TOPO-SEQUENCE ANALYSIS OF CLIMATE VARIABILITY AND LAND USE CHANGES AMONG SMALLHOLDER FARMERS IN MERU COUNTY, KENYA

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A Thesis Submitted in Fulfilment of the Requirements for Award of the Degree of Doctor of Philosophy in the School of Environment Studies of Kenyatta University

October 2014
DECLARATION

This thesis is my original work and has not been presented in any other university for any degree or any other award.

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DEDICATION

This work is dedicated to God Almighty, who is worthy all the glory and honour, to my understanding caring and loving wife mama Munene and in memory of my late parents.
Finally, the culmination of a journey that started with a single step and gradually developed into one mighty task! My joy and sense of fulfilment would not be complete without making mention of everyone who offered help and support, in one way or another, during the entire period of this PhD study. The brevity of this acknowledgement does not in any way downplay the support I have received from anyone mentioned, or not mentioned, herein. Firstly, I am sincerely grateful to Dr Fuchaka Waswa and Prof. Joy Obando through, their vast experience in this field of study. They offered invaluable and constructive advice, and guidance to make this PhD study come to fruition. I am thankful to Dr Samuel Muigai the National Coordinator Kenya Agricultural productivity and Agribusiness Project (KAPAP) for his mentorship and motivation and the Department of Resource Survey and Remote Sensing (DRSRS) for making available land cover data and other related information from their Library resources. Specifically, I acknowledge Mr. Vincent Imala. I also acknowledge all my friends and colleagues who assisted me in their various capacities. Dr. Kathurima Gichuru of coffee research foundation, Mr. Murithi Mutuma Agriculture Department University of Nairobi, Kenneth Munene of Meru University, Mr. Dickson Makuba the Meru County statistics officer, Mr Martin Muriuki Wanjohi of Geo-spatial Department University of Nairobi. More sincerely I acknowledge the services of my enumerators, Lydia Guido, Miecheck Kiara, Stella Muthee, Mr William Kibiti, Samuel Ngaire, Joshua, Obed Gitonga, Winfred Kimathi, Cornelius Miriti, William Bururia, Jeremy Thuo, Karani Jebi and Mr. Murage. Thanks to my nephew Peter Murithi and Kelvin Mutuma for your tireless effort in processing the household survey data. My colleagues at work Mr Edwin Mutegi and Rhoda Kirera for your cooperation and support. Many thanks to equity bank for a quick credit to clear the fee. I thank my entire family for always being there for me. Knowing that they always held me in their thoughts and prayers gave me strength to go on. Special thanks to my wife Irene for her help and patience, for every period I was away or burnt the midnight oil. Over and above all, I thank God who saw me through it all.
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DEFINITIONS OF KEY TERMS

Agro-ecological Zone: is a land resource mapping units in terms of climate, land form, soils and land cover and having a specific range of potentials and constraints for land use.

Assets: stocks of different types of capital that can be used directly or indirectly to generate livelihoods. They can give rise to a flow of output, possibly becoming depleted as a consequence, or may be accumulated as a surplus to be invested in future productive activities.

Climate variability: The way climate fluctuates yearly above or below a long-term average value or variations in the mean state of the climate and variations in other statistics (such as the occurrence of extremes) on all temporal and spatial scales beyond that of individual weather events.

Climate change: Is a long-term change in the state of the climate and which is identified by changes in the means and/or changes in the variability, or changes in the frequencies or intensities of extreme events.

Coping strategies: Often a short-term response to a specific shock, such as drought. Actions could include switching to cultivation of drought-resistant crops.

Coping capacity: Degree to which a system can successfully grapple with a stimulus (similar to adaptability, but includes more than adaptive means of “grappling”).

Land use: Human uses of the land, including actions that modify or convert land cover from one type to another.

Resilience: Degree to which a system rebounds, recoups, or recovers from an external perturbation

Response: Way in which a system reacts to stimuli (broader than cope and adapt because responses need not be “successful”)

Smallholder farm: the size of the farm within the study area that was less or equal to twelve hectares

Topo-sequences: Synonymous with a long the topography and hence based on agro-ecological zones.
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ABSTRACT

Land use change in Meru is increasingly being influenced by among other factors climatic variability, with consequent implications on community livelihoods. This study sought to assess the relationship between land use changes and climatic variability in this area with the ultimate aim of deriving lessons towards sustainable agricultural land management. A topo-sequence approach was used in order to capture specific effects across different agro-ecological zones. Rainfall data ranging from 1976 to 2009 for three stations, daily temperature and stream flow discharge served as hydro-climatic data. Geographic Information Systems generated land use data for the period 1976-2011. This information was triangulated with data from household surveys, key informants interviews, and focused group discussions. Other data were analysed using standard procedures. Future implications of land use changes were assessed by use of exploratory scenarios analysis. Findings indicated that the key evidence of climate variability was variations in rainfall, which influences planning for land productivity. In the low highland 1, coefficient of variability in rainfall amount for first season (i.e. March-May) was 0.43 and 0.26 for second season (i.e. October-January). For the upper midland 2 and in the transition zone with upper midland 3 the coefficient of variability for first season was 0.36 and 0.37 respectively. As such the first season was the main determinant of land use performance in both upper midland and low highland agro-ecological zones. Stream flow coefficient of variability ranged between 0.22 and 0.44 with months of February and September being more variable, while April and December were less variable. Therefore, proper management of water resources in the months of February and September is critical. There were variations in mean annual temperature with highland 1 and in upper midland 2. The observed increase in annual mean temperature trends in low highland 1 was linked to decreasing forest cover. That majority of the respondents (91.6%) concurred that there was climate variability is indicative of increasing awareness of this global threat and hence opportunity for spontaneous community participation in intervention measures. Observed land use changes could not however be linked to decadal rainfall trends, implying that other factors were at play in influencing land use trends. In six out of the seven sub-agroecological zones there were changes in land use types but no marked changes were detected in low midland 4 perhaps as a result low population density arising from absentee land lords, boundary disputes and poor infrastructure. While in low highland 1, upper midland 1, 2 and 3 and low midland 3, areas under agricultural use increased while that under forest decreased. In low midland 6 shrubs were replaced by rainfed crops ($r^2 = 0.98$) an indication that natural vegetation was being cleared for cultivation. Scenarios analysis suggests that agricultural land use would cover up to 86% by 2025, thus effectively replacing forested area and hence services there-from. Since there was some divergence in observed and perceived climate variability parameters, there is need to integrate farmers and scientific approaches in mitigation planning against effects of climate variability. Planning for effective land performance needs to be season based and agro-ecological zone specific. Emerging land uses which included tea and irrigated crops have had only short term gains. Continuing reduction in forest cover and stream volumes are likely to negatively impact community livelihoods in future. Strategic interventions that integrate policies, structures and process are needed for land use planning at the county and household levels to mitigate and adapt to climatic variability and its implications.
CHAPTER 1: INTRODUCTION

1.1 Background
According to the intergovernmental panel on climate change (IPCC) climate variability is occurring and manifested in the intra- and inter-seasonal events such as intense rainfall and prolonged dry spells (IPCC, 2007a). Climate variability is known to cause adverse effects such as droughts, floods and landslides. Agriculture remains one of the most climate sensitive sectors. Considering a “business as usual scenario”, agricultural productivity could generally decline by between 10 to 25 percent by 2080, with some countries experiencing a decrease estimated at 50 percent (IFAD, 2008). Further, the IPCC has warned that a higher frequency of intense extreme events across the world is possible as a result of the projected global warming. Although global warming through the 20th century was at the rate of about 0.05°C per decade, Hulme et al (2001) predicts that under intermediate warming scenarios, equatorial East Africa will likely experience 5-20% increased rainfall from December-February and 5-10% decreased rainfall from June-August by 2050. Changes of this magnitude will have far-reaching, effects on agriculture and overall economic development.

Variability of climatic factors influences agriculture by aggravating the frequency and distribution of adverse weather conditions, reducing water supplies hence limiting irrigation and exacerbating soil erosion (IPCC, 2001). In many areas of the world smallholder farmers have often developed farming systems adapted to the local conditions, enabling farmers to generate sustained farm production to meet their subsistence needs despite marginal land endowments, climatic variability and low use of external inputs (IFPRI, 2010).

Smallholder farmers in African countries are believed to be among those adversely affected by climate variability (IPCC, 2007b) and are assumed to have inadequate knowledge and resources regarding response mechanisms. Studies done on effects of climate variability on agriculture have relatively focused on the wider global scale ignoring both individual country and intra country levels (AIACC, 2007). Smallholder farming is complex making modelling or predicting climate impact on predominantly
subsistence farming households at international levels a cumbersome task (Morton, 2007). Little work has been done to explore what responses would be sustainable for African farmers (Mendelsohn et al., 2000). Further, the global prescriptions may have little or no relevance to the prevailing local and regional situation. Smallholder farming is critical for Kenya’s economic development and therefore key to pursue (IFAD, 2008). Smallholder farming is concentrated in the Central and parts of Eastern Kenya around the Mount Kenya region, and in central Rift valley. Most of the country’s natural and exotic forest vegetation and water catchments are found in these areas. Most of the tea, coffee, dairy, vegetables and fruits are grown here. The area constitutes approximately 9% of the country and ecologically the most important zone (Odingo, 1986).

In the Meru region of Kenya, excessive rains have had negative impacts, lives have been lost and a larger number of others rendered homeless due to landslides. In the same region, the lowlands have had prolonged droughts (Khisa, 2001; Takaoka, 2005 and Mbagathi et al., 2009). According to government reports, high human population growth has led to low per capita land sizes (Jaetzold et al., 2007) including the agricultural land. The study sought to understand land use trends and management implications in realization of smallholder farmers’ sustainable livelihoods.

1.2 Problem Statement and Justification
The staple food production for instance maize in LM3 of Meru County declined from 3320 kg/ha in first season and 3,378kg/ha in second season in 1978 to 695 and 887 kg/ha for first and second season respectively in 2004 (Jaetzold et al.,2007). Further, between 1995 and 2000, the indigenous forest in the lower Imenti forest reserve was illegally converted into cropland (Vanleeuwe et al., 2003). Predictions indicates a loss of approximately 240,000 hectares of gazetted forest land by 2030 in Kenya and may aggravate soil erosion or loss of soil fertility, alteration of local hydro-climatic conditions and changes in biodiversity (KEFRI, 2002). Kenya National Bureau of Statistics (KNBS) reports indicate that the number of rural poor people in Meru County increased by 16.5% from 1998 to 2008. Majority (88%) of the county residents are rural based and practice farming for their livelihood, unchecked negative changes in land use...
will undermine both county and national development agenda. Land use changes in Meru could be attributed to among other factors, climate variability. A vibrant agricultural sector is expected to contribute to the attainment of Kenya’s Vision 2030, particularly in terms of food security, agri-business development and environmental sustainability. Being a high potential zone, the role of Meru County in this regard cannot be overemphasized. Understanding how the quality of land and its uses is changing with the threat from climatic variability remains vital for land use planning and management, hence the focus of this study.

1.3 Research Hypotheses
i. There is a relationship between climate variability and changes in land use in Meru County
ii. There is a negative relationship between changing land uses and community livelihood in Meru County.

1.4 Objectives
The overall objective of this study was to assess the relationship between land use changes and climatic variability and their effects on smallholder livelihoods with the ultimate aim of deriving lessons towards sustainable agricultural land management. The specific objectives were:

i. To assess the perceived and observed evidence of climate variability.

ii. To determine the relationship between emerging land use changes and climate variability.

iii. To assess the effects of emerging land use changes on community livelihoods.

iv. To assess future scenarios in land use and livelihoods based on exploratory scenarios analysis.

1.5 Research Questions
This study was guided by the following key questions:

i. Which evidence exists to suggest that there is climate variability in Meru County?
ii. Are the observed trends in land use changes due to climate variability or other factors?

iii. How have land use changes affected household livelihoods across agro-ecological zones?

iv. Which lessons for the future can be derived from an exploratory scenarios analysis on the trends of land use changes in Meru County

1.6 Conceptual Framework

The sustainable livelihoods (SL) approach provides a basic framework for linking events like climate and land use change to specific effects on the household’s livelihoods at the local level. Households and communities have differential assets (Figure 1). The interaction between climate variability and land use changes influence the resilience levels of smallholder farmers. In the context of this work, climate variability variables would serve as independent variables, while land use change would be the dependent variable.

Figure 1: Sustainable Livelihood Framework (Modified from Ashley & Carney, 1999)
Substantial literature on livelihood approaches has been developed (Ashley & Carney, 1999; De Haan and Zoomers, 2005). Current scholars make use of the general concepts and frameworks in initial livelihood models a base in articulating arguments from previous work done by (Scoones, 1998; Sen, 1985). Ellis (2000) has been instrumental in deepening comprehension of relationship between assets, activities and outcomes within a mediating environment.

The most widely cited definition of livelihood in the development literature is that of Chambers and Conway (1992) ‘A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living’. Some modifications have been introduced by other scholars such as Scoones (1998) who views a livelihood as sustainable if it can cope with and recover from stresses and shocks, and maintain its abilities and assets both in present and in the future. Another contribution was on the issue of claims and access and the impact of social relations and institutions that mediate an individual or household ability to acquire a means of living (Ellis, 2000).

Livelihood research has helped explain the differences in responses using understanding of endowments, entitlements and capabilities within organizational hierarchy and power principles or by individuals or households at local level (Scoones, 1998). Morris et al (2000) indicated that livelihood models target the household as the most preferable social unit for the investigation of livelihoods; however, social interventions may be used as external measures to manage risks. Depending on the assets available to people, they engage in livelihood activities and employ strategies that best generate the desired livelihood outcomes.

The decision on what assets to utilize, when and how, constitutes a household’s livelihood strategy. Different scholars identify and articulate various types of strategies. Ellis (2000) classified them into natural resource-based strategies and non-natural resource based strategies (including remittances and other transfers). Scoones (1998) categorizes strategies into agricultural intensification and extensification; livelihood diversification that includes both paid employment and rural enterprises; and migration.
for income generation and remittances. Various livelihood activities are carried out in the different livelihood strategies.

Livelihood can therefore be defined as the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household. This modified sustainable livelihood framework illustrates how an individual, a household, or a community behaves under specific conditions.

This conceptual framework accentuates household as the basic unit of socio-economic analysis whose livelihood assets are subjected to climate variability and land use changes interactions. It focuses attention on asset for development of underlying resources and capacities needed to cope with climate variability and land use changes to escape poverty on a sustainable basis. It recognises the impact of changes on household vary with elevation of the location (topo-sequence). It depicts the critical mass of assets needed to cope with stresses and shocks, and to maintain and enhance capabilities now and in the future. It recognizes that everyone has assets on which to build and support individuals and families to acquire assets needed for long-term well-being. These assets are shaped by the structures and processes i.e. social, institutional and organisation settings as they create assets; determine access and influence rates of asset accumulation. This approach emphasizes on identifying and building capabilities, rather than just examining vulnerability. The focus on strengths, demonstrates clear synergies with a focus on building resilience to climatic variations and land use changes. Analysis of ownership of assets tends to focus on what farmers have and what they need.
CHAPTER 2: LITERATURE REVIEW

2.1 Global Discourse on Climate Variability

The state of knowledge about the Earth’s climate is informed by several studies which entail individuals, national, regional and global institutions including the intergovernmental panel on climate change (IPCC). These entities have indicated that the planet is warming; but have recommended continued research more so to quantify the timing, location and extent of climate variations (IPCC, 2001). On the contrary other organizations and individuals have disputed the conclusion that climate is changing (Lockwood, 2010; Douglass et al., 2007). What seem debatable are adequate explanations of climate change to warrant dead certainties. Projecting future conditions or quantifying cause and effect is difficult due to the earth’s complex climatic systems where observations are impacted by multiplicity of factors. However, use of climate observations and models arising from simulations affirms existence of natural and human induced climate variability which happens over seasons or years (DB group climate change advisors, 2010). The global circulation models provides a general trend that indicates climate is becoming more variable in the Africa continent without certainties in nature and extent of changes in precipitation, temperature and extreme events (Elasha et al., 2006). Some studies have suggested there might be hidden variations in the general modelled trends among African zones (Hulme et al., 2001). This discourse happens in the midst of tremendous multifaceted interventions at global, regional, national and local levels.

During the late nineteenth century anecdotal evidence of anthropogenic climate change and variability started to emerge. In the late 1950s there was insinuation of human influence on global climate when the Scripps institution of Oceanography began to measure the concentration of carbon dioxide in ice-cores. The findings of these studies revealed that global carbon dioxide concentrations were rising and linked the rise in concentration to an increase in global temperatures. Carbon dioxide had been known then to have a greenhouse or warming effect, which is the inherent ability to trap and retain infrared radiation (Keeling et al., 2005).
Increased global environmental concerns were experienced in 1960s and 70s that culminated into the release of the Brundtland Report (also commonly known as Our Common Future) in 1987. The report alluded to various global environmental concerns and more so those associated with increasing atmospheric concentrations of greenhouse gases (GHGs) climate change and variability was considered one of the undesirable consequences of man’s unsustainable development practices. Emanating from this, two UN bodies- the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) – jointly established the Intergovernmental Panel on Climate Change (IPCC) in 1989 to provide broad and balanced information about climate change and variability (UNEP, 2007). The IPCC does this by reviewing and assessing the most recent scientific, technical and socioeconomic information produced worldwide and translates this information into IPCC assessment reports. The UNFCCC recognizes that consequences occur at all levels (local, regional and global) and have the potential to disrupt the earth’s ecological systems with serious negative impacts on agricultural production, forests, water supply, health systems and overall human development. In Article 2 UNFCCC has called on the world’s governments to take action aimed at reducing and stabilizing concentrations of GHGs in the atmosphere at a level that would avoid dangerous anthropogenic interference with the climate system (UNEP, 2007).

Increased temperatures are projected to cause more frequent and more intense extreme weather events, such as heavy rain, storms, flooding, fires, hurricanes, tropical storms and El Niño events (IPCC, 2001). Extreme rainfall and subsequent heavy flooding damage will also have serious effects on agriculture including the erosion of topsoil, inundation of previously arid soils, and leaching nutrients from the soil. Warming of land and sea surface temperatures are projected to cause more frequent and intense hurricanes and tropical storms that inundate coastal areas (IPCC, 2001). These same extreme weather events can lead to decreased precipitation in interior regions, causing increased drought and desertification, subsequently threatening food security. Threats to food security can then lead to widespread migration of human settlements in order to seek better agricultural land, more available water resources, and escape increased exposure to diseases. The impacts of climate change also have the potential to disrupt
and potentially reverse progress made in improving the socio-economic well-being of the people (IPCC, 2001).

Recent research also suggests that sea surface temperatures are warming, especially in the southwest Indian Ocean. In addition to inter-annual climate variability (i.e., El Niño/Southern Oscillation (ENSO)) may play a key role in Kenyan rainfall patterns and may be linked to the change in rainfall across some parts of equatorial-subtropical. Warm sea surface temperatures are thought to be responsible for the recent droughts in equatorial Kenya during the 1980s to the 2000s (Funk et al., 2005). The number of food crises per year has tripled from the 1980s to 2000s (FAO, 2004). Frequent droughts led to diminished water supplies, reduced crop productivity resulting to widespread famine in the region. In the tea-producing areas of Kenya, the world’s second largest exporter of tea, a small temperature increase (1.2 °c from now) and changes in precipitation would render large areas of land that are supporting tea cultivation to be unusable. Economically, this would have far-reaching impacts because tea exports account for roughly 25% of Kenya’s export earnings and employs over three million Kenyans (10% of the population) (Simms, 2005).

It is projected that there will be variations of frequency, intensity, and predictability of precipitation (IPCC, 2007a). A change in precipitation ultimately affects soil moisture and consequently vegetation. Projections suggest that East Africa region will experience warmer temperatures and a 5-20% increased rainfall from December-February and 5-10% decreased rainfall from June-August by 2050 (Hulme et al., 2001; IPCC, 2001). These changes are expected not to be uniform throughout the year but sporadic and unpredictable. It may also, be likely that the increased precipitation will come in a few very large rainstorms mostly during the already wet season thereby causing mud slides, floods and soil erosion. It is also expected that there will be less precipitation during the already dry season, which may cause more frequent and severe droughts and increased desertification in the region (Hulme et al., 2001).

Smallholder farming depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to rainfall variability (IPCC, 2001). For example, from 1996 to 2003, there has been a decline in rainfall between the range of 50-150 mm
per season (March to May) and corresponding decline in long-cycle crops (e.g., slowly maturing varieties of sorghum and maize) across most of eastern Africa (Funk et al., 2005). Long-cycle crops depend upon rain during the typically wet season and progressive moisture deficit would result in low crop yields, thereby affecting the available food supply. Increased variability (i.e., deviation from the mean) is a major concern of smallholder crop producers in the region. Inter-annual climate variability (e.g. El Niño/Southern Oscillation (ENSO) has huge impacts on the region’s climate. Warm El Niño/Southern Oscillation (ENSO) events also referred to as El Niño events produce abnormally high amounts of precipitation resulting in flooding and decreased agricultural yields. There has been a correlation between past El Niño events and warm sea surface temperatures with more than 60% of the change between above and below average agricultural production of maize (Case, 2006).

In sub-Saharan Africa, several ecosystems are shown to be highly sensitive to short-term availability of water due to climate variability (Vanacker et al., 2005). This is because water resources on the planet are an integral part of the global hydrologic cycle. Precipitation originates from land and the oceans through evaporation. Soil moisture is used by plants, which return more moisture to the atmosphere. Water that does not evaporate or transpire or seep into aquifers runs off to form the nation’s streams and rivers. Snow stored on the mountains provides water for rivers. Storms bring extra moisture; droughts arise from protracted periods of low rainfall, all as part of our natural climate.

Dry tropical plants suffer severe water stress at the beginning of the growing season and that a warmer climate may accelerate the depletion of deep-soil water that tree species depend on for survival. Growth in these species also depends highly upon the timing, intensity and duration of rainfall. Climate projections suggest that during already dry months, less precipitation will occur likely reducing the resilience of these plants (Vanacker et al., 2005). Cumulative effects of climate variability may also affect species range, which could have profound impacts on species population size. Species ranges will probably not shift in cohesive and intact units, but are likely to become more fragmented as they shift in response to changing climate (Channel and Lomolino,
Species and agro ecosystems are likely to change under varying climate scenarios (Erasmus et al., 2002). Change of biodiversity will influence both crops and livestock production (mixed farming) which accounts for the bulk of smallholder farming systems. Climatic conditions significantly influence changes in biodiversity and agro diversity as species struggle to adapt to changing conditions (Lovett et al., 2005). Species that have the capability to keep up with climate shifts may survive; others that cannot respond will likely suffer (Hély et al., 2006).

The projected rapid rise in temperature combined with other stresses, such as the destruction of habitats from land use change, could easily disrupt the connectedness among species, transforming existing communities, and showing variable movements of species through ecosystems, which could lead to numerous localized extinctions (Malcolm et al., 2002). If some plant species are not able to respond to the changes, the result could be increased vulnerability of ecosystems to natural and anthropogenic disturbance, resulting in reduced species diversity (Malcolm et al., 2002). Seasonal changes in vegetation have the potential to alter migratory routes of some species like herbivores, which may also increase conflicts with humans impacting on livelihoods (Thirgood et al., 2004). Large changes in ecosystem composition and function would have cascading effects on species diversity (Sykes and Prentice, 1996). Vast forest disappearance has substantially affected species composition and global geochemical cycling; particularly the carbon cycle (Malcolm et al., 2002).

Researchers have in the past decades recognized linkages between LULC changes, processes and broader changes in global environment. Human disturbance through land use and land cover change has substantially altered the world’s natural ecosystems, resulting in landscapes widely dominated by cultivation, grazing, pasture or urban development (Lambin et al., 2003). The greatest interest in land use and land cover results from their direct relationship to many of the earth’s fundamental characteristics and processes, such as land productivity and biodiversity among others. Systematic analysis of local scale land use change over a range of time scales helps to uncover general principles to provide an explanation and prediction of new land use changes (Lambin et al., 2003).
Environmental changes such as climate extremes cause natural disasters which repeatedly wipe out the gains from development, destroying lives and livelihoods. The most vulnerable households are those with assets and livelihoods exposed and sensitive to climate (temperature and precipitation) and who have weak risk management capacity. The adverse effects of climate variability and change are borne disproportionately by the small farmers and this depends on how equipped they are to withstand the climate shocks (Altieri & Koohafkan, 2008).

2.2 International Responses to Climate Variability

International efforts to combat climate variability and change in the recent past focused more on mitigation aimed at reducing GHG emissions. The formation of UNFCCC and IPCC in collaboration with other global, regional and national bodies have played a key role in propelling international agenda associated with responses to climate variability (UNEP, 2007). On mitigation UNFCCC did not set binding GHG emission reduction targets, but instead ‘encouraged’ parties endeavours to take measures to reduce their GHG emissions according to their capabilities. This was a major weakness of UNFCCC which prompted the third Conference of the Parties (COP3) to the UNFCCC 184 parties gathered in Kyoto, Japan to adopt the Kyoto Protocol, which would commit them to reduce GHG emissions in 1997. The protocol commits 37 industrialized countries to reduce their emissions by 5.2% below 1990 levels during the first commitment period, which was 2008 to 2012 (GOK, 2010a).

The Kyoto protocol globally initiated a low-carbon growth path. The protocol has led to development of carbon market, an international market regime of three 'strategies' geared towards sustainable development through tackling of climate problems in cost effective approach. Two of these strategies - the Clean Development Mechanism (CDM) and the Joint Implementation (JI) – are project-based. The CDM and JI were created under Articles 12 and 6 of the protocol, respectively. They are designed to help reduce GHG emissions through project activities involving renewable energy, energy efficiency, reforestation/afforestation, low-emission public transportation. The CDM is relevant to developing countries that have undertaken to tackle climate change, but are
not obliged to take on legally binding GHG emission reduction targets (UNEP, 2007). Other key highlights since the adoption of the Kyoto Protocol is inclusion of the European Union’s Emissions Trading System (EU ETS) that commenced in January 2005 and is the world’s largest emissions trading scheme with 30 nations covering nearly 400 million people in the world’s most industrialized region. Currently 27 EU member States and three non-EU member states (Iceland, Norway and Liechtenstein) engage in the trading-scheme (UNEP, 2007). The 32 states in the USA and eight provinces in Canada began developing ambitious climate change programmes primarily focusing on targets permitting “entities” (usually companies), since 2006 to trade emission reductions with one another to achieve overall GHG emissions reductions (UNEP, 2007).

Opportunities exist in global policies on finance and technology to transform the challenges into development to leap-frog the carbon-intensive phase of development and move directly to cleaner and more advanced land-use solutions (GOK, 2010a). The developing countries are in the process of building its infrastructure and have therefore the opportunity of inculcating a development paradigm on a low carbon pathway with a view to investing in sustainable infrastructure. This is the ‘development first’ approach that offers the organizing principle to pursue development strategies with ancillary climate benefits and enhance capabilities of countries to implement climate resilient strategies (ACPC, 2011). Green economy offers opportunities for mobilizing resources towards a low emission, climate–resilient development pathway. As such, emphasizes on Policies and investments aimed at sustaining and enhancing livelihood assets.

The subsequent stages of international efforts are targeting adaptation, that is, ways of coping with climate impacts that cannot be avoided. The term “adaptation” is used broadly, but in some instances it requires refinement. Depending on the frequency, duration, and suddenness in the onset of a stress, and on the resilience of a system, either coping or adaptive responses or both are employed (IASC, 2010). In their discussion on the term “adaptive” Berkes and Jolly (2001) apply terminology long used in anthropology. McCay (1997) used the development literature to distinguish between coping mechanisms and adaptive strategies. Coping responses are more of short-term
responses to potential impacts that can be successfully applied season-to-season or year-to-year as needed to protect a resource or livelihood. Some forms of coping are explicitly anticipatory and take the form of, for example, insurance schemes and emergency preparedness. Deliberate adaptation responses refer to the ways individuals, households, and communities change their productive activities and modify their rules and institutions to minimize risk to their resources and livelihoods (IASC, 2010). Adaptation depends greatly on the adaptive capacity or adaptability of an affected system, region, or community to cope with the impacts and risks of climate change. The adaptive capacity of communities is determined by their socioeconomic characteristics. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Smit and Pilifosova, 2001).

Four scales of responses to impacts of climate variability have been distinguished as mega, macro, meso and micro with the mega and macro scale being formulated and mainly facilitated at global and national level respectively (Ahmed et al., 1999). There have been plans to support adaptation in both developed and developing nations. Currently, two funds have been created under the UNFCCC to enhance adaptation. The least Developed Countries fund (LDCF) created under Article 4.9 of the UNFCCC supports the preparation of National Adaptation Programmes of Action (NAPAS) in countries classified as LDCs by the United Nations Development Programme (UNDP). The NAPAS help LDCs identify priority activities that respond to their urgent and immediate needs to adapt to climate change, where further delay would increase future vulnerability and or costs (GOK, 2010a).

Implementation of priority actions identified in NAPAS begun in selected LDCs, with about 26 projects having been approved for funding. The Special Climate Change Fund (SCCF) is the other UNFCCC fund through which adaptation programmes and projects are financed. This fund was established in 2001 under decision 7 of COP& (Decision 9/CP.7) to finance projects relating to adaptation, technology transfer and capacity building, energy, transport, industry, agriculture, forestry, waste management, and
economic diversification. The fund is not dedicated to adaptation activities, although adaptation remains the key priority (UNEP, 2007). The only fund strictly dedicated to adaptation is the Adaptation Fund (AF). This fund was established under Article 12.8 of the Kyoto Protocol and Decision 10/CP.7) to ‘finance concentrate adaptation projects and programmes in developing country parties that are parties to the Kyoto protocol, as well as activities identified in paragraph 8 of decision 5/CP.7. ‘ such activities include water resources management, land management, agriculture, health, unflustered development, fragile ecosystems including mountainous ecosystems and integrated coastal zone management. The AF revenue is to be delivered from voluntary contributions and an international levy of two percent of Certified Emission Reductions (CERs) from CDM projects, which is known as the ‘share of proceeds’. In general, the three funds (LCDF, SCCF and AF) are said to be inadequate to fund the massive adaptation needs of developing countries, many of which are already being ravaged by climate variability and change, at present; the funds mainly constitute pledges by donor countries and agencies. As history shows pledges do not always lead to actual delivery and implementation of the funds. Again, even with the pledges included, the funds still fall short of the US$ 100 billion per annum which developed countries have pledged to mobilize under Copenhagen accord to help address climate needs of developing countries by 2020 (GOK, 2010a). In any case, even this proposed figure is considered by many as a gross underestimate because it is based on scenario where the global temperature increase would be limited to 2°C, whilst some climate models show that current emissions pathway leads us to a much warmer world 30°C and upward) and consequently higher costs (Parry et al., 2009).

At the Meso scale, vulnerability vary from one community to another, depending on the capacity and physiographic characteristics at this level, location specific adaptation and coping options are employed depending on the community asset portfolio (Ahmed et al., 1999). At micro-scale, family units and individuals would experience vulnerabilities irrespective of origin of the process and employ adaptations or coping strategies within their particular economic and socio-cultural constraints (Smit and Pilifosova, 2001; Ahmed et al., 1999). The smallholder strategies are shaped by control and access of human, natural, productive, financial and social capital (Valdivia and
Gilles, 2001). Strategies in adapting and coping to events can be classified into ex-ante strategies like diversification of activities, products and resources to smooth income and consumption through times of variability and ex-post strategies to cope with stress and shock, which may include liquidating different types of assets, borrowing, migrating temporarily or relying on remittances (Murdoch, 1995).

Responses have been implicitly and explicitly linked with development-focused action, particularly the IPCC have underscored that developing countries are disproportionately vulnerable to climate change and lack adaptive capacity (IPCC, 2007a & b). Enhancing the capacity to respond to effects of climate variability and change is fundamental to equity and sustainable development (Smit and Pilifosova, 2001).

2.3 Overview of National Responses to climate variability

Since the ratification of the United Nations Framework Convention on Climate Change (UNFCCC), various international research programs have been initiated to build the capacity of developing countries to cope with the effects of climate variability. On the climate science side IPCC reviews and coordinates research on a range of climate change related issues and records climate data in its data distribution centres’ (UNEP, 2007). Lack of the necessary tools, both human and instruments makes Kenya to a large extent depend on organizations based in Europe and North America for climate forecasting capacity. Three organizations—the NOAA (National Oceanic and Atmospheric Administration, USA), UK Met Office/Hadley Centre (UK) and the CNRS (Centre National de la Recherche Scientifique, France) make seasonal climate forecasts for African region based on their respective GCM models. Among these three institutions, the most widely consulted is the Hadley Centre, and specifically their dynamically downscaled PRECIS model. The ICPAC established as the Drought Monitoring Centre in Nairobi (DMCN) in an effort to minimize the negative impacts of extreme climate events like droughts and floods along the Greater Horn of Africa has recently started to work on generating climate change projection data, mainly through the use of the PRECIS dynamical downscaling model (GOK, 2010a). The major goal of the ICPAC is to improve and enhance the production and provision of sector-relevant climate information and applications in the region, focusing on decadal, monthly and
seasonal forecasts. The ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), with regional hubs in Niger and Kenya, has used regional IPCC data to explore the impact of a 3°C warming on a variety of crops. Some of these IPCC data are obtained from the download options (Ziervogel and Zermoglio, 2009).

There are a number of on-going regional projects in Kenya including climate adaptation in Africa (CCAA) that targets capacity building, research and empowerment of vulnerable groups to adapt to climate variability and change. The Adaptation programme (AP) which aims to strengthen Kenya overall adaptation capacity and Kenya adaptation to climate change in Arid and Semi-arid lands (KACCAL) which focuses to facilitation of main stakeholders for long term adaptation in ASALS (GOK, 2010a). It is estimated that the annual cost of addressing climate change and variability could increase from estimated US$500 million to between US$ 1-2 billion by the year 2030 (SEI, 2009). This calls for immediate action at all levels to fast track all measures geared towards combating effects of climate variability in Kenya. However, the nation has not been vigilant in pursuant of the funding opportunities provided. For instant articles 4-7 of the UNFCCC present opportunities for Kenya to access funding. For research, mitigation, adaptation technology development, transfer and diffusion, capacity building, maintaining GHG emission inventory, education and awareness creation through the global environmental facility (GEF) while, article 12 of the Kyoto Protocol provides an avenue for funding through Clean Development mechanism (CDM) only three CDM project have been registered in Kenya namely lake Turkana 3310mw wind power project and Ol karia II Geothermal Expansion project and Ol karia III phase II Geothermal Expansion project (GOK, 2010a).

Development plans are anchored on the Kenya nation vision 2030. The vision recognizes that the main sectors of the economy are climate dependent but fails to articulately incorporate aspects of climate variability in the set goals under the social, economic and political pillar. Climate variability and change is missing in the national environmental management and coordination act of 1999 (EMCA). Integrating climate into national policy and governance is imperative for mainstreaming response mechanisms in the national development agenda (GOK, 2011). Currently, there are no
specific policy instruments dealing with climate variability and change. It was in 2010 the ministry of environment and mineral resources developed a National Climate Change Strategy (NCCS). The strategy proposes activities needed to combat climate variability and change as the country meets its development goals while fulfilling global obligations. However, strategies require to be connected with policy and legal platform for effective institutionalization of the envisaged activities. Kenya stands to gain from such a policy because it would promote investment geared towards mitigation and adaptation to the effects of climate variability and change. The national climate policy would also provide a framework for stakeholders’ participation and a precursor for integrated sustainable development concepts in all stages of projects cycle managements that would perpetuate into improved wellbeing. A further interrogation of interventions proposed in NCCS in view of sustainable development and livelihoods is necessary (GOK, 2011).

There has been little or no coordination on climate variability and changes matters in Kenya. However, there are numerous institutions addressing issues of climate variability and change although usually depends on their interest and mandate. These institutions range from community based organizations, local non-governmental organizations and government agencies to international organization. The main development partners have come together and formed a donor climate change coordination group which includes DANIDA, USAID, WORLD BANK, JICA, SIDA, GIZ and FANNIDA. They aim to support activities at various both national and sub-national levels (GOK, 2010a).

There have been regional initiatives geared towards resource mobilization, capacity building, technology transfer mitigation and adaptation. For instance the EAC has a policy and a master plan providing partner states with guidelines for preparation and implementation of collective responses. AU assembly of heads of state and government, held in Libya in 2009, approved the conference of African Heads of state and government on climate change (CAHOSCC) with an aim of taking a united position in global climate change issues. COMESA also has a fund that supports low carbon projects and carbon sequestration initiative (GOK, 2010a).
2.4 Climatic Variability and Sustainable Land Management

Land provides not only an environment for agriculture production but is also an essential condition for improved environmental management including source/sink functions for greenhouse gases, recycling of nutrients, amelioration and filtering of pollutants and transmission and purification of water as part of the hydrologic cycle (Terr Africa, 2009). Human activities are compromising natural processes and this dynamic is being further amplified by increasing climate variability. Crop and livestock yields in sub-Saharan Africa are already the lowest in the world, placing a 0.5 percent to 9 percent drag on agricultural gross domestic product, while deforestation proceeds at the highest rate in the world. As pointed out by the IPCC, such conditions make Africa one of the world most vulnerable areas to the adverse impacts of climate change (Terr Africa, 2009). Land quality varies with the impacts of human interventions on the landscape. It is acknowledged that interest in land quality is higher now than at any time in the past, due to the need to increase food production and its importance to ecosystem functions and global life support systems (Stott et al., 2001). Concurrently, there are increasing opportunities to mobilize monitoring and evaluation activities under international conventions particularly the convention to combat desertification, convention on biodiversity and framework convention on climate change. Although these conventions do not always provide extra funding, it provides a useful instrument under which to better coordinate activities (Stott et al., 2001).

The objective of sustainable land management (SLM) is to harmonize the complementary goals of providing environmental, economical and social opportunities for the benefit of present and future generations, while maintaining and enhancing the quality of the land (soil, water and air) resource. SLM is the use of land to meeting changing human needs (agriculture, forestry, conservation) while ensuring the long-term socioeconomic and ecological functions of the land. It is also a necessary building block for sustainable agriculture development and it is a key element in Agenda 21’s goal of sustainable development (Stott et al., 2001). It combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns so as to simultaneously; maintain and enhance soil capacity to buffer against degradation process (stability/resilience), reduce the level of production risk, be
economically viable (viability), socially acceptable and assure access to the benefits from improved land management (acceptability/equity) (World Bank, 2006). Sustainable land management is an off-shoot of the broad discourse of sustainable agriculture, a complex concept with different meaning from different people. However, it comprises of integrating land, water, biodiversity and environmental management to meet the rising food and fibre demands while sustaining ecosystem services and livelihoods (Stott et al., 2001).

It combines technologies, policies and activities that are aimed at integrating socioeconomic principles with some environmental concerns. Experiences gained from developing and developed countries have identified principles for sustainable land management. At global level the concerns entails a call for a collective effort for those directly responsible for resource management. This requires a policy environment that empowers farmers and other decision makers to reap benefits for good land-use decisions and also to be held responsible for inappropriate land issues (Stott et al., 2001).

The other global concerns is integration of economic and environmental interests in a comprehensive manner and the need to resolve the global challenges to feed the rising populations, while at the same time preserving the biological production potential resilience and environmental maintenance systems of the land. Sustainable Agricultural implies more ecologically balanced land management can achieve both economic and environmental benefits and this must be the foundation, or linchpin, for faster rural intervention (investment). Without good land management other investment in the rural sector are likely to be disappointing (World Bank, 2006). At the same time asking for the continued maintenance of agriculture without reference to environmental sustainability is increasingly difficult. Agricultural intensification is often necessary to achieve more sustainable systems. This requires shifts to higher value productivity or higher yields with more inputs per unit of production and higher (more knowledge – intensive) standards of management. However, sustainable agriculture has to work within the bounds of nature not against them. Many yield improvements can be
achieved by optimizing efficiency of external inputs rather than trying to maximize yields (World Bank, 2006).

It is widely recognized agriculture and environmental management are inseparably linked and that tackling problems of natural resource degradation must be seen as part of a wider set of actions to revitalize the rural sector as a whole. Promoting rural development strategy that has “win-win” outcomes for agricultural and environmental related livelihoods has been mainstreamed since it is a vital policy for provision of future productivity growth and poverty alleviation (Terr Africa, 2009). Sustainable land management has been established as the heart of such strategies. The concepts and criteria of sustainable land management employs agro ecological principles of farming, participating and decentralized approach that values natural and social capital enhancements in addition to gains accrued from economic efficiency. It also underscores the role of strong and self reliant rural institutions (Terr Africa, 2009).

The term ‘sustainable adaptation’ has emerged with the realization that while adaptation to climate variability and change will be increasingly required over the next decades, we know little about the wider or longer term impacts and implications of adaptation itself. This is because we are not certain whether responses to climate variability are sustainable either socially or environmentally, nor how they are likely to contribute to human well-being and poverty alleviation in future. Previous studies have highlighted how climate change represents both a threat and an opportunity for sustainable development (Yohe et al., 2007). There is emerging evidence that many of our responses run counter to principles of sustainable development. This suggests that adaptation policies and interventions that focus on reducing specific climate sensitivities such as predicted changes in precipitation or hydrological regimes can, even if benefiting some interests can create social inequity, as well as unintentionally undermine environmental integrity. Eriksen and Brown (2011) highlighted the importance of ensuring that adaptation is socially and environmentally sustainable, contributing to poverty reduction as well as confronting the socio-environmental processes driving vulnerability hence sustainable adaptation.
The primary agents of change towards sustainable agricultural systems are the rural communities who depend on the land for their livelihoods and the emphasis is on community-based or farmer-centred interventions (Stott *et al.*, 2001). Smallholder subsistence farmers are important custodians of the environment, who require the tools and knowledge to manage their natural resources and agro-ecosystems in the face of climate variability. They need support to enable them cope or adapt management practices and venture into new approaches to based resilience to increasing climate variability and change, using sustainable land management practices which can protect or restore ecosystem services, increase yields and reduce climate risks (Stott *et al.*, 2001).

Constraints exist on assessing impacts of SLM. For instance lack of comprehensive quantitative data on the precise beneficial impacts of practices in the range of soils and agro-ecological zones of the region (Terr Africa, 2009). Also it is not possible to state quantitatively with reasonable certainty the impacts of applying a particular practice, although these will, in almost all cases, be beneficial. There are also complexities relating to the impacts of SLM practices for mitigation. Some can act on mainly one GHG while others on more than one GHG. In the latter case, there may be positive impacts on more than one GHG, or there may be trade-offs between gases (Terr Africa, 2009).

The absence of quantitative data should not be used as a reason to delay initiatives to promote the scaling-up of implementation of the SLM practices. However, as opportunities become available especially from those activities related to climate variability or change responses, it will be vital to develop monitoring systems and have scientifically robust quantitative data on the benefits of SLM in different agro-ecological zones and soil types. Such information will also be useful to optimize restoration of degraded Soils (Terr Africa, 2009).
2.5 Summary of Research Gaps

Critical research areas on themes relating to impacts and responses of climate variability and change and livelihoods have been identified in dryland ecosystems (Mwang’ombe et al., 2006). However, due to agro-ecological diversity some sections of the midlands and highlands may be even more vulnerable to climate change and variability than the dry lands impressing the need for intensifying climate variability research in all agro-ecological zones.

Rainfall projections models and scenarios in Kenya are inconsistent (Herrero et al., 2010; Funk et al., 2008). Knowledge of climatic impacts in different locations and the potential responses to cope with them is still rudimentary (IFAD, 2008). Further, responses, whether focused on policy or practice, rarely integrate climate science to the necessary extent in a way that is clear and understandable for policymakers, hence, the need for locally generated knowledge.

The National Research council in United States identified land-use dynamics as one of the global challenges for environmental research (NRC, 2001). The international research community has been charged to contribute towards reducing the novel challenges as such undertaking scientific studies on land-use patterns and solutions that would lead to realizing the envisioned transformation of increasing carbon sinks in good time (Richardson et al., 2009). Further, the role of land-use and land-cover change was suggested for further research by IPCC aimed at enhancing understanding of its interaction with climate dynamics (Boko et al., 2007). Kenyans economy is anchored on smallholder farming whose systems depend on land productivity. The declining agricultural yields pose concerns that call for integrated approach in investigating land use, climate and livelihood dynamics.

The rural community-based or farmer-centred interventions depend on the land for their livelihoods. Studies conducted in 2004 revealed declining production per unit area of land was linked to loss of soil nutrients Jaetzold et al (2007) resulting from land use practices. Using up to date knowledge generated from data gathered from land use practices one can protect or restore ecosystem services, increase yields and reduce climate risks which impacts on farmers’ livelihoods (Stott et al., 2001). However, there
has been no analysis on emerging land use livelihood relationship in Meru County. Therefore, the need for empirical data on the current land dependent livelihoods more so smallholder farmers who constitute the bulk of the population is critical especially in the current governance epoch for elaborate prescriptions of county development interventions.

Land use and cover change as a key driver of climate change has too elicited interest leading to several studies on predicting future land use and cover changes (Alcano et al., 2003). The need to develop future scenarios is for the purpose instituting measures to counter negative impacts (Waswa et al., 2007). Knowledge generated in this study signifies negative or positive impacts of land use changes on the community livelihoods. This forms the basis for predicting future land use scenarios. The need for future imaging is in tandem with national vision 2030 in reference to devolved units (Meru County). This information is vital in anticipation of unfolding crises, envisioned alternative futures or provision of appropriate choices.
CHAPTER 3: METHODOLOGY

3.1 Study Area Characteristic
Meru County shares borders with Laikipia County to the west, Nyeri County to the south west, Tharaka-Nithi County to the east and Isiolo County to the north. It lies within latitudes 0°3’45” N and about 0° 2’30” S, and longitude 37° and 38° E (Figure 2).

Figure 2: Location of the study area

Meru County lies in the eastern slopes of Mt Kenya. It has a wide range of altitude which varies between 500M to 5,199M above sea level from the lowest point in the
county to the peak of Mt. Kenya. The county has a total area of approximately 6,936.2 KM² while forest cover is 1,776.1 KM². Meru County had a population of 1,356,301 people during the 2009 population and housing census. This is projected to be 1,474,916 people by the year 2017 (GOK, 2010b). The drainage pattern in the county is characterized by rivers and streams originating from catchment areas such as Mt. Kenya and Nyambene ranges in the North. The rivers cut through the hilly terrain on the upper zones to the lower zones and drain into the Indian Ocean via Tana River and Uaso Nyiro River.

It comprises of twenty sub-AEZs. This study was carried out in the seven of the twenty. The study targeted the four sub-counties of Meru County namely Imenti South, Meru Central, Imenti North and Buuri, but for the purpose of future land use projections the whole county was considered. The rationale for the selection of the study area was due to her wide range of agro ecological zones a typical representation of highlands, midlands and lowlands where both mixed farming and agro-pastoralism were practised. About 60% of this area has high to medium agricultural potential with cash crop and livestock farming as main source of livelihood. However, of late there has been increased frequency of climate shocks leading to loss in productivity. The other 40% are the lowlands which are the major food production areas. The County straddles the equator.

The altitude, annual average temperature and rainfall range, predominant enterprises and the percentage area of the zone to the total target area (the four sub-counties) characterized the sub-agroecological zones (Jaetzold et al., 2007). This study concentrated on LH₁, UM₁, UM₂, UM₃, LM₃, LM₄ and LM₆ depicted by different colours ranging from the highest to the lowest sub-agroecological zone (Figure 3).
### Figure 3: Sequence and characterized Sub-Agro-ecological zones of this study

### 3.2 Research Design

A survey design with a mixed method orientation was employed for this study to broaden understanding by incorporating both qualitative and quantitative methods. Existing data derived from remote sensing and aerial surveys, hydro-climatic data also
PRA tools such as FGD and transect walk were applied. An approach was employed to better understand or build on the results from other approaches.

3.3 Target Population
The study targeted smallholder farmers in the seven major sub-agro ecological zones of Meru, Kenya. These zones were LH₁ (tea & dairy zone), UM₁ (Tea/coffee zone), UM₂ (Main coffee zone), UM₃ (Marginal coffee zone), LM₁ (Cotton zone), LM₄ (Marginal cotton zone) and LM₆ (Millet-livestock zone). This area is inhabited by the Imenti ethnic group who basically thrive on mixed farming with a wide scope of crops. Imenti constitute the largest sub tribe of Meru community with an estimated population of 0.5 million (GOK, 2010b). These people primarily depend on land. However, there has been a tendency to switch to different land uses unlike in the north and southern parts.

3.4. Sample Size and Sampling Procedure
A total of 280 households comprising of forty households from each of the sub-AEZ were sampled for the survey. A sample size of 10% for large populations and 20% for small is adequate (Gay, 1987). In addition, larger sample size is believed to generate more reliable data. Further, considering other factors such as accuracy, cost, possible absentees, type of sampling and the kind of study a sample size ranging between 30% and 60% per unit (Sub-AEZ) was deemed appropriate (Table1). For each minor subgroup in the sample 20 to 50 elements is adequate (Israel, 1992). Smallholder farmers in Meru were the major sample while each of the 7 sub-AEZ was the sub group. Therefore, a sample size of 40 household heads or representatives was used per every sub-AEZ. Consequently the total number of respondents in the household survey was (40 Respondentsx7 Sub-AEZ=280 as Total sample).

Stratified random sampling was employed in this survey. The sample of smallholder farmers in Meru was stratified according to sub-AEZ. Using a list of administrative units’ as sampling frame one village per sub-AEZ was randomly selected as the target area. Selection of respondents and sites was handled on case by case basis, since the study deployed both qualitative and quantitative methods for data collection. Whereby, for the FGD each group consisted of 8-12 participants purposefully sampled within the
socio-economic groups of interest. This was done with the assistance of village elder
and frontline extension worker. Targeting of the most vulnerable/poor, the rich and Key
informants FDGs for elderly and experienced was done through homogeneous
sampling. The selection of 2 innovative farmers and 2 most vulnerable farmers in the
three main study AEZs (LH, UM & LM) as participants In-depth interview was done
during FGD.

Table 1: Sample size

<table>
<thead>
<tr>
<th>Sub-AEZ</th>
<th>Village</th>
<th>No. of HH</th>
<th>Sample size</th>
<th>Respondents</th>
<th>% of target pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH1</td>
<td>Nkuriga</td>
<td>99</td>
<td>40</td>
<td>39</td>
<td>39.4</td>
</tr>
<tr>
<td>UM1</td>
<td>Giumpu</td>
<td>110</td>
<td>40</td>
<td>38</td>
<td>34.5</td>
</tr>
<tr>
<td>UM2</td>
<td>Marega</td>
<td>123</td>
<td>40</td>
<td>40</td>
<td>32.5</td>
</tr>
<tr>
<td>UM3</td>
<td>Mukungu</td>
<td>117</td>
<td>40</td>
<td>39</td>
<td>33.3</td>
</tr>
<tr>
<td>LM1</td>
<td>Gachua 1</td>
<td>100</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>LM2</td>
<td>Kioru</td>
<td>71</td>
<td>40</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>LM3</td>
<td>Mugae</td>
<td>77</td>
<td>40</td>
<td>39</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>697</td>
<td>280</td>
<td>275</td>
<td>39.4</td>
</tr>
</tbody>
</table>

3.5. Data Collection Methods

3.5.1 Reconnaissance Survey

A range of methods were employed to address the specific objectives of this study
(Figure 4). This is because it entailed collecting diverse types of data which in essence
best provide an understanding of the research problem. Four research assistants
comprising of extension personnel and Bachelor of Science graduates were identified
and taken through a 2 days training on how to carry out the survey.
Relevant consultations with key stakeholders like KNBS, Ministry of Agriculture, NEMA, Ministry of Water and Irrigation. A preliminary visit to all the study areas was conducted by the research team. Consultative meetings with area managers and chief were done in the seven research sites for logistical and planning purposes. Two Separate checklists that are in Appendix 7.1 and 7.2 were used to gather information from both Government and non-Government service providers respectively. Whereby 10 were self administered by the non-Government actors and 10 other checklist self administered by heads of Agriculture and environment sector departments. This aimed at gathering available biophysical and socio-economic information of the study area from relevant agencies to understand the local, national and regional content of the communities. This was followed by pre-testing of the field survey tools at Ruiri.
location, Kamutune village in UM3. Corrections and relevant adjustments in the research instruments were appropriately done to enhance smooth administration.

3.5.2 Hydro-climatic data
The hydro-climatic data was sourced from local ministry of water offices and institutional weather stations. Initially a total of 20 rainfall stations (1967-2011), 4 temperature stations (1984-2011) and 2 river gauging stations (1980-2011) were considered. However, rainfall stations with more than one year missing were disqualified and ended up with a total of 3 stations. Rainfall data available from stations with adequate and consistent daily records was collected from Githongo tea factory for the period 1984 to 2011 and for 1967 to 2011 for both Meru forest station and Meru meteorological stations. Maximum and minimum temperature figures from Githongo tea factory and Meru meteorological stations were also provided for same time period.

The stream flow gauge at Kaguru S00.09215’ E037.66183’; 1460M above sea level in sub-AEZ UM2 daily data for over the last 30 years was recorded by the ministry of water and irrigation services Meru office. Due to scarcity of consistent data station with at least 20 years of daily rainfall, minimum and maximum temperature records were included, hence Githongo tea factory station qualified this criteria. In addition world meteorological organization (WMO) standard was applied in selection of appropriate set of data, that one should not fill more than 10% missing monthly data.

3.5.3 Land use land cover
Raster remote sensing data was used for this study. Raster comprises of pixels whereby spatial data is expressed as a matrix of cells or pixels with spatial position implicit in the ordering of the pixels. Each cell was represented by rectangle and had location coordinates as well as an attribute value. Raster data was employed in overlays and area calculations particularly for land use and land cover. Topographical maps at the scale of 1:50,000 of Isiolo, Marania, Meru, Mitunguu, Mount Kenya and Nkubu were used for reconnaissance and interpretation for this study. After confirming the scene of Meru Central District as P180R060 the next step was to acquire images of the same area for the years 1976, 1987, 2000, 2007 and FAO Africover data for 2011 in order to come up with a LULC analysis of 1976 to 2011. The Landsat Enhanced Thematic Mapper Plus
(ETM+) though the most improved sensor started continuously imaging since July 1999. The TM sensor has improved quality and images are available from 1984. The MSS sensor provides the oldest LANDSAT data and images are available from 1972; therefore, the reason for using the data from these sensors. The scenes (images) were acquired as bands 3, 2 and 1 with each band representing a particular feature in false colour composite. The bands used in this study are suitable for depicting land use land cover and specifically vegetation cover enhanced in infra-red. The raw bands P180R060_2M1976_Tiff, P168R060_02_1987_Tiff, P168R060_02_2000_Tiff and P168R060_02_2007 were used for image interpretation and analysis respectively.

Further, for the purpose of projecting future land use land cover Scenarios in Mount Kenya region thematic map of the satellite image with the major six classes which included; Mixed forest, Agriculture, Single species forest, Open ground, Arid land and others was the primary source of data. Year 2000 LULC image from (ETM+) was used as the baseline this was because the Landsat ETM+ which was most the improved sensor started imaging in 1999. In addition, to confirm that the trends were in tandem with a subsequent year we needed available data at least for an extra year following the base year which was provided by year 2007.

3.5.4 Household Survey
The structured questionnaire (Appendix 7.3) was administered using the local language to a total 275 out of 280 farming household heads sampled within the 7 Sub-AEZ. The questionnaire contained questions on demographic and socio-economic characterize of the households, household assets portfolio, perceptions on climate variability and their effects on smallholder livelihoods. This survey was conducted during August 2010 because the month is generally dry with few farm activities hence making most farmers available to better participate in such an exercise.

3.5.5 Focused Group Discussions
Focus group discussions were done in the LM_6 and UM_1 where marked incidences of climate shocks and land degradation were more pronounced. The FGD consisted a total of 4 groups each comprising of 8-12 participants. Targeted the most vulnerable/poor,
the rich and Key informants and elderly (above 60 years). Discussions were guided by a checklist (Appendix 7.4). A combination of various participatory techniques was employed among others; time line analysis, stakeholder analysis, risk and opportunity analysis, land use and livelihoods mapping. Focus group discussion was also employed to determine the community’s perspectives on climate variability and the land use changes. The discussions were expected to enrich the content of survey questionnaire and in-depth interview checklists.

3.5.6 In-Depth Interviews

The purpose of information emanating from In-depth interview was for triangulation with that from household survey and in the FGDs. The interview guide was based on the outcomes of the household survey and the focus group discussions (Appendix 7.5). A total of eight respondents were interviewed. It entailed asking questions, listening to and recording the answers, and then posing additional questions to clarify or expand on a particular issue. Respondents were also encouraged to express their perceptions in their own words. Video-recording provided an accurate verbatim record of the interview.

3.5.7 Transect walk

A transect from 00.0513’S 37.56193’ E to 00.11349’S 037.788766 was carried out and observations on type of vegetation cover, elevations, land use and other physical features were recorded. During the walk a checklist (Appendix 7.6) was used aimed at capturing information on land use changes and its driving force. Three over 90 year old provided their views also using this tool.

3.6 Data Analysis Methods

3.6.1 Reconnaissance survey

The qualitative data provided by the local experts and service providers was synthesized and grouped to capture their views and general trends on climatic factors, land use/land cover change and livelihoods. This information helped in the accessing baseline information of the study area, developments and review of the study instruments.
3.6.2 Hydro-climatic data

XL STAT and Excel version 2010 was used to generate the annual average cumulative departure index on seasonal rainfall trends ranging between 20 to 34 years for 3 weather stations. March, April and May were picked for the first season rains while October, November, December and in addition January was considered since its inclusion was valued in previous studies (Shisanya, 1996 and Recha, 2013)). Seasonal rainfall departure from the mean was calculated by:

\[ X = \left[ \sum_{i=1}^{N} \Delta t_{ij} \bar{X}_{ij} \right] \left[ \sum_{i=1}^{N} \Delta t_{ij} \right]^{-1} \]

Where;

- \( X_{ij} \) = Rainfall in mm per day in season \( j \) of year \( i \).
- \( \bar{X}_{ij} \) = the mean seasonal value of precipitation in season \( j \) over the years of the base period \( (\bar{X}_{ij}) \) is therefore expressed as a rate in the same units as \( X_{ij} \).
- \( \Delta t_{ij} \) = the time in season \( j \) of year \( i \), in units corresponding to the rate of \( X_{ij} \).
- \( N \) = number of years of record in the base period.

The \( \Delta t_{ij} \) is included in the equation so that mean seasonal values calculated from March to May (92 days) and October to January (123 days) will be time weighted according to number of days. The base period could be defined as the entire period of record during which the mean seasonal values computed by this equation are considered to be representative of the long term average conditions. The departure from the mean, for each season \( j \) and year \( i \), is defined as:

\[ D_{X_{ij}} = X_{ij} - \bar{X}_{ij} \]

A positive departure of precipitation, for example, indicates that the rate of precipitation for that season exceeds the long-term average for that season. The cumulative departure is given by:

\[ D_{X}(t) = \sum_{j=1}^{t} \Delta t_{ij} D_{X_{ij}} \]

While, the temperature (1992-2012) both daily minimum and maximum average monthly temperatures but in 2 of the stations and stream flow departure from normal (1980-2011) was computed by calculating the difference between long term annual mean and yearly mean figures. Determination of rainy season was based on the first 3 to 4 months after the start of a rainy season. ANOVA was carried out to test whether seasonal rainfall means of the sub-AEZs differed significantly. Further a Tukey Post
Hoc test was done to identify which Sub-AEZs differed significantly from each other. Since there were only two data sets of 22 years for temperature, a two tailed t-test was used to determine whether the means were different under the assumption that variances were different for the two. This assumption was confirmed through F-test. A regression analysis (scatter plots) was undertaken to illustrate and project the cumulative departure of both minimum and maximum temperature trends. Stream flow variability was computed using mean and standard deviation results derived from Excel of a 30 year period; daily monthly average River Kithino discharge at S00.09215˚ E037.66183˚; 1460M above sea level and trends developed. To ensure reliability of the findings the hydro-climatic data used requires being as homogenous as possible. This was done after cleaning the data. If data missed for less than 3 consecutive days in a station, it was filled using the ordinary least square (OLS) (Helsel and Hirch, 1992). Then, subjected the cleaned data to Buishand range test for homogeneity (Buishand, 1982).

3.6.3 Land use and land cover data
Remote sensing and GIS software ERDAS and ARCVIEW were used in analysing land use land cover changes using 1976, 1987, 2000, 2007 and 2011 data to generate 15 land use classes. Using SPSS regression and ANOVA was done to assess the relationship between changes in area under various land uses and decadal average rainfall among the 15 land use classes. Further the relationship between changes in various land use classes across sub-AEZ was determined.

Future land use scenarios
In the past, various approaches have been employed in predicting the destiny including premising future projections on a single forecast or representing “most likely” or business as usual approach. The Global Scenario Group suggests the business as usual tends to imply the probability of particular futures is objectively known (Raskin et al., 2002). Condone (2012) further concurs that there are disparities in conceptualizing scenario analysis. Scenario development as an evolving concept has not been codified into a common set of definitions and procedures therefore creating a methodological ambiguity (Swart et al., 2004). The future is unknown and therefore scenario development is but probable pathways to human destiny with uncertainties. For instance
scenarios developed in past whether mathematical models or otherwise drifted from reality (Condone, 2012). However, there is consensus from Global Scenario Group that purpose of developing future scenarios is to warn and prepare present and future generations (Swart et al., 2004 and Raskin et al., 2002). This leaves both approaches of imagining the future open. This study therefore, used both business as usual mathematical projection approach and the likely outcome approach based past drivers of land use change.

A Land use and time series analysis was carried out to simulate future land use scenarios and generate LULC outlook for the Meru County using CLUE-S (Conversion of Land Use and its Effects at Small regional extent), (Verburg et al., 2002). The spatial allocations (imaged) are based restricting the land use type under “other” to fulfil CLUE-S programming requirements. A conversion matrix for the land use change sequences was also created. The land use types were identified based on experience (Table 2).

**Table 2: The conversion elasticity parameters for the six classes**

<table>
<thead>
<tr>
<th>Series</th>
<th>Classes of Land Use</th>
<th>Conversion elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Mixed forest</td>
<td>0.2</td>
</tr>
<tr>
<td>II</td>
<td>Agriculture</td>
<td>0.4</td>
</tr>
<tr>
<td>III</td>
<td>Single species forest</td>
<td>0.3</td>
</tr>
<tr>
<td>IV</td>
<td>Open Ground</td>
<td>0</td>
</tr>
<tr>
<td>V</td>
<td>Arid Land</td>
<td>0.7</td>
</tr>
<tr>
<td>VI</td>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

0: Means that all changes for that land use type are allowed, independent from the current land use of a location. This means that a certain land use type can be removed at one place and allocated at another place at the same time, e.g. shifting cultivation.
0<X<1: Means that changes are allowed, however, the higher the value, the higher the preference that will be given to locations that are already under this land use type. This setting is relevant for land use types with high conversion costs.

1: Means that grid cells with one land use type can never be added and removed at the same time. This is relevant for land use types that are difficult to convert, e.g. water body. A value of one stabilizes the system.

All the cover classes and their respective area coverage for the year 2000 to 2010 were loaded into a land requirements file. Using semi-average estimation method, the calculated values for 2015 to 2025 were also used in the land requirements file. Land use projections up to year 2025 with 2000 as the base year were explored using \( X(t) = T(t) \times S(t) \times C(t) \times R(t) \) (Equation) where \( X(t) \) is the forecast for time period \( t \), \( T(t) \) is the trend for time period \( t \), \( S(t) \) is the seasonality component for time period \( t \), \( R(t) \) is the random component for time period \( t \), while \( C(t) \) is the cyclic component of time period \( t \). However, because land uses changes are regular over a long period of time the forecast can be estimated by the seasonality component as below:

\[ X(t) = S(t) \]

Finally, the Dyna CLUES program was run and the resultant ASCII files were converted to raster images.

**Qualitative scenarios**

Household survey output, general trends of rainfall, temperature, stream flow and land use change triangulated with narratives and results from observations derived from transect walk and brainstorming with key informants in the focused group discussion were employed in identifying possible land use change driving forces that aided in developing storylines for exploring future scenarios underpinning the three classes of global scenarios that is conventional, barbarisation and great transition worldview.
3.6.4 Household Survey Data
Perceptions on climate variability were analysed using descriptive methods expressed as frequencies and also factor-component score was used to identify coping strategies that contributed significantly to the household. Assessment of livelihoods various assets parameters analysis of variance (ANOVA) in case of means of the quantitative data, frequencies, use of graphs and charts using SPSS for windows version 17 were done. Based on sustainable livelihood approach five capitals defines household livelihoods portfolio. Each of these capitals or factors constitutes a number of variables. This analysis is based on variables of household capitals. Factor analysis was then used to reduce these inter-dependable variables into statistically significant variables. It can be used for several purposes but in this study we used the method to select a subset of variables or factors from a larger set of human, financial and physical capital variables using scores presented in a component pattern matrix. All variables collected in the household survey and that describes the mentioned household assets, were subjected to a K-means cluster analysis. Cluster Analysis (CA) is a classification method that is used to arrange a set of cases into clusters which both minimize within-group variation and maximize between-group variation. Variables are classified such that each variable is very similar to others in its cluster with respect to some predetermined selection criteria (Hair et al., 1987). This procedure aided to identify relatively homogeneous groups of cases based on the proportion of household livelihood assets. The households were classified into three typologies defined by the level of livelihood capabilities that reflected the contribution (effect) of land use on the respondents’ household among smallholder farming community.

3.6.5 Focused Group Discussion
This constituted the qualitative data of the study. Information gathered was from few samples inadequate to warrant use of software and therefore was processed manually by grouping the data. Data was synthesized to identify the perceived climate variability and extremes experienced by local communities in the past at least two decades. They were also used to determine the effects of land use change and climate variability on livelihoods including the effectiveness of coping strategies in terms of enhancing sustainable livelihoods and development.
3.6.6 In-Depth Interviews
The recorded Video clips were played and key points written down and triangulated with the results of household survey and FGDs.

3.6.7 Transect walk
Data on type of vegetation cover, elevations, land use and other physical features was processed. This was then triangulated with results emanating from all other methods and inferences made. While data collected through observations during the transect walk was triangulated with secondary data and data emanating from other methods deployed in this study to better the understanding to the driving forces behind ecological changes.

3.7 Ethical Dimension
For ethical reasons, each respondent was enlightened on the objectives of the study, need for them to participate, and associated risks, envisioned benefits and confidentiality measure. Permission to undertake research was sought and granted by the relevant institutions at district and university level.
CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Evidence and Perceptions on Climate Variability
The hydro-climatic findings indicated variability of rainfall amounts, stream flow discharge and temperature. Most of the respondents (91.6%) were of the view that climate variability exist.

4.1.1 Observed climate variability
This study used the three rainfall, one stream flow gauge and two temperature stations. Buishand range test employed in all the hydro-climatic data set used in this study under the null hypothesis that data was homogenous and alternative that data was inhomogeneous; resulted to failure of rejecting the null hypothesis implying that the data was homogeneous. Seasonal rainfall amount were significantly variable along Sub-AEZ and across seasons while both monthly maximum and minimum temperatures were variable within and across Sub-AEZ as daily stream flow discharge varied in different months.

The Buishand Range Test;
Hypothesis - H₀: the data is homogeneous verses H₁: data is inhomogeneous

The adjusted partial sum : S₀ = 0 and Sₘₙ = \sum_{i=1}^{y} (Y_i - \bar{Y}), y(number of years)= 1,2…n, \bar{Y} is annual mean and Yᵢ is the iᵗʰ year value.

When the series is homogenous, the value of S₀ oscillates around zero. The rescaled adjusted range, R is obtained as:
\[ R = \frac{\max_{0 \leq y \leq n} S_y - \min_{0 \leq y \leq n} S_y}{S} \], where \( S \) is the standard deviation and \( S_y \) is as computed above. Then, we compute \( \frac{R}{\sqrt{n}} \) and compare it with the critical values given by the table (Buishand, 1982).

The computed value is less than the critical value hence we don’t reject null hypothesis implying that the data is homogeneous for all the cases (Table 3).

Table 3: The Buishand Range Test Results;

<table>
<thead>
<tr>
<th>Data set</th>
<th>Sample size (years)</th>
<th>( \frac{R}{\sqrt{n}} )</th>
<th>Critical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kithino River Discharge</td>
<td>32</td>
<td>0.73</td>
<td>1.5</td>
</tr>
<tr>
<td>Githongo Tea FC Rainfall data</td>
<td>MAM(26)</td>
<td>0.72</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>ONDJ(26)</td>
<td>0.99</td>
<td>1.5</td>
</tr>
<tr>
<td>Meru Forest Rainfall</td>
<td>MAM (37)</td>
<td>0.78</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>ONDJ (37)</td>
<td>0.82</td>
<td>1.53</td>
</tr>
<tr>
<td>Meru Rainfall</td>
<td>MAM (33)</td>
<td>0.86</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>ONDJ (33)</td>
<td>0.89</td>
<td>1.5</td>
</tr>
<tr>
<td>Githongo Temperatures</td>
<td>22</td>
<td>0.56</td>
<td>1.43</td>
</tr>
<tr>
<td>Meru Temperatures</td>
<td>22</td>
<td>1.00</td>
<td>1.43</td>
</tr>
</tbody>
</table>

Hence this data can be used for further analysis.

Rainfall Trends and Variability

The trends depicted in Figure 5 and 6 illustrate differences in departure from the mean seasonal rainfall amounts among sub-AEZs over time. Results indicate existence of inter-annual rainfall variability.
Cumulative departure for Githongo tea factory station (LH1), Meru Meteorological station (UM2) and Meru forest (UM2,3) for March, April and May (MAM) depicts coherent rainfall patterns. Rainfall in LH1 appeared to have a greater increase than UM2 and UM2,3. The peaks represent above the normal rainfall and dips indicate below
normal rainfall where normal refers to a long term mean. There was a tendency for the Peak Cumulative departure index (CDI) to alternate with a depression. These fluctuations are not completely random but appear to occur within a scale of 2 to 5 years. There was enhanced rainfall in the years 1977/78, 1997/98 and 2002/03 with CDI of above 6. There was a peak in 1997/98 because during ENSO year’s rainfall is enhanced. Considerably more rain fell between October and December in 1997 than proceeding 1998 MAM season. Around year 1984, 1995 and 2000 the CDI was at below -3 and 2005/06 implying that the area experienced both intermittent droughts and floods. When there was positive departure the higher areas received relatively greater change than the lower areas. This is because Mt Kenya influences the climate of the eastern slopes in that the closer to the mountain the higher the rainfall. According to Nicholson (1996) rainfall in the Eastern African region is quasi-periodic with dominate time scales of variability of 5 to 6 years which is a dominant time scale for southern oscillation phenomenon and for sea-surface temperature (SST) fluctuations in equatorial Indian Ocean.

The last day of ONDJ (2nd) season is considered January 31st, though most of the rains fall during the OND season with an extension to the month of January included. The last day of MAM (1st) season is 31st May. The two Seasonal rainfall accounts for over 85% of the annual rainfall and OND season receive more rain than MAM season. The significant difference of means (at P=0.05) of ONDJ and MAM seasons using ANOVA. From the computation, (P<0.05) therefore the difference in mean rainfall for the two seasons was significant in LH1, UM2 and UM2-3 (Table 4).

<table>
<thead>
<tr>
<th>STATION</th>
<th>Sub-AEZ</th>
<th>MAM</th>
<th>p-value</th>
<th>CV</th>
<th>ONDJ</th>
<th>p-value</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Githongo T.F</td>
<td>LH1</td>
<td>744.7</td>
<td>0.00</td>
<td>0.43</td>
<td>1329.9</td>
<td>0.00</td>
<td>0.26</td>
</tr>
<tr>
<td>Meru Forest</td>
<td>UM2-3</td>
<td>478.1</td>
<td>0.00</td>
<td>0.37</td>
<td>811.2</td>
<td>0.00</td>
<td>0.34</td>
</tr>
<tr>
<td>Meru Met.</td>
<td>UM2</td>
<td>466.2</td>
<td>0.00</td>
<td>0.36</td>
<td>789.5</td>
<td>0.00</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Differences in mean rainfall amounts exist between the three areas in the same season. It is also evident that high amounts are received in ONDJ than MAM season. Rainfall variability changes across Sub-AEZ while the closely related sub-AEZ had approximately or equal coefficient of variation (CV) in both seasons. Like rainfall amount, ONDJ season is longer than MAM. Both MAM and ONDJ rainfall are variable as depicted by the CV values. Githongo (LH1) had CV of 0.43 for MAM season and CV 0.26 for ONDJ. While Meru Met. Station UM2 and UM2,3 had identical ONDJ CV of 0.34. MAM CV was 0.36 and 0.37 for UM2 and UM2,3 respectively implying that MAM rainfall amount is more variable and less in amounts compared to OND within the three sub-AEZs. This implies that the performance of MAM is the main determinant of annual rainfall variability in UM2 and UM2,3.

March, April and May season rainfall is more variable in LH1 than in UM2 and UM2,3, however the average seasonal amounts of over 700mm are adequate for crop production in LH1, to maximize the benefits there is need to employ meteorological seasonal predictions in planning for this season. This entails having the appropriate cropping mix, varieties and technologies that would regulate soil moisture. Subsequently, the same would apply in UM2 and UM2,3. The trend suggests that rainfall variability decreases in the ONDJ season as you go to upper Sub-AEZ. This study area has a bimodal rainfall and the OND season is considered more reliable than MAM. Since a sizeable proportion of the Meru County is within highlands that is low highlands (LH) and upper midlands (UM), MAM season is effectively considered as short rains in Meru unlike most parts of Kenya. The very lower areas of LM4 and LM6 are more prone to drought hence need for better land use planning, as such rainfed crop could be discouraged in LM4 and replaced with pastoralism. Further consideration, under rainfed conditions, drought tolerant crops would be more suitable in LM4. In related studies, in the lowlands of Eastern Mt Kenya (Tharaka) Recha (2013), found CV of between 0.35 and 0.36 for MAM season in LM4, LM4,5 and IL 5, while OND had a CV of between 0.36 and 0.44 for rainfall amount. Therefore, there is a tendency for OND CV to increase as you go towards the lowland, whereas the MAM CV decreases. Elevation of Mt Kenya influences seasons in the LH1, UM1 and UM2 (Majule et al., 2004). These findings also concur with other studies (Jaetzold et al., 2007 and Takaoka, 2005).
Variability in the seasonal average rainfall

Variations exist between seasons and across the Sub-AEZ. There is significant difference in average rainfall amounts within MAM season between LH₁ and UM₂,₃ (P<0.05) and between LH₁ and UM₂ (P= 0.00). There is no significant difference between UM₂ and UM₂,₃ (P>0.05). While, for the OND seasonal mean there is significant difference between LH₁ and UM₂-3, (P<0.05), same as LH₁ and UM₂ (P<0.05); but no significant difference between UM₂,₃ and UM₂ (P>0.05) (Table 5).

Table 5: Results of multiple comparison of seasonal mean

<table>
<thead>
<tr>
<th>(I) GROUP</th>
<th>Season</th>
<th>Paired</th>
<th>Std. Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₁</td>
<td>MAM</td>
<td>UM₂,₃</td>
<td>19.10302</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂</td>
<td>18.36032</td>
<td>.000</td>
</tr>
<tr>
<td>UM₂,₃</td>
<td>LH₁</td>
<td>UM₂</td>
<td>19.10302</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂</td>
<td>16.68060</td>
<td>.442</td>
</tr>
<tr>
<td>UM₂</td>
<td>LH₁</td>
<td>UM₂</td>
<td>18.36032</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂,₃</td>
<td>16.68060</td>
<td>.442</td>
</tr>
<tr>
<td>LH₁</td>
<td>OND</td>
<td>UM₂,₃</td>
<td>29.54631</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂</td>
<td>28.35063</td>
<td>.000</td>
</tr>
<tr>
<td>UM₂-3</td>
<td>LH₁</td>
<td>UM₂</td>
<td>29.54631</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂</td>
<td>25.97994</td>
<td>.620</td>
</tr>
<tr>
<td>UM₂</td>
<td>LH₁</td>
<td>UM₂</td>
<td>28.35063</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UM₂,₃</td>
<td>25.97994</td>
<td>.620</td>
</tr>
</tbody>
</table>

This implies that similar treatments can be applicable for UM₂ and UM₂,₃ for both seasons unlike in LH₁. Seasonal forecasts are provided at least one month before the normal onset of rainfall by Kenya Meteorological Department (KMD). The KMD information is based on probability of rainfall performance based on observations of global systems that influence our rainfall and use of statistical analytical techniques. In a county situation where there are few reliable weather stations generating sufficient thirty year weather record sets as a basis for trend development and prediction is
difficult. Therefore, presumably the information used to make ‘regional’ weather forecast is based on the average scenario whose projections emanate from meagre reliable whether stations that maintains long term records. As such it would be inappropriate to make a general prediction for a county or region with diverse sub-AEZ hence the need to increase weather monitoring facilities and ensure at least each Sub-AEZ has a reliable weather station.

Temperature variability
The observed mean annual temperatures for 22 years of Githongo T.F station (LH1) was 19.72 °C and that of Meru Met station (UM2) was 13.09 °C. Test for whether these two means are significantly different under the assumption that the variance in the data is different for the two Agro-Ecological zones was undertaken and F-statistic hypothesis test for the difference in variance for LH1 is 4.85 and that of UM2 is 0.13. Variance for Githongo T.F station is denoted as $G S^2$ and that of Meru Met station as $M S^2$

Test hypothesis;

$H_0: G S^2 = M S^2$ versus $H_1: G S^2 \neq M S^2$

$F = G S^2 / M S^2$ i.e. $F = 4.85 / 0.13 = 37.31$

The F-statistic from the F-table at 0.05 level of significance and 21 df in the two sample sizes; i.e. $F_{0.05, 21, 21} = 2.41$.

Since the calculated F-statistic is greater than the one from the F-table i.e. 37.31 > 2.41, otherwise it falls in the Rejection Region, we reject the null hypothesis. Therefore, the temperature variations are different for the two AEZ, UM2 and LH1.

Then, test for significant difference in the observed mean annual temperature using t-test to test the hypothesis that:

$H_0: \mu_g = \mu_m$ versus $H_1: \mu_g \neq \mu_m$, where $\mu_g$ is the mean annual temperature for LH1 and $\mu_m$ is the mean annual temperature for UM2.

The sample statistics mean for LH1 = 19.72 and mean for UM2 = 13.09.

The computed t-statistic is obtained to be 13.81 and that from the t-table is 12.71.

Hence reject the null hypothesis. Therefore the mean annual temperatures experienced in LH1 are significantly different from those experienced in UM2.
Further analysis on annual mean temperature deviation from the long term mean (normal) revealed that there was a positive change in minimum and maximum temperature especially over the recent two decades (Figure 7 and 8).

![Figure 7: Trend of annual average minimum temperature departure](image)

The temperature deviations from normal for Githongo T. F station were generally higher than that of Meru Met station. In Githongo T. F, there has been a steady increase in annual average temperature from year 2001 to 2009 compared to 1991 to 1998 which remained below normal while in Meru Met temperature were near normal within the good part of the period under review shown by the slight slope of the trend line. However; year 2000 and 2006 had above normal with a remark decrease recorded in 1992. The positive deviation (peaks) signals a warming trend. Such slight changes in temperature trends are known to interrupt the plant physiological process. Regressing Githongo T. F temperature changes representing LH1 a tea - diary zone portrays rising minimum average temperatures that would in future alter suitability of tea production in this area.
Figure 8: Trend of annual average maximum temperature departure

Using simple linear regression ($y = a + bx$). It implies that the average minimum temperature departure for every additional year was 0.003°C and 0.008°C for the maximum in Githongo T.F station. The average minimum temperature departure for every additional year was 0.00°C and <0.001°C for the maximum in for Meru Met station. Therefore, if this scenario continues minimum and maximum average temperatures in LH$_1$ are likely to increase by 0.3°C and 0.8°C respectively after 100 years ceteris paribus while in UM$_2$ slight increase in average minimum (less than 0.1°C) and no change for the maximum temperature in the same time period. In the past there has been clearing of on farm trees, natural vegetation and forest this has reduced shading and probably the cause of temperature increase. This has caused vegetation change, displacement of adaptable fauna and flora and in future may shift the sub-AEZ.

According to Hulme et al (2001) Africa has warmed 0.7°C over the 20th century. These findings are similar to those of Laderach and Eitzinger (2011) where monthly minimum and maximum temperatures were to increase progressively by year 2050 and projected a decrease in the tea production areas in Kenya by 2050. The results are also in concurrence with other studies that suggest a warming trend in East African region (Aguilar et al., 2009; Christy et al., 2009).
Stream Flow Variability

The computed Monthly means from 1980-2011 and the calculated coefficient of variation (CV) signified a high reduction in stream discharge in all the months over the years. The CV ranged between 0.40 to 0.22 with the highest variation recorded in the months of February and September and the lowest in April and December (Table 6).

Table 6: River Kithino Stream Discharge $\bar{X}$, SD and C.V

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.87</td>
<td>0.77</td>
<td>0.81</td>
<td>0.87</td>
<td>0.95</td>
<td>0.82</td>
<td>0.82</td>
<td>0.67</td>
<td>0.63</td>
<td>0.79</td>
<td>0.85</td>
<td>0.90</td>
</tr>
<tr>
<td>SD</td>
<td>0.25</td>
<td>0.31</td>
<td>0.20</td>
<td>0.19</td>
<td>0.31</td>
<td>0.21</td>
<td>0.32</td>
<td>0.22</td>
<td>0.25</td>
<td>0.27</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>C.V</td>
<td>0.27</td>
<td>0.40</td>
<td>0.25</td>
<td>0.22</td>
<td>0.33</td>
<td>0.26</td>
<td>0.39</td>
<td>0.33</td>
<td>0.40</td>
<td>0.34</td>
<td>0.24</td>
<td>0.22</td>
</tr>
</tbody>
</table>

September and February are generally the driest/hottest months with minimal precipitation but with reported increased fluctuation in rainfall in January and August/September coupled with subsequent melting of Mount Kenya ice cap may be the cause for relatively high variability during these months. River Kithino is the main water supply and originates from slopes of Mt Kenya. Nevertheless, there has been increased runoff and sedimentation. During rainy seasons, this causes flooding. In the drier months the water demand supersedes supply, while in wet seasons the river discharge increases due to enhanced water volumes from surface runoff, raised water table, precipitation and reduced evaporation. This negates the effects of hydrological cycle in maintaining sustainable environmental conditions for well-being. Groisman et al (1994) postulated some relationship between increases in heavy precipitation and changes in high stream flow. Lins and Slack (1999) found a significant and coherent signal of increasing heavy precipitation contributing to increasing high stream flows. The stream discharge trend is generally decreasing. The trend was above normal from 1981 to 1995 with a peak around 1986 and 1990 but remained below normal between 1995 and 2004. In year 2008/09 there was a dip (Figure 9).
Figure 9: Trend of departure from long term average of Kithino River

This suggests that either or both natural and human activities have intensified in the recent years. Key informants perceived irrigation as the major contributor to the decreasing stream discharge during the dry months. Kithino River in Imenti South is one of the most significant sources of water for irrigation and domestic use in the region. The river has its source in Mount Kenya forest. Abstraction of Water through gravity is easy because of contours along the river. Over 53 water projects have been authorized to abstract water from the river known for its generosity among others includes some of the largest schemes in the region namely Nguru ngakero Irrigation and Ciomucogia irrigation scheme. There was exponential increment of irrigated crop from 2007 to 2011(Figure 10).
The expansion of area under irrigated crops is an indication that the community is shifting from rain dependant agriculture. The steep increase from 2007 to 2011 was has a result of completion of more irrigation projects (Giaki- Kioru Irrigation project in 2009, Nkabune Irrigation Project in 2010 among others). Findings from the focused groups’ discussions revealed that whenever rains failed farmers reverted to irrigation leading to increased competition for water. Competition for irrigation water was a major source of conflicts among and across water user associations. A case in point was when the National Irrigation Board (NIB) undertook to expand Mitunguu Irrigation scheme in 2011 by abstracting more water from Kithino River but the Kithino water user association protested and destroyed the intake NIB had started constructing (Judy Regional WRMA manager per comm.). Due to unpredictable rains irrigation would assure farmers of production to meet household and market demands. As a result water use conflicts among irrigation, livestock and environmental conservation is quite common.

Data from Ministry of Irrigation and Water on licensed water projects indicated that majority (72.6%) of the projects were for irrigation purpose. Household survey results indicated that 34.3% of respondents practiced irrigation. Those who were practising
irrigation (87%) indicated that unreliability of rainfall was the main reason for venturing into irrigation. Other reasons were; demand for constant market supply and maximizing returns per unit land. However, stream flow dynamics and seasonal climatic variations are intertwined and both drive irrigation among other factors. In the upper midland agro-ecological zone 65% of irrigated farms majored on commercial banana production 5% napier grass for dairy enterprise, 29.5% on vegetables and 0.5% other crops.

Kenya is a chronically water-scarce country. The country’s natural endowment of freshwater is limited, with an annual renewable freshwater supply of about 647 cubic meters per capita, below the 1,000 M³ per capita set as the marker for water scarcity (Mogaka et al., 2005). This is exacerbated by the long term degradation of catchments, lakes and aquifers which costs Kenya 0.5% of its GDP annually and an uneven spatial and temporal distribution of resources. This renders this country vulnerable to perturbations in water supply, particularly from climate variability (Mogaka et al., 2005). Climate variability leads to changes in precipitation and potential evapotranspiration (PET). Study findings have associated trends of stream flow and discharge to climate variability (Jones et al., 2012; Yuting et al., 2011; Mogaka et al., 2005). Other findings indicated that human activities such various land use types were found to affect the river level (Garbrecht et al., 2004; ZHAO et al., 2009).

4.1.2 Perceived climate variability
Farmers perceived the current climatic conditions to have deviated from the normal in the past decades. The findings of the HH survey indicated that majority (91.6%) give a positive response when asked whether from own experience the long term climatic conditions had deviated (Table 7)
Table 7: Farmers perceptions on climate variability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Response</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>When you compare your childhood years &amp; today, has climatic conditions remarkably deviated?</td>
<td>Yes</td>
<td>91.6</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>8.4</td>
</tr>
<tr>
<td>What did climatic variation entail?</td>
<td>Erratic rainfall</td>
<td>50.9</td>
</tr>
<tr>
<td></td>
<td>Decreased precipitation</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>Increased precipitation</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Sources: Field Survey, 2010 (n=273)

These findings were based on the respondent memory, variations in rainfall (erratic rainfall, decreased precipitation and increased precipitation) was interpreted as climate variability by a combined 87.9% of the respondents with most of them (50.9%) stating that in the recent years rainfall was becoming more erratic or unpredictable. Findings of the FGD revealed that farmers understood erratic rainfall in terms of both temporal and spatial dimensions. Whereas decreasing rainfall meant less than normal amounts or fewer rainy days, while above normal amount or prolonged rainfall season was considered as increased rainfall. There was no mention of temperature changes. About 12% had difficulty in responding to this question or were indifferent. Rainfall amounts and distribution are key determinant of farm output. A good season is associated to adequate and ‘well’ distributed rainfall. Years and seasons of excessive rains or inadequate rains are memorable periods in the history of the study community and are often catastrophic in nature. Such episodes have been locally named and children or animals born during such times adopt the names that in essence remind people of the event. Over years traditionally data has been stored this way. Perceived climate variability is based on economic and social impact it has on personal lives and those of peers. They are also important in response mechanisms as they determine decisions in land use planning and management.
Most respondents (24.5%) associated climate variability with decreased precipitation compared to 12.5% who attributed it to increased precipitation as a result of the need for adequate rains in terms of amounts and distribution within a growing season. This implies that, at local level, any interventions directed towards addressing climate variability should aim at manipulating rainfall in order for the community to identify with them. Other studies done on perceived climate variability suggested that perceptions had influence on personal and community values and goals (Moyo et al., 2012; Madison, 2007). Needs of the peoples are often conceived as a form of benchmark when they compare individual years (Wilhite, 2000). Climate variability was perceived to cause food insecurity, landslides, road damage, floods, crop diseases, soil erosion, crop spoilage and livestock deaths (Table 8).

Table 8: Farmers perceived impacts

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Insecurity</td>
<td>64.8</td>
</tr>
<tr>
<td>Land slide</td>
<td>9.2</td>
</tr>
<tr>
<td>Road damages</td>
<td>10.6</td>
</tr>
<tr>
<td>Floods</td>
<td>2.9</td>
</tr>
<tr>
<td>Increased crop diseases</td>
<td>2.2</td>
</tr>
<tr>
<td>Increased crop pest</td>
<td>0.7</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>0.4</td>
</tr>
<tr>
<td>Spoilt crop</td>
<td>0.4</td>
</tr>
<tr>
<td>Livestock death</td>
<td>0.4</td>
</tr>
<tr>
<td>Don’t know</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Sources: Field Survey, 2010 (n=273)

Food insecurity having been identified by majority of the respondents (64.8%) as one of the climate variability impacts was an indication that the community experienced food shortages. This problem would be aggravated by land degradation as a result of landslides and soil erosion as mentioned by 9.2% and 0.4% of the respondents respectively.
Crop Pests, diseases and livestock deaths also cause low production, while, road damage would further, worsen the situation by constraining access to both produce and inputs market. In most of this study area, rural road had an earth surface, weak or temporary bridges and poorly maintained, they are often destroyed by runoff water. Farms on steep slopes were more prone to incidences of landslides and soil erosion while the planes are prone to floods. Intense rainfall aggravates flooding of streams and rivers, siltation, river bank destruction and soil erosion. Therefore, these impacts may not necessary be as a result of climate variability but might arise from a multiplicity of other forces. However, elements of climate variability exacerbate manifestation of these impacts. For instance unsustainable land management practices and use of inappropriate technologies are known to cause soil and water erosion but worsens under excessive rains or wind. These findings concurred with other studies (Simelton et al., 2011).

Coping mechanisms to effects of climatic variability

Majority of the respondents (74.5%) perceived prolonged and intense drought as the problematic climate variability condition they encounter. On the contrary 6.5% indicted that excessive and intense rainfall created a situation that needed to cope with. Seasonal fluctuation in rainfall was identified as a constraint by 7.3%. Those who perceived excess heat or increased temperature as a constraint to cope with were 0.4% while 11.3% were unresponsive (Figure 11).

These findings imply dependency on rain-fed farming makes deviation of rainfall below or above normal not escape the minds of the respondents because exposure to drought directly and detrimentally affects their livelihoods. Perceived problems were predominately related to rainfall and 0.4% associated to temperature. Challenge or constraint is an important factor that shapes individuals’ perceptions, in terms of seasonality, with previous experiences of poor seasons bringing in memories and being responsible for how farmers may tend to react “perception is a necessary prerequisite for response”. It was evident from the empirical results that there was inter-seasonal rainfall variability which explains the perceived rainfall fluctuations. Further, during the FDG participants from various AEZ concurred that the first rain season were more erratic in that are abrupt, either start late or disappear earlier than expected.
Perceived climate variability concurs with the results computed from measured climatic parameters though with some divergence. A number of studies highlighted divergence between measured climate variability parameters and perceptions (Moyo et al., 2012; Cooper et al., 2008; Meze-Hausken, 2004). Reasons for the divergence between perceptions and measured parameters can be associated with changes in peoples’ need for rainfall or be linked to various socio-economic and biophysical changes which rise demand for water or may be a misunderstanding of the drivers of change.

**Strategies employed to cope with perceived climate variability related effects**

Based on the component scores adoption of more drought and disease tolerant varieties, migration to trouble free areas, change of cropping systems, maintaining household food reserves on farm or in stores, controlled stocking levels and breeds and exploiting emerging production opportunities such as irrigated crop and green houses were the coping strategies that contributed significant loadings in the area of study (Table 9).
Whilst this matrix provides a useful general regional picture, it is recognized that, of importance climate shocks have temporal and spatial variations, a driving force to the type of coping strategies employed. For instance any sub-AEZ has a chance to experience prolonged intense rains, drought or encounter short term weather changes at the middle of a cropping season (mid season rainfall fluctuations).

**Coping with seasonal rainfall fluctuations**

There were five strategies employed in the farms to cope with unexpected mid-season rainfall fluctuations; Planting 1 – 2 months prior to rain onset under irrigation, crop diversification with adaptable varieties/cultivars, Irrigation, livelihood Diversification, Change of land use from crop farming. Multiple strategies were concurrently used within a farm (Table 10).
Table 10: Coping strategies for seasonal rainfall fluctuations

<table>
<thead>
<tr>
<th>Strategy</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting 1 – 2 months prior to rain onset</td>
<td>55.3</td>
</tr>
<tr>
<td>Crop diversification with adaptable varieties/cultivars</td>
<td>62.9</td>
</tr>
<tr>
<td>Irrigation</td>
<td>10.5</td>
</tr>
<tr>
<td>Livelihood Diversification</td>
<td>10.5</td>
</tr>
<tr>
<td>Change from crop farming</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Source: Field Survey; 2010; (n=273)

Most (82.3%) of the farmers employed more than one coping strategy with 62.9% diversifying crop by use of varieties or cultivars that are more adaptable to moisture stress such as sorghum, deep rooted and dry land maize varieties, *Dolicus lab lab*, beans, pigeon peas, cowpeas, millets and indigenous vegetables. Early planting was another widely used measure because seasons are marked by date of rain onset and these dates have always been traditionally believed by Meru farmers as 15th March for the first season and 15th October for second season. Farmers (55.3%) planted 1-2 months prior to rain onset to cushion against depressed rain. Further, rains met established plants in case the crop was irrigated while, where irrigation was absent the seed took advantage of first rains and nitrogen flush leading to better growth, development and more importantly improved yields. Incidences of abrupt changes in weather conditions between seasons are common especially in the region where climate is complex and influenced by local and global factors. This situation is aggravated further by inadequate technology and lack of modern equipments (Nicholson, 1996).

Subjecting the five “unexpected mid-season rainfall fluctuations strategies” to factor analysis; planting 1-2 months prior to rain set date under irrigation, shifting from crop farming and diversification with adaptable crop varieties or cultivars scored significantly (Table 11).
Table 11: Component score matrix for rainfall fluctuations coping strategies

<table>
<thead>
<tr>
<th>Coping strategies</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting 1-2 months prior to rain set date</td>
<td>.513</td>
<td><strong>.824</strong></td>
<td>.171</td>
</tr>
<tr>
<td>Irrigation</td>
<td>.909</td>
<td>.081</td>
<td>-.026</td>
</tr>
<tr>
<td>Change from crop farming</td>
<td><strong>.928</strong></td>
<td>-.049</td>
<td>-.215</td>
</tr>
<tr>
<td>diversify livelihood</td>
<td>.830</td>
<td>-.294</td>
<td>-.352</td>
</tr>
<tr>
<td>crop diversification with adaptable varieties/cultivars</td>
<td>.591</td>
<td>-.350</td>
<td><strong>.723</strong></td>
</tr>
</tbody>
</table>

Irrigation and livelihood diversification score were not significant in managing the mid-season rainfall fluctuations. In past the priority has been clean drinking water, however, the need to feed the growing population is drumming support for irrigated agriculture. Irrigation requires heavy investment; therefore, limited external support curtails attaining the full potential. Smallholder farming is predominately rainfed and tends to grow annual crops whose production cycle synchronizes with seasonality. These findings imply that, if the diversification occurred among crops only, the households will be more vulnerable to climate; it would be less vulnerable if non-agricultural activities are incorporated though however insignificant. It is therefore imperative that these results are only considered based on on-farm coping strategies and not from the smallholder sector approach perspective. Other studies have identified similar coping strategies in Meru County (Simelton et al., 2011; Khisa, 2001).

Coping with drought
Reduction in dependence on agriculture, Decreased livestock units, seeking other sources of livelihood and migration to less drought prone areas were the drought coping strategies employed by respondents (Table 12). The two drought coping strategies that scored significantly were decreased dependence on agriculture and migration to less drought prone areas with a coefficient score of 0.894 and 0.884 respectively. Migration to less drought prone areas was an option in high drought risk areas in the leeward side of Mount Kenya. Information gathered from key informants and FGD suggested that major droughts occurred once in lower highlands and upper midlands in every 10 years, twice in LM3 and LM4 while in LM6 drought occurs twice every 5 years.
Table 12: Component score matrix for drought coping strategies

<table>
<thead>
<tr>
<th>Coping Strategies</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease farming/ dependence on agriculture</td>
<td>0.354</td>
<td><strong>0.894</strong></td>
</tr>
<tr>
<td>Decreased livestock units</td>
<td>0.683</td>
<td>0.066</td>
</tr>
<tr>
<td>Migration to less drought prone areas</td>
<td><strong>0.884</strong></td>
<td>0.033</td>
</tr>
<tr>
<td>Seeking other sources of livelihood/diversify</td>
<td>0.750</td>
<td>-0.520</td>
</tr>
</tbody>
</table>

**Coping with intense Rainfall**

The strategies employed to deal with effects of prolonged intense rainfall were predominately planned in adverse. Majority (94%) of the farms applied soil and water conservation measures to counter runoff (Figure 12).

![Figure 12: Strategies to cope with prolonged intense rains (Source: Field Survey; 2010)](image)

However, soil and water conservation methods adopted by farmers varied across the Sub-AEZ and depended on the gradient of the farmland. For structures, strength of the embankment was proportional to the magnitude of slope. The predominate soil and water conservation measures taken in various Sub-AEZ were as follows:
i. LH₁ and UM₁: Tea and nappier cover crops, mulch, contour cropping, agro forestry, cut off drains and terraces.

ii. UM₂: Cover crops, nappier grass, pulses (beans and cowpeas), contour cropping, agro forestry, terraces, cut off drains, retention ditches, banana, and coffee micro-catchments.

iii. UM₃: The order of preference for structures was bananas micro catchments, terraces retention ditches, cover crops comprising nappier grass, sweet potatoes, nappier grass, grass strips, contour cropping and agro forestry.

iv. LM₃: Banana and fruit trees micro catchment, terraces, retention ditches cover crops (nappier grass and sweet potatoes and pulses), and contour cropping took lead.

v. LM₄: Ridges, trash lines, cover crops and contour cropping were the most preferred fanya juu and stone lines were the most preferred.

vi. LM₆: This Sub-zone is not recommended for crop production but those cultivating use trash lines, and grass strips or minimum tillage while the dominant structures were stone lines and Fanya juu terraces.

Other cultural practices that aided in soil and water conservation across the sub-AEZ included; crop rotation, use of farm of yard manure, Intercropping and riverbanks protection. The importance of soil and water conservation in the development of sustainable natural resource and mitigating effects of intense rainfall is crucial as demonstrated in other studies (Mbagathi et al., 2009; Muriuki and Macharia, 2011).

**Gender sensitive coping strategies**

Key informants and FGD indicated that some coping strategies were preferred by one gender than the other (Table 13). Though, women and men tended to participant in all strategies a higher proportion of women were involved in self-help groups and small vegetable/fruits business while seeking casual jobs and improving management on their farms were men preferences. Therefore, it implies that any prescriptions geared towards supporting certain strategies would benefit the dominant gender more than the other. For instance development practitioners advocate group approach however; chances are that more women will get empowered through self help groups than men. Traditionally
Men are the household bread winners and as such their interventions were biased towards raising income hence the reason why they preferred strategies that dwelt on seeking additional jobs and improving farm management. While, women being traditionally home managers preferred those activities that may not demand being away from the home vicinity. These findings tend to agree with others, for instance Bynoe (2009) found that the indigenous Guyana community embraced strategies that were gender sensitive.

**Table 13: Ratio of Men to Women preferring use of the Strategy**

<table>
<thead>
<tr>
<th>Coping strategy</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>By seeking additional jobs</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>By improved farm management</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>By diversification of food sources</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Involve in other income generating activities</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>By self help group interventions</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>Small vegetable/fruits business</td>
<td>1</td>
<td>40</td>
</tr>
</tbody>
</table>

Source: Field Survey; 2010
4.2 Trends in Land Use Changes

The natural landscape was fragmented and modified by agricultural and forestry developments since 1976 to 2011. Plate I depicts 1976 images showing land use using composite colours a scene of Mount Kenya.

Plate I: layer stack images for the Land use and cover changes of Mt Kenya scene
The area of interest (AOI) was clipped from the 1987 image for detailed analysis of land use changes in the targeted AEZ for the study (Plate II). Agricultural area accounts for about 60% of the total area, with (33%) under Mount Kenya forest national reserve and the remaining 7% under other types of vegetation cover and land use (Table 14).
Table 14: Percentage Area under Various land use classes 1976 to 2011

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed crop</td>
<td>17.19</td>
<td>25.53</td>
<td>27.16</td>
<td>26.53</td>
<td>25.95</td>
</tr>
<tr>
<td>shrub land</td>
<td>2.96</td>
<td>2.87</td>
<td>2.26</td>
<td>2.26</td>
<td>1.45</td>
</tr>
<tr>
<td>irrigated crop</td>
<td>0.00</td>
<td>0.28</td>
<td>0.33</td>
<td>0.43</td>
<td>1.33</td>
</tr>
<tr>
<td>Urban settlement</td>
<td>0.07</td>
<td>0.14</td>
<td>0.19</td>
<td>0.19</td>
<td>0.2</td>
</tr>
<tr>
<td>Woodland</td>
<td>5.07</td>
<td>0.35</td>
<td>0.27</td>
<td>0.27</td>
<td>0.26</td>
</tr>
<tr>
<td>Glass land</td>
<td>7.33</td>
<td>6.02</td>
<td>5.72</td>
<td>5.72</td>
<td>4.77</td>
</tr>
<tr>
<td>River line vegetation</td>
<td>0.17</td>
<td>0.18</td>
<td>0.14</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>Water body</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Natural forest</td>
<td>20.6</td>
<td>18.05</td>
<td>16.52</td>
<td>17.82</td>
<td>17.84</td>
</tr>
<tr>
<td>Moorland</td>
<td>16.22</td>
<td>16.05</td>
<td>16.03</td>
<td>16.03</td>
<td>16.05</td>
</tr>
<tr>
<td>Open Forest</td>
<td>2.34</td>
<td>0.43</td>
<td>0.4</td>
<td>0.38</td>
<td>0.37</td>
</tr>
<tr>
<td>Rainfed crop &amp; trees</td>
<td>22.54</td>
<td>20.94</td>
<td>22.3</td>
<td>20.6</td>
<td>19.66</td>
</tr>
<tr>
<td>Rainfed crop &amp; shrub</td>
<td>4.87</td>
<td>3.59</td>
<td>3.13</td>
<td>3.13</td>
<td>3.84</td>
</tr>
<tr>
<td>Tea zone</td>
<td>0.6</td>
<td>4.79</td>
<td>4.79</td>
<td>5.56</td>
<td>7.24</td>
</tr>
<tr>
<td>Cleared Forest</td>
<td>0.02</td>
<td>0.76</td>
<td>0.74</td>
<td>0.94</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Source: Computed from DRSRS Data

The patterns of land use ranging from 1976 to 2011 indicates most notable changes were observed in area under forests, agriculture, shrubs, grassland and urban settlement. The estimated combined forested area was 30% including 16.05% under moorland as part of the Mount Kenya. Nevertheless, some of the classes experienced fluctuations. The drop in forested area would be associated to the establishment of Nyayo tea zones around Mount Kenya forest, logging and shamba system. However since year 2000, the government reversed the system of management of the Mount Kenya forest by introducing stricter government enforcement of law and regulations. Thus, cultivation was no longer allowed in the forest plantations. Enforcement also included forced removal of squatters. There were 1000 households from Karuri section Timau division of Mt Kenya forest that were evicted in 2003 to 2005. According to Meru central DFS zonal officer about 3000Ha of forestland was rescued from Karuri section and about
10,000 people prevented from illegal access to forest land. There has been a concerted effort to protect the forest from cultivation, a halt to logging hardwood for national and international market, use of permits to control firewood collection and grazing, the designation of the forest as a national reserve under management of the Kenya wildlife service and removal of administrators found to have engaged in illegal forest activities. Area under rainfed agriculture exhibited an increasing trend up to 2000 but appeared to have slightly decreased until 2011. A more pronounced change was found in the proportions of area under rainfed crops, Tea zone and irrigated crops. The area under tea and irrigated crops depicted an increasing trend up to year 2011. A five year cropped area trends (Figure 13) portrays general increase of hectares under most of crops in the study area.

Figure 13: Area under major crops 1996 to 2011 in Meru central Region (Source: DAO’s annual reports)

Area under various crops remained stable with a drop in 1998 due to El Niño rains experienced throughout the year interrupting cultivation. The area under bananas depicted an increasing trend from 2005 after introduction of improved varieties and collapse of coffee sector.
Relationship between Land use changes and Decadal annual average rainfall

Considering the F-statistic column, the values of F-statistic found do not show any statistically significant differences in the variances of the means of decadal average rainfall received and trends in land use. At 95 per cent confidence, the significance (P-value) column depicts values that are above 0.05. Therefore, there is insufficient evidence to confirm that the trends observed in land use are caused by the decadal average rainfall trends (Table 15).

Table 15: Results of decadal average rainfall trend against land use types

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Un-standardized coefficient; B</th>
<th>F-statistics</th>
<th>P-value (significant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed crops</td>
<td>16.372</td>
<td>0.062</td>
<td>0.819</td>
</tr>
<tr>
<td></td>
<td>0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated crops</td>
<td>2.205</td>
<td>0.196</td>
<td>0.688</td>
</tr>
<tr>
<td></td>
<td>-0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grassland</td>
<td>3.299</td>
<td>0.058</td>
<td>0.826</td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Forest</td>
<td>26.88</td>
<td>0.657</td>
<td>0.477</td>
</tr>
<tr>
<td></td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea Zone</td>
<td>9.799</td>
<td>0.073</td>
<td>0.805</td>
</tr>
<tr>
<td></td>
<td>-0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleared Forest</td>
<td>1.407</td>
<td>0.058</td>
<td>0.825</td>
</tr>
<tr>
<td></td>
<td>-0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Therefore, under the hypothesis: \( H_0: \beta_1=0 \) vs \( H_a: \beta_1 \neq 0 \), we fail to reject the null hypothesis and conclude that these trends are caused by other factors. However, lack of sufficient evidence to show effect of decadal average rainfall trends on land use trends do not mean total lack of effect. There might be some effect although statistically insignificant. As depicted in the significance column, there is a statistically significant difference between the average land use through rain fed crops and trees in the five sub-ecological zones (Table 16).
Table 16: Multiple Comparisons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>(I-J)</th>
<th>Error</th>
<th>Sig.</th>
<th>95% Confidence</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Upper</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH1</td>
<td>UM1</td>
<td>-57.9500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-62.6388</td>
<td>-53.2612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM3</td>
<td>-79.4000(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-84.0888</td>
<td>-74.7112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM1</td>
<td>-33.1500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-37.8388</td>
<td>-28.4612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM4</td>
<td>-6.5750(*)</td>
<td>1.51844</td>
<td>.005</td>
<td>-11.2638</td>
<td>-1.8862</td>
<td></td>
</tr>
<tr>
<td>UM1</td>
<td>LH1</td>
<td>57.9500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>53.2612</td>
<td>62.6388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM3</td>
<td>-21.4500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-26.1388</td>
<td>-16.7612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM1</td>
<td>24.8000(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>20.1112</td>
<td>29.4888</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM4</td>
<td>51.3750(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>46.6862</td>
<td>56.0638</td>
<td></td>
</tr>
<tr>
<td>UM3</td>
<td>LH1</td>
<td>79.4000(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>74.7112</td>
<td>84.0888</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM1</td>
<td>21.4500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>16.7612</td>
<td>26.1388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM1</td>
<td>46.2500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>41.5612</td>
<td>50.9388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM4</td>
<td>72.8250(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>68.1362</td>
<td>77.5138</td>
<td></td>
</tr>
<tr>
<td>LM1</td>
<td>LH1</td>
<td>33.1500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>28.4612</td>
<td>37.8388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM1</td>
<td>-24.8000(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-29.4888</td>
<td>-20.1112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM3</td>
<td>-46.2500(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-50.9388</td>
<td>-41.5612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LM4</td>
<td>26.5750(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>21.8862</td>
<td>31.2638</td>
<td></td>
</tr>
<tr>
<td>LM4</td>
<td>LH1</td>
<td>6.5750(*)</td>
<td>1.51844</td>
<td>.005</td>
<td>1.8862</td>
<td>11.2638</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM1</td>
<td>-51.3750(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-56.0638</td>
<td>-46.6862</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UM3</td>
<td>-72.8250(*)</td>
<td>1.51844</td>
<td>.000</td>
<td>-77.5138</td>
<td>-68.1362</td>
<td></td>
</tr>
</tbody>
</table>

(Variable: rainfed crops and trees (Tukey HSD))

Where:

* The mean difference is significant at the .05 level.

(I) land use through rainfed crops & trees; (J) Land use through rainfed crops and trees;
(I-J) Mean Difference. Therefore, this signified that variations exist across sub-Agro-
ecological zones, hence the need to understand the land use changes in each of the sub-agro-ecological zones.

**Land Use and Land Cover**

Transect walk across the AEZs, revealed the biophysical characteristics of the area and also possible causes associated with the land use changes were identified. The highlands were dominated by traditional cash crop such as tea while in the upper midland there were signs of coffee being replaced by bananas this was manifested by abandoned coffee trees under banana canopy. Intercropping and agro forestry was a common practice in the farms. Results indicated that the banana farming has overtaken coffee in UM2 and extended to the unfamiliar grounds in UM1 (Tea zone). This is because farmers perceived bananas to offer better returns than coffee. Also findings suggest that beside other forces both colonial and post colonial Government policies have influenced land use changes (Table 17).
### Table 17: Transect walk from 2213.4M forest line to 890M ASL

<table>
<thead>
<tr>
<th>SAEZ</th>
<th>LH1</th>
<th>LH1</th>
<th>LH1</th>
<th>UM1</th>
<th>UM2</th>
<th>UM3</th>
<th>LM3</th>
<th>LM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation (M)</td>
<td>2213.4</td>
<td>2153.4</td>
<td>2099.4</td>
<td>1995.3</td>
<td>1752.6</td>
<td>1526.1</td>
<td>1324.5</td>
<td>910</td>
</tr>
<tr>
<td>GPS coordinates</td>
<td>00.0513'S 37.56193'E</td>
<td>00.0527'S 037.56280'E</td>
<td>00.05215'S 037.56992'E</td>
<td>00.05499'2'S 37.58143'E</td>
<td>00.06334' S 037.61772' E</td>
<td>00.09746'S 037.70385'4'E</td>
<td>00.09625'S 037.73648'E</td>
<td>00.11349'S 037.78876'6</td>
</tr>
<tr>
<td>Distance along</td>
<td>0.3KM</td>
<td>3.3 KM</td>
<td>6.3km</td>
<td>8.3 KM</td>
<td>14.3km</td>
<td>18.3km</td>
<td>22.3KM</td>
<td></td>
</tr>
<tr>
<td>Dominant crops</td>
<td>Natural forest</td>
<td>Nyayo tea zone</td>
<td>tea and horticultural crops (tree tomato, potatoes, snaps/peas, cabbages, carrots)</td>
<td>Tea horticulture and maize</td>
<td>Coffee, Tea &amp; bananas are emerging</td>
<td>Bananas, and coffee</td>
<td>Bananas, cereals, horticulture, bananas</td>
<td>cereals and legumes</td>
</tr>
<tr>
<td>Key features</td>
<td>Thick forest</td>
<td>Tea belt</td>
<td>Marimba GOK livestock breeding farm, Meru-chogoria road and Marimba-Mitunguu all tarmac</td>
<td>Imenti tea factory</td>
<td>Emerging rural community centre</td>
<td>Urban centre ‘Nkubu’</td>
<td>Banana orchards</td>
<td>Ministry of Energy, Mitunguu-Ishiara road under construction</td>
</tr>
<tr>
<td>Land use &amp; cover type</td>
<td>Forest with dense undergrowth</td>
<td>Rain fed &amp; trees with some irrigation</td>
<td>Rain fed &amp; trees with some irrigation</td>
<td>Rain fed &amp; trees with some irrigation</td>
<td>Irrigated crop is dominant &amp; rainfed crop.</td>
<td>Rain fed &amp; trees with some irrigation</td>
<td>Irrigated crop / rain fed crop / shrubs &amp; trees</td>
<td></td>
</tr>
<tr>
<td>Land use dynamics</td>
<td>Established by Presidential order in 1986 and Act of Parliament in 1988. Now under Nyayo tea zones corporation</td>
<td>Bush was cleared by colonialist to act as buffer security zone in late 1930s. Declared special land in 1942. Handed over to individual owners &amp; title issued in 1946. Grazing, maize and peas. 1949 tea establishment after a colonial declaration to get income tax. Post-independence land sub-division leading to reduced free range hence Napier grass was introduced.</td>
<td>Tea &amp; coffee, but changing to banana, tea and dairy</td>
<td>This zone was predominantly coffee zone from 1960s to 1990s but coffee has been replaced by irrigated bananas.</td>
<td>This zone was predominantly cereals but is now mostly covered by irrigated bananas.</td>
<td>This is the Mitunguu irrigation scheme set aside by government in 1984. originally the scheme was dominated by improved mangoes, pawpaw, Asian vegetables &amp; French beans but have been replaced by bananas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LH₁-The Dairy Tea Zone

The sub-zone (LH₁) was predominately under forest and tea, with over 60% of the area forested and slightly above 32% under tea as rainfed crop and trees occupied 4.4%. The Area under open and natural forest decreased within the period under review as the area under tea, rainfed crops and trees and cleared forest increase (Table 18).

Table 18: Percentage Land use change in LH₁

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleared Forest</td>
<td>1.3</td>
<td>0</td>
<td>1.2</td>
<td>1.4</td>
<td>0.975</td>
</tr>
<tr>
<td>Open Forest</td>
<td>0</td>
<td>3.2</td>
<td>2.6</td>
<td>2.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Natural Forest</td>
<td>66</td>
<td>62.3</td>
<td>56.5</td>
<td>56.5</td>
<td>60.325</td>
</tr>
<tr>
<td><strong>Sub Total (Forest)</strong></td>
<td><strong>67.3</strong></td>
<td><strong>65.5</strong></td>
<td><strong>60.3</strong></td>
<td><strong>60.5</strong></td>
<td><strong>63.4</strong></td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>4.2</td>
<td>4.3</td>
<td>4.7</td>
<td>4.5</td>
<td>4.425</td>
</tr>
<tr>
<td>Tea Zone</td>
<td>28.5</td>
<td>30.2</td>
<td>35</td>
<td>35</td>
<td>32.175</td>
</tr>
<tr>
<td><strong>Sub Total(Agriculture)</strong></td>
<td><strong>32.7</strong></td>
<td><strong>34.5</strong></td>
<td><strong>39.7</strong></td>
<td><strong>39.5</strong></td>
<td><strong>36.6</strong></td>
</tr>
</tbody>
</table>

Therefore, substantial area under this sub-zone was gazetted as Mt Kenya forest. The Forest comprises of both indigenous and exotic tree species. Sustainability of land use system in their current status while improving on the forested area would ensure maintenance of carbon sinks for enhanced mitigation of climate variability and change. Conservation of the Mount Kenya water towers is another benefit that would go a long way in facilitating the hydrological cycle that enhances rainfall. The Sub-AEZ is also suitable for tea and dairy. Farm households practised mixed farming with livestock under zero-grazing system. Zero grazing is advantageous in that stocking is regulated, however, waste emanating from livestock need proper management to control methane which would be detrimental to the environment through increased green house gases. There is need for an empirical assessment of the impact of zero grazing on green house gases in dairy AEZs. Other crops besides tea include potatoes, cabbages, spinach, Kales, onions, carrots, tomatoes, peas, passion fruits, tree tomatoes, nappier grass, maize and beans. These crops mainly grow throughout the year with supplement irrigation especially in June to October and January to March. However, tea is
predominantly rainfed and since the economic yield is basically vegetative productivity depends on rainfall and therefore sensitive to rainfall variability. Extreme temperatures decreases production with low temperatures resulting to frost burns and high temperatures leading to reduced vegetation. Further, it was revealed that the total area under agricultural land use increased (tea and others crops) as the total area under forest decreased (Figure 14).

There was an inverse linear relationship ($r = -1$) Forest area decreased by a unit for each additional unit of agricultural area. This implies that land under forest was being replaced by Agriculture. Transect walk findings revealed that around 100M (width) along the Mt Kenya forest edge was cleared by government for tea production in late 1980s by the Nyayo tea zones development corporation. Change of forest management policies by inclusion of a smallholder agro-forestry system in the forest reserve with an intention of making farmers intercrop tree seedlings with food crops inside the forest reserve ‘Shamba system’ this lead to reduction of natural forest and increased area under rainfed crop tree intercrop cover. Several studies indicated that in return this would provide for farmers livelihood through crop proceeds while the forest department enjoy free labour in establishment and management of the tree plantations. However, farmers would only cultivate a parcel for about three years before being hampered by
the tree canopy and therefore, would be allocated another new site in the ensuing year “some form of “shifting cultivation” (KFWG, 2001; Gachanja, 2003; Kariuki, 2009). The policy has been revised and the system transformed into plantation establishment and livelihood improvement scheme targeting farming communities neighbouring the forest. Kenya forest service’s regional office indicated that by April 2012, 1037Ha of forest area was under this system with an estimated 95% under potato, tree seedling intercrop. The legislative framework gave the state the central role in management and control of forest land where the president and the minister for lands had power to allocate forest land in essence encouraged change of forest land to agriculture land.

Upper Midland One- Tea-Coffee Zone
The Tea- Coffee zone had an average of 91.75% of the area under Agriculture 65.5% attributed to area under Tea the rest of the area was under forest. Area under tea increased while, the Area under rainfed crop with trees, natural and cleared forest declined (Table 19). As the forested area decreased there was an additional unit of agricultural area ($r^2 =1$). This implied that over the years there was a tendency for the agriculture to replace forested area. Like LH1 carbon sinks were being exhausted an impediment to sustainable development and more so mitigation of climate change and variability. Findings of the transect walk revealed that the subzone was dominated by cash crop production and moderately supplemented with overhead irrigation during the dry season in order to sustain a year round supply. Among the crops were snow peas, tomatoes, onions, french beans, tree tomato, passion fruits, macadamia, avocados, bananas, tea, coffee, maize and beans. There was a tendency to abandon, replace or intercrop coffee with the seasonal crops an indication that even though this was a tea-coffee producing zone coffee was being abandoned and replaced by more paying enterprises.
Table 19: Percentage Land use change in UM1

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleared Forest</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.25</td>
</tr>
<tr>
<td>Open Forest</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0.25</td>
</tr>
<tr>
<td>Natural Forest</td>
<td>8.2</td>
<td>8.2</td>
<td>7.3</td>
<td>7.3</td>
<td>7.75</td>
</tr>
<tr>
<td><strong>Total Forest</strong></td>
<td><strong>9.2</strong></td>
<td><strong>8.7</strong></td>
<td><strong>7.8</strong></td>
<td><strong>7.3</strong></td>
<td><strong>8.25</strong></td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>26.8</td>
<td>27</td>
<td>27.5</td>
<td>23.7</td>
<td>26.25</td>
</tr>
<tr>
<td>Tea Zone</td>
<td>64</td>
<td>64.3</td>
<td>64.7</td>
<td>69</td>
<td>65.5</td>
</tr>
<tr>
<td><strong>Total Agriculture</strong></td>
<td><strong>90.8</strong></td>
<td><strong>91.3</strong></td>
<td><strong>92.2</strong></td>
<td><strong>92.7</strong></td>
<td><strong>91.75</strong></td>
</tr>
</tbody>
</table>

The structural adjustment programme policies introduced to Kenya by British wood institutions is believed to have impacted negatively on coffee development through the coffee cooperative movements (major market outlet) and as such continues to dwindle. The driving forces of land use changes in this sub-zone are complex however, is a combination of socio-economic, biophysical and policy factors. Other studies in concurrence include Jaetzold et al. (2007) coffee was ranked last in order of importance while Tea was first. Laderach and Eitzinger (2011) postulated that coffee farming was losing most of its suitability but Pea, passion-fruit and banana performed quite well on predicted changes on tea- coffee areas while Jaramillo et al. (2013) indicted that coffee farming was replaced by more profitable land uses. The high population density puts pressure on land. Rapid population growth led to subdivision of land into smaller units, land degradation and declining yields narrowing the scope for further expansion on production. The region faces threats of deforestation, depletion of natural resources and loss of natural habitat and further probable encroachment into the forests. Other findings that have indicated possible replacement of coffee due to environment changes include (Schepp, 2010; Laderach et al., 2010).

**Upper Midland Two- Main Coffee Zone**

There was an estimated 84.2% of the area being under agricultural land uses and around 14.8% under forest, while, urban settlement had occupied 2.2% of the area by year 2007. Over the years total area under forest decreased but stabilized from 2000 to 2007.
at 13.2% as that under agriculture increased but slightly declined by 1% by 2007. Over time area under irrigated crops, tea zone and urban settlement demonstrated a gradual increment (Table 20).

Table 20: Land use change in UM

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleared Forest</td>
<td>4.1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.025</td>
</tr>
<tr>
<td>Open Forest</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Natural Forest</td>
<td>14.8</td>
<td>14</td>
<td>13.2</td>
<td>13.2</td>
<td>13.8</td>
</tr>
<tr>
<td>Total Forest</td>
<td>18.9</td>
<td>14</td>
<td>13.2</td>
<td>13.2</td>
<td>14.825</td>
</tr>
<tr>
<td>Rainfed Crops</td>
<td>15.3</td>
<td>18.5</td>
<td>17.2</td>
<td>13.8</td>
<td>16.2</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>65</td>
<td>64</td>
<td>64</td>
<td>56.5</td>
<td>62.375</td>
</tr>
<tr>
<td>Irrigated crop</td>
<td>0</td>
<td>1.2</td>
<td>2.9</td>
<td>11.6</td>
<td>3.925</td>
</tr>
<tr>
<td>Tea Zone</td>
<td>1.1</td>
<td>1.4</td>
<td>1.5</td>
<td>2.7</td>
<td>1.675</td>
</tr>
<tr>
<td>Total Agriculture</td>
<td>81.4</td>
<td>85.1</td>
<td>85.6</td>
<td>84.6</td>
<td>84.175</td>
</tr>
<tr>
<td>Urban Settlement</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
<td>2.2</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Between 1976 and 1987, 4% of the cleared forest was mainly replaced by rainfed crops while between 1987 and 2000, 0.8% of area under natural forest and 1.3% of rainfed crops appear to have been converted into irrigated crops, tea zone and urban settlement. Further, between 2000 and 2007, 10.9% of area under rainfed crops and rainfed crops with trees was converted to irrigated crops, tea zone and urban settlement. Results derived from a scatter plot depicted a strong correlation between the change in total area under agricultural use and that under forest \( (r^2 = 0.936) \) since forest was being converted to agriculture while a weak correlation existed between agriculture and urban settlement \( (r^2 = 0.1645) \) than between change in forest and urban settlement \( (r^2 = 0.3885) \). Encroachment of upper Imenti forest for food production in 1980s and excision of some of the area for development by Agriculture Society of Kenya (ASK), Kenya Methodist University and Kenya Reinsurance Company led to decline in natural forest. Further, results revealed that the changes in the sum of area under rainfed crops alone and that of rainfed crops with trees were strongly correlated to changes in area under irrigated
crops ($r^2 = 0.902$); area under tea ($r^2 = 0.8697$) and area under urban settlement ($r^2 = 0.8533$). This implies that area under rainfed crops and tree intercrop was being replaced by irrigated crops, tea and urban settlement.

Ground truthing revealed that coffee was represented mainly by rainfed crop with trees land cover type while rainfed crops represented mainly maize and beans, fodder crops. Area under irrigated crops was a domain for bananas orchards. Over years, new varieties of more marketable bananas have been introduced. This changed the area once known as coffee belt to a banana zone. Technology development also enhanced the rapid increased of area under bananas due to introduction of tissue culture materials in Meru central region in 1997. Review of annual reports from the Coffee Board of Kenya (CBK) confirmed that there has been a general decline in cherry production attributable to drop in coffee prices and failure to pay farmers during 1988/89 and 1999/2000 leading to clearing of coffee bushes (CBK, 2004 to 2011). In tea farming, introduction of more drought tolerate clones has led to extension of the tea growing zone beyond UM1 to UM2. UM2 is well served with road network which unlike other zones since 1985 was served by a bitumen road encouraging expansion of urban centres coupled with hosting district administration headquarters namely Meru town, Nkubu, Kariene Kanyakine, and Igoji. These urban centres are expanding. This has led to conversion of agricultural land (area under rainfed crops and trees) to not only urban settlement but also embraced irrigation to meet the urban food supply without relying on the rainfall (seasons). Climate variability appear not to have directly influenced land use changes in UM2 but other forces seem to have had a more direct effect. This agrees with other study that other factors including expansion of urban areas can lead to land use changes (Jaramillo et al., 2013).

**Upper Midland Three- Marginal Coffee Zone**

There was an estimated average of 86.8% of the area being under agricultural land uses and around 12.8% under forest, while, urban settlement had occupied 0.4% of the area throughout the period. Over the years total area under forest remained stable but had a depression between 2000 and 2007 at 6.4 % when 4% was cleared. As from 1987 the
area under rainfed crops and shrubs was fully transformed because by 2000 the 2.9% area under rainfall and shrubs had been converted to rainfed crops and trees (Table 21).

Table 21: Land use change in UM3

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Forest</td>
<td>13.5</td>
<td>13.5</td>
<td>6.4</td>
<td>13.6</td>
<td>11.8</td>
</tr>
<tr>
<td>Cleared Forest</td>
<td>0</td>
<td>0</td>
<td>4.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Forest</strong></td>
<td>13.5</td>
<td>13.5</td>
<td><strong>10.4</strong></td>
<td>13.6</td>
<td><strong>12.8</strong></td>
</tr>
<tr>
<td>Rainfed Crops &amp; Shrubs</td>
<td>0</td>
<td>2.6</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Rainfed Crops</td>
<td>1.8</td>
<td>2.9</td>
<td>2.9</td>
<td>1.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>84.2</td>
<td>80.6</td>
<td>86.3</td>
<td>84.2</td>
<td>83.8</td>
</tr>
<tr>
<td><strong>Total Agriculture</strong></td>
<td>86</td>
<td>86.1</td>
<td>89.2</td>
<td>86</td>
<td>86.8</td>
</tr>
<tr>
<td>Urban Settlement</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The Changes in the forested area correlated with changes in agriculture area ($r^2 = 0.999$) a near linear relationship in that as forest decreased agriculture area increased almost at the same rate. UM3 harbours a portion of the lower Imenti natural forest and by year 2000 an estimated 30% of the natural forest was cleared giving way to rainfed crops tree intercrop. This was because prior to 1997 elections (a local official allocated parcels to farmers from nearby areas) but by 2007 corrective measures had been taken and initial area under forest restored. Imenti forest is important for wildlife conservation because it forms the elephant migration corridor linking Mt Kenya national reserve with the Meru National park (Mworia Mugambi - Per comm.). The area being a marginal coffee zone that experiences high evapotranspiration rate coupled with low precipitation. Presence of rainfed crop and tree land cover type modifies the climatic conditions. Like in UM2 bananas are replacing other crops. The livelihood source ‘coffee’ collapsed due to endless leadership wrangles coupled with low prices due to effects of structural adjustment programmes on cooperative sector. Like other AEZ in this study area farming was mainly mixed but growing of food crops was the major (97.4%) activity. Most farmers (92.4%) intercropped pulses and maize in both seasons however during the ONDJ season maize acted as the main crop while in MAM season
pulses that included beans, cowpeas, *Dolichus lab lab* beans and pigeon peas were the major crops. It was indicated that planting of tree crops like bananas, coffee, fruit trees and afforestation in general takes place in the long rains for it to access adequate moisture for establishment. The inter crop was perceived as a strategy to ensure some output is achieved despite the prevailing climatic conditions. Seasonal rainfall variability was an important aspect of land uses in this Sub-AEZ especially the crop mix. However, in absence of the yields data it would be insufficient to articulate the significance of seasonal/ rainfall variability. These findings tend to agree with those of other studies (Herrero *et al.*, 2010; Jaetzold *et al.*, 2007; Olson *et al.*, 2004).

**Lower Midland Three- Cotton Zone**

There was an estimated average of 96.8% of the area being under Agricultural land uses and around 2.97% under forest and grassland. Over the years total area under forest remained stable but had a sharp decline between 1987 and 2000 at 0.5 % when close to 3% was converted to rainfed crops and trees but area under grassland remained stable for the entire period. However except for irrigated crop that gradually increased area under most of the land use categories was relatively stable (Table 22).

**Table 22: Land use change in LM3**

<table>
<thead>
<tr>
<th>LULC TYPE</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>0.4</td>
<td>0.39</td>
<td>0.39</td>
<td>0.39</td>
<td>0.3925</td>
</tr>
<tr>
<td>River-line vegetation</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Natural Forest</td>
<td>3.5</td>
<td>3.3</td>
<td>0.5</td>
<td>3</td>
<td>2.575</td>
</tr>
<tr>
<td><strong>Total Forest&amp; grassland</strong></td>
<td><strong>3.9</strong></td>
<td><strong>3.69</strong></td>
<td><strong>0.89</strong></td>
<td><strong>3.39</strong></td>
<td><strong>2.9675</strong></td>
</tr>
<tr>
<td>Rainfed Crops</td>
<td>47.5</td>
<td>47.6</td>
<td>47.97</td>
<td>47.67</td>
<td>47.7</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Shrubs</td>
<td>12</td>
<td>11.35</td>
<td>11.35</td>
<td>11.35</td>
<td>11.55</td>
</tr>
<tr>
<td>Irrigated Crops</td>
<td>0.0</td>
<td>0.05</td>
<td>0.08</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>36.7</td>
<td>37</td>
<td>39.5</td>
<td>37</td>
<td>37.55</td>
</tr>
<tr>
<td><strong>Total Agriculture</strong></td>
<td><strong>96.2</strong></td>
<td><strong>96</strong></td>
<td><strong>98.9</strong></td>
<td><strong>96.1</strong></td>
<td><strong>96.8</strong></td>
</tr>
</tbody>
</table>
Changes in area under forest and grassland were strongly correlated to changes in agricultural area ($r^2 = 0.9673$) that is the area agricultural land use increased as forest and grassland decreased. Area under irrigated crops seem to be slowly replacing other agricultural land uses ($r^2 = 0.0108$). LM3 is dominated by crop based agricultural systems which are evolving from rainfed crops and shrubs to that of agro-forestry and crops alone. Reasons for decline in natural forest were as a result of encroachment of the lower section of lower Imenti forest for food crop production. Between 1987 and 2000, 84.7% of initial natural forest was replaced by rainfed agricultural practices. Though a cotton zone no single farm was observed to have the crop along the transect path. This is because cotton industry has undergone through difficulties rendering close down of the two local ginneries coupled with marketing constraints. The crops found in the farm were bananas, maize, beans, sorghum, pigeon peas, mangoes and pawpaw. In presence of irrigation facility adoption of banana production as a cash crop has gained root. Mitunguu irrigation scheme which was started in 1980s had changed the cropping system from Asian vegetables and French beans to improved bananas varieties. More importantly, over 85% of the scheme was under bananas (Per comm, Lydia Guido). Area under river-line vegetation was detected in year 2000 but disappeared by 2007. This area was cleared and converted for arrow roots, sweet potato, and banana and dry season vegetable production. Farmers tended to cultivate valley bottoms whenever there was drought. Findings of the FGD indicated that during the period there has been increased frequency of drought.

The banana plant has a sparse, shallow root system. Most feeding roots are spread laterally near the surface. Field observation revealed that rooting depth generally does not exceed 0.75 meters and water is obtained from the first 0.5 to 0.8 m soil depth ($D = 0.5-0.8$ m) with 60 percent from the first 0.3 m. As such for economic yields, banana production is better done under irrigation to supplement moisture requirements. Absence of cotton in a cotton zone due to collapse of the industry in Uganda was observed by Ebanyat et al (2010) on a study of land use drivers. Cotton was conspicuously missing in LM3 (Jaetzold et al., 2007). Olson et al (2004) noted cotton was an important crop in 1960s and 1970s since marketing was organized by a parastatal their findings also revealed that the former cotton belt of Mbeere and Embu
were being replaced by Maize, Miraa (*Catha edulis Forsk*) and horticultural crops such as melons.

**Lower Midland Four- Marginal Cotton Zone**

There was no land use changes detected based on this analysis during the 31 year period. This would therefore stand out as one of the most stable ecosystems. To a large extent the zone has 91.1% of the area under agricultural (crops) uses and the remaining under other natural vegetation comprising of forest and grassland (Table 23). This is one of the smallest sub zone constituting 1.8% of the Meru central region. There were grassland, natural forest, open forest, rainfed crop, rainfed crop with shrub and rainfed crop with trees land cover typologies. The area has a wide variety of crops which includes maize, sunflower, beans, bulrush millet, sorghum, cowpeas, green grams and mangoes. This is a sub zone that has persistently grown some of the traditional food crops since time in memorial. Road network is also poor and during wet season they are impassable. The area was perceived as malaria zone and people opted for alternative areas to settle but retained ownership rights.

**Table 23: Land use change in LM 4**

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Natural Forest</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Open Forest</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Rainfed Crops</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Shrubs</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Rainfed Crops &amp; Trees</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Imagine land was being dished out for settlement but our people looked for excuses, because they were resistant to change of their traditional habitat areas. Malaria and tsetse fly was perceived as a menace. However, later prospectively same people acquired land in Kiagu (LM 4.5), Makandune (LM 3 & 4) and Kiburine (LM 3 & 4) since it is comparatively cheaper than in the upper areas - remarked a former councillor Mzee Peter Kiruki.
Land adjudication in these areas is yet to be complete and as such selling of land is constrained. Prospectors from the upper zones hoard substantial hectarage as absentee land lords. The sub zone lies along the Meru and Tharaka-Nithi counties boundary. The belt constitutes a disputed boundary compounded with historical inter ethnic land conflicts. This has hampered meaningful land use changes.

**Lower Midland Six -Ranching zone**

Area under grassland remained unchanged for the entire period while, between 1976 and 1987 area under rainfed crop and shrubs evolved to rainfed crops, an indication that shrubs were cleared. Further between 1987 and 2000 area under woodland was cleared to pave way for rainfed crops area. The end result was a 93.06% of the area was under rainfed crops by 2007(Table 24).

**Table 24: Land use change in LM6**

<table>
<thead>
<tr>
<th>LULC Type</th>
<th>1976</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>6.94</td>
<td>6.94</td>
<td>6.94</td>
<td>6.94</td>
</tr>
<tr>
<td>Rainfed crop</td>
<td>30.097</td>
<td>83.97</td>
<td>93.063</td>
<td>93.063</td>
</tr>
<tr>
<td>Rainfed crop and shrub</td>
<td>53.88</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Woodland</td>
<td>9.089</td>
<td>9.089</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Shortage of good farmland led some Imenti ethnic group to migrate to the lower land, which receives less rainfall. These migrants established the new villages at Mugae in 1980. According to 2009 census report the population density in the study area ranges from 38 Persons/KM$^2$ in Mugae (LM6) to 657 Persons/KM$^2$ in Mariene (UM2) and on average 343 Persons/KM$^2$. There was a correlation between area under rainfed crops with shrubs and rainfed crops ($r^2 = 0.772$). Area under woodland was also strongly correlated with that of rainfed crops ($r^2 = 0.826$) (Figure 15).

This implies that over time, rainfed crop has replaced shrubs and woodland. The area receives rainfall of less than 400mm annually and not suitable for crop production. Growing of beans and maize is common in both seasons however FGD indicated that
economic yields were tenable within a span of 5 to 7 years more so during excessive rains (El Niño). This is because migrants tend to transfer high elevation crop varieties, livestock breeds and technologies to this area which is drier. Shrubs and trees are used for charcoal which forms a substantial source of income. Intrusion by camels among other livestock from the neighbouring nomads especially during dry season has been a source of conflict between farmers’ pastoralists.

![Figure 15: Trend lines between area under rainfed crops and other land use types](image)

The sub-zone constitutes 4.6% area of the Meru Central region and only found in Buuri District with Buuri division taking the bulk. Migration patterns were primarily from the upper midland areas to the highlands and recently to the drier areas of lower elevations. FGD findings indicted that some of the migrants to the drier areas found the land not conducive for agricultural production and vacated. LM6 was carved from northern grazing area and as such pastoralism was the main livelihood during pre-independence and briefly after independence. The livelihood systems have evolved to agro-pastoralism with biases towards crop production. These findings concurred with other studies done on the same location (Takaoka, 2005; Khisa, 2001). Khisa (2001) identified a similar pattern and blamed cultural reason for failure of the migrants to thrive in the harsh environment. Other studies that had identified similar patterns include (Olson et al., 2004). Oginosako et al (2006) found out that there was less vegetation in lower zones than highlands.
Drivers of land use change
In this study it was statistically insufficient to significantly associate rainfall variability, temperature or stream discharge among other measurable parameters as a driving force to land use change. However qualitative results suggest that land use varied from one sub-AEZ to another (Table 25).

Table 25: Summary of distribution of drivers of LULCC among Sub-AEZ

<table>
<thead>
<tr>
<th>Sub-AEZ</th>
<th>Drivers of LULCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₁</td>
<td>Rural population density, GOK policy on forest, topography &amp; organized tea market</td>
</tr>
<tr>
<td>UM₁</td>
<td>Landslides/precipitation, decline in coffee prices, collapse of coffee cooperatives; Rural-Population density and topography</td>
</tr>
<tr>
<td>UM₂</td>
<td>Decline in coffee prices, irrigation facility, collapse of coffee cooperatives, Rural-urban population, roads development, topography and tea clones on UM₁₂</td>
</tr>
<tr>
<td>UM₃</td>
<td>Decline in coffee prices, irrigation facility, SAPs on cooperatives, improved banana varieties and market prices</td>
</tr>
<tr>
<td>LM₃</td>
<td>Irrigation facility and improved banana varieties</td>
</tr>
<tr>
<td>LM₄</td>
<td>Absentee landlords, delayed land adjudication, drought, culture and Poor road network</td>
</tr>
<tr>
<td>LM₆</td>
<td>Drought, culture, delayed land adjudication, absentee landlords and good road network</td>
</tr>
</tbody>
</table>

Population pressure led to clamour for arable land and settlement and subsequently to encroachment of catchment areas, community forests, grazing areas and hill tops transforming such areas into fragile ecosystems with altered land use. The legislative frameworks give the state the central role in management and control of forest land. Introduction of SAPs led to liberalization of coffee industry resulting to mismanagement and low market prices and eventual abandonment and replacement of coffee with bananas in UM₂ and UM₃, Tea in UM₁. This was further accelerated by rapid multiplication of tissue culture planting materials.

4.3 Emerging Land Uses

In the recent years other land use types have been replaced by tea in LH\textsubscript{1} and UM\textsubscript{1}. In UM\textsubscript{2} other land uses were being converted into tea areas, irrigated crops or urban settlement as rainfed crops and tree land use type smothered other uses in UM\textsubscript{3}. Irrigated crops were the emerging land use type in LM\textsubscript{3} while in LM\textsubscript{6} the rainfed crop was the upcoming land use type. Each land use type is represented by a specific colour (Table26).

Table 26: Result of the emerging land uses within sub-AEZ

<table>
<thead>
<tr>
<th>Sub-AEZ/land use types</th>
<th>Rainfed crops</th>
<th>Rainfed crops &amp; trees</th>
<th>Irrigated crops</th>
<th>Tea</th>
<th>Urban settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH\textsubscript{1}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UM\textsubscript{1}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UM\textsubscript{2}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UM\textsubscript{3}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM\textsubscript{3}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM\textsubscript{4}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM\textsubscript{6}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The forested area in LH\textsubscript{1} (tea and dairy zone) experienced gradual clearance giving way to tea plantations. Tea have had relatively good prices overtime, compared to crops like coffee which is conducive also in UM\textsubscript{1} (tea and coffee zones) and UM\textsubscript{2} (main coffee zones). Based on the distribution of the sub-AEZ; UM\textsubscript{2} is centrally located besides its moderate climatic conditions. The colonial government had most of the divisional and
district administrative headquarters within UM₂ making it a fore-runner. It is also better served with infrastructural and other amenities, an impetus for urban expansion. Adoption of commercial banana production has increased the demand for irrigation infrastructure in UM₂. Rainfed crops and trees replaced shrubs in UM₃. This was caused by the population growth which aggravated demand for arable land in marginal (UM₃) and semi-arid (LM₆) therefore clearing the shrubs for rainfed agriculture. Main cotton zone (LM₃) have had irrigation infrastructure since 1986 when Mitunguu scheme was initiated among other projects leading to conversion of less profitable crops such as cotton, tobacco and grasslands into irrigated crops area.

**Main Livelihood types**

Farming was the major source of livelihood as indicated by 94.9% of the respondents. The other sources of livelihoods comprised of Professional employment, casual labour and small business combined constituted 4.4% of the smallholder farmers and 0.7% local brew (Figure 16). This underscores the importance of smallholder farmers in Meru County. It also portrays that the economy of the study area depended on how land was used. Farming is also climate dependant. Many households depended on farm livelihoods than other sources; this has exerted pressure on land as more people join the farming occupation since the number of smallholder households has in the past increased with the population.
The presence of local brew considered as an illicit enterprise may be as a result of limited livelihood alternatives. Interruptions on land use coupled with variations in climatic factors affect farming. For instance clearing of the natural vegetation to give way for crop and livestock production depletes soils and causes land degradation. Appropriate land management is imperative for enhanced sustainable agriculture. Ong’wen and Wright (2007) underscore the importance of small-scale agriculture in stimulating local and national economies. Small farms are numerically significant and an integral part of the rural community and a major contributor to household income. Agriculture in general is by far the largest single source of livelihoods and income (Ohlsson, 2000).

**Main farming Activities**

Majority (45.8%) of the respondents engaged in food crops production as their main farming activity. This was followed by cash crops production at 41.8%, dairy farming at 4.0%, poultry farming at 3.3% and livestock/beef farming at 1.8% (Figure 17).

---

**Figure 16: Households major livelihood types (Source: Field Survey, 2010)**
Majority of the respondents mainly engaging in crop production are more prone to the vulnerability caused by climatic extremes, variability and change with adverse implication on the community livelihoods. Farming in the study area was mainly mixed with more emphasis on crop production than livestock farming. Preference for food crops was slightly higher than cash crops. This is because smallholder farming is mainly subsistence, endeavouring to meet household food needs prior to the market. However, dominance of crop production in the area is enormous compared to other farm enterprises. These findings concur with that of Kibaara et al (2009) that within the central highlands where most of the household land was allocated to crop production with food crops taking over 50% shares.

**Livelihood Assets**

Factors that contribute to the economic reliance of households on a particular economic activity in general and on livelihood asset in particular may vary depending on the type of resource endowment. Therefore, the level and degree of reliance on certain livelihood sources differ across households. DFID (2001) stipulated that smallholder farming as a livelihood practice comprises of human, natural, social, physical and financial assets that they access to use through employment of appropriate strategies attain to desirable outcomes.
Human assets

Human assets in this study entailed size of household, age of household head, education level of household head, sex of household head and labour. The average household size was 5 persons. Majority (78.5%) of the household heads were male while the minority (21.5%) were female. The low number of female-headed farm household was attributable to Meru traditions, whereby the males inherit land hence giving them more access and control than their female counterparts. The average age of farm household head was 47 years with a statistical mode of 55 years, implying that the old shoves agriculture production. This poses serious questions on the future of the current agricultural practices and the appropriate alternatives to replace the ones the young perceive as outdated practices. Less youth involved in the agriculture has been a serious concern for the sector and studies have been carried out not only to find best ways of engaging youth in the sector but also to unveil their reasons for underlined minimal interest in farming. Smallholder farming operations are manual and labour intensive hence the need for the young and energetic population. The household survey established that 44.4% of the smallholders hired workers, 8.4% attributable to employment on monthly basis and the 36% under casual arrangements.

The computed total dependency ratio was 69.5% while the child dependency was 62% arising from survey data of various population age groups implying that about 69 non-working people depend on every 100 working people. While, about 62 children depend on 100 working people meaning that much of the earnings are invested in the young who are in school (education). Appropriate interventions are required in order to attract the youthful age group into farming. Therefore, mainstreaming youth programmes and working on their attitudes towards agriculture should be encouraged at all levels. The youth potential need to be tapped and injected in economic development to mitigate insecurity (Njonjo, 2010). Njenga et al (2012) identified factors that inhibit youth participation in agriculture and recommended ways that would accelerate its transformation from a non-economic traditional means of livelihood to a vibrant sector that can attract new ideas and energies that are represented by the youth. Youth and agriculture in Kenya, research conducted while compiling the regional youth in agriculture strategy 2011–2015 revealed that youth used words like ‘embarrassment’,
‘shame’ and ‘dirty job’ when discussing why young people did not engage in agriculture.

It was established that majority (54.5%) of the household heads had up to primary school level of education. Those with secondary school level of education were 26.2% while 11.6% of the household heads had never gone to school and 7.6% of the household heads had up to post-secondary level of education (Figure 18).

![Figure 18: Distribution in percentage of education level of household heads (Source: Field Survey, 2010, n=275)](image)

Smallholder farming is not highly skilled. Results suggest that farming is dominated by those who do not proceed with Education. The small proportion of household with post-secondary education might have been caused by unemployment or retirees. Traditionally the academically challenged have found solace in farming and other unskilled jobs. This poses challenges in passing knowledge on climate variability and acceptable innovations for adoption to an uninformed farmer. Expectation is that the literacy level of household head influences adoption decisions on certain coping measures. Findings by Tizale (2007) and Ibrahim et al (2011) suggested that education level significantly affect adoption of some climate variability related coping strategies.
Natural Assets
The average farm size was 1.29 Ha per household sizes ranged from 0.75Ha in UM2 to 2.93Ha in LM6. The general trend exhibited in (Table 27) indicated smaller land sizes in upper midland and lower highland zones.

Table 27: Distribution of Average land sizes in the seven Sub-AEZ

<table>
<thead>
<tr>
<th>Agro-Ecological Zone</th>
<th>Village</th>
<th>Average Land size (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH1</td>
<td>Baitegeto</td>
<td>0.86</td>
</tr>
<tr>
<td>UM1</td>
<td>Giumpu</td>
<td>0.95</td>
</tr>
<tr>
<td>UM2</td>
<td>Mariene</td>
<td>0.75</td>
</tr>
<tr>
<td>UM3</td>
<td>Heka ijili</td>
<td>0.75</td>
</tr>
<tr>
<td>LM3</td>
<td>Gachua</td>
<td>1.20</td>
</tr>
<tr>
<td>LM4</td>
<td>Kioru</td>
<td>1.60</td>
</tr>
<tr>
<td>LM6</td>
<td>Mugae</td>
<td>2.93</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2010

The rapid rate of population increase has exerted pressure on land. The upper midlands had a higher population density. The majority (76.4%) of the respondents inherited the land, while, 8.7% were allowed to use the land by various authorities, 8.4% purchased the land while 0.4% hired, leased or got the land as a gift. Further, (55.1%) of the respondents had title deeds, 42.7% lacked title deeds reason being either succession processes was incomplete or adjudication/registration process was ongoing, while, 1.5% of the respondents had title deeds for only some parcels. Historical profiles indicated that upper midland zones were the earliest settled areas. Delayed demarcation and adjudication in Lower midland areas did not only hamper developments on the land but was also a security concern within the affected ethnic groups. Key informants indicated that boundary conflicts had been experienced in the past between Tigania and Imenti around Mugae (LM6, LM5, LM4); Imenti and Tharaka along LM4; LM3 and inter clan conflicts in Mweru area of Igoji division (LM3).

“Delayed issuing of title deeds was the cause of inter and intra ethnic boundary disputes in Mugae and Rwarera location in general” remarked one of the land owners in Mugae (LM6) Mr Zachary Murithi
These views concurred with that of the area chief and Meru County land office. This in consistence with Smucker and Wisner (2008) that type of land tenure and lack of land registration led to unsustainable land use and increased conflict.

**Physical Assets**
A network of transport and communication infrastructure served the study area. Most of the roads to the farms had earth surface. Data from the Meru county roads department indicated that 257.5 km were under bitumen surface, 266.7 Km under gravel surface, and 767.5 KM under earth surface. The national grid electricity supply served the area but was not easily accessible to the rural smallholder households due to high cost of installation. Firewood was the major (98%) source of cooking fuel and 0.2% electricity, while, majority 80% used paraffin for lighting and 4% electricity. Mobile telephony had 95% connections. Physical assets especially infrastructure are playing a key role in agricultural development. Aker and Mbiti (2010) demonstrated the untapped potential that exists in enhancing agribusiness within the sector and overall economic development through information and communication technologies among other infrastructure.

**Financial Assets**
Financial institutions such as banks, savings and credit cooperative societies (SACCOs) and microfinance institutions are common and important within the study area. These institutions were the major sources of credit and other financial facilities to farmers. There were 25 SACCOs in Meru County of which 20 had Meru central region as their area of jurisdiction. There were also 16 commercial banks with branches concentrated within the major urban centres of Meru County with Equity bank, cooperative bank of Kenya having enhanced accessibility through agent banking. There were eight micro finance and four village banks. A total of 31.4% of the respondents had acquired credit in the past 2 years from these sources. SACCOs offered credit to most (51%) of the respondents than the other sources Figure 19).
Uses of credit were diverse with the majority (45.6%) of the respondents having acquired farm assets, 22.6% used the credit to meet education expenses, and 20% use the credit in off farm businesses while 9% were spent on medical services. The minority (2.8%) of the respondents used the credit for social obligations. Ministry of cooperative development and marketing (MCDM) Kenya estimates that 63 % of Kenya’s population participates directly or indirectly in cooperative based enterprises (MCDM, 2008). Various findings provide reasons why SACCOs are a major source of credit as they link borrowers and savers. The savers pool their money as savings and shares against which they borrow in form of loans. SACCOs are non-profit organizations as their basic purpose is to help members save. SACCOs are cooperatives, which provide their members with convenient and secure means of saving money and obtaining credit at affordable interest rates. SACCOs have led to the development of agriculture through credit access to acquire farm inputs, development of farm structures and equipments (Kyendo, 2011; Tache, 2006)).

Social Assets
Most (81%) of the respondents were members of one or more social groups. The general trend indicated a low likelihood of having one being a member to many groups ranging between 28% who were members of one group to 1% who were members to a total of six groups (Figure 20).
Figure 20: Distribution of number of groups household heads are affiliated to (Source: Field Survey, 2010; n=221).

This because of the level of commitment required in terms of time, financial contribution and service. Social asset, indicated by membership in a community organization in this study, appeared high considering the number of groups in existence. According to department of social services reports there were over 4500 registered groups within the study area with an estimated membership of 130,000. There was a number of social networking among smallholder farmers in the study area. Groups were used as channels of various development programmes, extension services and credit facility. Communities were empowered through groups. Group participation and reliance on support networks was a common practice in the region. The key benefits associated with the groups were, social/moral support, farm labour, irrigation water, cash/soft loan through group security and training (Table28).
Table 28: Proportional of respondents accruing group benefits

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social/moral support/clan</td>
<td>16</td>
</tr>
<tr>
<td>Irrigation water</td>
<td>18</td>
</tr>
<tr>
<td>Cash/soft loan through group security(savings credit)</td>
<td>24</td>
</tr>
<tr>
<td>Training/technological support(extension)</td>
<td>4</td>
</tr>
<tr>
<td>Sponsorship(grants)</td>
<td>6</td>
</tr>
<tr>
<td>Buying of household assets and utensils</td>
<td>1</td>
</tr>
<tr>
<td>Selling &amp; buying of farm produce(Agri-business)</td>
<td>8</td>
</tr>
<tr>
<td>Farm labour (production)</td>
<td>22</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2010

Social interaction generated benefits of collective action. Membership to social groups enhanced social networking which aided in coping with the effects of climate variability. Social associations played an integral (or critical) role in driving rural livelihoods for instant savings in form of millions of shillings were common once a community become organized into a self help group. This money was used to undertake certain projects. In this study water projects were among the activities funded this way. Also during drought and years of exceptional stress, it was pointed out that people utilized social networks to overcome shortages in that families in areas that were more affected by the stress moved to their relatives (clans) living in less affected area. For instance in the event of three days of heavy down fall families living on the landslide risky areas hibernated their relatives in safer areas. During drought periods families in lowlands traced their origin upstream in search for livelihoods. In other instances clans harboured kingship culture that assisted to cope with difficult seasons, however this system was being smothered by modernisation. Other findings that concur with this study include (Khisa, 2001; Moser, 1998).
Characterization of the smallholder households

Based on sustainable livelihood framework household assets are classifiable into human, natural, financial, physical and social capital. The variables defining these classes or factors in the sample population were generated from HH survey outputs (Table 29).

Table 29: Livelihood assets as the factor and their corresponding variables

<table>
<thead>
<tr>
<th>Factor</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical assets</td>
<td>Total value of crops</td>
</tr>
<tr>
<td></td>
<td>Total value of livestock</td>
</tr>
<tr>
<td></td>
<td>Total farm equipments value</td>
</tr>
<tr>
<td></td>
<td>Total value of household goods</td>
</tr>
<tr>
<td>Social assets</td>
<td>Membership in a community group</td>
</tr>
<tr>
<td></td>
<td>Groups one is a member</td>
</tr>
<tr>
<td>Financial assets</td>
<td>Access to loans</td>
</tr>
<tr>
<td></td>
<td>Remittances</td>
</tr>
<tr>
<td></td>
<td>Gifts/ financial aid</td>
</tr>
<tr>
<td>Human assets</td>
<td>Size of household</td>
</tr>
<tr>
<td></td>
<td>Education level of the household head</td>
</tr>
<tr>
<td></td>
<td>Age of the household head</td>
</tr>
<tr>
<td></td>
<td>Farm workers</td>
</tr>
<tr>
<td></td>
<td>Hired/employed workers</td>
</tr>
<tr>
<td></td>
<td>Gender of the household head</td>
</tr>
<tr>
<td></td>
<td>Members working off the HH's land</td>
</tr>
<tr>
<td>Natural assets</td>
<td>Size of arable agricultural land</td>
</tr>
</tbody>
</table>

Source: field survey, 2010

While recognizing that, households and communities have differential assets, the factors that contribute to the economic reliance of households on a particular economic activity in general and on livelihood asset in particular may vary depending on the type of resource endowment. Inter and intra assets variations also exist among different
variables or factors. The result indicates that 11 component score variables are representative of, and can replace the 15 original variables with only a 7.3% loss of information (Figure 21).

This implies that the remaining variables would explain the variations in household characteristics of smallholder farmers with only 11% information loss. Their contribution therefore to the household traits contained in each component was 92.7% cumulative variance. The scree plot determines the optimal number of components. Plotting of Eigen value of each component in the initial solution depicts components on the shallow slope contribute little to the solution. The component matrix (Table 3) shows rotated component matrix, which helps to determine what the components represent.
### Table 30: Results of components score analysis

<table>
<thead>
<tr>
<th>Components</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of education of HH</td>
<td>0.275</td>
<td>-0.56</td>
<td>-0.136</td>
<td>0.317</td>
<td>-0.277</td>
<td>-0.328</td>
<td>0.054</td>
<td>0.408</td>
<td>0.203</td>
<td>-0.021</td>
<td>0.319</td>
</tr>
<tr>
<td>Income from off farm employment</td>
<td>0.526</td>
<td>-0.181</td>
<td>0.198</td>
<td>0.492</td>
<td>0.357</td>
<td>0.177</td>
<td>-0.176</td>
<td>-0.296</td>
<td>-0.05</td>
<td>0.473</td>
<td>0.206</td>
</tr>
<tr>
<td>Value of all livestock in the farm</td>
<td>0.153</td>
<td>0.462</td>
<td>0.572</td>
<td>0.222</td>
<td>-0.38</td>
<td>0.026</td>
<td>0.164</td>
<td>-0.157</td>
<td>0.523</td>
<td>-0.143</td>
<td>0.18</td>
</tr>
<tr>
<td>Value of HH assets</td>
<td>0.554</td>
<td>0.058</td>
<td>0.176</td>
<td>0.032</td>
<td>0.268</td>
<td>-0.034</td>
<td>0.555</td>
<td>0.274</td>
<td>-0.305</td>
<td>0.212</td>
<td>0.173</td>
</tr>
<tr>
<td>Sex of HHH</td>
<td>-0.342</td>
<td>-0.368</td>
<td>-0.028</td>
<td>-0.136</td>
<td>-0.093</td>
<td>0.702</td>
<td>0.277</td>
<td>-0.065</td>
<td>0.23</td>
<td>0.218</td>
<td>0.17</td>
</tr>
<tr>
<td>How many work off the HH's land</td>
<td>0.3</td>
<td>0.47</td>
<td>-0.152</td>
<td>0.11</td>
<td>0.204</td>
<td>0.388</td>
<td>-0.454</td>
<td>0.45</td>
<td>0.064</td>
<td>-0.092</td>
<td>0.136</td>
</tr>
<tr>
<td>Land size in acres</td>
<td>-0.151</td>
<td>0.533</td>
<td>0.616</td>
<td>0.202</td>
<td>-0.277</td>
<td>-0.078</td>
<td>-0.071</td>
<td>0.059</td>
<td>-0.088</td>
<td>0.198</td>
<td>0.013</td>
</tr>
<tr>
<td>Are you a member of a SHG</td>
<td>-0.399</td>
<td>-0.156</td>
<td>0.403</td>
<td>-0.076</td>
<td>0.554</td>
<td>-0.224</td>
<td>0.179</td>
<td>0.075</td>
<td>0.425</td>
<td>-0.174</td>
<td>0.013</td>
</tr>
<tr>
<td>Years of HHH</td>
<td>0.359</td>
<td>0.658</td>
<td>-0.33</td>
<td>-0.098</td>
<td>0.033</td>
<td>-0.027</td>
<td>0.127</td>
<td>0.058</td>
<td>0.41</td>
<td>0.173</td>
<td>-0.148</td>
</tr>
<tr>
<td>Income from crops in the farm</td>
<td>0.66</td>
<td>0.048</td>
<td>0.233</td>
<td>-0.251</td>
<td>0.011</td>
<td>0.266</td>
<td>0.299</td>
<td>0.107</td>
<td>-0.084</td>
<td>-0.344</td>
<td>-0.29</td>
</tr>
<tr>
<td>Income from remittances/gifts/aid</td>
<td>0.437</td>
<td>-0.279</td>
<td>0.152</td>
<td>0.637</td>
<td>0.166</td>
<td>0.067</td>
<td>-0.066</td>
<td>-0.057</td>
<td>0.122</td>
<td>0.282</td>
<td>-0.37</td>
</tr>
<tr>
<td>HH Size</td>
<td>0.482</td>
<td>0.388</td>
<td>-0.476</td>
<td>-0.065</td>
<td>0.237</td>
<td>-0.209</td>
<td>0.133</td>
<td>-0.319</td>
<td>0.033</td>
<td>0.058</td>
<td>0.189</td>
</tr>
<tr>
<td>No’ of groups one is a member</td>
<td>0.637</td>
<td>-0.203</td>
<td>-0.333</td>
<td>0.138</td>
<td>-0.456</td>
<td>0.029</td>
<td>0.11</td>
<td>-0.094</td>
<td>0.102</td>
<td>-0.154</td>
<td>-0.021</td>
</tr>
<tr>
<td>No’ of farm workers</td>
<td>0.553</td>
<td>-0.227</td>
<td>0.358</td>
<td>-0.582</td>
<td>-0.039</td>
<td>-0.079</td>
<td>-0.237</td>
<td>-0.014</td>
<td>0.065</td>
<td>0.124</td>
<td>-0.045</td>
</tr>
<tr>
<td>Do you hire or employ workers</td>
<td>-0.672</td>
<td>0.269</td>
<td>-0.268</td>
<td>0.431</td>
<td>0.015</td>
<td>0.051</td>
<td>0.269</td>
<td>0.071</td>
<td>-0.088</td>
<td>-0.141</td>
<td>-0.142</td>
</tr>
</tbody>
</table>
Component 1 is highly correlated with the number of workers employed on the farms and total income from crops in the farm. Therefore, the highest between the two shall represent the other in that component. The second component is much correlated with the years of the age of the house head. The third component is much correlated with the average land size.

The 11 variables that were most correlated with the components were identified based on the highest scores as Level of education of household head (HHH); Estimated Income from off farm employment; Estimated Value of all livestock in the farm; Estimated Value of household (HH) assets; Gender of HHH; No. of HH members working off the HH's land; Land size in acres; Membership to a group; Age of HHH; Estimated Income from crops in the farm; Estimated Income from remittances/gifts/aid. Component scores are values for observations on the new (components) and reflect their values on the original variables. Thus the larger the value an observation has on an original variable, which has high loadings on a component, the higher the score on the new variable.

These 11 factors also indicate they contributed significantly and therefore led to formation of homogeneous subgroups. Analysis of variance (F statistics) was done to help in knowing the contribution of each variable in the sub-grouping process. Confidence level of 0.95 was used to check for the significant variables. Variables with large F values provide the greatest separation between subgroup (Table 31). While these statistics are opportunistic (the procedure tries to cluster or form groups that do differ), the relative size of the statistics provided information about each variable's contribution to the separation of the groups. The F test was used only for descriptive purposes because the subgroups were chosen to maximize the differences among cases in different subgroup. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the subgroup means are equal.
Table 31: Results of Analysis of Variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Error Mean Square</th>
<th>df</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of education of HHH</td>
<td>0.707</td>
<td>246</td>
<td>2.225</td>
</tr>
<tr>
<td>Income from off farm employment</td>
<td></td>
<td>246</td>
<td>9.633</td>
</tr>
<tr>
<td>Value of all livestock in the farm</td>
<td>54607.137</td>
<td>246</td>
<td>2.569</td>
</tr>
<tr>
<td>Value of household assets</td>
<td>4659.536</td>
<td>246</td>
<td>2.569</td>
</tr>
<tr>
<td>Gender of HHH</td>
<td>0.194</td>
<td>246</td>
<td>0.761</td>
</tr>
<tr>
<td>No. working off the HH's land</td>
<td>1.068</td>
<td>246</td>
<td>1.966</td>
</tr>
<tr>
<td>Land size in acres</td>
<td>19.283</td>
<td>246</td>
<td>2.10</td>
</tr>
<tr>
<td>Are you a member of a self help group</td>
<td>0.194</td>
<td>246</td>
<td>1.616</td>
</tr>
<tr>
<td>Age of HH</td>
<td>220.043</td>
<td>246</td>
<td>1.790</td>
</tr>
<tr>
<td>Total income from crops in the farm</td>
<td>26685.710</td>
<td>246</td>
<td>94.278</td>
</tr>
<tr>
<td>Income from remittances/gifts/aid</td>
<td>1144976366.093</td>
<td>246</td>
<td>.804</td>
</tr>
</tbody>
</table>

Differences exist in heterogeneity of the farm households in terms of the livelihood activities, and resource endowments. These differences also considerably determine how households’ accumulate resources or respond to various stresses and shocks (Scoones, 1998; Ellis, 2000). Therefore, classification of the sampled household into sets of homogenous groups (types) with similar socio-economic characteristic is vital in assessing the level of their assets capabilities. Since assets are the livelihood building blocks DFID (2001), changes on land use (land anchors smallholder farmers’ livelihood) would affect their households. Literature on household classification exists. For example in a study conducted by Salasya (2005) in a crop production and soil nutrient management economic analysis of households in Western and Central Kenya, used variables related to management decisions, structured farm household characteristics and distance to the nearest market to classify farms in her study. Tittonell et al (2005) used production activities, household objectives and the main constraints faced by farmers to characterize farms in assessing nutrient depletion and soil degradation in Western Kenya. Nguthi (2007) in her study on adoption of agricultural innovations by tissue culture farmers in Muranga characterized households using the five livelihood capitals. Recha (2013) characterized agro-ecological zones in Tharaka district based on rainfall...
distribution and amounts. Households Type I were closest to Type II and furthest to Type III. Type II was far from Type III compared to Type I (Table 32). Therefore, this process resulted to three household types that are defined by the means of the 11 variables. The trait for each variable was shown along the household types which reflect the characteristics of the typical case for each of the three types (Table 33).

<table>
<thead>
<tr>
<th>Cluster</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>836804.769</td>
<td>727239.642</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>836804.769</td>
<td>952438.771</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>727239.642</td>
<td>952438.771</td>
<td></td>
</tr>
</tbody>
</table>

Each of the three clusters was therefore identifiable based on the unique attributes of household livelihood assets they owned. HH_I: endowed with farm assets; HH_II: poorly endowed with assets and HH_III: endowed with non-farm assets. The household type I had a bigger proportion of their assets from crops and livestock than type I and III. An approximately 23% of the respondents also belonged to household type I and had an average of shillings 548,750 as total incomes from crops as compared to Ksh 52,128 and Ksh 94,667 of type II and III respectively. With a total Livestock value of Ksh 147,762; household type I had more livestock related assets compared to Ksh 42,297 (type II) and Ksh 40,000 (type III).
Table 33: Characteristics of household types

<table>
<thead>
<tr>
<th>Variable</th>
<th>Types(socio-economic category)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HHI</td>
</tr>
<tr>
<td>Age of House Head</td>
<td>57</td>
</tr>
<tr>
<td>Household size</td>
<td>7</td>
</tr>
<tr>
<td>Gender of HHH (%)</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Membership to a self-help group (%)</td>
<td>5.5</td>
</tr>
<tr>
<td>Education level of HHH(approx%)</td>
<td>0º:1º:2º:3º*</td>
</tr>
<tr>
<td>Land size in acres</td>
<td>3.7</td>
</tr>
<tr>
<td>Total income from crops in the farm</td>
<td>548,750.00</td>
</tr>
<tr>
<td>Total value of all livestock in the farm</td>
<td>147,762.50</td>
</tr>
<tr>
<td>Total income from off farm employment</td>
<td>158,487.50</td>
</tr>
<tr>
<td>Total value of household assets</td>
<td>206,875.00</td>
</tr>
<tr>
<td>Total income from remittances/gifts</td>
<td>22,500.00</td>
</tr>
</tbody>
</table>

*0º= Not gone to school; 1º=primary level; 2º= secondary level; 3º= post-secondary

Characteristics of Smallholder Household Type I

The type represents aged. This category of farmers had substantial wealthy in both crop and livestock the category was approximately 23% of the sample an indication that few smallholders are resource endowed. Based on their level of resource endowment the household stands a better chance to respond to shock and stress and may have resources to exploit opportunities created by positive effects. It is also presumed to have better capacity to adapt to climate variability.

Characteristics of Smallholder Household Type II

The sub group had the youngest household heads and the least experienced. This class of farmers has the lowest income levels as compared to first and third types. Cases per sub group analysis indicated that this was the largest (approximately 72%). The sub group dominated resource poor households. Results of the focused group discussion revealed poverty visible indictor in a household as Grass roofed Mud house; inability to educate children and in extreme poverty foot paths leading to the poor home are weedy a signs of not frequently stepped on. During the focused group discussions it was observed that residents of Mugae and steep slopes
of Giumpu were categorical that lack of capital hampered them from migrating to more environmentally stable sites. The type II households in were therefore constrained to either cope or exploit land use opportunities presented by climate variability. The resource poor are most vulnerable and the share of surveyed smallholder households in most continents falling below the poverty line is over 55% (Altieri & Koohafkan, 2008).

**Characteristics of Smallholder Household Type III**

The sub-group was similar age group with type I. It comprised of some the former employees who have retired into farming. This category of farmers had their capital concentrated in off farm activities. Further analysis of cases per sub-group revealed that the category comprised of 5% and had accumulated moderate assets from the on farm activities. The value of their household assets was the highest probably due to better levels of off farm incomes enabled them acquire more assets compared to full time farmers (group I & II) whose incomes were seasonal. They attained livelihoods diversification through off farm activities that would complement the on farm activities rendering group III less vulnerable to climate variability and land use dynamics.

**Distributions of household types within Sub Agro-ecological Zones (SAEZ)**

Results revealed that in all the SAEZ, over 80% of the households were categorized as type II except in LH1 and UM2 which had 37.5% and 42.5% respectively of the households in this category. Substantial proportion of households in LH1 (45%) and UM2 (37.5%) were type 1 (Figure 22). There was tendency of LH1 as the zone with the highest likelihood of finding household which were more economically endowed followed by UM2 a deviation from the expected UM1 while, LM6 had the no household in type II and 2.7% in type I an indication that LM6 was dominated by resource poor category. Results of FGD indicted that there were 80 households living in the highly landslide risk area of Giumpu. Households residing on landslide risk portion declined the Government evacuation and relocation order of 2002. Giumpu Residents live under fear coupled with social problems and as such have not invested much on the land.
On the other hand, Mugae was originally a part of the northern grazing area but through political interventions, the land got allocated to landless people. The migrants came from the highlands. Unable to adapt to pastoralism, they migrated with what they knew most as midland maize varieties (5series), beans and even Irish potatoes. The culture persists. Mugae suffer frequent droughts with one good season in five years. The FGDs revealed that Mugae residents live there for lack of better alternatives and if one acquired what they term as wealth status “Gitonga” quits and settles elsewhere. The coping strategies are limited to unsustainable exploitation of natural resources majoring in charcoal burning and mining ballast stones. The coffee zones (UM2 i.e. Mariene and UM3 i.e. Ruiri) happened to have a relatively high number of coping strategies this was because after collapse of the industry in early 1990s farmers diversified livelihood sources. LH1 dominated by tea farming had less livelihood diversity. Tea prices have had an increasing trend. Suitable alternatives to tea were horticulture and dairy enterprises which had remained stable over time. The resource poor in LH1 also got employment in the tea, horticulture and dairy sub

“In case of two to three days of heavy down fall we hibernate to Yururu (neighbouring low risk areas). Therefore, these are people on the run and cannot undertake meaningful developments on their sloppy farms” affirmed Giumpu sub chief.
sectors. Except households in LH1 and UM1, the other Sub-AEZ has above 80% of the households in the resource poor category. Higher number of households (97.3%) in LM6 fall on least resource endowed household type ‘2’ depicted in (Table 35). LM6 is on the leeward side of Mount Kenya and borders Isiolo district. The area is categorised as one of the ASALS (Arid and Semi Arid Lands) in Kenya. Though a portion of the northern grazing zone results of household and FGD indicated less pastoral activity and more of crop farming. The historical perceptive indicated that; in the late 1960’s a former state official, allocated people land from the densely populated upper zones. Some families settled in the area at the time, others sold their parcels or held them vacant for future. The early settlers struggled to survive under wildlife menace and harsh weather. A new generation of people, however, is emerging who are making efforts to exploit underground and surface water to supplement crop moisture requirement. Interventions by Meru dry land farming project an initiative of SOS Sahel of United kingdom to promote drought tolerant crops and agro-forestry trees led to adoption of dryland technologies that have improved resilience of the residents. Otherwise due to the proximity of the proposed vision 2030 satellite Isiolo city of the area is now strategically positioned for urbanisation.

Characteristically household UM1 has a high productivity potential closer to LH1 (Jaetzold et al., 2007; Olson et al., 2004) and was therefore expected to have fewer households in type II than UM2 or UM3. Sample of UM1 were selected from the highly sloppy areas of Abogeta Division. This was one of the fragile areas, characterized by frequent landslides during rainy seasons. Results of FGD indicated that 80 households living on the most risky portion of Giumpu village were dislocated by the Government after the catastrophic 2002 landslide to the lowlands (Mitunguu), but migrated back to the area. People live in fear of eviction and landslides. The zones would be the least economically endowed hence has highest likelihood of being rendered vulnerable in cases of climate shocks. Studies demonstrated that spatial and temporal considerations are vital and are determinants of driving forces of land use land cover change (Alcano et al., 2003; Campbell et al., 2005). Other studies suggested that unless in cases of modification, Agricultural productivity potential decreases from humid (high elevation) to (low elevation) arid areas (Olson et al., 2004; Jaetzold et al., 2007; Fischer et al., 2005; Smucker, T.A
and Wisner, B., 2008). However, environmental degradation is known to erode the potential and if unabated may render the area vulnerable to hazards (Majule, 2003). Furthermore the land is severely degraded making it expensive to rehabilitate.

4.4 Future projections on land use and cover types
Agriculture land use comprised of cultivated area under crops and grazing. Area under Mount Kenya forest, open forest of lower and upper Imeni constituted mixed Forest land use while, area under single species forest comprised of reafforested areas under pure tree stand of pines, cypress, eucalyptus; and agro forestry trees such as graviliea. Other common features of this land use type include wood lots. Open ground land use type comprised of land that was bare. This is the land mostly in the non-arable areas that contains murrum, rocks or sand. The arid land use was concentrated in the pastoralist area in the northern grazing zone towards Isiolo County.

The other land use type mainly comprised of water body, riverline vegetation and built up area constituted 0.02%. Due to its small size it is difficult to locate in the image unless magnified. Area under agriculture increased by 28.66% while the combined forested area decreased by 31.14% by 2025 (Figure 23).

Figure 23: Quantitative projections of trends in land use
This scenario projection was based on assumption that the existing land use trend continues (holding all other factors constant). The past and current practices emphasised on expansion of area under agricultural production. In 2000, area under the mixed forest land use type occupied an estimated 21.5% of the county but decreased to around 1.5% in 2025. The area under single species forest accounted for approximately 26% in the year 2000 but declined to 14.3% by 2025. The area under open ground comprised of approximately 0.1% in size by 2000 but increased to around 0.28% in 2025. The area under arid land use though small in size increased to 0.558% by 2025 from 0.456% in 2000. Other land use type was restricted as per the conversion of land use and its effects at small regional extent programming requirement and therefore no changes were envisaged. The trees found in areas would be lost and replaced with crops due to diminishing forested area and increasing agricultural area. This aggravated land degradation leading to extension of open ground and area under arid lands (Figure 24).

Figure 24: Spatial outlook in 2000 and projected outlook in 2025
Expansion of farming under the existing smallholder practices would mean more of rainfed agriculture, which would extend to lower midland zones for instant LM3, LM4 and LM6 but due to fragile nature of these ecosystems, land degradation would be accelerated. These areas also experience frequent crop failure which would leave the soils bare and vulnerable to erosion during both dry and wet season. When faced with increased demand for agricultural production the reaction has been to gradually spread cultivation to the unused land rather than pursue innovative options for instant new technologies for increased productivity. Clearing of vegetation leads to loss of biodiversity, reduced carbon sinks and eventual desertification. This scenario portrays that, the unprotected land exist for farming, in disregard of the environmental consequences.

Land sizes are smaller in LH1, UM1, UM2 and UM3 than in lowlands due to high population density. Areas with small land sizes would lean towards intensive farming now and in future contrary to LM3, LM4 and LM6 where expansion (extensification) is possible. When land is available and accessible intensification is unlikely. In the LM4 and LM6 where ownership rights are not assured by the legal requirements (incomplete adjudication) there is tendency to extensify than intensify land use. The precarious nature of smallholder rain-fed farming is risk averse, making intensification a poor alternative.

Numerous constraints tend to affect agriculture, including inadequate capital, market development, inadequate resource allocation, technological limitations, and tenure insecurity and lack of awareness of issues and alternatives and environmental degradation. These limitations cause low production per unit land and therefore rendering the smallholder farmers into a cycle of food insecurity and poverty. Under such circumstances farmers are constrained to access inputs in order to improve production and therefore, forced to pursue other options of expanding or shifting to more fertile lands. To create an enabling environment for intensive farming there is need to commercialize while ensuring availability of well organized markets, input accessibility and appropriate infrastructural network.

In the lowland zones (LM3, LM4 and LM6) crops would thrive better under irrigation which may lead to further depletion of surface and ground water hence impact on
the natural hydrological cycle that would disturb rainfall. Irrigation also ensures continuous cropping throughout the year. This is believed to enhance intensification. However, it depletes water volumes affecting human activities downstream. Irrigation development remains a major vision 2030 strategy for boosting the national food security. Posing a dilemma which can be viewed as an intensification paradox in that to achieve better productivity through intensification, irrigation is imperative; the intervention that threatens the already scarce water resources.

The determinant of which direction agricultural developments takes depends on livelihood capabilities, structures and processes that facilitates the households in embracing livelihood strategies to achieve wellbeing. The proportion (72%) of the sampled household found within the bracket resource poor sub-group is indicative that there exist land use associated constraints in reference to smallholder farms in Meru County. This has been exacerbated further by declining river stream discharge and erratic rainfall.

This scenario fails to recognize global and local policies. Past experiences in Kenya where natural forest were excised for human settlement, water catchment destroyed, indiscriminate logging and rampart grabbing of land are indicative that such a scenario is likely. This would perpetuate into cyclic conflicts as people fight for the depleted natural resources, poverty and later natural selection of some form would set in. Malthusian theory articulates that the growth of human populations tends to outstrip the productive capabilities of land resources. The result is that resources place a direct restriction on population growth and size and ‘positive’ checks (famine and increased mortality) or preventative checks (limitation of family size), implying that uncontrolled exploitation of land can be a precursor for destruction of living earth systems (Marquette, 1997). Waswa et al (2007) observed that for a more logical and effective approach in pursuit for sustainable development, it would be advisable for a shift in thinking and practice towards restructuring the human-environment relationship that the human activities may be synergized in tandem with the ecosystem process. Boserup agriculture intensification theory stipulated that demand for increased agriculture production, when land is scarce will result to agriculture intensification (Marquette, 1997). However, Reenberg et al (2003) argued that both expansion and intensification are indicators of agriculture
development but that takes place at different stages of the process. Poor agricultural intensification for development in turn implies tendency to convert forests and other marginal lands to crop production. In developing economies the decline in forest was associated to land conversion, particular agriculture expansion (FAO, 2003). This scenario thrives best in narcissistic society that fails to recognize the role of natural environment as a human life support system. Under the global qualitative scenario discourse the trends in this scenario are coherent with barbarisation world view (Raskin et al., 2002).

Projections for year 2030 and beyond the calculated values for area under agriculture exceeded 100% and that of mixed forest were below 0% this demonstrates some weakness of quantitative scenarios and that projecting land use beyond 2025 becomes unrealistic. The uncertainty of addressing the deficient land required implies extending land allocation to other counties which are administratively autonomous. Therefore, projection up to year 2025 was to avoid a lot of grave uncertainty in the evolution of land use. Butcher (1999) concurs that it is impossible to develop realistic land use extrapolations for a period of more than 20 to 30 years. The qualitative scenario development addresses such weaknesses.

**Qualitative scenarios**

Qualitative scenarios are plausible. They give alternative pathways that are possible in future and therefore address deficiencies in the quantitative scenarios. Drivers of land use change as extracted from the results of participatory methodologies were summarized. Storylines guided by main drivers of land use culminated into qualitative scenarios which were in tandem with conventional and great transition worldviews.

**Scenario 2: Market driven**

Market forces scenario was partly based on the historical trends followed by developed countries but at a faster rate because most of these technologies are ready. It underscores Kenya becomes industrialized and middle income economy with functional environmental management policies. Agriculture intensification with enhanced adoption of appropriate technology rehabilitated the degraded land improving yields and therefore reduced demand for expansion of area under
agriculture from a peak of 62% in 2015 to 56% in the period 2025-2035. Area under fast growing trees (single species) combined with the slow growing indigenous trees in the mixed forest increased to meet the growing demand of wood products therefore reduced the rate of deforestation. Maintenance of balanced carbon sinks was upheld through elaborate support and reward systems. Area under mixed forest (predominately natural) surpassed single species forest by 2020 at over 20% attaining a combined forest cover of 42% of the total area year 2030 to 2035 (Figure 25).

Figure 25: Land use trends under “market forces” scenario

Existing and new policies were reviewed to realign with sustainable development concepts and practices. In return optimum agriculture yields were attained. Farmers adopted agribusiness approaches and in addition empowered to institutionalize their enterprises which enhanced implementation of sustainable land management interventions. Findings indicated that the County is using commodity value chain approaches which were in the process of formalizing marketing entities (cooperatives, producer business groups or companies). Increased commercial agriculture led to development of profit oriented farming systems that emphasized
on economic efficiency resulting to increased yields per unit area. The food demand was compensated for by adoption of technologies, cropping intensity and increased use of inputs such as fertilizers. Foods and other products that were cheap elsewhere were imported stabilizing area under agriculture at between 60% and 50%. Over 60% of the population was 35 years and below but perceived to dislike agriculture. This posed challenges on the future of the traditional agricultural practices. However, enhancing and integrating among others information technologies into agricultural system would attract the young. Private sector was perceived to have done better than public in this sub-sector; therefore enhancing private public partnerships policies would accelerate commercialisation by embracing the information technologies. Agrarian reform at a time when available technologies are more advanced compared to initial era of agrarian revolution fast tracked food and fibre sufficiency. Thorton (2010) predicted increased demand for food between 2010 and 2025 driven by a rise in population and dietary change spurred by the economy, while meat and cereal demands are expected to double between 2000 and 2050. Therefore, the world food markets are likely to be influenced by increasing resource scarcity. A key modulating factor will be enhanced investments in farm output and intensification on agriculture area. Around 78% of the global increases in agriculture supply have been achieved through increased yield and greater efficiency in the supply chain; while a mere 15% has come from expansion of arable area (Smith et al., 2010).

Irrigation development remains a major strategy for boosting the national food security. Meru County targets a 30% growth in area under irrigation for the next 5 years from the current 13,000Ha. Though, experts peg the potential irrigatable area in Meru County at between 60,000 and 80,000 Ha. Under existing water management practices would be a challenge and therefore need to investment in appropriate market driven technologies such as drip irrigation and water harvesting and conservation.

Restriction from access to natural forests created opportunities for development of farm forest to meet growing demand. Deforestation resumed from 2015 but at a slower rate due to the demand of forest products by mainly the construction. The increasing population coupled with industrialisation increased demand for forest
products. However, synthetic fibre leveraged the demand lowering the rate of deforestation to 0.3% between 2015 and 2025.

Area under other land use types which includes built area increased gradually with the growth of national economy. The expected development in mining industry and improved infrastructure accelerated industrialization and urbanization with the establishment of Isiolo city. Such developments stimulated and aggravated urbanisation in Meru County due its infrastructural, economic advantage and proximity to Isiolo city. About 32.3% of Kenyans live in urban areas compared to 12% of Meru county urban population an indication that Meru is largely a rural county. Annual Urbanisation rate in Meru County has had a declining trend, between 1979 to 1989 it was 1% and 1989 to 1999 was 0.98%. Urbanization rate increased to 2.1% between 1999 and 2009 (GOK, 2010d and computations from Kenya population census reports, 2009, 1999, 1989 and 1979). The increase from 0.98% to 2.1% was as a result of established institutions of high learning. The Kenya Methodist University and Meru University of Science and Technology among others in the urban centres of Meru, Nkubu and Maua expanded bringing more people to urban centres. The current national annual rate of urbanisation of 4.36% exceeds that of Meru. The rate of change for built up area ranges between 0.2% and 0.3% therefore from 2010 to 2025 it was pegged at an average rate of 0.24%.

The market forces scenario is a culmination of a chaotic world depicted in the barbarisation scenario which precipitated into clamour for reforms. Implementation of constitution of Kenya 2010 was delayed therefore pushed actualization of the new dispensation to 2015. People expressed their dissatisfaction resulting to a new dawn where ways of ensuring the rule of law was articulated. The devolved units underwent a turbulent period that formed lessons for subsequent government. After 2017 there was sanity in running of devolved government. Leaders were called to account. The proximity of the county government to the people coupled with application of Information Technology and Communication (ITC) hastened investigation apprehending those who had misappropriated resources. Agitation for transformation culminated into the government embracing a conventional world view that emphasized on fast tracking economic growth, environmental equity
through better technology and management that evolved to new values of life the art of living. Appropriate policy reforms were carried out and measures were institutionalised to implement these reforms with the support of a majority of the citizens. Accountability, transparency and other desirable attributes of good governance intrinsically resonated with the populace. The transformative development path was entrenched and actualized leading to improved human well being. This led to realisation of vision 2030 where national equity was equivalent to that of the developed world.

Scenario 3: A paradigm shift towards the dreamland

The great transition depicts a transition from gloom world (2000-2017) via economic growth, environmental equity through better technology and management (2017- 2030) to sustainability as progressive global social evolution beyond 2030. In return optimum agriculture yields were attained at 50% area under agriculture from the current 59% with a peak of 62%. The mixed /natural forest slightly but steadily increased while, single species /exotic forests were restored and stabilized leading to a total tree cover of 47.6% of the total area (Figure 26).

![Figure 26: Land use trends “paradigm shift towards the dreamland” scenario](image)

The global orders shifted towards a humane world beyond 2030 where life values were emphasized. Materialism was shelved; people co-existed and shared what was available for common good. The longevity increased the aging population leading to establishment of welfare systems that attracted local and global support. The
Population increase was managed, agricultural productivity increased as people valued quality of food than quantity. Environmentally acceptable technologies were adopted such as integrated crop and soil management, agro-forestry, minimum tillage, soil and water conservation were employed in all the agroecological zones. This accelerated rehabilitation of the degraded land. Good agricultural practices were attained through transformation of extension, marketing and research service delivery systems to a more balanced agriculture that endeavours to meet the present needs not neglecting the needs of the future generation. Use of natural and organic inputs and in long run increased yields and health foods. This also protected land against degradation. Therefore, this combined with technology advancement led to a record increase in agricultural yields.

The area under ‘others’ slightly increased due to urbanisation in order to accommodate rural-urban migrants. Awareness and education on appropriate environment led to transformation of residential areas into better habitation. Clean development mechanisms (CDM) adopted in development of upcoming industries as existing ones work within defined timelines to make systems CDM compliant. Standardization framework articulated for green homes were adopted in pursuit for better life. Reforestation and afforestation of 2020 to 2030 culminated into a stable forest close to half (47.6%) of the total area of the county. Conservation of forest enhanced ecosystem balance increasing biodiversity. Community awareness on the importance of green world instilled value in not only good living but more so on life support systems. Local communities enhanced rewards and compensation processes that were mainstreamed in management of sustainable natural resource to protect indigenous species and natural systems. Scenario authors have attempted to discern the likely outcome of a range of expected trends, outlining the implications of various assumptions not necessarily chosen on the basis of likelihood or examine the likelihood and implications of desirable futures or risks of unwelcome ones (Raskin et al., 2002). The paradigm shift towards dreamland scenario is in term with the great transition. Great transition envisages essential social and institutional transformation towards sustainable forms of social, environmental and economic development resulting to enhanced human civilization (Swart et al., 2004).
CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary
The main objective of this study was to assess the relationship between land use changes and climatic variability and their effects on smallholder livelihoods with the ultimate aim of deriving lessons towards sustainable agricultural land management. There has been variability of climatic factors. Majority (91.6%) of the respondents concurred that there was climate variability, which 50.9% linked it to the rains becoming more erratic. Food insecurity was identified by 64.8% as a major negative effect of climate variability.

The emerging land uses which include tea and irrigated crops have had short term gains; however, there was insufficient evidence to confirm that the trends observed in land use are caused by decadal rainfall trends. In six out of the seven sub-agroecological zones changes in inter-land use types occurred but no marked changes were detected in low midland sub-zone four. These changes were linked to different drivers from one agroecological zone to another but were inclined towards technology development and adoption, policy changes and infrastructure. In low midland four and six, among others drought, insecurity and culture were land use drivers’.

Tea farming was the emerging land use type in low highland one and upper midland one. In upper midland two other land uses were being converted into tea areas, irrigated crops or urban settlement as rainfed crops and tree smothered other uses in upper midland three. Irrigated crops were the emerging land use type in low midland three while in low midland six the rainfed crop emerged. How households used land determined the level of asset endowment. This led to 97.3% in Low midland six being in least resource endowed households type since, though a livestock zone, the area was predominately used for food crop production. In absence of landslides and drought interruptions a coherent relationship existed between household resource endowment and agro-ecological zone. Whereas a big proportion of respondents in tea-dairy and main coffee zone had enhanced assets, majority (86.84%) in tea-coffee zone that had experienced landslide belonged to the least asset endowed household
type. Emergence of crop production in livestock zone eroded livelihood assets in lower midland six.

The projected land use under quantitative scenarios depicted agricultural land use would cover up to 86% by 2025 replacing 31% of forested area as more land become arid and open ground. This scenario was synonymous to barbarisation world view under qualitative scenario. Under conventional world view “market forces” area under agriculture reduced from 61% in 2010 whereas combined forest cover of 42% of the total area was maintained from year 2030 to 2035. Under great transition scenario “paradigm shift towards dreamland” driven by the desire for a humane world, area under agriculture reduced from the current 59% to 50% while mixed/natural forest slightly but steadily increased while, single species/exotic forests were restored and stabilized leading to a total tree cover of 47.6% of the total area.

5.2 Conclusions

Whereas some divergence between measured parameters and respondents’ perceptions on climate variability parameters occurred, climatic variability is increasingly being seen as a reality and no longer a perception. Changes in rainfall remain the key indicator of climatic variability among farmers. Since variability in rainfall was more pronounced in the first season than in second season, more careful planning for land performance is needed during season one. Farmers’ responses to perceived forms of climate variability were haphazard and not articulatedly implemented as evidenced by uncontrolled abstraction of stream water for irrigation, or the tendency of planting crops one to two months before onset of rainfall to mitigate effects of perceived drought risk. Such parallels between community perceptions and empirical findings would undermine development of solutions against declining agricultural productivity.

Climate variability was linked to land use changes in short term since seasonal rainfall variability influenced changes in farming practices and by implication determined land use performance. However, there was no evidence to associate changes in land use to decadal rainfall trends. Land use changes were certainly being caused by other factors such as population growth and government policy, whose relative importance calls for further studies. Existence of good roads led to urbanization in upper midland 2, whereas irrigation development drove changes in
upper midland 1 and 2; and low highland 1 and low midland 3. Land use changes in low midland sub-zone six and upper midland sub zone one were driven by drought and landslides and in addition aggravated by climate variability.

Increasing conversion of land to agricultural is associated with decline in forest cover and stream volumes, hence their services to communities. Replacement of some of the predominate livelihood crops such as coffee and cotton with crops such as bananas are likely to cause significant disruptions in livelihoods in the short term and perhaps stabilize in future.

Extrapolating land use changes depicts a scenario of declining forest cover and more intensive agriculture, commensurate with the increasing population. Planning for sustainable intensive agriculture at both household and county levels will be inevitable. Similarly, protection and conservation of threatened forest cover, and proper management of stream water for irrigation need careful planning.

5.3 Recommendations
This study recommends the following:
To integrate community perceptions with the empirical findings to build synergy for enhanced responses to climate variability. This could be achieved through embracing participatory approaches to identifying and analysing envisaged trends of variability using both measured and perceived data to develop community action plans to drive a harmonized implementation. For instance a topo sequenced participatory seasonal weather forecast scenario development for stakeholders could generate sub-agroecological zone specific interventions in subsequent seasons. Further, for continuous improvement it may necessitate putting in place a feedback mechanism such as review forums.

Mitigation of negative effects of climate variability on land use which focuses on seasonal land use patterns for enhanced land use performance or productivity. This may be done through identification, development, dissemination and adoption of appropriate technologies through participatory processes. Such interventions would be tailored for specific agroecological targeting. Further, studies to ascertain the driving forces of land use changes in various agroecological zones.
Restoration of forest and degraded lands through reforestation, afforestation and soil and water conservation practices. Liberate more land for forest development through agriculture intensification for increased production per unit area and diversification to non-agricultural livelihoods. Also undertake measures to empower smallholder farmers to rehabilitate their farmland such as compensation schemes while enforcing environmental management statutes for improved livelihoods.

To maximise on future planning for mitigating and or adapting to the effects of climate change, people-centred scenarios analysis that integrates current realities and visions of the future need to be mainstreamed at county level. The line ministries, civil societies and other key stakeholders in climate change dialogue should play vital roles in this.
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7. APPENDICES

7.1 The Government Departmental Head

Department ……………………………………………………………………………………
Title ……………………………………………………………………………………
of Respondent………………………………………………………………………
Specialty ……………………………highest grade attained…………………………
District…………………………….di ision where applicable………………………..

1. Distribution of Agro Ecological Zone (AEZ)/sub AEZ in your district/ division.

<table>
<thead>
<tr>
<th>AEZ</th>
<th>Division</th>
<th>proportion of area covered by the AEZ as a % of total divisional area</th>
<th>3 Major enterprises found in the area</th>
<th>Key sources of livelihoods</th>
<th>Climate related risks associated with the sources of livelihoods</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH1</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UM1</td>
<td></td>
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<tr>
<td>UM2</td>
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<tr>
<td>UM3</td>
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<tr>
<td>LM3</td>
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<tr>
<td>LM4</td>
<td></td>
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</tr>
<tr>
<td>LM5</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

2. Briefly explain how changes in climatic conditions have impacted on your clientele in the district? Please categorize the impacts, drought/Elnino; short season rainfall variation s; long season rainfall variations; high temperatures) e.g. drought causes food insecurity; loss of cover vegetation accelerating soil erosion etc.
3. Does the intensity of these impacts vary from one AEZ to another?
   Yes [ ]   No [ ]

4. If yes please indicate how climate extremes, variability and change impacts affect the AEZ?

<table>
<thead>
<tr>
<th>LH1</th>
<th>UM1</th>
<th>UM2</th>
<th>UM3</th>
<th>LM1</th>
<th>LM2</th>
<th>LM3</th>
</tr>
</thead>
</table>

5. Considering the key enterprises that contributes to the well being of the people in various AEZ listed (Q1) above. Please briefly explain how climate extremes, variability and change impacts on each of the enterprises.

<table>
<thead>
<tr>
<th>LH1</th>
<th>UM1</th>
<th>UM2</th>
<th>UM3</th>
<th>LM3</th>
<th>LM4</th>
<th>LM5</th>
</tr>
</thead>
</table>

6. How is your department addressing the impacts of climate extremes, variability and change in (Q2)?

7. What challenges are you facing as you intervene to the impacts of climate extremes, variability and change and how are you overcoming them?

...........
8. For the livelihoods that are dependent on climatic conditions how do your department help the community cope or adjust to negative impacts of climate extremes, variability and change?

9. Does your department perceive some portions of population or locations (areas) of the farming communities more vulnerable than others?
   Yes [ ] No [ ]

10. If yes who are they and why?

11. What projects/programmes do have that target the most vulnerable smallholder farmers.

12. Are there specific programs that only target climate induced vulnerability?
   Yes [ ] No [ ]

13. If yes which one.

14. If you are to rank causes of vulnerability, where would you place climate induced.
   Very high rated. [ ]
   Moderate [ ]
   Low [ ]
   Negligible [ ]

15. Is there a set criterion that your department uses to identify vulnerable groups among small holder farmers? Please explain.

16. What indicators do you use to identify vulnerable groups?


17. Rank AEZ according to how vulnerable they are to

<table>
<thead>
<tr>
<th>AEZ</th>
<th>Drought and Lanino</th>
<th>Elnino</th>
<th>Short rains failure</th>
<th>Long rains failure</th>
<th>High temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₁</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>UM₁</td>
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<tr>
<td>UM₂</td>
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<tr>
<td>LM₅</td>
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</tbody>
</table>

Indicate 1, 2, 3, 4 or 5 in the boxes where: 1-very vulnerable; 2- vulnerable; 3- moderately vulnerable 4- slightly vulnerable; 5-not vulnerable

NB. Vulnerability implies to the likelihood to suffer disaster in case of drought, storm, Elnino insufficient long rains or any other climate shock.

18. Rank the 5 most vulnerable locations in your district starting with most vulnerable and give reasons of each.

Coping and Adaptation Strategies

Coping strategies are short term measures geared to assisting the target group of people recovers from the effects of bad weather. Whole adoption strategies are planned activities or automatically adjustment aimed at assisting the target groups of people recover from effects of bad weather.

Irrigation project is adoption strategy but famine handouts to drought stricken population is a coping strategy.

19. How is your department assisting smallholder farmers
   a. Cope with bad weather

..................................................................................................................................................
b. Adapt to bad weather.

…………………………………………………………………………………………

c. Take advantage of good seasons

…………………………………………………………………………………………

d. Adapt to challenging climate.

…………………………………………………………………………………………

e. Mitigate the effects of green house gases/global warming.

…………………………………………………………………………………………

20. Has your department put in place any deliberate measures in relation to adaptation to current and future climate change impacts?
   Yes [ ] No [ ] Do Not Know. [ ]

21. If yes which ones?

…………………………………………………………………………………………
…………………………………………………………………………………………

22. At district/divisional level have you put any deliberate plans to address the impacts climate change, variability and extreme?
   Yes [ ] No [ ]

23. If yes which ones?

…………………………………………………………………………………………
…………………………………………………………………………………………

24. In your own opinion do you think smallholder farmers have been coping and adapting by use of either traditional or indigenous techniques?
   Yes [ ] No[ ]

25. If yes how?

…………………………………………………………………………………………
…………………………………………………………………………………………

26. Do you think the smallholder contribution towards offering solutions to climate change, variability and extreme challenges is significant?
   Yes [ ] No. [ ]
27. If yes explain?

…………………………………………………………………………………………
…………………………………………………………………………………………

28. If No explain?

…………………………………………………………………………………………
…………………………………………………………………………………………

29. Are there other institutions in the District that are addressing climate change, variability and extreme impacts?

Yes [ ] No [ ]

30. Who are they and how are they addressing climate change, variability and extreme impacts?

…………………………………………………………………………………………
…………………………………………………………………………………………

31. In the climate change discourse do you see any opportunities to exploit?

Yes [ ] No [ ]

32. If yes list and describe them?

…………………………………………………………………………………………
…………………………………………………………………………………………

33. Comment regarding the future of smallholder farming in reference to the land use dynamics, land degradation what mechanisms ought we need to employ for a more sustainable land management system (Prepare this for a brainstorming group discussion for future scenario development).

7.2. Non-state service providers

Name of organization……………………………………………….
Name of respondent……………………………………………….
No. of years worked in disaster management……………………….
District…………………………………………………………………….
Division…………………………………………………………………….
Location………………………….Sub-location…………………….

34. From the institutional point of view has there been climate change, variability or extreme weather conditions? Explain briefly.
35. What are the impacts of climate change on the 4 districts of Meru central region?

36. Based on your experience on sources of livelihood, are there groups of people that are more vulnerable to impacts of climate change variability and extremes (CCVE)?

Yes [ ] 2. No [ ]

37. If yes list them down according to their sources of livelihoods starting with the most vulnerable.

38. Briefly describe your roles in disaster /vulnerability management in relation to impacts of climate change variability and extremes.

39. Briefly explain the deliberate measures your organization has taken in management of past and future climate related disasters in the region. Please indicate the type of disaster when & where it occurred and its impact on the community.

40. Briefly describe your previous, current and planned programmes (please indicate the locality, magnitude or coverage, target population, type of assistance, programme period, programme budget etc) targeting the following:-

1. Drought stricken people.

2. Land slide or mud slide affected communities.

3. Floods affected communities.
4. El-nino affected communities
5. Wind affected communities
6. Famine affected communities.
7. Soil improvement management constrained communities.
8. Water and irrigation management constrained communities.
9. Other weather related constrained communities
41. At organizational level what opportunities have you identified or think climate change provides (positive impacts)
42. How do you intend to use the identified opportunities to improve the livelihoods of your client in Meru central region?
43. What are your major challenges in dealing with the impacts of climate change variability and extremes?
44. How do you intend /plan to overcome these challenges?

45. How are the smallholder farmer coping and adapting to impacts of climate change variability and extremes?

46. What challenges do the small holder farmers face in addressing impacts of climate change variability and extremes?

47. Comment regarding the future of smallholder farming in reference to the land use dynamics, land degradation what mechanisms ought we need to employ for a more sustainable land management system (Prepare this for a brainstorming group discussion)

7.3: Household Survey Questionnaire

Questionnaire No… Date of interview……………………………
Division …………………………………………………………………
Location …………………………………………………………………
Sub-location ……………………………………………………………
Village ………………………..Administrative unit…………………………
Name of household head …………………………………………………
Main respondent relationship to h/head (if different from h/head)……………………
Interviewee’s name ………………………………………

Section 1: Household Demography, Education Status and Occupation

1. What is the age (years) of Household head?

2. Can you describe your household in terms of age and gender?

3.
<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td></td>
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<tr>
<td>15-30</td>
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<td>30-45</td>
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<td>45-60</td>
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<td>60+</td>
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<tr>
<td>Total</td>
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</tbody>
</table>

4. What is the Marital status of Household head
   Married [ ] Single [ ] Divorced [ ]
   Separated [ ] Widowed [ ]

5. Education status of Household head
   Illiterate [ ] Primary [ ] Secondary [ ]
   Post-secondary [ ]

6. Do you hire or have you employed farm workers
   Yes [ ] No [ ]

7. If yes how many & on what basis
   Monthly [ ] Daily [ ] Piece meal [ ]

8. (a) Which is your major activity?
   Cash crops farming [ ] Food crop farming [ ] Dairy farming [ ]
   Beef/livestock production [ ] Poultry farming [ ] Small business [ ]
   Casual labour [ ] Professional Employment [ ]
   Not applicable [ ]
   Other specify ……………………………………………………………

(b) Occupation (refer to 7a above)

9. How long have you been involved in farming (years)?
10. Is it
   Rain fed production [ ] Irrigated production [ ] or
   Both production [ ]

Section II: Off-Farm Income and Business Activities

10. Did you or any other members of the household work off the household’s land either on someone else’s land or in some other employment against payment in cash or in kind?
   Yes [ ] No [ ]
11. If yes how many members of the household were involved in the last 12 months?

12. What kind of work were they involved in?
   Farm [ ] Professional [ ]
   Skilled labour [ ] Unskilled [ ]
   Others……………………………………

13. What was the nature of employment?
   Permanent [ ] Contract [ ] Daily [ ]

14. Fraction of the money earned from the off-farm activities to total household incomes?

48. Who are the Employers
   Smaller farmers [ ] Commercial farmers [ ] GOK [ ]
   NGO [ ] Urban Dwellers [ ] Not applicable [ ]
   Others specify [ ]

49. If small farmers which enterprise?
   Dairy [ ] Horticulture cultural crops [ ]
   Industrial crops coffee/ tea /cotton [ ] Food crop [ ]
   Other specify……………………………………………………………………

50. What other off-farm activities did household members participate?

18. What is the income from off-farm activities used for? (The two most important).
   Maintenance and own consumption [ ] Investment in business [ ]
   Education/Training expenditures [ ] Savings [ ]
   Investment in farm/land. [ ] Pay back debts [ ]
   Non-education support for children [ ]
   Not Applicable [ ]
   Others specify

Section III: Natural Assets & use

19. What is the size (Ha) of your land? ……………….Ha

20. How did you acquire it?
Inherited [ ] Permission to use [ ] Purchased [ ]

Inherited and purchased [ ] Marriage [ ]

21. Do you have a title deed? Yes [ ] No [ ] only some part [ ]

22. Is there any natural water on sections of your farm? Yes [ ] No [ ]
23. Give details about the plots cultivated and harvested during the last 12 months or 2010. First mention the plots cultivated during the last rainy seasons. Then mention all plot cultivated during the dry season. Plot with permanent crops are recorded as rainy season crops.

A plot is a contiguous area that is not separated by a natural obstacle or by land from another plot. It may be planted with different crops or with one crop only. Two plots are physically separated and may be planted with the same or different crops. If the land is inter-cropped then the area should be divided by the number of crops grown on the plot (if 2 crops, by 2; if 3 crops, by 3 etc.).

<table>
<thead>
<tr>
<th>Season</th>
<th>Plot</th>
<th>Crop code (a)</th>
<th>Area (acre)</th>
<th>Average distance from home (min)</th>
<th>Was the land intercropped? 1. (Yes) 2. (No)</th>
<th>Land quality code (b)</th>
<th>Slope code c</th>
<th>Was the land cultivated both seasons? 1. Yes 2. No</th>
<th>Was the land irrigated? 1. Yes 2. No</th>
<th>If yes % the land irrigated?</th>
</tr>
</thead>
</table>
1) Maize
2) Beans
3) Potatoes
4) Banana
5) Tea
6) Coffee
7) Wheat
8) Fruits trees
9) Fodder crop: Napier/fodder trees/
10) Vegetables
11) Other pulses: Dolicus lab lab/pigeon pea/cow pea/green gram

24. Rank above best five crops in 25 according to their importance

<table>
<thead>
<tr>
<th>POSITION</th>
<th>ENTERPRISE</th>
<th>REASON FOR THAT POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

25. How do you use it? Domestic [ ] crop production [ ] fish farming [ ] others. .................................................................

26. At what level?
Commercial [ ] subsistence [ ] domestic [ ]

27. Record any other natural assets observed in the farm?
...........................................................................................................................................................................

Section III: Physical Assets

<table>
<thead>
<tr>
<th>Asset</th>
<th>Quantity</th>
<th>Estimated total value KSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Pump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ploughs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
28. Motorized sprayers
   Ox cart
   Radio, television
   Bicycles, Motorcycle
   Farm produce store
   Solar panels
   Biogas systems
   Power generators
   Water storage tank
   Chap cutter
   Hay storage facility
   Others specify

   Number of Household & Farm assets and value

29. Housing condition
   a) Iron sheet
      Yes [ ] No[ ]
   b) Cemented floor
      Yes [ ] No [ ]
   c) concrete/stone wall
      Yes [ ] No[ ]
   d) Wooden/iron sheet wall
      Yes [ ] No[ ]

Section IV: Livestock Ownership

30. Can you tell us about your livestock herd at present and your gross income from the sale of animal products in the last 12 months?

<table>
<thead>
<tr>
<th>Type</th>
<th>Number owned &amp; present at your farm</th>
<th>Current value KSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves</td>
<td>A</td>
<td>K</td>
</tr>
<tr>
<td>Bulls</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td>Oxen</td>
<td>C</td>
<td>M</td>
</tr>
<tr>
<td>Heifer</td>
<td>D</td>
<td>N</td>
</tr>
<tr>
<td>Cows</td>
<td>E</td>
<td>O</td>
</tr>
<tr>
<td>Sheep</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>Goat</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>Donkeys</td>
<td>H</td>
<td>R</td>
</tr>
<tr>
<td>Chicken</td>
<td>I</td>
<td>S</td>
</tr>
<tr>
<td>Beehives</td>
<td>J</td>
<td>T</td>
</tr>
<tr>
<td>Type</td>
<td>Do you sell them</td>
<td>Total revenue from the sale of the type? KShs.</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Meat</td>
<td>1) Yes 2) No</td>
<td></td>
</tr>
<tr>
<td>Hides/skins</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Milk/cream</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>Chicken eggs</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Honey</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Live animals</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Manure</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

31. Did you get any income from hiring out oxen during the last two cropping season?
Yes [ ] No [ ]

51. If yes, how much did you earn?(KShs)

33. Did you fatten livestock to make money (business) in the last 12 months?
Yes [ ] No [ ]

34. If yes indicate the profit earned? (Kshs)

35. In the last 12 months have you had any expenditure related to livestock (Labour for herding purchased feed, Veterinary Services, Medicine, and vaccination)?

36. If yes how much did you spend?

37. How long does it take from your production point to the delivery or market point?

38. How do you evaluate the road condition from your home to nearby town or market?
Good [ ] Poor [ ]

39. Average walking time to your farm to nearest shopping centre?

40. Did you have contact with extension agent to get advices in the past 12 months? Yes [ ] No [ ]
Section V: Social Assets

41. Are you a group member? Yes [ ] No [ ]
42. If yes, how old is the group since its formation? (Years)

43. How many members do you have in your group?

44. How long have you been a member?

45. Is the group registered with the social services? Yes [ ] No [ ]
46. What kind of a group?
   Farmer group [ ] Rotating savings-and-credit associations [ ] Burial Society [ ]
   Neighbourhood/village committee [ ] Clan/family [ ] Trader or business association [ ]
   Religious group [ ] Health Group [ ]
   others specify…………………………

47. Are you a member of any agricultural organization? Yes [ ] No [ ]
48. If yes for how long (Years)?

49. What benefits have accrued from the group, List 3 major benefits?

Section VI: Financial Assets

50. Are you a member for Credit organization?
   Yes [ ] No [ ]
51. How long have you been a member in yrs)?

52. Have you got any credit service during the past 2 yrs?
   Yes [ ] No [ ]
53. If yes from which organization?
   SACCO [ ] Commercial bank [ ] Micro finance [ ]
   Group [ ] Friend/relatives [ ] AFC [ ] Private leaders [ ]
   Others specify…………………………

54. How did use the credit Buy farm assets [ ] Off-farm business [ ]
Social obligations [ ] Medical expenses [ ] Education [ ]

55. Did your household receive any kind of remittances (gifts from relatives, food aid etc) transfers (such as pension and other sources of income during the last 12 months? Yes [ ] No [ ]

50. If yes how much income did you receive (KShs) or what % of your total incomes? .................................................................

Section VII: Climate variability and Coping Strategies

1. From experience your own are the climatic conditions deviating from normal?
   Yes [ ] No [ ]

2. If yes what do you perceive as the possible causes?
   Global warming [ ] Deforestation [ ] Increased pollution [ ]

3. Can you identify some past weather experiences that impacted negatively on your livelihood? Yes [ ] No [ ]

4. If yes which ones? Intense prolonged rains (El Niño) [ ]
   Prolonged dry spell (La Niña) [ ] Unpredictable rains/mid-season uncertainties [ ]
   Too much heat [ ]

5. What was the effect of the impact? Food insecurity [ ] Land slide [ ]
   Road damages [ ] floods [ ] increased crop diseases [ ]
   Increased crop pest [ ] increased livestock diseases [ ]
   Soil erosion [ ] spoilt crop [ ] wildlife menace [ ] livestock death [ ]
   Fluctuation of nature waters [ ] others specify....................................................

6. From your experience what factors causes low crop production
   Unpredictable rainfall/ mid season uncertainty [ ]
   Increased pests and diseases [ ]
   Low soil fertility [ ]
   Lack of farm implements [ ]
   High price of farm implements [ ]
   Low access to farm inputs [ ]
   Shortage of labour [ ]
   Poor agricultural practices [ ]
   Inadequate farm land [ ]
   Others...............................................................

...........
7. From your experience what factors reduces livestock production
   Inadequate feeds due bad weather [  ]
   Increased pests and diseases [  ]
   Poor breeds [  ]
   High price of farm implements [  ]
   Low access to farm inputs [  ]
   Shortage of labour [  ]
   Poor agricultural practices [  ]
   Others…………………………………………………………………………………………

8. What are your perceived long term changes in temperatures in the recent past?
   Increased temperature [  ] Decreased temperature [  ]
   Altered climatic range [  ].No change [  ].Don’t know [  ]

9. What are your perceived long term changes in precipitation in the recent past?
   Increased precipitation [  ] Decreased precipitation [  ]
   Changed timing of rains [  ].No change [  ].Don’t know [  ]

10. What action have taken counter the challenges of changing climate
   Planting different crops [  ] Planting different varieties [  ]
   Practicing crop diversification [  ].Different planting dates [  ]
   Shorten length of growing period [  ].Move to different site [  ]
   Change amount of land [  ].Changes from crops to livestock [  ]
   Changes from livestock to crops [  ].Adjust livestock management practices [  ]
   Farming to non-farming [  ]. Non-farming to farming [  ]
   Increase irrigation [  ].Change use of chemicals, fertilizers and pesticides [  ]
   Increase water conservation [  ].Soil conservation [  ].Shading & shelter [  ]
   Use insurance [  ].Prayer [  ].Others [  ]. None [  ]

10B. Identify a strategy among the above that you that would most important in coping with variations in weather patterns?...............................

11. Are there coping strategies that are more biased towards men or women (1) yes (2) no
   (b) How do men in your household coping with climate variability?
      (1) Decreased food consumption;
      (2) Seeking of additional jobs
      (3) Improved farm management;
      (4) Increased labour input.
12. How do women in your household cope with climate variability?
(1) Diversification of food sources/change of family diet,
(2) Work as domestic help, and got involved in other income generating activities,
(3) Self help group interventions
(4) Alternative income sources (for example, casual labour)
(5) Others…………………………………………………………………………………

13. Are droughts becoming more frequent? Yes [ ] No [ ]

14. What on farm crop production and management practices do you perceive has helped you get some harvest when there is a drought?
…………………………………………………………………………………………

15. What on farm livestock production and management practices do you perceive has helped you cope with the drought?
…………………………………………………………………………………………

16. Are unpredictable rains becoming more frequent? Yes [ ] No [ ]

17. What on farm crop production and management practices do you perceive has helped you get some harvest when there is too much rain?
…………………………………………………………………………………………

18. What on farm livestock production and management practices do you perceive has helped you cope during El Nino?
…………………………………………………………………………………………

19. Have done something to improve watering/irrigation systems? Yes [ ] No[ ]

20. If yes what have you done?
Starte irradiating [ ]
Improved system [ ]
21. Have done something for more efficient water use? Yes [ ] No [ ]

22. If yes what have you done?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………

23. Have done something to improve soil fertility and conserve soil? Yes [ ] No [ ]

24. If yes, how?……………………………………

25. Do you do pest management? Yes [ ] No [ ]

26. If yes, how………………………………………………………………………………

27. If yes which ones? (Mark the category and give specific examples)

<table>
<thead>
<tr>
<th>Category</th>
<th>Specific examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreading risks through Diversifying livelihood sources(alternative sources of income)</td>
<td></td>
</tr>
<tr>
<td>Maintaining On farm (root crops)&amp; household food reserves(granary)</td>
<td></td>
</tr>
<tr>
<td>Controlled stocking levels/breeds and adopting livestock feed preservation techniques</td>
<td></td>
</tr>
<tr>
<td>Migrating to trouble free areas or for alternative sources of livelihoods</td>
<td></td>
</tr>
<tr>
<td>Exploiting and Use of new production opportunities</td>
<td></td>
</tr>
<tr>
<td>Change of cropping systems</td>
<td></td>
</tr>
<tr>
<td>Aforestation &amp; reforestation, Linked to carbon sink financiers</td>
<td></td>
</tr>
<tr>
<td>Others specify…………………</td>
<td></td>
</tr>
</tbody>
</table>

28. What major challenges do face in your efforts to cope with the changing climate?

……………………………………………………………………………………………………
7.4: Focus Group Discussion

Key questions to gather the perceptions of people regarding changes in climate over the past decades

- Has the village changed over the past ten years? If yes, how has it changed and what are the reasons for these changes? Does the change have anything to do with an experienced change in climatic conditions?
- Is the village better off or worse off now? Why?
- How have climatic shocks in the past affected the way the village has developed in ten years?
- Which types of households were affected and how? Who in particular was affected?
- Is there anything that can be done in advance to prevent or soften the impact of this type of event? If so, what? Does anyone do this?
- Do people in the village have any savings, either in cash or kind? For what purpose might they have savings?
- Is there any way by which people have access to financial aid in case of an emergency or unforeseen event or shock? If yes, who usually gives these loans? What is the rate of interest? What happens if one cannot repay the loan?
- Do people ever borrow money in order to buy something (consumption or investment loans)? If so, what is usually purchased with borrowed money?
- What are all the extra costs a family must meet when they lose different members (in the event of migration or sudden death in the family)?
- What are the ways that an extended family, community group or caste group cooperates to help its members?
- Have any children been left without any close relatives (parents, grandparents, aunts and uncles) who could take them into their households in case of the emergencies or in case of a climatic shock?
- What kinds of help did people in the community provide to those affected? Who provided help, and what kind:
  - Relatives (extended family)?
  - Neighbours (nonrelatives)?
  - Landlord or employer?
  - Community group?
• Club or association?
• Religious leaders?
• Local government?
• NGOs or donors?
• Other government officials

Vulnerabilities and adaptation strategies - Additional Probing questions -
Definition of drought/flooding/any climatic event or shock from farmers’ perspectives
Farmers’ experience of drought/flooding/any climatic event or shock
Decline/increase in rainfall; Dust storms; Deforestation; Soil erosion
Decline in soil moisture; declining soil fertility
Loss of biodiversity
Vulnerability to drought/flooding/any climatic event or shock
Incidence of drought/flooding/any climatic event or shock and Impacts on agriculture
Coping with drought/flooding/any climatic event or shock
Major decisions taken to cope with drought/flooding/any climatic event or shock
Existing plans in an event a climatic shock occurs very soon
Major strategies to cope with future drought/flooding/any climatic event or shock
How do/can climate variability, change and extreme affect major food crops, cash crops, food crops and Dairy farming?
• What are the major challenges and constraints encountered in development of the key sources of livelihood?
• Discuss the effects of intense/excessive precipitation or El Nino, Prolonged Drought on major sources of livelihoods along various stages of value chain or product development.
• What opportunities the above climatic conditions and change provide?
• How have farmers, community and service provider institutions exploited the each of the opportunities stated above?
• Are there practices that you feel were used by ancient generations that enabled them to cope with the extreme weather effects but not practiced now days? Explain
• Why were they abandoned by current generations?
Main livelihood options

- Is the income from the primary livelihood system enough for the families round the year?
- If no, how do you overcome the deficit
- Which activities does your household resort to other than primary livelihood system?
- What are the reasons that led your household to resort to one or more of the above activities?
- How do you evaluate viability of agriculture for future? If less viable, why?
- Which livelihood system (s) will be viable for your family in the future?
- What strategies do you practice to deal with environmental stress like drought?
- Do the community members support each other during bad and good times?
- If your household had a problem and needed money or food urgently, would you be able to get it from your community or from relatives?
- How many people could you ask for this kind of help?
- In past 12 months what type of assistance did the village receive from government or aid agencies? What type
- During the last rain season, did any households in the village suffer any shortage of food?
- If yes, in which months was food shortage most acute?
- How many months did the food shortage last?
- During that worst month, how many times a day did the adults and children in a household eat?
- In the periods given below is or was your village situation better, the same or worse?

Last year
Last 5 years
Last 10 years
Last 15 years
2. Wealth Ranking

- In any village there are two extreme classes of people the richest and the poorest does your village have the same? (Place the two headers in two extreme corners)
- Are there people who fall in between these categories? If yes what are the various categories? note the number of categories mentioned by the group
- Point to the pile and ask them to pick random names and place them in various categories a maximum of 10 examples per category is sufficient.
- Why is a person rich? Or poor? Or other category? (Enter the information below the names in quantifiable manner; E.g. Peter has two cows, Yin has a large family size of 6 members, etc)

3. Timelines

- When was the village established and by whom
- What is the earliest major event that you remember that has impacted the village?
  (Note down the approximate year if possible. The approximate year can be coinciding with a historical event that the village can relate to e.g year of independence)
- What is the most recent, major event in the village that has impacted the village as a whole? (Note down the year)
- Write these two events in the chart/sand/paper on two extreme corners

  Pointing to these two events, map all the events that have happened between these two times in the village. The villagers usually go back and forth in remembering the years or events, which is fine. (Every event mentioned and the year has to be recorded immediately by the Reporters in the order it was said and it can be adjusted later on)

  Likewise map all the events as far as they can remember. In case of positive events probe as to how it affected specific or different sections of people in the village.) e.g if a drought relief measure was available to all). For negative events identify how the village coped with the event and how individuals in certain sections coped with it (eg.
- How did the poor vs rich cope with the hailstorm?)
4. Social and Resource Maps

- What are the major resources in the village? (E.g: Water Tank, School, etc)
- In which year was it established?
- Who benefits from these resources and who does not? Why/why not?
- Are there any resources that existed earlier, which are not present today?
- What was the reason for their closure?
- What additional resources are required in the village?
- What are the approximate boundaries of the community with regard to social interaction and social services?
- What social structures and institutions are found in the community?
- How did public buildings develop?
- Who built the community centres?
- Who uses the community centres?
- What are the religious groups and where do they live?
- How do people in the community decide on places of worship?
- What are the ethnic groups and where do they live?
- How many households are in the community and where are they located?
- Which households are headed by females and where are they located?
- How is land distributed for housing?
- What is the soil type that is there in the village and how is it distributed?
- Is the number of households growing or shrinking? (This is where the timelines will come to use where the researcher can correspond it with the past years and present conditions. This can lead to discussions of issues on migration and the reasons for the same and whether the changing climatic conditions have been responsible for the same.)
- Has this rate of growth or shrinkage caused problems for particular households or for the community in general?
- What do people do about new immigrants or growing households?
- How does access to community economic, social and political resources differ by household or social group?
- What resources are abundant or scarce?
• Which resources have the most problems or are harmful to the village and why/why not?
• How does access to land (or another specified resource) vary between households or social groups?
• Who makes decisions about land (or another specified resource) allocation?
• What are the water sources available in the village and how are they located in the village?
• Where do people obtain water and firewood?
• Who collects water and firewood?
• Where do people take livestock to graze?
• What additional resources are required in the village?

5. Seasonal Calendars

Seasonal Maps

Seasonal Livelihood Calendar
- Indicates the source of livelihood for both men and women against different months in a year

Seasonal Food Calendar
- As per your calendar how many seasons would you say you have?
- Could you describe to us the activities that are undertaken in each season?
- Is there any particular kind of food or diseases that are particular to any season?
- Have you seen any alterations that have happened in the seasons? In what form?
- Has it been hotter or colder than usual or have the monsoons been affected?
- What have you done as a result of the same (this depending on the response)?

6. Life History and Narrative (Documentation)

• How has the lifestyle in your village changed since the past twenty years?
• Have you felt any change in climatic conditions in this period?
• How has your village reacted to crisis situations?
7. Venn Diagrams

- Can you identify the institutions that are present in your village?
- Which according to you have the most importance and why?
- Who would you approach first in the case of a climatic shock and why?

7.5: In-Depth Interview Guide

1. Introduction & Climate setting (5-10min)
2. Brief history of the area
3. Details on the seasonality
4. Issues on fluctuations in key climate parameters encountered
5. Differences in rainfall and stream discharge as compared to childhood years
6. Give an encounter of some the best seasons
7. Production/yields of various enterprises in a good and normal season
8. Give an encounter of hasty weather conditions ever experienced
9. In case of climate related disaster e.g. slides or drought details should be sought
10. What was perceived as best farming practice
11. Discussions on what was perceived to hinder agricultural productivity and the overall development in the area
12. Views on what should be done to improve the area
13. Another issue that may found relevant or the respondent would like to air
7.6: Transect Walk checklist

1. **Personal Particulars**

1.1 Name…………………………………………………………………………………………
   Age………………………… Sex …………………
   Relationship to HH…………………………………………………………

1.2 Location………………………………………………………………………………

1.3 Sub-
   location………………………………………………………………………………

1.4 Village………………………………………………………………………………

1.5 GPS of the Homestead………………………………………………………

2. **Land**

2.1 Farm size in Acres…………………………………………………………

2.2 How it was acquired…………………………………………………………

2.3 When was the place first settled?………………………………………………

2.4 Before settlement what was the land use?……………………………………

2.5 Over years narrate the use changes encountered

<table>
<thead>
<tr>
<th>Year/Period</th>
<th>Land Use Type</th>
<th>Possible Reasons Of Having The Land Use Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Land Use Drivers**

3.1 Rank the following factors starting with the one that affect land use change most.

<table>
<thead>
<tr>
<th>RANK</th>
<th>FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Climate variability (temperature &amp; Rainfall)</td>
</tr>
<tr>
<td></td>
<td>Soil suitability (degradation/fertility)</td>
</tr>
<tr>
<td></td>
<td>Population pressure</td>
</tr>
</tbody>
</table>
3.2 Do you think under the current climate variability discourse agriculture production can be sustained?
(A) Yes    (B) NO
3.3 If yes how?..........................................................................................................
3.4 If no why? ...........................................................................................................

3.5 Do you of any farmer within who you perceive to have managed effects of climate variability very effectively?  (A) Yes    (B) No
3.6 Who?
..........................................................................................................................
3.7 What coping/adoption measures does he/she take or taking and why?
..........................................................................................................................

3.8 Visit the farm for a in depth interview if you prove is really good.
- Video typing the techniques.
- Taking GPS coordinates of points where the technology is sited etc.
  e.g.
- Soil and water conservation.
- Water harvesting.
- Diversified enterprise mix.
- Unique & new technologies.