ASSESSMENT OF LAND-USE ACTIVITIES AND THEIR CONTRIBUTION TO LAND DEGRADATION IN OROBA WATER CATCHMENT, NANDI/ KISUMU COUNTIES, KENYA.

BY

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DECLARATION

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ABBREVIATIONS & ACRONYMS

ASALS	Arid and Semi-arid Lands
FAO	Food and Agricultural Organization
LVILMP	Lake Victoria Integrated Land Management Project
LADA	Land degradation assessment
GLASOD	Global Assessment of Soil Degradation
GIS	Geographical Information System
UNCED	United Nations commission on environmental development
DPSIR	Drivers, pressure, state impacts and Response
GPS	Global positioning system
DEM	Digital elevation model
ETM	Enhanced thematic mapper
TM	Thematic mapper

OPERATIONAL DEFINITION OF TERMS

- **Land**; means the terrestrial bio-productive system that comprises soil, vegetation-including crops, human activity, landform, other biota, and ecological, climate and hydrological processes that operate within the system influencing land use.
- **Land degradation;** refers to temporary or permanent reduction on productive capacity of land (decline in land quality) as a result of human action or natural processes **or** Land degradation is the resultant of multiple processes that directly or indirectly reduce the utility of land.
- **Land use; is** the management of land to meet human needs. This embraces rural land use such as agriculture, forestry, and aquaculture as well as all forms of urban and industrial use.
- **Land use activities;** may be defined as various developments on land undertaken by human for economic, social or physical purposes.
- **Land use planning;** is a coherent set of decisions about the use of land and ways to achieve the desired use. A land use plan consists of a definition of goals; an ordering of land, human and material resources; an explained statement schedule to be used; and agreed targets.
- **Water catchment;** is an area of land where water from rain and melting ice or snow drain downhill into a body of water.
- **Land quality;** This ability of the land to sustain land utility.
- Poverty; Human population earning less than one dollar.

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Land is a vital economic resource in Kenya and elsewhere. Therefore, its degradation and decline in productivity affects the overall development of the country. Globally and in Kenya land degradation is a major environmental and socio-economic problem and it is anchored in the United Nations convention to combat Desertification, convention on Biodiversity; the Kyoto Protocol on Global climate Change adopted in 1997 in Kyoto, Japan and the Millennium development Goals (UNCED, 1992, UNEP, 2007). Kenya is a signatory to this convention which reflects the country's commitment to addressing the impact of man's activity on the environment. There is pressing need for an up -to-date, quantitative and reproducible assessment to support policy development for food and water security, environmental integrity, international aid programs and national strategies for economic development and resource conservation.

Land degradation is the result of multiple processes that directly or indirectly reduce the utility of land. The direct effects are pollution of land, loss of; soil structure, soil nutrients and water quality. Long time ignorance on environmental issues has escalated land degradation. In this respect it is vital to understand its nature, extent and distribution in order to be able to address the local regional and global environmental challenges of the 21st century (Berry et. al., 2003)

The importance of water catchments is that it provides river flow regulation on environmental flow, water storage, recharge of groundwater, water purification, reduced soil erosion and siltation, protection of biodiversity, regulation of micro-climate,

favourable conditions for optimum crop production, carbon reservoir, supports livelihood, provide water to urban centers and other socio-economic developments. The water catchment in Kenya plays a major role in economic, social and environmental development issues (UNDP, 2008).

In recent years the government of Kenya (GoK) has taken significant steps towards addressing the threat of rapid ecological degradation of the catchments resources for example the most vital Mau catchment that occupies an area of 416,542 ha^3 and has the largest forest canopy in East Africa. The government adopted a new forest policy and law in the year 2005, the law has placed significant emphasis on co-management of the catchment resources with local communities and the private sector.

The Oroba Water Catchment falls within Kisumu and Nandi County, which is in the greater Lake Victoria Basin and the source of the river is Nandi South forest. Land degradation in Oroba water catchment is the resultant of multiple processes that both directly and indirectly reduce the utility of land, and is a global development and an environmental issue that afflicts Kenya greatly (Odada, et al., 2009).

Population pressure, poverty and lack of technology have contributed greatly to intensification of the land use activities by the land users to meet their immediate needs. The community in the highlands (Upper and Middle catchment) are agro-pastoralist who cultivate crops like tea, coffee and sugarcane as their cash crop), maize, beans, vegetables' and keep livestock both indigenous and exotic (dairy). In the lower catchment farmers grow sugarcane; cotton and rice as cash crop, maize, beans, sorghum, vegetables', keep livestock and fishing. The land use activities such as intensive agriculture without observing appropriate land management practices has resulted to

several draw backs such as loss of soil fertility hence decline in yields (Onyango et al., 1997).

Increased urbanization and infrastructural development, deforestation and settlement have resulted to unpredictable rainfall pattern and drought, reduction of crop land, siltation of rivers and lakes. The traditional way of maintaining soil fertility by leaving it fallow for a certain period is no longer possible within the study area because of high population density which is over 300 persons per km^2 according to national census of 2009, Kenya.

The vision 2030 plan covers water catchment management and recognizes that deforestation has caused severe degradation of the main water towers such as the Mau forest complex. A Task Force was established to undertake and provide recommendation to restore the Mau catchment ecosystem on sustainable basis for future conservation and management (GoK, 2009). The outcome from the task force was expected to apply to other water catchments in Kenya.

About 17% of Kenya's total area is of high and medium potential, while the remaining 83% is classified as arid and semi-arid lands (ASALs). Presently, 57 % of Kenya's population lives in poverty and is largely reliant on climate sensitive economic activities including rain fed subsistence agriculture (FAO, 2010). Land use is influenced by a number of factors, the main ones being climate, socio-economic (culture and population dynamics; population size and densities) and government policies. However, the use of land changes with time and have resulted in land degradation which is the results of improper land use practices, increasing population density and demand for land has led to widespread clearing of vegetation, overgrazing, settlements, deforestation, poor

irrigation, infrastructure developments, over-exploitation of aquifers, intensive tillage and cropping, recurrent droughts and climatic changes. Human activities in the catchment negatively impacts on public health and on landscape structures such as loss of biodiversity, vegetative cover loss, poor soil and water resources conservation

The assessment of land-use activities and their contribution to land degradation is vital for sustainable land management and is a prerequisite to any attempt to planning land resources which is an issue in Kenya, regional and global level. This recognition resulted in the FAO attempt to produce a world map of land degradation compiled from existing regional data and maps (Annon, 1977). The estimated surface area affected by human-induced soil degradation is 24 percent of the inhabited land areas (Olderman et al., 1991).

The Western region of the Lake Victoria drainage basin in Kenya, where Oroba Water catchments is situated is characterized by poor and dense populations. The study area covers 267.9 km^2 and is within Kisumu and Nandi counties with a population density of 300 and 301 per square kilometer respectively.

The Kenya's population and housing census of 2009 report indicates that 69.95 per cent of people in Kisumu and 26.64 per cent in Nandi live below poverty line earning less than one US dollar per day.

According to Were et al, (2010 and 2011), encroachment on the steep slope of Nyando escarpments by farmers and their livestock's to the areas prone to erosion zones and the wetlands (swampy areas) in Kano plains, natural forest in Nandi south and other critical ecosystem within the region for agriculture, fuel wood, timber production, grazing and settlement have led to environmental degradation.

Published studies on soil degradation and erosion in Kenya focus more on the effects than causes ("Orders of magnitude" of erosion and runoff losses in the higher agricultural areas and those in the semi-arid areas (Pereira et al., 1967, Dune, 1977; Barba et al., 1979 and 1981) provide a wealth of information such as quantitative measurements of soil losses in sediment load annual soil losses in ton/ha/year. Crop growth in terms of tons of yield reduction or losses, nutrient depletion in terms of nutrient losses and their replacement costs, would provide valuable data.

Studies conducted by Lake Victoria Integrated Land Management Project in the Lake Victoria Basin revealed that severe land degradation was taking place in the greater Lake Victoria region. Analysis of the sediments collected at Nyando estuary showed that the rate of sediment deposition in the region had increased four-fold over the last Century (Olago et al,. 2007). This is more similar to the situation at Winam Gulf of Lake Victoria, the largest quantity of sediment deposition emanated from agricultural areas leading to decline in soil fertility, heavy Siltation of the surrounding rivers and streams. Similarly, studies carried out on water erosion hazard in Kenya indicated that erosion severity level was 24.6% (i.e. severe) on Nandi escarpments, 6.3% (i.e. slightly severe) on the lower areas and 10.3 % (i.e. very slight) on the plains (Gatahi and Okoth, 1990) done at a scale 1:1,000,000.

The diminishing precipitation, recurrent droughts, natural floods and the large loss of vegetation experienced in the region have also raised concerns. Vegetative loss aggravates the already dismal situation resulting in deficiency of food, poverty, migration, loss of flora and fauna and other vital biological resources. In Oroba clearance of woody vegetation for crop (i.e. sugarcane, cereals etc) cultivation, fuel wood, timber,

settlements and other infrastructure has also had ramifications on the local climate. Unlike trees, crops do not have the capacity to capture vast amounts of carbon, which subsequently escape into the atmosphere as carbon dioxide leading to enhanced greenhouse effects and concentrations of atmospheric carbon. Lack of adequate and quality data on land degradation which are prerequisite for effective and sustainable land-use planning has been a major drawback in land management.

This study suggests to asses land use activities and their contribution to land degradation in Oroba Water Catchment of Lake Victoria basin and provide valuable scientific information on understanding the degree of their influence on land degradation. Socio-economic information provides understanding of extent of loss on the natural resources that would aid planners, researchers and policy makers to come up with acceptable and adoptable recommendations at local and national level. The knowledge of Geographical Information System (GIS) and remote sensing make it easier to capture information on the inaccessible areas, thus providing appropriate management skills of the catchments scarce resources that would guarantee preservation of the environment and monitoring (temporal and spatial) for the future.

1.2 Problem Statement

In Oroba Water Catchment land degradation is a major threat to livelihood that is caused by various land use activities (Were et al, 2010). Land degradation in recent years has manifested through; surface water pollution, decline of soil fertility, surface soil erosion features such as rill and gulley (Nekesa 1999, Odada et al.2009 and Gatahi et al. 1993). Increased population has exerted much pressure on the scarce natural resources resulting in high demand for more agricultural land for food and energy production. Land cover

reduction on the upper catchment, loss of top soil has led to decline in soil fertility according to study carried out on maize (staple) yield in Lake Victoria basin that was below 0.5 ton/ha/season (Nekesa, 1999, Okalebo et al., 2005 and Omollo et al, 2007). However its unclear if any attention has been paid to the systematic measurements, compilation and interpretation of land-use activities and their contribution to land degradation in Oroba water catchment of Lake Victoria basin and design of alternative landuse planning intervention. Therefore, this study aims to bridge this gap by assessing land use activities and their contribution to land degradation in Oroba Water catchment of Lake Victoria basin and design an appropriate alternative planning intervention. Information gathered and analyzed in the study area would provide land users with appropriate data to base decisions making on future planning interventions.

1.3 General Objective

The general objective is to assess land-use activities and their contribution to land degradation and design appropriate sustainable land use planning intervention;

1.3.1 Specific objectives

1) To determine land-use activities in the study area.
2) To assess the contribution of land-use activities to land degradation
3) To design alternative land use intervention that can ensure suitable land use practices to reduce land degradation in the Oroba Water Catchment.

1.3.2 Research Questions

- What are the land-use activities in the area?
- What are the observable land degradation effects?
- Which land use practices impact the most and

- Which are the soil conservation methods for planning interventions in the area of study?

1.4 Justification

Lack of adequate data on land use activities has resulted to land degradation in the study area. Thus this research is concerned with filling the information gaps in order to know the nature and extent land degradation. The water catchments in Kenya play a major role in economic, social and environmental development issues and so to Oroba water catchment. Oroba water catchment provides river flow regulation, water storage, and recharge of groundwater, water purification, reduced soil erosion and siltation, protection of biodiversity, regulation of micro-climate, favourable conditions for optimum crop production, carbon reservoir and provides water to urban centers for economic development and supports livelihood. There is need therefore to conserve Oroba water catchment by providing an appropriate alternative planning intervention to its land use activities.

In the study area land degradation is due to natural and human activities such as encroachment of farmers and livestock on the steep slopes, forested areas of the Nandi Hills escarpment as well as the wetlands, flooding of the lower lands. Others include flooding of the lowlands, landslides in the upper and middle catchment, the increased infrastructural developments all has resulted to land degradation.

The average population density is 300 per kilometre^2 according to Kenya Population and Housing Census of 2009 for both the Nandi and Kisumu Counties. This density exerts a lot of pressure on the available land leading to invasion of the riparian zones and

resulting to loss of biodiversity in these areas. Decline in soil fertility due to erosion is of great concern and therefore there is urgent need to rehabilitate the degraded area to contain further destruction. This study would provide valuable baseline information on the extent, severity and location of degradation that would assist stakeholders, planners and policy makers in coming with appropriate planning intervention on developments in the catchment for optimal utilization of the catchment.

1.5 Study area

The Oroba water catchments are located within Lake Victoria drainage basin in western Kenya as shown in (Figure 1.1); it shows drainage, boundaries and towns. They cover parts of Kisumu and Nandi Counties and are bound by latitudes 0˚ 15’ and 0˚15’N and longitudes 34˚45’E and 35˚03E. The landscape morphology and climate make the catchment soils very fragile and sensitive to uses which do not consider soil suitability and its limitations. Due to environmental conditions, the land degradation problem is a great problem as this has led to diminishing precipitation; recurrent droughts, natural floods and the large loss of vegetation experienced in the region has also raised concerns.

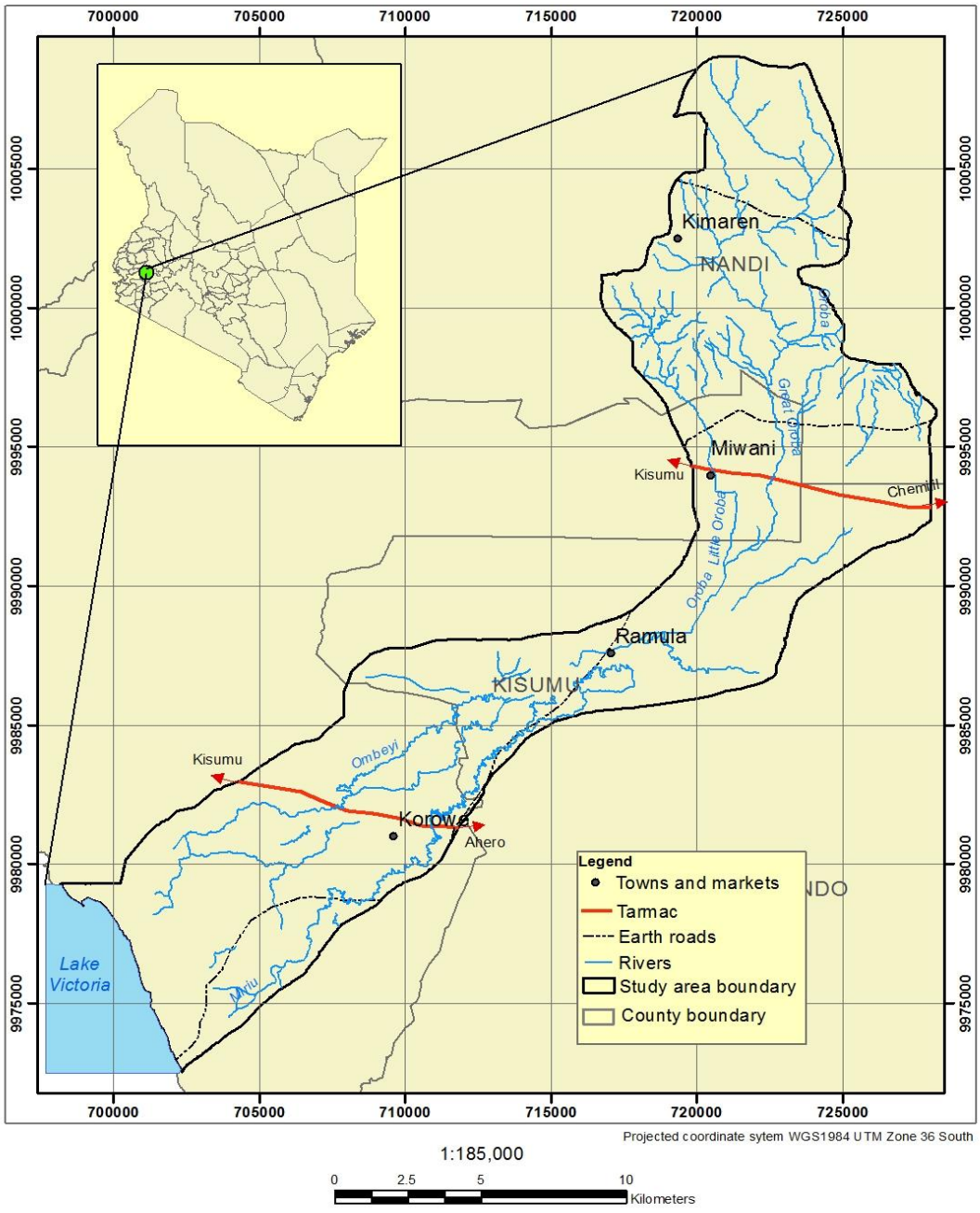

Figure 1.1: Map of Oroba water catchment (Source, Author,2012)

The catchment area spans over 267.91 km^2 and is diverse consisting of various physiographic units with elevation ranging from 1,130 m on the shores of Lake Victoria in the Lower catchment to about 2,060 m in the Upper catchment as illustrated in figure 1.2 below, swampy grounds which is lacustrine in origin, plains of slopes 0 to 5 per cent, steep scarps of varying slopes of 9 to 30 per cent, plateau of slopes 0 to 8 per cent and hills of varying slope greater than 9 per cent. The study area has a number of tarmac roads net works in Kisumu-Kericho, Serem-Kaptumo, Kisumu-Miwani-Chemelil and supported by a number of murram roads that serve as feeder roads. The communication systems are of great importance to transport of agricultural produce and products, and human transport in the study area.

1.5.1 Climate

The climate of Oroba water catchment of Lake Victoria Drainage Basin (LVDB) is influenced by its position relative to the equator, varied topography, its proximity to Lake Victoria and falls into three agro-climatic Zone (ACZ) I, II and III (Figure 4.22). The soils are of various types determined by physiography, parent material and climate.

1.5.2 Hydrology

The Oroba water catchment is drained by permanent rivers namely Great Oroba and Little Oroba (Figure 1.1). Its tributaries are Ombeyi and Nyakoko. The water source is the Nandi South Forest that is a source of many streams, rivers such as Kibos and Yala Rivers. The Great River Oroba has a length of approximately 40 Km from the source to the mouth and drains into the Lake Victoria through the swamps on the lake shores.

1.5.3 Physiography and Soils

The soils of the Oroba water Catchment can be grouped into three major physiographic units:

i) Soils of the major scarps and foot slopes. The soils are excessively drained to well drained and of sandy clay loam to clay. Commonly associated with sheet and gulley erosion (Altitude: 1300 to 3030 m and slopes between 9 and greater than 30 percent). Developed from undifferentiated basement system rocks; classified as Nitisols, Leptosols and Cambisols;

ii) Soils of the Plateau, piedmont and sedimentary plains. The soil are well drained to imperfectly drained and of sandy clay loam to clay. Commonly associated with sheet, rill and gulley (Altitude: 1140 to 1500 m and slopes of 0 to 8 percent). Developed from intermediate igneous rocks and others on alluvium undifferentiated basement system rocks and from volcanic ashes and lake deposits. Classified as Cambisols, Leptosols, Luvisols, Nitisols, some with sodic and salic phases and;

iii) Soils of the river terraces, floodplains and minor valleys (Altitude: 1130 to 1220 m and slopes from 0 to 5 percent). Poorly drained to very poorly drained soils and of silty clay to clay. Classified as Luvisols, Vertisols and Fluvisols salic and sodic phases. (Wanjogu and Waruru, 2004).

1.6 Scope and limitation of the study

The study was limited to assessing land use activities in Oroba Water catchment and their contributions to land degradation in the catchment in the months of May, June and July of 2012. The catchment is located in the two counties of Nandi and Kisumu. The research

used both qualitative and quantitative research design with sample size of 117 households in the questionnaire survey which targeted household heads.

In certain parts of the study areas the residents refused to participate in the research due to land and cattle rustling issues sensitivity in those areas.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter entails literature review on previous studies such as human activities in water catchments, effect of human activities in the catchment and alternative measures. It also considers theoretical and conceptual frameworks and finally a summary of the chapter.

2.2 Previous studies

Land use activities are defined as human processes which negatively affect the land to function effectively within an ecosystem.

Land degradation activities such as overgrazing, deforestation, charcoal burning, and poor agricultural practices have continued unabated in the face of inadequate empirical data on their exact extent, status and distribution at both regional and global level(Berry et al., 2003 and GLASOD,1988).

The global development and environmental issues that have been highlighted in the UN Convention to combat Desertification, the convention on Biodiversity, the Kyoto Protocol on climate change and the Millennium Goals (UNEP 2007), to address land degradation have not offered any feasible solution to date. The Unsustainable land use change is the driving force behind land degradation: soil erosion, nutrient depletion, salinity, water scarcity, pollution, disruption of biological cycles and loss of biodiversity. The only harmonized assessment, the Global assessment of human-induced soil

degradation (Olderman et al., 1991) is a map of perception – the kinds and degree of degradation- not a measure of degradation.

Human-induced soil degradation is symptomatic of a negative interaction between socio-cultural, economic and environmental factors that govern decision on land use planning and utilization at local, regional and global level (Thang et al., 1999). About 6 million hectares of agricultural land worldwide become unproductive every year due to the various soil degradation processes. The problem is much more serious in tropical than in temperate areas since tropical soils are more prone to degradation because of the nature of their properties and the prevalent climatic conditions. Countries in Asia and Africa that depend upon agriculture as the engine of economic
growth are believed to suffer the greatest impact of soil degradation (Lynden and Oldeman, 1997).

Water component plays a significant role in landscape structure due to the hydrologic cycle. Land-use activities impacts on landscape structure which eventually results to changes in water sources. Studies have established that forests increase catchment evapo-transpiration compared to grass catchments which has implication for catchment water balance in terms of land-use management and rehabilitation strategies (Thang et al., 1999).

In Kenya, soil degradation is one of the most serious ecological problems today. It occurs because of drastic changes or disruption in the normal processes of soil formation due to human activities. Since natural degradation is slow, the present concept of soil degradation according to the Global Assessment of Soil Degradation (GLASOD, 1988) focuses on a human-induced process.

Soil degradation is defined as a process that describes human-induced phenomenon which lowers the current and/ or future capacity of the soil does support human life (GLASOD, 1988). This is a consonance with the definition made by (Lal et al., 1985) as the decline in soil quality caused through its misuse by humans. They grouped soil degradation into three categories (a) physical degradation (b) biological degradation, and (c) chemical degradation. Besides vegetation degradation, soil degradation comprises the most degradation process which is water erosion, wind erosion, salinization, soil fertility loss, soil compaction and crusting.

According to land cover change study carried out in Oroba-Kibos water catchment (Were et al., 2010 and 2011), cropland is the major land cover type in the area accounting for about 65% (57,122 ha) and 7% (64,772 ha) of the total land in 1994 and 2008 respectively. This implies that agriculture is the fundamental source of livelihood in the area and at the same time catchment encroachment is visible.

2.2.1 Human activities in the catchment

Human activities in the study area include agriculture, urbanization, animal grazing, settlement, deforestation and infrastructural development.

2.3 The effects of human activities in the catchment

The visible human activities are soil erosion, land fragmentation, shortage of farm labour because of urbanization, soil degradation due to poor agricultural practices.

2.4 Severe land degradation due to agricultural activities

Annual cropping (including shifting cultivation) is regarded as a major cause of land degradation. The global extent of agricultural land severe to very severely degrade is 12.4 M km², which is 35% of the total area of severely degraded land from all causes. The

total area recorded, by land use statistics, as being presently under arable use is only slightly greater than this, 13.5 M km². Fourteen countries have 100% of land with agriculturally -caused degradation in the Severe and Very Severe classes (GLASOD, 1988).

2.4.1 Soil degradation

Land degradation refers to the temporary or permanent reduction in the productive capacity of land as a result of human action. It is recognized that land degradation is a problem that is widespread, and in some areas severe. Until recently, however, there was little or no basis for estimating its extent and severity (Oldermman 1999). Exaggerated claims were sometimes made for the extent of soil erosion and desertification. The first attempt to improve upon this absence of data was made in the late 1980s, when the International Soil Reference and Information Centre (ISRIC), in conjunction with UNEP, undertook a global inventory of the status of human-induced soil degradation (Oldeman et *al*. 1991, UNEP, 1992 and Oldeman, 1999).The Global Assessment of Soil Degradation (GLASOD) was based on a structured recording of the type, severity and extent of degradation, together with its major causes. The GLASOD survey remains the only uniform global source of land degradation data.

The problem of soil erosion was identified in 1935 in Kenya as an environmental problem. When Kenya resorted to advisory policy approach on soil conservation other than of enforcement this led to breakdown to soil conservation practices. As from 1970s focus has been on land management and conservation practices with a view of reducing problem of soil erosion but not soil degradation.

2.5 Alternative areas in the catchment

2.5.1 Data and Management Requirement

The study by (Olago and Odada, 2007) established the absence of long term instrumental data records on the East Africa's transboundary river and Lake Basins are associated with lack of developed effective sound sediment management strategies. The scientific understanding of the environmental issues that can be used in analyzing environmental data on; Climate and hydrological, land use/cover changes, sediment sources, transport pathways, flux measurements and historical perspectives is inadequate. The management of environmental problem in the lake and river basins has been also been inadequate, in part due to addressing the problem from sectoral and mono-disciplinary perspectives that fails to recognize the complex interplay of environmental factors, and hence these problems are not addressed in a holistic context. Management requirements therefore include: integrated water catchment basin management with legal provisions for environmental, water and sediment management policies and strategies: education and participation of stakeholders in the management programmes; and increased use of knowledge based strategies for sediment management (George et al., 1993).

2.5.2 Agricultural Policies and Legislation

The Agriculture Act Cap 318 of the Laws of Kenya seeks to promote and maintain a stable agriculture, to provide for the conservation of the soil and its fertility and to stimulate the development of agricultural land in accordance with the accepted practices of good land management and good husbandry.

The Act provides legislative control over soil conservation and land management. Any activities that may destabilize river beds are prohibited and the Ministry of Agriculture

can impose land conservation orders to control cultivation, grazing and clearing of vegetation. The recently gazetted Farm Forestry Rules, 2009 aims at promoting and maintaining farm forest cover of at least 10 per cent of every agricultural land holding and to preserve and sustain the environment in combating climate change.

The agricultural sector will remain at the heart of the environmental management discourse in Kenya, source of direct environmental damage by way of land-based pollution, Greenhouse gas emissions and ultimately the modification of the overall hydro-meteorological cycle. Specifically, agricultural activities are often responsible for the reduction of biodiversity, destruction of soils, pollution of water sources and pollution of wetlands through siltation and adverse landscape changes (Olago et al., 2007).

2.5.3 The Energy Act

The Energy sector is governed by the Energy Act, No. 12 of 2006. The Act empowers the Minister responsible for energy to promote the development and use of renewable energy including (i) providing an enabling framework for efficient and sustainable production, distribution and marketing of biomass, solar, wind, small hydros, geothermal and charcoal; (ii) promoting the use of fast maturing trees for energy production such as biofuels and the establishment of commercial woodlots within peri-urban plantations; (iii) promoting international cooperation on programmes focusing on renewable energy; (iv) harnessing opportunities offered under clean development mechanism and other mechanisms including, carbon credit trading to promote development and exploitation of renewable energy; (v) promoting the utilization of renewable energy sources of power generation and transportation; and (vi) promoting the production and use of gasohol and biodiesel.

2.5.4 The Land Policy

The Sessional Paper No. 3 of 2009 on National Land Policy was formulated to address the critical issues of land administration, access to land, land use planning and environmental degradation. It also addresses restitution of historical injustices, conflicts, unplanned proliferation of informal urban settlements and information management. It recognizes the need for security of tenure for all Kenyans. The overall objective of the National Land Policy is to secure rights over land and provide for sustainable growth, investment and the reduction of poverty in line with the Government's overall development objectives. Among others, the Policy offers a framework of policies and laws designed to ensure the maintenance of a system of land administration and management that will provide efficient and effective utilization of land and land based resources.

The Policy designates all land in Kenya as public, community and private land. Most significantly, the Policy establishes a mechanism for securing the tenure of public land by placing all public land under the National land Commission to hold and manage the land in trust for the people of Kenya.

2.5.5 Urbanization

Urbanization is a dominant demographic trend worldwide with high rate of socio-economic development in developing countries especially in Africa. The resulting growth of cities and town population, lack of infrastructure, environmental degradation are a few of the major issues in sustainable development which Lake Victoria basin in Kenya is experiencing as a result of urban sprawl (Olago et al., 2007)

Conversion of agricultural land, reclaiming wetland and forest for urban use, and infrastructure that is rampant in the area of study results in environmental degradation. These actions causes' high pressures on the neighboring areas particularly low lying places hence frequent floods during heavy rainfall occurrence. In rural areas people are victims of unpredictable weather conditions such as drought and floods which occasionally adversely affect their livelihood.

Environmental impacts of urbanization are air and water pollution, destruction of habitats and increased temperatures. Establishment of human settlements near natural resources threatens their quality (Peter et al., 2004)

2.6 Theoretical and Conceptual Framework

The definitions of conceptual and theoretical framework was defined by Warmbrod (1986) defined as a systematic ordering of ideas about the phenomena being investigated or as a systematic account of the relationship among a set of variables.

Camp (2001) defined the difference between conceptual and theoretical framework. A conceptual framework is a structure of what has been learned to best explain the natural progression of a phenomenon that is being studied.

Comparatively, the theoretical framework is explanation about the phenomenon. Mariam (2001) provided additional clarity by stating a theoretical framework provides the researcher the lens to view the world.

2.6.1 Theoretical Framework

Explaining land use activities

Land is used to meet a multiplicity of human needs and to serve numerous, diverse purposes. When the users of land decide to employ its resources towards different purposes, land use change occurs producing both desirable and undesirable impacts. The analysis of land use change is essentially the analysis of the relationship between people and land. It is important to understand land use change for making decisions for future sustainable uses of land.

Explanation of land use activities and their contribution to land degradation – answering the questions of "why", "what", “how”, “when” and “where.” Meaningful explanation of land use activities and change (and of its impacts) at a given level of any scale, requires that the relevant explanatory factors are identified at the levels of the particular scale at which they operate in reality. The critical point is that "the relevant explanatory factors" – with the exception of the bio-physical determinants – are associated with particular individual and collective actors – agents involved directly or indirectly in the process of land use activities. Essential explanation focuses on these agents, their differing resource endowments to influence land use activities, and their actions through which land is affected. For example, to explain land use activities and its impacts at the farm or the parcel level, relevant explanatory factors may include soil status, slope, water availability, local climate, and the characteristics of the household.

There are factors which operate at the same level of the spatial and perhaps of the temporal scale. However, other relevant factors which influence land use activities at the farm or the parcel level operate at other – higher and/or lower – levels of the spatial and temporal as well as of economic, organizational, and institutional scales such as financial

assistance, environmental and agricultural policies, product prices, climate change, past types of land use, past policies, etc.

Therefore, there is need to employ a nested set of scales for a comprehensive explanation of land uses activities in concrete settings. The drivers of land use activities as well as the determinants of the resulting impacts have to be sought at a variety of scales and levels of these scales.

DPSIR assessment framework

The framework is an integrated environmental assessment (Peter, 2004). It distinguishes driving forces, pressures, states, Impacts and responses. The framework has structures within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future.

DPSIR framework has a chain of causal links starting with ‘driving forces’ (economic sectors, Human activities) through ‘pressures’ (emissions, waste) to ‘states’ (physical, chemical and biological) and ‘impacts’ on ecosystems, human health and function, eventually leading to political ‘responses’ (prioritization, target setting, indicators).

The researcher finds DPSIR model (Figure 2.1) suitable to use on socio-economic and environmental issues for the conceptual framework building of this study because of its holistic nature approach. Knowledge of non-linear relationships between variables gives planners the potential to effect large changes in a desired variable with relatively small change in another. The model influences planners to broaden their perspective, and to consider how the decisions will affect the other component of the system and the environment. The model examines causal and relationship.

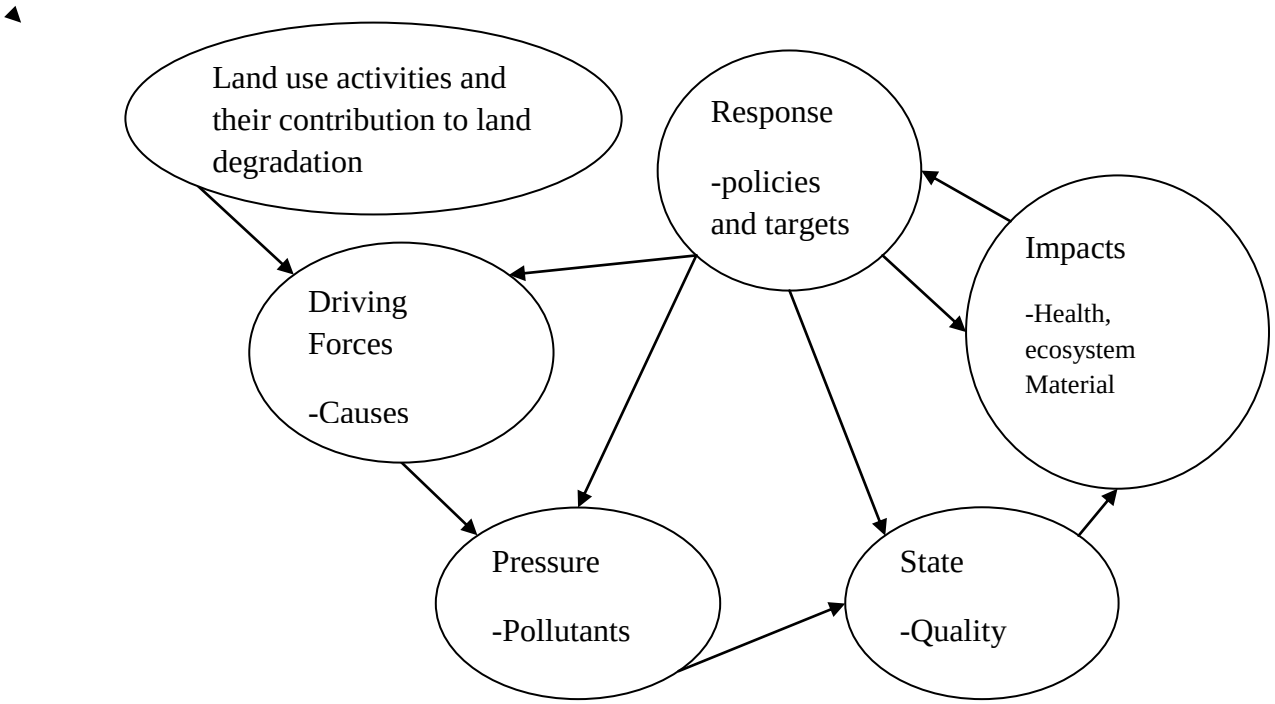

Figure 2. 1: Source: Based on EEA 1998.Guidelines for Data Collection and Processing- EU State of Environment Report Annex 3. National Institute of Public Health and Environment, Bilthoven, Netherlands.

Definition

'Drivers'(overgrazing', agricultural activities) through 'pressures' (population increase, land fragmentation, soil erosion) to 'states' (land degradation, encroachment of riparian, chemical and biological) and 'impacts' on ecosystems (soil erosion, decline in fertility, loss of biodiversity), 'responses' (conservation measures, planning intervention policies and resource use policies (prioritization, target setting, indicators).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the materials and equipments used in data collection as well as the specific image processing steps and map digitization. The research design and sampling strategy used to collect household survey data on socio-economic indicators is also outlined.

3.2 Materials

Data collection involved equipment and tools preparation. The field equipment and tools included: topographic maps which were used to assist in direction and provided other key features as a field guide and delineation of the study area. The clinometer was used in taking slope percentages and GPS receivers (Garmin) for taking household survey coordinate positions that were recorded on field forms. Photographs were taken at sites of interest for illustration purposes.

3.3 Research design

This study was carried out in Oroba water catchment in Lake Victoria basin. It utilized both qualitative and quantitative research design for the purpose of collecting both primary and secondary data. The primary data collection techniques included: field observations of erosion features; sheet, rill, gulley, conservation structures and drainage ways. The field measurements were mainly for slope angle and elevation. Structured questionnaires were administered on targeted household heads who had stayed in the study area for more than 20 years and are knowledgeable on socio-economic drivers to land degradation.The secondary data was main review of published and unpublished data on the study area problem.

3.4 Sampling Strategy

Sampling involved sampling design, sampling units, sample size and response design for the structured interview schedule.

The study area was stratified into three strata according to agro-ecological zones and designated as Upper, Middle and Lower catchments. Due to non homogeneity of the strata, random sampling was done in each of the strata's based on sample size of 33, 39 and 45 in the Upper, Middle and Lower catchment strata's respectively totaling to 117 sample size in this study. Initial target sample size of 40 in each stratum was not achieved but the sample size used was representative enough for the study area population. In each of strata's sample size, data was collected on socio-economic and environmental during the months of May, June and July of 2012 using household survey interviewing schedules forms (Appendix 1) by nine trained enumerators. The household survey sites were marked by a GPS receiver at approximately 3-5 km interval, and were done randomly by visiting farms and skipping two or three homes depending on how far apart and assess ability at least 50 meters for the purpose of mapping and then the points were downloaded into ArcGIS 9.2 and geo-referenced. Focused structured interviews on household heads were done based on their knowledge on socio-economic issues in the area and long stay.

3.5 Data Analysis

The socio-economic data from household survey questionnaires was coded and keyed into the computer and then processed using SPSS version18 software to generate descriptive statistics presented in various graphical presentation. This was necessary to facilitate overlaying with other datasets. GPS marked household survey sites were geo-

referencing using topographical sheets together with land use map in ArcGIS 9.2 soft ware using geo-referencing tool to facilitate overlaying.

3.5.1 Image processing of Landsat and DEM

Land use map of Oroba catchment was prepared from satellite imageries (Landsat TM5/ETM). This was downloaded from site www.golvis.gov of 2010 using Path /Row 170/60. Four bands of the land sat were downloaded bands 1, 2, 3 and 4 and the bands were clipped to the study areas using study areas shape file. The spatial resolution of the data was 30 meters. Preprocessing was done by creating color composites to enhance legibility of the details. The composite was of bands 2, 3 and 4 false colours. This was done in Erdas Imagine 9.2. The primary land use/cover classification scheme used in this study was derived from the Anderson classification system level IV (Anderson et al., 1976) and used to derive a classification applied on land sat 5 Thematic Mapper (TM) from 2010. The image composite was classified using supervised classification of 10 training sites and 10 class land use/ cover map was generated (figure 4.23).

Digital elevation model (DEM) was also downloaded from same website, Path and Row as land sat. From the DEM, slope severity map was generated and classified as low, moderate and high in ArcGIS 9.2 surface in spatial analysis tool. Then the planning intervention map was developed from the slope severity map.

3.5.2 Map Digitization

Topographic maps (Sheets 102/4,116/11, 103/3) from Survey of Kenya were acquired and used to prepare a mosaic of the whole study area. This was then geo-referenced and digitized in ArcGIS 9.2 using digitizing tablet on the digitizer. A total of two control points were selected on each topographical map corners and their corresponding location

on the next sheet was also digitized generating a RMS of 0.0001 which was accepted. Then feature digitization was done starting with: catchment boundaries (drainage), rivers, towns, roads, railway line and agro-ecological zones of the study area.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents and discusses results on various land use activities and their contribution to land degradation in the catchment. The discussions are organized under sub headings: Land use activities, their effects in terms of socio-economic and environmental, discussions on results and the summary on the results. The results are presented in forms of maps, bar graphs, pie charts and tables.

4.2 Principal Socio-Economic Causes of Land Degradation in Oroba water catchment

The principal socio-economic causes of land degradation in Oroba water catchment were identified as population pressure, education (awareness and exposure), labour availability, input availability (manure and fertilizer), land tenure and poverty. The catchment showed an increase in population as per the respondents view (Figure 4.1) and census results of 2009 also recorded increase, and this meant more demand for shelter, creation of employment opportunities and food production on fixed land size that is experiencing cropland reduction due to urbanization and inheritance in fulfillment of cultural practices.

4.2.1 Demographic and Socio-economic characteristics of respondents

In Kisumu county 62% of the respondents interviewed felt that population is medium while in Nandi it was 34% compared to previous years. In Nandi 50% of the respondent felt that the population is low compared to the previous years and Kisumu was 24%. In Nandi 16% respondents reported high increase in population and 14.3% in Kisumu (Figure 4.1)**.**

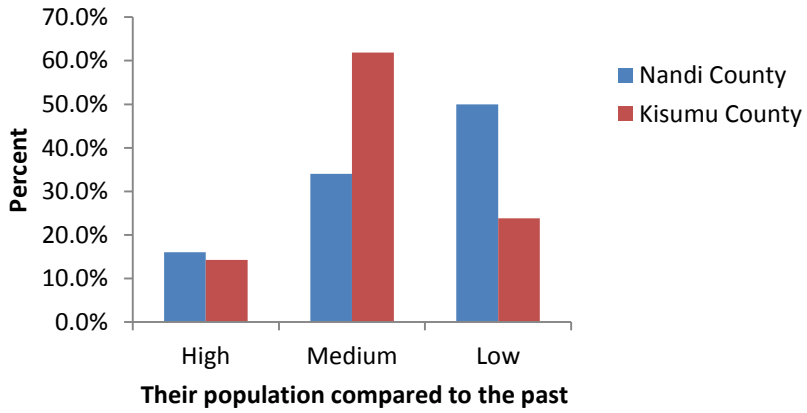

Figure 4. 1 : Population rating in Oroba water catchment

4.2.2 Distribution Crop Types within Households per County

In Kisumu county 72.4 % of the respondents grow cereals and legumes, while in Nandi it is 29.6% (Table 4.1).This indicates higher soil fertility rates in lower catchment than in upper.

Table 4. 1: Distribution of Crop types within households per county

Crop type	Nandi (households) %	Kisumu (households) %
Cereals and Legumes	29.6	72.4
Legumes and Tea	9.3	0.0
Cereals, Legumes and Tea	5.6	2.3
Cereals, Legumes and Coffee	3.7	0.0
Sugarcane	51.9	16.3
Sugarcane, Cereals and Legumes	0.0	9.3

4.2.3 Education

In Nandi county 97.1% of the households interviewed had attended secondary education while in Kisumu they were 2.9% (Figure 4.2). This is an indicator of high poverty levels in the lower catchment than in the upper catchment and middle.

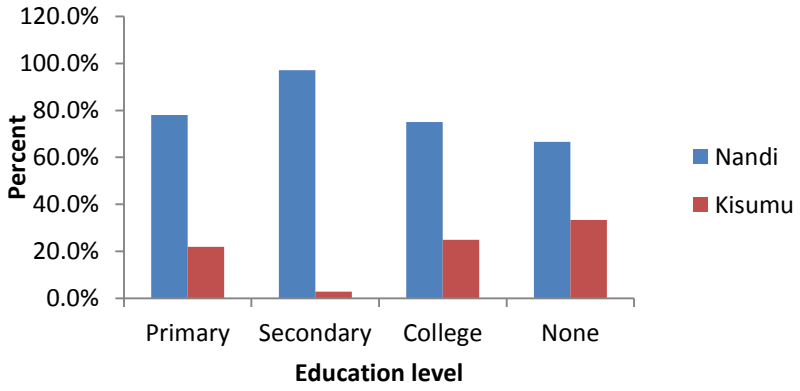

Figure 4. 2 : Education level in Oroba water catchment

4.2.4 Land ownership

In Kisumu County 59 % of respondents interviewed own private land while in Nandi 67% of respondents own private land (Figure 4.3). This is an indicator that land ownership in Nandi County has experienced tremendous subdivision as compared to Kisumu County. This impedes the use of land as a factor of large scale production.

Figure 4. 3 : Land ownership in Oroba water catchment

4.2.5 Occupation levels in Oroba water catchment

In Oroba catchment farming activities takes the largest portion of 77.6% while self employment takes 6.1%. This makes farming to be the main economic activity in the catchment leading to land degradation as a result of higher dependence rate (Figure 4.4).

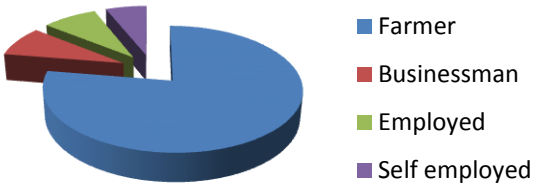

Figure 4. 4 : Occupation levels in Oroba water catchment

4.2.6 Age characteristics

The age characteristics of the respondents interviewed show that those aged more than 50 years were the least constituting 21.7% whereas 30-40 years was the largest representing 32.6% .This implies that older people who own land are less in number while the majority who are the young are more but unproductive due to land ownership issues and thus they have resorted to rural –urban migration (Figure 4.5).

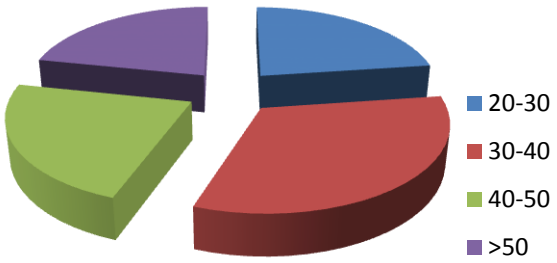

Figure 4. 5: Age of respondents in Oroba water catchment

4.2.7 Deforestation

In Nandi county 44% of the respondents get their timber from the forest while in Kisumu it is 5%. Nandi county experiences high rate of deforestation compared to Kisumu (Figure 4.6).

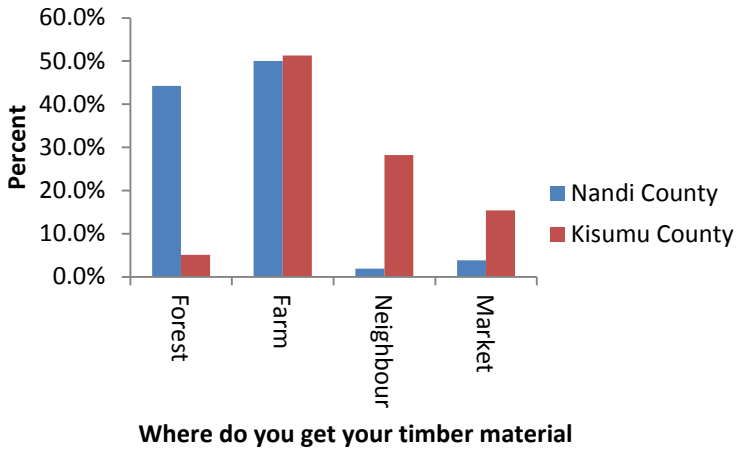

Figure 4. 6: Timber harvesting in Oroba water catchment

4.3 Effects of Land use activities in Oroba water catchment

The effects of land use activities in Oroba water catchment were categorized in this study as; social, economic and Environmental effect:

4.3.1 Social Effects

The social effects are caused by population increase, change in age characteristics, migration, unemployment and settlement among others.

4.3.1.1 Catchment household population

In Nandi County 38% of respondents have family size of between 5-10 members while in Kisumu County it is 33% (Figure 4.7).This indicates that Nandi County has large family sizes compared to Kisumu, this increases pressure on the available land.

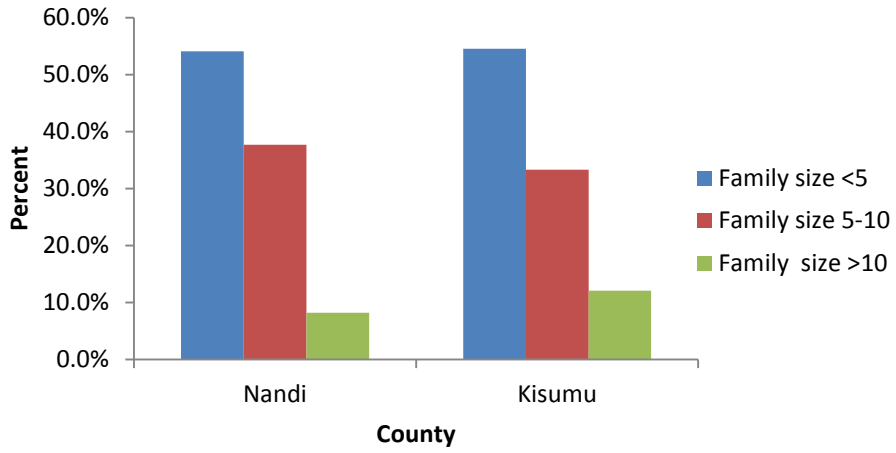

Figure 4. 7 : Members of household in Oroba water catchment

4.3.1.2 Farm land sizes

In Nandi county 51.9% of the respondents own less than 1ha while in Kisumu 29.3% of the respondents own less than 1ha (Figure 4.8). This indicates that there is high population density in Nandi compared to Kisumu mounting high pressure on the available arable land.

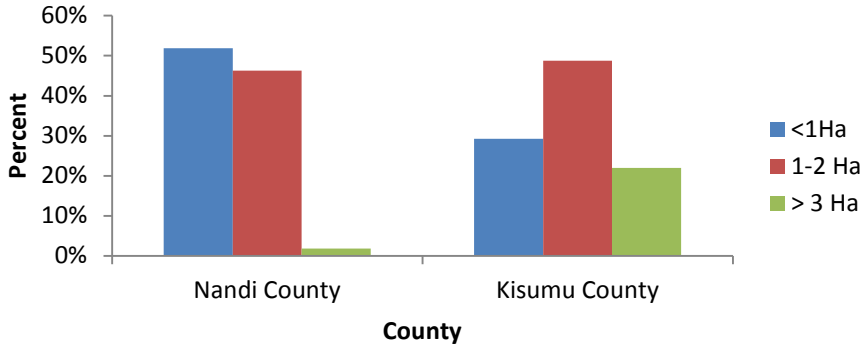

Figure 4. 8 : Farm land sizes of respondents in Oroba water catchment

4.3.1.3 Farm management awareness

In Nandi county 33% of the respondents had received training on appropriate agricultural practices from the agricultural extension officers while in Kisumu it was 23% (Figure 4.9).This means that in both counties the percentages of farmers with formal agricultural education are less compared to the total population. This is an indicator of high levels of degradation in both counties.

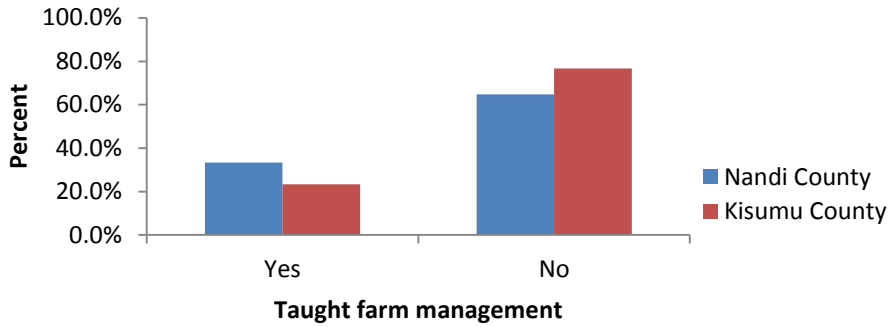

Figure 4. 9: Farm management awareness in Oroba water catchment

4.3. 2 Economic Effects

This includes crop yield decline, household earnings, Population of livestock per household in the study area.

4.3.2.1 Earnings per household in each county of Oroba catchment

In Nandi county 47% of respondents earn 100-200 Kshs, while in Kisumu County 37% of the respondents earn the same amount (Figure 4.10). In Kisumu the earnings are less hence prompting them to look for alternative sources including to car washing causing pollution.

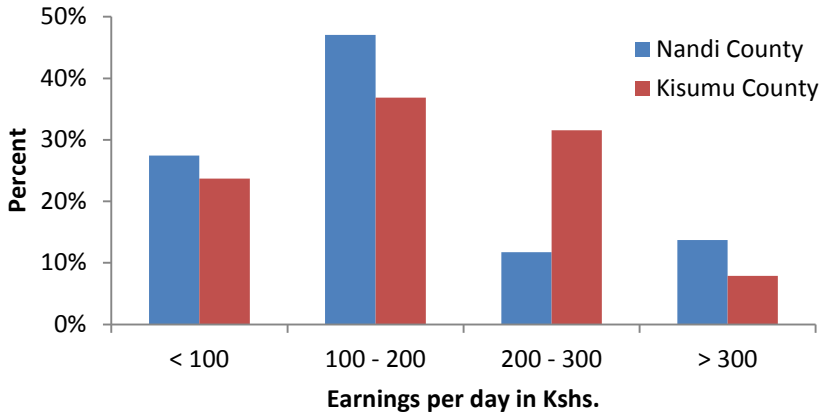

Figure 4. 10 : Respondents earnings per day per county

4.3.2.2 Crop yield

In Nandi county 60% of the respondents interviewed agree that the effect of land degradation is moderate to crop yield while in Kisumu 53% are of the same opinion (Figure 4.11).This indicates high levels of degradation in Nandi county than Kisumu. Loss of top soil in Nandi and therefore decline in soil fertility hence reduction in crop yield.

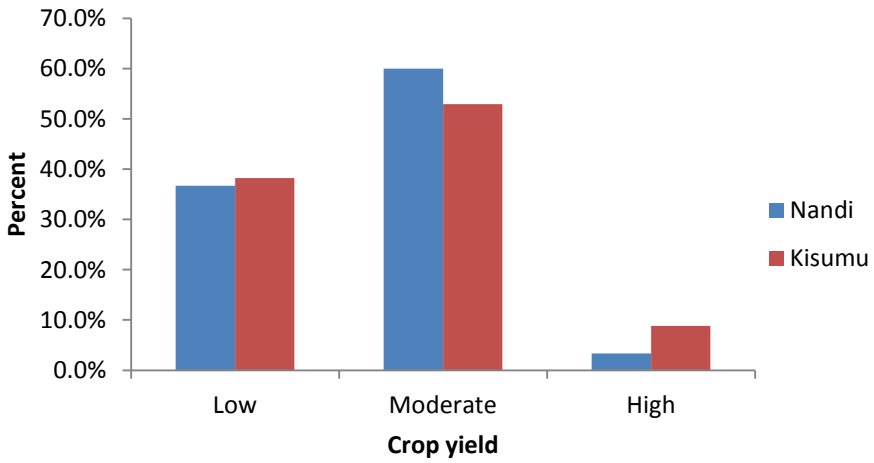

Figure 4. 11 : Crop yield in Oroba water catchment

4.3.3 Livestock Population

In Nandi County 37% of respondents kept 3-6 animals whereas in Kisumu County it is 31%.This is a clear indicator of higher degradation in Nandi than Kisumu (Figure 4.12).This is a reflection of high erosion by trampling of land surface by large number of livestock hence high water run- off.

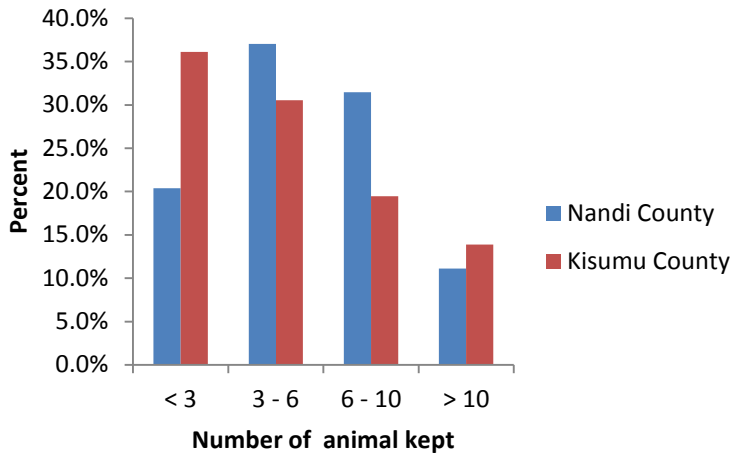

Figure 4. 12: Population of livestock kept per household in Oroba water catchment

4.3.4 Environmental Effects

This includes the following in Oroba water catchment: siltation, overgrazing by livestock, water pollution, pools of sewer in the urban/trade centers and lowering of surface and underground water quality, flooding as a result of river sedimentation, unpredictable rainfall distribution, reduction of vegetative cover density, and reduced population of some organisms such as amphibians (frogs), fish, birds, reptiles (snakes) and soil acidity and alkalinity.

4.3.4.1 Siltation

89% of the respondents in Nandi County reported that siltation was observable in their rivers and 65% in Kisumu observed the same in their rivers (Figure 4.13).This indicates that Nandi County currently is experiencing more siltation than earlier. Kisumu people

are used to turbid water hence less response. The turbidity also detracts certain aquatic organisms in such water bodies. Especially certain species of fish cannot survive in such conditions.

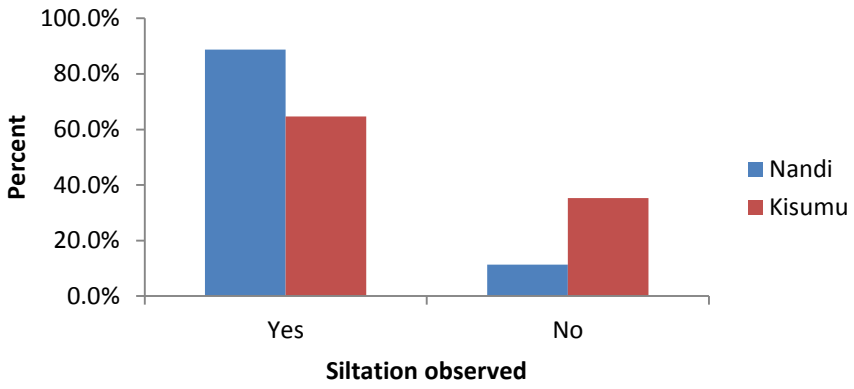

Figure 4. 13 : Siltation in Oroba water catchment

4.3.4.2 Animal grazing

In Nandi county open grazing was reported by 95% of the respondent while in Kisumu it was reported by 83% of the interviewed respondents. Nandi County has undulating terrain gradient which when exposed to open grazing experiences high land degradation as compared Kisumu with almost flat terrain (Figure 4.14). Areas prone to high erosion in Nandi are steep areas of the Nandi escarpment with greater than 25% slope are the ones which were frequented by browsing (goats) and grazing (cattle) livestock and they fell within altitude of 1325 to 1525.

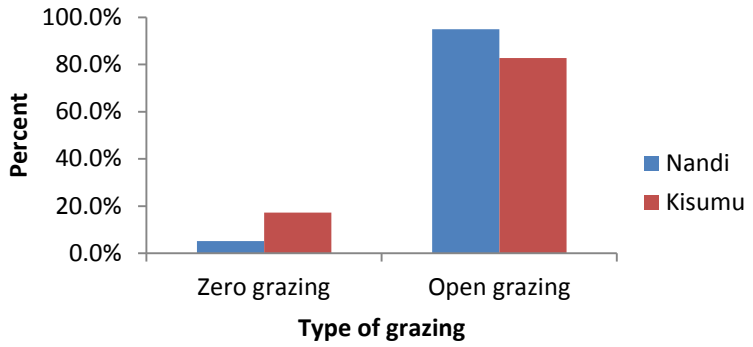

Figure 4. 14 : Animal grazing in Oroba water catchment

The algae bloom was observed on the imagery and is shown in (Figure 4.15) and this is an indicator of the reason why fishermen complain of fish population reduction in the lake shores due to pollution. The region falls where the river Oroba's mouth is located. It was found that degradation was low in the slopes of less than 5%, while slopes of 5 to 10% were moderate and the highest degradation occurred on the steep slopes of more than 10% (Table 4.2).

Table 4. 2: Slope Severity level in Oroba water catchment

Slope classes %	Slope severity level
<5	Low
5 – 10	Moderate
>10	High

The current land degradation levels and percentages are shown in (Figure 4.15 and Table 4.2) which display the spatial distribution in the Oroba Water Catchment as per the field data analyzed. The severity level is an indication of the seriousness of land use activities effects in the catchment that need to be mitigated on, to protect and prevent further

deterioration of the environment for sustainability. This can only be realized if this information is given appropriate planning intervention to mitigate against the effects of land use activities on the catchment.

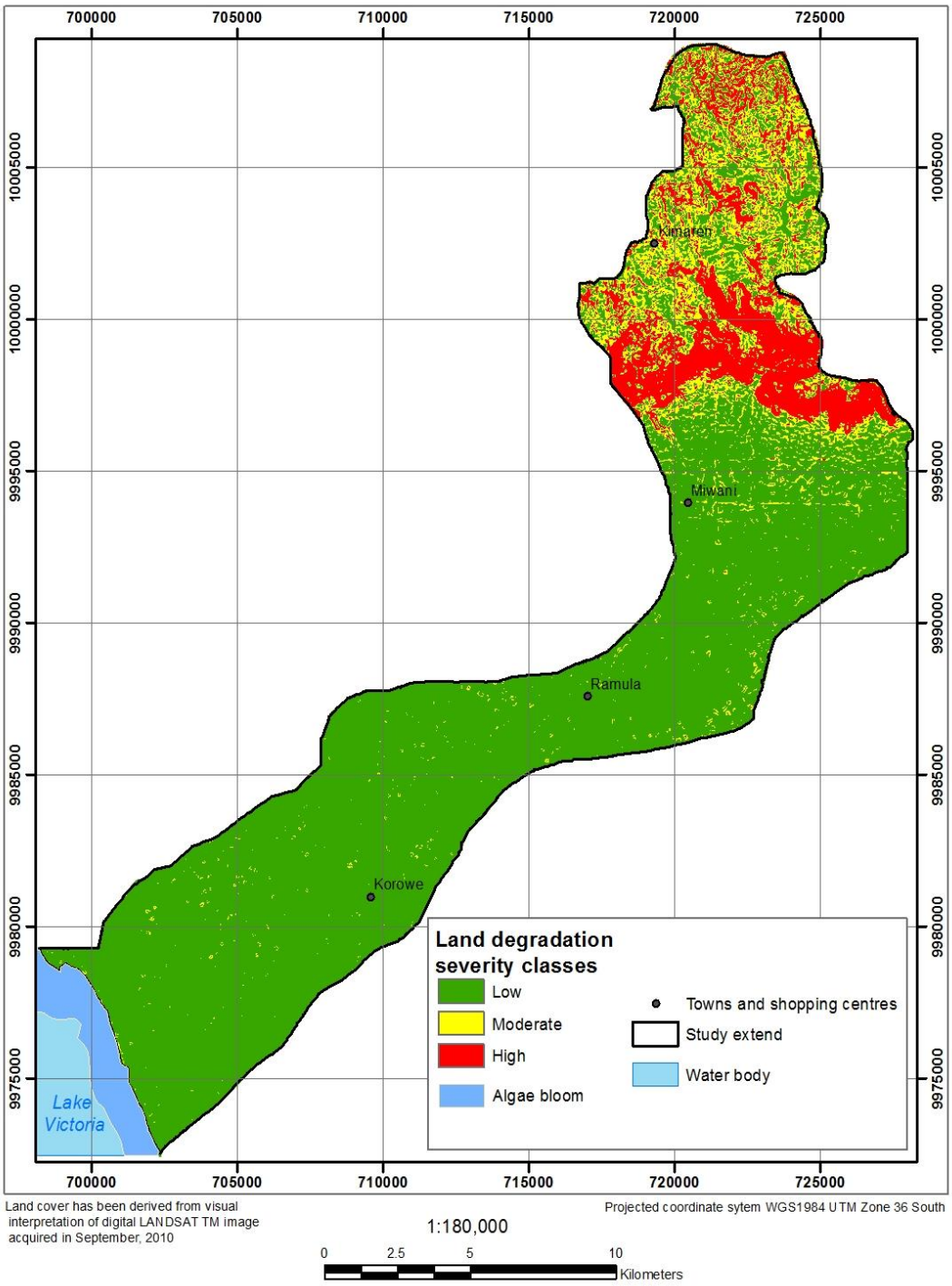

Figure 4.15: Land degradation map of Oroba water catchment (Source:Author, 2012)

4.3.4.4 Pesticides application

In both counties 58% of the respondents interviewed do not apply pesticides on their farms; while 40% apply (Figure 4.16).This contributes to less pollution of the rivers in the catchment.

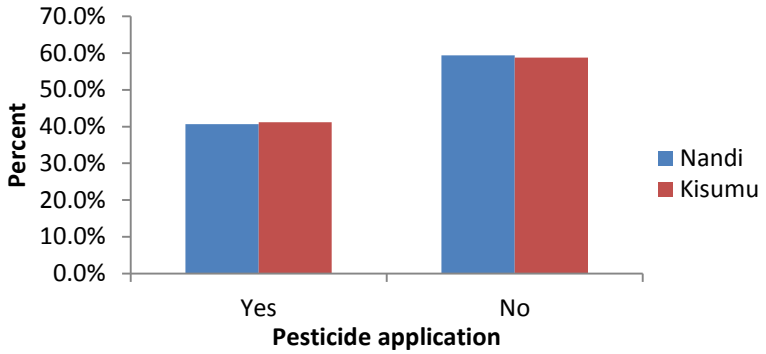

Figure 4. 16 : Pesticides application in Oroba water catchment

4.3.4.5 Soil fertility

In Nandi County 38% of the respondents interviewed rate soil fertility as good while in Kisumu it is 39% (Figure 4.17). Generally soil fertility in both counties has declined implying high levels of degradation.

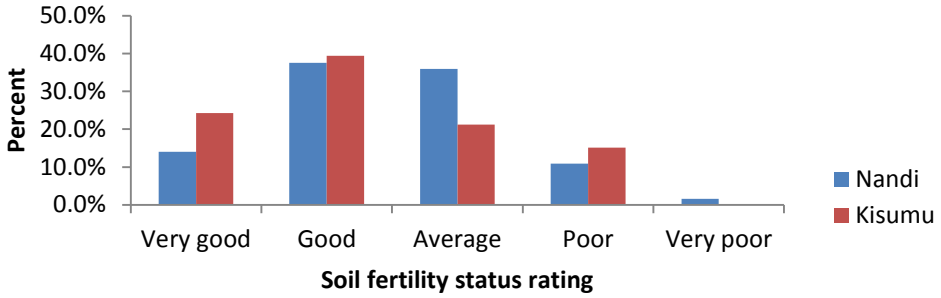

Figure 4. 17 : Soil fertility status in Oroba water catchment

4.3.4.6 Land use activity and soil degradation

Pollution was reported by 36% of Nandi county respondents to be the main contributor to land degradation while 17% of Kisumu county respondents hold the same opinion (Figure 4.18).This is attributed to high use of fertilizers and chemicals on horticultural crops and tea farms in Nandi County.

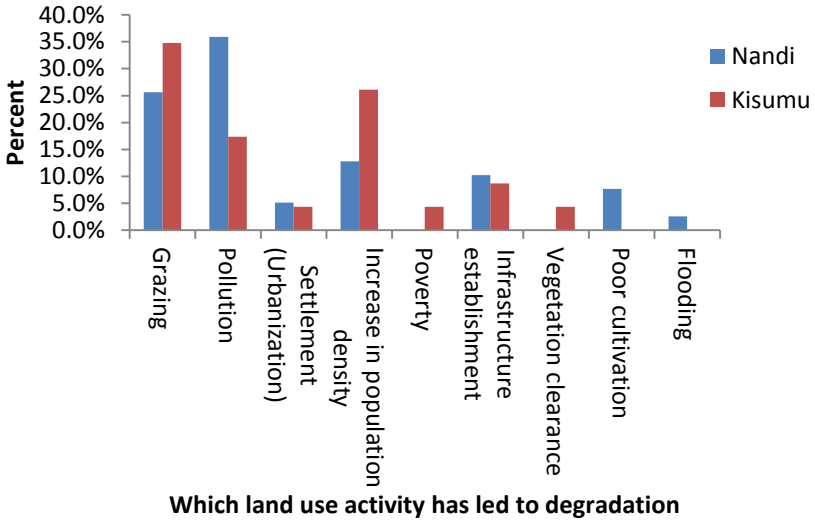

Figure 4. 18 : Land use activities in Oroba water catchment

4.3.4.7 Floods in the catchment

Flooding is experienced both in Nandi and Kisumu Counties .This can be attributed to lower vegetative cover in both counties (Figure 4.19).

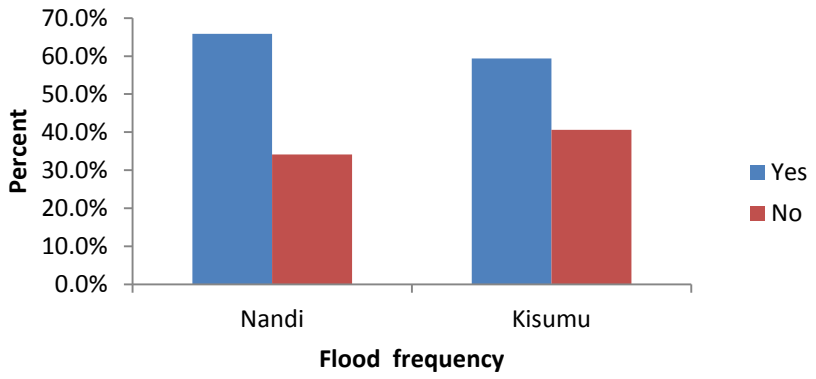

Figure 4. 19: Floods in Oroba water catchment

4.3.4.8 Rainfall

In Nandi and Kisumu counties, the respondents reported that rainfall was high and 11% reported rainfall was low (Figure 4.20).The high rainfall in areas with less vegetative cover leads to soil nutrient loss and low rainfall inhibits crop production and soil nutrient replenishment.

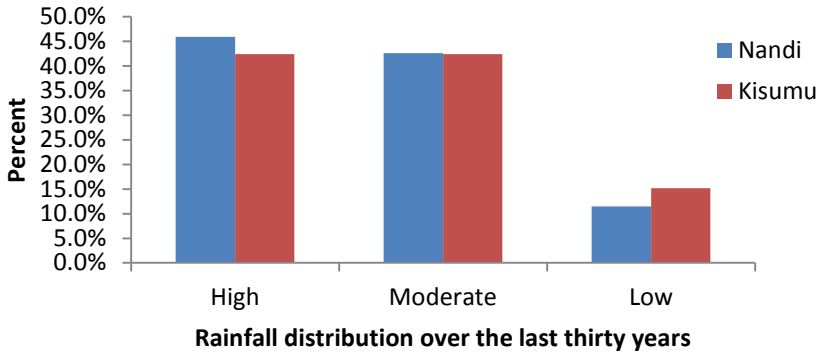

Figure 4. 20 : Rainfall distribution in Oroba water catchment

4.3.4.9 Aquatic organisms

In both Nandi and Kisumu counties 90% and 100% respectively of the respondents accepted there were aquatic organisms (snakes, frogs and fish) in river Oroba while none reported no in Kisumu (Figure 4.21). There is high level of biodiversity degradation in Nandi County due to river pollution and vegetation clearing. Both respondents agreed there was reduction in a number of organisms it Oroba water catchment.

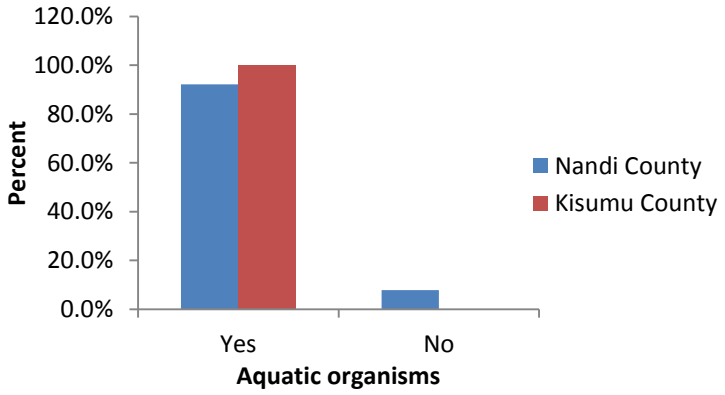

Figure 4. 21 : Presence of other organisms in river Oroba

4.3.4.10 Vegetative land covers in the catchment

In Nandi County 64% of the respondents reported that vegetative cover density was low as compared to the past (in the last or more than 20 years) while Kisumu it is 58%. Meanwhile, 18% of the responded recorded high vegetation compared to the past in Kisumu and Nandi it is 10% (Figure 4.22).This indicates high vegetative clearance in the upper catchment than in the lower catchment. In Kisumu the respondents claimed when they settled in the area the vegetative cover was very low and the settlement has contributed to improvement cover it is only the harsh long hot and dry conditions and the frequent floods they experience has limited there efforts of survival of the planted trees.

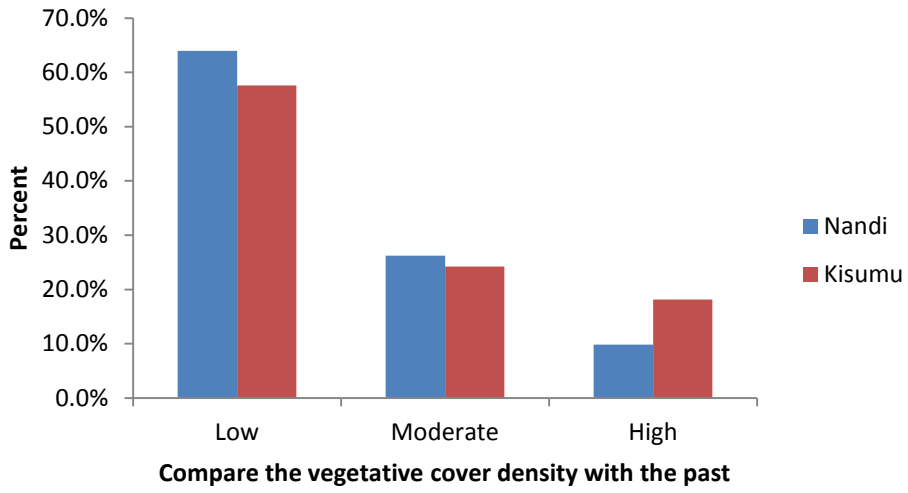

Figure 4. 22: Vegetative cover density in Oroba water catchment

4.3.4.11 Water quality

In Nandi county 48% of the respondents reported that the water quality was good while 52% in Kisumu are of the same opinion. In Nandi County 11% of respondents' rate water quality as very good while in Kisumu 18% are of similar view (Figure 4.23).

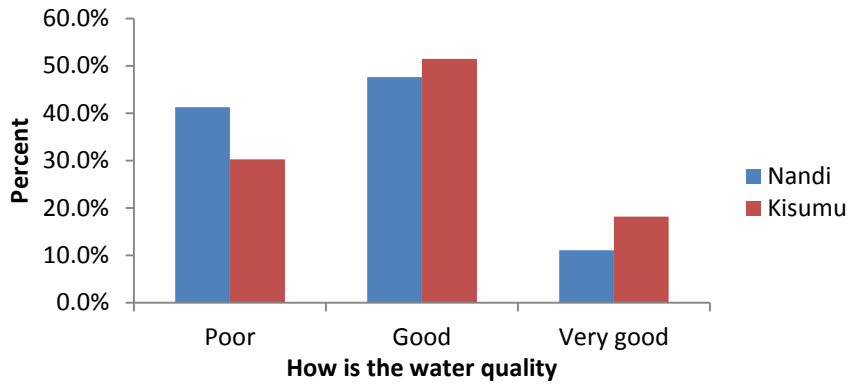

Figure 4. 23 : Water quality in Oroba water catchment

4.4 Land use activities in Oroba Water Catchment

The land use activities identified were; deforestation, agriculture (rain fed and irrigated), grazing, urbanization/settlement, charcoal burning, infrastructure (institutions, roads, mining). Rain fed agriculture is the most extensive land use activity (74.54%) and settlement at (0.05%) being the least extensive in the catchment (Table 4.3).The land use types found in the catchment are described in detailed together with their associated land use activities.

Table 4. 3: Area and percentages covered by land use in Oroba Water catchment

Land Use	Area (Ha)	Percent cover %
Bare land	45.03	0.17
Built up area	12.48	0.05
Agriculture(Cropland irrigated)	3002.54	11.21
Agriculture (Cropland rain fed)	19975.91	74.56
Forest	705.74	2.63
Grassland	526.48	1.97
Shrub land	1386.21	5.17
Shrub land & grassland	528.23	1.97
Swamp	502.09	1.87
Water body	106.51	0.40
Total	**2,6791.23**	**100.00**

These land use activities are common in upper, middle and lower catchment strata.

The land use map (Figure 4.24) shows 10 detailed land use classes and their spatial distribution in the Water Catchment. Generated from satellite imagery and classified based on Anderson classification scheme. The land cover types are associated with each land use types and each indicates extend.

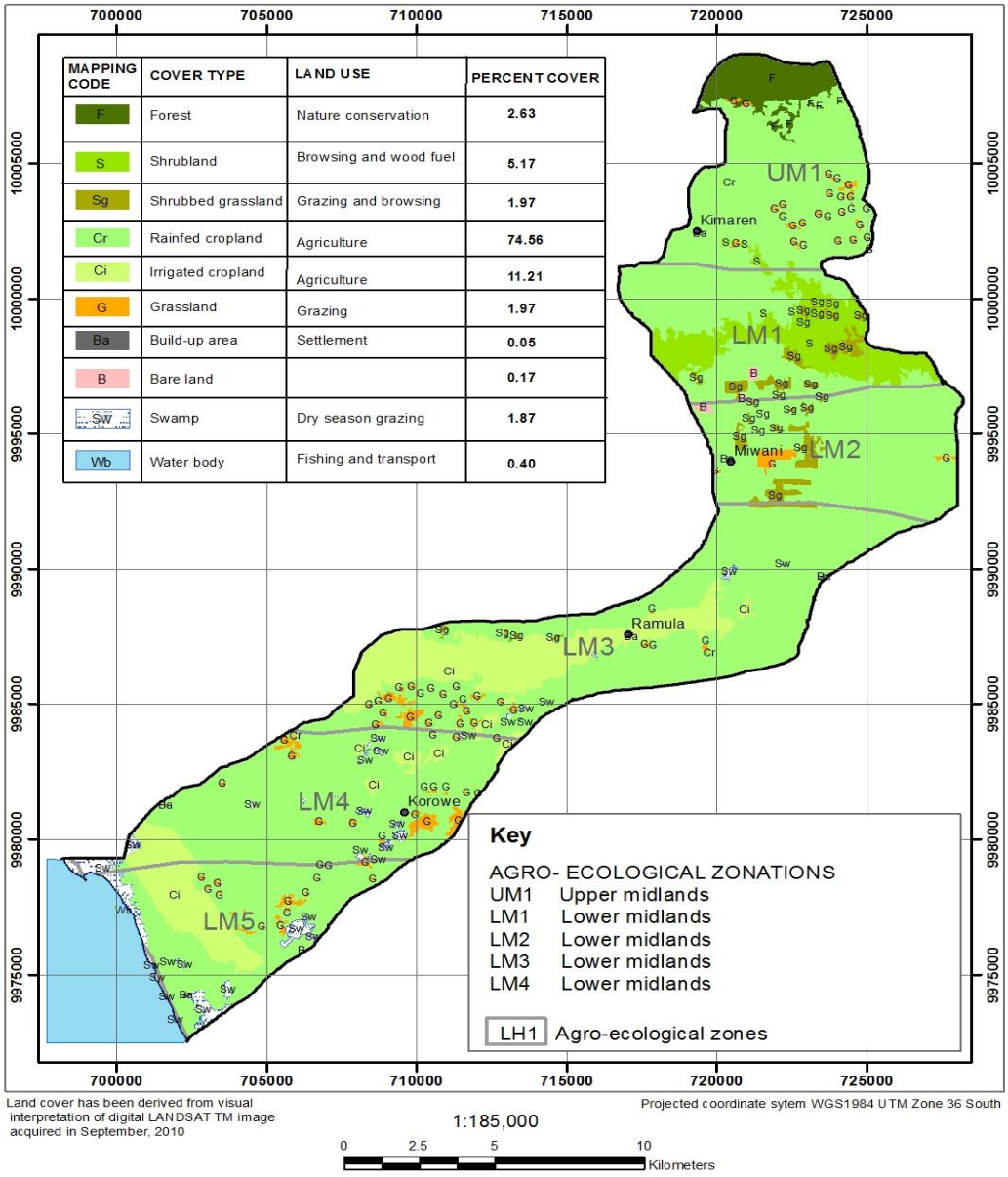

Figure 4.24: Land use map of Oroba water catchment based on landsat imagery for Sept, 2010 (Source: Author, 2012).

4.5 Discussion of Results

4.5.1 Household survey sampling points

Majority of the households are in the lower and middle parts of the catchment (Figure 4.25). This is due to improved accessibility of road networks and people's hospitality unlike upper where most accessibility is poor and hospitality. The enumerators did not reach certain areas. The residents didn't just want to participate in the research due to land and cattle rustling issues sensitivity in those areas.

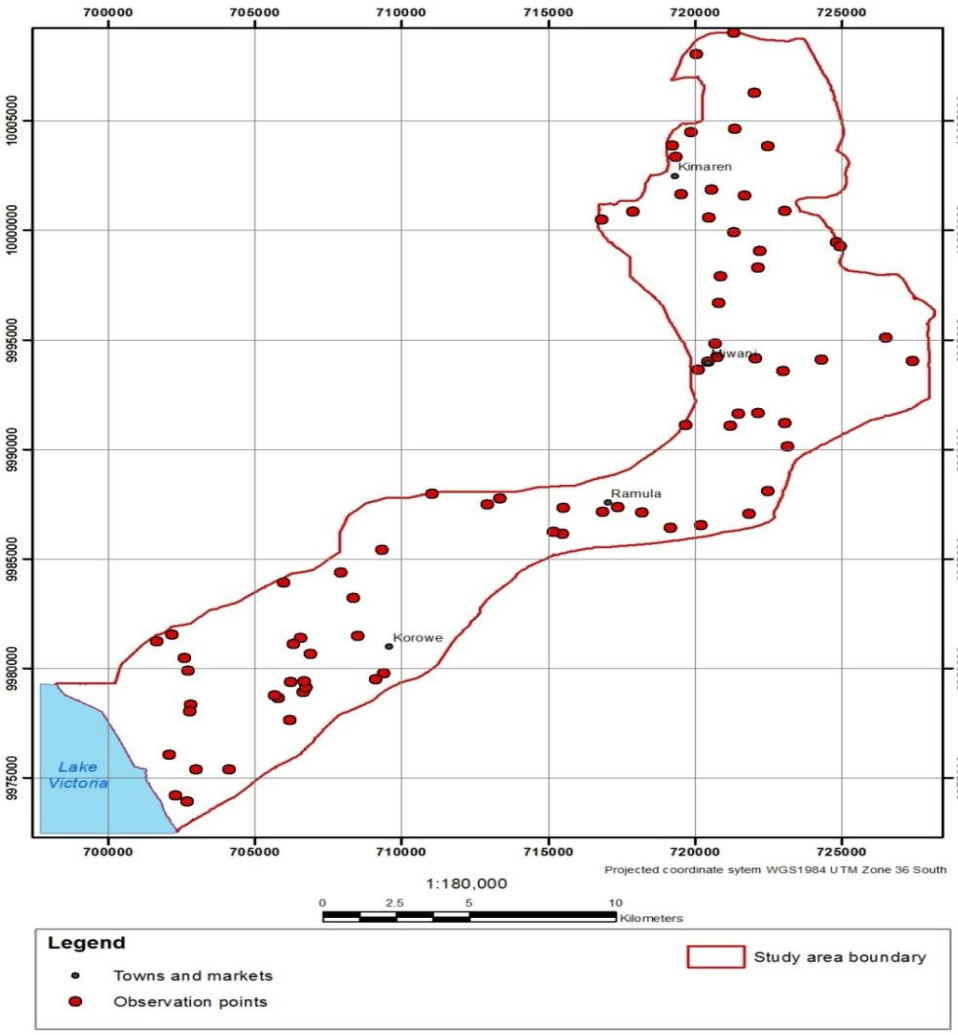

Figure 4.25: Household survey sampling point in oroba water catchment(Source:Author,2012).

4.5.2 Infrastructure in the study area

In terms of infrastructural development (factory, school, roads) in the catchment one could say it is fairly done. The road transport network is mainly of earth roads which are sometimes impassable during rainy periods (Plate 4.1) and drainage ways are poorly done or not done at all. As a result during rainy period the roads are flooded thus rendering them impassable. The roads also act as conduits for overland flow where drainage is not

established or poorly maintained and the vehicle traffic contribute to sediment discharge to the rivers, streams and eventually to the lake.

In the Middle catchment, specifically on the steep hilly escarpment the roads are eroded and thus exposing the rocky outcrops and sharp stones that make the road difficult to use by vehicles, and only left to tractors and donkeys transport. The catchment is served with three tarmac roads that pass through to other destinations. The Kisumu - Nairobi, Kisumu - Chemelil in Kisumu County, and Serem - Kaptumo in Nyando County. The Kisumu – Chemelil road is in pathetic condition, this has made transport in that area a nightmare.

Plate 4. 1: Vehicle stuck in lower Oroba water catchment (Source: Author,2012)

Sugarcane transporters are also making huge postharvest losses as they transport the harvested cane. There are constant breakages to their tractors, accidents (tractors losing control and falling) and falling off of canes from the tractors. The Miwani – Kimaren is stony and rocky due to water erosion and is impassable by small vehicles and is only left for tractors and motorbikes that can maneuver.

Alongside the roads catchment there are shopping centers that have emerged due to business along the roads. These towns along these roads are not planned and therefore

they lack public amenities. As a result of lack of planning pollution is prevalent and disease outbreaks are common and cases of epidemic outbreaks are common such as typhoid, cholera, malaria especially in Kisumu County during rainy periods that is accompanied by floods. In the Nandi County the occurrence is low but is on the increase as per the responses by the respondents contacted. The Kisumu – Nairobi railway line which is rarely functional these days used to be a major means of transportation of goods and human. This boosted business in the lower catchment but now most of the businesses are closed after the collapse of Kenya Railway thus led to dwindling of the areas economies. This resulted to the catchments rise in poverty levels due to loss of means of income.

Sand harvesting (Plate 4.2) which is common during rainy seasons generates good income but those done along the road is destructive and accelerates rate of erosion in the catchment, river banks are damaged as well and the river banks end up being eroded hence more eroded material into the streams, rivers and finally to the lake causing heavy siltation (figure 4.13). The poor road maintenance results to road erosion and these eroded materials are deposited into the surface water bodies. The drainage ways normally end up being rendered dysfunctional.

Plate 4. 2: Sand harvesting in river Oroba and along the road in Oroba lower water catchment (Source: Author, 2012).

Some of the roads are stony and rocky in the upper catchment ending up with protruded rock outcrops (Plate 4.3) which has lead to some roads impassable during wet and dry weather.

Plate 4. 3: Roads eroded by water in lower and upper Oroba water catchment (Source: Author, 2012).

The Serem – Kaptumo tarmac road has really eased the transport situation in the highland area. Housing development in Kano plains is expensive and extremely difficult due to the type of soil (black cotton soil) and, lack of proper drainage system in the entire area. Over ninety per cent of natives are on temporary house structures with only a few owning permanent houses in the Oroba Lower catchment.

Established baseline information on environmental land use activities in the catchment is very vital since it provide planners and other stakeholders with what to expect and what mitigation measures to apply that would lead to the improvement of current situation into a sustainable future of the physical environment.

4.5.3 Settlement in the study area

Fragmentation of farm land to accommodate the increase in population has resulted to reduction of arable land and this is a cultural practice of inheritance in the area and yet the land size is fixed (Figure 4.3 and Figure 4.8). The cultural practice of settling the families in the same land also contribute to land degradation since some are settled in the steep sloppy areas and therefore encroach into vulnerable areas prone to water erosion hence landslides. Settled areas on the steep slopes are causing soil erosion which is observable as sheet, rill and gullies have developed in some areas because no soil conservation structures are in place and they lack awareness (Plate 4.8).

4.5.4 Housing and Urbanization

In the upper zone the housing development are mainly permanent and few semi permanent as compared to the lower zones whose urban housing are of mainly temporary and semi-permanent due to the frequent flooding problem. Increase in permanent structures in urban centers and rural homesteads are contributing to storm water built up in urban areas as well as rural areas. Increase in storm waters accelerates degradation by water erosion hence faster development of rill and gulley features and even floods. The household's size was captured to relate to land parcel size (Figure 4.7) in order to have an informed picture of land demand (pressure) in future and ownership (Figure 4.3). The

built up areas are eating into cropland thus reduction in farm size which translates to lower crop yield production.

4.5.5 Agricultural activities in the study area

Agriculture is the mainstay of the Kenyan economy and represents 24 per cent of growth domestic product (GDP) and this was demonstrated in the catchment. The catchment comprised of different types of agricultural activities these were tea, sugarcane, maize, legumes, rice, spices, sorghum, millet, cattle, goats, poultry, sheep, vegetables, cotton, coffee, fruit and fish to mention a few. Cash crops are mainly for export (tea and coffee) and horticultural.

Staple crops (cereals - maize, rice, legumes etc) meat and fish are for immediate consumption.

Poor plowing method such as plowing up slope was common in some steep areas and in the lower catchment it was occurring in Miwani Factory Nuclear Estate which was due to ignorance. This resulted to more run-offs in their sugarcane plantation. An indicator of this effect was cane seed were left exposed to the surface or washed away during heavy rains (Plate 4.6).

On steep slopes it is far much detrimental because there is no room for infiltration of water into the soil therefore more top soil loss and when the slope length is longer, then erosion is worsen and this was experienced on the shoulder and foot slopes of Nandi escarpment and piedmont plains of Lower catchment. The effect of continual cultivation of land and mono-cropping has led to decline in soil fertility (Figure 4.16). This is manifested in crop yield decrease (Figure 4.11), decrease in vegetative cover (Figure

4.21). The degradation has resulted to the fall of farm productivity and incomes (Figure 4.10).

Migration of the youth to urban centers is taking tall of available labour force in the farms since loss of energetic people have left, only the aged and weak are left behind to do farming hence food insecurity (Figure 4.5).

The stalled Miwani Sugar Factory has contributed greatly to degradation of the forest in the catchment since majority who were employed by the factory are jobless and resorted to charcoal burning (Figure 4.4). Water erosion is threat to sustainable land use activities in the catchment as it affects soil productivity. Some farms are located in areas with a slope of more than 20% on a slope length of more than 50 to 70 meters with no soil conservation measures put in place (Plate 4.4). Farmers cultivate up to the river bank which is not allowed by the Kenya law (Agricultural Act Cap 318) that those with farms next to the river should be prosecuted if they go beyond 20 metres to the river bank (Figure 5.2). To minimize destruction of the forest the Kenya government under former President His Excellency D.T. Arap Moi created a buffer zone referred to as Nyayo Tea Zone (Plate 4.5) and this has managed to control degradation of forest edges of Nandi South.

A number of the respondents expressed concern that they were applying more fertilizer than the amount recommended getting higher yield (Figure 4.10, Figure 4.15 and 4.16) and in certain cases it had reached a point that they were not getting the yield as expected no matter how more they added above the required. It appeared the soil had become acidic and therefore needed advice from agricultural experts who can determine the amount of lime to be applied to arrest the situation (Figure 5.3). Terracing and farming

along the contour was being practiced in the Upper catchment where tea was being grown on steeper slopes and a few farmers in the middle catchment.

The unreliability of rainfall distribution is heavily felt in the lower zone of the catchment. Timing of the rains is not easy at times and results to loss of seeds and crop, even the experienced farmers complained on rainfall unreliability (Figure 4.19).

Plate 4. 4: Clearance of vegetation for cultivation on steep slopes in Oroba water catchment (Source: Author ,2012).

Plate 4. 5: Nyayo tea zone acting as a buffer at the edge of Nandi South Forest in the Upper Oroba water catchment (Source:Author,2012).

High population density and cultural practices (inheritance) have led to highly fragmented farms that are uneconomical to utilize. Brick making is done within the counties and therefore a vital source of income and degrades the area because it requires more fuel wood and excavation of soil result to open depressions with poor soils. Some farmers have started woodlot for commercial purposes in the lower zone to meet the demand of market which is readily available in brick making and as fuel wood for domestic use.

Farmers were not aware of Agricultural policy that bar them from cultivating on slopes of more than 16 percent without putting soil conservation structures to control soil erosion. There was very little evidence of conservation measures within the cultivated areas such as lack of field drain in the steep slopes and therefore this was an indication of high

erosive flows that contributed to high sediment transport in overland flow to the streams and rivers in the catchment (Table 4.2).

The few farmers who were aware of the soil conservation had learnt it in school or from other places where the practice was on such as central and eastern provinces (Figure 4.9). A great number of farmers kept a large number of livestock in the catchment especially in the middle and the upper zone where 90.6% keep livestock and 90.9% rely on open grazing in the nearby shrub land and forest (Figure 4.12). Overstocking of livestock has by passed the land carrying capacity and this was demonstrated by shortage of pasture and fodder in the catchment.

In the Miwani sugar nuclear estate farming up the slope is rampart since the management (Factory under receivership) sees it as cost effective yet it has lead to top soil erosion (Plate 4.6). The result is evidenced by decline in yields of sugarcane production as well as in other crops such as maize which is the staple food crop in the catchment as it is globally (Figure 4.11). Agricultural activities on the edge of the rivers were a potential for sediment discharge given close proximity to the rivers.

Plate 4. 6: Young sugarcane seed is almost being washed in a nuclear sugar estate (Source; Author, 2012).

4.5.6 Urbanization in the Oroba water catchment

Rapid urbanization within the catchment has resulted to change to the land cover within the catchment from vegetation to impervious surfaces such as building, roofs and roads. The reduction of cover and increase of structures contribute to increased storm waters that contribute to flooding in the Kano plains (Figure 4.18 and Plate 4.10). All the urban centers in the study area are unplanned and as such lack social amenities such as sanitation therefore conditions are not healthy to humans and other organisms.

The urban set up that is coming up haphazardly is life threatening environmentally since outbreak of diseases was reported common within the Oroba catchment. Most of the streets are an eye sore, flowing with sewage waste (Plates 4.7) and these are means of transmission of diseases. Pit latrines are common and therefore dangers of fresh

underground water being contaminated and definitely there is overflow of this into the streams and rivers. Urbanization is also eating into cropland and the result is food insecurity.

Plate 4. 7: Unplanned town and trading centres drain sewers into rivers and streams in Oroba water catchment (Source: Author, 2012).

4.5.7 Overgrazing by livestock

In both the counties livestock is kept for cultural and security purposes. In both counties the majority keep 3-6 cattle per household. In the Nandi 98.1% of the respondents kept livestock and this is understood because the natives are pastoral in culture while in the Kisumu County it was 81.4% for security and customary reasons (Figure 4.14). In the Nandi County 79.5% kept over three cattle while in Kisumu County it was 63.9%. The livestock in the catchment normally graze in open spaces, shrub land in the hilly areas and those near the forest graze in it. Grazing in the hills and forest is because farmers have overstocked their livestock that is beyond the pasture carrying capacity. Trampling by livestock as they graze on the open fields and in the steep hilly areas has caused

surface sealing and has resulted to soil being very compact and thus very hard to work on with the farm implements; heavy surface run-off hence accelerated sheet and rill erosion that was observable in the catchment (Plate 4.8). Overgrazing contributes to flooding in the lower catchment.

Plate 4. 8: A rill is forming in the farm in lower Oroba water catchment (Source: Author, 2012)

4.5.8 Deforestation in Oroba Catchment

The forest protects, serves as watershed, ensures good water quality, prevents erosion, a source of herbal plants, reserves biodiversity and prevents downstream flooding. Therefore, unplanned continuous clearing of vegetation for charcoal burning, timber and fuel wood that is in high demand in the neighbouring towns and trading centers and is very lucrative (Figure 4.6). Burning of charcoal was common in the hilly areas of the catchment which was more of shrub land and is regarded as a source of income. Locally it is bought at Kshs. 500 to 600 and sold between Kshs. 1,000 to 1,300 in the nearby

urban areas thus it is a source of livelihood for some families, since it's their income provider that they have known for many years.

The income bracket when considered and compared to the international standards and with the current situation in Kenya, it is very low. Seventy percent of the respondents interviewed earned less than Kshs.200 per day and only thirty percent generates more than kshs.200 (Figure 4.10) and if one relates it to family size (Figure 4.8) in a house hold in both the counties; it is disastrous since one cannot comfortably feed a family with this earning hence malnutrition. It can be deduced that poverty is prevalent within the catchment. Lack of employment opportunities drive some to thrive on charcoal burning.

In the lower catchment fishing (Plate 4.9) is an economic activity that benefits the communities in the lower catchment and this depends on water from the upper catchment.

Plate 4. 9: **Fishermen at work in river Oroba (Source: Author, 2012).**

4.5.9 Flood Occurrence in the study area

Flooding was a major cause of land degradation that have led to poor socio-economic conditions and the deterioration of the natural ecosystems (Figure 4.18). Anthropogenic activities such as deforestation, excessive use of chemical fertilizers, overgrazing, construction works, unscientific farming on the steep slopes of the Nandi escarpment have resulted in loss of flora, fauna and erosion of top soil, occurrence of landslides in the uplands and hilly areas of the catchment, flooding in the Kano plains (Plate 4.10).

These causes have led to severe environmental degradation leading to poor socio-economic condition and disruption of natural ecosystem in the Oroba Water Catchment.

Plate 4. 10: Flooded homes and farms in Lower Oroba water catchment-Kano plains (Source:Author,2012)

The increased pressure on pasture and shrub land beyond its carrying capacity on the hilly area has accelerated soil erosion without consideration of improved farming practices such as terracing and use of organic manure. The rivers turbidity which is as a result of erosion from agricultural farms that is composed of chemicals is harmful to the aquatic organisms such as fish **(**Figure 4.20).

During floods most bridges are washed away (Plate 4.11), livestock are killed, crops are lost, properties are destroyed such as houses and sometimes human lives is lost and displacement of population. The floods are normally accompanied by disease outbreaks such as cholera, bilharzias, malaria. Malaria and other associated sicknesses renders the locals affected ineffective in meeting their work potential. Roads are rendered impassable and produce from farms cannot be transported in good time and those easily perishable rot in the farms (Plate 4.1).

Plate 4. 11: A bridge across river Oroba is almost being washed away by floods (Source: Author, 2012).

During floods fish from the lakes are normally in abundant in the plain and therefore the natives in these areas enjoy a good catch but fish being easily perishable most do not reach the market when the means of transport is disrupted (Plate 4.1)

The floods also do deposit fertile top soils washed from the farms upstream and this is normally utilized when the floods have receded (Figure 4.16). After the rains those with irrigation facilities do benefit during the dry periods. Rivers and streams are normally silted (Plate 4.12) and (Figure 4.13) thus more contributes to flooding of surrounding farms and homes. Floods destroys houses and therefore many people in the plains construct temporary and semi-permanent houses to minimize loses, in every house there is a hole to allow free flow of water when floods occur.

Plate 4. 12: River bank erosion and siltation occurring in lower Oroba water catchment (Source: Author,2012).

4.5. 10 Pollution of Catchment Water

Contamination of the catchment waters is normally done by washing of vehicles along the particular river or stream spots along the main roads (Plate 4.13). Heavy commercial vehicles to motorbikes are washed in these places and this means oil and other wastes that contain heavy metals. The plants can uptake these heavy metals like zinc and when consumed by human beings and animals can be lethal to their health.

Plate 4. 13: Car wash by the road side along river Oroba in Lower water catchment (Source:Author,2012).

Application of fertilizers, pesticides and other chemicals by horticultural and irrigated rice farmers is a threat to fish and even the soils of the lower areas (Figure 4.15 and 4.16). Farmers and commercial farmers in the sugarcane production for example Miwani Sugar Company under receivership complained that no matter how much they increase input of fertilizer there is no increase in yield and therefore they are worried the soils have been destroyed and asking for solutions.

Swampy areas have been encroached by horticultural and rice farmers (Plate 4.14) and therefore loss of biodiversity in those areas due to application of pesticides, herbicides and fertilizer. Water quality of the surface and underground water cannot be guaranteed under the prevailing conditions in the catchment, increase in the use of pit latrines, oil and fuel leaks from storage tanks as well as vehicles and motorbikes and a few septic tanks that have been constructed without following the recommended standards. The sewage from the septic tanks discharge is normally unknown and therefore possibly discharged into a water way some where secretly.

Plate 4. 14: Irrigated rice paddy where heavy application of fertilizer and other chemicals used on horticultural crops during dry periods(Source:Author,2012)

Pollution of the streams and rivers was evidently displayed by the rivers turbidity and heavy sedimentation occurred on a small portion of the Middle catchment and more prominent in the Lower catchment. In the Upper zone the water was fairly clear.

The Oroba rivers (Great and Little) are polluted with underutilized fertilizers and pesticides and there is possibility that groundwater is also being contaminated by these chemicals. Pollution goes on unabated yet there is Environmental and Coordination (Wetlands, Riverbanks, Lakeshore and Seashore Management) Regulations, 2006 protects aquatic environments from effluent pollution by setting appropriate standards for effluent discharge.

4.5.11 Effects of water erosion on land

Inappropriate land use activities have continued to cause soil erosion by water, trampling of livestock on the land make the top soil impermeable hence more run-off, road constructions without putting proper drainage ways and increased built-up areas results to increase in volume of run-off and minimal infiltration of water combined with minimal

time the run off occurrences is greater as it reaches the waterways compared to an undisturbed catchment experiencing the same rainfall. This causes intensive downstream flooding of rivers and streams in the catchment. The rivers and other waterways are heavily silted and this could be one reason why floods are common in the lower zone (Figure 4.18). There were several water erosion effects and of livestock trampling (Plate 4.15). Sheet and rill erosion were common and worse cases were resulting to galleys.

Plate 4. 15: Water erosion effect on land in the Upper, Middle and Lower Oroba water catchment(Source:Author,2012)

Surface sealing and crust were observed in the open grassland fields due to livestock trampling and made the soils compact hence very little infiltration thus flooding during rainy period.

4.5.12 Effects on water quality in Oroba Catchment

Water quality of surface or groundwater reduces as it flows away from the source which is in the Nandi South Forest (Figure 4.22). In the Upper catchment zone the water is still clear up to a certain portion of the Middle catchment (Plate 4.16) from where its turbidity and sediment level intensifies when it approaches the lower zone (Plate 4.17) up to the lake. The water quality is low in the lower zone and yet it provides for domestic,

livestock and institutions within the catchment. The natives entirely depend on River Oroba water and have protected it from being contaminated by factories and institutions using it, the communities do not allow any discharge of waste into the river.

Contamination is more in the irrigation schemes since they use more fertilizer and other chemicals. There were incidences where some respondents had notice a lower ground water recharge where bore holes were. Increased households contribute to pollution of rivers during heavy rains leading to poor water quality.

Plate 4. 16: Observed clear water in river Oroba water Upper Catchment(Source:Author,2012).

Plate 4. 17: Observed turbid waters in river Oroba Lower water catchment (Source:Author,2012).

Degradation of water resources was evidenced by siltation of rivers and their state of turbidity became poorer (more turbid) towards the low lying areas (Kano plains) as opposed to the highlands which was more clear at the source in the forest.

The quality of water was suspects because disappearance of certain fish species, reptiles and amphibians as a result of application of chemical fertilizers, herbicides and pesticides in the farms and worse on farms next to the rivers and during flooding and irrigation in the plains.

Policy of increasing food production to a certain extent would be said to contribute degradation because they emphasize on use of fertilizer and this has resulted to over application of chemicals hence acidic soil condition. In Kano plains flooding is the biggest hindrance to development since its occurrence is associated with destruction of crops in the farms loss of property, displacement for sometimes from homes, disease outbreaks such as dysentery, malaria, cholera, bilharzias and loss of lives. Poor

infrastructure development such as lack of construction bridges results to people drowning during rainy periods when rivers are swollen.

4.6 Integrated Land use Planning for Oroba Water Catchment

4.6.1 Introduction

The main goal of the study was to asses land use activities and their contribution to land degradation in Oroba Water Catchment in Western Kenya and develop management alternative land use intervention plan that will ensure sustainable land use practices. This can only be implemented through appropriate management planning techniques discussed in this chapter.

4.6.2 Integrated Land use Planning

Planning is necessary to counter actions expected to occur and accomplish them without causing destruction. Planning ensures goods and services are rendered sustainably in a stable environment. Well thought planning, establishes acceptable land use patterns in a catchment and prevents inappropriate use of land resources. Generally, planning is a process of making rational decision about future actions aimed at attaining the societal goals (sustainability).

Land use planning has been a human activity since time immemorial at local level. The World Food and Agricultural Organization has been involved in land use planning and developed set of guidelines that has in cooperated environmental and ecological considerations. A number of Publications has been initiated such as “A Framework for Land Evaluation” (FAO, 1976), Application to “Rain fed Agriculture” (FAO, 1983), “Land evaluation for Forestry” (FAO, 1985) and to “Extensive Grazing” (FAO, 1990).

Land use planning methodology has been applied at catchment levels in Brazilian Amazon Region where Agro-Ecological Zoning Methodology was used and proved to be a valuable tool for planning at the national and provincial levels. It was used in identification of areas that are not self-sufficient in food production, areas of potential resettlement and agricultural development. The above mentioned publications have been of great benefit to planners for guidance purposes in their daily work.

4.6.3 Current Land degradation severity level in the catchment

Land use activities in the study area have produced adverse effects upon the economy of the study area and this definitely translates negatively to the region's economy. Land degradation differed among different land use activities and landscapes as illustrated in (figure 4.17) and (table 4.4) on land use activities; therefore, degradation causes differed from zone to zone (Figure 4.3).

In the lower catchment land degradation drawbacks are; flooding; surface crusting, compaction and sealing, pollution, improper road construction and destruction of houses.

In Middle catchment degradation was mainly from agricultural activities due to over application of chemicals (pollution) due to intensive farming, vegetation clearance, rural urban immigration, landslides, high population, farming on steep slopes, deforestation.

In the upper catchment the problem was majorly due to over application of chemicals and deforestation (Figure 4.16). The effects studied were on agricultural activities on farms - arable land showed productivity had declined. Poor road infrastructure, deforestation, overgrazing and offsite effects as sedimentation contributed greatly to land degradation.

Table 4.4: Current land degradation % in Oroba Water catchment

Degradation Classes	Area (Ha)	Percentages (%)
Low	19773.99	76.82955
Moderate	2997.72	11.64729
High	2965.77	11.52316
Total	25737.48	100

4.6.4 Planning Intervention

Planning intervention for Oroba catchment is to alleviate land degradation for the establishment of sustainable land use and management practices within Oroba catchment and is a fundamental process in the restoration of the catchments resources. The findings from this research should aid the planner, land user and policy makers in making informed decision on development undertakings. This could only be achieved by devising sustainable management practices which would require creation of dialogue among the stakeholders and linking the relationship between the catchment resources, technology and the public livelihood. Societal planning is a process that requires making rational decisions about future actions aimed at attaining public goals.

Land and water resources are vital for farming, forestry, transport, grazing, wildlife, urban development and environmental matters. Maintenance of stability in the environment requires regulation of land use to avoid future land use conflict. There are government instruments and institutions to create awareness, to inform on government

policies on appropriate management of public resources and to advice on efficient utilization of natural resources.

There is an Agricultural Act Cap 318 that provides for legislative control over soil conservation and land management. The Agricultural Act aims at promoting and maintaining stable agriculture, to provide for the conservation of soil and its fertility.

The acts is supported by Farm Forestry Rules, 2009 which aims at promoting and maintaining farm forest cover of at least 10 per cent of every agricultural land, Kenya Water Act, 2002 ensures management, conservation and control of water resources and the National Environmental Management Authority that monitors and ensures environmental regulation and laws are adhered to as laid down in the Kenya's constitution.

The interventions recommended are per the problems encountered within the Oroba catchment and are expected to address concerns of land degradation efficiently and effectively such as soil erosion that is amplified by human activities, vegetation clearance, poor road maintenance, overgrazing and pollution.

It is important that land degradation is handled in a more holistic approach and in a multi-disciplinary that is participatory. This would ensure establishment of links with the driving forces, the pressures, state of land degradation and the impact on the human and the environment that would arrest the effects sustainably. To manage Oroba Water Catchment would require zonation of the catchment into Upper, Middle and Lower for ease of management since they are of different landscape and fall under different agro-ecological zones (Figure 4.26).

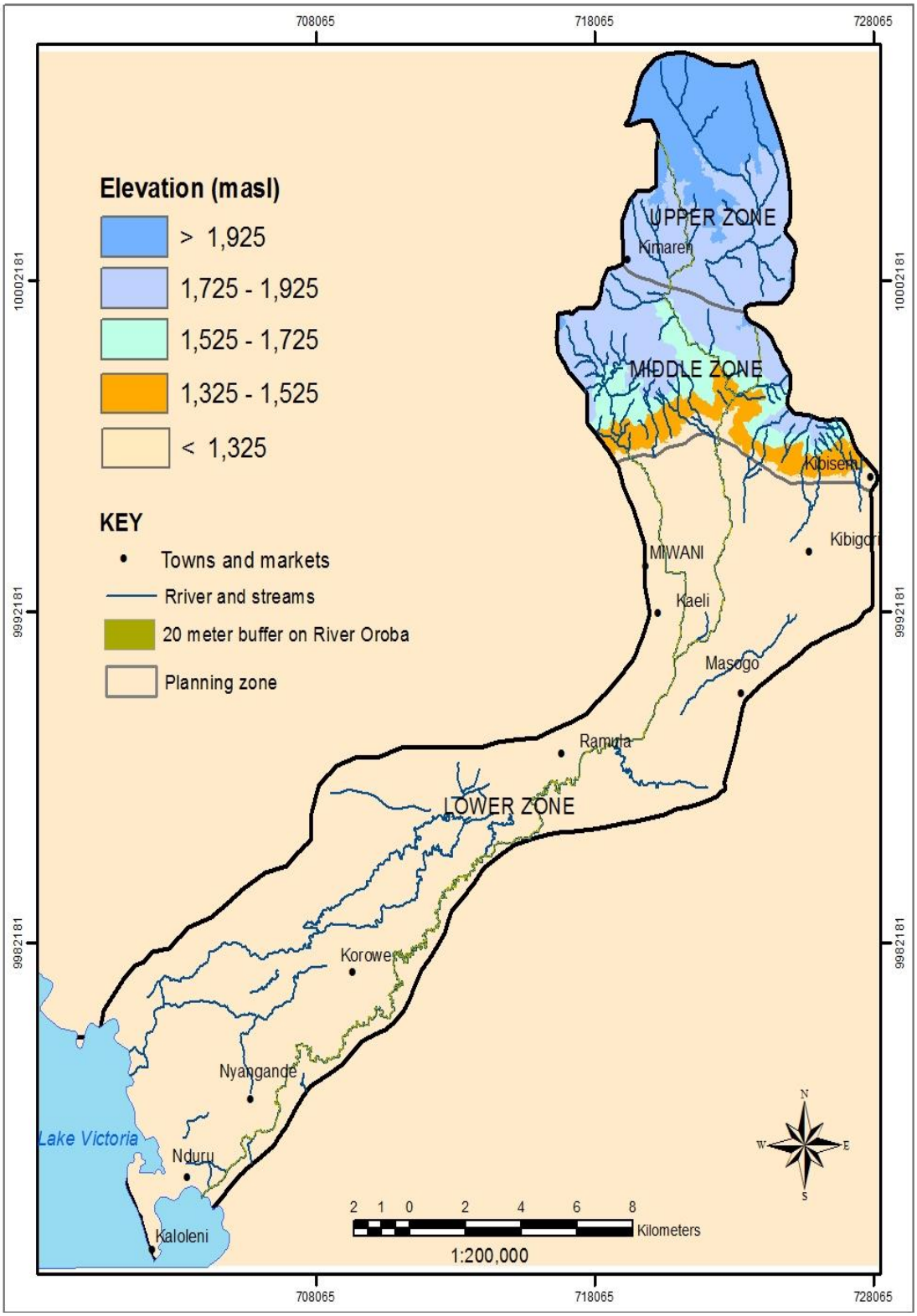

Figure 4. 26: Planning Map of Oroba water catchment (Source:Author,2012).

4.6.5 Upper Zone

The Upper zone is the region within the Oroba catchment and is above 1,800 meters above sea level and covers an area of 36.81km^2 as shown in (Figure 4.26). It falls under agro-ecological zone of the Upper midlands (UM1) and is the source of river Oroba. The zone comprise of Nandi South Forest, is majorly tea growing and dairy farming (cross breeds and few exotic), maize is also grown and horticultural under intensive farming. Generally, fertilizer is more used in the tea farms and in other crops.

Continual use of fertilizer has made soil to be acidic and crop yields has declined hence need of soil to be sampled and taken for further analysis in agricultural laboratories to determine the soil nutrient requirement. The recommendation from the soil fertility experts may solve the problem of acidity and low decline of crop yield. Pressures on crop land due to settlement as a result of population increase can be minimized only on change of cultural practices and attitude. The natives being agro-pastoralist should be discouraged from keeping large number of livestock that is causing degradation of pasture and land. The locals should be advised by agricultural extension workers on keeping very few exotic dairy cattle on zero grazing that is economical and more beneficial in giving quick high returns that would raise their standard of living since the market is readily available in their nearby urban towns.

They community should be discouraged from carrying out cultivation near the rivers and be advised on fodders, trees and pastures (agro-forestry) that are beneficial to the livestock and humans that would stop degradation along the riparian.

The farmers should be made aware of the 20 metre buffer zone along the river. Awareness be made on responsible timber harvesting and more planting of appropriate

trees by forest officers to meet 10 per cent of constitutional requirement. Farmers should be advised on wise use of chemicals and safe way of disposing them after use in order to protect the water quality. Farmers should be trained on the usefulness of farm terracing, grass strip and on crop rotation for soil conservation purposes.

The authorities concerned with road construction and maintenance should be advised on ensuring drainage ways are in place and well maintained. The responsible institution that gives permission to contractors to mining must ensures they rehabilitate the quarries.

4.6.6 Middle Zone

The middle zone covers an area of 40.2 km^2 and lies between 1,525 metres and 1850 metres above sea level. It is a region lower midlands one (LM1) of mixed cropping and livestock keeping (local zebu and cross-breeds). The crops are coffee, sugarcane, maize, sweet potato, sorghum, millet, horticultural crops and few practice agro-forestry. It is a densely populated region and the landscape is heterogeneous. The zone is hilly and rolling landscape, with pockets of rocky outcrops and stony areas which are difficult to work on. The roads are earth roads and poorly maintained. The zone includes the steep Nyando escarpment that is dominated by shrub land. Charcoal burning is common in this region and the market is the neighbouring urban towns such as Kisumu and Miwani. It is a sensitive and remote region that needs mobilization and sensitization of the local community on sustainable farming practices. The region needs an integrated management that offers alternative livelihood options that empowers them to adapt to the new way of life. Communication need to be improved as well as goods and services in the upcoming urban and trade centers. Soil and water conservation should be emphasized and

cultivation on steep slope (Plate 4.18) in the catchment escarpment be terminated. Cultural practices and attitude be reviewed in order to cope with the dynamics of the present life of today.

Plate 4.18: A recently cleared area for cultivation in the Middle of Oroba catchment (Source: Author, 2012).

4.6.7 Lower Zone

The lower zone is very expansive covering an area of 191.92km^2 and falls below an altitude of 1,325 meters above sea level. The area is mainly Kano plains and of flat to gentle slopping. It falls within the Kisumu sugar belt and therefore major cash crop is sugarcane, rice and cotton. They grow maize, sorghum, cassava, mangoes, millet, sweet potato and horticultural crops. It is sparsely populated and flood prone area with a number of swamps which have been encroached by farmers. Fishing is common being an area near the lake and dominated by the Luo tribe.

The locals keep livestock mostly the local zebu because of harsh conditions in the zone. It falls in the Lower midlands (LM2, LM3, LM4 and LM5) (Figure 4.23).

Flood that occurs in this area is normally very destructive and happens almost after two years. Addressing the flood is only by constructing a large dam in the upper zone for multipurpose use that would provide water for small farm hold irrigation and other small ponds for fish farming, hydro-power production and water for domestic and industrial use. This should involve construction of permanent canals to distribute water by gravitational force. If the recommendation can be implemented this would be a major crop production area that would boost the counties and national economy. It would provide a large source of employment and hence poverty alleviation.

4.6.8 Infrastructure

Road infrastructure must be looked at critically by regular maintenance of earth roads and tarmac ones. The ministries responsible should ensure road drainage ways and culverts are in place and specification followed to the letter by contractors. The silted and blocked should be cleared before the long and short rains to allow the smooth and fast flows of overland flow. This would reduce the difficulties being experienced by motorist during the rains. The railway network should be revived to improve transport network in the catchment and linking other areas in trade.

Quarries left unattended should be rehabilitated for them to be utilized to become economically viable such as introduction of agro-forestry on these sites.

4.6.9 Soil and water conservation

Soil and water conservation plays a vital role in farming system. Therefore, to protect the Oroba water catchment there is need, to create natural vegetative buffer zones along the riparian that would be acceptable socially and economically by the locals particularly tree crops. The tree crops must give good economic returns to the farmers and should be allowed to establish until a pure stand of tree cover is attained to provide a natural protection on the riparian zone.

On steeper slopes terraces, stone lining, strip cropping be practiced where it is not possible to resettle the farmers otherwise cultivating on steeper slopes be discouraged as well as grazing.

Appropriate land management accompanied by good crop and livestock husbandry practices should be emphasized in the catchment to minimize land degradation (Table 4.5).

Table 4.5: Respondents opinion on how to manage land degradation

	County	
Land conservation measures	**Kisumu (%)**	**Nandi (%)**
Advise on soil conservation		14.28
Avoid overstocking	14.28	
Avoid plowing along rivers		14.28
Avoid siltation	14.28	
Built Adam	14.28	
Built Gabions		14.28
Built Terraces		14.28
Education land use		14.28
Crop rotation	14.28	
Use CBOs	14.28	
Channels to drain water	14.28	
Avoid cultivation along slopes		
Deploy extension Officers	14.28	
Family planning		14.28
Total	**100**	**100**

Agricultural extension officers should be sent to advice farmers on appropriate farming methods and technology (Figure 4.27). In the catchment over 80% respondents in Nandi County had not been visited by Agricultural Extension Officers while less than 5% of Kisumu respondents reported that they had been visited by Agricultural Extension Officers.

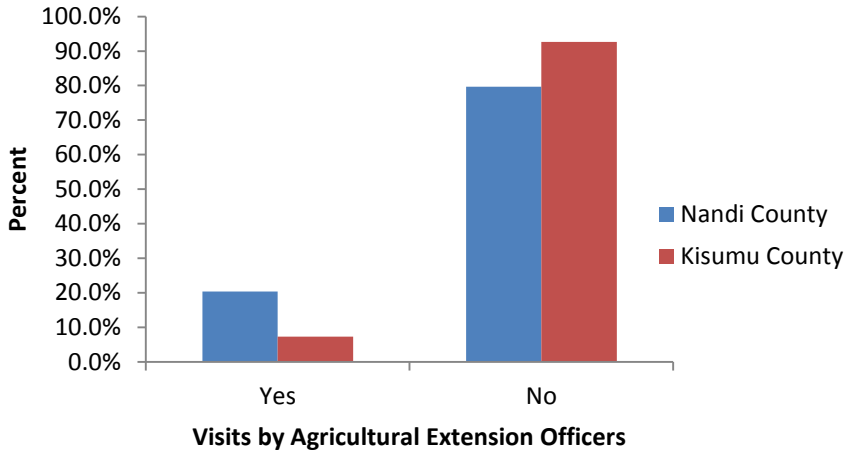

Figure 4.27: Visits by Agricultural Extension Officers in Oroba water catchment

Acidic problem being experienced in some soils in the catchment can be addressed by applying lime which the amount can be determined after carrying out the soil tests. The soil analysis results recommendation would provide a more sustainable way of managing the soils fertility. Replenished soil fertility would lead to better water holding capacity and reduced run-off hence low sediment transport of to the surface waters.

Agricultural extension workers should advice farmers on reduction of the numbers of cattle they keep. Zero grazing for dairy farming should be emphasized by the extension staff since its return is higher compared to keeping the indigenous cattle and is sustainable.

4.6.10 Urbanization and settlement

Counties within the catchment need to plan for basic social amenities (health services, recreation and schools) in the developing trading centers. There were a growing number of young people migrating from rural to urban areas to seek employment opportunities (Plate 4.19 and 4.20).

Plate 4.19: Trading center in the Oroba upper water catchment that attracts the youth and offer employment hence loss of labour in the farms(Source:Author,2012).

Plate 4. 20: Trading center in Oroba lower water catchment with "Boda boda" activities (Source:Author,2012)

The road and other communication network, drainage ways, water and sewerage facilities. If planning is implemented pollution would be minimized, traffic would be controlled, and housing problem once addressed there would be no slum development. Fragmentation of land should be discouraged and this can be addressed by changing our cultural attitude approach to land inheritance. Encroachment of the steep slopes and shrub land would need political good will from the local and national leaders.

Policies on land use need to be accompanied by enforcement laws. Political leaders should the stop impunity of dishing land to their supporters without considering environmental problems.

4.6.11 Flood control

To address the flood and drought problem within the catchment would require construction of dams for hydroelectricity generation, for domestic and industrial use, and establish small holder irrigation project in the entire plain with concrete drainage ways that supplies the water for irrigation purpose. Re-a forestation in the shrub land and agro-

forestry in farms be emphasized. The land cover would eventually improve thus reduction of soil erosion and water run-off. This would reduce the volume and force of water run-off from the highlands and control flooding events that is very destructive in the lower zone and would empower the lower zone communities since they would be able to cultivate throughout the year thus improving the food security, standard of living locally and nationally thus achieving the government's vision of 2030 on poverty alleviation. The aquatic and marine ecosystem would be improved since there would be minimal eutrophication of the water. The above proposals would not be an obvious choice for policy makers because it is costly and takes longer time but it is more sustainable in the long term plan.

Planners need to utilize Geographical Information System (GIS) as a tool for managing spatial information and interaction with appropriate model provides problem solving capabilities useful for efficient and effective decision making for establishing guidelines and the necessary standards for regulation purposes for planners.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

From the findings land use activities such as deforestation, overgrazing, poor agricultural practices, unplanned urbanization, ignored and abandoned infrastructural development particularly road maintenance and stalled Miwani sugar factory, abandoned quarries, settlement, sand harvesting and charcoal burning are the major contributors of land degradation in the catchment. Generally, land degradation is indicated by state of soil degradation, vegetation degradation, degradation of water resources and ignorance and all these are actors in the degradation of the catchment. Deforestation is the major contributor to land degradation followed by agriculture activities as they expose the land to forces of erosion and pollution.

It was found out that increased land use activities was as a result of meeting the demands of the increasing population that meant need for more food production, more requirement of energy, more water requirement, better civic amenities for a reasonable quality of life, more infrastructural development and these activities must be sustainably achievable to address their impacts. The government efforts to address encroachments of the steep hills particularly the escarpment and the wetland are inadequate. This is a reflection of policies which are weak, sectoral and ineffective or lack of enforcement law.

This was happening even though the country is a signatory to Ramsar convention of 1971. The convention was signed in the city of Ramsar in Iran and Kenya contracted it in 1990. The convention on wetland mission was for conservation and wise use of wetlands for the sustainable management. If the national legislation of section 42 and 55 of the Environmental Management and Coordination Act (EMCA, 1999) that provides for the

protection of wetlands and water resources in the country could be implemented participatorilly with good political will much can be achieved.

From the discussions above it is necessary to have accurate information about present land use activities so as to prepare an integrated plan for optimal utilization of natural resources in the catchment as it is obvious that land degradation have occurred through physical, chemical and biological processes which was directly or indirectly induced by human activities through soil erosion, compaction, acidification, leaching, salinization, depletion of soil nutrients and decline in biodiversity.

5.2 CONCLUSIONS

The objective of this research was to assess land use activities and their contributions to land degradation in Oroba water catchment. This objective was achieved through research on specific objectives. The **first** specific objective was to identify the land use activities in oroba water catchment. The major land use activities that have contributed to land degradation in the Oroba Water Catchment were identified as; deforestation, overgrazing of livestock brought by overstocking, poor agriculture practices, urbanization, settlement, charcoal burning and lack of road maintenance with agricultural activities as the main contributor. Most of the land use activities were unplanned or mismanaged by the users. These land use activities such as deforestation (for timber and charcoal burning), clearance of vegetation for settlement and cultivation, improper land practices for various land use without environmental consideration has led to reduction of land cover.

The **second** specific objective of this study was to assess the contribution of land use activities on land degradation. From the study it can be deduced that poor agricultural practices is the main contributor of nutrients and sediments which are heavy contaminators of rivers in Oroba Water Catchment this is evident by the presence of algal bloom on the lakeshore, encroachment of wetlands and invasion of swamps for farming purposes, and the nutrient loss from the farm lands in the highlands has led to devaluing of environmental economic system in relation to productivity of land for agriculture, flora, fauna and human habitation. Soil and water degradation have resulted in severe destructive floods, and high water turbidity in the lowlands of Kano plain, heavy soil erosion from the Nandi highlands. This has caused depletion of soil nutrients hence decline in crop yield thus food insecurity, terrain deformation by gully incision and loss of biodiversity due to destruction of the environmental organisms in the habitats of Oroba Water Catchment and this could be said to have contributed to climate change. Harvesting of trees and shrubs in the forest and shrub land has impacted most negatively in the Catchment and is more associated with land degradation in the area.

Infrastructural developments due to work constructions such as roads were not well done and lacked maintenance that made them impassable during wet and even dry weather conditions. Towns lacked social amenities like drainage ways, sanitation (solid waste and

sewerage discharge) to mention a few that may lead to degradation of underground and surface waters.

The **third** specific objective of this research can be argued to be achieved by the following: A proposal on appropriate planning and employing sustainable land management techniques such as terracing, minimum land tillage, plowing along the contour, avoid cultivation on very steep slopes, avoid overstocking and practice zero grazing, discourage encroachment of wet lands and practice agro-forestry on land management could overcome problem of land degradation and food insecurity. In addition, it would provide a diversified production and consequently greater food diversity. Only very few farmers practiced soil conservation measures they learnt from others inside and outside the area. Majority of the local community are not informed on soil conservation structures and its importance.

It is important to note that from the findings that land use activities have vital environmental impacts upon geomorphology; hydrological processes, human health and aquatic ecosystem. Cultural and traditional practice such as of inheritance and Land tenure issues are also an obstacle in proper management of land resource in the catchment and it is in both Kisumu and Nandi Counties contribute to land degradation. Rainfall, slope and land use pattern influence level of soil erosion and nutrient depletion. The resulting maps in the text present indication to planners of most favorable areas for certain land use activities in the catchment that would minimize land degradation.

5.3 RECOMMENDATIONS

The recommendations for this study are presented as recommendations from research findings and areas for further research.

5.3.1 Recommendation from research findings

Planning Intervention measures are required to minimize degradation of the catchment soil and land use practices.

The findings on causes and effects of land degradation in the catchment if incorporated in the planning process could address this major problem of degradation and prevent it in the future. This is achievable by incorporating stakeholders in planning, development and at implementation stages.

Emphasis on agro-forestry in the catchment be encouraged and supported by the government agencies and non-governmental organizations (NGOs).

Need to educate and train the communities, encourage them on Soil Conservation Practices and good farm management in the catchment and expose them to areas that have succeeded in conservation practices like Mount Kenya region specifically Kirinyaga County, upper areas of Embu County and Chuka in Meru County.

Apply integrated water catchment management approach in planning and protection.

Cultural constraints can be addressed through policy intervention and programmes.

Emphasis on appropriate agricultural method practices by deploying more agricultural extension officers to the catchment and;

Enforcement of laws laid down for protection of natural resources.

Avoid pollution of rivers by oil spills and excess fertilization of farms.

Discourage encroachment of riparian area and the wetland.

Need regular maintenances of roads, improve drainage by constructing drainage ways in the lower catchment and rehabilitation of open quarries in the catchment.

Water Dam and Reservoir Construction for Small Holder Irrigation Project and generation of electricity would reduce flooding effects (regulation of water), provide treated domestic water and empower the communities relying on the river water.

Planning should be extended to those areas that are not highly potential.

Monitoring and Evaluation of Land use in the catchment.

5.3.2 Areas for further research

There is need to carry out a biophysical, soil hydrological properties and socio-economic survey for sustainable management of the catchment.

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APPENDIX: QUESTIONAIRE

Title: Assessment of land-use activities and their contribution to land degradation in Oroba Water Catchments in Western Kenya.

Preamble:

I am Peter Onyango Owenga a post-graduate masters student in School of Environmental Studies, Chepkoilel University College (A Constituent College of Moi University), conducting a research on land-use activities and their contribution to land degradation in Oroba Water Catchments in western Kenya.

Your contribution will be treated with confidentiality.

QUESTIONNAIRE

OROBA WATER CATCHMENT

(A) IDENTIFICATION OF RESPONDENTS

Respondent name ……. (optional)

Date……..

GPS readings …….. UTM ……. Elevation……..

District: Nandi South (1) Nyando (2)

Zone……..Upper (1) Middle (2) Lower (3)

(B) DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

1) Male(1) Female (2)
2) Age: 20-30 (1) 30-40 (2) 40-50 (3) >50 (4)
3) Education level? None (1) Primary (2) Secondary (3) College (4)

4) What is the size of your family? <5 (1) 5-10 (2) >10 (3)
5) Occupation: Farmer (1) Businessman (2) Employed (3) Self employed (4)
6) What was the land use when you first settled here? (1) Forest (2) Crop (3) Pasture
7) What is the acreage of your farm? <1ha (1) 1-2ha (2) >3ha
8) Is your land: private (1) communal (2) hired (3) public (4)
9) How long have you lived in the area? <10yrs(1) 10-20yrs (2) 20-30 30-40 (3) >50 (4)
10) What crops do you grow? Cereals and legumes (1) Legumes and Tea (2) Cereals+Legumes+Tea (3) Cereals+Legumes+coffee (4) sugarcane (5) sugarcane+cereals+legumes
11) Have you been taught on how to manage your farm? Yes (1) No (2)
12) How much do you produce in your farm (maize yield in bags) is it? High> 20 (1) Moderate 10-20 (2) Low (3) 0-10
13) How do you compare past yield with the present years? (1) Low (2) Moderate (3) High
14) Have you tested your soil for fertility? Yes (1) No (2) Reason ……
15) Do you practice crop rotation? Yes (1) No (2). If Yes. Reason ……
16) Do you apply fertilizer (inorganic)Yes (1) No (2)
17) According to you is fertilizer expensive? Yes (1) No (2)
18) Do you apply pesticides/insecticide/fungicide? Yes (1) No (2)
19) If you don't apply fertilizer how will your yield behave High (1) moderate (2) low (3)
20) What are possible reasons why yield is low? used for a long time (1) lack of fertilizer (2)

21) Do you have any other source of income (off-farm)? Yes (1) No (2)

22) How do you rate your farm soil fertility status? Very good (1) Good (2) Average (3) poor (4) Very poor (5)

23) How do you rate the population growth in this area? Low (1) Moderate (2) High (3)

24) Do you own a rental house? Yes (1) No (2)

25) Is it paying more than farming? Yes (1) No (2)

26) Generally you make how much Kshs. per day? <100 (1)100-200 (2) 200-300 (3) >300(4)

27) Do you keep livestock Yes (1) No (2)

28) How many cattle do you keep? <3 (1) 3-6 (2) 6-10 (3) >10 (4)

How do they graze? Zero grazing (1) Open grazing (2)

(C) LAND USE ACTIVITIES

29) What are the land-use activities on your land currently? Deforestation (1) Agriculture (2) Urbanization (3) Grazing (4) Settlement (5) Infrastructure land (6)charcoal burning (7)

Activities	Deforestation	Agriculture	Urbanization	Charcoal burning	Grazing	Settlement	Infrastructure

Rank from most to lowest (1-5)							

(D) CONTRIBUTION TO LAND DEGRADATION

30) Which land use activity has led to degradation? Grazing (1)Urbanization (2) Settlement (3) Charcoal Burning (4) Infrastructure (5) Deforestation (6) Agriculture (7)

Land use activities	Agriculture	Urbanization	Grazing	Settlement	Deforestation	Charcoal burning	Infrastructure
Rank from most to lowest (1-7)							

(E) EFFECTS OF LAND DEGRADATION

31) How is water quality? Poor (1) Good (2) Very good (3)

32) Is there observed reduction in water volume in rivers? Yes (1) No (2)

33) Siltation observed? Yes (1) No (2)

34) Are there frequent floods? Yes (1) No (2)

35) Crop yield? Low (1) Moderate (2) High (3)

36) How do you compare the vegetative cover (forest) density with the past? Low (1) Moderate (2) High (3)

37) Are you aware of government policy on environment, water, forest, Agriculture Yes (1) No (2)

38) How is the rainfall distribution over the last thirty years? High (1) Moderate (2) Low (3)

39) Give reason on the above answer? ……

40) Are you visited by Agricultural extension officers? Yes (1) No (2)

41) Have you experienced or observed soil erosion in the area? Yes (1) No (2)

42) How do you rate the soil erosion in your farm in the area? None(1) less severe (2) Severe (3) Very severe (4)

(F) LAND USE PLANNING APPROACHES

43) Do you practice soil conservation measures on the land? Yes (1) No (2)

44) Is there good farming husbandry? Yes (1) No (2)

45) Explain your comment? .....

46) Are you aware of tree planting policy? Yes (1) No (2)

47) Do you have a woodlot in your farm? Yes (1) No (2)

48) Are you aware of agro-forestry? Yes (1) No (2)

49) Do you encourage agro-forestry? Yes (1) No (2)

50) What is your source of energy? Fuelwood+Kerosin (1) Fuelwood +kerosin+Electricity (2)

51) Where do you get your timber material? Forest (1) Farm (2) Neighbour (3)

52) What is your main source of water? Spring (1) River (2) Piped water (3) Borehole (4)

Activities	Spring	River	Piped water	Borehole
Rank as per the reliability (1-4)				

53) What is the quality of water compared to previous years? Very good (1) Good (2) Average (3) Poor (4)

54) Do you have organisms such as frog? Fish and others in the rivers nearby? Yes (1) No (2)

55) What is their population compared to the past High (1) Medium (2) Low (3)

56) Give your own opinion on how to manage land degradation……..

57) Whom do you think should undertake the above task (Q56)? ……. ……