EFFECTS OF LAND DEGRADATION ON AGRICULTURAL LAND USE: A CASE STUDY OF SMALLHOLDER FARMERS INDIGENOUS KNOWLEDGE ON LAND USE PLANNING AND MANAGEMENT IN KALAMA DIVISION, MACHAKOS COUNTY

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REG. NO: I501/WTE/20354/2013

A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of Master of Science in Environmental Management the School of Environment and Natural Resources Management of South Eastern Kenya University

February 2016

DECLARATION

I declare that this is my original work and it has not been presented anywhere else for the attainment of any degree.

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DEDICATION

I dedicate this thesis to Jonathan M. Kyavi and Veronicah N. Masila, my parents.

ACKNOWLEDGEMENT

I would like to acknowledge the following people for the input they have made into this work. First I appreciate the efforts of my academic advisors Dr. Matheaus K. Kauti and Dr. Jacinta M. Kimiti for their guidance and support during research the study. My gratitude goes to all South Eastern Kenya University (SEKU) members of staff especially the Director, Wote Town Campus, Dr. Patrick Kisangau. Not forgetting staff members of St John's Malivani Secondary School and my friend Antony Nthenge for their support.

God bless you all.

ABSTRACT

The aim of this study was to investigate the effects of land degradation on agricultural land use, planning and management in Kalama Division, Machakos County; and specifically determined farmers' considerations of land suitability for selected types of agricultural land uses in varying cropping zones, investigated farmers' local environmental knowledge of land degradation indicators and finally documented farmers' land management strategies and practices for soil and water conservation. Data was collected using an open ended questionnaire, along a road transect cutting across upper, middle and lower zones (parts) of a slope. A total of 40 households along the transect on the three zones were interviewed and the collected data was analyzed using SPSS for windows. Results obtained revealed that crop farming, livestock, poultry, farm forestry and bee keeping were the major agricultural land use activities carried out in the study area. Overall, steep slope was the most important factor considered for farm forestry (17%) (5.29 STDEV). Bee farming was the least land use practice accounting for only 1% of total land use. Most land degradation (15%) was reported in the middle zone while lowest land degradation (7%) was reported in the upper zone. The study found out that most households were aware of land degradation indicators in their local environment and described them using their indigenous environmental knowledge. The smallholder farmers prevented further land degradation by use of their local or traditional ways such as application of organic manure, planting of trees, crop rotation, use of gabions and stone lines. Different zones had different land use and management practices due to differences in terrain and other physical and biophysical characteristics. Overall, the major land management practices included tree planting (23%) (4.04 STDEV) and water conservation and gabion making (10%) (2.52 STDEV). This study clearly established an existence of smallholder farmers' indigenous knowledge, perceptions, and beliefs of the local environmental factors of land condition which are necessary for the farmer's decision-making on land use planning and management. On the basis of these findings, the study argues for place-based analysis and understanding of the landscape structure and local micro-environments in enhancing understanding of local-level decision-making on land use planning and management by smallholder farmers in maintaining livelihood security. Even though the study is limited to the local scope, it can provide a basis for designing policies aimed at rural livelihood security improvement and inform and facilitate targeting of outside interventions such as land use planning and management programs which can be built on existing indigenous knowledge.

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ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
CDTF	Community Development Trust Fund
FAO	Food and Agricultural Organization
HIV	Human Immunodeficiency Virus
IPCC	Intergovernmental Panel on Climate Change
ISFM	Integrated Soil Fertility Management
KADEG	Kalama Development Group
LUCID	Land Use Change Impacts and Dynamics
NGO	Non-Governmental Organization
NPP	Net Primary Product
PLEC	People Land Management and Environmental Change
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
STDEV	Standard Deviation
UN	United Nation
UNCCD	United Nation Convention to Compact Desertification
UNCED	United Nation Conference on Environment and Development
UNEP	United Nation Environmental Programme

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Land degradation is widely recognized as a global problem associated with desertification in arid and semi-arid zones, which cover about 47% of the globe's total surface area (UNEP, 1997). This is considered to be highly variable arising from different causes and affecting people differentially according to their economic and social circumstances. According to Thomas, *et al*., (1997), land degradation affects a large number of people over a significant proportion of the earth's surface which has led to extreme poverty and hunger. This is associated with declining status of natural resources, and environmental un-sustainability. Around the world, land degradation can be viewed as any change or disturbance to land perceived to be undesirable that affect human activities like agriculture and settlements (Eswaran, *et al*., 2001).

According to Intergovernmental Panel on Climate Change (2001), in Africa agriculture has been the main contributor to current economy ranging from 10% to 70% of Gross Domestic Product (GDP) and is highly affected by land degradation leading to exploitation of natural resources like forests, settlement and cultivating of fragile land, like hills and sloppy areas. Due to the information gap among people in Africa on land conservation, this has led to miss-management of natural resources causing land use change, although this has been highly challenged by global warming throughout the world.

In the early 2000s, approximately 30% of Kenya was affected by very severe land degradation (UNEP, 2000) and an estimated 12 million people, or a third of the Kenya's population, depended directly on land that is being degraded (Bai, *et al*., 2008). The droughts of 1970-2000 accelerated soil degradation and reduced per-capita food production (GoK, 2002). According to Muchena (2008), land degradation estimate is increasing in severity and extent in many areas and that over 20% of all cultivated areas, 30 per cent of forests and 10 per cent of grasslands are subject to degradation. The expansion of cropping into forested and water catchment zones accounts for much of this degradation. The damage to soil, loss of habitat, change of land use, water shortages and siltation leads to reduced ecosystem services. Since the 1972 United Nations Conference on Human Environment held at Stockholm, Sweden, the Government of Kenya has continued to reinforce formulation of policies and strategies that would address land degradation. As Murage, *et al*., (2000) noted, farmers' perceptions and experiences are paramount when planning to implement an enterprise counteracting the on-going land degradation. Moreover, recent diagnostic participatory approaches are increasingly showing that farmers clearly perceive and articulate differences in the levels of soil fertility on their farms.

This study recognizes that smallholder farmer's behaviors in maintaining livelihood are controlled not only by socio-ecosystem condition but also by the land condition. Therefore, understanding of the environmental factors of land condition is necessary for the farmer's land use and management. One of the innovative approaches in this endeavor which has received attention in the recent past calls for greater integration of scientific expertise with local knowledge in assessing land degradation indicators (Barrera-Bassols, *et al.*, (2009). This research used similar approach but went beyond to link farmers land use and management practices with land degradation indicators. It, therefore, sought to reveal the existing differences in knowledge, perceptions, beliefs in decision-making on land use planning and management in Kalama Division, Machakos County, Kenya and hopes to aid understanding of the landscape structure and local micro-environments.

1.2 Statement of the Research Problem

Scientific techniques such as satellite remote sensing, ecological assessment, the measurement of soil properties, economic analyses, expert opinions and interviews (Reed and Dougill, 2002) have all been used to identify, measure and monitor land degradation. However, science has its limitations and cannot always provide an accurate diagnosis or solutions (Fairhead and Leach, 1995).

There is increasing calls for integrating scientifically proven knowledge with those of the farmers' indigenous knowledge on the current land degradation indicators to develop suitable options for improving land management (Barrios, *et al*., 2006; Gobbin, *et al*., 2000; Mannaerts and Saavedra, 2003; Pla, 2003; Roose, 2003). Studies have reported wide scale knowledge of land users employing these indicators for instance in estimating the extent and effect of soil erosion on soil productivity potential (Okoba and Sterk, 2006). The erosion indicators not only reflect the changes in the soil properties but also determine the current status of severity of soil erosion and crop production potential (Gameda and Dumaski, 2004). According to Barrera-Bassols, *et al*., (2009), information need in land use management practices include: local and/ or linguistic soil classification, soil fertility assessment, Soil and water conservation measures, spatial distribution of soil in the farm field, soil erosion recognition and soil quality assessment. The information is useful for large and smallholder agricultural development projects, enabling farmers ability to have high production in a given land use.

The study was carried out in Kakayuni, Kyangala and Kinoi sub-locations which lie in Kalama Division. The study area is divided further into upper, middle and lower zones due to differences in terrain. The area was characterized by recurrent soil erosion, landslides, deforestation for agricultural practices and increased water scarcity due to destroyed catchment zones; this has affected agricultural land use negatively (Ellenkamp, 2004). Bare rocks have been left with little or no soil covering in most parts of the area hence smallholder farmers are left to diversify on other sources of livelihood leading to change of their farm plan and management to cope with land degradation. Therefore there is need to incorporate the local knowledge, land use suitability and land management strategies to control land degradation in Kalama Division Machakos County.

1.3 Study objectives

The main objective of the study is to investigate the effects of land degradation on agricultural land use, planning and management. The specific objectives are to:

1. Determine farmers' considerations of land suitability for selected types of agricultural land uses in varying cropping zones.
2. Investigate farmers' local environmental knowledge of land degradation indicators.
3. Document farmers' land management strategies and practices for soil and water conservation.

1.4 Research questions

1. What are farmers' considerations of land suitability for selected types of agricultural land uses?
2. Do farmers' have local environmental knowledge of land degradation indicators?
3. What are the farmers' land management strategies and practices for soil and water conservation?

1.5 Justification of the study

It has been suggested that African semi-arid rangelands are trapped in irreversible and uncontrollably worsening degradation (Barrow, 1991; Drechsel, *et al*., 2001). This phenomenon is experienced in the study site were land degradation is to the extreme being caused by deforestation, loose soil, steep terrain and poor agricultural practices. Alternatively, others argue that human-induced land degradation can stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods (Zaal and Oostendorp, 2002).

It is clear that science has played a key role in providing large-scale responses to land degradation throughout the last 30 years of global discussions on the desertification problem (Corell, 1999). However, Scientific knowledge has limitations and cannot always provide an accurate diagnosis or solution (Fairhead and Leach, 1995; Thomas, *et al*., 1997), as evidenced by the vastly different solutions to perceived degradation that national and inter-governmental agencies have attempted over the last three decades. Top-down applications of scientific knowledge rarely integrate different components of land degradation, focusing instead on single issues, which can lead to bias and prevent an appreciation of the multi-faceted nature of the problem. Local communities who are affected by land degradation rarely participate in science-led approaches, or derive results that can improve the sustainability of their land management.

There is, therefore, a need to involve local knowledge on land use change among smallholder farm planning and management so that communities are able to fully realize their capacity to adapt to the challenges of land degradation (Reed, *et al*., 2006). The rationale for this study emanates from this recognition, and therefore seeks to incorporate the land use suitability and land management strategies to control land degradation.

1.6 Assumption of the study

The study is based on the following assumptions:

1. The land planning and management by smallholder farmers is influenced by land degradation and terrain.
2. The study area has existing land conservation programs to control land degradation.

1.7 Scope of the study

The study only considers smallholder farmers as most affected by land degradation leading to change on land use, planning and management in Kalama Division, Machakos County. Locations within the study area include Kyangala location, Lumbwa location, Kalama location and Kola location.

CHAPTER TWO: LITERATURE REVIEW

2.1 Global land degradation challenges and land use change

According to Stringer, *et al*., (2012), soil is considered one of the world's limited, non-renewable resources. The continued maintenance of fertile soil is essential in order to meet basic human needs and provide ecosystem services such as food production, and provides the basis of livelihoods for millions of people across the world. Achieving the goal of land and soil sustainability requires an interdisciplinary approach, and provides an enormous challenge to policy makers, scientists and land users.

While land and soil resources are generally owned and managed at a local level, their condition is determined by the cumulative interactions of biophysical, social, economic and political structures and processes, operating across a range of spatial and temporal scales (Stringer, *et al*., 2007). Some of these variables move slowly and operate over long time frames, while others are more rapid. The experience of land and soil degradation becomes apparent at the local scale (Warren, 2002), where it is experienced as a creeping phenomenon with the populations most acutely dependent on the natural resource base for their survival (often the poor and marginalized) being the most vulnerable to its effects.

The degradation of land and soil resource being degraded relates to national sovereignty concerns, while the indirect impacts of degradation transcend village, district and national boundaries and affect food prices, food security and ecosystem service provision in downstream locations, far away from the site of degradation. However, these complex multi-scale linkages present a clear need to frame land and soil degradation as global issues that require international recognition particularly in driving investment in funding, technology transfer and capacity building to tackle the land and soil challenges (Lambin, *et al*., 2002). In the absence of the sustainable use and management of land and soil resources, global sustainable development and environmental sustainability are at risk (Bai, *et al*., 2008).

Globally land degradation is most rapid during the conversion of land use towards continuous cropping. As the agricultural sector becomes more profitable and other conditions more favorable, farmers invest more in land use planning and management. Policies and programs may have a large impact during this transition period, when returns to investment in the soil may be met in the short to medium term. The situation is most critical in the marginal areas where vulnerability of human and environmental systems overlaps. This is where the mixed crop and livestock system is expanding, placing even more people at risk of productivity declines and highly variable rainfall. As we seek solutions for these problems, it is important to note a number of trends some of which are influenced by global changes. These include: Land use change and intensification which have allowed more people to live on vulnerable land. Diversification, towards a mixture of crops and livestock, cash and food crops, and farm and non-farm income, will continue to be a critical means for households to reduce their risk in face of these changes (Ellis, 2000).

Soil fertility depletion has been described as the major biophysical root cause of the declining per-capita food availability in smallholder farms in sub-Saharan Africa (SSA), with a decline from 150 to 130 kg per person over the past 35 years in production (Jaetzold, *et al*., (2006). Adequate and better solutions to combat nutrients depletion where known, are often limited in application because of the dynamics and heterogeneity of the African agro-ecosystems in terms of biophysical and socio-economic gradients. This calls for system-specific or flexible recommendations, rather than monolithic technical solutions such as blanket fertilizer recommendations. Despite diversity of approaches and solutions and the investment of time and resources by a wide range of institutions, soil fertility degradation continues to prove to be a substantially intransigent problem, and as the single most important constraint to food security in the continent. Return to investment in soil fertility has not been commensurate to research outputs. Farmers are only likely to adopt sound soil management if they are assured of return on their investment (Jaetzold, *et al*., (2006).

Therefore due to continued land degradation; Integrated Soil Fertility Management (ISFM) is now regarded as a strategy that helps low resource endowed farmers, mitigate many problems and the characteristics of poverty and food insecurity by improving the quantity and quality of food, income and resilience of soil productive capacity. There are five technologies for maintenance, replenishment and improvement of soil fertility as adopted from ISFM (Rao and Mathuva, 2000) which are as follows.

1. ***Terracing:*** Despite the heavy handed interventions of the colonial government and some policy reversals in the immediate post-independence period, adoption of terracing increased steadily as farmers discovered the benefits of terracing (Thomas, *et al*., 1997). In addition to being the most popular soil and water conservation, terracing increased productivity per hectare in the Machakos District (Tiffen, *et al*., 1994). Using the so-called '*Fanya Juu'*, it involved making a ridge by digging a channel and throwing the soil uphill.

2. *Fallowing:* Increasing population pressure on the land has led to increased continuous cultivation of land and a decline in fallowing (Drechsel, *et al*. 2001). Improved fallow systems offer a quick way to regenerate soil fertility because they require shorter fallow periods than natural fallow and the only investment required is seed. In Western Kenya, it has been proved scientifically that fields sown with maize and beans in which the improved fallow was *Crotolaria gramiana* or *Tephrosia vogelii* was used had higher economic return than where natural fallow was used or the continuous cropped fields (Jaetzold, *et al*., (2006). Extending improved fallow systems for soil fertility improvement should be reasonably easy in Kenya given that many smallholder farmers know the value of leaving land to fallow naturally.

3. *Organic manures and fertilizers:* A relatively broad definition of organic fertilizer comprises: crop residues (e.g. maize stocks, bean trash, napier grass trash, tree cuttings), animal manure (e.g. cattle, sheep, goat, pig, poultry), compost, and mulching using organic matter collected on or off-farm. In Zimbabwe, applying farmyard manure for 3 years to sandy soils at relatively high rates enabled a clear response to fertilizer where such response was not visible before rehabilitation (Zingore, *et al*. 2007).Organic fertilizer use is a mature technology, like terracing. However, many have very limited access to organic material for production of organic fertilizers, so quantities applied are often quite small.

4. *Inorganic or mineral fertilizers:* Most inorganic fertilizers are mined from ores or sedimentary deposits, except for those that contain nitrogen (N) which is synthesized with high energy input by n-fixers from the air. Because of the high element concentration and high solubility of the inorganic fertilizers, their beneficial effects on plant growth are quick and easy to recognize.

5. *Rotation and inter cropping*: Crop rotations can be defined as temporal arrangements and allocations by growers of crop types to specific fields through time. It is one of the oldest and most fundamental agronomical practices and is thought to have been critical in sustaining the industrial revolution in Britain by increasing crop production (Sanginga, *et al*., 2003).

Wibberley, (1996) defines crop rotation as ‘‘the sequence of crops grown in succession on a particular field”. The use of different crops in cropping systems, either as intercrops or in rotations with other crops, for improving soil fertility is a well-known practice in the tropics (Rao and Mathuva, 2000).

2.2 Indigenous soil knowledge, characterization and conservation

Soil knowledge is key towards agricultural production as well as it`s characterization. Farming is a dynamic practice and the type of crops that farmers grow or introduce into their farming system is a reflection of prevailing biophysical characteristics (Gachimbi, *et al*., 2003). According to Barrera-Bassols, *et al*., (2009) Pichataro’s farmers in Central Mexico recognized five major soil types when referring to mutually exclusive taxonomic units: powdery soils, clayey soils, sandy soils, gravelly soils and hard and sticky soils. Moreover, farmers distinguish composite soils at the plot level as textural or colour intergrades, e.g. powdery-clayey soils or powdery black-yellow soils. Intergrades are related to the soil position on the landscape, adjacent landscape units and the volume of accumulated debris.

Farmers recognize different types of soil on the field, their mental soil maps are based on the concept of ‘composite soil’, a concept similar to that of soil association. Thus, farmers use ways of thinking similar to those of soil scientists for soil classification and mapping. An analysis of the local soil nomenclature and classification in Central Mexico revealed a deep understanding of soil landscapes by farmers. Farmers combine and modify descriptive classes to reflect gradual or abrupt variations in soil pattern. Local soil knowledge is expressed in rules which are shared by all members of the community and transferred from generation to generation.

In the Roraima state of Brazil where there is limited soil information, do Vale, *et al*., (2007) assessed agricultural productivity and management in an area occupied by Uapixana and Malacacheta people and found that the farmers had a local knowledge of practicing land use practices according to distribution of soil within the landscape. In the highlands of northern Thailand that have been settled by the Black Lahu ethnic group over the last 40 years, a participatory soil study was used for evaluating land suitability for a variety of crops and designing an agreed land-use plan (Schuler, *et al*., 2006). In this same locality, the study was further developed by use of integrated the soil survey map with land-use data by combining socio-economic attributes and local perception of soil fertility and land suitability for selected crops. In Africa, traditional participatory research was conducted with pastoralists to evaluate management options from the literature and identify local knowledge of alternative strategies that have the capacity to prevent, reduce, reverse or help people adapt to land degradation in communal rangelands (Reed, *et al*., (2007).

In southeast Nigeria, participatory studies were conducted in an area of small farmer immigrants to tackle environmental issues caused by increasing pressure on agricultural land (Gobin, *et al*., 2000). Assessing the impact of rainfall uncertainty on grain legume production was the goal of a participatory soil survey with Ovambo people in northern Namibia (Hillyer, *et al*., 2006). These studies recommended the need of environmental conservation.

According to Okoba and Sterk (2005), the effect of soil erosion on crop production in Gikuuri catchment in central highland of Kenya generally leads to reduction of yield between seasons. The yield differences are due to inherited or *in situ* soil physical properties represented by different erosion indicators that fertilizers cannot eliminate. Soils prone to rill and sheet (splash-pedestals) are more productive than where red soils are observed. This can be attributed to efficient removal of nutrient-rich topsoil through the rill channels and surface runoff that enhance decline in soil–water and plant nutrients storage reserves in topsoil profiles required for crop development. Red soils tend to have coarse subsoil aggregates, which in effect reduced surface runoff to some extent though they are low in plant nutrients due to past loss of its dark topsoil profile. Farmers can lose over 50% of their yields due to observed past or current erosion phenomenon in agricultural lands.

Lal, *et al*., (2000) observed growing inconsistent superiority of sedimentation zones over the more eroded upslope fields in crop yields between years. These observations could illustrate the importance of communal approach in planning and timely implementation of soil erosion control measures in both upstream and downstream areas within a hydrological catchment. Organic fertilizers might still prove uneconomical given the loss of soil rooting depth.

2.3 Land degradation in Kenya

The impacts of land degradation and desertification include a reduction in crop and pasture productivity, fuel wood and non-timber forest products, which are closely linked to poverty and food insecurity (Bai, *et al*., 2008). In the early 2000s, approximately 30 per cent of

Kenya was affected by very severe to severe land degradation (UNEP, 2000) and an estimated 12 million people, or a third of the Kenya's population, depended directly on land that is being degraded (Bai, *et al*., 2008). The droughts of 1970-2000 accelerated land degradation and reduced per-capita food production (GoK, 2002). More recent studies extrapolating on local findings of spatial and temporal patterns of land degradation estimate that land degradation is increasing its severity and extent in many areas that over 20 per cent of all cultivated areas, 30 per cent of forests, and 10 per cent of grasslands are subject to degradation (Muchena, 2008).

In Kenya around 30% of the population lives in harsh areas within arid and semi-arid zones (Sanyu, 2001). Improved management of semi-arid regions is vitally important in many countries and especially in Kenya, where most of the population live in the crowded 20% of the country with moderate to high rainfall, (Hudson, 1987). Kenya is facing one of the highest annual population growth rates in the world, estimated in 2000 to 2.3 % per year (World Bank, 2000). The growing population combined with limited land availability in the agriculturally productive highlands has led to increasing land use. On the other hand constant water shortages and environmental deterioration restrict productive agriculture and livestock keeping, i.e. the local people's primary livelihood (Sanyu, 2001).

2.4 Coping strategies to land degradation

A number of studies have been conducted on coping strategies to land degradation, for instance Maitima, *et al*., (2010) observed that although most coping strategies are affected by global changes, diversification of agricultural production is crucial. According to Okoba and Sterk (2006), continuous neglect of the land degradation challenge makes it hard to to restore land for food crop production instead converted to other enterprises like stone crushing for construction materials and sand excavation. Soil conservation activities can also be adopted in lowland zones by use of large gabions placed at regular distances in the stream (Johansson and Svensson, 2002).

The exposure of land to erosion usually varies within catchments. The factors that control erosion are: the nature of the plant cover, the erodibility of the soil, the erositivity of the eroding agent and the slope of the land (Morgan, 1995). In Some areas farmers cope with land degradation by increasing crop diversity. Use of livestock manures and crop vegetative residues by farmers maintains more fertile and more productive farms. By contrast, in traditional rural societies that still represent the majority of small farmers worldwide, the use of conventional soil survey information frequently fails because it does not take into account soil knowledge of local people and their experience in working with soils (Osunade, 1994; Sillitoe, 2004; WinklerPrins, 1998; Barrera-Bassols, 2003; WinklerPrins & Barrera-Bassols, 2004). Approaches have been proposed to incorporate environmental knowledge of rural communities through the participation of local farmers (in land use planning), either from a study of soil point of view (Sillitoe, 2004). Due to lack of appropriate approaches to evaluate land degradation, the land-use planners in most countries have adopted recommendations that are derived from site-specific experiments or based on modeling approaches that are not fitted to the local conditions. Lal, (1994) observed that land use planning decisions based on unreliable data could lead to costly and gross errors.

2.5 Planning and management of farms in Kenya

Land-use change is one of the main drivers of environmental change which influences the basic resources of land like soil and vegetation (IPCC, 2001). Its impacts often occur so creepingly that land managers hardly contemplate initiating counter-balance measures. Poor land management has degraded vast amounts of land which have reduced the ability to produce enough food to feed the ever increasing population, causing a major threat to rural livelihoods in many developing countries (Bai, *et al*., 2008). Land use around the globe and most parts of East Africa and especially in Kenya is changing fast, while some areas are undergoing expansion of cultivation and grazing. Common to all is that there are impacts on sustainability of the natural systems on which productivity depends on. There is an urgent need for a regional framework and guidelines for sustainable land management including all sectors of land use like agriculture and urbanization (Maitima, *et al*., 2010)

Evaluation of land resource, their management and planning has become an important component of sustainability throughout the world. Planning and farm management is determined by terrain (Ceballos-Silva and Lopez-Blanco, 2003). Quantification of terrain for land suitability necessitates compilation of data on requirements of land-use and land-cover, determination of biophysical potentials and identification of more or less homogeneous land mapping units (Kilic, *et al*., 2005). Thus, land suitability analysis is an inventory on land resources in terms of limitations and potentials which is useful in land management and planning. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a defined use (Chen, *et al*., 2010; Bhagat, *et al*. 2009). According to Laskar, (2003) the global concern about food security, quality of future life and growing awareness of environmental degradation is posing serious question to the achievements of natural resource sustainability. Land suitability evaluation and agricultural land use planning is very necessary and is the basic information for right decision making afterward (Van Chuong, 2008).

According to Maitima, *et al.,* (2010) land use change analysis in Sango Bay, Uganda along with several other areas in East Africa reported little changes in land use between 1955 and 2000. These observations led Mugisha (2002), to conclude that there was insignificant land use intensification in Sango Bay between 1955 and 2000. However the Land Use Change Impacts and Dynamics (LUCID) project based on socio-economic surveys showed that there is significant land use intensification, especially in grazing.

The rate of agricultural management appears to be minimal in several areas like around Mt. Kilimanjaro on both sides of Kenyan and Tanzanian and on the eastern slopes of Mt. Kenya. This condition is occurring especially where the conversion frontier is in drought-prone land. The rate of rural population growth is also slowing in many places (Olson, *et al*., 2003). In other areas the expansion of agriculture is continuing at a rapid pace (Tukahirwa, 2002). As land is converted, the patchwork of cultivation and natural vegetation gives way to private cultivated farm-land (Maitima *et al*., 2004). Methods of maintaining soil productivity such as shifting cultivation and long term fallowing are no longer practiced, which leads to erosion and declines in soil organic carbon and soil nutrients are often severe in such areas.

Systems undergoing intensified change and moving towards continuous cropping include fuel wood collection which is impacting watersheds and other natural resources. Trees are cut for curing of tea in upper zones and to sell as charcoal to cities in lower zones (Olson, *et al*., 2004). Land use change from bush to grazing leads to reduced organic carbon content, soil moisture, pH, bulk density and nitrogen loss in the soil. This does not affect forage productivity until grazing intensity reaches a certain level (Kamau, 2004). It is clear that in Kenya most farmers credit the application of manure for productivity increases and blame the lack of manure for decreases (Maitima, *et al*., 2004).

2.6 Conceptual framework on agricultural land use planning and management

Land degradation has affected land use: crop farming, livestock keeping farm forestry and bee keeping within the study area. This has been clearly given by the land degradation indicators which include: Reduced productivity, land-slides, field erosion and loss of vegetation cover (Okoba and Sterk, 2005). The damage on the land can only be tackled through proper land management strategies both in soil and water; for example use of Integrated Soil Fertility Management (Jaetzold, *et al.*, 2006), afforestation, use of gabions and contour farming. This brings about healing of the land hence well distribution of land use practices on the farm field.

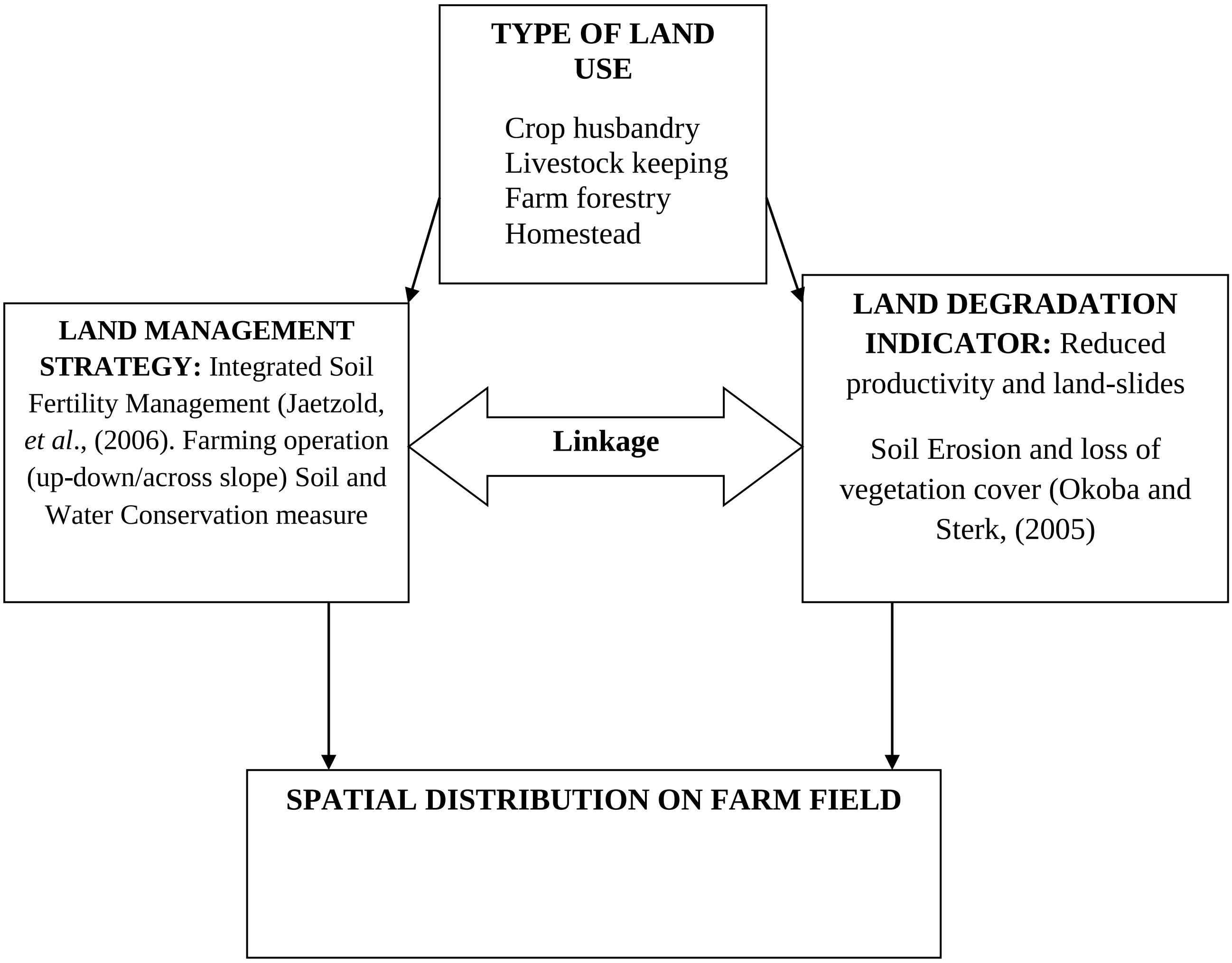

Figure 2.1: Conceptual framework

CHAPTER THREE: METHODOLOGY

3.1 Study area

3.1.1 Physical location

The study was undertaken at Kyangala Location, Kalama Division, Machakos County (Figure 1). Kalama Division covers an area of 200 square kilometers, located between 1º37' S and 1º45' S latitude and 37º15' E and 37º23' E longitude.

The choice of the study site was based on several considerations emanating from the research problem. There is increasing soil erosion due to steep terrain and loose soils. According to Ellenkamp (2004), there is also encroachment of forest for settlement, land use change and charcoal burning and generally loss of vegetation within the study area that has affected agricultural land use negatively. Bare rocks have been left with little or no soil covering in most parts of the area hence smallholder farmers are left to diversify on other sources of livelihood leading to change of their farm plan and management to cope with land degradation.

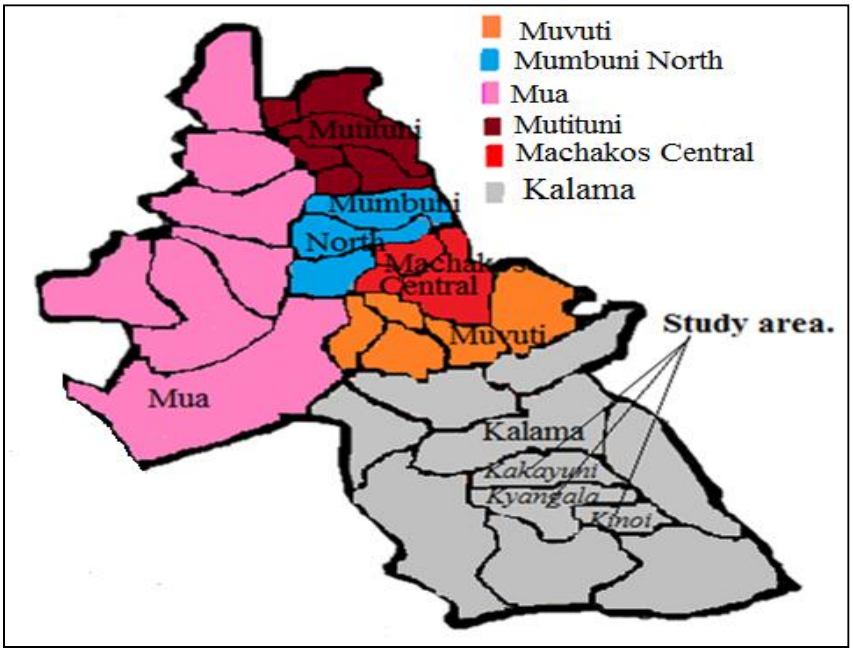

Figure 3.1: Location of study area in Machakos County

Source: Ministry of State for Planning, Development and Vision 2030

3.1.2 Population and demography

Kalama Division has four locations and eight sub-locations (Table 3.1). Kakayuni location is the largest and has steep hills and experiences highest soil erosion compared to other locations. The hill tops are defforestated due to extended settlements and farming activities.

Table 3.1: Population and demographic characteristics of Kalama Division

Division	Location	Sub-location	Total Population	Area in Sq. Km.	Population Density	Households
Kalama	Kola	Iiuni	4,415	26.62	165.87	986
		Katanga	7,695	34.18	225.13	1,643
	Lumbwa	Muumandu	12,475	148.63	83.93	2,820
	Kalama	Nziuni	4,870	17.55	277.44	1,015
		Kiitini	6,285	35.37	177.71	1,419
	Kyangala	Kinoi	2,342	11.89	197.04	543
		Kakayuni	2,454	7.84	312.98	568
		Kyangala	2,298	10.46	219.69	541
Total			7094	30.19	729.71	1652

Source: Kenya, Republic of Kenya (2010). “2009 Kenya Population and Housing Census Volume 1 A, Population Distribution by Administrative Units,” Nairobi, Kenya National Bureau of Statistics

3.1.3 Physiography and soils

The study area has metamorphic rocks which form the roots of these mountains. The mountains consist of excessively drained, reddish brown, stony and rocky sandy clay loam soils, that vary in depth (Siderius, 1978). The plains and uplands that surround the mountains consist of poorly drained, black cracking and swelling firm clay soils. In the dissected uplands well drained dark reddish brown clay and sandy clay soils are formed.

3.1.4 Hydrology and drainage

The study area is drained by two seasonal rivers: Thwake and Kaiti. According to Ellenkamp, (2004) the mean annual rainfall of the area is 602 mm, distributed over a long (March-May) and a short (October-December) rain season, separated by a distinct dry season. The rains on the southern and eastern slopes of the mountains tend to be prolonged. The average monthly maximum temperature varies between 22.2°C and 27.3°C and the minimum temperature varies between 11.1°C and 15.2°C.

3.1.5 Land use

The study area is used as arable land. Farms sizes vary from 500m^2 to 1,000 m^2 and most farms are terraced. Mixed cropping is the main farming activity, with maize, pigeon peas, beans and fruit trees as the main crops (Onduru, *et al.*, 2001). Most farms have livestock (cows and goats) which are kept for dairy products and manure

3.2 Research design

The study employed a survey research design. According to Orodho (2005), survey concerns describing, recording, analyzing and reporting conditions that exist or have existed. Agronomic survey was used where crop calendar, farming practices and production systems were captured. The second component of the research design was land management strategy having Integrated Soil Fertility Management (ISFM) (Jaetzold, *et al*., (2006) soil and water conservation measures and farming operations (Okoba and Sterk, (2006), which was captured through ethnographic survey techniques (Barrera-Bassols, *et al*., (2009). Lastly land degradation indicators were achieved through ethnopedologic survey technique (Barrera-Bassols, *et al*., (2009) and the data collected were based on local knowledge/expertise. The survey was designed to collect views from smallholder farmers in each of the three zones i.e.

the upper zone, middle zone and lower zone of Kakayuni, Kyangala and Kinoi sub-locations Kalama Division Machakos County.

3.3 Sampling method

The study adopted a transect sampling design whereby a road based transect was designed to cover as much ecological variability of land uses as possible within the study site. A similar approach was used by Maitima and Olson, (2002) and Orloci and Stanek, (1980). The approach was based on the distribution of patterns along environmental lines to give a description of the full range of land use in a region by sampling along the full range of environmental variability.

The area was divided into three zones i.e. upper zone (hills), mid zone and lower zone. In the upper zone there is encroachment of forest for settlement, land use change and charcoal burning. The middle zone is characterized by increasing soil erosion due to steep terrain and loose soils while the lower zone has fewer observable land degradation indicators. Within each zone, systematic random sampling along a transect road was carried out to select every second household for answering of questionnaires. The transect sampling design was relevant to the study as the research aimed to investigate the effect of land degradation to the farm planning and management within the study area.

3.4 Sample size and sampling procedure

Each zone has a road cutting across hence the roads that cut across the three zones, upper, middle and lower zones were followed and households that fell within the road to an estimate of 2km in each of the three zones were sampled. During the sampling 13 questionnaires were administered in both the upper and middle zones and 14 households were sampled in the lower zone. The stratification was done according to agro-ecological zones (AEZ) as identified by Jaetzold and Schmidt (1983) in Kenya and Tanzania.

3.5 Data analysis

The collected data was coded and entered into the computer for analysis using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. Quantitative data was analyzed using descriptive statistical tools of percentages and means. The results of data analysis were presented in percentage tables.

CHAPTER FOUR: RESULTS

4.1 Farmer's considerations of land suitability for selected types of agricultural land uses

Results obtained on farmers' consideration of land suitability revealed that livestock production, crop farming, farm forestry, poultry farming and bee keeping were the agricultural land use practices in the area (Table 4.1). All household practiced crop farming (34%) in the three zones (1.15 STDEV). Crop farming was followed by livestock keeping at 30% (upper zone), 33% (middle zone) and 33 % (lower zone) (1.73 STDEV). Poultry keeping followed crop farming and livestock keeping with upper zone having 28%, middle zone (33%) and lower zone (33%) (STDEV 2.89). Farm forestry was practiced in upper, middle zone and lower zone at 25%, 23% and 18%, respectively. However, bee keeping was practiced only in the lower zone by 3% of the households interviewed.

Table 4.1 Agricultural land use practices in study area

Land use practice	Zones Percentage (%)				
	Upper	Middle	Lower	Mean (%)	STDEV
Livestock production	30	33	33	32	1.73
Crop farming	33	33	35	34	1.15
Farm forestry	25	23	18	22	3.61
Poultry farming	28	33	33	31	2.89
Bee keeping	0	0	3	1	1.73
Mean (%)	24	24	24		

Results on reasons for farmers' selection of the field for a particular land use were influenced by its suitability for the particular use. Thus livestock were kept where there was sufficient pasture land; fertile soils influenced crop farming; sloppy areas were chosen for tree planting while chicken were kept where there was security from theft (Table 4.2)

Table 4.2 Farmer’s considerations for choice of land for agricultural use

Agricultural Practice	Reason for Choice of Land	Zones Percentage (%) Upper	Middle	Lower	Mean (%)	STDEV
Livestock production	Sufficient pasture and water	28	15	30	24	8.14
	Accessibility	0	0	3	1	1.73
	Conducive climate	0	0	3	1	1.73
	Nearness to homestead	0	3	0	1	1.73
	Security	3	0	3	2	1.73
Crop farming	Fertile soils	25	20	38	28	9.29
	Availability of water	0	3	3	2	1.73
	Conducive climate	0	3	0	1	1.73
	Gentle slope	0	3	3	2	1.73
	Lack of stones	3	3	5	4	1.15
Farm forestry	Steep slope	23	13	15	17	5.29
	To act as wind breaker	3	3	3	3	0
	To conserve soil	5	8	3	5	2.52
	Conducive climate	3	3	3	3	0
	Availability of water	3	0	3	2	1.73
	Fertile soils	0	3	0	1	1.73
Poultry farming	Security (Theft and low draught)	23	33	35	30	6.43
	Availability of feed	0	3	3	2	1.73
	Direction of wind	0	5	5	3	2.89
	Minimal disturbance	0	3	0	1	1.73
Mean (%)						
Bee keeping	Safety (Minimal disturbance)	0	0	3	1	1.73

4.2 Farmer’s local environmental knowledge of land degradation indicators

Dry land communities possess vast amounts of indigenous knowledge that science could benefit from by learning about local ways of recognizing, coping and adapting to degradation. This section is devoted to a discussion of this body of indigenous knowledge. According to the study the community was aware of many land degradation indicators which they observed during their daily land use cores. The households identified a consensus list of land degradation indicators which they clearly described in the local language.

Seven common land degradation indicators were identified in the research area (Table 4.3). The respondents described them as follows:

1) Field erosion - The respondents said that their fields had gullies and rills as compared to the last five years. The observed change caused loss of the fertile top soil hence reduced production within the fields. This also made the plants weak and not well anchored in the soil.
2) Stone appearance - The farmers clearly panted that the stone appearance had increased due to land degradation. The land was highly covered by soil and vegetation but currently a greater surface is covered by stones which have occurred due to erosion.
3) Tree reduction - Generally forest cover in the study area has reduced as compared to the past. Most of the respondents stated that climate change had brought reduced survival rates of trees especially those which required high amount of moisture. The vegetation cover generally was affected negatively hence the land left bear.
4) Terrace slide - Terraces had highly slide and lost their uniformity causing reduced water hold-age within the field and soil. This has also led to deposition of soil to the lower sides of the *Shamba*.
5) Appearance of tree root - The study area had lost most of the top soil, this caused root appearance of the tree roots hence reduced quantity of water uptake and limited tree support. The loose soil and steep slope zone within the study area accelerated the root exposure leading even to vegetation drought.
6) Water scarcity - The farmers indicated that the amount of water in wells and in streams had reduced within the study area. Exhaustion/exploitation of water catchment zones and reduced vegetation/soil led to water scarcity.
7) Increased anthills - Increased number of anthills were reported as the temperatures increased and dried woody materials hence high termite infestation for food. The residents alleged that the ants made the anthills to adapt to climate change.

Field erosion was highest in the middle (28%) and the lower zones (28%) and was in overall the commonest land degradation indicator (21%) reported in the three zones. Further, highest incidences of land degradation indicators were reported in the middle zone where field erosion and tree reduction were the commonest (28%) reported indicators.

Table 4.3 Land degradation indicators within the three zones

	Zones Percentage (%)				
Land degradation indicator	Upper	Middle	Lower	Mean (%)	STDEV
Field erosion	8	28	28	21	11.55
Stone appearance	8	18	5	10	6.81
Tree reduction	15	28	5	16	11.53
Appearance of tree roots	8	5	5	6	1.73
Water scarcity	0	10	0	3	5.77
Terrace slide	10	15	8	11	3.61
Increased ant-hill	0	0	3	1	1.73
Mean (%)	7	15	8		

Results obtained revealed that heavy rainfall according to the farmers was the main cause of field erosion (20%) (7.51 STDEV) in all the three zones followed by deforestation (14%) and overstocking (8%) (Table 4.4). The least important cause of field erosion was loose soil (5%). Across the three zones deforestation (13%) and heavy rain (7%) were the highest causes of stone appearance. According to the farmers heavy rainfall (9%) caused tree reduction in the mid-zone. Loose soil was the least cause of tree reduction (3%).

Appearance of tree roots was mostly caused by deforestation (9%), followed by heavy rainfall (4%) and overstocking (4%); the least was loose soil (3%). Terrace slide was commonly caused by rainfall (9%) and deforestation (8%); loose soil (8%) and the least was overstocking (4%).

Table 4.4 Perceived causes of land degradation in selected zones

		Zones Percentage (%)				
Land degradation indicator	Perceived cause	Upper	Middle	Lower	Means	STDEV
Field erosion	Heavy rainfall	13	28	20	20	7.51
	Overstocking	3	5	15	8	6.43
	Deforestation	20	10	13	14	5.13
	Loose soil	5	8	3	5	2.52
Stone appearance	Heavy rainfall	3	13	5	7	5.29
	Overstocking	5	3	10	6	3.61
	Deforestation	18	8	13	13	5
	Loose soil	3	3	5	4	1.15
Tree reduction	Heavy rainfall	3	18	5	9	8.14
	Overstocking	5	3	8	5	2.52
	Deforestation	8	3	5	5	2.52
	Loose soil	3	5	0	3	2.52
Appearance of tree roots	Heavy rainfall	5	3	3	4	1.15
	Overstocking	3	3	5	4	1.15
	Deforestation	5	13	8	9	4.04
	Loose soil	3	3	3	3	0
Water scarcity	Heavy rainfall	5	10	15	10	5
	Overstocking	15	23	3	14	10.07
	Deforestation	3	5	3	4	1.15
	Loose soil	3	3	5	4	1.15
Terrace slide	Heavy rainfall	8	15	3	9	6.03
	Overstocking	5	3	3	4	1.15
	Deforestation	10	5	10	8	2.89
	Loose soil	8	5	10	8	2.52

4.3 Farmer's land management strategies and practices for soil and water conservation

In the study area, farmers practiced land management strategies for soil which included: planting of grass, afforestation, terracing, stone-line, organic fertilizer application and crop rotation (Table 4.5). The study revealed that the upper zone led in land management strategies for soil and water conservation (18%). In this zone planting of trees was the commonest strategy (25%), followed by terracing (23%) and finally stone line (10%). The mid-zone was the second in soil conservation strategies (16%). In this zone planting of napier grass was the commonest strategy (28%) and the lowest was crop rotation (8%). The lastly was the lower zone in land management strategies for soil with a mean percentage of 14%. As in upper zone tree planting was also the most practiced strategy in lower zone (23%), while stone-line was the least used strategy (11%). Within the three zones tree planting was the mostly practiced land management strategy for soil (23%) (4.04 STDEV), followed by grass/napier grass planting (20%), terrace making (16%), organic fertilizers use (13%), crop rotation (13%) and finally stone line making (11%) (6.56 STDEV) (Table 4.5).

Table 4.5 Land management strategies for soil conservation in selected zones

Land management strategy	Zones Percentage (%)				
	Upper	Middle	Lower	Mean	STDEV
Planting of grass	18	28	13	20	7.64
Afforestation	25	18	25	23	4.04
Terracing	23	13	13	16	5.77
Stone-line	10	18	5	11	6.56
Use of organic fertilizers	18	10	10	13	4.62
Crop rotation	13	8	18	13	5
Mean (%)	18	16	14		

Results obtained on water conservation strategies in the study sites revealed that water harvesting, afforestation, micro-dam making, gabion making, mulching and terracing were the commonest conservation methods used (Table 4.6). Overall most water management strategies were practiced in the middle zone (8%). In addition, water harvesting (10%) (2.52 STDEV), gabion making (10%), afforestation (7%) and terracing (7%) (2.89 STDEV) were the commonly reported water conservation strategies in all the three zones. However, with respect to zones, water harvesting and afforestation were commonest in the middle zone

(13%), water harvesting in the upper zone (23%), gabion making in the lower zone (10%) and terracing in the middle zone (10%).

Table 4.6 Water conservation strategies in selected zones

Water management strategy	Zones Percentage (%)				
	Upper	Middle	Lower	Mean (%)	STDEV
Water harvesting	10	13	8	10	2.52
Afforestation	5	13	3	7	5.29
Micro-dam making	8	3	3	5	2.89
Gabion making	5	10	15	10	5
Mulching	3	0	3	2	1.73
Terracing	5	10	5	7	2.89
Mean (%)	6	8	6		

At first this chapter has looked at agricultural land use practices commonly practiced in study area. Crop farming and livestock rearing were common while the least was bee keeping. Farmers' selection of farm fields and considerations of land suitability were highly determined basing on the following factors: climate, soil type and fertility, water availability, terrain and security. Farmer's local environmental knowledge of land degradation was clearly brought out by the study in this chapter. The community is a wear of land degradation and gave out that: field erosion, stone appearance, tree reduction, terrace slide, appearance of tree roots, water scarcity and increased anthills were the major land degradation indicators experienced. Lastly the study revealed that land management strategies for soil and water were practiced in the study area by the smallholder farmers.

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Farmer's considerations of land suitability for selected types of agricultural land uses

Crop farming, livestock, poultry farming, forestry and bee keeping were identified as the major agricultural land uses in the three selected zones. Crop farming and livestock were among the leading practices in most of the households. It was noted that all households identified crop farming as the main agricultural land use in the study area followed by livestock production. The phenomenon could be influenced by socio-economic factors as in agreement with Waters-Bayer, *et al*., (2003); since occupation play a key role towards planning and management of land use as formally employed farmers had the greatest percentage across the three zones (Appendix 1). This most probably could have made the smallholder farmers to acquire fertilizers, highbred seeds and breeds and able to employ farm labour. Nonetheless the self-employed household heads possibly could have enough time to care, plan and manage their farm land. Most of these practices may highly require experience especially poultry farming which is upcoming in the current economic growth. Moreover farm forestry was mostly practiced in the upper zone and mid-zone this could have been influenced by their steep terrain hence the need to conserve the soil from extreme degradation. In similar study Morgan (1995) found that development of different soil erosion indicator at different slope positions does indicate the strong influence of velocity of overland flow and slope steepness- length factors. In support of farmers' observations, Mutchler and Greer (1980) observed a tendency of rills forming as slopes became steeper mainly as a result of concentrated overland flow that increased depth and number of rills on steeper slopes than less steep slopes.

General overview of household land use practices indicated that farmers had reasons for choosing the field, for the land use practices. For example livestock was majorly undertaken in fields with sufficient pasture across the three zones which may have been attributed to quality and quantity production at minimal cost for the smallholder farmers. Accessibility to the field and conducive climate were least considered as the farmer's could have been concerned with pasture to avoid decline in livestock production; these findings are confirmed by studies undertaken by Fynn and O'Connor (2000). Results further indicated that crop farming was practiced in accordance to several reasons which included fertile soil across the three zones but majorly in the lower zone. This might have been influenced by availability of high nutrient supply in soil, aeration and organic matter decomposition which leads to increased crop productivity as supported by Maitima, *et al*., (2004). Lack of stones in the lower zone most likely influenced crop production. Presence of stones could have highly affected soil structure hence hindering crop growth. Gentle slope slows down surface run off minimizing soil erosion and encouraging water retention. These findings are in agreement with Ceballos-Silva and Lopez-Blanco, (2003) who noted that planning and farm management is determined by terrain.

Forestry farming was mostly practiced in steep slopes across the three zones but majorly in upper zone. This implied that upper zone farmers could have high experience in reducing soil erosion and maintaining the soil structure hence being clear that their environment was well maintained. The mid-zone recorded the lowest forest cover hence was most likely suitable for crop product and other activities. Which could be attributed to low availability of water and increased land degradation due to steep terrain hence hindering tree growth; this findings are similar to those arrived at by Morgan, (1995). Trees are commonly planted on steep slopes because of challenging terrain.

Theft and draught control were the major reasons for keeping poultry across the three zones. Also minimal disturbance and direction of wind triggered the poultry keeping. Lastly bee keeping was overtaken by the other agricultural land use practices in the study area which could be attributed to minimal acreage ownership of land among the farmer's since majority own less than three acres (Appendix 1). Bee keeping was practiced in lower zone most probably due to households' awareness and training in their management in this zone.

5.2 Farmer's local environmental knowledge of land degradation indicators

Great deal of work has been carried out with appreciable attempt to estimate land degradation in the perceived high, moderate and low erosion sites (Bergsma and Farshad, 2003). Results from this study unveiled that the local communities were aware of land degradation indicators which they observed during their daily land use chores. However, this awareness did not differ across the three zones as perceived by the respondents. The households identified a consensus list of land degradation indicators and outlined what they perceived as the development of these indicators (Table 4.3).

An examination of land degradation indicators within the three zones (Table 4.3) revealed that all the land degradation indicators were highly experienced at the mid-zone. This was most probably due to reduced vegetation cover, steep land slope and loose soil (Morgan, 1995). The lower- zone experienced the lowest land degradation indicators; this may be due to gentle slope which was mostly present in this zone. The upper zone experienced moderate land degradation indicators. This could be attributed to forest encroachment for settlement, agricultural land use practices and charcoal burning (Muchena, 2008).

Field erosion was the main land degradation indicator across the three zones. Erosion plays a more important role to overall soil loss amount (Collins and Dunne, 1986). Therefore, it can be noted that most households were aware of land degradation indicators in their local environment. Such levels of land degradation, according to Kilewe and Mbuvi (1990), can lead to partial or total loss of soil resource for land uses whereby even addition of higher rates of inorganic and organic fertilizers might still prove uneconomical given the loss of soil rooting depth.

Having looked at the land degradation indicators, it was important to examine the perceived causes of the identified land degradation (Table 4.4). Results from this study clearly revealed that natural and anthropogenic factors were the main causes of land degradation across the three zones. Heavy rainfall which caused flash floods highly in middle zone was the major cause of field erosion as supported by Diouf and Lambin (2001). Deforestation was the major perceived cause of field erosion in upper zone. This could have probably led to reduction of vegetation cover hence bear land increasing surface run off. Livestock keeping which is an anthropogenic factor could have been one of the major causes of land degradation indicators mostly affecting the middle and lower zones where most livestock was kept (Table 4.1). Lastly loose soil was perceived as an indicator of land degradation which highly influences terrace slide in lower zone and field erosion in upper and lower zones. Boserupian theorists have argued that human-induced land degradation could stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods in the dry lands of Africa (Zaal and Oostendorp, 2002).

5.3 Farmer's land management strategies and practices for soil and water conservation

It is evident from this study that tree planting was the major soil conservation measure across the three zones but mostly in the upper zone most likely due to favorable climatic conditions suitable for tree growth. According to Stringer, *et al*., (2012), soil is considered one of the world's limited, non-renewable resources. In addition to conserving soil, the other possible reason of afforestation can be a source of; wood-fuel, timber, trees act as wind breakers and is source of food for both human beings and livestock. The middle zone was characterized by steep slope, high water scarcity and loose soils hence more likely supported grass planting as a measure of soil conservation. The grass can do well in shallow soils with little amount of moisture and boosts soil fertility by adding organic matter. Due to minimal land degradation indicators the residents in the lower zone were most probably reluctant to carry out soil conservation measures. Planning and farm management is determined by terrain (Ceballos-Silva and Lopez-Blanco, 2003). Stone line was mostly used in the middle zone; this could be most likely attributed to availability of stones brought about by high land degradation in the mid-zone. This method is likely to be cheap and possibly does not require high skills; also it is more likely to create more space for crop production.

Land management strategies for water in the three zones included; water conservation. Water conservation was done through water harvesting across the three zones. The middle zone led in water conservation strategies most likely due to availability of rocks in the zone which acted as water catchment during rains. The area also had trees and presence of stone lines which reduced surface runoff thereby increasing water infiltration. This zone was characterized by steep terrain and streams hence less use of micro-dams as water conservation strategy; these findings are in consistent with those of Ceballos-Silva and Lopez-Blanco, (2003). The lower zone had limited water conservation strategies. This was most probably because the zone was suitable for water catchment because most of the runoff from the upper zones concentrated at this zone probably forming gullies and streams hence need for gabions to conserve water at the lower zone. This observation agreed with the findings by Johansson and Svensson, (2002).

5.4 Conclusions

From the results obtained in this study it can be concluded that:

1. Smallholder farmers possess vast amounts of indigenous knowledge of their local environment and were aware of land degradation indicators which they observed during their daily land use cores and have local ways of recognizing and describing them.

2. Land degradation was prevented by use of practices such as application of organic manure, planting of trees, crop rotation, use of gabions and stone lines.

3. Different zones had different land use and management practices due to differences in terrain and other physical and biophysical characteristics.

5.5 Recommendations

From the results obtained in this study, it is recommended that;

1. Agricultural land use planning and management should be informed by smallholder farmer's knowledge of landscape structure and local micro-environments hence informed decision making.

2. There is need of designing policies aimed at rural livelihood diversification improvement.

3. There is need for more research in: Soil fertility and water availability in the three zones.

4. Further research is required on participatory degradation assessments and quantification and matching with agricultural production.

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APPENDICES: 1

Table 4.1: Selected household socio-economic characteristics, December 2014 (N=40)

Socio-Economic Variable	Zones (%)				
	Upper	Middle	Lower	Mean (%)	STDEV
Gender of household head					
Male	30	30	33	31	1.73
Female	3	3	3	0	0
Average age of household head					
Husband	18	18	18	18	0
Wife	15	15	18	16	1.73
Occupation					
Formal	23	23	15	20	4.62
Self employed	10	13	25	16	7.94
Household size					
1-3	0	0	3	1	1.73
4-6	28	23	13	21	7.64
7-9	5	10	15	10	5
10-12	0	5	3	3	2.52
Above 12	0	0	3	1	1.73
Land Size (acres)					
Below 3	23	10	23	19	7.51
4-6	10	20	10	13	5.77
7-9	0	8	0	3	4.62
10-12	0	0	0	0	0
Above 12	0	0	3	1	1.73
House roof type (households)					
Thatched	5	3	0	3	2.52
Iron sheets	28	33	35	32	3.61
House wall type					
Wooden	0	3	0	1	1.73
Bricks	25	28	28	27	1.73
Stone	8	5	13	9	4.04

APPENDICES: 2

Effects of Land Degradation on Agricultural Land Use: The Case of Smallholder Farmers Land Use Planning and Management in Kalama Division Machakos District

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

Informed Consent Form

A research is being undertaken to assess the effects of land degradation on agricultural land use by a student from South Eastern Kenya University. You have been identified as a key stakeholder in this research and therefore a respondent to a few questions. The information you provide will be treated with confidentiality and will be used for academic purposes only.

MODULE A: HOUSEHOLD IDENTIFICATION:

A1. Date of interview	Day:	Month:	Year:
A2. Name and gender of household head	Name:		Gender:
A3. Name of respondent/relation with h/head	Name:	Relation:	Gender:
A4. Village name			
A5. Questionnaire serial no.			

SECTION B: HOUSEHOLD GENERAL INFORMATION

B1. Age of Household Head Husband:__________Wife:_____________

B2. Level of education of household head

1. None ☐
2. Primary ☐
3. Secondary ☐
4. Post Secondary ☐
5. B3. Occupation of Household head____________________
   1. Formal i.e.

i. Teacher [ ]
ii. Administrator [ ]
iii. Police [ ]
iv. Driver [ ]
v. Accountant [ ]
vi. Preacher [ ]
vii. Others (specify)---
----

2. Self Employed [ ]

B4. Household size____________________

B5. Land size (acres) __________________

B6. House Roofing Type: 1. Thatched [ ] 2. Iron-sheets [ ] 3. Tiles [ ]

B7. House Wall Type: 1. Mud [ ] 2.Wooden [ ] 3.Brick [ ] 4. Stones [ ]

MODULE C: AGRICULTURAL LAND USE

C1. Which agricultural practices do you carry out on your farm?

1. Livestock keeping [ ]
2. Crop farming [ ]
3. Farm forestry [ ]
4. Poultry [ ]
5. Bee keeping [ ]
6. Others (Specify)---

C2. Rank the agricultural practices stated in C1 in order of their contribution to household income with 1 being the highest ranked practice.

1. Livestock keeping [ ]
2. Crop farming [ ]

3. Farm forestry ☐
4. Poultry ☐
5. Bee keeping ☐
6. Others (Specify) ☐

C3. For the agricultural land use stated in C2 above where do you practice in your farm?

SN	Type of land use	Name of Field (Shamba) Where done	Farmers reasons for choosing the Field (Shamba) for the type of use	Acreage	Type of Soil	Type of land slope etc	Water qualities (retention, logging)
1	Livestock						
2	Crop farming						
3	Farm forestry						
4	Poultry						
5	Bee keeping						
6	Housing						
7	Others (Specify)						

C4 (a) Which crops do you grow in the field indicated in C3 above as 'crop farming' in your farm currently?

SN	Type of Crop	Name of Field (Shamba) where grown	Farmers reasons for choosing the Field (Shamba) for the crop	Acreage	Type of Soil	Type of land slope etc	Water qualities (retention, logging)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

C4 (b) Which crops did you grow in the field indicated in C3 above as 'crop farming' in your farm last planting season?

SN	Type of Crop	Name of Field (Shamba) where grown	Farmers reasons for choosing the Field (Shamba) for the crop	Acreage	Type of Soil	Type of land slope etc	Water qualities (retention, logging)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

C5. Has the choice of field for crops changed for the last three years?

1. Yes ☐ 2. No ☐

C6. If yes why?

1. Poor crop performance
2. Land size
3. Land production
4. Climate change
5. Change of soil fertility
6. Others (specify)

C7. How have you solved the challenge in C6 above?

1. Crop rotation
2. Intercropping
3. Livestock culling and breeding
4. Changing enterprises
5. Changing of planning dates
6. Planting of highbred crop varieties
7. Others (specify)

MODULE D: LOCAL KNOWLEDGE, PERCEPTION OF LAND DEGRADATION, EVALUATION AND CLASSIFICATION

D1. Fill out the table below on awareness of land degradation

SN	Land degradation indicator (in Kikamba)	Describe the visual/physical attributes of the indicator	Perceived Causes
1	For example Kutwawa kwa muunda		
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

D2. For each of the land degradation indicator in D1 above, how do you control it?

SN	Land degradation indicator (in Kikamba)	Land management strategies and measures
1	For example Kutwawa kwa muunda	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

D3. Fill out the table below on types of local (Kikamba) soil terminology

SN	Local (Kikamba) soil terminology	Describe the visual/physical attributes of the soil	Preferred use of the soil
1	For example Muthanga wa ilimba		
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

MODULE E: LAND MANAGEMENT STRATEGIES

E1.	**Do you practice the following Integrated Soil Fertility Management (ISFM) Strategies?**	**Yes/No** 1. Yes 2. No	**Agent (source of information) within the village** 1. Neighbor 2. Relative 3. Market 4. Agri. Extension Officer 5. Formal training 6. Others (specify)---------------------
1	Terracing		
2	Fallowing		
3	Organic Fertilizer		
4	Inorganic or mineral fertilizer		
5	Rotation and inter cropping		
E2.	**Do you practice any other land management strategy in your farm?**		
A	List soil conservation strategies practiced (in Kikamba)		
1			
2			
3			
4			

5			
B	List water conservation strategies practiced (in Kikamba)		
1			
2			
3			
4			
5			

E3. What challenges do you face in management of your land for better productivity?

1. ____

2. ____

3. ____

4. ____

5. ____

E5. What are the possible solutions to the challenges faced?

1. ____

2. ____

3. ____

4. ____

5. ____

THANK YOU