ng'ang'a J. K., Gichuki F. N. (2007). Contour Hedgerows and Grass Strips in Erosion and Runoff Control on Sloping Land in Semi-Arid Kenya Arid land Research and management. Volume 21 pp 1-19

Krüger, H.-J., Fantaw, B. Mihaell, Y.G. Kajela, K. (1997): Inventory of indigenous soil and water conservation measures on selected sites in the Ethiopian Highland. Soil Conservation Programme Ethiopia. Research Report 34. Bern, London.

Lal R. (2007). Crop residues and soil carbon: carbon management and sequestration center. Ohio State University, Columbus OH 43210

Lambin, E.F., Turner, B.L. II, Geist, H.J., Agbola, S.B., Angelsen, A., et. al. (2001). The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change: Human and Policy Dimensions 11(4): 5-13.

Laukkonen, J., Blanco, K.P., Lenhar P., Keiner, M., Cavric B and Kinuthia-Njenga, C. (2009). Combining climate change adaptation and mitigation measures at the local level. Habitat International. Vol 33, issue 3, pp 287-292.

Li H., Zhang X., Chenxichang G., Lu.W (2001). Soil and water conservation strategies on Red and Yellow soils of South China. In: Stoh D.E., Mohtar R.H., Sreinhavolt A.C (eds). Sustaining the global farm.

Lorent H. Sonnenschein R., Tsiourlis G., Hostert P., Lambin E. (2009). Land degradation and subsidies dependency and market vulnerability of stock breeding households in central crete. 7th International science conference on the human dimensions of global change 26-30 April, 2009 Bonn, Germany

Mahdi Al-Kaisi, (2008). Department of Agronomy, Iowa State University

Makumbi, M. and Okubal, P. (2000) 'Rethinking Natural Resource Degradation in Semi-Arid Africa – Implications for Policy: Toroma – Uganda Case Study'.

Mc Namara K.T., Wetzstein M.E., Dorce G.K. (1991). Factors affecting peanut producer adoption of intergrated pest management. Review of agricultural economics 13:129-139.

MEA (Millenium Ecosystem Assessment). (2005a). Ecosystem and human –well being: Synthesis. Island Press. Washington, DC.

MEA (Millenium Ecosystem Assessment). (2005b). Ecosystem and human –well being:Current State and Trend. Vol.1. Island Press: Washington, DC, 585-621.

Meng Q.H. (2002). The effect of land use system on soil erosion and nutrient loss in the hilly slope of Loess Plateau, China. PhD dissertation. Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences: Beijing.

Miller E. L. and Shrader W. D. (1973). Efffect of Level Terraces on Soil Moisture Content and Utilization by Corn. American Society of Agronomy. Agron J 65-600-603

Moran, E. F. (2001). Progress in the last ten tears in the study of land use/cover change and the outlook for the next decade. In A. Diekman et al. (eds.). Human dimensions of global change. Cambridge, MA.: MIT Press.

Morgan R.P.C. (2005). Soil Erosion and Conservation, Blackwell Publishing, USA. pp.304

Morgan, R.P.C. (1999): Soil Erosion and Soil Conservation, Longman.

Mortimore M. (2006). Managing soil fertility on small family farms in African drylands. In: Norman Uphoff, Andrew S ball, E fernandes, H Herren, Olivier Husson, Mark Laing, Cheryl Palm, Jules Pretty, Pedro Sanchez, Nteranya Sanginga, Janice Thies (eds.), Biological approaches to sustainable soil systems.

Muchemi J., Crawhall N., Pedone G., Konante J., Kiptum Y., Kuria P (2009). Participatory 3-Dimension modeling. Kenya case study.

Mulwa F.W. and Nguluu S. N. (2003).Participatory monitoring and evaluation. Eldoret and Nairobi. Zapf Chancery.

Mundia CN., Murayama Y. (2009). Analysis of land use/cover changes and animal population dynamic in a wildlife sanctuary in East Africa. Journal.Remote Sens. 1, 952-970

Murphy J. (1993). The farmers and organizations. Major actors in development.The International Bank of Reconstuction and Development. Washington D.C. U.S.A.

Nadhomi D and Tenywa J.S. (2009). Development of an erosion assessment framework and control strategy in the lake Victoria basin of Uganda. 7th International science conference on the human dimensions of global change 26-30 April, 2009 Bonn, Germany

Nyariki D.M. (2008). Household data collection for socio=economic research in agriculture. Approaches and challenges in developing countries. JSS. 785.

Odimegwu C.O. (2000).Methodological issues in the use of focus group discussion as a data collection tool. Journal of social sciences. 4(2-3): 207-212.

Ong C. K., Wilson J., Deans J. D., Mulayta J., Raussen T. and Wajja-Musukwe N. (2002) Tree-crop interaction: manipulation of water use and root function. Journal of Agricultural Water management, Vol 53, 1-3 Pp. 171-186

Okoba B. O. and De Graaff J. (2005). Farmers' knowledge and perceptions of soil erosion and conservation measures in the Central Highlands, Kenya.Land degradation and development. Vol.16 (5) 475-487.

Oostendoro R.H. and Zaal F. (2011). Understanding adoption of soil and water conservation technologies: The role of new owners. CSAE Working paper WPS/2011-05

Ovuka, M. (2000). More people,more erosion? Land use, soil erosion and soil properties in Muranga, Kenya. Lnd degradation and development 11 (2): 111-124.

Owino J.O., Owido S.F.O., Chemelil M.C. (2006). Nutrients on runoff from a clay loam soil protected by narrow grass strips. Journal, Soil Til.l Res. pp. 116-122.

Pansak W., Dercon G., Hilger T.H., Kongkaew T. and Cadisch G. (2007). 13C isotopic discrimination: a starting point for new insights in competition for nitrogen and water under contour hedgerow systems in tropical mountainous regions, Plant Soil 298, pp. 175–189.

Pansak W., Hilger T.H., Dercon G., Kongkaew T., Cadisch G. (2008). Changes in the relationship between soil erosion and N loss pathways after establishing soil conservation systems in uplands of Northeast Thailand. Agriculture, Ecosystems and Environment. Vol. 128, Issue 3.

Rai S. C., Sharma P. (2009). Carbon dynamics change with land-use/cover: an analysis from a watershed of north-east India. IOP Conference. Series: Earth and Environmental Science (6) 34:20-36

Rambaldi G. (2005). Who owns the map Legend? URISA Journal 17: 5-13.

Reynolds F.J., Smith S.D.M., Lambin F.E., Turner II. B.L., Mortimore, M., Batterbury J.P.S., Dowing E.T., Dowlatabadi H., Fernández J.R., Herrick E.J., Huber-Sannwald E., Jiang H., Leemans R., Lynam T., Maestre T.F., Ayarza M., Walke B. (2007). Global Desertification: Building a Science for Dryland Development.

Richter, G. (ed.) (1998): Bodenerosion. Analyse und Bilanz eines Umweltproblems. Darmstadt

Rogers E. 1995. Diffusion of Innovations. http://www.stanford.edu/class/symbsys205/Diffusion%20of%20Innovation.htm. Accessed: 16/03/2011

Sherbinin. (2002). A guide to land use and land cover change (LUCC). A collaborative effort of SEDAC and The IGBP/IHDP LUCC Project.

Sitek, RO. (1996). Evaluation of grass strip performance in soil and water conservation, MSc. Thesis, Dept. of Agricultural Engineering, University of Nairobi

Soil and Water conservation manual for Kenya. (1997).

Tenge AJM (2005). Participatory appraisal for farm level sdoil and water conservation planning in West Usambara highlands, Tanzania. PhD Thesis, Wagenigen University, The Nerthlands, pp 165.

Thomas, DB (1988). Conservation of cropland on steep slopes of Eastern Africa. In: Conservation farming on steeplands. (Eds. WC Moldenhauler and NW Hudson). SWCS 48: 22-27.

Thomas, DB (1993). Terrace riser stabilisation and fodder production. Paper presented to the Fourth National Workshop on land and water Management In Kenya, Wida Highway Motel, Kenya

Tiffen M., Mortimore, M., Gichuki, F. (1994). More People, Less Erosion. Environmental Recovery in Kenya. Wiley, New York, 311 pp.

Tidemann, E. (1996): Watershed Management. Guidelines for Indian conditions. New Delhi.

Turner, B.L. (2001). Land-use and land-cover change: advances in 1.5 decades of sustained international research. GAIA-Ecological Perspectives in Science, Humanities, and Economics 10(4): 269-272.

Vien H.T. (2009). The linkages between land reform and land use changes: A case of Vietnam. 7th International science conference on the human dimensions of global change. Bonn, Germany

Vth World Park Congress. (2003) Protected areas managed by private landowners: The case for private sector investment in conservation. An African Perspective. Durban, South Africa. WPC Governance stream.

Wimmer, T. H. (2002): Watershed Management to regulate erosion processes in tropical and subtropical regions. In: Schütt, B.; Mekonen, A. and Förch, G. (2002): Field Study 'Landscape Sensitivity'. Landscape sensitivity of Hare River catchment area, South Ethiopia – with special focus on water budget and soil erosion. Field Guide. Arba Minch, Berlin, Siegen, p. 53-65.

Woyessa Y.E., Pretorius E., Heerden P.S., Hensley N., Rensburgvan L.D. (2006). Impact of land use on River Basin Water Balance: A case study of Modder River Basin, South Africa.

Wu, J and Babcock B.A. (1998). The choice of tillage, rotation and soil testing practices: Economic and Environmental Implication. American Journal of Agriculture and Economics, 80: 494-511.

Zondag and Borsboom (2009). Driving forces of land use change: 49th ESRA conference. Lodz, Poland.

CHAPTER 5

Farmers' Views on Soil Erosion and Soil and Water Conservation Technologies at Kathekakai Location, Machakos District

Abstract

The study identified factors that influence adoption of soil and water conservation measures (SWC) at Kathekakai location of Machakos District. An interview schedule was used to collected data from 62 farmers. Results show that most (86%) farmers experience serious soil erosion. A large number of farmers said they got information on SWC from other farmers (65%). Investment in SWC was mainly influenced by extent of water damage, slope of land and other farmers. Most farmers had witnessed reduced water damage (25%) and increased yield (10%) after investing in SWC. Terraces and cover crops were the largely used in SWC. Training, pest, and diseases were identified as the major constraints in adoption of SWC. Lack of finances, labour, and land subdivision are other factors that were said to contribute to low adoption of SWC. The urgent need for researchers to develop control measures for termites was identified as crops, napier and trees planted were adversely destroyed. The study also recommends that extension agents concentrate on properly training few farmers who then become the transfer agents.

Introduction

Soil erosion is the major limiting factors to crop production and is more severe in semi-arid region, of Kenya, often characterized by extreme weather conditions and poor vegetation cover. Population pressure and tribal conflicts have further forced many farming communities to settle in marginal dry areas. In addition, the sizes of land parcels have continued to decrease with time due to subdivision. This coupled with the need to produce more food for the growing population has led to further land degradation through accelerated soil erosion and runoff.

Most of the soil and water conservation measures advocated by extension agents are expensive and usually do not incorporate farmers knowledge which has made many farmers to remain largely unconvinced on the value of undertaking soil and water management approaches, and this consequently translates to low adoption rates (Tenge, 2005). Charlotte and Slaymaker (2000) demonstrated that investment in SWC was greatly influenced by the degree to which agriculture is a source of livelihood, shortage of agricultural land; and/or the potential to increase yields and especially of high value crops. Farmers in Bantieniema, Burkina Faso where agriculture is the main source of income reclaimed abandoned land (Bandre and Batta, 1999) while those in Pankshin, Nigeria continue to cultivate land, which could be considered unsuitable for agricultural farming (Ahmed et al., 2000). In both cases, the importance of agriculture in rural livelihoods and the shortage of agricultural land are driving forces for investment in SWC. Areas with low agricultural productivity have also shown low interest in investing in SWC (Bandre and Batta, 1999). A study in Uganda pointed out continued livelihood insecurity and market collapse as major driving forces to the desire to invest in SWC (Makumbi and Okubal, 2000). Reduction of 15–25% of the cropping area due to additional hedgerow planting and competition between hedgerows and crops, as well as high labour requirements are other concerns of farmers when applying SWC (Pansak et al. 2008; Hatibu et al. 2000).

and livestock farming. The crops grown include maize, beans, peas, millet, and sorghum, while cattle rearing is the main activity in livestock production

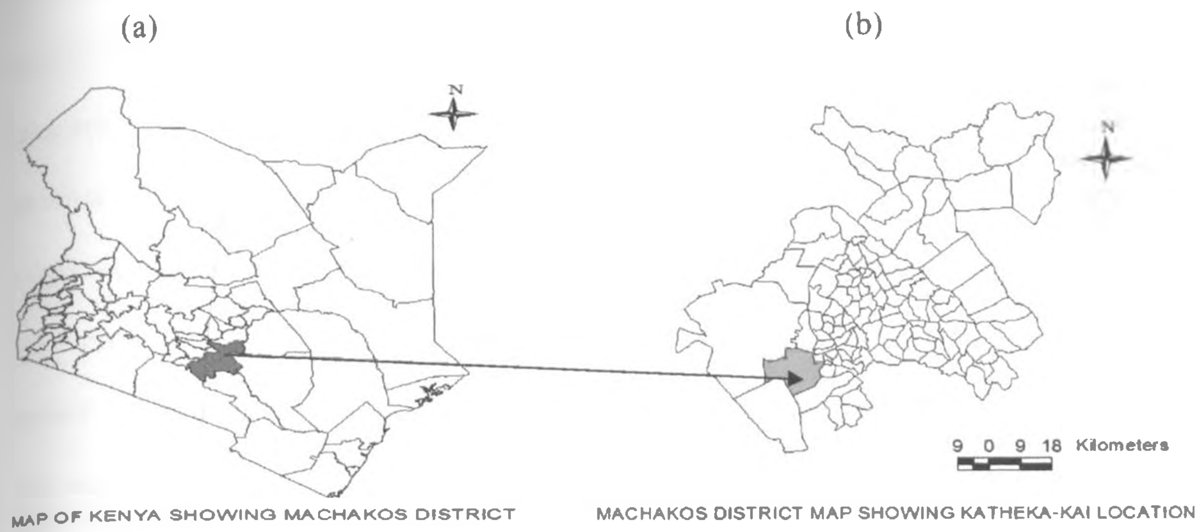

Fig 1: a) Location of site and b) study site

Population and sampling procedure

The population size for the study consisted of six households from each of the five villages in Kathekakai location. This gave a sample population of 62 households, which is greater than the statistical requirement to have a minimum size of 30 sample units (Freund and Williams, 1984).The interviewers selected household by walking through identified feeder roads and systematically selecting every fifth household on either side of the road.

Data collection

Data was collected through house hold interviews using structured questionnaire (appendix 1), field visits (transect drive) and to determine farmers perception on SWC status and constraints

Economic factors also play an important role in determining whether farmers will adopt soil and water conservation technologies. The potential to improve yields and especially of selected high-value crops has been identified as a significant factor in SWC investment (ENDA Pronat, 2000). However, the technologies pose challenges on land investment. One disadvantage of contour hedgerow, one of the most advocated soil and water conservation technology is that they provide only limited early returns on investment (Bayard et al. 2007). Furthermore, the general feeling of farmers is that improved yield only comes several years after SWC establishment (Kiepe, 1996). This requires that alternatives measures, which reduce soil erosion and at the same time better meet other farmers' interests be developed. It also shows that adoption of SWC is not only greatly influenced by different factors, but also is site specific and this study therefore aims to identify factors that influence adoption of SWC in Machakos District, Kenya.

Method of study

Site

The study was carried out in Kathekakai Settlement Scheme, in Machakos District of Kenya (Fig.1). The area, which was a ranching enterprise for nearly a hundred years, was subdivided in 1995 into individual farm holdings. Individual farmers opened-up the land (cutting trees and shrubs) for agricultural activities and other land developments. The climate of the district is typically semi-arid with mean annual temperature varying from 15 to 25°C and a total annual rainfall ranging from 400 and 800 mm. Rainfall distribution is bimodal with the long rains starting from March to May and short rains from November/December to early January. Short rains are more reliable than the long rains and therefore most important. The soils are mainly luvisols and of low inherent fertility (Gicheru and Ita, 1987). The main land use practice are crop

Results

Farmer characteristics

Data in Table 1 shows that majority (64%) of respondents were women. Conversely, 8% of the households interviewed were women owned and headed. The mean age of the respondent was 48 years and all of them had primary education. The main occupation is farming (92%) with crop production (45%) as the main activity. Despite this, casual labour (37%) and business (25%) are major sources of income while sale of farm produce contribute 11% to household income.

Table 1: Farmer characteristics

Characteristic	Percentage (%)	Characteristic	Percentage (%)
Sex		**Occupation**	
Male	36	Farming	92
Female	64	Casual labour	4
Leadership		Formal employment	2
Male Headed	68	Business	2
Female Headed	8	**Farming activities**	
Male Headed/female managed	25	Crop production	45
		Livestock production	31
Age		Farm forestry	14
Mean	48	**Contribution to income**	
Land ownership		Casual labour	37
Men owned	71	Business	25
Women owned	8	Formal employment	18
Family owned	18	Sale of farm produce	11
Educational status		Remittances	9
Primary level	53		
Secondary level	36		

Socio-economic characteristics of farmers (N=62)

Status of soil erosion and soil and water conservation measures

Table 2 shows that most (86%) of the respondents experience serious soil erosion. However, a majority (30%) do not know the indicators of soil erosion. A large number (10%) of those aware cited gullies and rills as the indicator for soil erosion. Terraces (50%) and cover crops (25%) were the largely used SWC measures. Majority (65%) of the respondents said they got information on SWC from other farmers. Still a good number (40%) said they got information from the Ministry of Agriculture while 30% used own experience to invest in SWC. Most (25%) of the respondents said that SWC had reduced water damage to the cropland, 10% had witnessed increased yield while 10% were not sure of any effect. Mainly, the used SWC measure was influenced by extent of water damage (20%), slope of land (20%) and other farmers (20%). Experts (government agents, researchers, NGO's) and increase in production influenced SWC use by 7% and 3% respectively.

Table 2: Status of soil erosion and soil and water conservation measures

Issue	Percentage	Issue	Percentage
Current situation of soil erosion		**Source of SWC information**	
Serious experience	86	Other farmers	65
Mild experience	7	Ministry of Agriculture	40
No soil erosion	7	Own experience	30
Awareness on soil erosion indictors		Researchers (KARI)	16
Do not know	30	**Perceived effect of SWC**	
Gullies and rills	10	Reduced water damage	25
Damaged terraces	5	Improved yield	10
Soil loss	5	Not sure of any effect	10
Bare land	3	**Factors influencing use of SWC measures**	
Low productivity	3	Extent of water damage	20
SWC measures used		Steep slope	20
Terraces	50	Other farmers	20
Crop cover	25	Experts (government agents, researchers, NGO's)	7
Agroforestry	15	Increase production	3
Preserved bush	4		
Sacks	4		

Constraints to SWC investment

Data in Table 3 reveals training (30%), pest and diseases (14%) as the major constraints in adoption of SWC. Lack of finances (7%), labor (5%), and knowledge on SWC (5%) are other factors contributing to low adoption of SWC. Land subdivision (4%) and grabbing of public land (4%) also influence adoption of SWC.

Table 3: Challenges in adoption of SWC

Challenge	Percentage (%)
Lack of trainings	30
Pest and diseases	14
Lack of finances	7
Labour	5
Poor soils	5
Knowledge on SWC	5
Poor relationship and harmony in family	5
Subdivision of land	4
Personalization of public land	4

Discussions

Although sale of farm produce contributes only 11% of household income, farming is still the major activity in this area. This is an important pointer to which SWC will be used as was demonstrated by Charlotte and Slaymaker (2000) that when agriculture is the source of livelihood, agricultural land is scarce and investing in SWC has the potential to increase yields, then the possibility that farmer will invest in SWC measures is high. Casual labor and business have the highest contribution to household income and this is an important factor in SWC investment. Investment in SWC is an expensive venture requiring both labor and finances. These two occupations would mean casual labor is available while business may provide finances needed to invest in SWC.

Although 86% of those interviewed said they experience serious soil erosion, still good (30%) did not know some of the indicators of soil erosion. This may explain why most of them cited gullies and rills as these are the obvious indicators, yet erosion is most damaging in terms of water, soil and nutrient loss (Gachene et.al. 1995). This is a wake-up call for the experts as gullies and rills become visible after the damage is already done. Mostly, terraces and cover crops are the SWC measures used in this area. The high investment in SWC measures is justified by the fact that 92% of people engage in farming activities as indicated in Table 1. However, 65% got information on SWC measure from other farmers suggesting that farmers are not receiving as much support from the extension service as needed, which consequently could translate to low innovation adoption and technology transfer. The challenge is to have farmers equipped with the right information.

Even though 40% of respondents said they got information from Ministry of Agriculture staff, farmers own experience also played a big role in information transfer. Exchange of ideas among farmers has been found to be more frequent and efficient with those familiar and similar to them (Murphy, 1993), and hence farmer field schools (FFS) become crucial in extension services. Farmer field schools encourage peer learning and by so doing develop farmer expertise that enables them make their own crop management decisions. This approach has been shown to increase adoption rate of technology. Dinpanah et.al. (2010) reported that 63.9% of farmers who participated in FFS adopted rice production technologies compared to only 13.3% who had not participated in FFS and adopted the technology.

The extent to which other farmers and own experience influenced use of SWC was found to be as important as other factors (e.g. extent of water damage and slope of land). Agwu et. al. (2008) found a positive relationship between farming experience/social participation and adoption of improved technologies. The observation suggests that constant interaction and contact with fellow farmers helps them become aware of new technologies. This means that farmers are more likely to obtain information and be influenced in their farming practices and management decisions by other farmers than extension workers. However, it should be important to note that information from other farmers may be wrong and/or obsolete especially if they were not well informed. Lack of proper information can be associated with the observation made in plate 1 where farmer laid terrace intersects with Expert laid terrace.

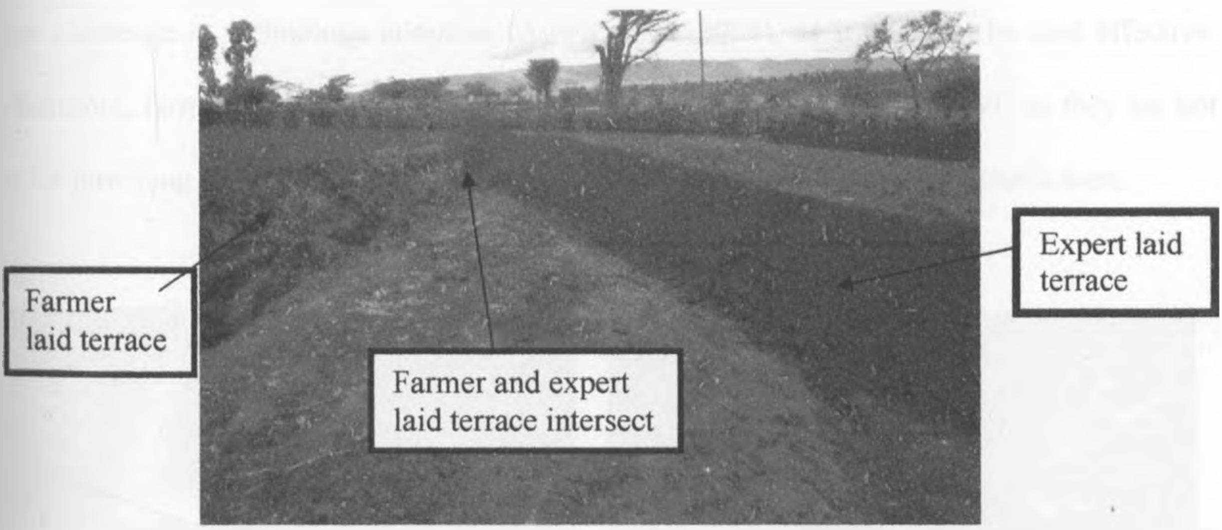

Plate 1: Terrace developed through own experience and experts intersects

Increase in production had least influence on adoption of SWC measures. Farmers are interested in investments that have immediate benefits. More often, SWC measures offer long term benefits and it may be important to design a range of technologies with short-term and long-term benefits.

A good number (30%) of farmers identified lack of training as a major constraint to adoption of SWC measures which suggests that farmers were not receiving as much extension support as needed and consequently this may affect adoption of innovations and transfer of technologies. With minimal number of agricultural staff, it may not be possible to visit each of the farmers in this vast area, and farmer field schools, field days and demonstration sites become an important method of doing extension.

Termite is a significant pest that affects land productivity in this area (Plate 2, 3, 4, 5). Mature maize crops, grevillea and napier mostly used in SWC measures were found to be infested by termites. This greatly reduces expected benefits and hence lead to low SWC measures adoption rate. Land sub-division leads to relatively small farm land. Investing in small farm constitutes a major challenge to technology adoption (Agwu et. al. 2008), as it may not be cost effective. Furthermore, farmers living on public land e.g. on hills may not invest in SWC as they are not sure for how long they will be on such land and hence feel investing may not benefit them.

Plate 2: Napier grass infested by termites

Plate 3: Maize cob infested by termites

Plate 4: Grevillea tree infested by termites

Plate 5: People settled on the hill

Conclusion and recommendation

The finding of this study reveal that other famers are a major source of information on improved SWC. They also greatly influence adoption of SWC. This shows that farmer to farmer extension as the best practices. To ensure that farmers convey the and right message to their fellow farmers, extension agent will have to concentrate on training of trainers who then become the agents of technology transfer. The study also puts a challenge to researchers in pest control. Termites were found to be a great threat to adoption of SWC as they infested the crop, napier and trees used, and it will require that researchers develop methods of pest control.

CHAPTER 6

Farmers Perception on Changes in Natural Resource Base at Kathekakai Settlement Scheme, Machakos District, Kenya

Abstract

This study analyzed changes in natural resources in Kathakakai settlement scheme, Machakos District using participatory mental resource mapping. The area, which was a ranching enterprise for nearly a hundred years, was sub divided in 1995 into individual farm holdings with average farm size of 2.5 hectares per household. Individual farmers opened-up the land for agricultural activities and other land developments. The results show that natural resources have decreased since the ranch became a settlement scheme in 1995. Farmers indicated that the natural forests decreased and have been replaced by exotic trees. Vast land has been cleared for cultivation, rivers, and dams dried-up and soil erosion increased. A majority of farmers (98%) said they had observed a general change in climate of the area. They cited declining crop production (29%), increased drought (15%), and increased temperatures (10%) as some of the major pointers to climate change. However, farmers have adopted various coping strategies. Drought tolerant crops (25%), early maturing crops (17%), and water harvesting (14%) were some of the strategies adopted by farmers in response to the emerging changes. The results also show that resource base management at the community level is still a challenge and a lot of investment needs to be done in this area for sustainable management.

Introduction

Participatory mapping is the creation of maps by local communities usually with the guidance of organizations e.g. government agencies, non-governmental organizations, universities, other stakeholders interested in development and land planning. The activity provides a platform for community to represent in visual terms a place and significant features within it (IFAD, 2009). These features may range from natural physical features, resource and social cultural features known by the community.

Participatory mapping is a powerful tool to good governance and this has lead to increased use of this initiative for the last 20 years throughout the world (IFAD, 2009). It is a useful medium for communities to communicate land related information at present and future needs to government to better understand the community and environment, and hence aid in planning (McCall, 2004). The exercise facilitates management of land, resources, and supports community advocacy on land related issues (Di Gessa, 2009). This is one of the best ways to 'empower' community, as participation prioritizes local decision-making and reinforces responsibilities.

The ability of individual citizens and communities to share their understanding of the past, present and visions for the future is an important pre-requisite to informed planning and, through this, to building a consensus on complex issues such as sustainable development (Curwell and Hamilton, 2003). Through maps, communities are able to communicate long but invisible history of managing resources. The process therefore assists the community to articulate and communicate desired management plans to local or regional planners, which could enable the community to access productive natural resources and promote decentralized management of resources (Aberley, 1993). Participatory mapping therefore contributes to planning and management of local resources by enabling the community information to be incorporated and compared with government planning information and processes (IFAD, 2009).

In a number of cases worldwide, communities have succeeded to demand for legal recognition resource rights through maps (McCall and Minang, 2005). In Guyana, Amerindian people claimed ancestral land titles (Griffiths, 2002) as a result of participatory mapping of resources through Participatory Geographical Information Systems (PGIS); the Zuni pueblo of New Mexico prepared digital maps of 'non-graphic descriptions' of their appropriated lands to receive a quarter of a million acres as compensation (Marozas, 1991). In the Philippines, claiming Ancestral Domain Title is conditional on preparing a resource management map for the area (Rambaldi and Callosa-Tarr, 2002); and in Indonesia, through participatory mapping it was possible to identify traditional village territories and competing rights claims (Sirait et al. 1994), that were crucial for planning. Futherstill, the Ogeik, Sengwer and Yaiku indeginous communities in Kenya were able to initiate their own ancestral land rights, cultural rights and natural land resource management projects after a participatory resource mapping exercise carried out in 2006 (Muchemi et.al. 2009).

This study sought to use farmers' knowledge to 1) determine changes in natural resources (e.g. land, water, forests, soil) in Kathekakai location, Machakos District, and 2) assess strategies used by the community to cope with these changes

Method of study

The study area is as described in chapter 5.

Study methodology

Data was collected through focus group discussion (FGDs) during which a mental resource mapping exercise was carried out. The discussions were conducted in a free environment where the participants commented, asked questions or responded to comments of others (Mulwa and Nguluu, 2003). Most of the studies on social economic dynamics as well as natural resource management employ FGDs (Odimegwu, 2000). In this study, FDGs were used to establish changes that have taken place since the first people settled in Kathekaka in 1995.

A Participatory Rapid Appraisal exercise involving 30 farmers (13 men and 17 women) from Kathekakai location was conducted through focus group discussion and mental resource mapping. Based on the objective of the study, two FDGs consisting of 12 members each were formed. The first group consisted of farmers who were the pioneer settler (between 1995 and 1999), who drew the map of Kathekakai as they found it when they first settled. The second group had farmers who recently settled (from 2000 to date) and they drew a map showing the current natural resource situation of the area. To verify the finding, household interviews were done, with 62 farmers (36% men and 64% women) A comparison of the two sketch maps drawn was made based on natural resources .

Results

Farmers' characteristics

According to the farmers, the farm was initially a co-operative society. The enterprise was poorly managed and divided to individual share holders and hence, the land is now under private ownership. About 71% of the land is owned by men. Women own 8%, mostly through succession after death of the husband. The rest (21%) is under family ownership. Although this is a farming community (92%), most households derive their income from casual labour (37%), business (25%), formal employment (18%), sale of farm produce (11%) and remittances (9%).

Natural resource at time of settlement

Plate 1 shows group one drawing a sketch map of resources in Kathekakai location at the time of settlement.

Plate 1: Group one drawing resources time of settlement

Different types of old natural and traditional trees and shrubs were available at the time of settlement (Plate 2). Acacia tree varieties were common in the area. The rivers that passed through the area had clean and safe water for drinking and flowed throughout the year. Big earth dams for water harvesting had been constructed and wind vanes were used to pump water into well established water tanks throughout the ranch, both for livestock and human drinking. The roads, though not many, were well maintained at the time.

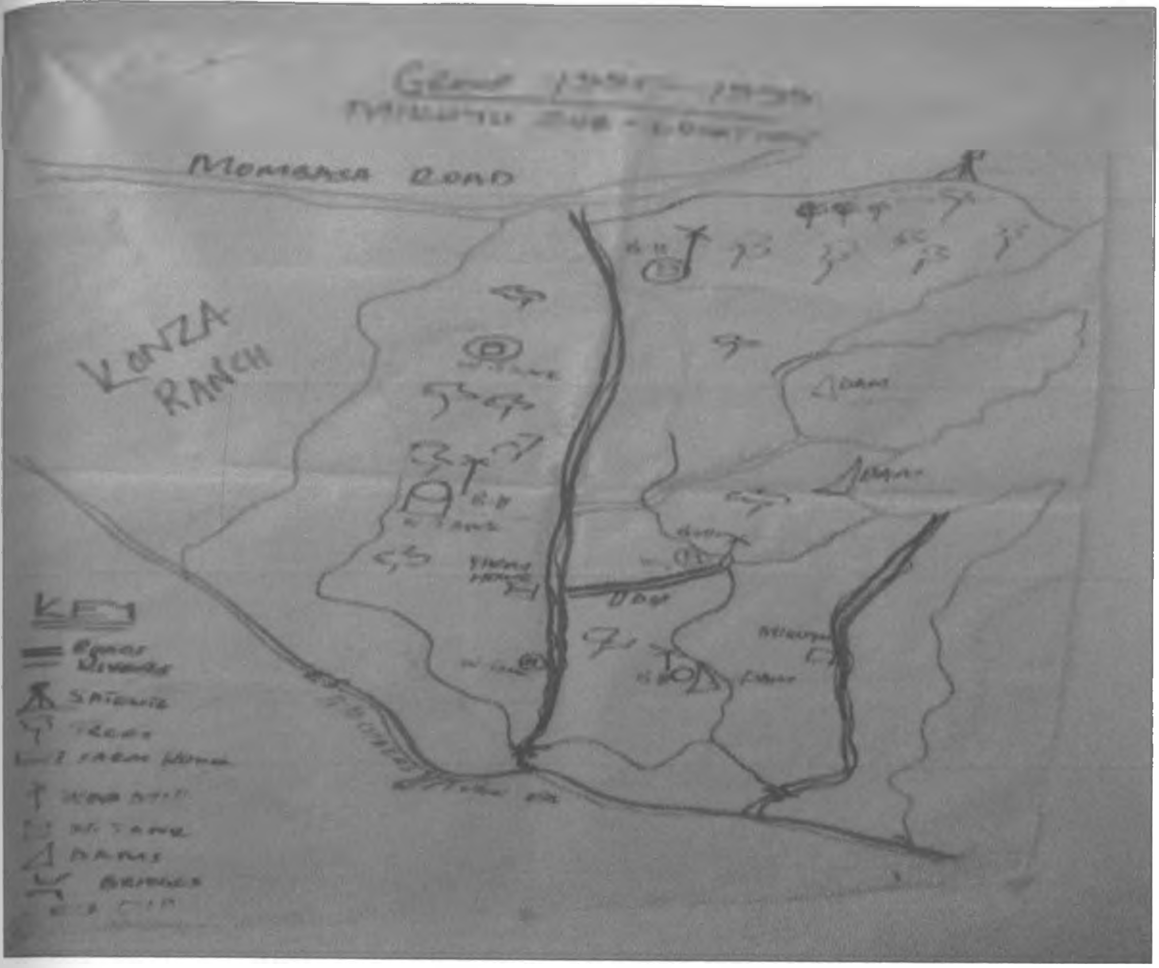

Plate 2: Sketch map showing natural resource endowment at time of settlement

Resource change

Plate 3 shows the second groups drawing a sketch map of resources in Kathekakai location by year 2009. The ranch was endowed with a lot of natural resources according to farmers. Presently, the scenario has changed as most of the resources are no longer in exsistence (Plate 4), and even where they exist, they are in poor condition. The number of people settling is increasing year after year, a situation farmers associated to its proximity to Nairobi, capital city of Kenya. This has led to more land being cleared to pave way for cultivation and other developments. Natural trees have also been cut down to cater for various uses including building, firewood and charcoal, and have been replaced by exotic trees e.g grevillea. Farmers reported the opening of new land and cutting down of trees as a major contributing factors to increased soil erosion that has led to declining land productivity, a situation that has increased food insecurity and poverty in the area. We observed this during household interviews where school going children were still at home due to hunger. This was latter confirmed when during a meeting, as the Ministry of Agriculture distributed food and planting seed to poor farmers.

Plate 3: Mental drawing sketch of resources at present

Plate 4: Sketch map showing current state of natural resources

Currently rivers that used to be perenial have become seasonal and piped water never runs anymore. Farmers also reported that dams that were available ended up belonging to individua lfarmers after land subdivision and can therefore not be used by the community. Most households either walk for long distances to draw water or buy from residents who have either dug boreholes or constructed dams. The trend, according to the residents is worrying as the increasing population exceed the limits to live on the hills, the source of the most basic need, water. This has accelerated the rate of soil erosion and has caused most water rivers to be unfit for consumption. Settlement on hills has rendered roads impassable especially during rainy seasons when mud flow from the mountains blocks the roads (Plate 5). Farmers also reported that

Plate 5: Settlement at Kiima Kimwe hill (Machakos District)

Farming systems

Farmers in this area practise mixed farming with about 45% under crop production. However, farming systems have changed with time. Farmers are abandoning the traditional crops e.g sweet potato (19%), cassava (16%) , sorghum (15%), green grams (9%), millet (8%) for modern and high value crops mostly for economic purposes. Farmers also relate this to climate change, which demands for change in the way thing are done. Livestock takes about 31% and is hence an important component of the farming systems in this area, highly contributing to food (40.2%), income (33.5%), manure (12.3%) and family labour (7.9%). Inorder of importance farmers keep poultry (mostly local chicken), cows, sheep, goats bulls and oxen. The main grazing systems are free range (40.7%), semi- grazing (33.9%) and zero-grazing (19%). The free range and semi-grazing systems also accounts for increased soil erosion as large numbers of livestock graze on land with very low vegetation. Additionally, farmers graze terraced land during the dry season which leads to damaging of the terraces.

Farm forestry (14%) is also an important system in Katheka-kai. About (64%) of farmers have planted different trees e.g. agroforestry trees (34%), fruit trees (4.9%), and leguminous trees (2.4%). The trees are planted for various reasons including windbreaking (12%), shade (11%) and firewood (10%). Fruits are planted for household use as well as income generation.

Coping strategies

Most (98%) of the farmers believe that climate has changed with time (Table 1). Some factors identified as contributing to change include cutting trees, clearing land for cultivation, sand harvesting, population pressure, increased fuelwood demand and lack of planting trees,. They agreed that this change had decreased crop production (29%), increased drought and temperatures (15% and 10% respectively). However, farmers have adopted certain measures to cope with climate change (Table 1).

Table 1: Coping strategies to change

Coping strategy	% of respondents
Drought resistant crops	25
Early maturing crops	17
Water harvesting	14
De-stocking	10
Conservation agriculture	6
Irrigation	5
Off-farm employment	8
Change of livestock breeds	3

Discussions

Changes in resources have been observed in Kathekakai location, Machakos District since 1995 when land was subdivided to private owners. The new settlers were at liberty to use the land in order to get maximum benefits. It has been reported that when individual members acquire private land with title deeds, they gets rights to make land use decisions based on the returns (Mundia and Muranyan, 2009; Serneels and Lambing, 2001). According to Mundia and Muranyan (2009), changing land tenure policy results in expansion of agricultual land. Due to its proximity to Nairobi city, the area has continued to attract a large population as a suburban area. Farmers at Katheka-kai location have continued to clear more land and cut down trees to pave way for agricultural land to meet demands for the households as well as for the ever increasing population. Therefore, small scale farmers are forced to work harder, on small farm sizes in the marginal areas, to maintain household incomes. A study carried out by Laukkonen et al. (2009) reported population growth as a major driver of environmental change in Africa, causing significant impacts on the natural resource base with the primary and most direct impact as land cover change mainly through opening of new land for agriculture, and other developments.

The area has witnessed changes in farming systems. Farmers have abandoned local and traditional crops and adopted those deemed to have high returns and preferred by the swelling population. The able farmers have embarked on irrigated agriculture and green house farming from the few flowing rivers. It has been reported that population growth shapes patterns of production and consumption in the world usually by increasing demand for food, water, arable land, fuel wood, and other amenities (UNEP, 2008), and hence determines the farming systems in an area. However, the increased agricultural activities led to encroachment into forests and woodlands, accelerated soil erosion and soil fertility and food insecurity and rise in poverty levels.

As good as agricultural activities are in sustaining household livelihoods in the short-run, if poorly managed they may have detrimental impacts on environmental resources. Felling of trees for agricultural land and timber products and settlement on hills has degraded watersheds and interfered with hydrological functioning resulting in low yield. Extensive economic activities and population congestion has increased pressure on water for various uses including domestic, livestock and industrial use, among others, causing conflict over water resources. This may result in natural resource base degradation, which in turn impinges on the livelihoods, with most of the consequences more pronounced in the rural communities (Laukkonen et al, 2009).

Diversification in the agricultural activities becomes paramount to cushion against adverse effects climate change. It has been indicated that in the absence of alternative opportunities, lack of sustainable management of natural resource and alternative opportunities to meet the needs of the increasing population results in environmental degradation and resource depletion (Laukkonen et al, 2009). Farmers in this area are taking precautions by adopting some of the coping strategies e.g. drought resistant crops, early maturing crops, water harvesting, and de-stocking. However, a lot of advocacy on mitigation and adaptation strategies has to be done for increased adoption rate.

Conclusion and recommendation

The process of resource mapping open the minds of farmers to understand the past, present and future situation, and the problems facing the community. Decreasing trends in natural resource base after settlement was witnessed and associated with increased population and poor management especially of communal resources. Farmers in this area are aware of environmental change though issues on mitigation and coping strategies needs to be addressed. Most of the farmers still rely on their past farming experience and this poses a great challenge to development of any area. It would be important to impress to the community where they will be in future if appropriate environment conservation measures are not employed and continue doing "Business as usual."

CHAPTER 7

Trends in Land Use and Land Cover Changes over a 21 Year Period in Kathekakai Settlement Scheme, Machakos District, Kenya

Abstract

This study monitored and analyzed land use/cover changes in Kathekakai location of Machakos District using Landsat data between 1988 and 2009 and attempted to discuss possible socioeconomic backgrounds for changes. Supervised classification approach coupled with geographical information systems (GIS) analysis was employed to generate land use/cover maps with seven classes; forests, cultivated land, savannah grassland, bare land, rocky areas, water bodies, and built-up areas. A post-classification comparison change detection technique revealed different trends in land use/cover changes between 1988 and 2009. Changes were observed across all land use/cover regardless of agricultural potential. Savanna grassland, forest cover, cultivated land and built-up areas increased by 15.8, 2.7, 1.8 and 0.5% respectively between 1988 and 2009, while rocky areas, bareland and water bodies decreased by 12.8, 7.4 and 0.5% respectively within the same period. Rocky areas and bare land were the most affected with substatial area becoming forested. Most of the changes in land use/cover were associated with population, land owership, infrastucture and proximity to Nairobi city and Machakos town. The trend is expected to continue especially for cultivated and built-up areas noting that population of the area is on an upward trend.

Introduction

The state of the world's vegetation has become a major subject of research; the reason being that vegetation is a key indicator for overall environmental conditions. With satellite remote sensing, it is now possible to document the status of land use and cover changes at a global, regional, and local level over multi-year period.

Land use change is the most ancient phenomenon of all human-induced environmental impacts, and the first to obtain a magnitude to warrant the title "global change" (Sherbinin, 2002). In effect, global environmental change has been associated with humans as a dominant force (Moran, 2001; Turner, 2001; Lambin et al., 2001). This is largely through changes in the way people use and manage land (Millennium Ecosystem Assessment (MEA), 2005a; Gobin et.al. 2001). Some of the side effects of an expanding human population include habitat destruction for farming activities, human settlement, and pollution (MEA, 2005b; Grime, 1997). Population growth also leads to expansion of agricultural activities to drier land coupled with unsupervised agricultural practices (Juneidi and Zanat, 1993; Taimeh, 1989). These changes result in landscape change and consequently influence environmental conditions. The strong interest in land-use and cover results from their direct relationship to many of the planet's fundamental characteristics and processes, including the productivity of the land, diversity of plant and animal species, and the biochemical and hydrological cycle. By altering ecosystem services, changes in land-use and cover affect the ability of biological systems to support human needs making places and people more vulnerable to climatic, economic, or socio-political perturbations (Sherbinin, 2002).

A large proportion of earth surface serving as source and sink to most of the materials and energy have been transformed by the rapid growing population (Weng, 2001). The change, mostly permanent land development, results in environmental induced problems e.g. declining biodiversity, water scarcity and poor quality due to increased sedimentation and, poor soil fertility and quality, soil erosion and run off respectively (Steffen et.al., 1992 and Jonathan et. al., 2005). In effect, global carbon and hydrologic cycle get interrupted and climate change sets in. It therefore becomes important to understand processes and patterns of land use/cover change as this is, to a great extent, associated with sustainable socio-economic development (Lambin et. al., 1999). The study area, (Kathekakai Settlement Scheme) was until 1995 a ranching scheme. The change to individual farms has transformed the land use state and this provides a niche in studying land use change in the area over the last 21 years. The objective of this study was thertefore to assess land-use and cover change pattern of the Kathekakai settlement scheme for the last 21 years.

Method of study

The study site is as described in chapter 5.

Study methodology

To detect changes in land use and cover, at least two time- period data sets are required (Jenson, 1986). In this study, One Thematic Mapper 4 (TM) and one Enhanced Thematic Mapper 7 (ETM+) landsat maps were used to assess land use and cover change over a 21 year period in Kathekakai settlement scheme (Table 1)

Table 1: Satellite images

Characteristics /sensor	Landsat TM	Landsat ETM+
Date	1988-10-01	2009-09-25
Path - row	168-61	168-61
Elevation source	GLS2000	GLS2000
Spatial resolution	30	30

The dates of the images were purposely chosen to avoid uncertainties and were acquired within the same season (dry period) in a year. This is to avoid temporary land cover evident in wet season. Cloudiness was also a factor that was considered especially in the area of study.

Landsat map examination

Using Geographical Positioning System (GPS), points of areas (training areas) corresponding to each class (i.e. forests, savanna grassland, cultivated land, bareland, rocky areas and water bodies) were taken. Analysis of landsat maps was done using ENVI 4.7 software. Bands 4, 3, 2 were used to transform the black and white images to false color images. This helped in identifying areas/classes associated with certain spectral reflectance. Cursor location/value (Geographical position) for identified training areas from defined Regions Of Interest (ROI) were ascertained and each class was allocated the color that matched that on the landsat map. Maximum Likelihood classification was used. The method assumes that the statistics for each class in each band is evenly distributed and calculates the probability that a given pixel belong to certain class. The training points were as uniform in color as possible and their location maintained for the two images to ensure that correct pixel identified the correct class. The descriptions (Table 2) were used to identify each of the seven classes (forests, cultivated land, savannah grassland, water bodies, built-up land, rocky areas, and bare land).

Table 2: Land use classes

Class	Description
Forests	Native trees
Cultivated land	Crop land
Savannah grassland	Grasses, scrubland, pastureland
Water bodies	Lakes, rivers, dams, streams
Built-up land	Buildings, roads, warehouses, green houses
Rocky areas	Large areas with visible rocky cover
Bare land	Bare soil, very sparse vegetation

Change detection

Thematic change detection for Landsat TM and Landsat ETM+ was established using ENVI EX. This was done by selecting two images of the same scene, with same number of classes and same names at different times. The software identifies differences between the images and with a resultant classification image. Thematic change vectors created during classification were saved to a shape file; while statistics on image change was saved as thematic change statistics and opened in a Microsoft excel spreadsheet. The results were then examined and analyzed for land use change.

Results

Spatial land coverage for land use/cover as derived from Landsat maps are illustrated in figures 1 and 2. During the period of 1988 - 2009, the major land use/cover was savannah grassland, bare land, rocky areas, and forest. Cultivated land, built-up areas, and water bodies had the least land cover. The land use/cover change has been dynamic with about 68.6% land changing from one land use to another between 1988 and 2009.

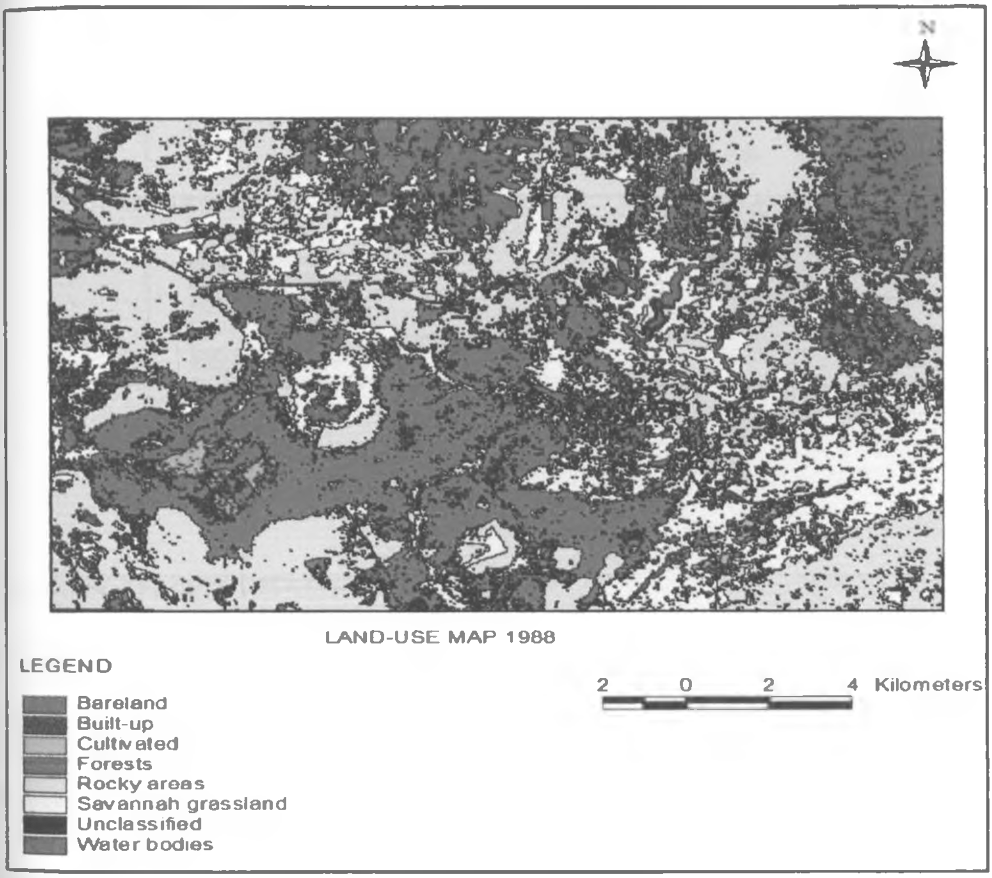

Figure 1: Land use/cover 1988

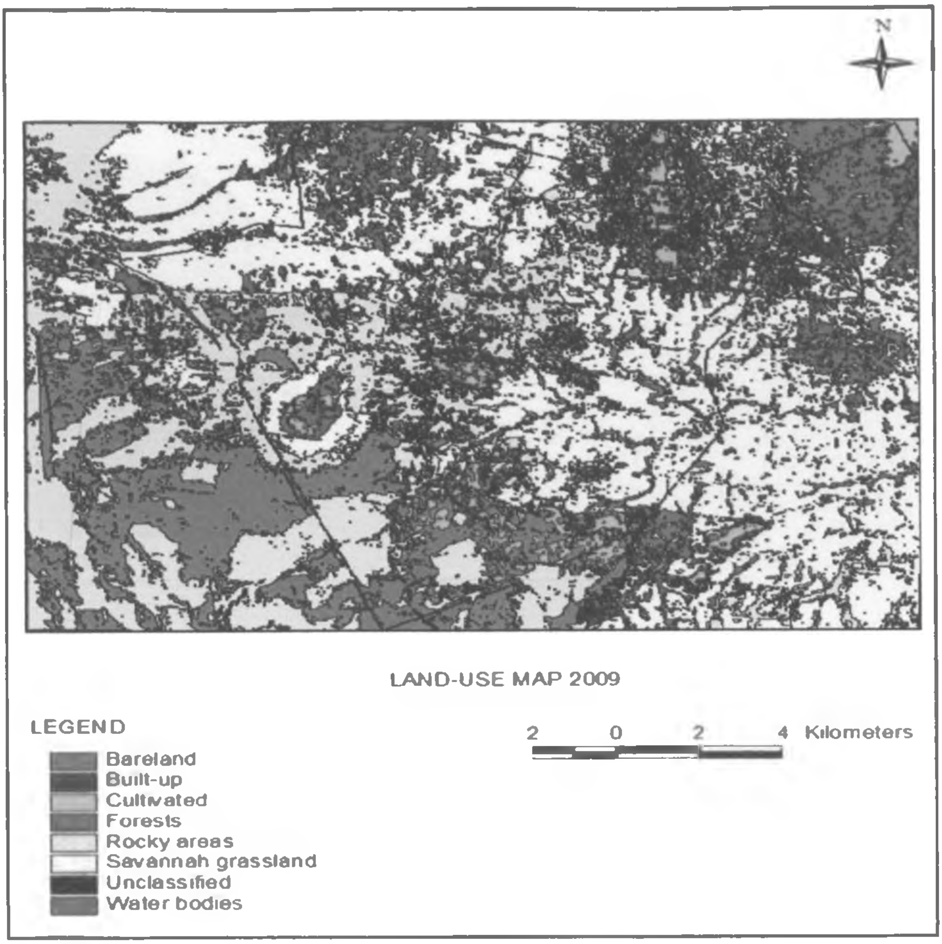

Figure 2: Land use/cover 2009

Land use changes between 1988 and 2009

Percentage land use/cover in 1988 are illustrated in figure 3. The results show that rocky areas occupied the largest land cover (39.5%) followed by savannah (24.2%), bareland (23.1%) and forests (4.2%)). Water bodies, cultivated and built-up areas covered 1.1, 1.0 and 0.1% each respectively.

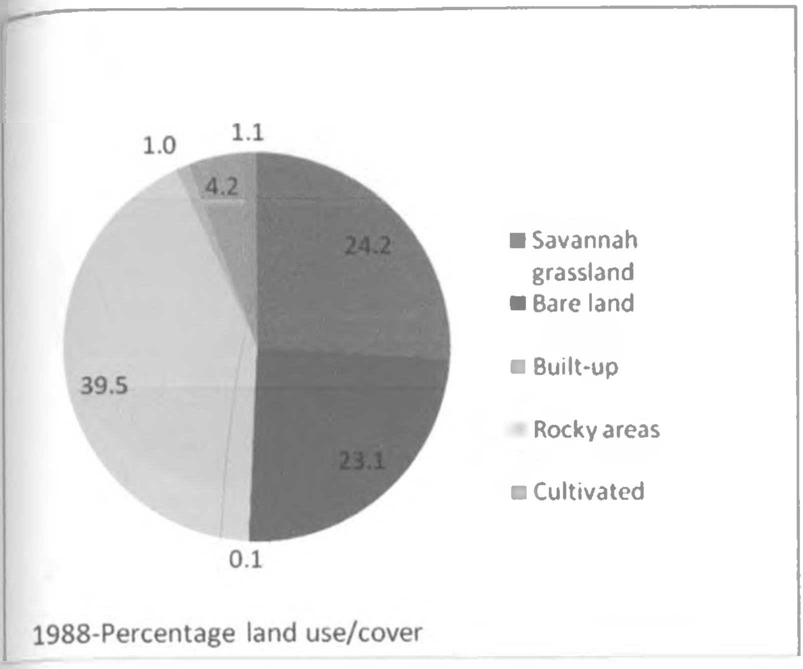

Figure 3: Percentage land use/cover in 1988

Figure 4 shows the percentage land area for each land use/cover in year 2009. Land under savanna grassland (40.0%), rocky areas (26.7%) and bareland (15.7%) still ocupied the largest area in 2009. Land under forest cover, cultivation and build-up increased to 6.9, 2.8 and 0.6% respectively. Savanna grassland, forest cover, cultivated land and built-up areas increased by 15.8, 2.7, 1.8 and 0.5% respectively between 1988 and 2009, while rocky areas, bareland and water bodies decreased by 12.8, 7.4 and 0.5% respectively within the same period (Figure 4).

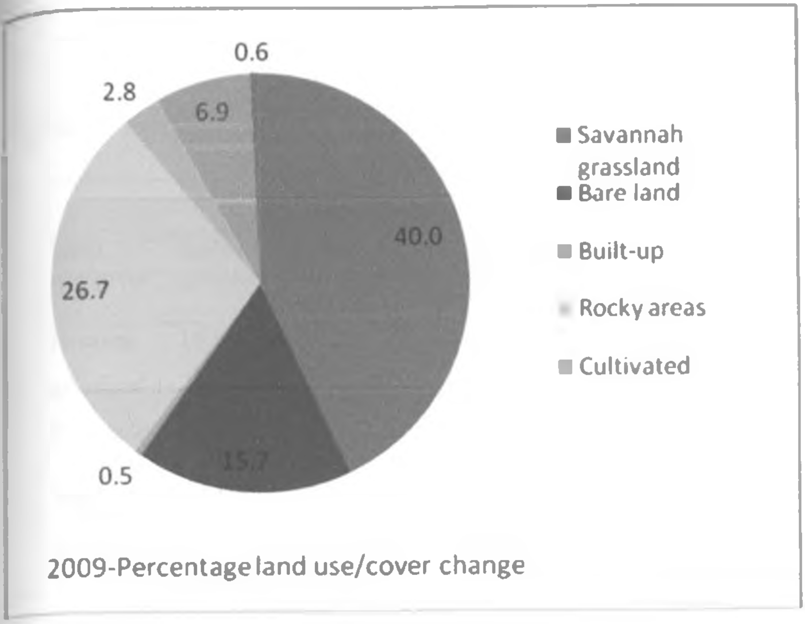

Figure 4: Percentage land use/cover in 2009

Land-use and cover transformation from 1988 to 2009

The 15.8% increase recorded in savanna grassland was at the expense of rocky areas, forest cover and bareland that lost 18.7, 2.9 and 2.1% respectively (Table 3). Despite the loss, forest cover still recorded 2.7% increase between 1988 and 2009 mostly from rocky areas (1.6%) and bare land (1.2%). Apart from becoming savanna grassland, most of the bare land was converted to rocky areas (7.6%), cultivated land (1.8%) and forests (1.2%) and this explains the 7.4% decrease in area under bareland. Cultivated land witnessed a 1.8% increase between 1988 and 2009 and was due to conversion of bare land (1.8%) and forest cover (0.6%) into cultivated land. Increase in percentage area under built-up areas (0.5%) was as result of conversion of bare land (0.2%), rocky areas (0.2%) and savanna grassland (0.1%). Water bodies changed to become savanna grassland (0.7%) and rocky areas (0.4%) and this led to 0.5% decline in land under water bodies.

Table 3: Percentage land use/ cover converted to other land uses between year 1988 and 2009

	% Land use/cover transformed to other land use/cover									
Land use/cover	Savanna grassland	Bare land	Built-up	Rocky areas	Cultivated land	Forests	Water bodies	2009 % land use/cover	2009 % unchanged land use	% Total gain
Savanna grassland	15.6	2.1	0.0	18.7	0.0	2.9	0.7	40.0	15.6	24.4
Bare land	2.0	10.2	0.0	2.8	0.7	0.0	0.0	15.7	10.2	5.5
Built-up	0.1	0.2	0.1	0.2	0.0	0.0	0.0	0.6	0.1	0.5
Rocky areas	2.9	7.6	0.0	15.7	0.0	0.1	0.4	26.7	15.7	11.0
Cultivated land	0.0	1.8	0.0	0.1	0.2	0.6	0.0	2.8	0.2	2.6
Forests	3.5	1.2	0.0	1.6	0.1	0.6	0.0	6.9	0.6	6.3
Water bodies	0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.6	0.0	0.6
use/cover	24.2	23.1	0.1	39.5	1.0	4.2	1.1			
land use/cover	15.6	10.2	0.1	15.7	0.2	0.6	0.0			
oss	8.6	12.9	0.0	23.8	0.8	3.6	1.1			

Land use change dynamics

Fig 5 shows the dynaimcs (unchanged, gained, lost land as well as total land affected) of each land use/cover from 1988 to 2009. In all land use/cover, percentage land affected exceeded the unchanged land. The most affected land uses include rocky areas (34.7%), savanna grassland (33.0%), bare land (18.3%) and forests (9.9%). Percentage unchanged land was less than that affected in all land uses (Figure 5). However, all land under water bodies was affected. Apart from savanna grassland, cultivated land and forest cover that had gained more than was lost, all other land uses lost more land compared to what was gained.

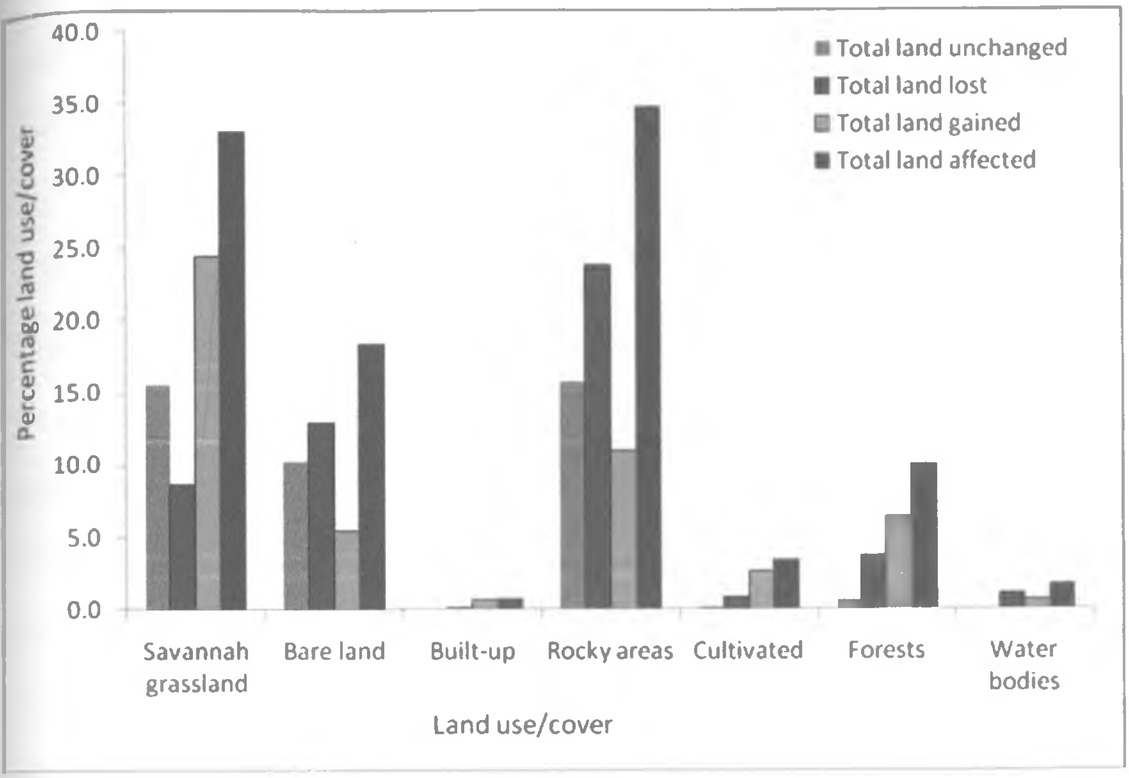

Figure 5: Land use/cover dynamics

Discussions

Changes in land use/cover have taken place in Kathekakai location, Machakos District between 1988 and 2009. The study shows that savanna grassland, bare land and rocky areas are the dominating land uses/cover throughout this period. This is expected as the area is a rangeland initially hosting a range of wildlife animals. Kathekakai ranch which was a home to many animals now hosts only a few animals as the area has become populated by human. The increasing population has forced more land to be opened up inorder to meet the rising demand for land both for development and agricultural activities. This could explain the increase in land cover under cultivation and built-up areas. Again, the land which was initially a private ranch became a communal ranch in 1995 when the land was subdivided to private owners. The new settlers were at liberty to use the land in whichever way deemed best to them after acquiring title deeds for the land.

A study carried out by Gathaara et. al. (2010) in the same area reported that most of the farmers resulted in agricultural activities to meet household and increasing population demand as well as for economic gains. Similarly, Mundia and Muranyan (2009) reported that changing land tenure policy resulted in expansion of agricultual land. Furthermore, after subdivision and issuance of title deeds to individual members, the owner gets the rights to make land use decisions based on benefits (Mundia and Muranyan, 2009; Serneels and Lambing, 2001). The area is also near Machakos town, a major rural centre. This together with its proximity to Nairobi, the capital city of Kenya makes the area to continually attract a big population as a suburban area. Another important factor is the road network. Mombasa road that serves the port of Kenya passes through this area. These could be cited as some of the factors responsible for the mushrooming of permanent settlement, also associated with increasing agricultural activities. Similar finding were reported by Audirac (2003) that closeness to cities and roads were some of the key factors that led to rapid land development.

A notable increase in savannah grassland was observed between 1988 and 2009. The gain was mainly at the expense of rocky areas, bare land and forest cover (Table 3). Gathaara et. al. (2010) reported that Kathekakai was dominated by absentee farmers, who after acquiring land, fenced the land to keep off intruders. This together with reduced number of animals could have provided enough time for vegetation growth on both rocky areas and bare land with minimal disturbance from either livestock or wild animals, and hence the increase in area under savanna grassland. During farmers interviews and focus group discussions, it was reported that cutting down of trees was a rampant activity in the area to give way to land development, provide fuelwood and for building materials. A study carried out by Gathaara et.al. (2010) on adoption and opportunities for improving soil and water conservation practices found comparable results.

Despite tree clearing, forest cover did not decrease but rather increased within this period with most of the savanna grassland, rocky areas and bare land becoming forests (Table 3). A tree planting project conducted by International Centre for Research and Agroforestry (ICRAF) in 1996 in the area saw most of the farmers in the area embarking on planting exotic trees such as *Grevillea robusta* while still re-introducing indigenious trees (e.g *Melia volkensii)* that are almost becoming extinct, and this could have resulted in increase in forest cover. Percentage land cover under water bodies decreased between 1988 and 2009 with most land becoming and other converted to savanna grassland. This was confirmed during ground truthing where rivers had dried up and farmers either bought water from vendors or walked for long distances in search of water. Gathaara et.al. (2010) also reported water as a scarce commodity in Kathekakai location, a situation farmers associated with climate change during focus group discussions.

Changes were observed across all land use/cover regardless of agricultural potential. Rocky areas and bare land were the most affected with 1.6 and 1.2% becoming forested respectively. Studies have reported side effects of an expanding human population including habitat destruction for farming activities, human settlement, and pollution ((Millennium Ecosystem Assessment) MEA, 2005b; Grime, 1997), usually associated with how people use and manage land (MEA, 2005a;

Gobin et.al. 2001). However, the findings of this study suggest otherwise and in agreement with Tiffen et al. (1994). Despite the increased population, savanna grassland and forest cover increased implying that increased population led to better land management practices, hence changing the landscape of the area.

Conclusions

It is evident that land use change has taken place in this area. Savanna grassland, forest cover, cultivated land and built-up area had an upward trend over the 21 year period. Most of the changes in land use/cover were associated with population, land owership, infrastucture and proximity to cities. This trend is expected to continue especially for cultivated and built-up areas noting that population for the area is on an increasing trend. Athough human activities have been associated with negative land use changes especially forest disapperance and loss of vegetation, the sudy suggests a boost to environmental conditions in this area as forest cover increases while rocky areas and bareland decrease which can be exploited for carbon trading under Clean Development Project. However, more studies to confirm these trends cover in the sorrounding area may be necessary.

CHAPTER 8

Effects of Vegetative Macro Contour Line on Soil Moisture Conservation and Crop Perforformance in Kathekakai Settlement Scheme, Machakos District

Abstract

This study was carried out in Kathekakai Settlement Scheme, Machakos District. The objective was to assess the effect of terraced and unterraced vegetative macro contour line on soil moisture conservation and crop performance. The trial involved three treatments: Terraced vegetative macro contour line with maize mono crop and ditch (TVMD), Un-terraced vegetative macro contour line with maize-dolicos intercrop (UVMDD) and Terraced vegetative macro contour line with maize-dolicos intercrop and ditch (TVMDD). The experiment was established on four randomly selected farms that served as blocks. Soil moisture content was measured at three different slope positions (i.e. upper, middle, lower and ditch or grass strip positions) along the bench terrace. Percentage soil moisture content was determined gravimetrically in the laboratory. Plant height was taken from radomally selected crops at each slope position. Plant samples were also collected for biomass yield data.

Results indicate higher soil moisture levels along the ditch than all other slope positions along the bench. Although there were no significant differences between treatments, terraced benches recorded 15 and 13% higher soil moisture in TVMDD and TVMD treatments respectively compared to UVMD treatment. Furthermore, the upper and lower slope positions tended to give significantly ($P \leq 0.05$) higher soil moisture content compared to middle position. Moreover, plant height and biomass yield trend on the bench terrace was similar to that observed for soil moisture. Further, taller plants and higher biomass yield was observed for benches, upper and

lower slope positions than the unterraced and middle slope position though not signifacantly different. The results show some degree of effectiveness to conserve soil moisture associated with the ditch which seems to serve as a water collection and storage site. The findings thus, signifies the possibility of enhancing productivity through establishment of terraced vegetative macro contour line. For this reason, the technology ought to be considered when advising on and implementing agricultural activites in the study area.

Introduction

The ever growing population places high demand for food and hence calls for increased production. At the same time the resources are continuing to be scarce and it is therefore extremely important to harness and appropriately manage these resources, soil and water being the most important among these production resources. To achieve this, an intergrated approach to soil and water management becomes vital, especially in the dry lands which are characterized by infertile soils and water scarcity. The aim is to increase production while still ensuring sustainability of natural resource base.

Soil erosion and runoff is a serious and widespread phenomenon in many parts of the world, and is resposible for the extensive land degradation, leading to decline in land productivity. The damage is even more severe in drylands, frequented by heavy, erratic rainfall, long dry periods, and poor vegetation cover (Thomas et al. 1993), thus exposing soil surface to soil nutrient and water erosion. In Kenya, runoff and soil erosion has been identified as one of the major factors that has contributed to low crop yields since the 1930s, mostly through loss of water (Tiffen et al. 1994), plant nutrients (Gachene et al. 2004), and reduction in effective rooting depth (Gachene 2002). Recognizing the need to address this livelihood threatening problem, farmers use indigenous soil conservation technologies (Hallsworth 1987) e.g. grass strips, trash lines, pits, earth bunds, stone lines, and protection ditches. Though these technologies are popular with farmers, mostly because they are inexpensive, they may not adequately address runoff and soil loss problem. This requires that researchers develop soil and water management technologies that apart from conserving soil and water, will also adequately and effectively address farmer's needs. Therefore, designing technologies through manipulation and integration of farmers and scientific soil and water conservation technologies becomes crucial in solving the escalating problems experienced with runoff.

A range of technologies have been developed for the purpose of soil and water conservation. Among the most commonly used technologies is bench terrace. Though the technology has a high initial investment capital expenses, the fact that it can offer multiple benefits makes it the most preferred option among the farmers. Farmers are able to grow trees for fuel wood, fodder for animals and food crops both for domestic and income generation, consequently get multiple benefits which becomes a strong driving force to adoption of this technology (Ong et.al. 2002).

Terraces have been associated with reduced runoff and increased soil moisture (Kannam, 2010) as well as control of nutrient loss (Owino et al. 2006). In order to design appropriate cropping systems on a bench terrace, it becomes imperative to understand exactly how soil moisture is distributed along the bench terrace. Despite the successes associated with bench terracing, most studies have focused on relative crop yield and only scanty information is available on distribution of soil moisture along and within a bench terrace. Therefore, the aim of this study was to assess how vegetative macro contour line would influence soil moisture distribution as well as crop performance on a bench terrace.

Vegetative macro contour line is a soil and water conservation technology, designed to provide multiple benefits and is effective for soil erosion and runoff control and, soil fertility replenishment. The benefits include: minimum competition for resources between food crops and creeping legume and shrubby legume, replenishing soil fertility through nitrogen fixation, trapping sediments and nutrient pumping, high quality fodder, microclimate, fuel wood, timber, erosion reduction and terrace stabilization. This novel approach to soil and water conservation is more efficient, cost effective and thus easily adoptable by smallholder farmers in the drylands. This will in turn bring about sustained exploitation of the soil and water for agriculture with resultant increased food production for the growing population and a well-protected environment. Consequently, the majority of the resource poor small-scale farmers will enjoy improved livelihood.

Research methodology

The study site is as described in chapter 5.

Experimental treatments

The trial involved three treatments: Terraced vegetative macro contour line with maize mono crop and ditch (TVMD), Un-terraced vegetative macro contour line with maize-dolichos intercrop (UVMD) and Terraced vegetative macro contour line with maize-dolicos intercrop and ditch (TVMDD). The experiment was established on four randomly selected farms that served as blocks, and had the three treatments arranged in a Randomised Complete Block Design (RCBD) giving a replica of four for each of the treatments. Each treatment measured 15m in length while the width was dependent on the slope of the land. Fertilizer was applied to maize during planting at the recommended rate of 60 kg/ha Di-Ammonium Phosphate (DAP) in all plots. Figure 1: shows a layout of the technology.

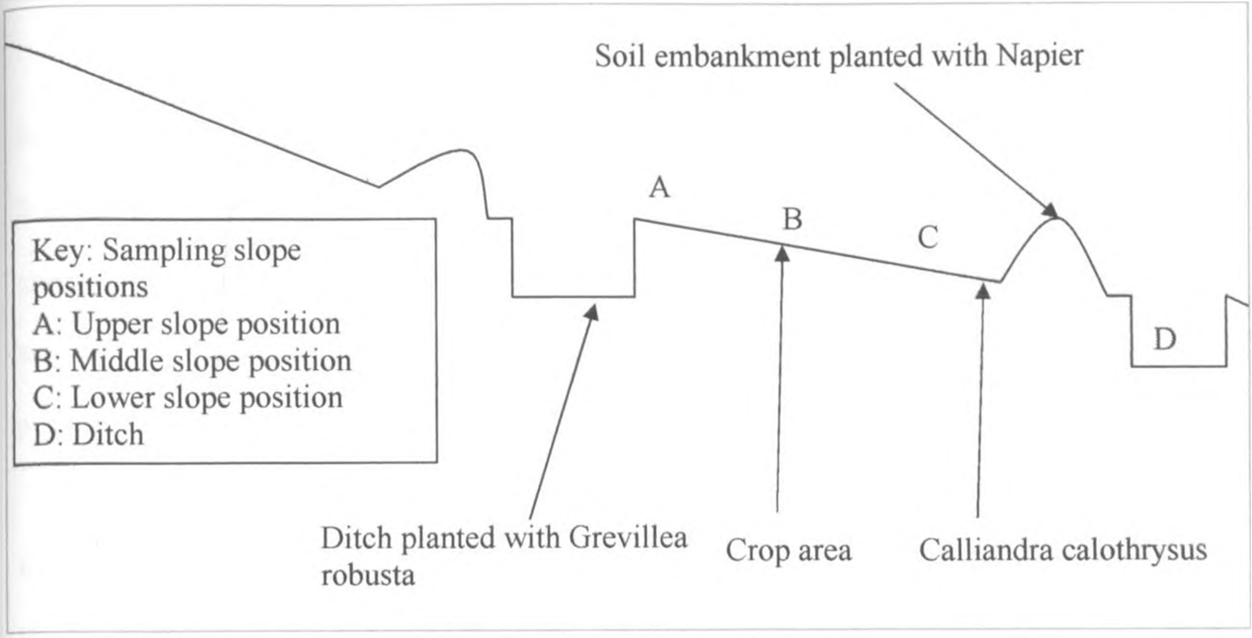

Figure 1: Vegetative macro contour line layout

Plant arrangements

The crop within the bench was either maize mono crop or maize/dolicos lab lab (*Lablab purpureus)* intercrop. These are among the common crops grown in this area. After consulting with farmers, Grevillea was planted 3m apart along the ditch. Napier grass was planted at the soil embankment and calliandra followed immediately after.

Land preparation and planting

Tilling of the land was done before planting using hand hoes. Fertilizer was applied at planting. Maize (hybrid, Duma 43) was planted at a spacing of 0.75 cm by 0.25 cm between and within rows respectively in maize mono crop plots. In maize-dolicos intercrop, spacing for maize was double (1.5cm by 0.5 cm) that in mono crop and dolicos was planted between maize plants.

Soil samples

Soil samples for moisture analysis were collected at 0-30 cm during critical stages (germination and tassling) of plant development as well as when the crop showed moisture stress. The samples were collected at three positions across the bench terrace i.e. upper, middle and lower slope positions.

Plant height

Plant height was measured at tassling stage by taking an average height of five randomly selected maize plants at each slope position.

Maize harvesting

Maize was harvested at maturity stage as biomass from an area of 3m by 3m at each slope position and oven dried at 60^{O}C until a constant weight was attained.

Soil moisture determination

Soil moisture content was determined by oven drying about 200 g sub sample at 105°C for 24 hours. Moisture content was calculated using the following formula:

$$\%\text{Moisture content} = \frac{(\text{Sample fresh weight} - \text{Sample dry weight})}{\text{Sample dry weight}} \times 100$$

Data analysis

To determine the treatment effect on soil moisture content and crop performance, analysis of Variance (ANOVA) was conducted and means separated at 5% least Significant Difference (LSD) using Genstat Discovery Edition 3.

Results

Effects on soil moisture content

Means of soil moisture content in each treatment are represented in Figure 2. The tendency for TVMDD treatment to yield higher soil moisture content than UVMD and TVMD during the two seasons was deduced. Indeed soil moisture content was found to be significantly ($P \leq 0.05$) lower in UVMD treatment than in TVMDD and TVMD treatments in December-2009 and August-2010 respectively (Figure 2). A more even trend indicating higher soil moisture content for terraced treatments (TVMDD and TVMD) than un-terraced treatment was also established. Except in the month of August-2010, TVMDD treatment also tended to record higher soil moisture content than TVMD treatment through out the study period (Figure 2).

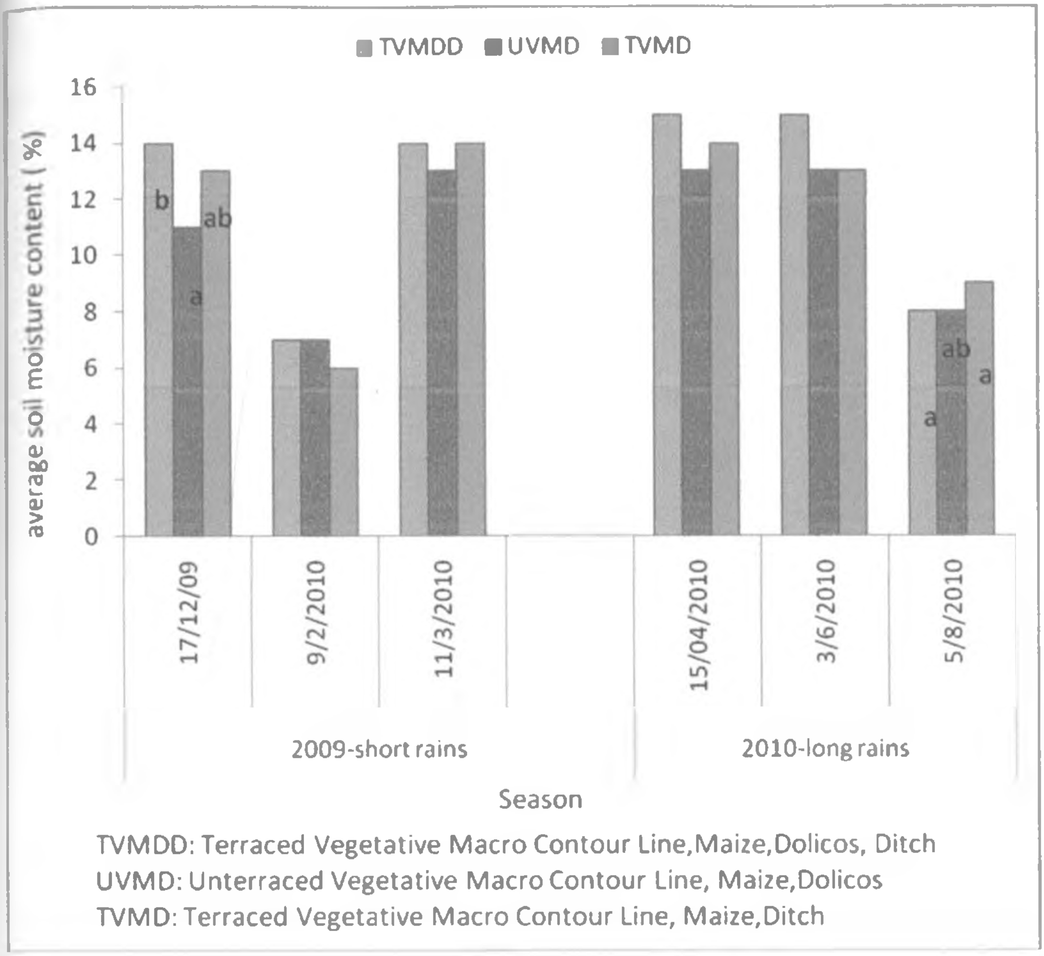

Figure 2: Average soil moisture content across treatments (*Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at* $P \leq 0.05$).

Figure 3 illustrates soil moisture content at the upper slope position. Generally, soil moisture content measured in the terraced treatment was found to be higher than in un-terraced treatment. Although the trend was not definite, results indicate a likelihood for TVMDD treatment to give higher soil moisture content than other treatments (Figure 3). In effect, TVMDD treatment had signifincantly higher soil moisture content than UVMD treatment in December-2009 and April-2010, and than TVMD treatment in March-2010. Moreover, TVMDD treatment tended to record higher soil moisture than TVMD treatment and the difference was found to be significant in March-2010 (Figure 3).

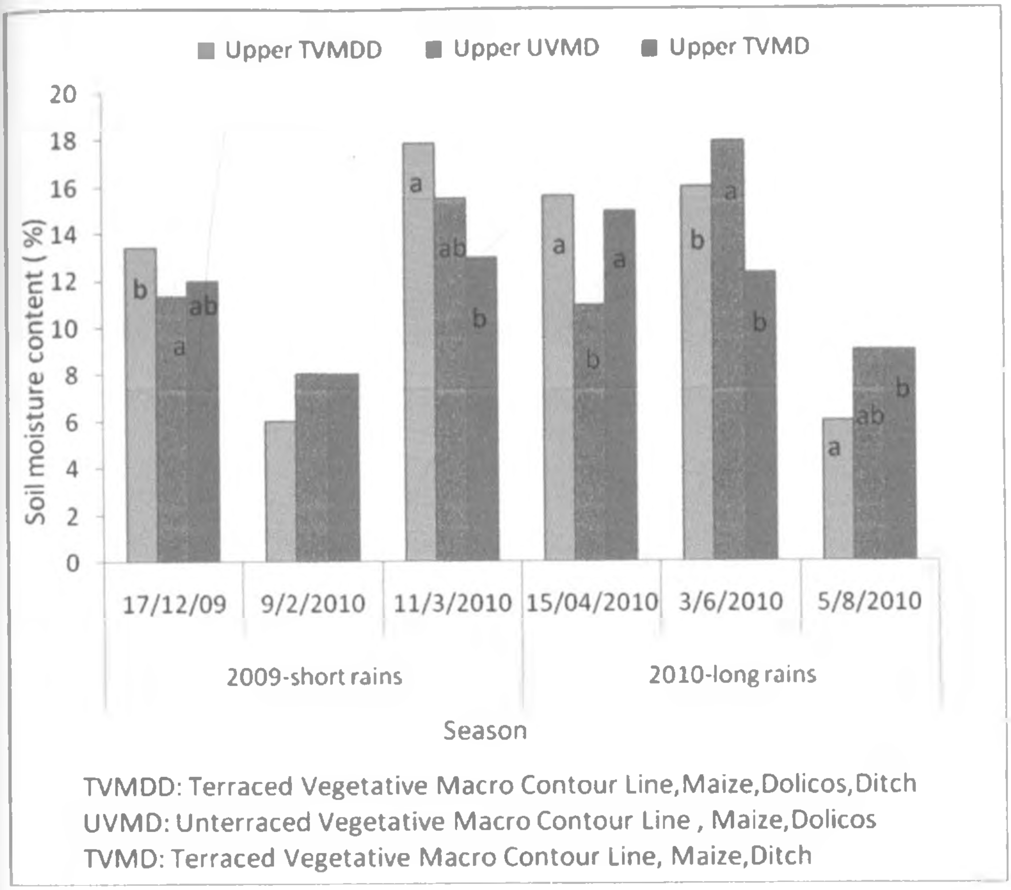

Figure 3: Soil moisture content at upper slope position *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$).*

Plate 1 shows water collected in a ditch after heavy rains could possibly explain the high soil moisture content measured at the terraced treatments and upper slope position compared to un-terraced treatment and middle slope position.

Plate 1: Water collected in the ditch after the rains

Figure 4 shows soil moisture distribution at the middle slope position. The trend was found to be inconsistent and soil moisture content values insignificantly diferrent through out the study period (Figure 4). In December-2009 and February-2010-short rains, the middle position in TVMDD and UVMD treatment had higher and equal soil moisture content than TVMD treatment. During 2010 long rains, middle position in TVMDD gave higher soil moisture content than middle UVMD and TVMD treatments in April-2010 and June-2010, while in August-2010, it recorded the lowest soil moisture content.

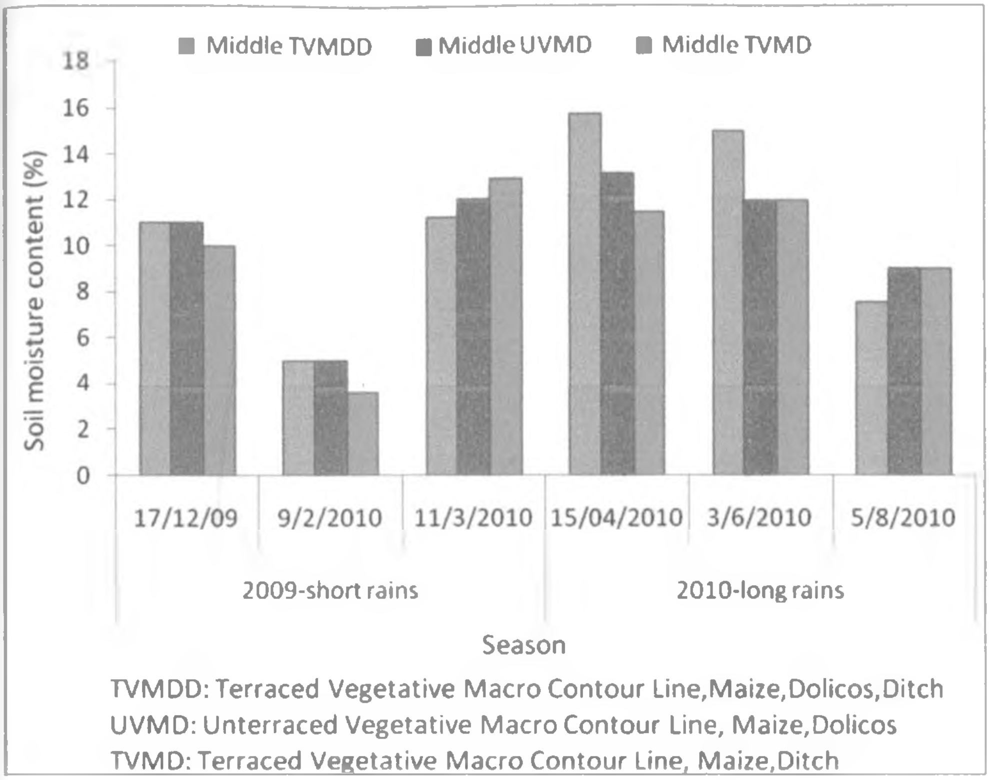

Figure 4: Soil moisture content at middle slope position (*Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$)*

A comparison of soil moisture content across treatments at lower position is shown in Figure 5. Results reveal higher soil moisture content in terraced treaments (TVMDD and TVMD) compared to unterraced treatment (UVMD) except in Feb-2010 throughout the study period. The likelihood for TMVDD treatment to record higher soil moisture content than UVMD and TVMD treatments was also observed. Certainly, TVMDD treatment recorded significantly ($P \leq 0.05$) higher soil moisture content than UVMD treatment in December-2009 and June-2010 (Figure 5). The tendency for TVMDD treatment to record higher soil moisture content than TVMD treatment was clear and in December-2009, it was signifincantly higher. Moreover, UVMD had the lowest values of soil moisture content through out the study period except in Feb-2010.

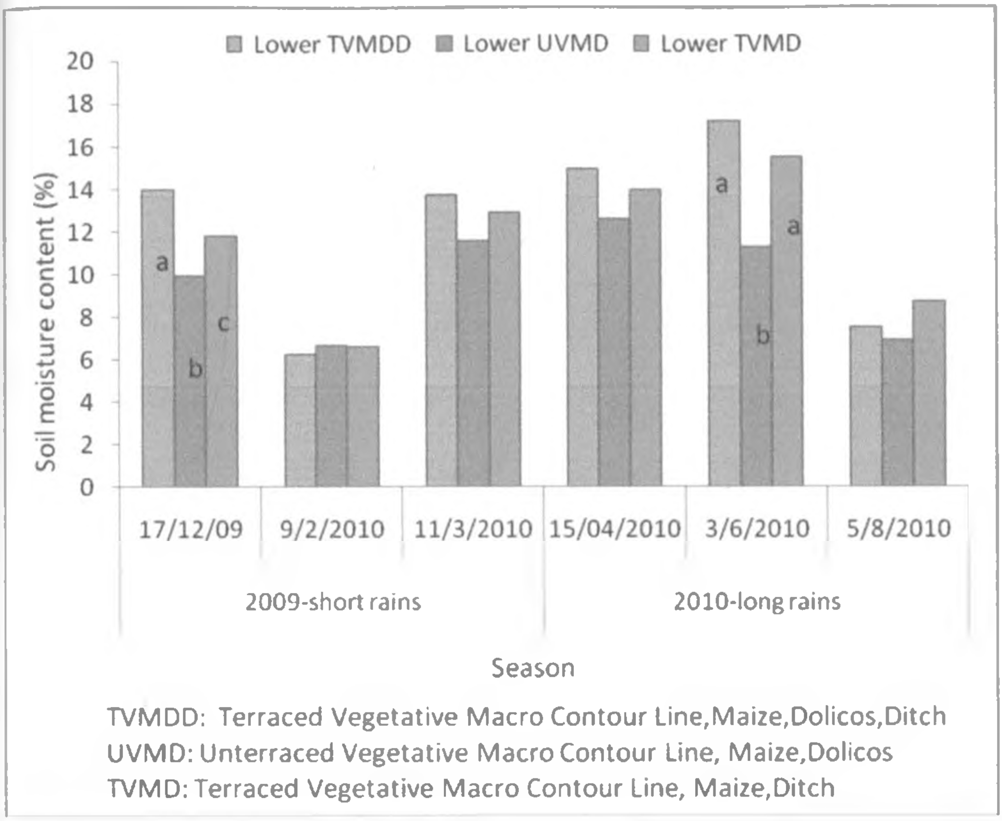

Figure 5: Soil moisture content at lower slope position *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$)*

Table 1 tabulates soil moisture content measured at different slope position in TVMDD treatment. The inclination was for the middle slope position to record lower soil moisture than upper and lower slope position. Additionally, soil moisture content was found to be significantly lower ($P \leq 0.05$) at middle than upper slope position in March-2010 (Table 1). However, no consistent trend or significant differences were observed in UVMD treatment.

Table 1: Soil moisture content at sampling slope position in TVMDD treatment

Month	Dec-2009	Feb-2010	March-2010	April-2010	June-2010	August-2010
Lower slope	14.0[a]	6.2[a]	13.7[ab]	15.0[a]	17.2[a]	7.6[a]
Middle slope	11.5[a]	4.6[a]	11.2[a]	15.8[a]	15.0[a]	7.6[a]
Upper slope	13.4[a]	6.0[a]	17.8[b]	15.6[a]	12.1[a]	6.5[a]

(Values followed by different letters differ significantly, while values followed by same letters do not differ significantly at P≤0.05)

Soil moisture content measured at different sampling slope positions in TVMD treatment is indicated in Table 2. The trend was similar to that observed in TVMDD treatment. Middle slope position gave lower soil moisture than upper and lower slope position and was found to be signifincantly lower (P≤0.05) than upper slope position in February-2010 (Table 2). Besides, upper slope position tended to give higher soil moisture content than lower slope position though the difference was not significant (Table 2).

Table 2: Soil moisture content at sampling slope positions in TVMD treatment

Month	**Dec-2009**	**Feb-2010**	**March-2010**	**April-2010**	**June-2010**	**August-2010**
Lower slope	11.8[a]	6.6[ab]	12.9[a]	14.0[a]	15.5[a]	8.7[a]
Middle slope	11.9[a]	3.6[a]	12.9[a]	11.5[a]	11.6[a]	9.4[a]
Upper slope	12.6[a]	7.6[b]	13.0[a]	15.0[a]	12.3[a]	9.3[a]

(Values followed by different letters differ significantly, while values followed by same letters do not differ significantly at P≤0.05)

Treatment effect on crop height during-2009 short rains and 2010 long rains

There was no significant difference ($P \leq 0.05$) established across treatment but taller plants were associated with treatments under terraces (i.e. TVMDD and TVMD) (Figure 6).

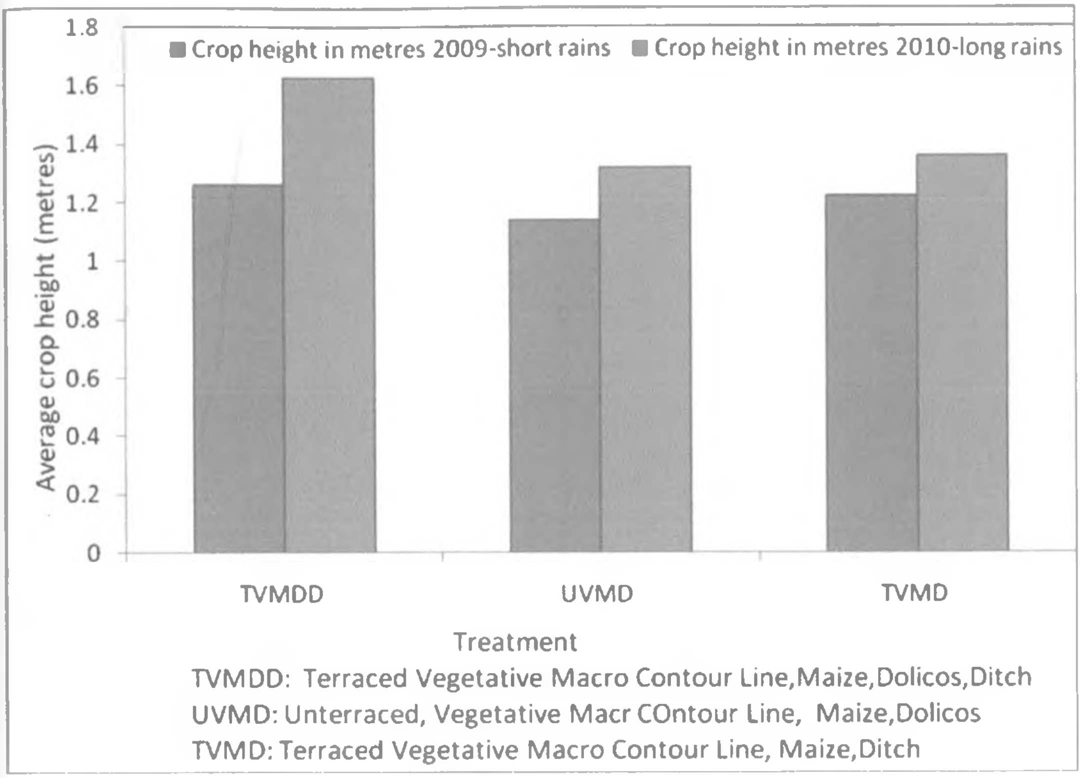

Figure 6: Average crop height across treatments (*Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at* $P \leq 0.05$)

Figure 7 shows crop height data along sampling slope positions. Results reveal a more even trend for taller crops in upper and lower than in middle slope position for all treatments during the two seasons. However, no significant differences were observed across treatment and sampling slope positions. Nevertheless, the findings correspond very well with the results on soil moisture content discussed earlier in this paper. Field observations revealed clear differences in height at different slope positions (Plate 2a and b). Although the differences were not significant, upper and lower slope positions tended to have taller plants than lower slope position. However, UVMD treatment did not show a clear trend in plant height (Figure 7).

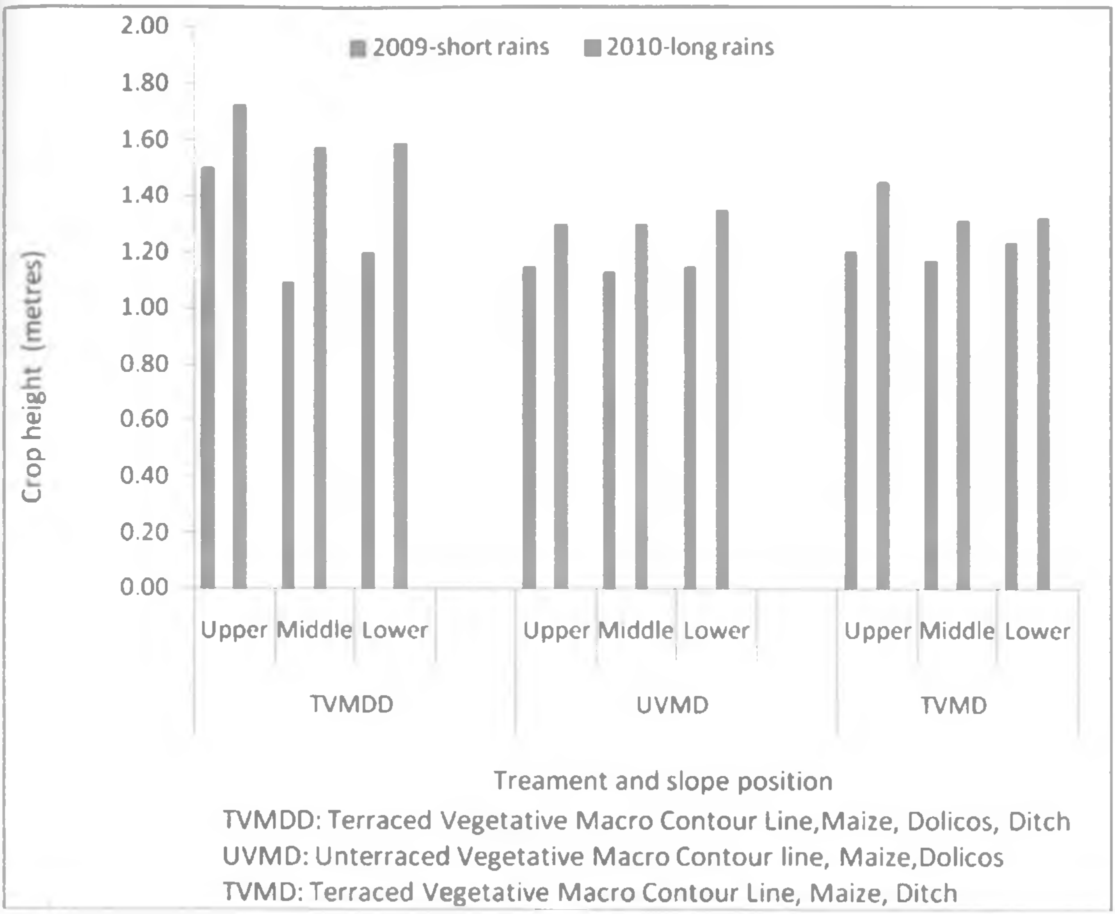

Figure 7: Effect of slope position on crop height *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at P≤0.05)*

Plate 2a: Crop height upper slope position (Note: the shorter plant height as you move down the bench)

Plate 2b: Crop height at lower slope position

Figure 8 compares crop height at the same sampling slope postion under different treatments. The predisposition for the UVMD to have shorter plants than TVMDD and TVMD was deduced though the differences were not significant ($P \leq 0.05$). Further still, TVMD treatment had taller plants than TVMDD during 2010-long rains

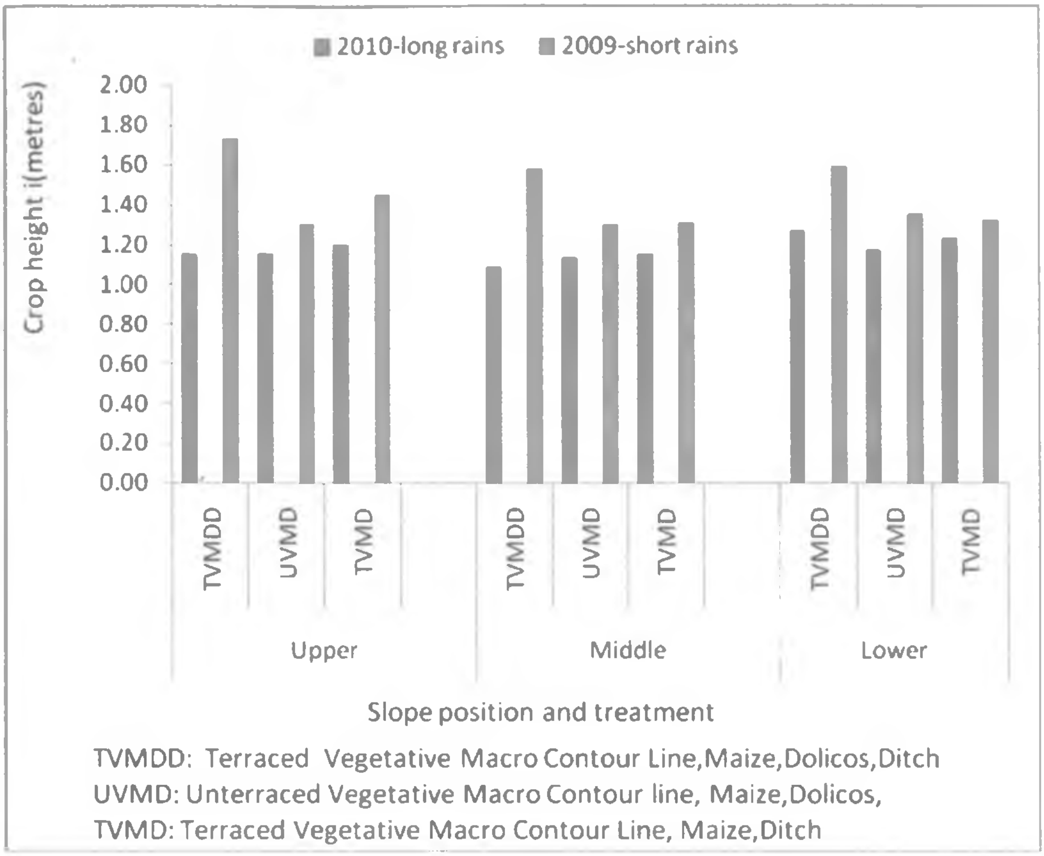

Figure 8: Treatment and slope position effect on crop height *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$)*

Treament effect on biomass yield during 2009-short rains and 2010- long rains

Figure 9 shows biomass yield under different treatments. Though no significant differences ($P \leq 0.05$) were observed between different treatments, the terraced treatments (TVMDD and TVMD) had higher biomass compared to the un-terraced treatment.

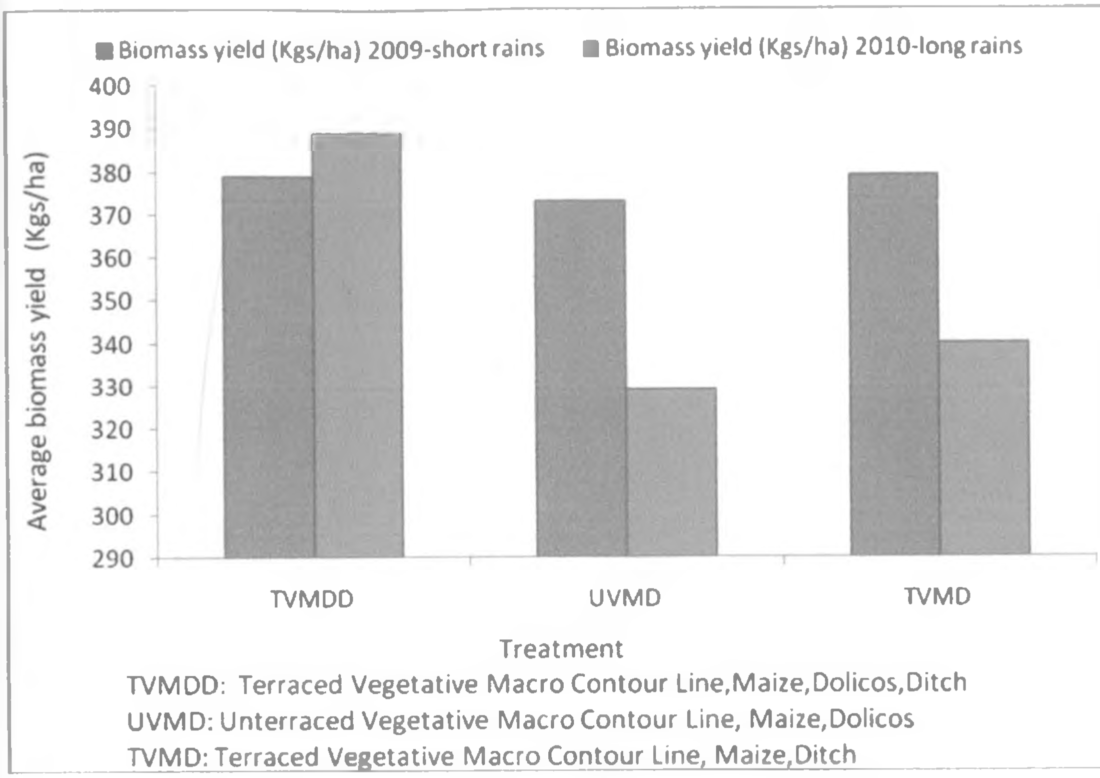

Figure 9: Treatment effect on biomass yield *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at P≤0.05)*

Figure 10 exhibits biomass yield data within treatments at different slope positions. Although no significant differences were observed, results indicate higher biomass yield for upper and lower compared to middle slope position in both TVMDD and TVMD treatments. The results match very well with those on soil moisture content and plant height as described earlier. While higher biomass yield was measured at lower and upper positions in TVMDD and TVMD treatment respectively, UVMD did not give a defined trend along the different slope positions.

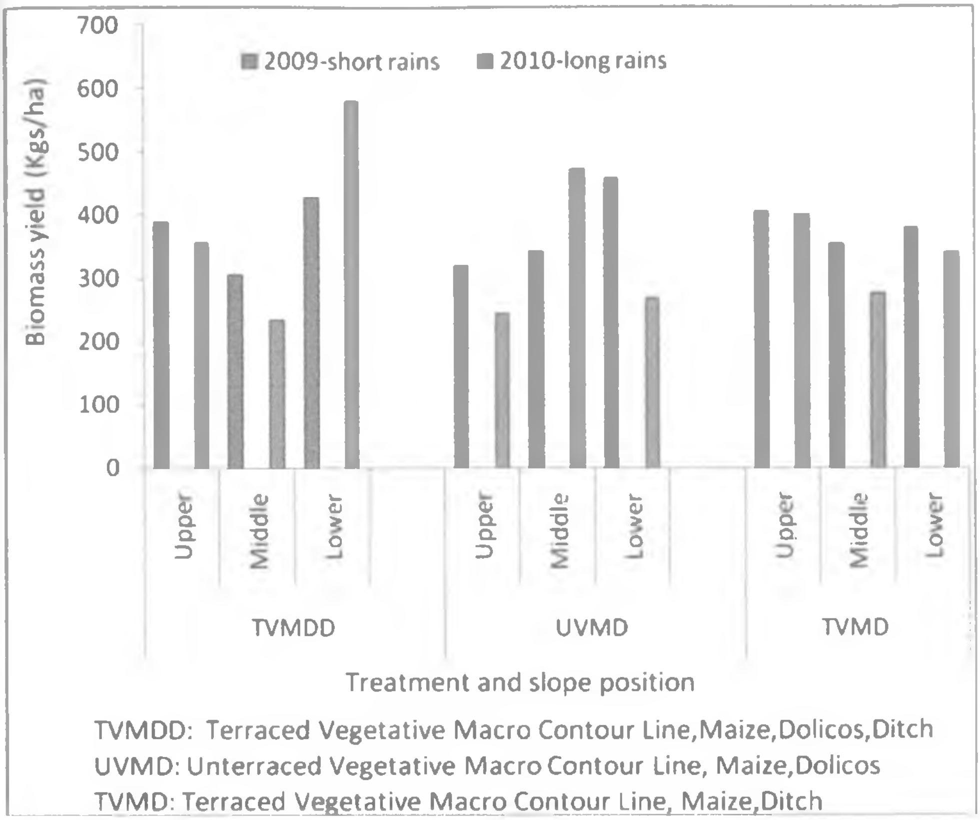

Figure 10: Effect of sampling slope position on biomass yield *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$)*

Figure 11 shows biomass yield across treatment and slope positions. Although the trend was not explicit, biomass yield recorded at upper and lower slope position tended to be higher in TVMDD and TVMD treatments compared to UVMD treatment and was found to be signficantly lower than at the upper slope position in TVMDD and middle slope position in TVDD treatment during 2009-short rains and 2010-long rains respectively. The trend was more clear during the 2009-short rains when UVMD tended to give lower biomass yeild than all the other treatments.

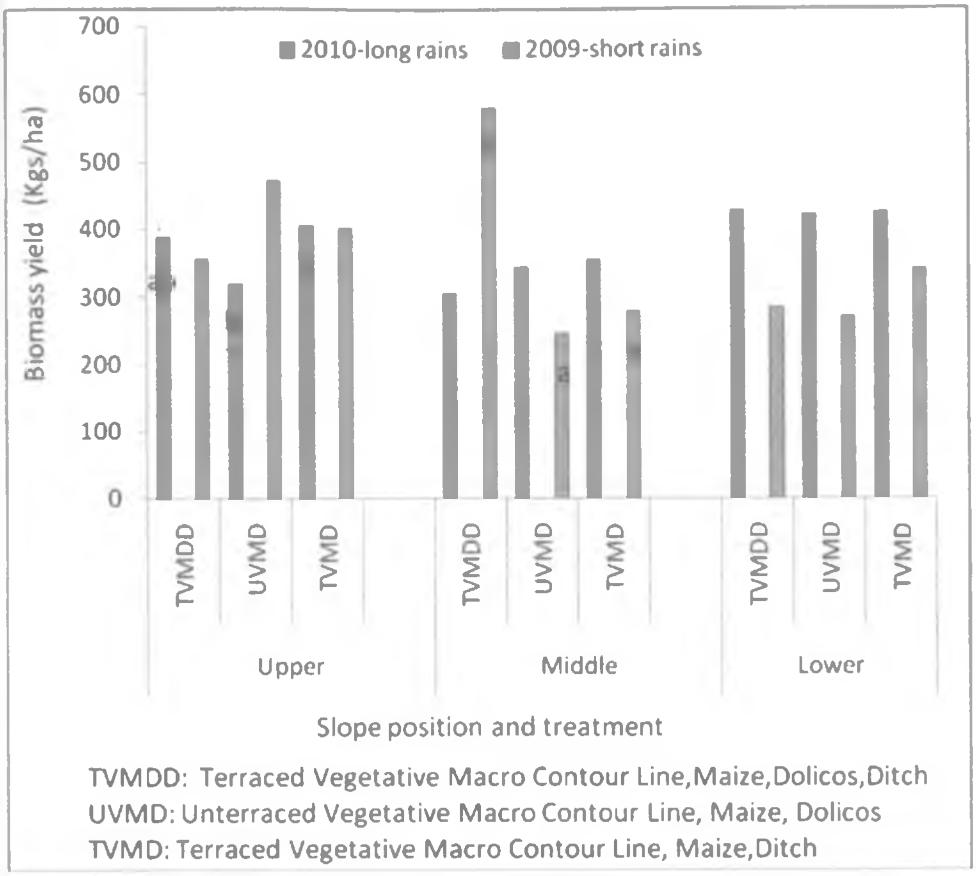

Figure 11: Effect of treatment and slope position on biomass yield *(Values followed by different letters differ significantly, while values followed by same letters as well as those with no letters do not differ significantly at $P \leq 0.05$)*

Discussions

Results of this study point towards high soil moisture content in the ditch compared to all other slope positions assessed along the bench terrace. Rain water that could otherwise have been lost through runoff was collected and stored in the ditch (Plate 2a and b), and so the high moisture content recorded. In addition, soil moisture content was also found to be higher at the upper and lower slope positions compared to the middle position. It is possible that water retained in the ditch could have infiltrated, through lateral seepage, to the upper position consequently explaining the higher soil moisture content measured. Soil conservation measures are known to enhance rain water infiltration (Woyessa et al., 2006). In addition, the bench embankment at the lower slope position acts as a barrier to water flow, thus allowing water infiltration, which also explains the high soil moisture content. Besides, the high soil moisture content observed in the upper and lower position justifies the taller plants and higher biomass yield at these two slope positions.

These findings are similar to what many authors have established. A study carried out on Integrated Rain Water Harvesting (IRWH) reported that rain water collected in micro basins resulted in reduced runoff and hence water use efficiency that increased land productivity (Woyessa et. al. 2006). Similar observations were also made by Hensley et.al. (2000) who reported reduced runoff and soil erosion and increased infiltration in a cropland under use of IRWH, eventually increasing crop yield. However, soil moisture at the lower slope position was usually found to be lower than at upper slope position within the terrace. This outcome may be attributed to soil disturbance during ditch establishment. The soil, which was dug from as deep as 2m was thrown to the upper side of the ditch and being sub-soil, was low in soil organic matter hence low water hold capacity. These findings together with lack of soil nutrients too, could explain why crop height and biomass yield were also low at lower than upper slope positions. Botha et.al (2003) highlighted soil moisture as a major factor in explaining crop performance variations.

Terraced plots were found to conserve more moisture than the un-terraced plots. This puts to position the importance of terraces as soil and water conservation measures. Apart from reducing soil and water loss, the ditch also serves as water reservoir that collects water and by slowly seeping through in to the soil, makes it available along the terraced plot. The water is then accessible for crop use and thus, the better crop performance on the terraced plots. These results agree with the conclusion drawn by Kannam (2010) and Miller and Shrader (1973), that terraces are more efficient in moisture conservation. This phenomenon has been associated with reduced soil and water flow along the bench terrace, hence allowing more time for water to infiltrate into the soil (Woyessa et. al. 2006). In a comparison of slopes with and without soil and water conservation measures carried out in Central Province of Kenya, Ovuka, (2000) suggested that the low transportation of soil nutrient along slopes with soil and water conservation measures was responsible for the more evenly distributed values of nutrients.

In both TVMDD and TVMD treatments, soil moisture measured in TVMD was found to generally be lower than in TVMDD, suggesting other factors are in play. The only other difference between the two treatments was the cropping system. While TVMDD treatment had maize-dolicos intercrop, TVMD was a maize mono-crop treatment. The TVMDD treatment was also subjected to minimum soil disturbance as dolichos was in the field for more than one season. The high moisture content observed in TVMDD treatment could be attributed to dolicos, which serves as a cover crop, thus reducing soil exposure to evaporation and increasing infiltration rate. These results are consistent with what many authors have highlighted. For example, Marongwe et.al. (2011) reported that, undisturbed soil had improved soil physical properties, which in effect enhanced infiltration. In addition, regional trials have also established increased infiltration leading to water productivity in Conservation Agriculture, as compared to conventional farming (Thierfelder and wall, 2009).

There was no explicit trend in soil moisture, crop height, or yield under UVMD treatment. It is expected that the grass strip under UVMD treatment would trap soil and eventually a bench terrace be developed. However, this may take a number of years. This could explain why no consistent trend was observed under un-terraced vegetative macro contour line. In addition, no water was harvested and the treatment had an intercrop, meaning the competition for water and nutrients was high and hence the poor crop performance.

Conclusions and Recommendations

From this study the following conclusions and recommendations can be made:

Vegetative macro contour line is a technology, appropriate for soil and water management. The technology will reduce, harvest and retain runoff, increase water infiltration and reduce soil moisture evaporation, which leads to effective use of water and thus increasing agricultural productivity in a sustainable manner. The appropriateness of this technology is that even the very poor farmers, who may not be able to venture into irrigation farming, can still be able to harness rain water using vegetative macro contour line, and in effect improve their livelihoods.

Adoption of this technology is faced with some major challenges e.g. capital, labour and appropriate knowledge. High adoption requires that these concerns be addressed and here, the government plays a key role in advancing this technology. Success is dependent on how far farmers are involved in the development and establishment of the technology. This will assist in identifying the right planting materials to use.

However, more research is needed to establish the appropriate vegetative macro contour line design. How deep, shallow, wide or narrow the ditch should be for optimum soil and water conservation efficiency is yet to be ascertained. Also, it is crucial to establish the right cropping systems on a vegetative macro contour line. Since the results are based on only two seasons, it would as well be important to find out how the system functions in future especially after the terraces stabilize and trees are fully grown.

REFERENCES

Aberley, D. (1993).Boundaries of home: Mapping for local empowerment. Cabrida Island, New Society Publisher

Agwu A.E., Ekwueme J.N., Anyanmu A.C. (2008).Adoption of improved agricultural technologies via radio farmer programme by farmers in Enugu State, Nigeris. African Journal of technology. Vol. 7 (9), pp. 1277-1286.

Ahmed, B., Longtau, S.R. and Odunze, A.C. (2000) 'Soil and Water Conservation in Nothern Nigeria: Case Study Report' prepared by Eco Systems Development Organisation (EDO), Jos, Nigeria for the Overseas Development Institute.

Audirac I. (2003). Information-Age landscapes outside the developed world.Bangalore, India and Guadalajara, Mexico. Journal of America Planning Association. Vol. 69,1.

Bandre, P. and Batta, F. (1999) 'Conservation des Eaux et des Sols (CES) au Burkina Faso'. Rapport Final October 1999. Voisins Mondiaux, Ouagadougou.

Bayard B., Jolly C.M. and Shannon D.A. (2007). The economics of adoption and management of alley cropping in Haiti, J. Environ. Manage. 84 (2007), pp. 62–70.

Botha et.al. (2003). Water conservation techniques on small plots of semi- arid areas to enhance rainfall use efficiency, food security, and sustainable crop production. Report No.1176/1/03.Water research commission (WRC). Pretoria, South Africa.

Charlotte B and Slaymaker T. (2000). Re-examining the 'more people less erosion' hypothesis: Special case or wider trend? Natural resource perceptive, No. 63, Overseas Development Institute

Curwell, S. and A. Hamilton (2003): The Intelcity roadmap. Report of the EU Intelcity project IST-2001-37373.

Di Gessa S. (2009). Participatory mapping as a tool for empowerment: Experiences and lesson learnt from ILC network. International land coalition.

Dinpanah G.,Mirdamadi M., Badragheh A., Sinaki J.M., Aborye F. (2010). Analysis of effect of farmer field school approach of biological control on rice producer'producer, characteristics in Iran. American-Eurasian J. Agric. And Environ.Sci. 7 (3) pp 247-254.

ENDA Pronat (2000) 'Pratiques de la Conservation de L'eau et des sols dans la region des Niayes (Senegal): Cas des villages de Dara, Beer, Mbawane et Keur Abdou Ndoye'. Rapport Final Octobre 1999. ENDA Pronat, Dakar, Senegal

Freund J.E. and Williams F.J. (1984). Modern business statistics. London, Pitman.

Gachene C.K.K. and Mureithii J.G. (2004). Lost and Reclaimed. A case of study of gully rehabilitation in Central Kenya highlands using low-cost measures proceedings of the 4th International Crop Science Congress on new directions for diverse plant. Brisbane, Australia, 26th Sep-1st Oct. 2004. Ed. Fischer I et.al. 2004. ISBN 1 920 843 217.

Gachene, C.K.K., Mureithi, J.G., Anyika, F. and Makau M. (2002). Incorporation of green manure cover crops in maize based cropping system in in Ndome and Ghazi, Taita Taveta, Kenya.

Gachene C.K.K. (1995) Evaluation and mapping of soil erosion susceptibility: an example from Kenya. **Soil Use and Management Vol 11 Pp: 1–4.**

Gathaara.V.N., Gachene C.K., Ngugi J.N., Thuranira E.G., Kilambya D.W., Baaru M.W. Adoption and opportunities for improving soil and water conservation practices in Kathekakai settlement scheme, Machakos District. Kenya Agricultural Research Institute (KARI), Nairobi, Kenya.

Gicheru, P.T. and Ita, B.N. (1987). Detailed soil survey of Katumani National Dryland Farming Research Station Fearms (Machakos District). *Report No. D43. Kenya Soil Survey Ministry of Agriculture, Nairobi, Kenya*

Gicheru, P.T. and Ita, B.N. (1987). Detailed soil survey of Katumani National Dryland Farming Research Station Fearms (Machakos District). *Report No. D43. Kenya Soil Survey Ministry of Agriculture, Nairobi, Kenya.*

Gobin. A., Campling P.,Feyen J. (2001) Spatial analysis of rural land ownership. Landscape and urban planning 55: 185-194.

Griffiths T (2002). Guyana: empowerment of indigenous peoples through participatory mapping. World Rainforest Movement Bulletin No. 62

Grime, J.P. (1997). Climate change and vegetation. In plant ecology, 2nd edition, Crawley M.J. (ed.) Blackwell Science: Oxford, UK: 582-594

Hallsworth E.G (1987). Earth surface processes and landforms. 14:361

Hatibu, N., Mahoo, H.F., Lazaro, E., and Rwehumbiza, F.B. (2000) 'Rethinking Natural Resource Degradation

Hensley M., Botha J.J., Anderson J.J., Van Staden P.P., Du Toit, A. (2000). Optimizing water use efficiency for developing farmers with limited access to irrigation water. Report No.878/1/00.Water research commission (WRC). Pretoria, South Africa: WRC

ICRAF, (1996). Farmer to farmer extension workshop held at Machakos Distict, Kenya

IFAD, 2009. Good practices in participatory mapping. A review prepared for international fund for agriculture, Rome, Italy

Jonathan, A.F., Defries R., Asner G.P., Barford C., Bonan G., Carpenter S.R., Chapin F.S., Coe M.T., Daily G.C., Gibbs H.K., Heelkowski J.H., Holloway T., Howard E.A., Kucharik

C.J., Monafreda C., Patz J.A., Prentice I.C., Ramankutty N., Snyder K. (2005). Global consquences of land use. Sci. Rev. 309: 309-574.

Juneidi, M. J and Abu-Zanat M 1993 Jordan agricultural sector review: low rainfall zone APAP II technical report no 132 vol I APAP II and USAID, Ministry of Agriculture, Amman, Jordan

Kannan N., Senthivel T., Rayar A.J., Mutesa F. (2010). Investigating water availability for introducing an additional crop yield in dry season on hill land ar Rubirizi, Rwanda. Journal, Agricultural Water Management, Vol. 97, Issue 5, Pp. 623-634

Kiepe P. (1996). Cover and barrier effect of *Cassia siamea* hedgerows on soil conservation in semi-arid Kenya, Soil Technol. 9 (1996), pp. 161–171.

Lambin, E.F., Baulies, X., Bockstael, N., Fischer, G., Krug Leemans, T.R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner, B.L. II, Vogel, C. (1999). Land-Use and Land-Cover Change (LUCC). Implementation Strategy. (IGBP Report 48, IHDP Report 10). Stockholm, Bonn: IGBP and IHDP Secretariats, 125 pp.

Lambin, E.F., Turner, B.L. II, Geist, H.J., Agbola, S.B., Angelsen, A., et. al. (2001). The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change: Human and Policy Dimensions 11(4): 5-13.

Laukkonen, J., Blanco, K.P., Lenhar P., Keiner, M., Cavric B and Kinuthia-Njenga, C. (2009). Combining climate change adaptation and mitigation measures at the local level. Habitat International. Vol 33, issue 3, P: 287-292.

Makumbi, M. and Okubal, P. (2000) ‘Rethinking Natural Resource Degradation in Semi-Arid Africa – Implications for Policy: Toroma – Uganda Case Study’.

Marongwe L.S., Kwazira K, Jerich M., Thierfelder C., Kassam A., Friedrich T. (2011). An African success: The case of conservation agriculture in Zimbabwe. International Journal of Agricultureal Sustainability. 9(1) Pp 133-139.

Marozas B A (1991). The role of GIS in American Indian land and water rights litigation American Indian Culture & Research Journal 15 77-93

McCall M K and Minang P.A (2005). Assessing participatory for community-based natural resource managememt: Claiming community forests in Cameroon. The journal of Geographical Vol.171 No.4, pp. 340-356.

McCall M. (2004). Can participatory GIS strengthen local level planning? Suggestions for better practice. 7th International Conference on GIS for developing countries. University Technology Malaysia.

MEA (Millenium Ecosystem Assessment). (2005a). Ecosystem and human –well being: Synthesis. Island Press. Washington, DC.

MEA (Millenium Ecosystem Assessment). (2005b). Ecosystem and human –well being:Current State and Trend. Vol.1. Island Press: Washington, DC, 585-621.

Miller E. L. and Shrader W. D. (1973). Efffect of Level Terraces on Soil Moisture Content and Utilization by Corn. American Society of Agronomy. Agron J 65-600-603

Moran, E. F. (2001). Progress in the last ten tears in the study of land use/cover change and the outlook for the next decade. In A. Diekman et al. (eds.). Human dimensions of global change. Cambridge, MA.: MIT Press.

Muchemi J., Crawhall N., Pedone G., Konante J., Kiptum Y., Kuria P (2009). Participatory 3-Dimension modeling. Kenya case study.

Mulwa F.W. and Nguluu S. N. (2003).Participatory monitoring and evaluation. Eldoret and Nairobi. Zapf Chancery.

Mundia CN., Murayama Y. (2009). Analysis of land use/cover changes and animal population dynamic in a wildlife sanctuary in East Africa. Journal.Remote Sens. 1, 952-970

Murphy J. (1993). The farmers and organizations. Major actors in development.The International Bank of Reconstuction and Development. Washington D.C. U.S.A.

Odimegwu C.O. (2000).Methodological issues in the use of focus group discussion as a data collection tool. Journal of social sciences. 4(2-3): 207-212.

Ong C.K. et.al. (2002). Tree- crop interaction: manipulation of water use and root function. Journal of Agricultural Water management, Vol 53, 1-3 Pp. 171-186

Ovuka M. (2000). Soil nutrient changes along slope transects in Murang'a District, Kenya. In: Effects of soil erosion on nutrient status and soil productivity in central highlands of Kenya (Thesis).

Owino et al., (2006) J.O. Owino, S.F.O. Owido and M.C. Chemelil, Nutrients in runoff from a clay loam soil protected by narrow grass strips, Soil Till. Res. 88 (2006), pp. 116–122.

Pansak W., Hilger T.H., Dercon G., Kongkaew T., Cadisch G. (2008). Changes in the relationship between soil erosion and N loss pathways after establishing soil conservation systems in uplands of Northeast Thailand. Agriculture, Ecosystems and Environment. Vol. 128, Issue 3.

Rambaldi G and Callosa-Tarr J (2002). Participatory 3-dimensional modelling: guiding principles and applications ASEAN Regional Centre for Biodiversity Conservation (ARCBC), Los Banos

Serneels S., Lambin E. (2001). Impact of land use changes on the wildbeest migration in the Northern part of the Serengeti Ecosystem. Journal. Biogeogr. 28, 391-407

Serneels, S., Lambin E. (2001). Impact of land use changes on the wildbeest migration in the Northern part of the Serengeti Ecosystem. Journal. Biogeogr. 28, 391-407.

Sherbinin. (2002). A guide to land use and land cover change (LUCC). A collaborative effort of SEDAC and The IGBP/IHDP LUCC Project.

Sirait M T, Prasodjo S, Podger N, Flavelle A and Fox J. (1994) Mapping customary land in East Kalimantan, Indonesia: a tool for forest management Ambio 23 411-17

Steffen,W.L., Walker B.H., Ingram J.J., Koch G.W. (1992). Global change and terrestial ecosystems. The operational plan. IGBP report No.21, International Geosphere-Biosphere Programme Stockholm.

Taimeh, A. (1989) Desertification in Jordan Proe disastri ambientalie e desertificazione Palermo June 237-61 Taylor J C, Bird A C, Brewer T R and Stuttard M J 1991 Landscape change in the National Parks of England and Wales final report vol II: Methodology Silsoe College, Cranfield University.

Tenge AJM (2005). Participatory appraisal for farm level sdoil and water conservation planning in West Usambara highlands, Tanzania. PhD Thesis, Wagenigen University, The Netherlands, 165 pp

Thierfelder C and Wall P.C (2009). Investigating conservation agriculture systems in Zambia ans Zimbambwe to mitigate future effects of ckimate change. African Crop Science Conference Proceedings Vol. 9 Pp 303-307.

Thomas, DB (1993). Terrace riser stabilisation and fodder production. Paper presented to the Fourth National Workshop on land and water Management In Kenya, Wida Highway Motel, Kenya.

Tiffen M., Mortimer, M., Gichuki, F., (1994). More People, Less Erosion. Environmental Recovery in Kenya. Wiley, New York, 311 pp.

Turner, B.L. (2001). Land-use and land-cover change: advances in 1.5 decades of sustained international research. GAIA-Ecological Perspectives in Science, Humanities, and Economics 10(4): 269-272.

UNEP, 2008. Environmental change and socioeconomic factors in Africa. In: Encyclopedia of Earth. Eds. Cutler J. Cleveland, Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment

Weng, Q. (2001). Aremote sensing-GIS evaluation of urban expansion and its impacts on surface temperature in the Zhujiang, Delta, China. Int.J. Remote Sens. 22(10). 1999-2014.

Woyessa Y.E., Pretorius E., Heerden P.S., Hensley N., Rensburgvan L.D. (2006). Impact of land use on River Basin Water Balance: A case study of Modder River Basin, South Africa.

APPENDIX

Farmers views on soil and water conservation, and changes in natural resource base measures at Katheka kai Settlement Scheme

1.1 Household Bio-data

1.1 Name of the respondent ………………………………………………………..

1.2 Number of household members ………………………..

1.3 Gender of the respondent Male………………..Female

1.4 Age of respondent……………Years

1.5 Highest level of education acquired

1. Primary 2. Secondary 3. Tertiary 4. None

1.6 Type of household

1) Male headed (MH)
2) Female headed (FH)
3) Male-headed, female managed (MHFM)

1.7 Land ownership

1) Under who is the land registered 2) When was the registration done

2.0. Farming systems

2.1 What is the size of your farm………………………Acres

2.2 What are the major land uses on your farm? (Tick the appropriately)

1. Crop Production
2. Grazing/pasture land
3. Kitchen garden
4. Farm forestry
5. Other (specify)………………..

2.3 Which crops do you grow on your on farm, in order of importance:

Type of crops	Area (acres)	Yields/acre

2.4 **Which crops have you introduced or abandoned with time and why**

Type of crops (introduced)	Reason
Type of crops (abandoned)	Reason

2.5 Have you planted any trees/leguminous crops in your farm? Yes=1 No=2

2.6 If yes, list them in order of importance:

1………………..2………………..3…………..4…………..5………..6……………..

2.7 For what reason did you plant these trees/leguminous crops in your farm?

2.8 What type of livestock are you keeping on the farm?

Type of livestock	No of animals
Milk cow	
Bulls	
Oxen	
Poultry	
Shoats (sheep/goats)	
Donkey	
Others (Specify)	

2.9 For what purpose are you keeping these animals on your farm?

3.0 Soil erosion status

3.1 How do you perceive the fertility of your soils?

1. Very fertile 2. Moderate 3. Very poor 4. Poor

3.2 Do you experience any type of soil erosion on your farm? Yes =1 No =2

3.3 If yes, how serious is it?

1. Very serious 2. Not serious

3.4 What are some of the soil erosion indicators you know?

4.0 Soil and water conservation measures

4.1 Are you using any soil and water practices on your land?

Yes =1 No= 2

4.2 If yes, which one (s) are you practicing? Tick appropriately from the table below:

Type of measure	Since when (year)
Fanya juu terraces	
Fanya chini terraces	
Grass strips	
Use of agro forestry	
Leguminous crops	
Use of cover crops	
Use of farm yard manure	
Use of compost manure	
Others specify)...	

4.3 How did you get to know about these measures?

4.4 What prompted you to use these measures?

Type of measure	Source
Ministry staff	
Researchers and NGOs	
Own experience	
Other farmers	
Others (Specify)	

5.0 Impact of soil and water conservation measures

5.1 Have experienced any benefits from the measures you have use?

1) Yes 2) No

5.2 If yes, what benefits?

3.6 What constraints limit your adoption of recommended soil and water management technologies?

1. High capital 2. Lack of information 3. High labour requirement 4. Low returns

6.0 Household Income

6.1 Do you sell any farm products? Yes 1= No = 2

6.2 If yes, fill the table below:

Crop Produce	**Amount sold (unit eg kg/ litres/ No etc**	**Price/ unit**	**Total income (in good season)**
Maize			
Beans			
Livestock Products			
Cattle			
Goats			
Sheep			
Milk			
Poultry			
Eggs			
Honey			
Others			
Charcoal			
Firewood			

6.3 What are the other sources of household income?

1. Formal employment 2. Business 3. Casual labourer 4. Others specify

....

6.4 What is the occupation of the spouse?

1. Housewife 2. Farmer 3.Formal employment
2. Business 3. Casual labour

7.0 Natural resource base change

7.1 What was the area like when you first settled here?

1) Forested 2) Grassland 3) Agricultural land 4) Bareland 5) Rocky 6) Water

7) Population
7.2 What changes have noticed since then?
7.3 What would say are the major causes of these changes
7.4 What changes have you done on your farm?
7.5 What do the changes mean to you and the people around?
7.5 Considering these changes, how do you expect the area to like in about 20 years to come?