Perceptions and Knowledge on Land Use and Land Cover Changes and Impact on Resources and Livelihoods in Nguruman Sub-catchment, Kajiado County, Kenya

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DECLARATION

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

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To my children Laura Christen and Jadon Christian for being my inspiration
My husband Alex Warekwa for having great confidence in my achievements
My parents Mr. and Mrs. Malaki Ojwang for lighting the candle of success in me

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ABBREVIATIONS AND ACRONYMS

AWF	African Wildlife Foundation
CIESIN	Centre for International Earth Science Information Network
DENR	Department of Environment and Natural Resources
ENVI	Environment for Visualizing Images
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
FGD	Focused Group Discussion
GIS	Geographical Information System
GPS	Global Positioning System
IFAW	International Fund for Animal Welfare
ILRI	International Livestock Research Institute,
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LANDSAT	Land Satellite
LULCC	Land Use and Land Cover Change
MEA	Millennium Ecosystem Assessment
MNL	Multinomial Logit
NGO	Non-Governmental Organization
NIPAP	National Integrated Protected Areas Programme
PAWB	Protected Areas and Wildlife Bureau
PGIS	Participatory GIS
UN-WATER	United Nations Water

GENERAL ABSTRACT

Sustainable management of the natural resources requires critical understanding of the dynamics of land use and land cover change (LULCC). Nguruman sub-catchment in the northern part of Kajiado County has experienced rapid land use and land cover changed over the past decades. However, the extent to which these changes have impacted on the ecosystem and indigenous livelihoods has not been assessed. This remains a critical challenge that must be addressed due to its potential severe impacts on rural human livelihoods especially in arid and semi-arid areas in Kenya. This study aimed at assessing the effects of LULCC from 1994 to 2014 on the indigenous livelihoods in Nguruman sub-catchment. In order to achieve a positive gain in management, the study aimed at investigating available options to engage the indigenous community in identifying and finding solutions to issues on management of land and water resources in the study area. An integrated approach combining LANDSAT image analysis, household surveys using questionnaires, Focused Group Discussions (FGDs) and Participatory GIS (PGIS) was employed in the study. This approach allowed conceptualizing LULCC from both a scientific and an indigenous community perspective. Household surveys and FGDs were conducted in Entasopia, Pakasse, Nguruman, Musenge and Shompole locations. Significant land use changes ($p<0.05$) were recorded in cropland, open water, open grasslands and bareland. Areas occupied by croplands increased significantly and forestland reduced. There were fluctuations in areas occupied by wetlands in the form of swamps (vegetated wetlands) and open water (rivers, ponds and lakes). The fluctuation in the two land covers showed similar trends with both increasing between 1994 and 2014 and reductions between 2004 and 2014 reported. Areas occupied by open water increased significantly ($p<0.05$) by 1.15% (1994-2014). Significant ($p<0.05$) reduction in bareland was also recorded between 1994 and 2014. Open grasslands increased significantly

($p<0.05$) while wooded grasslands reduced though this was not significant. Expansion of cropland has been identified as the main driving force of land use changes in Nguruman sub-catchment. This implies that more land is being converted to cropland. The results of household surveys and PGIS analysis demonstrated that the residents are aware of the dynamics and causes of LULCC. Majority of the respondents (67%, n=204) linked the changes to an expansion in cropland while 31% and 2% associated the change to an expansion in open grassland and forestland respectively. Significant expansion ($p < 0.05$) in irrigated cropland was observed in both Pakasse and Entasopia sub-locations between 1994 and 2014. Results from household surveys reveal that there has been a sudden shift from a traditional pastoral livelihood to extensive agro-pastoral practices. This poses a critical challenge on both rural livelihood and will consequently have negative consequence on the current and future sustainability of the ecosystem. Additionally, expansion of irrigated cropping which has become a major economic activity in the study area will continue to exert more pressure on the scarce water resources in the catchment. Such pressure will be directed along the riparian land where availability of water suitable soil conditions for farming is guaranteed. There is need to identify and implement best management practices to sustainably manage land and water resources in Nguruman sub-catchment. This should involve all key stakeholders including local communities in identifying, designing and implementing sustainable strategies for land and water resources management in Nguruman sub-catchment.

Keywords: Land use change, Community Perceptions, Participatory GIS, Nguruman catchment management

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background information

The current changes on the earth's land surface result from both anthropogenic and natural factors (Aspinall and Hill, 2008). These factors act either directly or indirectly to influence land use and land cover change (LULCC). Anthropogenic factors are human-induced and include deforestation, wetland drainage, overgrazing and the expansion of agricultural, industrial and urban areas. These are the most significant proximate causes of LULCC (Lambin *et al*., 2003, De Sherbinin, 2002). Natural factors include earthquakes, landslides, drought and floods. These changes result from complex interaction between socio-economic, cultural and policy factors on the biophysical environment (Campbell *et al.*, 2003, Verbug, 2006, Prakasam, 2010). The consequences of these interactions impact on land resources such as soil, water, and biodiversity. The rate at which these changes occur presents threat to the sustainability of ecosystems and livelihoods (Ellis and Pontius, 2007).

The local processes that drive land use change influence climate and the provision of ecosystem goods and services at a global scale (Koomen *et al.,* 2011b). These include changes in the atmosphere and oceans that exhibit cumulative effects (Lambin *et al.*, 2003) at broader scales (Turner 2003; Loveland *et al*., 2003). These impacts range from impairment in abiotic processes including nutrient cycling, surface runoff, ground water flow (Bronstert *et al.*, 2002; Lambin *et al.*, 2003) hydrological cycles and climate (IPCC 2007; Legesse *et al.*, 2003). Understanding the complex interaction between drivers of land use and land cover change is essential in implementing appropriate measures for sustainable management of land resources. This knowledge can help in future projection of land use and land cover changes to instigate appropriate policy interventions for achieving better land management.

1.2 Problem statement

Nguruman sub-catchment in Kajiado County has experienced rapid land use and land cover change over the past 30 years. This has mainly resulted from combination of anthropogenic and natural processes (Campbell *et al.*, 2000). The impacts from these changes are manifested through soil erosion, increased streams and river sedimentation, flooding and water scarcity. Unsustainable use of natural resources will further threaten the integrity of the ecosystem to support livelihoods in the area (Sambalino *et al*, 2015) if measures to stop land degradation is not implemented.

Water scarcity is the greatest challenge affecting local communities in the study area. Water is a very important resource that determines the type of livelihoods within a region. The lack of adequate water is linked to poverty (UN-Water and FAO 2007). Households facing water shortages are more likely to be poor than those not facing such shortages. Hence actions geared towards improving water availability and access is socially and economically important. The main source of water in the study area is Ewaso Ng'iro River. The water from the river supports domestic and industrial use. There are several streams that feed into the main river including Pakasse, Oloibortoto and Entasopia. Other temporary storage structures including subsurface dams, rock catchments, and water pans help to retain rainfall for use during the dry season. Water is skewed towards industrial, household, and agricultural use, with no consideration to sustainability of the ecosystem (Sambalino *et al*, 2015). This could further alter the flow of the river to Lake Natron to the extent of threatening the only known breeding ground of the Lesser Flamingos (Gereta *et al.*, 2003).

Climate variability characterized by frequent droughts has forced the local community to change from a traditional to an agro-pastoral system. This is seen as a means of diversifying livelihoods. The current economic activity in the study area is farming through irrigation. This is mainly practiced along the riparian land driven by availability of water and fertile soils (Homewood *et al.*, 2009, Coast 2002). In a region where the land is already water stressed with competing water users it is expected that this economic activity will further degraded the ecosystem. The lack of a clear plan to deal with future dynamics of water scarcity coupled with prolonged droughts and planned developments (Omenda, 2010) further increases the challenge.

The implications of overgrazed land in the study are manifested by recent invasion of *Prosopis juliflora* (Finlayson *et al.,* 2006). The plant is originally from Central America introduced to control erosion and desertification in the Horn of Africa. The rate of spread of the invasive plant species high rate yet its impact on the ecosystem of the study area is yet to be investigated (GIZ, 2014). The influx of new settlers to exploit farming could further trigger more changes on land and water resources. The increase in population and changing livelihood has further contributed to land subdivision and privatization. This study aimed at assessing the impacts of the past and current land use changes on land, water and livelihoods in Nguruman sub-catchment. The study provides recommendations for best land and water management to enhance the integrity of ecosystem in order to sustain local community in Nguruman sub-catchment.

1.3 Justification of the study

Nguruman sub-catchment lies within a key biodiversity site hosting important flora and fauna. The catchment is an important source of ecosystem goods and services. The local communities derive benefits such as forage for livestock, fuel wood, water for domestic and industrial use, medicinal products among others. Ecosystem services from the catchment includes role in hydrological functions such as regulating stream flow, minimize erosion, filtering the inflow to the river and stabilizing the underground water table. The catchment is an important source of water for several streams such as Sampu, Entasopia and Oloibortoto that drain into the main Ewaso Ng'iro south river.

The important ecological functions derived from the catchment calls for adoption of appropriate management practices to halt further land degradation. The implementation of rational policies for sustainable land use and water resource management in the catchment will ensure current observed trend in land use to not continue to detrimental state. Since the Local communities are worst affected, an understanding of the human concept and perceptions of these changes will provide critical information for identifying sustainable measures for management or rational formulation of policies. Understanding the drivers of observed changes is critical in devising sustainable measures directed to the causes. This call for acquisition of observed temporal and spatial data to assess the trends of land use and land cover changes. The observed data will help in quantifying the extent and magnitude of change and the land uses that have been most affected to aid in prioritizing management actions. This will guide in critical analysis and understanding of the underlying processes, change detection and future predictions to guide effective management of natural resources.

Acquisition of sufficient data requires combination of approaches. Most studies examining land use and land cover changes employ only LANDSAT imagery assessment. Very a few studies have combined this with information on the drivers of land cover change from a human perspective. The analysis of LANDSAT image in isolation does not reveal the underlying processes that drive land use changes. This study employed an integrated approach that combines LANDSAT images and participatory mapping surveys. This involved local community in mapping affected areas and quantifying the impacts to comprehensively understand the interaction between the society and the environment. This understanding will guide in prioritization of best management options for land and water resources in the catchment.

1.4 Research objectives

1.4.1 Broad objective

To investigate the perceptions and knowledge on land use and land cover changes on land resources and livelihoods in Nguruman sub-catchment, Kajiado County.

1.4.2 Specific objectives

i. To assess the perceptions of local community on land use and land cover changes in Nguruman sub-catchment.
ii. To investigate the level of knowledge on drivers and effects of land use and land cover change among local communities in Nguruman sub-catchment using PGIS approach.
iii. To assess the dynamics of land use and land cover change in Nguruman sub-catchment for the past 20 years using GIS.

1.4.3 Research questions.

i. What are the perceptions of local communities on land-use changes in Nguruman sub-catchment?
ii. To what extent are local communities knowledgeable about the drivers of land use and land cover change in Nguruman sub-catchment?
iii. What is the extent and magnitude of land-use and land cover changes in Nguruman sub-catchment from 1994 to 2014?

1.5 Outline of thesis

The chapters in this thesis are structured as papers in preparation for submission to peer-reviewed journals. **Chapter 1** introduces the background of study, justification, the research problem leading to the identification of the research objectives and the corresponding research questions. The chapter also provided information about the study area and research design pertinent to the research topic from which the study tried to achieve the identified research objectives**. Chapter 2** highlight relevant literature related to the current study. **Chapter 3** describes the general description of the study area while **Chapter 4** captures the implicit perception and understanding of local communities about the land use changes affecting the Nguruman sub-catchment. This is achieved through household surveys using both questionnaires and FGDs. **Chapter 5** focuses on the application of GIS and LANDSAT image analysis in assessing LULCC for the period 1994, 2004 and 2014. The extent, magnitude and projections for respective LULCC are discussed. **Chapter 6** presents the applications of PGIS approach. This is a participatory mapping tool employed in assessing LULCC and identifying associated challenges and proposes mitigations by involving local communities. It highlights the role of local community in identification and mapping of their natural resources and changes and how they can be useful stakeholders in implementing strategies that help in managing their own resources**. Chapter 7** highlights the general discussion of key findings including conclusions and recommendation from the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Global land use change

Global concerns in land use and land cover change have emerged due to realization that land surface processes influence climate and that change in these processes impact on ecosystem goods and services (Lambin *et al.*, 2003) and consequently have impact on livelihood strategies forcing people to cultivate more land to meet their needs (Campbell *et al*., 2003). Change in land-cover influence soil quality, water runoff, sedimentation rates, earth atmosphere interactions, biodiversity, the hydrological cycle, and biogeochemical cycling of carbon, nitrogen and other elements at regional to global scales (Loveland *et al*., 2003). The impacts of these land-use changes become globally significant through their accumulative effects at broader scales (Turner, 2003, Loveland *et al*., 2003).

Over the latest 50 years Africa has been characterized by remarkable changes, some related to progress, such as Pan-African political negotiations, advancements in health and education and in fact economic growth at least in urban areas. Africa has indeed become part of the global economy and society. It has become apparent that economic activities, energy use and trade relations in one country influence other countries, the environment and the economy. Infrastructure extension in the 21st century, global environmental changes are increasingly on top of the international scientific and political agenda. Global environmental changes are those that alter the Earth system of the atmosphere and oceans and hence are experienced globally and those that occur in distinct sites but are so widespread as to constitute a global change (Lambin *et al.*, 2002). Examples of the first category includes: changes in the composition of the atmosphere and climate change. The second is exemplified by land use change, loss of biological diversity, and biological invasions.

In the recent centuries, the impact of human activities on the land has grown enormously, altering landscapes and ultimately impacting the earth 's biodiversity, nutrient and hydrological cycles as well as climate (IPCC, 2007 Legesse *et al.* , 2003; Tilman & Lehman, 2001). The causes and consequences of human-induced environmental changes are not evenly distributed over the earth. They converge in certain regions where their impacts may threaten the long-term or the short-term sustainability of human-environmental relationships. Understanding their dynamics, how they affect human society both today and tomorrow and how we could prepare ourselves for the future is important.

2.2 Regional land use change

Impacts of land cover change on African climate include reduction in surface water transpiration and increases in surface temperature (Maynard and Royer, 2004), which have impacted hydrological systems, particularly in East Africa. Land use changes in East Africa have transformed land cover to farmlands, grazing lands, human settlements and urban centers at the expense of natural vegetation (Maitima *et al* 2009). Several studies have been done in Africa at the watershed, regional, and local level to look into LULC dynamics and results indicates that the effects of population growth modified by the local situation can be considered as an ultimate cause of LULC changes. Cadjoe (2007) points out that most of the studies in developing countries place a majority of their emphases on the local level, where direct causes of the land use /cover changes are observed. In studying cause-cover relationship, Cadjoe (2007) further indicates that linking people to the appropriate level to describe LULC changes is a challenge. However, population data can be linked easily at the regional, national, and district or municipal level and smaller (i.e., village level that makes the linkage difficult as it needs household survey data). A study on land cover change was done on the Sub-Saharan Africa region for a 25-year period by Brink and Eva (2009). This region shows a wide range of climatic and ecological diversity with differences in land cover types, population, and land management techniques. The study showed that agriculture increased at the expense of forests and natural vegetation and concluded that population increase (with the majority living in rural areas) was the main driving force.

At a smaller scale, Mundia and Aniya (2006) studied Kenya's Nairobi city as it had experienced rapid growth in population and spatial extent compared to other major cities in the region, and was showing disappearance of vegetation giving way to urban sprawl and agriculture. They found that rapid economic development and urban population growth were the main reasons for the observed changes. At the municipality level in Tanzania, Musamba *et al*. (2011) assessed the impact of such socioeconomic activities as fishing, tourism, crop production and livestock on LULC changes. The results showed that there was a strong relationship between the LULC changes and anthropogenic activities. Another study in South Africa (Giannecchini *et al*., 2007) involved three villages (at the local and household level) to see the relationship between land cover change and socioeconomics. The villages consistently showed an exponential increase in human settlement as a result of refugees in the mid 80's and a decrease in vegetation. In addition, weakening of institutional control at the local level over natural resources was observed in each village during times of political change. As a result, population growth, the weakening of control of property, and increased dependency of household livelihood on cash income enabled individuals to harvest live wood without impunity.

Other studies using watersheds to assess the land cover changes and its drivers were also completed in Africa. These studies were employed on the Kagera basin (Wasige *et al.*, 2013; Tolo *et al*., 2012), Malagarasi catchment in Tanzania (Kashaigili and Majaliwa, 2010), and the Barekese catchment in Ghana (Boakye *et al.*, 2008). Based on land change analysis done (Mugisha, 2002; Misana *et al.*, 2003; Olson *et al*., 2004) land use has changed to more cultivated area and less bush, forests and grass- lands. These changes have tremendously reduced areas with natural vegetation where in some sites there is hardly any natural vegetation. The findings from these studies indicated that land use was influenced by policy changes, lack of education, population growth, and socioeconomic issues. Generally, in sub-Saharan countries, the most important drivers of forest degradation have been identified as the extraction of fuel wood, where 80% of the population uses wood as its main source of energy, and agriculture, which represents the primary source of income for 70% of the population. Additionally, forest policy, persistent conflict and war, demography and population movement, low economic growth and poverty, debt and dependence on development assistance, constraints arising from globalization, predominance of the informal sector, and inadequate investment also are underlying drivers (Lambin *et al*., 2003).

2.3 Drivers of land use change

Of the challenges facing the Earth over the next century, land-use and land-cover changes are likely to be the most significant. This anthropogenic process affects many parts of the earth's system (e.g., climate, hydrology), global biodiversity, and the fundamental sustainability of lands. The patterns of land use and landcover as well as management are fashioned by complex interactions between biophysical, environmental and societal processes at local and global scale (Aspinall and Hill 2008). While the implications of environmental changes are often discussed in terms of global and regional consequences, there is growing recognition that many of the critical causes arise from interactions between societal and biophysical processes at the local level (Geist and Lambin, 2004; Lambin *et al*., 2003). In short, the driving forces of land use and land cover change are many faceted. They may change in relative influence over time, and their impact will vary as the local context changes. An assessment of the role of political and economic power, as manifested in land use and tenure policies and the evolution of access to the resources essential to local livelihood systems, is central to developing a more nuanced understanding of linkages between standard categories of driving forces and outcomes as observed in patterns of land use and land cover change. The relationship between land cover and use change and its causative factors is complex and dynamic. The land cover and use change is mainly manipulated by both natural and socio-economic factors. According to Lambin *et al* 2003, the five major driving causes for land use change are economics, institutions, technology, culture, and demographic change. Lambin *et al* 2003 summed up the factors into two major categories namely proximate (direct) and underlying (indirect drivers of land use change.) Proximate causes comprise of immediate actions that emanate from intended land use thus affecting land cover and operate at local levels e.g. deforestation, whereas underlying forces are extraneous forces that underpin the proximate cause e.g. land use policies. These drivers act synergistically in varying combinations rather than singly at aggregate level resulting in considerable effects on future land use and cover (Lambin *et al.*, 2003).

Commercialization and the growth of mainly timber markets as well as market failures are frequently reported to drive deforestation. It is striking that combinations of synergetic drivers rather than single drivers at aggregate level are associated with tropical deforestation. Institutional factors such as policies on land use and economic development, transportation, or subsidies for land-based activities, lack of adequate governance structures, land tenure and property rights issues, issues of open-access resources and squatting by landless farmers are the major driving causes of cover change. Technological factors in the wood and agriculture sectors, like technological changes in the forestry sector in the form of chain saws and heavy equipment, and in wood processing, agro-technological factors, modification of farming systems through intensification and intensification are playing significant role in cover change. Cultural factors include attitudes and perceptions such as unconcern for forests due to low morale and frontier mentalities, lack of stewardship values, and disregard for "nature", profit-orientation of actors, traditional or inherited modes of cultivation or land-exploitation, and a commonly expressed sentiment that it is necessary to clear the land to establish an exclusive claim.

Demographic factors such as natural increase or immigration is another driving factor. Most of its explanatory power tends to be derived from interlinkages with other underlying forces, especially in the full interplay of all five major drivers. Migration is an important demographic factor causing land-use change Spatial and demographic changes in have sharp impact on agricultural land. Population pressure has negative effect on LUC (Shiferaw, 2011). According to Lambin *et al*. (2003), increased population associated with government policies on management of agricultural and forest lands could trigger land use change. Knowledge about land cover change that occur, where and when they occur and rates at which they occur is requisite. Equally important is the awareness of drivers and processes that instigate the land cover changes.

2.4 Effects of land use on biodiversity

Land cover is a fundamental variable that influences many facets of the natural environment (Aspinall and Hill, 2008). Transformations of land cover for agricultural, residential and urban development concomitant to the increasing population affects the functioning of environmental system and processes in the long term. This provides rational for the recognition of LULCC. Monitoring and detection of land cover change is gaining currency in science as a way of comprehending human relationships and interactions with global earth systems to facilitate the management and sustainable use of natural resources (Lu *et al* 2004).

Land-use and land-cover change is a major threat to biodiversity leading to the destruction of the natural vegetation and the fragmentation of natural areas (Verburg, 2006). Some of the key outcomes of land-use change include environmental degradation, resource use conflicts, erosion, deforestation and decreasing river discharges. These also interact synergistically with other drivers of change including demographic changes, institutional factors, socio-economic transition, traditional and climate variation to shape the process and nature of land use. The total environmental effects such as change in vegetation cover, soil characteristics, flora and fauna population and hydrological cycle have been strongly influenced by the conversion of land and forest resources (Shiferaw 2011, Rientjes *et al*. 2011)

2.5 Land use change and livelihoods

Land-use changes are complex processes that arise from modifications in land-cover to land conversion process. Land use has been considered one important factor influencing livelihood of people (Noe, 2003). The change in farming system and land- use change on the hydrology of the rivers, can affect farmers' livelihoods strategies (Veldkamp and Lambin 2001). Despite this complexity, little is known about how human and environmental factors operate and how they interact to affect land-use patterns and ecological processes (Campbell, 2003). According to Lambin *et al.* (2003), land-use change is driven by the interaction in space and time between biophysical and human dimensions.

Most of the land cover changes of the present and the recent past are due to human actions. Intense human utilization of land resources has resulted in significant changes on the land-use and land-cover Bronstert *et al*. (2002, Lambin *et al*., 2003). Man kind's presence on the Earth and his modification of the landscape has had sound effect upon it. (Aspinall and Hill, 2008. Human activities including agriculture change have led to land and other natural resources degradation (Amare, 2013). Agriculture has also expanded into forests, savannas, and steppes in all parts of the world to meet the demand for food. (FAO, 2010) driven by human demand. Direct actors at local level are farmers involved in clearing of forest for food crop production thereby changing the landscape. Nonetheless, the policies encouraging privatization of agriculture and forest lands accelerated land use changes (Lambin *et al*.,2003).It is estimated that 1 to 2 million hectares of cropland are being taken out of production every year in developing countries to meet the land demand for housing, industry, infrastructure, and recreation (MEA 2005). This is likely to take place mostly on prime agricultural land located in river valleys and in many watersheds where constant supply of water is available in the dryland ecosystems. (Mertens and Lambin, 2000).

Most land in East Africa is a state of flux at a variety of spatial and temporal scale due to climatic variability and human activities. Kenya has undergone rapid land use and land cover change in response to the diverse political, economic, socio-cultural and demographic processes. The early colonial period between 1900 and 1930 was characterized by extensive land expropriation, large scale agricultural production and European settlement (Campbell *et al* 2003). The ensuing period leading to independence 1930-1963 experience the reduction of constraints on African land ownership and participation on commercial agricultural economy. This culminated in new interactions and conflicts among the agricultural and pastoral groups as farmers settled in high potential areas formerly used by pastoralists for dry season grazing.

In the post independent era, the state fostered rural development especially the expansion of cash crop production in central and western highlands. Due to ongoing migration and internal population growth, large areas have gradually been converted to agricultural land, including the cultivation of cash crops as soon as accessibility conditions allow (Campbell 2003). The 1990s saw a marked growth in Kenyan population owing to increased medical care, individualized land tenure and international competition for agricultural produce and dairy products. The rising population imposed lots of pressure on the land resources especially in arable lands that led to expansion of cultivation on wetter margins of rangelands and decline of savanna due to overgrazing and other unsustainable land uses (Campbell *et al* 2003).

2.6 Land use change and hydrological functions

Land use/cover changes are the most common cause of loss of biological productivity and biodiversity in aquatic and terrestrial ecosystems. The LULCC affect the climate of an area which in turn affects natural resources such as water, wetlands and biodiversity (IPCC, 2007; Gibbard *et al*., 2005). Degradation of the environment, which negatively impact ecosystem processes and function, especially conversion of wetlands to irrigated lands, represent significant challenges to biodiversity (Finlayson *et al*., 2006).

Land-use changes are known to have an impact on the hydrology of any catchment area (Bronstert *et al*., 2002). There is a growing consensus for the need to improve water resources management to meet new challenges posed by increasing demand and diminishing water supply. However, the options, processes and impacts of desired change are less clear (Hajkowicz, 2003). Therefore, a good understanding of the processes causing land-use change and their effects on the hydrology of small sub-catchment is essential. Such understanding includes both assessments of the anticipated rate and spatial pattern of land-use change as well as knowledge of the underlying human and biophysical drivers (Lambin *et al*., 2003; Turner *et al*., 2003).

2.7 Land use land cover and Hydrological changes

Processes that drive LULCC are complex and require the use of multiple methods of analysis and critical interpretation of social data in order to understand the drivers and impacts of change through time and across spatial scales (Jiang, 2003). LULC change models are used in finding patterns and predicting LULC change. LULC changes occur due to driver effects, these changes can be identified by the spatial patterns that can be seen in the area of interest. LULC changes are driven by various bio-physical (temperature, rainfall, slope, drainage etc.) and socio-economic drivers (the growth of population, industrialization, infrastructure and technological growth etc. (Campbell *et al*., 2003).

Relatively few studies have sought to combine analysis of Landsat imagery with longitudinal information on the drivers of land cover change at the landscape scale. Such analyses are important because they enable an understanding of the underlying processes that transform land use practices and create new trajectories of land cover change. However, analysis of imagery cannot reveal the complexity of driving forces that contribute to land use decisions. These include social and cultural, economic, and institutional processes together with the responses of people to changes in the availability of land and in the biophysical environment Understanding the implications of changes in the meaning and importance of ethnicity and local institutions is essential in interpreting the local dynamics of resource access and use.

Reflection on remotely-sensed information by itself provides little information on the drivers of change. A combination of field surveys can be made more effective by using information from the analysis of imagery. In combination, these two approaches contribute both a descriptive and an analytical understanding of patterns and processes of LULCC, and can thus better inform both policymakers and scientists developing modelling approaches that seek to extrapolate from the landscape scale to the regional-scale. The understanding of the effects through catchment modelling allows for monitoring and correlating environmental changes with factors such as socioeconomic and biophysical drivers (Troyer, 2002). In addition, it enables planners to formulate policies to minimize the undesirable effects of future land use changes on catchment hydrology (Mustafa *et al*., 2005).

CHAPTER THREE

GENERAL DESCRIPTION OF STUDY AREA

3.1 Geographic Location

Nguruman sub-catchment is located in South-western of Kenya at the border with Tanzania between latitude and longitude 36^o 30.0' E, 2^o 10.00' S and 36^o 30.0' E, 1^o 40.00' S (Figure 3.1). The study area lies within the Ewaso Ng'iro south river basin. The slope varies from approximately 900m above sea level on the flood-plain to 2,300m.

3.2 Hydrology

Wetlands in the area cover 4.5% of the catchment. These form a crucial source of fresh water for human, livestock and wildlife consumption. The distribution of wetlands in the study area is determined by the topography and drainage. The Ewaso Ng'iro river is the most important wetland system in the region with a catchment area of 8,536 km^2 draining into Lake Natron to the south. Wetlands in this region are characterized by fluctuation in size ranging from 15% to 30% between the wet and dry seasons. The fluctuations in wetland size are attributed to climate variability with unpredictable rainfall and high temperature patterns. The Ewaso Ng'iro river has its tributaries namely Oloibortoto, Entasopia, Sampu and Pakasse that run through the western side of Magadi cutting across Oldonyo Nyoike, Olkiramatian and Shompole locations. This river is a permanent and valuable source of water in the Pakasse and Entasopia irrigation schemes. Other wetlands comprise of natural depressions or dammed river channels and water reservoirs. Marshes, wet grasslands and artificial wetlands e.g. fishponds and dams also form part of the wetland ecosystems.

3.3 Climate

Annual rainfall in the study area is strongly influenced by altitude. Annual rainfall at the base of the eastern escarpment is approximately 400 mm rising to 750 mm on the forested ridges. Temperatures range from 34^oC around Lake Magadi to 15^oC in the Nguruman hills. The high potential evapo-transpiration experienced in the area ranges from 1,700 mm to 2,500 mm per year.

3.4 Vegetation and land use

The nature of vegetation growth in the study area is determined by rainfall, evaporation and temperature. The driest areas are Ol Donyo Nyokie and Magadi which are characterized by poor vegetation growth. The vegetation in the plains consists of open *Acacia tortilis* woodland, dense *Acacia–Commiphora* bush, *Tarchonanthus camphoratus* thicket, open grassland sub-montane forest. The riparian area is fringed with tall riparian forest of *Ficus* species. Beyond the escarpment crest is a mosaic of grassland, scrub and forest with tree species including *Podocarpus falcatus*, *P. latifolius* and *Diospyros abyssinica*.

3.5 Demographic characteristics and livelihoods

Population in the Study area is approximately 201,122 persons (KNBS 2009). Livelihood is characterized by pastoralism and agro-pastoralism is currently on the rise. However, horticulture is practiced in Entasopia, Oloibortoto and Pakasse using irrigation adjacent to the riparian land. Rain-fed and irrigation agriculture are practiced as a means of diversifying sources of income.

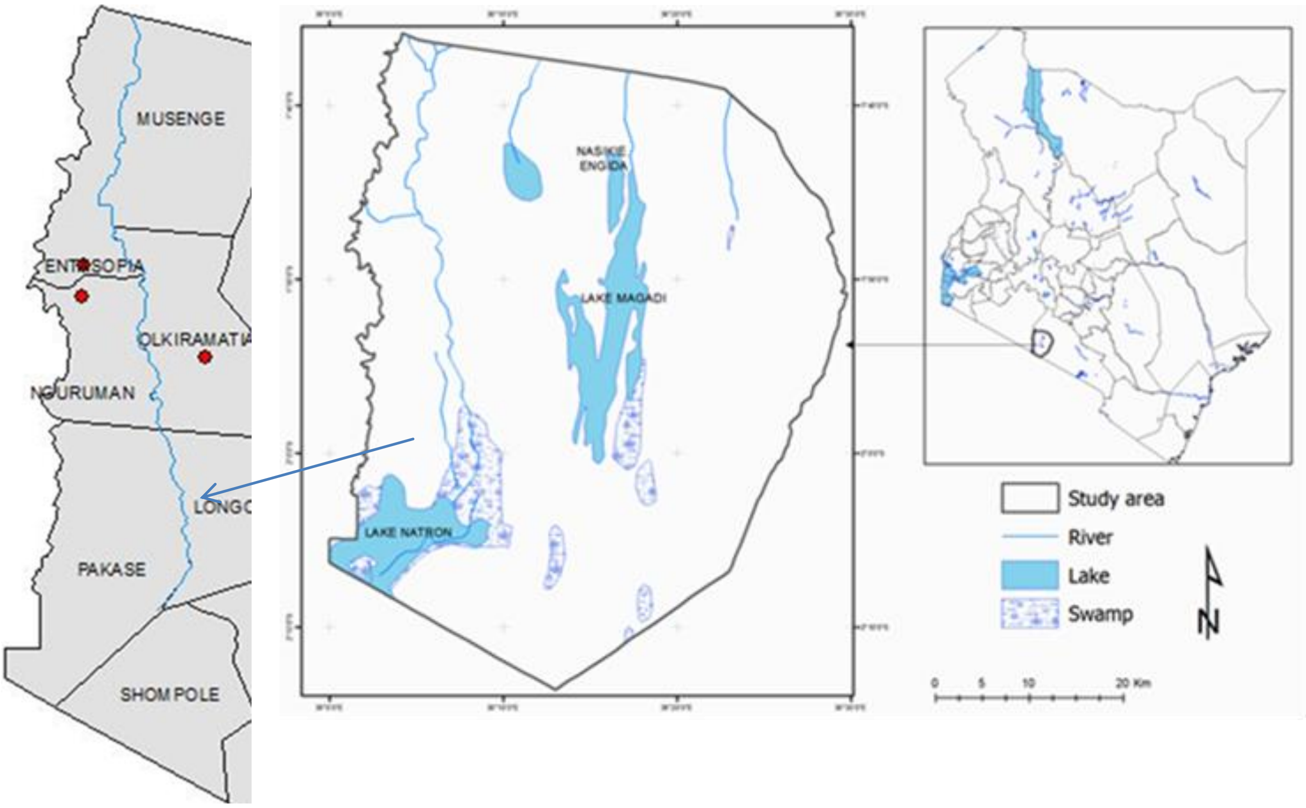

Figure 3.1 Location of study area

CHAPTER FOUR

PERCEPTIONS AND KNOWLEDGE OF LOCAL COMMUNITY ON LAND USE AND LAND COVER CHANGES IN NGURUMAN SUB-CATCHMENT

Abstract

Understanding local community perception on land use issues affecting catchment is critical for effective management. This study aimed at assessing local community perception and attitudes on land use and land cover change in Nguruman sub-catchment. House-hold survey using questionnaires was conducted in five sub-locations namely Entasopia, Pakasse, Nguruman, Musenge and Shompole. A systematic sampling procedure was employed in administering structured questionnaires to 204 respondents. Snowballing technique was used in areas where respondents were dispersed. Focused group discussions consisting of 10 to 12 individuals were conducted to elicit additional local knowledge on LULCC. Both descriptive and inferential statistics were generated from SPSS software to understand factors that influence LULCC in the study area. A multi-linear regression analysis was further performed to determine the most significant factors influencing LULCC as perceived by the community. Results demonstrated that the people were aware of the changes that have occurred over time within the various locations. More than 60% of the respondents affirmed that changes had occurred and linked that to expansion of cropland. However, 31% and 2% associated the change to expansion of grazing and forest land respectively. Water scarcity manifested by drying of streams, reduction in rainfall and increased temperatures was reported as the greatest effect from the changes experience by the community. Water abstraction was

mention as major cause of water shortage from the rivers. This study emphasizes the need to integrate community perceptions in managing land and water resources. Indigenous communities have a long history of interaction with their environment. Hence, being the ultimate beneficiaries of the resource they will easily adopt initiatives geared towards their protection. Communities should actively be incorporated in their own terms in order to achieve their objectives during planning and implementation of strategies that need to be addressed in land resource management.

4.1 Introduction

The complex interactions between environmental, economic and social-cultural factors (Geist and Lambin, 2004) contribute to varying degrees of land use and land cover changes (LULCC). These interactions contribute to pressures on the earths land surface (Reynolds *et al.*, 2007, Warren, 2002) when they operate synergistically with other phenomena such as climate change, biodiversity loss and water scarcity (MEA, 2005, Maitima *et al.*, 2009, Agyemang, 2012). The implications of these changes further lead to habitat degradation, climatic variability and poverty (Bremner *et al*., 2010). These changes are more severe in developing countries (Safriel, 2007; Bai *et al*., 2008) where local communities depend entirely on the natural resource for their livelihoods (Nkonya *et al.*, 2011). Land uses changes resulting from human activities are expected to continue in the future due to increasing population and their associated demands (Lambin *et al.*, 2003).

Understanding the dynamics of change, how they affect and interact with human society both present and future is important (Adger *et al* 2005) in designing interventions that enhance positive impacts on the environment. Integrating human perception on these interventions is critical in ensuring positive adoption of management practices as well as implementing effective natural resource management strategies. The perceptions of local communities on land use and land cover change can be gathered through using various tools including public meetings, focus group discussions, interviews, workshops, questionnaires and household surveys. These methods have been used successfully to solicit input from community members about watershed conditions (Leach *et al.,* 2002; Kaplowitz and Witter, 2008). This study employed structured questionnaires containing both closed and open ended questions to assess the perceptions of local communities on LULCC in Nguruman sub-catchment. The study highlights the need to integrate local community perceptions in decisions geared towards sustainable catchment management.

4.2 Materials and methods

Structured questionnaires (Appendix 1) containing both open-ended and closed-ended questions was administered to 204 respondents in Nguruman sub-catchment. Both purposive and systematic sampling techniques were used to select respondents. The same technic was employed in identifying key informants and focus group discussants. Questionnaires were administered and interviews conducted within every five homesteads. Snowballing technique was employed in areas where respondents were dispersed (Heckathorn 2015). Additional interviews were conducted with 12 key informants from each location who had special knowledge of various aspects of land use and land cover change in the study area. Key informants included chiefs, representatives of non-governmental organizations (NGOs), government officials and members of local community. (Kaplowitz and Witter, 2008).The questions targeted the respondents' perceptions and attitude on the land use and land cover changes. In addition, the respondents provided suggestions on measures that could help mitigate negative impacts arising from mentioned land use changes.

Descriptive statistics was used to analyze data on local perceptions. Multinomial regression analysis (Multinomial Logit (MNL) model) was performed in the spss statistical software to identify factors that influence land use changes in the study area (Starkweather and Moske, 2015). The regression model permits analysis across more than two categories in the dependent variable to determine the probability of occurrence of the different land use and land cove changes. In agricultural production economics, the modeling framework has been used to model acreage share choices, crop decisions, land use decisions and technology choice decisions (Carpentier and Letort, 2009).The method assumes that the data satisfy a critical assumption of the independence of irrelevant alternatives where the alternatives are not interdependent. In this study, the various land use changes could result in either increase, decrease or no change in the use. These are mutually exclusive alternatives that satisfy the key assumption of independence of irrelevant alternatives. In this case, it is the odds of land use changing by either an increase a decrease or no change. The model is therefore ideal for determination of probabilities for the various land use and land cover changes in the study area. The MNL is expressed as follows:

$$P(y=j/x) = exp(x\beta_j)/\left[1+\sum_{h=1}^{J} exp(x\beta_h)\right], \; j=1, 2 \ldots J$$

Where, y denotes a random variable taking on the values {1, 2..., J} for a positive integer and x denote a set of conditioning variables. X is a 1xK vector with first element unity and βj is a K×1 vector with j = 2... J. In this case y denotes Land use change or categories (Increase, Decrease, No Change) while x denotes independent variables such as age, gender, education, main land use etc. Independent variables refer to household and institutional characteristics describing the land owner.

4.3 Results and discussion

4.3.1 Local knowledge on dynamics of land use changes in Nguruman sub-catchment

The mean age of respondents interviewed ranged from 17 to 83years with 30% having attained primary education and more than 50% without any formal education. Results across the five sub-locations in Entasopia, Nguruman, Musenge, Shompole and Pakasse indicated that they were aware of the land use and land cover changes in their respective locations. In

Entasopia, 70.8% of the respondents affirmed knowledge of changes and linked these to increasing cropland. However, in Nguruman and Pakasse, 77.3% and 66.7% respectively affirmed and linked the changes to decreasing cropland. All the respondents in Musenge and Shompole linked the changes to increasing and decreasing pasture/grazing land respectively (Table 4.1).

Table 4.1. Knowledge of land use change by location and land use category

Sub location	Land use category	Increasing (N)	Decreasing(N)
Entasopia	Cropland	**70.8 (**17**)**	65.5 (19)
	Pasture land/Grazing	29.2 (7)	31(9)
	Forest land	0 (0)	3.4 (1)
	Overall	100(24)	100(29)
Musenge	Cropland	0 (0)	0 (0)
	Pasture land/Grazing	100 (1)	0 (0)
	Forest land	0 (0)	0 (0)
	Overall	100 (1)	0(0)
Nguruman	Cropland	72.7 (8)	**77.3** (17)
	Pasture land/Grazing	27.3 (3)	22.7(5)
	Forest land	0 (0)	0(0)
	Overall	100 (11)	100 (22)
Pakasse	Cropland	58.3 (7)	**66.7** (2)
	Pasture land/Grazing	33.3 (4)	33.3 (1)
	Forest land	8.3 (1)	0 (0)
	Overall	100 (12)	100 (3)
Shompole	Cropland	0 (0)	0 (0)
	Pasture land/Grazing	0 (0)	100 (2)
	Forest land	0 (0)	0 (0)
	Overall	0 (0)	100 (2)
Overall	Cropland	66.7 (32)	**67.9** (38)
	Pasture land/Grazing	31.3 (15)	30.4 (17)
	Forest land	2.1 (1)	1.8 (1)
	Overall	100 (48)	100 (56)

(n)= No. of respondents

Different dynamics in LULCC was reported in the various locations with Entasopia reporting increasing trends in cropland and the expense of forestland. Forestland areas expanded at the expense of cropland in both Nguruman and Pakasse. Pasture and grazing land expanded in Musenge and decreased in Shompole. Both Musenge and Shompole locations are characterized by more arid conditions that are unsuitable for farming. However, considering the entire sample of local communities perception there was no significant change between the land use changes ($p<0.05$, $\chi^2 = 0.052$, df = 2).

Further assessment revealed that local communities are aware of the time periods in which the changes have occurred over the last 20years (Table 4.2). Majority of the respondents (63.6%) noted that most changes occurred within the last 5 years while 22.7% reported that changes had occurred more than 20 years ago (Table 4.2). The overall perceptions on LULCC across the locations was very significant (df =3, f=11.8, $p< 0.01$). Majority of the respondents (85.9%) observed that major increase in cropland under irrigation took place within the last 5 years. This compares to 70.1% respondents who observed major changes within 5-10 years. Communal grasslands increased by 53.1% and bareland 58.1% while wetlands declined by 63.8%. Irrigated cropland increased at the expense of wetlands in <5 years in all the sub-locations. Communal grazing land increased in Entasopia and Musenge while it decreased in Shompole, Pakasse and Nguruman within <5 years. Bareland expanded in Nguruman and Pakasse while it reduced in Entasopia, Musenge and Shompole. These observations imply that increased cropland supported by irrigation has negative consequences on wetlands. More land is left bare in Nguruman and Pakase especially along the riparian areas as land is cleared for farming. This also exposes more land to degradation. A similar observation was made by Kairu (2001) and Terer *et al* (2005). They observed that expansion of cropland was skewed towards riparian land where environmental conditions including high soil moisture, fertile soils and the presence of freshwater favor agriculture. The shift from rain-fed farming to irrigated cropping is caused by unreliable rainfall in the study area. Other studies also recorded the same trend (Maitma *et al*., 2009).

These results conform to that of Pisannelli *et al* 2012 on a similar study conducted in a rural and mountainous area of Central Italy. The study confirmed that community members are able to recognize both positive and negative changes through long-term interaction with their environment. Young *et al,* 2006 emphasizes that human beings are able to modify environments based on their level of knowledge and expectations. Human perceptions and attitudes are indicative of their experiences and long-term interaction on the environment. Hence, designing appropriate strategies based on their understanding and appreciation of the dynamics on local environment can determine their level of commitment and participation in resource management (De Meo *et al*., 2010).

Table 4.2. Nature of land use and land cover change by location and period

Location	Nature of Land use	<5 years		5-10 years		10-20 years		>20 years	
		%DT	%IT	%DT	%IT	%DT	%I T	%DT	%IT
Entasopia	Rain-fed Cropland	**63.6**	29.5	**40.9**	20.5	**22.7**	20.5	**4.5**	22.7
	Irrigated Cropland	14.6	**85.4**	1.1	**76.4**	3.4	**52.8**	5.6	**14.6**
	Private Grassland	58.3	41.7	25	8.3	8.3	0	8.3	0
	Communal Grassland	38.9	**50**	5.6	16.7	0	5.6	0	5.6
	Forestland	79.5	16.9	78.3	1.2	55.4	1.2	10.8	8.4
	Wetland	73.3	20	60	6.7	30	3.3	16.7	20
	Bare land	40	60	64.4	15.6	33.3	8.9	17.8	24.4
Musenge	Rain-fed Cropland	0	100	0	0	0	0	0	0
	Irrigated Cropland	0	0	0	0	0	0	0	0
	Private Grassland	0	0	0	0	0	0	0	0
	Communal Grassland	16.7	**83.3**	50	0	16.7	16.7	0	66.7
	Forestland	57.1	42.9	42.9	0	14.3	0	57.1	0
	Wetland	**100**	0	100	0	0	0	100	0
	Bare land	40	60	0	40	20	0	0	0
Nguruman	Rain-fed Cropland	50	41.7	20.8	54.2	8.3	45.8	12.5	29.2
	Irrigated Cropland	17	80.9	17	55.3	14.9	23.4	8.5	12.8
	Private Grassland	61.5	30.8	23.1	23.1	23.1	15.4	23.1	15.4
	Communal Grassland	55.6	33.3	33.3	11.1	11.1	33.3	22.2	22.2
	Forestland	74.3	20	71.4	5.7	28.6	2.9	14.3	8.6
	Wetland	7.1	50	50	7.1	50	0	21.4	28.6
	Bare land	43.5	52.2	65.2	8.7	21.7	8.7	0	17.4
Pakasse	Rain-fed Cropland	55.6	44.4	77.8	22.2	0	44.4	0	33.3
	Irrigated Cropland	7.1	92.9	0	82.1	0	53.6	0	35.7
	Private Grassland	0	0	0	0	0	0	0	0
	Communal Grassland	60	33.3	53.3	6.7	33.3	6.7	0	0
	Forestland	92	8	64	8	48	12	24	4
	Wetland	66.7	16.7	33.3	16.7	33.3	0	0	0
	Bare land	46.7	53.3	66.7	6.7	26.7	6.7	0	20
Shompole	Rain-fed Cropland	0	0	0	0	0	0	0	0
	Irrigated Cropland	0	92.3	0	53.8	0	30.8	0	7.7
	Private Grassland	0	0	0	0	0	0	0	0
	Communal Grassland	25	75	12.5	6.3	0	6.3	0	0
	Forestland	60	40	50	10	30	5	5	5
	Wetland	88.9	11.1	38.9	0	11.1	5.6	5.6	5.6
	Bare land	20	80	20	0	0	20	0	0

DT = Decreasing trend, IT= Increasing Trend

The results also highlighted that even though land use changes can be localized within a location, the magnitude of change can be felt within a wider geographical scope. The increased irrigation cropland in Entasopia which is located upstream has affected the supply of water in areas located downstream such as Pakasse, Shompole and Musenge. On the other hand Musenge and Shompole sub-locations are primarily dry areas characterized by frequent droughts compared to the neighboring sub-locations hence unsuitable for farming. Shompole wetland as reported by the local community used to provide the only alternative for dry season grazing but due to reduced discharge from the streams, it can no longer support grazing. This has worsened the already arid conditions in these locations making them unsuitable for any productive form of livelihood. This confirms that water availability and climate influence the nature and trend of land use and land cover change in Nguruman sub-catchment. In addition, particular land use change could have influence on several other land uses due to the complex interaction between different forces of change (De Sherbinin, 2002, Lepers *et al* 2004, Rudel *et al*, 2005). For example the shift from rain-fed to irrigated cropping has greatly influenced the capacity of wetlands to hold sufficient water to support other form of livelihood. Consequently this has transformed the traditional pastoral livelihood to agro-pastoralism. This is seen as a way of diversifying income and mitigating impacts in the entire study area. The nature and magnitude of land use change are also dependent on the nature of natural environment and the availability of resources to be exploited (Mugisha, 2002). The expansion of irrigated cropland in Entasopia is attributed to the availability of water for irrigation and suitable soil conditions for farming (Sambalino *et al*., 2015). The opportunity to exploit farming has also attracted more immigrants who have moved in the area purposely for agriculture. The consequence of this is a decrease in forestland being cleared to support farming and settlements.

4.3.2 Perceptions of local communities on factors affecting different land use and land cover change

4.3.2.1 Rain-fed and irrigated cropland

The hypothesized factors that influenced the probability of changes observed in rain fed cropland sizes included, land acreage owned by locals, changes in the natural habitat, and water related issues in the catchment over the last 20 years. Factors that influenced rain-fed cropland over the last 5years included changes in irrigated cropland, private grasslands, forestland and bareland. These changes had significant effects ($p < 0.05$, $p < 0.01$, $p < 0.001$) on marginal probability of increasing, maintaining or reducing cropland under rainfed system (Table 4.3). The positive coefficient on the total land owned by the local communities in the catchment implies that an increase in size of land owned increases the probability of either reducing or expanding cropland under rain-fed system. Changes that occurred in the natural habitat over the last 20 years had a negative significant effect on decreasing the acreage under rain-fed cropland relative to maintenance of the original area. Thus changes in the natural habitat negatively affect cropland sizes under rain-fed production system.

Water related challenges are expected to cause major effects on land allocation between various agricultural enterprises and the intensities within a particular agricultural enterprise (Brown *et al.*, 2005). Water related challenges in the catchment had a negative significant effect on increasing cropland under rain-fed production system. Increasing water challenges would thus reduce the probability of households increasing their land allocation to rain-fed cropping. This is a clear indication that rain-fed crop production is influenced by precipitation changes (Maitma *et al.*, 2009). On the other hand, decreases in irrigated crop lands over the last 5years had a positive and significant effect on the probability of households increasing their land allocation for rain fed crop production. This implies that both irrigated and rainfed cropping systems are substitutes. An increase in one directly results in a decrease in another. This means that farmers tend to convert rain fed crop land to irrigated crop land depending on prevailing weather conditions.

The results also show changes in private grassland over the past 5years had a significant effect on the probability of the households reducing their land allocation to rainfed crop production. Maintaining the acreage under grassland would reduce area under cropland. Private grasslands seem to be curved out of the existing rainfed cropland. Changes in forestland and bareland over the last 5years both had negative significant effect on the probabilities to decrease rainfed cropland. The implication is that decreasing forestland and or bareland curbs the decline in cropland under rainfed system. This also infers that maintenance of both forestland and bareland would reduce area under cropland.

Table 4. 3. Determinants of crop land use changes under rain-fed system

Variables	Co-efficient (SE)	p>z
Total land owned in Nguruman catchment area	0.128(0.0542)	0.0330
Change in natural habitat over 20 years	-1.229(0.686)	0.0030
Water related issues experienced	-2.055(1.033)	0.0470
Changes in irrigated Cropland over 5 years	2.377(1.130)	0.0350
Changes in private grassland over 5 years	-1.425(1.479)	0.0200
Changes in forestland over 5 years	-0.919(0.971)	0.0040
Changes in forestland over 5 years	-1.706(1.138)	0.0060
Changes in bare-land over 5 years	-1.550(1.044)	0.0050
Changes in bare-land over 5 years	-2.235(0.824)	0.0000
Constant	4.157(3.583)	0.0850

Standard errors (SE) in parentheses, p = p value, n=204

Among the hypothesized factors that influence observed changes in irrigated cropland in the last 20 include, changes in rainfall patterns, total land owned in the catchment, status of land ownership , residential status, interventions by various institutions including non-governmental organizations (NGOs), international organizations, government or local groups, and change from traditional to modern farming methods. Changes in forestland and rainfed cropland over the past

5 years also had influence in irrigated cropland. These factors had significant effects ($p < 0.05$, $p < 0.01$, *and* $p < 0.001$) on the probabilities of households to increase or decrease the cropland acreage under irrigation (Table 4.4).

Table 4.4. Determinants of crop land use changes under irrigation system

Predictor Variables	Co-efficient (SE)		P>z	
	Decrease	**Increase**	**Decrease**	**Increase**
Change in rainfall patterns	8.121(3.092)	5.146(2.307)	0.0260	0.0090
Total land owned	0.220(0.233)	0.422(0.174)	0.0150	0.3440
Land ownership	-7.814(3.057)	-1.776(1.347)	0.1870	0.0110
Residential status	8.797(3.541)	6.959(3.084)	0.0240	0.0130
NGO interventions	-8.330(3.481)	-3.410(2.237)	0.1270	0.0170
International organization work	-7.052(3.555)	6.192(3.093)	0.0450	0.0470
Government interventions	-3.698(2.079)	-4.053(1.735)	0.0200	0.0750
Local groups interventions	-9.351(3.560)	7.212(2.948)	0.0140	0.0090
Change to modern farming > 20 years	8.289(2.437)	6.871(2.076)	0.0010	0.0010
Changes in forestland > 5 years	6.034(2.938)	5.444(2.533)	0.0350	0.4090
Changes in rain fed cropland >5 years	4.912(2.229)	1.426(1.535)	0.0040	0.9880
Constant	0.0471(3.022)	6.470(2.252)	0.0260	0.0280

Standard errors (SE) in parentheses, p = p value, n=204

The method of farming in Nguruman catchment is a function of availability of rainwater. Changes in rainfall patterns increased the probability of households decreasing cropland irrigation and also increased the probability to increase cropland under irrigation. This means that when there is a reduction in rainfall, farmers are more likely to increase their cropland under irrigation and vice versa. Results also indicate that an increase in acreage of land owned in the catchment would result in an increase in irrigated cropland. Hence the more land a household has, the more likely they are able to increase the acreage under cropland irrigation. Thus land ownership is perceived to be a critical factor in determining the type of land management. Land under communal ownership had a negative and significant effect on reducing irrigated cropland in the catchment area. This implies that communal land ownership curbs reduction in irrigated cropland. Communal land ownership is a collective land access regime controlled by many. This compares to a more individualized system of land ownership where the owner has exclusive rights to expand or reduce enterprise acreages, ensures more stability in land use. Immigrants had positive and significant effects on both expansion and reduction of irrigated cropland in the catchment (Table 4.4). This implies that most immigrants moved in the catchment solely to exploit the opportunities available for irrigation farming. Increased population growth has been linked to negative impact on land . Further increase in immigrants in the catchment would lead to population explosion that would have detrimental effects on the integrity of Nguruman sub-catchment to support more livelihoods.

Interventions by various institutions have the capacity to greatly influence the type of land management. Various land and water management interventions executed by various institutions, groups and organizations were reported. Results show that local NGOs, government and local community groups' involvement in the area had a negative significant effect on reduction in irrigated cropland. On the other hand interventions by foreign international organizations had a positive significant impact on the expansion of irrigated cropland. These observations highlight the existing contrasts on strategies employed by local and international organizations. The strategies employed by local institutions aim at curbing reduction in irrigated cropland by promoting agricultural production systems that are drought resistant. However, international organizations promoted crop production practices that enhanced irrigation in the area. The need for harmonization of interventions by various organizations is critical in adoption of strategies and implementation of appropriate land use practices. The inclusion of local communities in decision making processes has been shown to positively enhance adoption of appropriate practices that benefit both ecosystem and livelihood.

4.3.2.2 Communal grassland

Hypothesized factors that influence changes in acreage under grassland included, the type of land use management e.g. using land for pasture under private ownership has a negative significant influence on the decrease in communal grazing land over the last 5 years ($p < 0.05$, $p < 0.01$, $p < 0.001$; Table 4.5). This suggests that maintaining private pasture land resulted in reducing communal grasslands. Interventions by NGOs had a positive significant effect on the increase in communal grazing. This implies that NGOs promoted development and better management of the communal grasslands underscoring its importance to the community. Changes in natural habitat over the past 20 years had a positive significant effect on the decline in communal grassland. This implies that the changes (largely destructive) resulted in an increase in communal grasslands. In contrast, modernization of farming practices in the catchment area over the past 20 years had a negative significant effect on the decline in communal grasslands. This indicates that adoption of modern cropping techniques resulted in decline in sizes of communal grasslands. Modern agricultural technologies that include intensive farming using fertilizers, use of drought resistant crops encourage more production per unit land area aims at reducing pressure on land. Hence pressure to convert communal grassland in to cropland in minimal. Changes in both forestland and rain-fed cropland also had an influence on changes that occurred in communal grasslands. Decline in forestland had a negative significant effect on both the expansion and decline on communal grasslands. Decline in forests provided open areas for communal grazing. On the flip side, decline in forestland would result in availability of more fertile land for cropping. Additionally, reduction in rain-fed cropland had a positive significant influence in increasing communal grasslands.

Table 4.5. Determinants of communal grass land use changes

Independent variables	**Increased**	**Decreased**	**Increa**	**Decrease**
land use management	**0.664**(0.885)	**-1.634**(0.810)	0.4530	0.0440
NGO interventions	**1.915**(0.953)	**-17.61**(6224.0)	0.0450	0.9980
Change in natural habitat > 20 years	**-0.0940**(0.688)	**1.663**(0.699)	0.8910	0.0170
Traditional to modern farming > 20	**-0.433**(0.942)	**-2.035****(0.762)	0.6460	0.0080
Changes in forestland > 5 years	**-2.934**(0.918)	**-2.437**(0.976)	1.0000	0.9960
Changes in rain fed cropland > 5	**2.425**(1.187)	**2.134**(0.988)	0.0010	0.0130
Constant	-49.58(5975.1)	-18.00(3132.0)	0.9930	0.9950

Standard errors (SE) in parentheses, p = p value, n=204

4.3.2.3Forestland

Factors that significantly ($p< 0.05$, $p< 0.01$, $p< 0.001$) influenced the changes in forestland; over the last 5 years included residential status (immigrants and residents) , institutional interventions, changes on irrigated land, changes in rain-fed cropland and changes in communal grassland (Table 4.6). The immigrant households moved into the area purposely for farming had a negative significant influence on both increase and decrease in forestland. This implies that increasing immigrant population increases the demand for more land for farming with the only option of reducing areas under forestland. The interventions by the international NGO in the area had a negative significant influence on the increase in forestland. This organization mainly advocated for more agricultural production which would lead to destruction of more forests rather that intensive production per unit acreage. Extensive production as opposed to intensive production gives little regard to the integrity of the forests to support ecosystem services. Maintenance of rain fed cropland over the last 5 years had a positive and significant influence on the increase in forestland over the last 5 years. The implication of this is that maintenance of land area under rain-fed crop production has very minimal destructive impacts on forestland.

Table 4.6. Determinants of forest land changes

Independent variables	Increase	Decrease	Increas	Decreas
Residential status	**-5.412**(2.166)	**-2.162**(0.984)	0.0120	0.0280
NGO interventions	**-3.397**(1.473)	**-0.429**(0.991)	0.0210	0.6650
Changes in irrigated cropland > 5	**1.653**(1.450)	**-2.352**(0.922)	0.2540	0.0110
Changes in communal grassland > 5	**-2.752**(1.164)	**0.882**(0.880)	0.0180	0.3160
Changes in rain fed cropland > 5	**4.514**(1.437)	**-0.00924**(0.706)	0.0020	0.9900
Constant	-36.49(3499.9)	-0.796(1.979)	0.9920	0.6880

Standard errors (SE) in parentheses, p = p value, n=204

4.3.2.4 Factors affecting wetland

The principal factors that significantly influenced changes in wetlands over the last 5 years include changes in communal grazing land, rain-0fed cropland, gender of household head, NGOs and local groups' intervention. Conversion of wetland to cropland and windstorm patterns over the past 20 years also had significant impact on wetlands (Table 4.7). These results were significant at different levels ($p< 0.05$, $p< 0.01$, $p< 0.001$). The negative significant bearing on the decrease in wetlands indicate that male headed households contributed to increased decline of wetlands. This implies that women tend to utilize water more sustainably as their daily lives revolve around water. Similarly, interventions by NGOs and local groups through advocacy had a negative significant influence on the decline in wetlands. This could be an indication of failure in strategies employed by these groups to advocate for proper use of wetlands. Changes in communal grazing lands over the last 5 years had a negative and significant effect on increases and reduction in area under wetlands. This implies that the maintenance of communal grazing lands had a negative impact by reducing area under wetlands through conversion to other uses. On the other hand, increases in rainfed cropland significantly increased expansion of wetlands in some parts and caused declines in other parts of the catchment. The studies by Swallow *et al.*, 2008 conducted in Lake Victoria conforms to this findings indicating that land management practice could have both positive and negative impact on wetland ecosystems. Results also indicate that the impact of conversion of wetland to croplands over 20 years ago were positively significant on the probability of increasing or reducing wetlands in the catchment. Hence, any interventions need to consider historical LULCC in developing effective management strategies.

Table 4.7 Determinants of changes in wetland

Independent variables	**Increase (%)**	**Decrease (%)**		
Gender of household head	**-17.34**(2406.9)	**-3.483**(1.746)	0.9940	0.0460
NGO intervention	**-1.057**(2.073)	**-2.945**(1.434)	0.6100	0.0400
Local groups intervention	**-18.58**(2905.2)	**-3.522**(1.645)	0.9950	0.0320
Wetland to cropland change over	**6.795**(1.978)	**5.997**(1.377)	0.0010	0.0000
Change in windstorm patterns	**-2.249**(1.540)	**-1.923**(0.881)	0.1440	0.0290
Changes in communal grazing land	**-3.861**(1.829)	**-3.481**(1.139)	0.0350	0.0020
Changes in rainfed cropland over 5	**5.912**(2.752)	**2.694**(1.248)	0.1790	0.2650
Constant	-44.67(4543.2)	-41.93(3778.4)	0.9920	0.9910

Standard errors (SE) in parentheses, p = p value, n=204

4.3.2.5 Factor contributing to bareland

The factors that significantly ($p < 0.05$, $p < 0.01$, $p < 0.001$) influenced changes in bareland included status of land ownership, interventions by international organizations, changes in irrigated cropland and rainfed cropland over the last 5 years (Table 4.8). Communal land ownership reduced the probability of decreasing bareland. The theory of the tragedy of the commons explains this. Since no individual has exclusive rights over ownership of resources it becomes vulnerable to misuse resulting in increased land degradation contributing to expansion in bareland. However, interventions by international organizations were positively significantly influential in increasing bare-lands. This means that certain interventions were not beneficial to the course of soil and water management. Additionally the interventions proposed by the local communities may not have been adopted due to lack of inclusion of locals in the processes on making decisions. The interventions may have focused more on enhancing productivity without due considerations on environmental sustainability. Both maintenance and decreases in rain-fed cropland had positive and significant effect on expansion of bare lands. This is because land previously under cropping was left abandoned due to unsuitable conditions such as poor fertility, insufficient rains leaving this to the agents of land degradation thus contributing to expansion of bareland

Table 4.8. Determinants of changes in bareland

Independent variables	Increase	Decrease		
Land ownership (Communal=1)	**-0.502(0.656)**	**-1.587(0.719)**	**0.4440**	**0.0270**
International organization work	**1.034**(0.779)	**1.763**(0.764)	0.1840	0.0210
Changes in irrigated cropland over 5	**1.682**(0.854)	**-16.88**(1132.3)	0.3060	0.6660
Changes in rain fed cropland over 5	**1.975**(0.750)	**0.588**(0.927)	0.0000	0.7250
Constant	1.188(2.326)	0.689(2.279)	0.8390	0.6750

Standard errors (SE) in parentheses, p = p value, n=204

4.4 Conclusion and recommendations

The findings from this study indicate that the local communities in are knowledgeable about land use and land cover changes occurring within their territories. This follows their long-term interaction with their environment. Most of the changes experienced by the local community are reported to have occurred within the last five years. The key factor driving these changes is irrigation farming. This is concentrated along the riparian areas where availability of water and suitable soils for farming both Entasopia and Nguruman locations is guaranteed. Farming is a way of diversifying income and mitigating impacts of recurrent drought in the area. There has been dramatic expansion of farming supported by government agricultural policy to ensure food secure nation. The results of a diversified economy and increased food security will inevitably escalate more pressure on a water scarce and drought stricken region as population pressure imposes greater demand on the land. The opportunity to exploit water for irrigation in these locations has impacted positively on livelihoods by enhancing food security. However, this has contributed to reduction in natural forest and wetland. This will consequently have negative effects on the hydrological functions of the catchment.

Decisions affecting land uses by the community are influenced by factors such as land ownership, management interventions from private or government institutions, socio-cultural and economic factors. Government owned land which is mostly open access is more prone to changes compared to the private land. Access and rights over the management of land therefore are critical issues in influencing land use choices. Land management interventions from private institutions and NGOs in the study area have in most cases experience resentment. This is because the processes of developing strategies in most cases lock out local communities who are then expected to play key role in their implementations. Hence, inclusion of local communities from early stages of decision making is important for effective adoption of management practices from institutions. This study has revealed that historical land uses could have significant impacts on current conditions especially on wetland and forestland. Past land uses provide a picture of original conditions and could potentially be used to create models to predict future scenarios. This is important in preplanning for land use management.

Allocation of water for various resources uses in the study area is a major challenge. Water abstraction for crop production is the major cause of declines in stream flows in Entasopia, Nguruman and Pakasse locations. Other competing uses mentioned by the community include; domestic, industrial, livestock and wildlife. Water management is a concept that the local communities have to embrace in the face of competing water resource users. There is need to device sustainable mechanism for water harvesting to supplement the irrigation water from the streams in the catchment.

Interventions on best land and water management practices have been put in place by various actors to enable the community to best deal with experienced challenges. Government institutions tend to concentrate more on legal protection while non-government institutions concentrated on advocacy. Hence, there is need for collaboration among institutions to complement their roles to achieve effective management. In selecting management options, decisions must be made at individual household or community level to achieve their specific goals. The progress and impacts of interventions by the various actors on land and water management must be closely monitored for adoption if the community is to be steered through the path to development.

CHAPTER FIVE

ASSESSING LOCAL KNOWLEDGE OF LAND USE CHANGE IN NGURUMAN SUB-CATCHMENT USING PARTICIPATORY GIS APPROACH

Abstract

Effective management of natural resources requires robust, credible and adaptable system of local community participation to enhance adoption and implementation of sustainable resource management approaches. This ensures that the views of local communities are captured in decision making processes. This study employed participatory GIS (PGIS) in assessing drivers of land use and land cover changes in Nguruman sub-catchment. Data was collected in Entasopia and Pakasse locations representing both the upstream and downstream representing communities living under different environmental settings. Resource mapping exercise involving the local community was undertaken during Focus Group Discussion (FGDs). The FDGs consisted of 12 members with good background knowledge of changes that have occurred over the last 20 years. Participants identified, discussed and graphically presented the changes. The common land use and land cover categories identified in the two locations were forestland, cropland, grassland, wetland, settlement and bareland. In addition two distinct land use and land cover were identified, conservancy in Pakasse and land covered by *Prosopis juliflora,* an invasive species common to Entasopia location. The maps presented changes that had occurred in 3 time periods at 10 year interval for the years 1994, 2004 and 2014. Images of resulting mental maps were later captured using a digital camera. This followed a ground truth exercise for validation to allow for spatial analysis on GIS environment. Maps were further digitized and analyzed in GIS to

determine extent and magnitude of change based on local knowledge. Results showed major expansion of cropland and wetland in Pakasse between 1994 and 2004. Major changes occurred in grassland, bareland and wetland between 2004 and 2014. Forestland decreased by 4.3% and later increased by 22.47% in 2004 and 2014 respectively. Overall forestland expanded by 17.17% from 1994 to 2014. Cropland expanded by 40.66% and reduced by 63.73% in 2004 and 2014 respectively. There was an overall reduction in cropland by 48.98% in Pakasse. Grassland and bareland expanded throughout the period under investigation while wetland area decreased recording an overall reduction of 97.86%. Settlements showed an increase of 14.22% in 2004 and consequent reduction by 30.07% in 2004 and 2014 and on overall reduced by 20.84%. This study reveals that local communities have knowledge of both spatial and temporal changes occurring within their territories. They were able to conceptualize the changes both from a positive and negative perspective. They further made recommendations on strategies they perceived could bring positive changes that benefit both the environment and livelihoods. These included rainwater harvesting, community policing, cooperation from the county government and community involvement in natural resource management in their localities. This study highlights the need to involve local communities in decision making regarding natural resource management. The PGIS employed in this study is a tool that can be adopted by county governments in effectively engaging local communities in dialogue to build consensus in implementing interventions that drive positive change. The tool is a means of bridging gap between local communities and policy makers through a top down approach and also ensuring that the voice of the marginalized are captured. It represents a common way of communication between stakeholders by bridging the gaps brought about by disparities in education, dialects and mind-sets.

5.1 Introduction

Land use changes are caused by various bio-physical (e.g. temperature, rainfall, slope, drainage) and socio-economic drivers interacting simultaneously (e.g. the growth of population, industrialization, infrastructure and technological growth. Understanding the fundamental processes of underlying drivers and how they interact is basic in identifying suitable natural resource management approaches (Veldkamp and Lambin, 2001). Understanding the complexity of underlying processes that drive changes requires use of multiple methods of analysis. GIS has become a popular mapping tool in geographic research with many capabilities, including advanced geospatial analysis, computer mapping and digital display (Nyerges and Green 2000, Bowman *et al*. 2004). However, the cost of technology, concerns of access rights, basic skills requirement could marginalize local communities (Chambers *et al.,* 2004).

The success of adoption of land management policies and programs require the inclusion of targeted beneficiaries in identification, development and implementation (Rambadi *et al*, 2007). Acknowledging the critical role and participation of local community at all levels ensures successful adoption of the relevant management strategies. Local community participation in interpreting the local dynamics of resource use is crucial in understanding human environment interactions (Bernhardt and Palmer, 2007) for effective policy formulation (Troyer, 2002). The value of local community knowledge is embedded in their ecosystems. Their long term experiences and acquisition of extensive knowledge affects their view and interpretation of complex ecosystems where they adapt and respond to ecological feedback (Berkes *et al.,* 2000, Fazey *et al.,* 2005). This is particularly valuable for informing and guiding environmental management (Fazey *et al* 2005, Palmer *et al*., 2007). In addition, it enables planners to formulate sustainable policies that minimize undesirable effects of future land use changes on catchments (Mustafa *et al.*, 2005).

Modern knowledge systems have been criticized for marginalization of local knowledge politically, socially, and economically (Louis, 2007). In recent years, the divide between science and local knowledge has decreased. Researchers are attempting to understand the benefits of local knowledge in environmental research, government policy and resource management (Briggs, 2005). Emerging issues in land use and management has prompted the need to adopt methodologies that ensure local community participation in the decision making process. This has prompted the evolution from GIS to Participatory GIS (PGIS). This has emerged as an effective tool for social development (Brown 2005) in various fields including: urban planning, landscape ecology, natural resources and conservation biology (Sieber, 2006).

PGIS is the practice of gathering data using traditional methods such as interviews, questionnaires and FGDs to document spatial information. This information is further digitized for analysis using GIS software (Tulloch, 2007). Participatory GIS as a tool encourages community assessment of spatial and temporal land use and cover changes (McCall 2003, 2004, Rambaldi *et al*, 2007). As a tool for empowering local community through participation, it helps in building confidence in themselves and trust with decision makers. The aim is to foster social capital in the communities while paving way for new initiatives and development programs. The concept of community participation in resource management and conservation has been identified as is a key pillar in the sustainability of the world’s natural resources. Community participation mitigates the resentment in top-down centralized governance (IFAD, 2009). Communities are able to appreciate the spatial implications of policies and actions while the policy makers recognize the legitimacy of local interests (McCall and Minang 2005). The present study employed the PGIS approach local in assessing land use and land cover changes. The process engaged local communities in identifying issues and solutions to enhance sustainable land use and management in Nguruman sub-catchment to benefit both ecosystem and livelihoods.

5.2 Methodology

A combination of two approaches was applied; (i) consultation of expert knowledge and opinions using through FGDs and (ii) Community mapping exercises using participatory approaches (PGIS). Two PGIS sessions consisting of 12 members were conducted in Pakasse and Entasopia sub-locations. Mulwa and Nguluu (2003) recommended a similar approach in collecting information using FGDs. Most of the studies on social economic dynamics as well as natural resource management employ FGDs (Odimegwu, 2000). The locations were selected to represent both communities residing upstream and downstream within Nguruman sub-catchment.

The objective of the project and PGIS exercise was discussed and roles assigned to the participants. Participants were taken through the tools to be used for the PGIS exercise. These included geographical position system (GPS) for geo-referencing and ground truthing exercise, manilla papers for graphic presentation of spatial information, symbols representing different land use and land cover types that were agreed upon. Mapping involved graphically representing land use and cover types for periods 1994, 2004 and 2014 based on the local community knowledge of changes. The 10 year interval period chosen was considered reasonable enough for the participants to detect changes. Elderly participants were involved as they were able to determine how land has changed 20 years back with high level of certainty. Of importance was the extent and nature of different land use change. Once the maps were drawn discussions were carried out focusing on the accuracy of the mental maps for the two locations. The two locations represented communities living under different environmental setting. Modifications were made on the maps until there was consensus among the participants (Aynekulu *et al* 2006). Field surveys with representatives of the groups were undertaken to georeference and validate the mental maps using GPS. The common land use and land cover categories identified in the two locations were forestland, cropland, grassland, wetland, settlement and bareland. In addition two distinct land use and land cover were identified, conservancy in Pakasse and *Prosopis juliflora*, an invasive species common to Entasopia location.

The final mental maps were later digitized and prepared for analysis using GIS. The area under each land use and land cover category including extent and magnitude of change was calculated from the original extent. Percentage areas covered by various land uses and land cover were calculated in Excel. Chi-square goodness of fit was performed to test for the levels of significance of changes in land use and land cover (Zar, 1996). Participants were further engaged in discussions to elicit their own opinion and suggestion on strategies for mitigating negative effects resulting from land use and land cover changes experienced.

5.3 Results and discussion

5.3.1 Trends in land use and land cover changes in Pakasse and Entasopia

The areas covered by each land use and land cover category for the three time periods and their percentage changes for both Pakasse and Entasopia are presented in Table 5.1 and 5.2 respectively. Results of chi square goodness of fit test as shown in Table 5.3 (Pakasse) and 5.4 (Entasopia) locations recorded significant changes ($p<0.01$) in all land use and land cover categories. The graphical presentation for the changes in both Pakasse and Entasopia are shown in Figures 5.1a, b and c and 5.2a, b and c respectively.

Forestland declined by 64.28 % at the expense of cropland which increased by 26.5% in Entasopia from 1994 to 2014. However an expansion of 3.76% in forestland was recorded in Pakasse as cropland declined by 14.75%. Wetlands declined by 11.63% and 0.96% in both Pakasse and Entasopia respectively. These observations demonstrate that forestland and wetland are greatly affected by the pressures from human action in the study area. Other land uses and land cover that exhibited overall expansions from 1994-2014 include grassland, settlement and bareland. While *Prosopis juliflora* an invasive species introduced in the area to rehabilitate degraded areas continued to expand throughout the study period. Expansion recorded in grasslands resulted from wetland drainage to open up more land for farming. Expansions recorded in bareland resulted from increased land degradation as a consequence of increased settlements in Entasopia. However bareland in Pakasse expanded due to farmland that were left abandoned after farming in the area proved futile due to loss of soil fertility and lack of sufficient water from the streams to support irrigation. The community reported that high salinity and lack of sufficient water to sustain irrigation water could not sustain cropping hence the inhabitants moved out to find opportunities in neighboring Entasopia.

The increased settlements and expansion in cropland clearly demonstrate clearly that farming is the main economic activity attracting new settlers in the region. This is done at the expense of forestland and wetlands. Most of the farming is done under irrigation and this has resulted in wetland encroachment, over abstraction of water from streams and clearing of riparian land.

Conservancy is a unique form of land use in Pakasse. This increased initially and stabilized between 2004 and 2014. Fluctuations in land use and land cover change were observed in between the periods of study. For example, in Pakasse there was an initial expansion in forestland between 1994 and 2004 and gradual decline between 2004 and 2014 at expense of cropland. Wetland exhibited similar trend both in Entasopia and Pakasse, initially expanding in 2004 followed by declines in 2014. There was a steady trend in Settlement and bareland expansion in Entasopia. However in Pakasse an increase in settlement resulted in a similar decline in bareland. This results indicate that land use and land change differ both temporally and spatially. Similar land use and land cover changes within a given geographic scope will differ as a result of different interacting processes. The nature of resources to be exploited coupled with the decisions made by local community determine the direction of change.

Table 5. 1. Land use and land cover changes in Pakasse between 1994 and 2014

	Area (km^2)			% Change		
Land use/cover	**1994**	**2004**	**2014**	**1994-2004**	**2004-2014**	**1994-2014**
Forestland	30.18	26.96	34.18	-3.02	6.78	3.76
Cropland	20.74	22.14	5.03	1.31	-16.07	-14.75
Grassland	0.28	0.34	1.2	0.06	0.81	0.86
Wetland	12.65	3.11	0.27	-8.96	-2.67	-11.63
Settlement	10.65	20.16	13.97	8.93	-5.81	3.12
Bare land	7.45	9.24	24.46	1.68	14.29	15.97
Conservancy	24.54	24.54	27.38	0.00	2.67	2.67
Total	**106.49**	**106.49**	**106.49**	**0**	**0**	**0**

Table 5. 2. Land use and land cover changes in Entasopia between 1994 and 2014

	Area (km^2)			% Change		
Land use/cover	**1994**	**2004**	**2014**	**1994-2004**	**2004-2014**	**1994-2014**
Forestland	248.54	210.97	74	-13.84	-50.45	-64.28
Cropland	8.75	25.57	80.7	6.19	20.30	26.50
Grassland	11.22	20.05	27.77	3.25	2.84	6.10
Wetland	3	1.5	0.4	-0.55	-0.41	-0.96
Settlement	5	12.28	43.5	2.68	11.50	14.18
Bare land	0.08	1.07	7.12	0.36	2.23	2.59
Prosopis juliflora	0.01	0.08	38.03	0.03	13.98	14.00
Total	**271.52**	**271.52**	**271.52**	**0**	**0**	**0**

Table 5.3. Chi-Square goodness of fit test for the various land use and land cover change in Pakasse sub-location

Land use/cover	Area, Km^2			% Change	χ^2Test		
	1994	2004	2014	1994-2014	χ^2	df	p-value
Forestland	30.18	26.96	34.18	3.76	163.18	2	0.00
Cropland	20.74	22.14	5.03	-14.75	232.53	2	0.00
Grassland	0.28	0.34	1.2	0.86	315.85	2	0.00
Wetland	12.65	3.11	0.27	-11.63	289.00	2	0.00
Settlement	10.65	20.16	13.97	3.12	236.62	2	0.00
Bare land	7.45	9.24	24.46	15.97	244.11	2	0.00
Conservancy	24.54	24.54	27.38	2.67	184.90	2	0.00

Table 5.4. Chi-Square goodness of fit test for the various land use and land cover change in Entasopia sub-location

	Area, Km^2			% Change	χ^2Test		
Land use/cover	1994	2004	2014	1994-2014	χ^2	df	p-value
Forestland	248.54	210.97	74	-64.2826	159.14	2	0.00
Cropland	8.75	25.57	80.7	26.49897	611.2	2	0.00
Grassland	11.22	20.05	27.77	6.095315	701.26	2	0.00
Wetland	3	1.5	0.4	-0.95757	804.8	2	0.00
Settlement	5	12.28	43.5	14.17943	700.62	2	0.00
Prosopis juliflora	0.01	0.08	38.03	14.00265	743.65	2	0.00
Bare land	0.08	1.07	7.12	2.592811	798.21	2	0.00

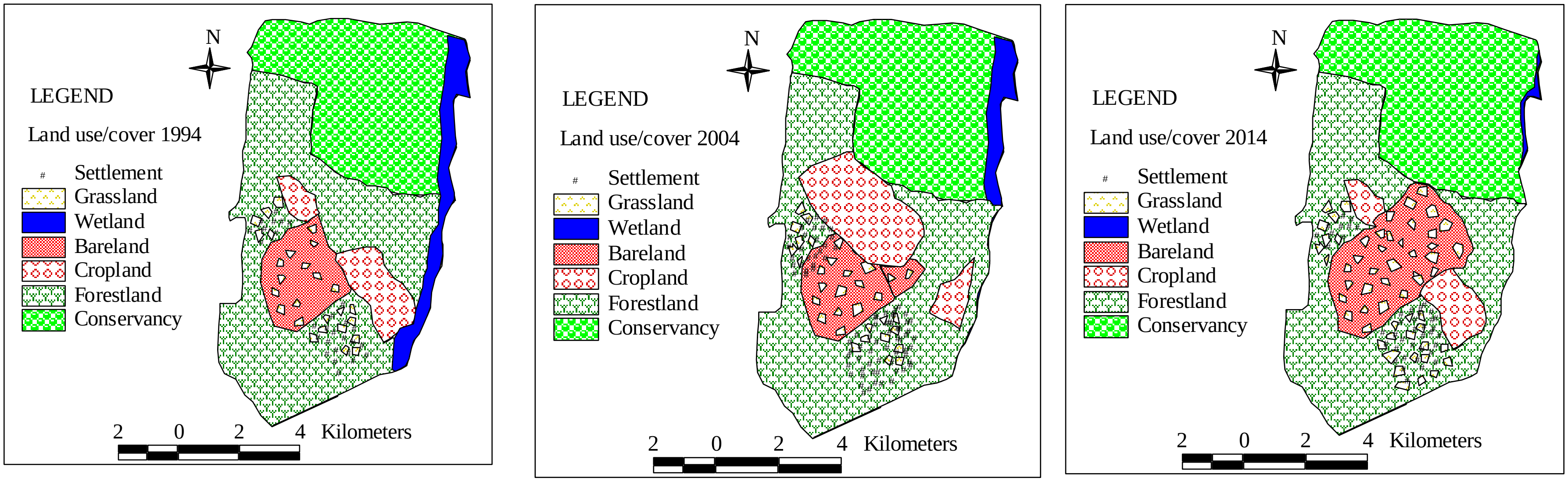

Figure 5. 1: Land use and land cover changes in Pakasse from a) 1994, b) 2004 and c) 2014

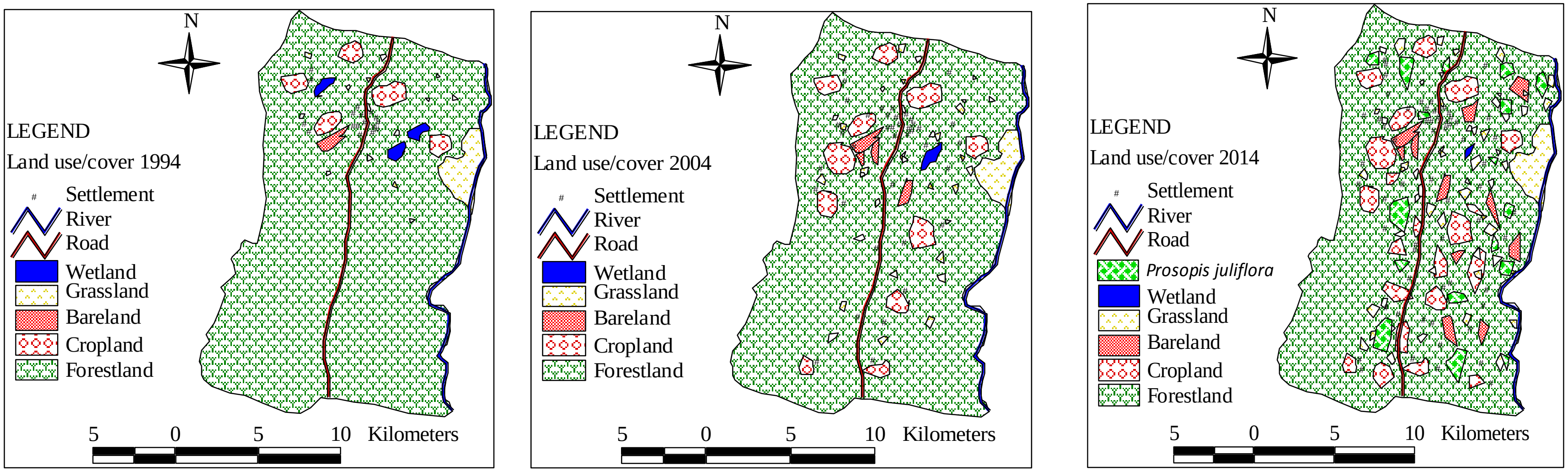

Figure 5. 2: Land use changes in Entasopia for a) 1994, b) 2004 and c) 2014

5.3.2 Results of PGIS and FGDs discussions

The method employed in this study is a clear indication that the locals have good knowledge of changes occurring on their environments. Results of discussions form the FGD and PGIS sessions confirm that the local communities in Entasopia and Pakasse are aware of trends and spatial changes taking place in their location. They noted an expansion of cropland, settlements, bareland at the expense of forestland and wetland. This implies that as people move in the catchment more land is being cleared for cropping under irrigation. The reduction in areas occupied by wetland is attributable to water abstraction to support irrigation. Clearing of natural vegetation along the riparian areas also contributes to reduction in areas occupied by wetlands due to their role in maintaining hydrological cycle.

In Entasopia, it was noted that, the indigenous vegetation is slowly being overtaken by an invasive species *Prosopis juliflora bush* which has continued to expand over the years. This poses a great challenge on the grazing areas. This could consequently threatened livelihoods of the indigenous community who are largely dependent on livestock making grazing areas a critical resource. Water is by far the cornerstone of livelihoods in this area, yet it is also becoming a scarce commodity due to demands from domestic, wildlife, industries and farming. This is significant threat to the survival of livelihoods in the study area.

There were fluctuations reported in the extent of land use with a reduction of forestland in 2004 and expansion in 2014 in Pakasse. These observations coincided with cropland expansion in 2004 and reduction in 2014. This result shows that there is a direct link between cropland and forestland as one increase the other experiences a reduction. Settlements increased with increase in cropland implying that the opportunity available for cropland attracted more settlers in the area.

There was a major concern of change in river courses in Pakasse as reported by the local community during the FGDs. This has resulted in drying riverbeds and swamps downstream. This is a result of cumulative impacts of intensive irrigation activities and human activities in the upper catchment. This is therefore calls for consultative measures involving both upstream and downstream communities to devise measures that benefit all stakeholders. Perhaps this could also explain the reason for fluctuating changes that occurred in forestland, cropland and settlement between 2004 and 2014 since the available supplies of water are not able to sustain irrigation forcing locals at one point to abandon farming leaving land fallow. When farmlands are left fallow they become prone to further degradation that cannot sustain human activities.

Private conservancy which was unique land use observed in Pakasse maintained status quo. This implies that land ownership has implications on land use change. This study confirms that drivers of land use change are specific to locations. This conforms to studies by Geist and Lambin (2004) and Lepers *et al.* (2004). However in a catchment perspective activities taking place upstream ultimately affect livelihoods downstream and this should be considered in catchment management plans.

The key drivers of land use change in Nguruman sub-catchment are driven by human activities as observed in both Entasopia and Pakasse. Climate variation in the area has also shaped livelihoods. Hence land use and land cover changes also occur as communities strive to mitigate the effects of climate factors e.g. unpredictable rainfall and long drought periods. drivers were also identified in similar studies (Framer *et al* 2006). The prevailing climatic conditions have brought about changes in livelihood from pastoralism to agro-pastoralism to meet basic livelihood requirements. The huge influx of new settlers moving in Nguruman with an aim of purchasing or leasing land for farming under irrigation has subsequently affected land cover especially clearing of forestland for settlement and farming.

Unpredictable climatic conditions will certainly have an impact on pasture production and sustainability for pastoral livelihoods.

Participatory GIS has had other application in resource mapping and advocating for best management practices e.g. Kathumo *et al* (2012) employed PGIS in mapping forest resources on the Lower Tana River Forest complex. Rambaldi *et al*. (2007) involved the Ogiek, Sengwer and Yaiku communities in Kenya in initiating their ancestral land rights, cultural rights and natural land resource management projects through participatory resource mapping. Baaru and Gachene (2016) applied PGIS in Kathekakai location, Machakos district to empower locals in natural resource assessment. Participatory approaches have also been useful in mapping areas for conservation (Bojorquez-Tapia *et al.,* 2003, Brown *et al.,* 2004, Kathumo *et al.,* 2012). As observed by Nabwire and Nyabenge (2006) and Kathumo *et al.,* 2012) participatory mapping, spatial inventories of natural resources, land use rights and perceived problems can be created for more equitable and sustainable natural resource management. Other successful applications of PGIS in resource mapping were reported by McCall and Minang, (2005) and Griffiths (2002) that involve acquisition of ancestral land rights. Claiming ancestral land title in the Philipines requires preparing a resource management map for the area (Rambaldi and Callosa-Tarr, 2000). Bedu shepherds in Jordan and Burkina Faso (Sedogo and Groten 2000) used PGIS to map indigenous technical knowledge is pastoral management.

The local communities were able to perceive some benefits associated with land use and land cover changes (Table 5.5 and 5.6).The benefits resulting from decreasing forestland include increased food production, employment for locals in the horticultural farms, economic empowerment of those involved in farming. Availability of water for irrigation has also attracted a lot of settlements as most immigrants move in purposely for farming. Increasing settlement has led to an increase in provision of basic services associated with demand from increasing population e.g. schools, hospitals and local markets. The activities have also attracted initiatives form various institutions including NGOs and other international organizations who have introduced programmes to advocate for sustainable use of resources in order to improve local livelihoods. Such initiatives had contributed significantly to improving their lives. They include partnerships with local communities through community-based organizations (CBOs) and non-governmental organizations (NGOs). The partnerships are mainly involved in advocacy and initiatives that aim at alleviating hardship being experienced by marginalized. The government has also started initiatives to improve roads in order to make the area accessible and to improve basic services**.** Recently KWS and other NGOs like AWF, IFAW and the private sector have been encouraging the community to diversify uses of wildlife resources by getting involved in eco-tourism.

Table 5. 5. Benefits of land use and land cover change as perceived by local community

	Location		**Community Rating**		
Benefits of land use land cover change	**Pakasse**	**Entasopia**	**Low**	**Medium**	**High**
Increased food production	x	x			■
Increased pastureland	✓			■	
Economic empowerment		✓		■	
Income and livelihood diversification	✓	✓		■	
Increased land for settlement		✓			■
Increased basic services e.g. schools, health		✓	■		
Improved infrastructure e.g. roads transport	✓	✓	■		
Increased collaboration with institutions	✓	✓		■	
More land for farming		✓			■
More water for irrigation		✓			■
Increased social cohesion among ethnic groups		✓		■	
Improved communication network and security			■		
Access to Fuel Wood	✓	✓			■
Access to medicinal plants	✓	✓		■	

The locals also outlined some of the challenges associated with the reduction in forest cover and expansion of both cropland and settlement as summarized in Table 6.6. The reduction in forestland has led to temperature increase and reduction in rainfall. Consequently this has led to reduction in water volumes from the rivers. Unreliable and insufficient rainfall has further resulted to low fodder production leading to weak animals that has contributed to most death of livestock. The shortage of water in rivers and streams has in turn contributed to limited water for irrigation. The expansion in cropping could further lead to soil erosion causing high soil erodibility and fertility loss in, steep farmland. The locals also noted that the expanding agricultural areas has caused human-wildlife conflict due to crops and assess damage, leading to negative attitude towards wildlife. The invasive plant species *Prosopis juliflora* being spread by wildlife and livestock feeding on its pods has invaded most areas in Entasopia location. This has led to loss of wildlife habitat and injury to animals and people.

Table 5.6.Challenges of land use and land cover change

	Location		**Community Rating**		
Effects of land use land cover change	**Pakasse**	**Entasopia**	**Low**	**Medium**	**High**
Low rainfall and high temperatures	✓	✓			■
Increased storm events				■	
Reduced stream river flows	✓	✓			■
Increased soil erosion and land		✓		■	■
Siltation of rivers	✓	✓			■
Reduced soil fertility		✓		■	
Reduced food production	✓			■	
Reduced pasture quantity and quality	✓			■	
Livestock diseases and death of livestock	✓		■		
Human-wildlife conflict (crop raiding)		✓		■	
Increased land conflicts	✓	✓			■
Land subdivision, fencing and		✓			■
Livelihood displacement	✓	✓		■	
Expansion of invasive species(Mathenge)	✓	✓		■	
Increased sale of land		✓		■	
Reduction in household income		✓		■	
Frequent water related conflicts	✓	✓		■	

5.4 Conclusion and recommendation

The results of the PGIS analysis indicate that the main driver of land use change in Nguruman sub-catchment is human activities. Key human activity in the study area is farming by irrigation. The opportunities to abstract water for irrigation and fertile soils along the catchment have attracted new settlers in the catchment. On the other hand land use change as perceived by local communities has also come with positive changes. The expansion of cropland has opened up employment opportunities for locals in the farm. Expansion of settlements have brought with them improved basic necessities including schools and medical facilities and also opening the region to other networks from investment.

On the other hand these have had negative impact on the area occupied by forest due to the need to cultivate more land for food and settlements for the immigrants. Wetlands in the area have also reduced flow in tandem with expansion in cropland due to water abstraction for irrigation and reduction in forestland. This however could have other detrimental effect both on the ecosystem integrity and livelihood disintegration if not checked. There is need to bring a balance between development and sustainable provision of ecosystem services.

The local community was able to link changes in land use and land cover to a number of benefits and challenges. Increased food production was the major benefit in the study area while reduction in water caused by insufficient and unpredictable rainfall as a result of reduction in forest cover, expansion of agricultural and settlement area in the study area was the major undesirable effects. The water situation in the entire ecosystem is, on the overall, glim because the demand by various economic sectors such as agriculture, livestock and wildlife is on the increase but the supply is dwindling due to the environmental threats facing the sources in form of rivers, springs and wetlands. Water resources are being lost because of water abstraction for irrigation which is putting the entire ecosystem at a tipping point. Climate change variability exhibited unpredictable rainfall and long drought seasons are likely to worsen the situation.

Local communities are not only aware of issues affecting their environment. This study clearly highlights that the community also perceive ways in which to protect the environment from degradation. They expressed the need to conserve the forests to improve the condition of natural resource and were able to propose a number of strategies for managing land resources that can enhance land use changes such as (i) advocacy to create awareness on importance of forests, (ii) tree planting , (iii) rain water harvesting , (iv) building dams, (v) improving infrastructure, (vi) enhance ecotourism activities, (vii) establish sanctuaries, (vii) introduction of greenhouses, (viii) agro-forestry practice, (ix) creation of buffer zone in riparian land, (x) rehabilitation of water resource, (xi) community policing, (xii) community dialogue with county government, (xiii) community involvement in Natural resource management of the area, (xiv) diversification of livelihoods, (xv) introduction of fuel saving jikos to reduce reliance on fuel wood, (xvi) improve equitable distribution of water resources and (xvii) Introduce soil and water conservation measures .

This study has confirmed that participatory GIS provide a good opportunity for addressing issues emerging from land use and land cover change. The local community was able to discuss and map their priority land use issues in a way that is not typically possible using modern technologies. This makes it possible to validate information through direct observation. The opportunity of interacting directly with land users provides immediate feedback for making timely decisions particularly for pertinent issues that require urgent attention. The success of PGIS in mapping land use changes and involving local communities in understanding the causes and effects of changes is clearly demonstrated in this study. This approach can be adopted by county governments to identify management challenges to enable prioritization of strategies and areas for intervention. Participatory GIS provides a bottom up approach towards management. This helps in building local community confidence and enhances dialogue between stakeholders while offering the communities the opportunity to participate in management matters with a positive mindset.

CHAPTER SIX

ASSESSMENT AND PROJECTION OF LAND USE AND LAND COVER CHANGE IN NGURUMAN SUB-CATCHMENT, KAJIADO COUNTY, KENYA

Abstract

Nguruman sub-catchment in Kajiado County has undergone rapid land use change. The dynamics and extent to which these changes have impacted on the ecological system is unknown. The current study employed Geographic Information System (GIS) and LANDSAT images to determine the extent and magnitude of land use and land cover changes (LULCC). LANDSAT Images for the period 1994, 2004 and 2014 were acquired and supervised classification performed using ENVI. Seven LULCC were identified as cropland, forestland, open grassland, open water, bare land, swamp and wooded grassland. The area under each Land use was determined and subjected to a change detection analysis for the period between 1994- 2004, 2004-2014 and 1994-2014. Significant land use changes ($p<0.05$) were recorded in cropland, open water, open grasslands and bareland. Ares occupied by Croplands increased significantly and forestland reduced. There were fluctuations in areas occupied by wetlands in the form of swamps (vegetated wetlands) and open water (rivers, ponds and lakes). The fluctuation in the two land cover showed similar trends with both increasing between 1994 and 2014 and reductions between 2004 and 2014 reported. Areas occupied by open water increased significantly ($p<0.05$) by 1.15% (1994-2014). Significant reductions ($p<0.05$) in bareland between 1994 and 2014. Open grasslands increased significantly ($p<0.05$) while wooded grasslands reduced though this was not significant. Expansion of cropland has been identified as the main driving force of land use changes in Nguruman sub-catchment. This implies that more land is being converted to cropland. This is

mainly practices along the riparian land. Consequently this would lead to increased runoff and sedimentation in the streams. Actions to reverse these trends are urgently required to avert further land degradation and water scarcity. Sustainable land use measures are needed to address the challenges of prevailing land use practices.

6.1 Introduction

Land-use refers to the specific utilisation allocated to land based on various natural characteristics while land-cover describes the vegetation attributes of the land (Ifeka and Akinbobola 2015). Land use and land cover change (LULCC) are a result from natural and anthropogenic processes. The latter is driven by the demand for essential goods and services to satisfy livelihoods (MEA 2005). The impacts range from conversion of natural forest to cropland due to demand for food, fibre and settlement. The current intensity and extent of this demand is far greater than ever in history impacting highly on ecosystems and environmental processes at different spatial scales (Ellis and Pontius 2007). These changes have led to global environmental concerns including climate change, biodiversity loss, impairment of nutrient and hydrological cycles, biological invasions and the pollution of water, soils and air (Tillman and Lehman, 2001, Legesse *et al.*, 2003, Steffen, 2004, Templer *et al.*, 2005 IPCC, 2007). These therefore necessitate the need to focus on monitoring and prioritizing research and policy issues that ensure sustainable production of essential goods and services (Ellis and Pontius, 2007).

Both qualitative and quantitative spatial data on land use and land cover are essential for planners, decision makers and land resource managers (Lambin *et al.*, 2003). Natural and anthropogenic changes can be determined using remotely sensed data (Mubea and Menz, 2012). Data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change. Traditionally, methods of studying LULCC depended on survey data, aerial photographs and fieldwork to obtain data. These approaches proved to be expensive and time-inefficient. Several reports have proposed the use of remote sensing techniques aided by GIS for monitoring dynamics and impacts of LULCC of watershed environment (Baldyga *et al*., 2008, Saran *et al*., 2009). Remote sensing allows gathering data on regional LULCC patterns (Rogan and Chen, 2004). Data obtained from remote sensing is essential for the characterization of land cover, environmental monitoring and analysis of the influence on anthropogenic activities on natural resource base (Turner 2003, Lu *et al*., 2004). Remote sensing provides objective information of human utilization of the landscape in situations of rapid and often unrecorded land use change (Ermias, 2006). This tool thus provides an accurate temporal and spatial evaluation of status of the world's natural resources (Ioannis and Meliadis. 2011).

6.2 Methodology

6.2.1 Data acquisition

Selection of appropriate satellite imagery was undertaken through image data processing. This involved analysis of LANDSAT TM and ETM images covering the area of study for the periods 1994, 2004 and 2014 sourced from United States Geological Survey website. The LANDSAT imageries used covered period of 10 years intervals. Data of different land use features such as bare areas, different sets of habitat features from ground- truthing was used to validate information gathered from satellite images.

6.2.2 Image classification and change detection

The images were later pre-processed by registration and sub setting using ground control points (GCPS) (Mwavu and Witkowski 2008). This was followed by undertaking image classification starting with unsupervised classification by comparing individual pixel to each discrete cluster to see which one it is closest to in order to derive the available classes then followed by supervised classification . ArcGIS spatial analysis extension was employed in producing signature files, class and cluster analysis by grouping raster cells or feature polygons into classes or clusters. Multi-temporal LANDSAT data processing using ENVI 4.7 software and classification was conducted to delineate the major land use cover types. After classification, the various classes were examined for homogeneity and those close together were merged into one class. This classification resulted in seven (7) land use and land cover categories (Table 6.1). Spatial analysis to determine extent, location and magnitude of each land use and land cover categories was conducted in ArcGIS for the periods 1994, 2004 and 2014. Chi-square goodness of fit test was further performed to test for significant change for the various land use and land cover categories.

Table 6.1. Descriptions of land cover types

Land use and land	**Descriptions**
Cropland	Include areas covered by growing crops , ploughed fields and horticultural farms
Forestland	Include areas covered by tree (>5m high) with closed canopies (>40% cover)
Open grassland	Include areas dominated by grasses(0-0.2m) and herbs (0-0.2m)
Open water	Include areas covered by open waters, rivers and lake
Bareland	Include areas completely non-vegetated or covered with very low percent vegetable
Swamp	Include areas covered by vegetated wetlands
Wooded grassland	Include areas characterized by a high percentage of shrub cover (2-5m high)

6.3 Results and discussion

Seven land cover types were identified from the classification. These were cropland, forestland, open grassland, open water, bare land, swamp and wooded grassland (Table 6.1). Wooded grassland was the main land cover type in the study area covering 62.9% followed by open grasslands (23.4%). The vegetated wetland (swamps) had the least coverage at 0.44%. The maps for the different LULCC for the year 1994, 2004 and 2014 are presented in Figures 5.1a; b and c) were generated from LANDSAT image analysis. From the results, it is evident that Nguruman sub-catchment has undergone rapid land use land cover changes in the last 20 years (Table 6.1). Significant land use changes ($p<0.05$) were recorded in cropland, open water, open grasslands and bareland (Table 6.1). Cropland expanded at the expense of forest land. Expansion of cropland has been identified as the main driving force of land use changes in the catchment (Figure 6.1). The expansion is mainly directed along the riparian land where water for irrigation and suitable environment support farming. Similar observations were reported in other developing countries e.g. in Brazil where the European exploitation of forest for rubber, coffee and sugar cane production caused the reduction in forest. Kundu *et al.,* 2008 employed remotely sensed data and ground survey methods to evaluate LULCC in Mau Forest for a period of about 40 years. The results showed agricultural expansion at the expense of forestland. High- resolution aerial surveys of selected forests in the Aberdares, Mt. Kenya, Mt. Elgon, and the Mau complex revealed that deforestation and general degradation was taking place significantly due to unplanned forest exploitation (Ayuyo and Sweta 2014, Baldyga *et al*., 2008). Similar results have also been reported by Haruna *et al*. (2014) and Singh and Khanduri (2011) where natural vegetation has been converted to cropland and open lands with increase in population. Similar results have been observed in Africa, Asia and Latin America whereby expansion in agriculture is resulting in deforestation. Such trends are also consistent with studies conducted by Enfors and Gordon 2007, Dessie and Christiansson, 2008; Ningal *et al.*, 2008; Parés-Ramos *et al.*, 2008; Kamusoko and Aniya, 2007; Reij et al. 2005, Zeleke and Hurni, 2001). Other factors responsible for expansion of cropland could be rapidly increasing population of both native population and immigrants leasing or purchasing land for farming. A study in developing countries by Jorgenson and Burns (2007) linked rural population growth to changes in land use. This result conforms to findings by Kioko and Okello (2010) in a study on environmental changes within the Amboseli ecosystem. Similar observations were made by Mbau 2013 on a study investigating the implication of land use and land cover change on human wildlife conflict in semi-arid Amboseli ecosystem. Areas occupied by open water are expected to decline due to expansion of cropland under irrigation. As forests reduce and croplands expand more deposits of sediment is expected in the streams, this coupled with increased water abstraction for irrigation purposes will reduce amount of river flows. Kathumo (2011) also made similar observations in river Gucha catchment. Garede and Amare 2013 found that expansion of cultivated and settlement over years in Ribb River watershed in Ethiopia was responsible for significant decrease in water bodies, forestland and bushland. The area under wooded grasslands is expected to increase as open grasslands are projected to decline mainly as a result of overgrazing in the southern reaches of the study area (Sambalimo, 2015).

Other drivers of land use change could be attributed to change of livelihood and increasing immigrant population (Okello *et al.,* 2012). Baaru, (2011) made similar observation where changes in land use and land cover were influenced by proximity of the area of study to ready markets for crop produce both in Kenya and Tanzania. Mbau (2013) in her study showed an expansion of cropland in Amboseli due to good road networks and markets. Similar results were observed in Budongo forest where forests were being converted to agriculture (Mwavu and Wirkowski, 2008). A study by Kathumo (2011) in Gucha River catchment also showed that more forestland was being cleared for Agriculture and settlement. In Mau forest complex changes in land use and land cover resulted in clearing of forest for farming and settlement (Ayuyo and Sweta, 2014).

Wetlands in the form of swamps (vegetated wetlands) and open water (rivers, ponds and lakes) recorded fluctuations. The fluctuation over the period of investigation could also be as a result of variation of rainfall from year to year that contributes to surface run off. Areas occupied by open water increased significantly ($p<0.05$) by 1.15% (1994-2014). Area occupied by swamps also fluctuated though this was not significant. The observed expansion in both swamps and open water could have been contributed by increased surface runoff from the El Nino rains in the years 1997/1998. The expansion in open water which included areas occupied by streams and rivers expanded between 1994 and 2004 due to clearing of land for cropland along the riparian land. Studies indicate that when more vegetation is cleared along the riparian land the volume of stream flow is expected to increase due to the reduction of water being intercepted within the catchment (Tabachi *et al*., 2000).

The significant reduction in bareland was mainly associated with more land being allocated for farming and settlement. The increase in populations contributed by the immigrants who move into the study area purposely for farming increases the demand for both farming and settlement (Sambalino, 2015). It is also possible that the conditions experienced in the southern part of the study area have resulted from cumulative impacts of irrigation farming and other activities emanating from the northern area. Further clearing of natural vegetation, intensive cultivation and overgrazing without consideration of environmental effects on these fragile lands are the probable land degradation Tsegaye *et al*. 2010).This result therefore points out to the need for proper land use planning and allocation to sustainable uses that do not have detrimental effects on the environment. Land and water management in the upper reaches of the catchment should not jeopardize the provision of ecosystem services to the downstream users. The determination of the potential of land for allocation of land uses is critical for both ecosystem and sustaining livelihoods in the study area.

Table 6.2 Chi-Square goodness of fit test for various LULCC in Nguruman sub-catchment

Land use/cover	Area Km^2			% Change			χ^2 Test		
	1994	2004	2014	1994-2004	2004-2014	1994-2014	χ^2	df	p-value
Cropland	24.9	51.92	70.16	1.00	0.68	1.68	21.12	2	0.00
Forestland	86.17	96.11	102.93	-0.25	-0.37	-0.62	1.45	2	0.48
Open grassland	619.63	640.44	716.16	0.77	2.82	3.59	6.25	2	0.04
Open water	33.75	69.8	64.77	1.34	-0.19	1.15	13.57	2	0.00
Bare land	240.6	200.97	154.64	-1.47	-1.72	-3.20	17.43	2	0.00
Vegetated wetland	11.82	13.45	13.55	0.06	0.00	0.06	0.24	2	0.89
Wooded grassland	1672.55	1616.73	1567.21	-2.08	-1.84	-3.92	2.14	2	0.34

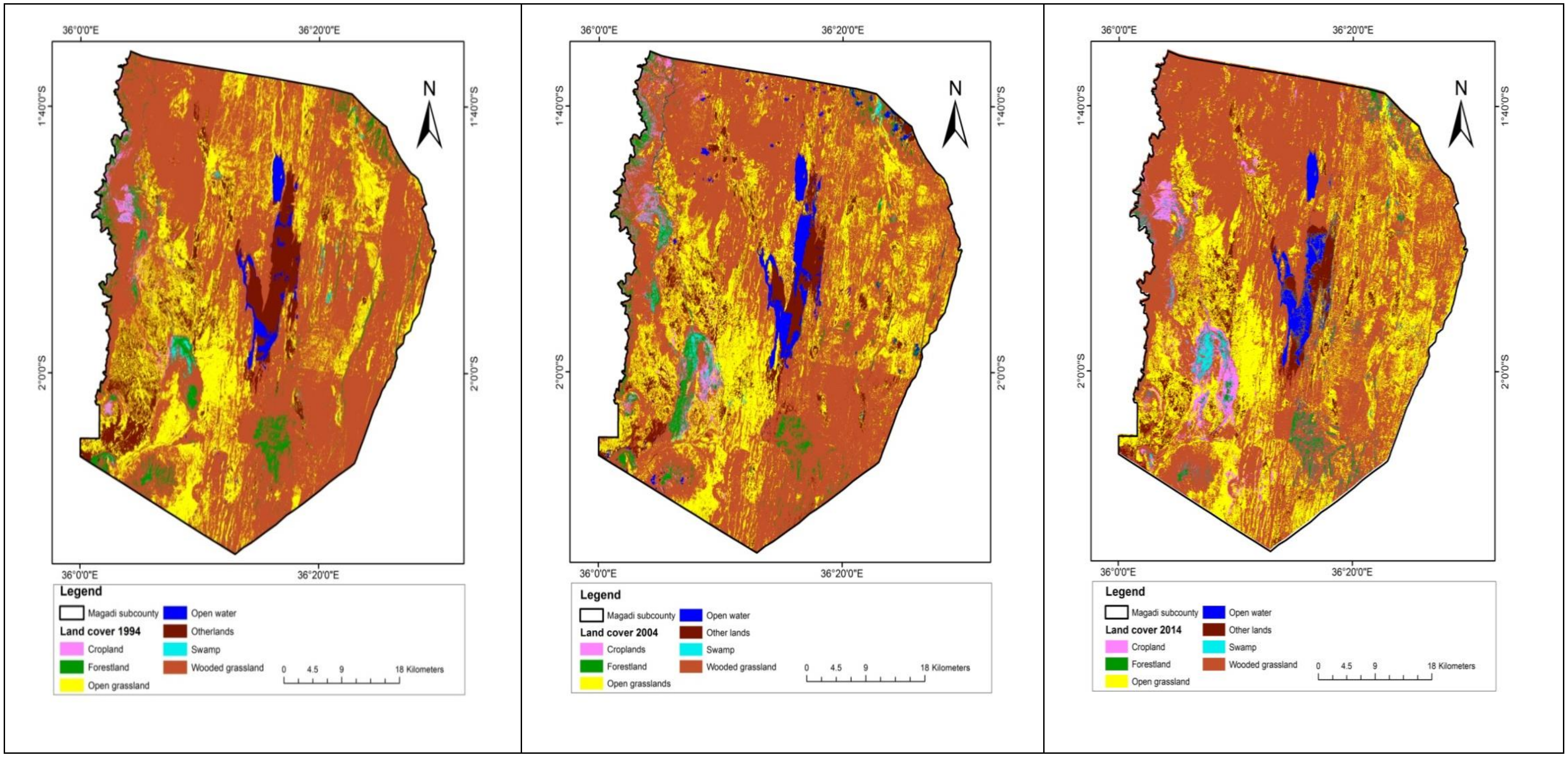

Figure 6.1. Land use and land cover changes in Nguruman for period a) 1994, b) 2004 and c) 2014

6.4 Conclusions and recommendations

Results of temporal and spatial analysis of land use and land cover change in Nguruman sub-catchment clearly indicate that changes have occurred over the last 20 years. The key driver of change is farming under irrigation along the riparian areas. Large areas previously occupied by forestland particularly along the riparian lands have been converted to croplands in the upstream section of the study area. This mediated by the availability of guaranteed water for irrigation and fertile soils for farming in the upper reaches. The cumulative impacts of the irrigation activities in the upstream section of the study area are already being experienced downstream. The shompole wetland and river pakasse which are key sources of water downstream have continued to dry or experienced unpredictable fluctuations as they no longer receive flows from the main Ewaso Ng'iro River. Hence measures to effectively apportion and diversify water sources for various uses should be explored to minimize pressure from the man source of water.

Water abstraction for irrigation in this area poses a great risk to the sustainability and integrity of the riparian ecosystem in Nguruman sub-catchment. The effects are not only directed to the ecosystem function but would also impact on livelihoods. This study highlights the need to protect the riparian land and the matrix of habitats that include the river systems of the catchment area. In the absence of measures to curb the negative trends of land use changes projected in this study it is expected that water scarcity and land degradation will escalate. Further implementation of best management practices should include proper land allocation for various uses. It is important to first assess the viability of various land uses in the study area from an environmental and economic perspective. Allocating land use that is not viable is detrimental to the ecosystem and livelihood in the long run.

CHAPTER SEVEN

GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

7.1 Land use and land cover change in Nguruman sub-catchment

The most important land conversions reported in this study was expansion of cropping into forestland especially along the riparian land. Similarly, the increase of the number of people engaged in the activities has continued through in the last decade as more immigrants move into the catchment to exploit farming opportunities. Continuation of the current trends in land use implies that the area under crop production is likely to increase by the year 2040, with a corresponding decrease in forest. There will be more encroachment on forests, increased settlements and cultivation in Nguruman sub-catchment that would lead to environmental degradation and impairment of the catchment hydrological functions. Significant land use changes in the study area have been influenced by demand for land to support increasing immigrant and local population. The change of livelihood from mainly traditional herding system towards a more sedentary agro-pastoral system has further led to clearing of more riparian vegetation. The change in livelihood is a strategy aimed at mitigating prevailing environmental conditions; however the implications of these changes on the ecosystem need further investigation. The findings also reveal that historical trends have had significant influence on the current state of land use and land cover change in the study area. Hence understanding historical trends is critical in formulating strategies for resource management. Nguruman sub-catchment has undergone rapid land use transformations leading to land cover changes as a result of a variety of processes of land-use change. The effects of land use change is currently being felt e.g. increased irregularity in rainfall and temperature patterns and declining soil fertility, resulting in more land being left abandoned and exposed to agents of degradation. This in turn is compromising the capacity of the ecosystem to perform its hydrological functions efficiently.

The Nguruman sub-catchment situated in Kenya section of the Great Rift Valley presents a good example of areas that have undergone extensive land use and land cover change and a subsequent rise in population. Increasingly growing small rural urban settlement has continued to grow culminating into a rise in human population. This growth in population and associated economic activities exert enormous pressure on the scarce wetland resource and forest habitats. The changes and their repercussions require urgent interventions and formulation of rational policies that effectively strike balance between economic development and environmental conservation. The conclusion from this study is that there is a clear trend of land use and land cover change in terms of declining forest cover, reduction of wetland and expansion of cultivated land from 1990 to the 2014. This land use change is exacerbated by the ever increasing population change contributed by immigrants who have mainly migrated to explored opportunities for farming. This requires a concise policy framework from which to generate holistic and integrated strategies and actions for wise use of land. There is need to further broaden LULCC studies from a local to broader scale so that necessarily critical linkages between socio-economic and biophysical processes that are elucidated by more local studies and that should be the focus of remedial strategies are not avoided.

7.2 Integrating local community knowledge and participation in catchment management

This study has highlighted the importance of integrating local community knowledge and enhancing their participation in resource management. Results have established that local communities have significant knowledge of land use dynamics in Nguruman sub-catchment. Participatory GIS is one of the participative approaches and tools that provide an avenue for local communities to spatially express their knowledge of land use change and discuss issues in a drawn map. It provides an opportunity to involve community members in developing baseline data and a common understanding of their environment. This experience allows them a better understanding of their environment and how they see themselves in relation to the various dynamics that exist in the area. The generated map and the documented realizations and insights of the community members are significant inputs into a development plan that integrates the social and economic essentials into the quality of their environment. The use of PGIS in this study greatly helped facilitate general understanding of the dynamics of land use and land cover change, including both positive and negative effects. Recognizing the importance of community mapping is a way to actively involve the members of the community and as a venue to allow for exchange of scientific, technical, and local knowledge about the condition of their natural resources in an area. The study shows that participatory resource mapping is a useful tool for engaging local communities in mapping the status of their resources, a prerequisite for sustainable community-based resource use planning and management. The PGIS also plays a critical role in bridging the gap brought about by disparities in education, culture while embracing a bottom up approach in resource management. The cultural integrity, practice and experiences of the local community relating to perceptions, rights, tenure systems, community institutions, conflict resolution among other value systems, must be respected and recognized as the basis for making decisions on land use.

7.3 Conclusions and recommendation

The current study has integrated diverse methodologies to understand the effects of land use and land cover change in Nguruman sub-catchment. These included applications of LANDSAT Images, Participatory mapping (PGIS), household interviews, structured questionnaires and

Focused group discussions. The study highlights the importance of applications of multiple technologies in understanding process that results in various land use changes. The use of participatory resource mapping provided an entry point for eliciting community perceptions of problems facing them in order to guide sustainable resource planning and action at a local level. The study shows that participatory resource mapping is a useful tool for engaging local communities in mapping the status of their resources, a prerequisite for sustainable community-based resource use planning and management. A resource mapping exercise conduction in two locations in Nguruman sub-catchment confirmed that the residents are not only able to assess trends but they were also able to determine the magnitude of changes by participating in mapping exercise that depicts exact changes on the ground for the different time periods. Accordingly they confirmed that irrigated cropland had increased at the expense of forestland especially in riparian land where they could take opportunity of available water for irrigation.

The different perceptions and varied knowledge in land use and land cover change translate into interest groups which could influence land policy in the country. Previous remote-sensing assessments of community-based conservation initiatives have tended to separate the physical and biological resources from the social environment. This has led to a lack of confidence among those involved in implementing the initiatives. There is a critical challenge for understanding how changes in social systems interact with changes in ecological systems to influence farming practices and agricultural land use trajectories. Thus, the study conducted in Nguruman makes novel contributions to the literature on dryland catchment management that seeks to understand how human communities in these environments perceive changes in their environment and how their responses to those perceived changes help shape various agricultural land use change trajectories. Consideration of local perceptions offers more informed basis to design and implementation of land use policies in ways that encourage active local participation, sustainable livelihoods development, and responsiveness to changing conditions. This departs from current conventional implementation systems, which are usually top-down and based on technical and political aspects of agricultural land management, but do not necessarily comprehend processes influencing the agency of local communities in shaping various land use outcomes

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APPENDIX

Questionnaire on Local Perception on Impacts of Land Use Change on Hydrology in Nguruman Catchment, Magadi, Kenya

Introduction

The aim of this questionnaire is to assess land use and land cover changes in the study area and how this land use land cover changes have impacted on land and water resources in Nguruman Catchment. In addition the project intends to document how local people feel about changes in land use and land cover. The findings will contribute to designing suitable measures to conserve land and water resources through sustainable land use practices.

Any assistance towards gathering this data will be highly appreciated.

Instructions: tick as appropriate

Section I: Personal details

1.0 Name/code of respondent (optional) ________________________________

1.1 Village / Sub-location / Location / Division ___________________________

1.2 Sex Male ( ) Female ( ) **Age** <20 ( ), 20-30( ), >30( )

1.3 Education Level: Primary ( ), Secondary ( ), Tertiary ( ) Informal Education ( )

1.4 Residential Status: indigenous () Immigrant ()

1.5 If immigrant, how long have you lived in the area? _______________________

1.6 If immigrant, what was your reason for moving in the area? Business (), Farming (), Work (), other () specify___________________________

Section II: Knowledge of benefits derived by Locals from Nguruman Catchment

2.0 Do you derive any benefit from Nguruman Catchment Yes ( ) No ( )

2.1 What benefits do you derive from the Catchment? Rank in order of importance

(5=highest value, 4=very high value, 3=high value, 2=low=1=very low)

Value	**Rank**
I. Fuel wood production	
II. Fodder production	
III. Farming activities	
IV. Dry season grazing land	
V. Pole and timber harvesting	
VI. Any Other (specify)	

2.2 Are there any restrictions prohibiting locals from deriving benefits from the catchment? Yes () No ()

2.3 Name those restrictions

I. Fee restrictions ()

II. Permit restrictions ()

III. Seasonal bann ()

IV. Total government bann()

V. Cultural restrictions

VI. Other ()_________________

2.4 are there any problems you face from deriving the benefits from the catchment mentioned above? Yes () No ( )

2.5 Name the Problems

I. Poaching ()

II. Human-Wildlife conflict

III. Human-human conflict

IV. Over exploitation of resource ()

V. Others specify ____

Section 3–Land use change, their drivers and impact

3.0 are there any changes in unit per parcel of land owned by households? Yes ( ) No( )

3.1 if yes, how is the size of land parcels changing among different households?

A**.** Increasing ( )

B**.** Decreasing ( ).

C. No change ()

D. Not aware ()

3.2 Have you noticed any change in land use and land cover in your locality. Yes ( ) No ( )

3.3 What are the major land use changes that have occurred on Nguruman Catchment since the 1990s in your locality ?(provide qualitative description; +, - & No change)?

What major shift in land use occurred

	<5 years		5-10 years ago		10-20 years ago	
	Area	Quality	Area	Quality	Area	Quality
Cropland – rainfed						
Cropland – irrigated						
Grassland land –private						
Grassland –communal						
Forest land						
Bushland						
Shrubland						
Wetland						
Bareland						

3.3 Please mention the nature of changes.

I. Natural forests to have been converted into cropland ( )

II. Markets and trading centers increased()

III. Human settlements have increased towards natural habitats ( ),

IV. Modern methods of agricultural farming introduced.( )

V. Wetlands have been converted to cropland ()

3.4 . What are the cause of the above mentioned changes a? Please list the causes from the most critical to least important cause. Highest score 5 and lowest 1

Cause	**Rank**
I. Livestock grazing	
II. Agricultural activities	
III. Fuel wood collection,	
IV. Charcoal production	
V. Tree felling for timber and poles	
VI. Bush fires	
VII. Other	

Section IV. Climate change related issues

4.0 Have you noticed any change in weather patterns? Yes () No () (specify period)

4.1 please tick the period which changes were observed

Period	Yes	No
20 years ago		
10 year ago		
< 5 years ago		

4.2 How has the weather patterns changed over time?

Weather	Increasing	Decreasing
Rainfall		
Temperatures		
Wind Storms		
Fires		
Others (mention)		

4.3 **H**as this weather patterns posed any problems to the livelihood of inhabitants within the catchment? Yes () No ()

4.4 What has been the nature of the threats

I. Flooding ()

II. Water shortages ()

III. Forage shortages()

IV. Migrating from lowlands to highlands ()………………….

V. Other Specify ()____

4.5 How do you cope with this changes mentioned?

____

Section V. Land and water related issues

5.0. What are the major problems associated with water resources in your locality?

I. Flooding ()

II. Water abstraction ()

III. Human settlement ()

IV. Water pollution ()

V. Water shortage ()

VI. Human-Wildlife conflict()

VII. Human-human conflict ()

VIII. Other specify____

5.1 Are there any activities involving water abstraction from the Catchment? Yes() N0()

5.2 If Yes Name the activities____

I. Domestic use ()

II. Livestock watering ()

III. Crop irrigation()

IV. Industrial use ()

V. Other() specify____

5.3 Have you notice changes in the trend of the river flows within in Nguruman catchment between ? Yes(), No ()

5.4 What has been the trend within the different periods below?

Period	Increasing	Decreasing	No Change	Not Aware
20 years ago				
10 year ago				
< 5 years ago				

5.5 Is land degradation a problem in your locality? Yes () No ()

5.6 What type of land cover is vulnerable to land degradation (in order of vulnerability score of 5(most vulnerable)-1 (list vulnerable)score)?

I. Crop irrigated

II. Crop rainfed

III. Forest ()

IV. Bushland ()

V. Shrubland ()

VI. Wetland ()

VII. Grassland ()

VIII. Others specify______________________

Provide reason for above response_____________________________________

5.7 What type of Soil degradation is prominent in your area in order of severity 5 most severe, 1-Least severe?

I. Soil erosion ()

II. Gully formation ()

III. Soil fertility decline ()

IV. Moisture stress ()

V. Others, specify ()

5.8 How do you evaluate trend of land degradation over?

	Now/2014	10 year	20 years	Next 10years?
Severity of land degradation 1				
Extent of land degradation 2				
Signs of land degradation 3				

1 1: light; 2: moderate; 3: severe; 4: very severe

2 1: absent; 2: present on vulnerable land units; 3: widespread everywhere

3: 1: soil erosion; 2: gully formation; 3: vegetation degradation; 4: soil fertility degradation; 5: water stress; 6: others (specify)

5.9. What land and water management practices are present in your locality and

Which ones are your preferences 5 to 1(most to least preferred)?

I. Conservation farming ()

II. Tree planting ()

III. Installing water tanks ()

IV. Constructing earth dams ()

V. Other Specify ()____

5.10 are there organizations are working towards management of various land and water based resources in your locality? Yes (), No ()

5.11 What initiatives are being done to protect the Catchment by different organizations? (name them under categories provided)

I. By Government institutions______________________________

II. By Local community

III. By community based organizations

IV. By County Government

V. By Non Governmental organizations

5.12 How do you evaluate the efforts made?

5.13 Excellent ()

I. Very good()

II. Good ()

III. Poor()

IV. Very poor()

5.13 What's not achieved so far and what could have been done

differently?____

4.14 What are the most priority issues in your locality that needs intervention and please suggest ways to address it?

I. land degradation ()

II. flood control ()

III. Water scarcity()

IV. Forage shortage()

V. Resource use conflict()

VI. Food shortage ()

VII. Poverty ()

VIII. Other ()……

Section VI - Institutional issues

6.0 What are the major factors that affect your decision related to land use or Management in order of importance (+explain)?

Factors	**Causes**
Natural factors	
Demographic factors	
Institutional factors, laws	
Political factors, policies	
Economic Factors, Policies	
Socio-Cultural factors	

6.1 . Describe new practices & regulations that influence land management in your locality at different points in time and their impact?

Period	**Regulation /Practices**
Last 5 years	
Between 5 and 10 years ago	
Between 10 and 20 years ago	
Other	

6.2 . What are the major changes in land use (area + quality) and management you noted in communal properties over the last 20 years and the institutional changes that go along with these

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

Section VII-Miscellaneous

6.3 Do you have additional issues to forward pertaining points discussed?

…………………………………………………………………………………………………….

6.4 . Would you like to make any comments, observations or recommendations that would be helpful to addressing the land use issues and water resources management?