ASSESSMENT OF LAND DEGRADATION IN THE RIVER LOBOI WATERSHED OF BARINGO COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been submitted to any other University for the award of any other degree.

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Recommendation

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DEDICATION

This work is dedicated to my husband Robert Bosire, my children Churchill Bosire and Sharon Nyaboke and my parents Christopher Gwako and Peris Gwako.

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ABSTRACT

Increased human population pressure and climate change constitute the global underlying root causes of accelerated and devastating land degradation processes in the Arid and Semi-Arid Lands (ASALs). River Loboi watershed, located at the lower part of the Lake Baringo Catchment, is not an exception. The area is characterized by severe soil degradation that has resulted in excessive vegetation deterioration. This study set to assess the land degradation menace in the river Loboi watershed with specific objectives of determining the vegetation cover and composition, investigating the physiochemical condition of the soil as well as assessing the socio-economic status of the inhabitants. The study undertook a socio-ecological cross-sectional survey of some selected biophysical and socio-economic indicators of land degradation. Tools for data collection included structured questionnaire, observation schedules, laboratory analysis and oral histories. The measured variables were analysed using frequencies, crosstabulations, one-way ANOVA and correlation analysis. Except for correlation analysis, all the analyses were done at α =0.05 level of significance. The results indicated that the whole watershed is has undergone both soil and vegetation degradation. The locals are not able to curb this problem primarily due to lack of appropriate knowledge and financial constrains. The vegetation cover is 59.6% and the watershed has transformed from the typical 'savannah' onto a shrubland. This vegetation change has negatively impacted on the soil condition and as a result signs of massive gully erosion are enormous. In addition, the soils are of low fertility. In general, 87.5% of the watershed is highly degraded with the remaining 12.5% moderately degraded. The middle section (Simotwe location) is the most affected part ('hotspot') in the watershed. It recorded the least soil organic matter level of 1.3% and least vegetation cover of 51.4%. These results demonstrate the urgency of developing and establishing more effective and scientific ways to curb and monitor land degradation processes in the watershed.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASAL	Arid and Semi-Arid Land
FAO	Food and Agricultural Organization
GIS	Geographical Information System
GPS	Global Positioning System
GoK	Government of Kenya
IPPC	Intergovernmental Panel on Climate Change
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
KARI	Kenya Agricultural Research Institute
KIHBS	Kenya Integrated Household Budget Survey
KNBS	Kenya National Bureau of Statistics
MDG	Millennium Development Goals
SOM	Soil Organic Matter
SPSS	Statistical Package for the Social Sciences
SWC	Soil and Water Conservation
USLE	Universal Soil Erosion Equation
UNEP	United Nations Environment Programme
VEC	Village Environmental Committee
WWF	World Wide Fund for Nature
WRI	World Resource Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

The Arid and Semi-Arid Lands (ASALs) are characterised by harsh climatic conditions and are ecologically sensitive environments (Akuja *et al.*, 2005 and Njoka *et al*., 2005). In Africa they are characterised by unpredictable rainfall and long periods of drought; limited water resource and inadequate knowledge and technology of water resource management. These regions are experiencing rapid population growth coupled with low or declining real incomes and low nutritional levels; serious environmental degradation and the externalities of modernization and economic development (Darkoh, 1996).

In Kenya, Arid and Semi-Arid land covers 80% of the country (Sutherland *et al*., 1990). The current rapid increase in population and the associated demand for land in the high potential areas, has led to migration of people to the ASALs (Johansson and Svensson, 2002 and Njoka *et al*., 2005). This has resulted in severe land degradation (Johansson and Svensson, 2002 and Akuja *et al*., 2005). According to Williams and Balling (1996) land degradation is the reduction of biological productivity of ASAL ecosystems, including rangeland pastures and rainfed and irrigated croplands, as a result of acceleration of certain natural, physical, chemical and hydrological processes. These processes may include erosion and deposition (by wind and water), salt accumulation in soils, ground water or surface run-off, a reduction in the amount of natural vegetation and a decline in the ability of soils to transmit and store water for plant growth. It basically involves deterioration in soil, water and vegetation resources (Chuchu, 2008).

The River Loboi watershed is undergoing land degradation through accelerated soil erosion and vegetation loss. The main causes of land degradation in the watershed are overgrazing, poor watershed management, poor farming practices and indiscriminate cutting of trees for fuel (GoK, 2002). The degradation has resulted in off-site effects like sediment accumulation in Lake Bogoria and Kiborgoch swamp. For instance, the Kiborgoch swamp, formerly known as the greater Loboi swamp, is said to be more than twice the present size and free from trees a few years ago. In addition, it has transformed from an expanse of tall cattail, *Typha domingesis* to a complex mosaic riddled with different species of Acacia trees. The consequences of such changes include loss of organic matter, erosion, loss of biodiversity and habitat changes for many plant and animal species.

Land degradation particularly soil deterioration and vegetation cover loss negatively impact on the watershed hydrology dynamics (ICRISAT, 1989 and Rose, 1990). It exposes the soils to agents of erosion and during rainfall, there is increased surface runoff (FAO, 1986; Gachene, 1995 and Johansson and Svensson, 2002). Consequently, underground water balance changes as a result of reduced rainwater infiltration (Jones, 1997 and Rose, 1990). These leads to shortage of water supply as springs and rivers have their duration of flow reduced drastically (FAO, 1986). The effects of land degradation are immense and with the fact that the ASALs are now the only areas still available for agricultural expansion, there is need for improved management of the ASALs (Johansson and Svenssson, 2002 and Njoka *et al.*, 2005). For instance, integrating watershed management concept onto soil and water conservation meseasures will results in increased annual yield of usable water for downstream users and reduced run-off volumes and peak discharges for moderating floods hence promoting environmental conservation (FAO, 1986 and ICRIAST, 1989).

A clear understanding of the status of biophysical degradation and the socio-economic condition of the locals is important for sound intervention in mitigating land degradation. The purpose of this research study was to assess the ground surface characteristics (especially the vegetation and soil resources) as well as the socio-economic factors so as to be able to establish the nature of the problem of land degradation in the watershed. The findings of the study will now be used as the basis of planning and designing of effective control, rehabilitation and preventive measures to combat the land degradation problem in the watershed. The common degradation effects in the area especially siltation and flooding experienced downstream will then be minimised. The findings can also be used to identify the areas most affected by land degradation ('hotspots') as well as provide a basis for monitoring the progress of rehabilitation efforts.

1.2 Statement of the Problem

As is the case in most parts of Africa, land degradation assessments in the Baringo County have basically embarked on the estimation of the rate of soil erosion (Johansson and Svensson, 2002 and Warren, 2002). Onyando *et al.*, 2005, estimated the potential soil erosion from River Pekerra catchment using the Universal Soil Loss Equation (USLE). Using a socio-economic approach, Johansson and Svensson, (2002) did a pilot study on the physical causes of land degradation in the semi-arid catchments of Lake Baringo. Chebet, (2002) also carried out a socio-economic survey on the utilization of lake Bogoria wetland ecosystem. These constitute some of the many studies whose interest revolve around the conservation of Lake Baringo and Lake Bogoria. Most of these studies are socio-economic in nature and/or lack a scientific integrated approach. In addition the spatial scale of some of the assessments is too large to effectively capture the local phenomena. Based on this, failure of past rehabilitation and restoration programmes in the area can be attributed to lack of consistent, site specific baseline information on land degradation which constrains effective designing of control measures; the identification of priority areas and monitoring of the consequences of rehabilitation actions (Campell *et al*., 2003 and Adeel *et al*., 2005). As a result Baringo County remains to be one of the highly degraded regions in Kenya. This continued land degradation has resulted to severe loss of arable land for rainfed crop production and extreme forage shortage for livestock production hence exacerbating food insecurity in the County. River Loboi watershed is one of the most affected areas in the County.

1.3 Objectives

1.3.1 General Objective

This study was to generate ground-based biophysical baseline information that can be used as a basis for making recommendations for sustainable land degradation control practices in the river Loboi watershed of Baringo County, Kenya.

1.3.2 Specific Objectives

i. To assess the socio-economic condition (especially aspects on education, access to social amenities and income level) of the inhabitants of river Loboi watershed.
ii. To assess the vegetation resource deterioration (cover, species composition and alterations) in the river Loboi watershed.

iii. To assess selected soil physiochemical characteristics (visible erosion, macro elements, organic matter and pH) in the river Loboi watershed.

1.4 Research Questions

i. What is the educational level and occupation of household heads; housing and sanitation facilities; average number of livestock and acreage holding per household in the river Loboi watershed?

ii. What is the vegetation cover, dominant type/plant species in the river Loboi watershed?

iii. What is the level of soil pH, organic matter and major macro-elements and which is most prominent erosion type (by water) in the river Loboi watershed?

1.5 Justification

With increasing human population and limited arable land, the ASALs remain the only areas still available for agricultural expansion (Johansson and Svenssson, 2002 and Njoka *et al.*, 2005). Therefore, the problem of land degradation in the ASALs requires urgent consideration. In spite of some studies and many projects that have been funded for purposes of combating land degradation in the Baringo County, it remains to be one of the highly degraded regions in Kenya. In attempting to curb land degradation, understanding its current status of is very important (Taddese, 2001 and Charbrillant *et al.*, 2002). Information on the current situation of land degradation problem assists in the designing and planning of appropriate control measures as well as identifying priority areas for intervention. This study was therefore intended to generate such information. The study findings can be used by policy makers, the community in the watershed, individual farmers, researchers and extension staff to enhance adoption of appropriate land degradation control measures in the river Loboi watershed and other similar conditions in the county. It will also ensure that rehabilitation efforts are well focused. Successful amelioration of the situation will reduce the soil erosion menace in the watershed and increase land potentiality and this will translate to increased agricultural productivity as stipulated in vision 2030. This will also enhance the achievement of two Millennium Development Goals: extreme poverty and hunger eradication (no. 1) and that of environmental sustainability (no.7).

1.6 Scope of Study

This research study was carried out in the River Loboi watershed that stretches from Kibomui village in Kapkechui location down to Kiborgoch swamp in Koibos Location. The study assessed the nature and extent of land degradation in the seasonal stretch of the watershed, using selected biophysical indicators. Parameters for physical degradation were soil organic matter content, nutrient levels, soil pH and the visible erosion type. Vegetation cover and alteration of key/dominant plant species constituted the indicators for biological degradation. Being a ground-based assessment, the study involved field measurements and laboratory analysis of the mentioned indicators. This biophysical assessment was then complemented by a household socio-economic survey on the inhabitants within the watershed.

1.7 Limitations of Study

The line-intercept method of measuring vegetation (cover and composition) records only a small amount of vegetation along each line. For desired precision, it is required that a relatively large number of transects ought to be established in the study area. Only eight transects were located in the watershed. To minimize this limitation, the step-point method was used together with the line-intercept method. In general, the change from the initial Y-sampling technique for data collection to the line transects technique was be attributed to the financial constraints experienced during the study.

A reliable estimate of household income was difficult to obtain within the watershed due to principally to unwillingness of household heads to divulge all sources and levels of income. To overcome this limitation, housing type, level of education and livestock numbers and rearing system were used as a proxy to household socio-economic status.

1.8 Definition of Terms

Arid and Semi-Arid Lands (ASALs)/dryland: refers to the terrestrial regions where water scarcity limits the production of crops, forage, wood and other ecosystem provisioning services.

Assessment: refers to evaluation of a situation, event, phenomena or condition.

Cover: this is the proportion of the ground obscured by a species's above ground leaves and stems (and flowers).

Household: comprises of a person or group of persons who are generally bound together by ties or kinship or joint financial decision who live together under a single roof or compound and are answerable to one person as the head.

Land: is the solid surface of the globe that usually supports biological production.

Land Degradation: is lowering in quality or deteriorating in the condition of land.

Land use: refers to mans' activities on land.

Soil: is the loose material composed of weathered rock and other materials and also partly decayed organic matter that covers large part of land.

Watershed: refers to the whole water gathering ground of river system.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Drylands include all terrestrial regions where production of crops, forage, wood and other ecosystem services are limited by water. Formally, the definition encompasses all lands where the climate is classified as dry sub-humid, semiarid, arid or hyper-arid (Adeel *at el*, 2005). They comprise of 41.3% of the global terrestrial area and hosts 34.7% of the global human population. Despite the fact that these regions are fragile and highly susceptible to desertification, they provide key environmental services (table 1). Fluctuation in the supply of these ecosystem services is normal but a persistent reduction in the levels of all services over an extended period constitutes desertification. This poses one of the greatest challenges currently facing the inhabitants in the drylands. Their attempts to alleviate poverty while maintaining life support ecological systems are always in vain.

Table 1: Key dryland ecosystem services

Provisioning services	**Regulatory services**	**Cultural services**	**Supporting services**
Food, fibre, forage, fuelwood and biochemicals	Water purification & regulation	Recreation & tourism	Soil development
	Pollination & seed dispersal	Cultural identity & diversity	Primary productivity
Water	Climate regulation	Cultural landscape & heritage values	Nutrient cycling
		Indigenous knowledge system	
		Spiritual aesthetic & inspirational services	

Source: Adeel *et al*., (2005)

There are many people inhabiting upland watersheds in the ASALs, who find themselves in a dilemma. They need to produce food and harvest fuelwood to exist. Yet, their intensive use degrades the natural resource base because the soil and vegetation systems cannot support high levels of use (FAO, 1986 and ICRISAT, 1989). This threatens their long-term survival and that of future generations. At the same time, downstream dwellers do not escape the impacts of such degradation; wood for fuel, construction and other purposes becomes scarce, reservoirs fill with sediment, and landslides and floods cause increasing looses of life and property (FAO, 1986). One of the greatest challenge facing the Baringo County as a whole is environmental degradation in the form of deforestation, desertification, pollution and climate change (GoK, 2014). Studied indicate that environmental sustainability can never ever be achieved under such conditions (Warren, 2002 and Berry and Esikuri, 2005).

In general terms, land degradation covers the many ways in which the quality and productivity of land may diminish from the point of view of the land user (and of the society at large). It includes changes to soil quality and the many ways in which the overall integrity of land is challenged by inappropriate use (Sombroek *et al.*, 1993). A severe stage of this land degradation, in which disturbances have gone beyond the resilience of the land and have caused an irreversible loss of the land's carrying capacity or biological production potential, is termed as desertification (Kaufmann *et al*., 2002). This is common in the ASALs/drylands because they are extremely vulnerable to over-exploitation of natural resources and inappropriate land use practices (Kaufmann *et al*., 2002 and Shrestha *et al*., 2005).

The concept of land degradation has been the subject of concern due to climate change and the need for more agricultural land for food production for the increasing human population (Divon, 2000; Winslow *et al.,* 2004 and Njoka *et al*., 2005)**.** Sometimes it may be thought that land degradation is principally brought about by the changing climate (Ding and Dai, 1994). For instance, in Kenya, the effects of the worst drought that started in 1998 on the environment did not end with the start of rains but instead new issues of severe erosion and poor ground coverage arose due to reduced amount of seeds (UNEP, 2000). Investigations have found out that the primary cause of degradation is the ever-increasing human population (Ci and Liu, 2000). However, evidence for a direct link between increasing populations and degradation is ambiguous.

Land degradation problem is worse in the third world countries compared to the developed countries for the simple reason that the low- income societies cannot get access to advanced methods of curbing the problem (Warren, 2002). In Africa, it is worsened by firstly the incomplete or fragmented and lack of knowledge on the current land degradation status for most parts and secondly the fact that the spatial scale of some assessments is either too large to effectively capture local phenomena or too local to provides a regional or global perspective. Land degradation assessments in the ASALs rely on evaluation of national, regional, and continental soil surveys, on models of carrying capacity, on experimental plot studies, on expert opinion, and on nutrient balance models. While each of these methods is sound in its own right, the findings can not simply be scaled up or down in time and space (Warren, 2002 and Adeel *at el*, 2005). This makes it extremely difficult to design and implement mitigation, rehabilitation and prevention measures (Kaufmann *et al*., 2002; Winslow *et al.*, 2004 and Adeel *at el*., 2005). For the period 2002-2008, the WWF experienced this problem in their attempt to rehabilitate the River Loboi watershed. They were not able to identify specific priority areas for rehabilitation due to lack of basic biophysical baseline data.

2.2 Forms of Land Degradation

In the ASALs, multiple types of land degradation happen to accelerate desertification. The common types of land degradation include soil erosion (by water and wind), foliage/vegetation deterioration, salinization, soil crusting and compaction, reduction in organic matter and acidification.

2.2.1 Soil Degradation.

Soil erosion (by both water and wind), salinization, soil crusting and compaction and reduction in Soil Organic Matter (SOM) constitute the readily quantifiable indicators of soil degradation (Squires and Sidahmed, 1998). Soil erosion is an inevitable happening and at its natural rate, it is also a constructive process. It is the accelerated erosion that is destructive and of which is related to both biophysical and anthropogenic factors. Accelerated soil erosion is regarded as the complete form of land degradation because its effects affect soil properties and its life support processes particularly the plant community (Lal and Stewart, 1990). This depletes organic matter and clay fractions, decreases the soil’s water and nutrient intensity and capacity factors, reduces effective rooting depth and plant available water reservoirs, and exposes relatively infertile subsoil to the surface (WRI, 1992; Gachene, 1995; Pimental *et al.*, 1995 and Kaufmann *et al*., 2002). It also sets in motion other degradation processes such as leaching, acidification, compaction, hardsetting, laterization and biological degradation (Frye *et al.*, 1982; Lal and Stewart, 1990 and Hairston *et al.*, 1998).

These effects of water erosion are complex. Some of the impacts may appear to be reversible by suitable soil conservation programmes and improving cultivation practices, whereas there are other types of degradation, which are irreversible such as land lost by gulling, or cases of severe sheet erosion where the soil cover has been removed to great extent (Gachene, 1995 and Ballayan, 2000). Gachene, (1995) emphasizes that significant losses of SOM occur in runoff water. In all forms of agricultural systems, whether traditional or modern, SOM plays essential role in sustaining crop production and preventing land degradation (Ouedraogo, 2004).

Several studies have given credence to the role of SOM in improving soil physical, chemical and biological properties (Paul and Clark, 1996 and Fernandes *et al*., 1997). Because of its positive influence on several soil processes, crop productivity and environmental quality, SOM is often considered to be the single most important indicator of soil quality and sustainable land management (Roming *et al*., 1995 and Doran, 2002). Wild (2003), emphasizes on the benefits associated with SOM (table 2). Therefore, quantification of SOM is important for the adoption of environmentally sound and sustainable systems (Fasching, 2003). On the other hand, Sojka and Upchurch (1999) suggest a cautious approach towards the adoption of SOM as a more or less universal index of soil quality. According to Sojka and Upchurch (1999), even though there is evidence in many soils that an increase in SOM levels tends to improve the quality of the soil, there are many frequently negative environmental and crop production impacts, for instance an increased requirement of pesticide addition for efficacy, increased P solubility, etc. in soils with high SOM.

Table 2: Beneficial effects of SOM

Physical	• Increases aggregation of soil particles, which improves infiltration of water and reduces surface sealing and crusting. • Increases supply of water to crops. • Fine roots and root hairs can grow readily. • May increase drainage and hence early growth of crops. • Gives greater flexibility for timing of cultivation.
Chemical	• Releases Nitrogen, Phosphorous and Sulfur on mineralization. • Protects nutrient cations against loss by leaching. • Acts as a pH buffer. • Reduces the environmental hazard of some metals like Aluminium. • Adsorbs pesticides and other organic compounds.
Biological	• Soil fauna create channels that increase infiltration and drainage of water and through which roots can grow. • Fauna and microorganisms decompose leaf litter and other debris, an essential function in nutrient cycling. • Is a source of Rhizobium for legumes and of fungi that form mycorrhizas. • Supports fauna and microorganisms which may help to control pests that attack plant roots.

Source: Wild, 2003

The major variables affecting soil erosion by water include climate, soil, vegetation and topography. Of these, vegetation and to some extent soil may be controlled. The climatic factors and topographic factors except slope length are beyond the power of man to control (Lal and Greenland, 1977). Based on this, in any geographical region, erosion control may be achieved by manipulating vegetation and soil factors. For instance, practices that can lead to soil enhancement and rebuilding include stopping the overuses that lead to the destruction of vegetation; controlling overgrazing of animals since their trampling and eating diminishes the vegetative cover and enhancing rehabilitation techniques by propagation of native species (FAO, 1986).

ASALs being fragile ecosystems, they are highly vulnerable to disturbance in the form of soil erosion. Accompanying land uses tend to exacerbate the effects of soil erosion in these ecosystems (Akuja *et al*., 2005). In Kenya, especially the Baringo County, soil erosion by water remain one of the most important land problems over decades (Stockdale, 1937; Sutherland *et* *al.*, 1990, Thomas *et al.,* 1997; Johansson and Svensson, 2002 and Olekaikai, 2008). However, this problem has taken a new meaning with the considerable immigration of people into this ASAL area. There are constant water shortages and increased environmental deterioration/stress, which restricts productive agricultural production that constitutes the local people's primary livelihood (Sanyu, 2001 and Gok, 2014).

On the watershed context, soil erosion in the uplands of watersheds is considered as consequent to unscientific management of land that results in the reduction of retention capacity of catchments for rainwater, as well as siltation of reservoirs downstream. As a result, drought and flood have become unavoidable consequences arising out of disrupted natural resources equilibrium, the occurrence of which needs to be prevented for sustainable production (ICRISAT, 1989). Johansson and Svensson, (2002) have indicated that it is difficult to curb riverbank erosion in Baringo County because the problem is induced further up in the watersheds. This is affirmed during this study. The frequent floods in the lower sections (perennial stretch) of river Loboi watershed can be attributed to massive erosion upstream.

2.2.2 Vegetation Deterioration

Vegetation degradation's principal manifestations include reduced cover and alteration of key vegetation species (Uchida, 1995 and Chabrillat *et al*., 2002). Cover is the proportion of the ground that is occupied by vegetation. Plant cover is also called forage density. Vegetation cover may consist of one or more layers (for example, forbs, shrubs, bushes and trees). Basal/ground cover particularly grass cover plays a bigger role in reducing detachment of soil particles by rain drop impact (Pratty, 1963; Stoddart *et al*., 1975; Taddese, 2001; Liu *et al*. 2003 and Stohlgren, 2007). Vegetation cover is damaged by cultivation, drought, rodents, fire, wood harvesting for charcoal and timber (Stohlgren, 2007). Excessive removal of vegetation reduces the protective cover and results in increased raindrop impact and overland flow, reduced soil moisture, decreased infiltration rates as well as increased runoff and erosion. Therefore, removing the protective cover leads to overall lower site potential (Hansen, 1986). Maintaining vegetation cover is a key preventive measure against desertification. Properly maintained vegetation cover also prevents loss of ecosystem services during drought episodes (Johansson and Svensson, 2002 and Adeel *et al.,* 2005). Often, in the ASALs percent cover increases as the soil condition declines due to the replacement of tall, erect species with low-growing, spreading species (Stoddart *et al*., 1975).

Edaphic factors determine the type, abundance and distribution of plant communities of an area (Stoddart *et al.*, 1975). Local accounts indicate that in Baringo County as a whole, grasses were formerly higher and more abundant but have been severely affected by overgrazing, so that even seed sources are now deficient (Johansson and Svensson, 2002). As a result fencing to control grazing seems insufficient to significantly increase perennial grass cover, but when the grasses are seeded the results are impressive. In addition, the *Acacia species* and *Combretum species* were the dominant tree species in the area while the herbaceous vegetation, mainly grasses included *Panicum species* and *Hyparrhenia species*, in the high-rainfall areas, together with *Aristida species* and *Cenchrus species,* in the drier areas, in the 1970s (Stoddart *et al*., 1975). *Rhus species*, *Olea species*, *Combretum species, Terminalia species* and *Acacia species* were the dominant vegetation species in the 1990s. The dominance of the *Acacia species* for all these decades is attributed to ground water support (Bryan, 1994).

In many semi-arid areas, there is a progressive shift occurring from grassland to shrubland that exacerbates soil erosion (Adeel *et al*., 2005). The transition from land fully covered by grasses to one covered by scattered bushes creates greater bare soil surfaces, which encourages increased runoff velocity, resulting in higher soil erosion. On the other hand, the introduction of non-indigenous species is recognized as one of the primary factors in the erosion of biodiversity throughout the world (Liu *et al*. 2003).

2.3 Causes and Consequences of Land Degradation

In regard to the causes of land degradation, recent understandings acknowledge that while the root causes are highly complex and site specific, the causes fall into two broad categories; natural and human related factors. Natural hazards include land topography and climatic factors such as steep slopes, frequent floods, blowing of high velocity wind, rains of high intensity and drought. De-vegetation of fragile land, overgrazing and non-adoption of soil conservation management practices, over-pumping of ground water (in excess of capacity of recharge) are some of the factors which comes under human intervention resulting in land degradation (FAO, 1986 and Ballayan, 2000).

2.3.1 Human Related Factors

Land degradation due to natural causes is believed to occur at a rate that is in balance with the rate of natural rehabilitation. However, human related factors are responsible for the accelerated forms of land degradation (Stocking and Murnaghan, 2001). The most frequently recognized human causes of land degradation include overgrazing of rangelands, over cultivation of croplands, waterlogging and salinization of irrigated lands, deforestation, and pollution and industrial causes. These causes manifest in two main biophysical forms of degradation; physical loss of the resource as determined from various indicators and loss in productivity as determined from indicators of production constraints. Knowledge of land degradation reveals that the underlying human causes are firmly rooted in the socio-economic environment in which they operate. An understanding of these social dimensions and impacts, besides the physical factors, are necessary before any meaningful interventions are proposed or undertaken (FAO, 1986; Squires and Sidahmed, 1998; Winslow *et al.*, 2004 and Waswa, 2012).

2.3.1.1 Poverty

Poverty is both an indicator and cause of land degradation. Poverty usually drives those affected to rely more on the natural resources for survival. As they do so the focus is more on immediate needs rather than those whose benefits may materialize only in the long term (Cunnigham *et al.*, 2005). Secondly, lack of relevant resources reduces options available for application of proper conservation practices. The end result is inappropriate use of land and hence degradation (Warren, 2002 and Winslow *et al*., 2004). Land degradation stresses the livelihoods of more than 1 billion people in the developing countries who rely heavily on land-based natural resources for food, water and materials. Although the relationship between poverty and land degradation is complex, they are closely linked. Any attach on rural poverty must include a substantial component that addresses increased and sustained rural productivity based on sustainable land management (Berry and Esikuri, 2005).

Consequences and causes of degradation seem to occur in a vicious cycle: one being responsible for the other (Squires and Sidahmed, 1998 and Winslow *et al.*, 2004). The main causes of poverty in Baringo County include low yields from livestock produce and inadequate and unreliable rainfall leading to crop failure and drought (GoK, 2014). The main consequence of land degradation in the ASALs is desertification, which manifests itself in various biophysical and socio-economic conditions. Effects of land degradation are experienced by a wide array of people differently. They range from an individual farmer, whose farm is undergoing or has undergone degradation, neighbouring farmer down hill, organizations (e.g. those responsible for hydroelectric power generation or ports), to national governments in terms of incomes accrued or costs.

Land degradation related processes such as reduction of vegetation cover, for instance, increase the formation of aerosols and dust. These, in turn, affect cloud formation and rainfall patterns, the global carbon cycle, and animal biodiversity. For example, visibility in Beijing is often adversely affected by dust storms originating in the Gobi Desert in springtime. Large dust storms emanating from China affect the Korean peninsula and Japan and are observed to even have an impact on North American air quality. Biophysical effects of land degradation include soil degradation, reduction in available water including its quality, diminution of vegetation sources amongst others. These effects provide the best indicators of land degradation (Uchida, 1995).

2.4 Land Degradation Assessment.

Land degradation assessment is a complex process (Waswa, 2012). Land degradation can be examined by many ways: by biophysical scientists, by those who have to distribute funding for mitigation, by economists and political scientists and from the point of view of land users. Similarly, land degradation evaluations are infinitely variable and very dynamic. The dynamism and variability are due to the difficulties experienced in the establishment of biophysical change as well as the diverse methods available for assessment (Warren, 2002). The need to assess and measure land degradation has increased not only for the development of a more thorough scientific understanding of the driving forces and process dynamics, but also as an important requirement for the drafting of development plans and policy decisions for the sustained use of land resources (Kaufmann *et al.,* 2002). Careful assessments of the degradation indicators provides a convenient description of the current state or condition of a resource and hence facilitate effective, scientific planning and designing of intervention measures to curb land degradation.

In the drylands of Africa, land degradation assessment has concentrated on two facets; nutrients and erosion. For each there are pessimists and optimists. As to nutrients, the pessimists see a crisis (Breman *et al*., 2001). While to erosion they rely on what evidence there is of high rates of erosion (UNEP, 1997). Based on this, the Sahel has been dubbed a hot-spot for soil erosion. For optimist, they evade full assessment with two stratagems. One is to use increased production as an index of the absence of degradation or to take the land user's definition of degradation in preference to or as a check on that of the scientist. The commonly used methods of assessing land degradation are GPS surveying interpretation of high-resolution satellite imagery and aerial photograph. They give both the spatial and temporal variation, and at the same time facilitate the assessment of the causes of soil erosion that cannot be identified using USLE (Kahlown *at el.*, 2003). However, these methodologies have the primary limitation of measuring the detailed characteristics of the ground surface (Uchida, 1995; Adeel *et al*., 2005 and Wasonga *et al*., 2011).

As for the already easily available models for land degradation prediction especially USLE for soil erosion, it is often quite risky to rely on it as it is mostly designed for different agro-ecological conditions or a specific preset of preconditions (which often are not met in the ASAL areas) (Thomas *et al*., 2004 and Onyando *et al*., 2005). Land degradation can be evaluated also under field conditions by simple surveys and / or measurement tools (Morgan, 1986). Direct measurements and observation at individual sites are the most accurate methods of detection of land degradation (Torrion, 2002 and Waswa, 2012). For purposes of ensuring that the information collected during this field assessment is realistic, feasible and acceptable in the analysis of the problem, there is need for the incorporation of the socio-economic factors (Reining, 1978; Sheikh, 1986 and Stocking and Murnaghan, 2001). The socio-economic investigation of the locals is also important given that any action programmes always require support from and implementation by local community (Bielders *et al*., 2001).

A critical analysis of the relevant indicators of land degradation is vital in all assessments methodologies. The indicators are variables which may show that land degradation has taken place – they are not necessarily the actual degradation itself. Among the widely used indicators of land degradation are crop yields, soil quality indicators (visual, physical, chemical and biological) and vegetation (Tucker, 1979). The visual soil indicators include notable presence of soil erosion features (Chabrillant *et al*., 2002Waswa, 2012). Degradation indicators are meant to describe the extent and severity of the problem (Squires and Sidahmed, 1998). They are used to show the status of the problem at a given time, trend of the severity with time upon monitoring and this can lead to the prediction of the impacts of the problem. This prediction is particularly important for policy makers to appreciate the significance of the problem (Squires and Sidahmed, 1998 and Akuja, 2003). These indicators are dynamic, signalling and reflecting change in variable over a certain period of time. For example, changing tree or grass cover or grass species composition in a given area over a period of a decade may reflect or signal processes of resource degradation due to competing land uses such as pastoralism and rainfed or irrigated agriculture.

The quantitative indicators are easier to measure and aggregate while the qualitative indicators are often better and able to capture the complexity of changing situations. Sometimes the indicators may be considered `direct’ or `indirect’. There is a wide range in the degree to which variables signal a process of land degradation or indicate the effects of action taken to control land degradation more or less indirectly. For example, the appearance of gullies is a direct indicator of soil erosion, and hence land degradation. The decreasing price of charcoal may sometimes be a more indirect reflection of increasing land degradation: increasing rates of wood clearing for charcoal making puts downward pressure on the charcoal price (on the informal market, as charcoal making is illegal) (Squires and Sidahmed, 1998). No single indicator can be used to assess or study land degradation. This is because land degradation has many faces and hence can only be assessed and understood through a multidisciplinary study of the changing characteristics and integrated trends of a variety of biophysical and socio-economic indicators (Reining, 1978; FAO, 1986; Squires and Sidahmed, 1998 and Waswa, 2012).

Generally, the land degradation indicators can be categorized into; Physical indicators of which include decrease in soil organic matter, decrease in soil fertility, soil compaction, decline in quality and quantity of surface water and increased seasonality of springs and small streams. The other category are the biological indicators i.e. decreased vegetation cover, alteration of key species distribution and frequency and the socio-economic indicators i.e. change in land use, change in population parameters, migration and decrease in income (Reining, 1978; Barrow 1994 and Chabrillat *et al.,* 2002). Although all these indicators are useful in the assessment of land degradation, the use of degradation of soil conditions is more reliable as it is less reversible. This is based on the fact that soil formation is a slow process (Rozanor, 1990 and Sombroek *et al*., 1993). Soil condition is the degree to which a soil maintains the ability to accept, store and release water, nutrients and energy, to promote and sustain root growth, soil biological and chemical processes, resist erosion and compaction. SOM level is the primary indicator of soil condition (Fasching, 2003). Similarly, apart from agricultural land and man-made land use, vegetation coverage may indicate the magnitude of land degradation in the ASALs (Uchida, 1995). For instance, change in plant cover during the dry season is an important indicator of degradation given that plants that are indicators of increasing degradation are not necessarily the dominant species in the community (Reining, 1978). However, there are problems associated with these indicators. These are none or scattered baseline information available, interpretations of cause-effect often are anecdotic and not mathematically correlated (even if correlations are high, their interpretation may differ) and that of too many indicators are proposed hence the need for careful selection (Squires and Sidahmed, 1998).

2.5 Watershed Concept on Land Degradation Control.

A watershed is the drainage area for an entire water body system, including lakes, streams, wetlands, groundwater and the land (Davenport, 2003). A watershed encompasses not only the water resources, but also all the land that drains into the resource. Therefore, any watershed rehabilitation is land rehabilitation with soil conservation as its core (FAO, 1986). The usefulness of watersheds is based on the understanding that the quantity and quality at a point on a stream reflect the aggregate of the characteristics of the topographic-up-gradient from that point (Davenport, 2003).

Watershed management is, in the broader sense, an undertaking to maintain the equilibrium between elements of the natural ecosystem of vegetation, land and water on the one end and man's activities in utilizing the elements on the other hand (FAO, 1986). In India, Tejwani, (1986) defined it as a `rational utilization of the land and water resources for optimum and sustained production with minimum hazard to natural resources. It essentially relates to soil and water conservation in the watershed which means proper land use, protecting land against all forms of deterioration, building and maintaining soil fertility, conserving water for farm use, proper management of water for drainage, flood protection, sediment reduction and increasing productivity from all land uses'. This entails working with the people to solve their problems (Davenport, 2003 and Adeel *et al*., 2005).

The watershed management approach focuses on hydrologically defined management units-watersheds-rather than on areas defined by political or ecoregion boundaries which is key in attaining environmental sustainability. It is a process that provides a dynamic and flexible approach to meet changing goals and needs (Jones *et al*., 2002 and Davenport, 2003). Therefore, the goal of any watershed management is to ensure that water and related resources are managed on a sustainable basis to provide for the environmental, social and economic well being of the stakeholders (FAO, 1986 and Davenport, 2003). The watershed management approach can also be viewed as a unifying concept as is the case in South Asia (Winslow *et al*., 2004).

Natural resources like soil and water are best managed on a watershed basis (ICRISAT, 1889). Johansson and Svensson, 2002 indicated that the integration of watershed concept onto the soil and water conservation practices is vital in addressing the serious riverbank erosion in the Baringo County. It is tempting to begin by fixing visible downstream problems without knowing the cause of the problem. Much money has been wasted treating the lower part of a watershed without addressing the real cause of the problem (Johansson and Svensson, 2002).

2.6 Theoretical Framework of Land Degradation Assessment

All ecosystems are in continuous state of spatial-temporal change caused by natural as well as man made drivers. At interfaces of change, ecosystems are likely to experience stresses and this can reflect in form of land degradation. The stresses make ecosystems unhealthy, unstable and unsustainable. Distressed ecosystems are characterised by reduced productivity and biodiversity, lower decomposition and nutrient cycling and reduced aesthetic value. By identifying 'hotspot' areas within the ecosystem experiencing environmental stress and by identifying the causes of these stresses, recommendation for restoration and conservation can be made. To do this requires the adoption of a framework that integrates all factors. The DPSIR (Driving force- Pressure-State-Impact-Response) framework (figure 2.1) was proposed by the European Environmental Agency (EEA) as an integrated approach to environmental management (EEA, 2000 and FAO, 2011). Based on the framework, social and economic developments as well as the natural conditions exert pressure on the environment and as a consequence the state of the environment changes. This leads to impacts on human health, ecosystems and materials, which may elicit a societal or government response that feeds back to the other elements. Therefore the framework can help deliver an integrated assessment of land degradation (Waswa, 2012).

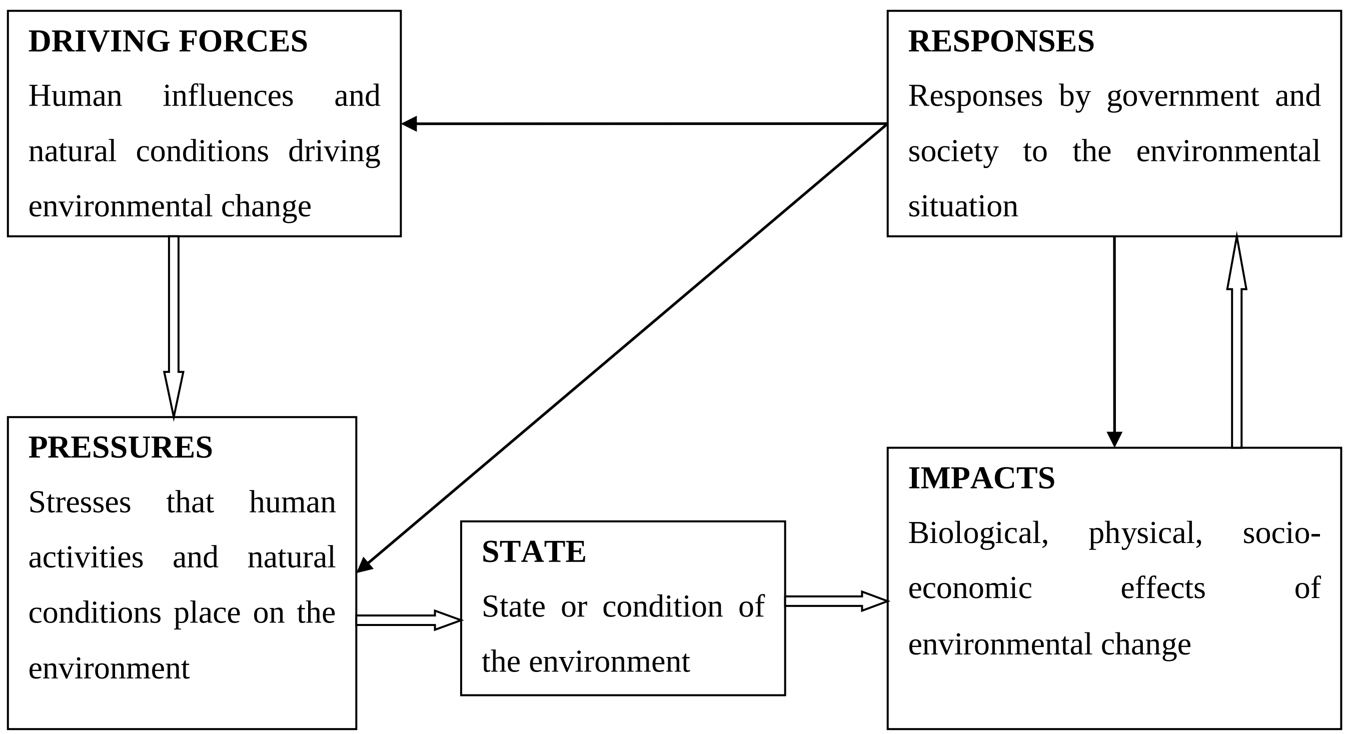

Figure 2.1: DPSIR Framework (adapted from Waswa, 2012)

2.7 Conceptual Framework

As indicated in the DPSIR framework, land degradation is complex and has many driving forces as well as symptoms, therefore, is no one single indicator or approach can be used to assess it. It can only be assessed through a multidisciplinary study of changing characteristics and integrated trends of a variety of biological, agricultural, physical and socio-economic indicators (Squires and Sidahmed, 1998 and Waswa, 2012). This study focused on parameters that could be assessed by ground methods and are considered as indicative, and or representative, of land degradation condition in the river Loboi watershed. The land degradation indicators constitute the independent variable in this study while the actual land degradation (problems/stresses associated with the relevant indicators) constituted the dependent variable.

The socio-economic indicators measure human development based on the basic factors of acquisition of knowledge and a reasonable living. These factors are measured by considering aspects such as education (level of education), access to social amenities (type of house, sanitation and access to clean water) and gross domestic product (main economic activity, land size and livestock numbers). In assessing soil chemical degradation, the variables considered were organic matter, soil pH and macro-element levels. Percent vegetation cover and reduction in or disappearance/alteration of key vegetation species were used in the assessment of vegetation degradation. All the measured variables and their relationships is as shown in figure 2.2. All the socio-economic indicators capture the Drivers, Pressures and Responses issues of the DPSIR framework, while the biophysical indicators involves the State and Impact components.

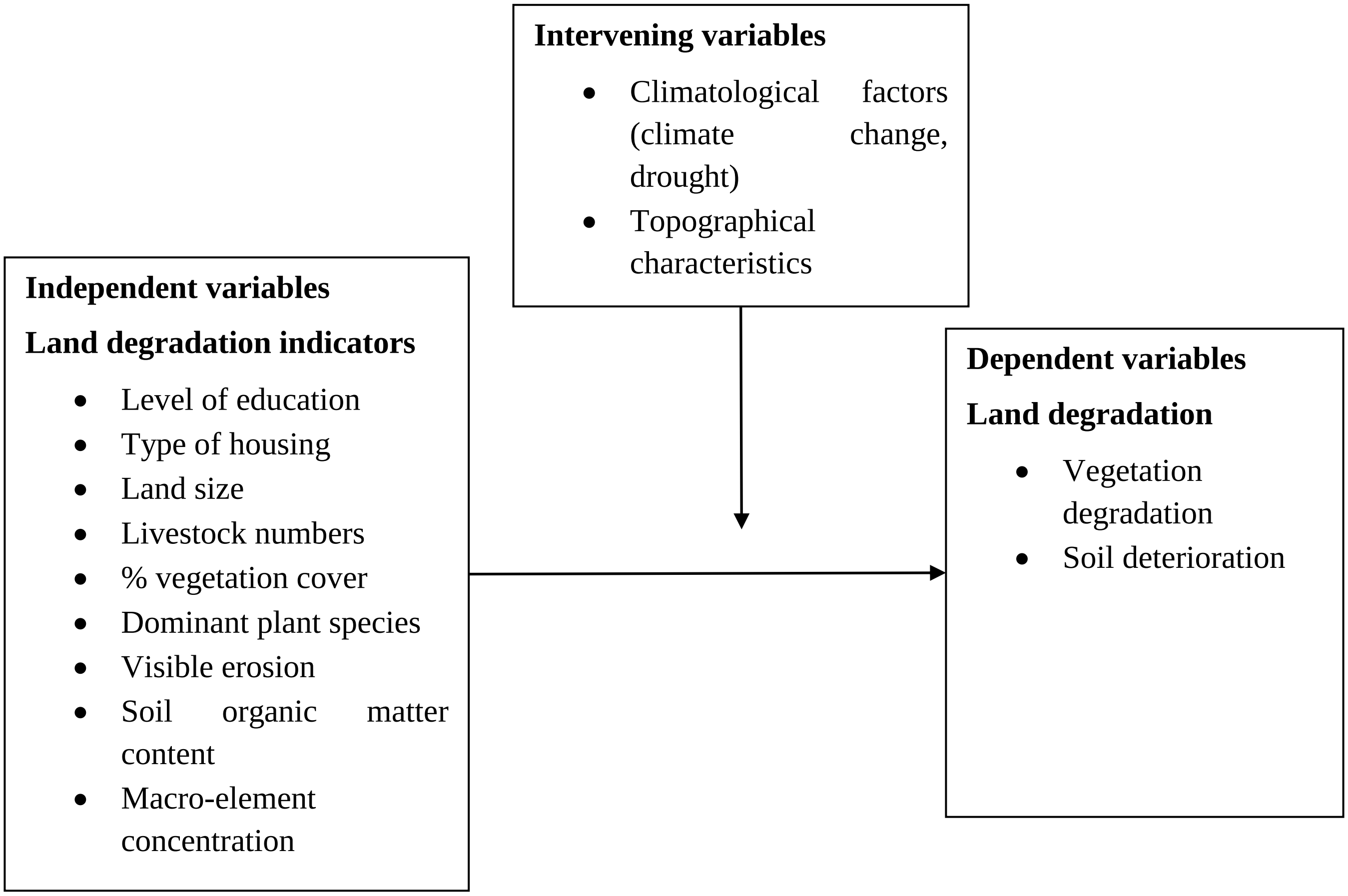

Figure 2.2: Land Degradation Assessment (modified from Chabrillant et al., 2002)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study Area

The research study was conducted in the upper, mid and lower sections of the River Loboi watershed of Baringo County, as shown in Figure 3.1 below. The study area constitutes the upper seasonal section of Majimoto River as commonly known by the locals. River Loboi originates at an elevation of 1850-1700m above sea level and descends in a northeastern direction terminating at the Loboi/Kiborgoch wetland with an elevation of 1411m above sea level. The river is located 0^0 $1^/$ N to 0^0 $8^/$ N and 36^0 $3^/$E to 36^0 $2^/$ E. The watershed covers an area of approximately 427.9 Km^2 but only 300 Km^2 was studied (seasonal section). The human population is 7,200 people (GoK, 2010).

The river Loboi watershed is a representative area of dryland in Kenya that is affected by land degradation processes caused by human activities and the vagaries of nature. The mean annual rainfall in the area ranges between 700-800mm per annum and an average temperature of 30^0C. The potential evaporation exceeds 2500mm per year (GoK, 2002). The amount and occurrence of wet season rainfalls are unreliable. The soils in the study area are described as soils of deep faulted floor of the rift valley developed on tertiary basic igneous rocks. They are well-drained, moderately deep dark reddish brown to reddish brown friable to firm and slightly smeary, boulderly and stony clay loam to clay, and in other places calcareous. When they occur in valley bottoms, they are imperfectly drained clay soils of varying calcareousness, salinity and sodicity, (Wahome, 1984). The fertility of the soil is described as moderate to high (GoK, 1994).

The vegetation in the watershed is predominately woody. *Acacia species* constitute the dominant woody species in the region over decades. Grasses are mainly found around the Loboi/Kiborgoch swamp. In the upstream there are patches of abandoned sisal fields. Where conditions allow, the rearing of indigenous livestock i.e. cattle, sheep and goats together with and subsistence cultivation, constitute peoples` way of life. Inadequate water supply and pasture has rendered cattle, sheep and goats rearing a difficult undertaking. Although, heavy losses of goats during the dry season are reported, they are more resilient than cattle and sheep. Poultry keeping is a new source of livelihood in the watershed.

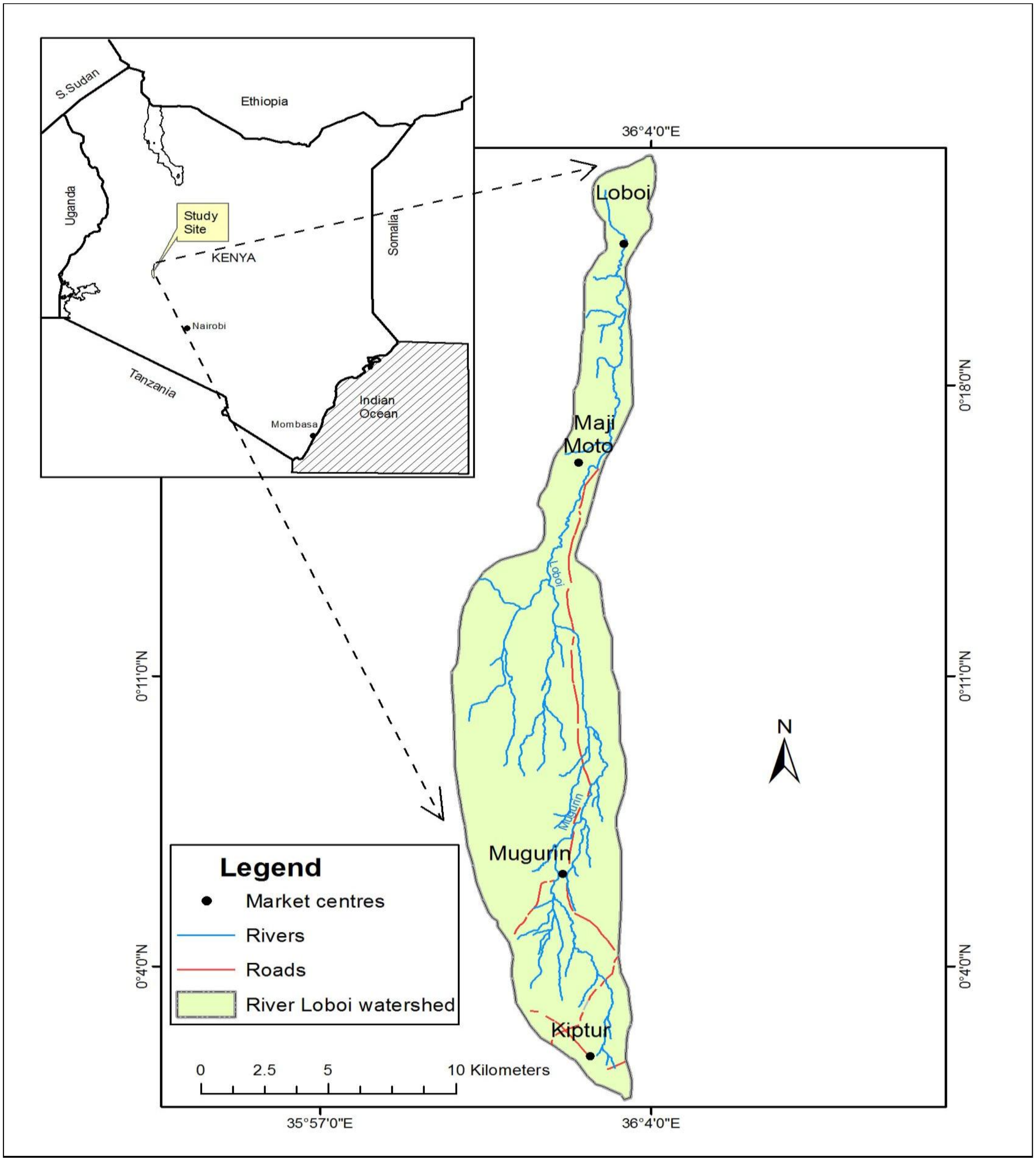

Figure 3.1: River Loboi Watershed

3.2 Research Design and sampling Design

In eliciting data, this study applied descriptive research design. The specific study method was a socio-ecological cross-sectional survey (Gupta, 2003 and Bluman, 2007). The assessment methodology was based on understanding the socio-economic condition of the inhabitants in the river Loboi watershed as well as gathering existing information and field surveys of existing natural resources of vegetation and soil.

3.2.1 Socio-economic status investigation

The socio-economic indicators were assessed using a semi-structured questionnaire (appendix 3). The sampling frame for this study was the total households in the watershed. The total number of households was 165. A stratified random sampling technique was employed to generate the sample. The strata were the administrative locations. Sample from each location was drawn using systematic random sampling. To determine the sample size, the following formula was used as adapted by Olekaikai, (2008).

$$n = NC^2/C^2 + (N-1)\,e^2$$

Where

n is the required sample size

N is the population size in study area

C is the coefficient of variation, ranging between 20% and 30%

e is the error margin (ranging between 0.02-0.05)

Therefore, $n = {165 \times 30\%^2}/{30\%^2} + (165-1)0.04^2$

$$= {165 \times 0.09}/{0.09 + 164 \times 0.0016}$$

$${14.85}/{0.3524}$$

$$n = 42$$

Therefore, a sample of 40 households was sufficient to be adopted by this study. Household heads were chosen as respondent based on the assumption that they had the historical and widest access to information regarding their homes especially land degradation.

Upon obtaining a numbered household list for each location and after selecting randomly the first household in each case (location), every fifth household was selected and included in the sample. 5, 18 and 17 households were selected from Kapkechui, Simotwe and Koibos locations respectively. Socio-economic status of the household was based on house type, the land size, livestock number and rearing system and household head educational level (Lyamchai, 1998 and KIHBS, 2006). These factors were assigned scores and computed to obtain low, medium and high socio-economic categories as shown in table 6. Tables 3 to 5 demonstrate how the various levels of the indicators were awarded marks. The scores were issued according to the perceived potential contribution of the level of the indicator to socio-economic status.

Table 3: Educational level and house type score levels

1). Educational level	**Score**	**2). House type**	**Score**
Tertiary	4	Semi permanent	3
Secondary	3	Mud walled with iron sheet roof	2
Primary	2	Mud walled with thatch roof	1
None	1		

As table 3 shows, the household head who has never been to school scored one point while the one who managed to go to tertiary education obtained 4 points. Similarly, household with a semi-permanent house were awarded three points while that with mud walled with thatch roof obtained one point. Table 4 below also displays how size of land as indicator of socio-economic status was also awarded scores. Respondent who had more than five acres of land obtained three points whereas the one with less than two acres of land scored one point.

Table 4: Land size score levels

Land Size	**Score**
5 acres and above	3
3-5 acres	2
Less 2 acres	1

Table 5: Livestock numbers and rearing system score levels

1). Rearing System	**Score**	**2). Number of Livestock**	**Score**
Zero grazing	4	More than 50	3
Paddocking	3	30-49	2
Free range	2	< 29	1
Other	1	nil	0

Table 5 above demonstrates how the two indicators of economic status (rearing system and number of livestock) were categorized and awarded scores. A household practising zero grazing attained three points while the one practising other method like tethering obtained one score. Likewise, a household head who has more than 50 animals (cattle, sheep and goats were considered) got three points while the one not rearing livestock scored zero.

Using the mentioned indicators, responses from the household survey were put together to arrive at the total score (index) for each household. The indices were put together into two classes; poor and high household socio-economic well being as shown in table 6.

Table 6: Categories of socio-economic status

Category	Score
Low	4 - 9
Medium	10 - 13
High	14 - 17

3.2.1.1. Validity and Reliability

The interview schedule was piloted in Lomolo area that is adjacent to Kibomui village of Kapkechui location. The area has similar climatic conditions with the study area. The pilot test made it possible to ascertain face validity for the instrument while content validity was ensured by comprehensive coverage of the study scope and objectives as well as revising the instrument (questionnaire) and its items (questions) as advised by the experts and supervisors. The testing established clarity of meaning and comprehensibility of the items. The pilot study also helped to gauge the time needed to administer one questionnaire and get the necessary information. After the pre-test, the instrument was improved accordingly.

3.2.2. Land degradation classification

Ground sampling locations were selected using stratified random sampling approach. The watershed was stratified into three blocks (10 km by 10 km) based on the topographical features. The first block constituted the headwater, the second at the midstream and the third at the lowland/tail waters. These strata almost matched onto the local administrative locations: - Kapkechui, Simotwe and Koibos locations respectfully. Within each block, transects (4km in length) were located. Four sample plots (30m by 30m) were systematically located along each transect. Mid-points of the plots were established where soil samples taken and vegetation measurements carried out. Observed type and signs of accelerated soil erosion as well as the dominant plant species within the plot were recorded. Additional information on plant diversity was obtained by interviewing the key informants, who included: village environmental committee members, community elders and chiefs. An index of the extent of land degradation was developed by the use of cover, dominant species and signs of accelerated soil erosion as shown in table 7. The chosen parameters are considered as indicative, and/or representative, of land degradation in Chabrillant *et al*., (2002). The vegetation cover classes adopted in this study are a modification of the commonly used Daubemires' classes while visible erosion classes were modified from Chabrillant *et al*., 2002 and Kakembo and Rowntree, 2002. Categorization of the dominant species/vegetation type was based on the perceived contribution to land degradation prevention as well as its palatability. In general, this approach took on from Chabrillant *et al*., (2002), Kahlown *et al*., (2003) and Stohlgren (2007). Other additional sources were Hansen, (1986) and Squires and Sidahmed, (1998).

Table 7: Land degradation classification parameters

Indicator	**Class 1 (low)**	**Class 2 (moderate)**	**Class 3 (high)**	**Class 4 (very high)**
Cover	> 70%	55-70%	45-55%	<45%
Visible erosion	None	Sheet	Rill	Gully
Dominant species	Graminiod	Herbaceous (indigenous) species	Shrubs and trees	Exotic/invader species

3.2.3 Vegetation measurement

Ground cover (cover below 15m) was measured using the step point method and the line-intercept method. Both methods involved the use of two ranging rods and stretching a tape measure straight across the centre of each plot. For the step point method, hit interval was 3m while the line intercept involved recording each plant species as well as the distance it occupies along the tape. Entries were made in the cover form (appendix 1). Then, the cover estimate was determined from the number of hits and distance intercepted. The choice of ground cover determination is based on the fact that forbs/herbaceous vegetation type play a very significant role in reducing detachment of soil particles by raindrop impact. Reduced basal cover makes land more susceptible to erosion by both water and wind. For species composition, plant species identification exercise was undertaken with assistance of a range ecologist. A total of 32 plots were sampled. Individual cover was used in the determination of dominant species as shown in table 8 below.

Table 8: Species abundance

Class	Cover
Dominant	>15%
Subdominant	6-14%
Minor	<5%

Source: modified from Stohlgren, 2007

3.2.4 Soil sampling, processing and analysis

Top soil (10-15cm depth) samples were collected at the centre of each plot and packed in a well labelled polythene bag for laboratory analysis. Soil sampling was done by use of a 50-mm auger and a total of 32 soil samples were collected. The samples were air-dried. The choice of air-dried sample was basically for handling convenience as well as to minimize variation due to soil moisture given the samples were from the semi-arid (dryland) environment. Out of the 32 samples collected only 30 samples were analysed at KARI National Plant Breeding Research Centre at Njoro using KARI standard methods. The samples were analyzed for pH, nutrient level and Organic carbon.

3.2.4.1 Soil pH Determination

Soil pH was determined on a 1:2 soil to water suspension ratio and read using a pH Meter (Hanna pH 211). This was done by placing 20g of air-dried soil into a 50ml beaker and adding 40ml of distilled water. The mixture was stirred for 10 minutes and allowed to stand for 30 minutes (Okalebo and Gathua, 2002). The resultant suspension was stirred for 2 minutes and the pH recorded using pH metre electrodes inserted into the suspension.

3.2.4.2 Organic Matter Determination

Organic carbon was analyzed on the UV/Visible spectrophotometer (Shimadzu UV 1700). Soil Organic Matter determination was done using Walkley Blaac Method as described in International Institute for Tropical Agriculture, IITA, (1979).

Each soil sample was sieved using 0.5mm sieve, weighed and placed in a 250ml Erlenmeyer flask. 20ml of 1.0N Potassium Dichromate ($K_2Cr_2O_7$) was added to the flask and mixed gently in order to disperse the soil in solution. 40ml of concentrated Sulphuric acid (H_2SO_4) was added to the suspension. The flask was swirled gently until the soil and reagents were mixed after which it was swirled vigorously for one minute. The flask was then allowed to stand on a sheet of asbestos for 30 minutes. 70ml of distilled water was added to the flask together with 3- 4 drops of ferroin indicator. This solution was titrated with 0.5 ferrous ammonium sulphate solution [Fe (NH_4) SO_4]. The end point was colour change from green to brown. A blank determination was prepared in the same manner. After which organic carbon computations followed using the formula:

$$\% \text{ Organic Carbon} = \frac{\text{Blank titre- Sample titre} \times \text{N of [Fe (}NH_4\text{) }SO_4\text{]} \times 0.003 \times f \times 100}{\text{Weight of air-dry soil used}}$$

Where:

f (correction factor) = 2

100% converts the ratio to percent

0.003 is derived from the fact that 1ml of 1.0N $K_2Cr_2O_7$ = 3.0mg of carbon.

Organic matter content is estimated from organic carbon on the assumption that organic matter of the average soil contains 58% carbon. Multiplying organic carbon in the soil by 1.724 gives an approximation of the organic matter content. Therefore,

% organic matter in the soil = % organic carbon × 1.724

3.2.4.3 Nutrient Levels

Macro elements (P, Na, K, Ca and Mg) were extracted using the Mehlich I method (Mehlich, 1953) and microelements (Cu, Zn, Mn and Fe) were extracted with 1% EDTA (ethylenediaminetetraacetic acid) solution. Sodium, K, Ca, Mg, Cu, Zn, Mn and Fe were analyzed on Atomic Absorption Spectrophotometer (Shimadzu, AAS 6300). Total Nitrogen was determined by micro-Kjeldahl digestion and analyzed on the Kjeltec Tecator 1002 distillation unit. Available Phosphorus was analyzed on the UV/Visible spectrophotometer (Shimadzu UV 1700).

3.3 Data Analysis

All data on household socio-economic characteristics and vegetation, statistical analyses were performed using Statistical Packages for Social Sciences (SPSS), version 16.0 for windows. Crosstabulations and frequencies were performed for characterization of the socio-economic condition of the inhabitants within the three locations in the watershed. To compare whether the variations in cover and species composition from the different study sites (plots/transects/locations) were significantly different, one-way Analyses of Variance (ANOVA) were performed. The mean number of species per plot was used as an index of species richness during the ANOVA (Lemenih, 2004). The Duncan Multiple Range Test (DMRT) was used for mean separation for the studied properties (cover and species composition).

Data normality was evaluated through test for skewness. No variables were found to be highly skewed, making it unnecessary to perform common logarithmic transformations before conducting Analysis of Variance. A 0.05 level of significance was maintained in all computations. Correlation analysis was performed to explore the relationship among different cover estimates under different vegetation types and sampling locations. Significant relationships were determined using Pearson-Product correlation coefficient. The data obtained from the soil laboratory analyses were subjected to one-way Analysis of Variance (ANOVA) for every sample from each plot. Determination of whether differences in the soil properties studied differed significantly between the three locations then followed. The Least significant difference (LSD) was used for mean separation for those properties that were found to be significantly different. The level of significance used was 0.05.

Table 9: Statistical analyses:

Study objective	Variable (s)	Type of statistical analysis	Specific statistical analysis
Assess the socio-economic status of the inhabitants	Educational level, house type, land size livestock numbers and rearing system	Descriptive statistics	Frequency/percentage Crosstabulation
Determine vegetation cover and composition	% cover and dominant species/type	Descriptive statistics Mean comparison Correlation analysis	Frequency/percentage Crosstabulation ANOVA (DMRT) Pearson product correlation coefficient
Assess selected soil chemical properties	Soil pH, OM and macro-element conc.	Mean comparison	ANOVA (LSD)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Household socio-economic status

4.1.1 Household general characteristics

Results on the general household characteristics are as illustrated in table 10. The results indicate that most (72.5%) of the household heads are married men with the remaining 27.5% being single/widowed women. In many African communities, men in the river Loboi watershed are believed to be the most influential people and decision makers at both village and household levels. This is unlikely in the female-headed households. Female-headed households have limited access to information on land degradation control and to land and other resources due to traditional barriers. Women are also more involved in many regular household activities than men (Lyamchai *et al.,* 1998).

Table 10: General household characteristics

Variable	**Description**	**Location**			**Total**
		Kapkechui	**Simotwe**	**Koibos**	
Sex (%)	Male	7.8	33.7	31.0	72.5
	Female	2.5	12.5	12.5	27.5
Age (%)	20-30yrs	2.5		2.6	5.1
	31-40yrs		15.4	15.4	30.8
	>40yrs	8.0	29.4	26.7	64.1

Source: Research data

The families are young and large; an average household consists of 7 persons. This figure is comparable with that of 8 persons per household in Aboud *et al*., (2002) in the county.

4.1.2 Household socio-economic characteristics

Results for socio-economic characteristics are as illustrated in table 11. The major livelihood activity is farming (70.8%). It was recorded that 90% of these farmers were agro-pastoralists while the remaining 10% engage in purely crop production. The 70.8% is less compared with the 91.9% recorded by KIHBS, (2006). The difference can be attributed to the fact that the forestry, agriculture and fishing constituted the main economic activity in the KIHBS, (2006) study while in this study only agriculture was considered. Business/trading is not an attractive adventure to most people in the watershed and this may be attributed to poor communication and infrastructure facilities in the region. The 2.9% and 3.5% figures for business income recorded by this study and KIHBS, (2006) respectively are comparable. Due to low education status, only 17% of the respondents engage in technical jobs. There is always a positive correlation between education and individual earnings. The better educated an individual, the more productive he/she is not only in the market but also in the household (GoK, 2014). Therefore, the relatively low educational status of the inhabitants in the watershed impede them from actively engaging in most economic activities. The results indicate that 47.5% of the household heads have primary school education, 12.5% attained secondary school education. The illiteracy level of the household heads in the watershed is however relatively low at 22.5%. This is comparable with the average illiteracy level of 28% in the Baringo County (GoK, 2014).

Educated household heads are expected to understand land degradation problem and its control. They are expected to access more information related to soil and water conservation (SWC) measures and easily adopt them. Simotwe location has relatively many household heads (35%) with formal education in the watershed compared to 7.5% and 17.5% for Kapkechui and Koibos locations respectively. The results of this study indicate that individuals in Simotwe location practice varying SWC measurers and this may be attributed to the fact that a relatively high proportion of household heads have formal education. Tenge *et al.*, (2004) too have indicated that the adoption of SWC technologies increased with higher level of education in the West Usambara highlands in Tanzania. Most respondents (97.5%) in the river Loboi watershed admitted that lack of knowledge was a constraint in their attempts to control land degradation in their farms. This study also established that 100% of the respondents who try to control soil erosion have not been trained by any individual or organisation an indication that they have limited knowledge to the modern SWC technologies. This probably explains why stone terraces constitute the most commonly practiced SWC measure in the whole watershed.

Table 11: Household socio-economic characteristics

Variable	Description	Location			Total
		Kapkechui	Simotwe	Koibos	
Occupation (%)	Farmer	12.3	43.2	15.3	70.8
	Watchman		2.9	5.9	8.8
	Business		2.9		2.9
	Welding		2.9		2.9
	Masonry		2.9	11.8	14.7
Education (%)	Secondary		10.0	2.5	12.5
	Primary	7.5	25.0	15.0	47.5
	None	2.5	7.5	12.5	22.5
	unknown		5.0	12.5	17.5
House type (%)	Semi-permanent	2.5		12.5	15.0
	Mud-walled with iron sheets	7.5	32.5	7.5	47.5
	Mud-walled with thatch roof		15.0	22.5	37.5
Rearing system (%)	Paddocking		2.8		2.8
	Free range	8.3	41.7	47.2	97.2
Livestock numbers (%)	>50	2.8	11.4	11.4	25.6
	30-49	2.6	10.2	18.0	30.8
	<29	4.8	19.2	11.9	35.9
	None		7.7		7.7
Land size (%)	3-5 acres	2.8	2.8	2.7	8.3
	>5 acres	8.6	40.1	43.0	91.7
SWC measures (%)	Stone terraces	8.1	34.9	13.4	56.4
	Contours		2.6	30.7	33.3
	Fanya juu	2.6	2.6		5.2
	Tree planting		5.1		5.1

Source: Research data

Most families (47.5%) in the river Loboi watershed live in mud-walled houses with iron sheet roofs. Similarly, a fairly large proportion (37.5%) of the households has one-room mud-walled houses with grass thatch roofs. The KIHBS, (2006) study indicated that many roofing were corrugated iron sheet at 60% and then grass-thatched roofing at 40% in Baringo County. This study affirms this as iron sheet roofing was recorded at 62.5% while grass-thatched roofing stood at 37.5%. Very few (5%) of these homesteads have pit latrines. Most (95%) homesteads use ‘bush’ as a means of disposing human waste. These figures contradict those recorded by GoK, 2014 for the county as a whole; households using bushes to relieve themselves constitute 49% while 46% use pit latrines in the county. The KIHBS (2006) consider the flush toilet and pit latrines as the adequate means of human waste disposal. Therefore, majority of the households in the watershed lack appropriate and adequate sanitation facilities. The poor sanitation poses healthy challenges to the locals as there are high chances of the human wastes contaminating the main water sources (dams, water pans and river) in the area.

Livestock (pastoralism) keeping constitute the major livelihood in the river Loboi watershed. Livestock are kept for subsistence and as a saving account. The farmer can sell his livestock at the local market whenever he is in need of urgent cash. The results of this study indicate that, on average, each household keep 33±2 animals. Most animal herds are dominated by goats. Although heavy losses of goats occur during the dry spells, they are considered more resilient than cattle and sheep. Free range rearing system is the most preferred. The fairly large land holdings per household promote the unrestricted animal movement over large areas in such of water and pasture. Over 90% of the households own more than five acres of land. The fact that most household heads (47.5%) have attained primary level education, alternative livelihoods pathways are limited to them. So they greatly depend on the natural resource base (land) hence degrading it. Many studies indicate that poverty leads to poor lifestyle and subsequent overexploitation or irresponsible uses of resources whose result is environmental degradation (Jamieson and Sylvan, 2001 and Cunnigham *et al.*, 2005).

Upon analysis of the wealth/asset factors, it was established that majority (50%) of the respondents belong to the middle socio-economic category while 20% are in the high category. The results also indicated that the socio-economic well being of the respondents in Simotwe location is far much better compared to that of the other two locations in the study area (figure 4.1). Based on results of this study, Simotwe seem to be more degraded compared to Kapkechui and Koibos locations. Studies indicate that well off households tend to cause more land degradation as they put much of their land into use (Bielders *et al.*, 2001; Holzel *et al.*, 2002; Warren, 2002 and Winslow *et al.*, 2004). Probably this may be happening in Simotwe location.

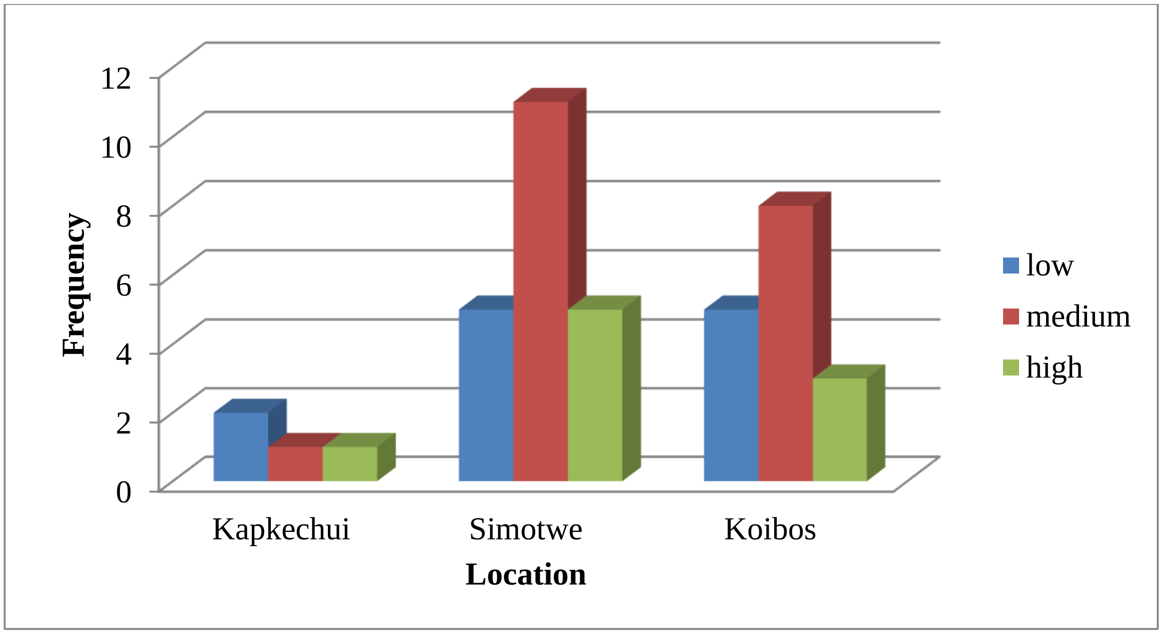

Figure 4.1: Socio-economic status of the inhabitants of river Loboi watershed

Although the results indicate that the inhabitants in the watershed are fairly well off property-wise, they have no/less economic capital available to them given that off-farm economic opportunities are minimal. This makes them insufficient in reacting to ecological challenges such as land degradation. Majority (75%) of the respondents indicated that lack of finances restricted their land degradation control efforts. Similarly, lack of appropriate tools and equipment for SWC practices as indicated by 97.5% of the respondents can be attributed to lack of finances. Warren, 2002 and Winslow *et al.*, 2004 reveal similar findings. In addition, as demonstrated in the next sections, the land resource is highly degraded making it difficult to efficiently support the people as well as their livestock. Therefore, the inhabitants continue to experience increased poverty levels. In 1997, the Welfare Monitoring Survey estimated that 35% of the population in Baringo County lived below the food poverty line (GoK, 2002). With the land degradation havoc, this figure may increase drastically.

4.2 Vegetation cover and composition in the river Loboi watershed

4.2.1 Vegetation cover

Table 12 displays the results on land cover within the river Loboi watershed. The current overall vegetation cover for river Loboi watershed is 59.6±2.3%. This proportion was higher compared to that of rock cover (22.5%) and bare ground (16.3%). Similar trend was observed within the three locations. The results also depicted a gradual increase in rock cover downstream; from 3.75% upstream to 40.8% downstream. Vegetation cover for Kapkechui location and Koibos location did not differ statistically. Similarly cover in Simotwe and Koibos locations were not significantly different. However, vegetation cover in the middle section of the river Loboi watershed is significantly different with that in the upper section of the watershed. Although it was difficult to establish the initial vegetation cover, what may be termed as the initial 'climax cover' in the watershed, the European literature described Baringo County as one of the most dependable sources of grain with water and grass available all year round (Sanyu, 2001). Implying cover was significantly sufficient in the early 1900's. However, initial actual cover estimates is lacking.

Table 12: Land cover in the river Loboi watershed

Location	**% bare**	**% rock**	**% vegetation cover**
Kapkechui	18.75	3.75	71.50**A**
Simotwe	21.85	15.97	51.41**B**
Koibos	9.17	40.83	59.80**AB**
Mean	**16.3**	**22.5**	**59.58**

Means followed by same letters are not significantly different from each other at α=0.05

Source: Research data

By analysis of satellite images, Johansson and Svensson in 2002 recorded a bush cover of 77% for the Semi-Arid catchment of Lake Baringo, of which river Loboi watershed is part. Bush cover consisted of everything between shrubland vegetation to very high evergreen bushes and cultivated fields. For this study, vegetation cover too constituted of both natural and crop vegetation. This implies that within a decade, vegetation cover has declined by 17.4% while bare ground has increased from 13% to 16.3%. The implication of this decline in cover is that the soil is not adequately protected from the raindrop impact of detachment, thereby resulting in increased soil erosion commonly observed in the area. The effectiveness of vegetation in preventing soil detachment by rainfall varies with the kind/type of vegetation; short vegetation especially grass is much more effective than taller vegetation (Stoddart *et al*., 1975; Taddese, 2001 and Gaoming *et al.*, 2005).

It was observed that most parts of the river can be easily accessed by livestock and locals for water and this has resulted in less cover (58.9%) near the river course although this was not significantly different with that further way (60.3%) at 5% level. It was also observed that there was no riparian cover along the Loboi river hence the river banks were prone to serious soil erosion (plate 1). Bossio and Geheb (2008) indicate that such riverbank erosion eats into productive land while increasing incidences of siltation and flooding downstream. During the rain season, flooding commonly occurs downstream especially at the Loboi bridge near Kiborgoch swamp where the river drains its water.

Plate 1: Riverbank erosion along the Loboi river (March, 2013)

Comparing the eastern and western sides of the river channel, the eastern is more degraded in terms of cover. The western side recorded cover of 64% while the eastern recorded 55.2% (table 13). The difference can be attributed to the settlement pattern. Due to topographical characteristics, there were more people settled on the eastern side compared to those on the west. Land on the eastern side is relatively flat with deep soils unlike the western side. This was observed during fieldwork.

Table 13: Cover on the either sides of the river Loboi

Plot ID		Cover	
1	East	54.51**A**	
	West	63.29**A**	
			58.90A
2	East	55.86**A**	
	West	64.66**A**	
			60.26A
Mean		**59.58**	

Means followed by same letters are not significantly different from each other at α=0.05

Source: Research data

Figure 4.2 illustrates the general trend for vegetation cover in the river Loboi watershed. The upper section (Kapkechu location) of the watershed recorded a highest cover of 71.5% (Metibelion/Kapkundul and Kibomui villages). This seemed sufficient in providing adequate protection to the soil in the area. There were few incidences of visible signs of accelerated soil erosion and of great environmental significance was the seasonal spring at Chepchukukto in Kibomui village (plate 2). People fetch water from the spring. Some distance from the spring, incidences of irrigated farming were observed (plate 3). This spring is almost 3Km from the main source of river Loboi, where the locals hold that there was once a spring. As is the case with most water sources (such as lakes Baringo, Bogoria and Nakuru) in the rift valley, the quantity of water in the spring has increased in the last three years. Stoddart *et al*. (1975) indicated that a >70% basal cover provides an adequate protection to the soil in the rangelands and forage for livestock production in East Africa. Based on field observations and cover results of Kapkechui location, this study affirms the figure for river Loboi watershed. Cover is a key factor in combating land degradation.

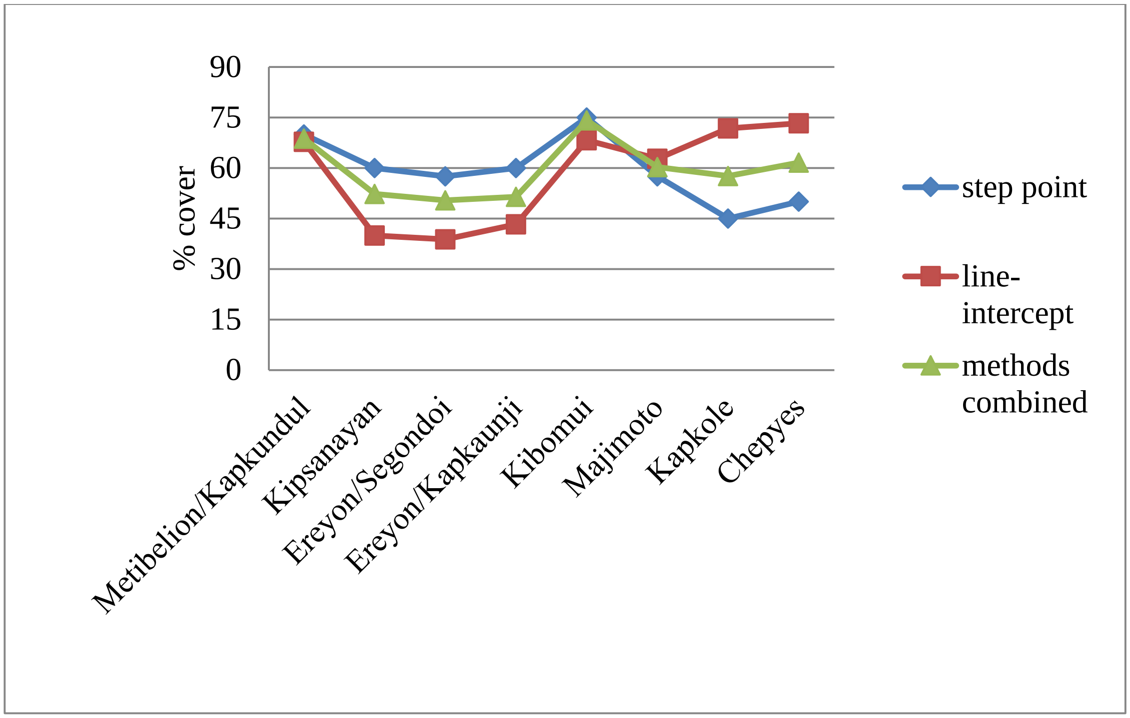

Figure 4.2: Cover along each transect/village

Plate 2: Seasonal spring at Chepchukukto in Kibomui village (March, 2013)

Plate 3: Irrigation farming near the seasonal spring at Chepchukukto (March, 2013)

The middle section (Simotwe location) of the watershed was found to be the most hit in terms of cover degradation. The location recorded the less cover of 51.4%. Transect 3 and 4 (Ereyon/segondoi and Kapkaunji villages) recorded the least covers (50.36% and 51.54% respectfully). The two transects constitute the priority areas (‘hotspot’) for future vegetation cover rehabilitation. However, the location recorded a higher basal cover compared to crown cover. Implying there was more herbaceous vegetation compared to trees. Stoddart *et al*., 1975 indicated that in the ASALs basal cover increases as the soil condition declines due to the replacement of tall, erect species with low-growing, spreading species. Cover in lower section of the watershed (Koibos location) was 59.8%. Koibos location is rocky and it was observed that the rocks were so large that at some points there was no vegetation at all. More crown cover was recorded in the location compared to the middle and upper sections. The high crown cover can be attributed to the many trees recorded in the location especially the *Acacia species.*

The main driving force for the observed and continued decline in cover in the watershed can be explained by continuous pressure from human disturbances for agricultural activities (crop and livestock production). As revealed by the socio-economic household survey, 100% of the respondents practised crop farming. Each household grew maize as the primary subsistence crop.

Sorghum, millet and beans are also grown for subsistence. Sisal is the only cash crop grown in the watershed (Kapkechui location), although in very small scale. It was observed that some farmers had abandoned their sisal farms. Crop farming contributes significantly to the seasonal cover dynamics of a region (Johansson and Svensson, 2002 and Stohlgren, 2007). Cover during rain season that corresponds with the cropping season is relatively higher compared that of dryspells when much of the crop farming have stopped and during land preparation when much of the land is looks bare (Johansson and Svensson, 2002). Based on this, the cover estimate (59.6%) is likely to reduce during the dry months of December to March.

Livestock production, particularly pastoralism, has for decades been recognized as a viable livelihood and land-use system within the ASALs. This study established that 10% of the respondents do not rear livestock. They purely engage in crop production. This may be the initial signals to the erosivity of pastoralism in the watershed. However, 90% of the respondents do keep livestock and practice subsistence crop production. The implication is, although a larger proportion of the inhabitants do keep livestock, land cultivation for crop production is taking root in the ASALs. Studies have shown that the action of animal hooves, especially the small cloven hooves of sheep and goats extremely damages vegetation cover (Taddese, 2001). Although this study never engaged in the scientific computations of right stocking rates for livestock production, from field observation of the available forage and responses on forage availability, this study reinforce the already known aspect of overgrazing as a contributing factor to reduced cover in Baringo County. Results of this study indicate that 100% of the agro-pastoralists experience forage shortage especially during the dry period (December and March).

The reduced cover in the watershed can also be attributed to wood harvesting for charcoal burning. The results of this study established that 87.5% of the respondents burn charcoal with 37.4% of them burning charcoal on a daily basis. This practice is dangerous to both vegetation cover and composition. The intensive charcoal burning in the watershed is due the high demand for the commodity in the market, especially Mogotio and Nakuru town. Due to the high demand for liquid capital by the locals, they are ignorant of the dangers associated with charcoal burning to the environment. Although most (87.5%) of the respondents practice charcoal burning, only 2.5% of the respondents agree that charcoal burning is harmful and is contributing to the observed land degradation in the watershed. This demonstrates that the focus of the locals is on their immediate needs rather than the long term benefits of environmental conservation. Cunnigham *et al*., (2005) too recognized similar observations. Low cover can too be explained by the poor soil condition in the watershed. Soil is a base to produce vegetation and its degradation corresponds to the restriction of vegetative activity (Uchida, 1995). Poor growth conditions inhibit or reduce proper plant growth and hence less cover (Pratty, 1993, Gachene, 1995 and Fasching, 2003). No vegetation no cover.

Many studies have shown that decline in cover leads to decline in both surface and ground water levels. Studies by Baldyga (2005) and Edebe and Kyalo (2009) indicated that cover degradation particularly through deforestation resulted in Njoro and Makalia rivers becoming seasonal in the watershed of Njoro river. Additional studies that affirm this cover-water relationship include Jones (1997), Squires and Ahmed (1998), Wild (2003), the Intergovernmental Panel on Climate Change (2007), Bossio and Geheb (2008) and Omweri *et al*. (2009). Based on this relationship, the resilience of the seasonal spring at Chepchukukto in Kibomui village as well as the durability of water in the sand dams along the river Loboi will, therefore, increase upon improved vegetation cover. The spring at Chepchukukto may with time become a first-order stream in the watershed.

4.2.2 Vegetation composition

The results of this study indicate that flora of the watershed contains 42 plant species belonging to 34 genera (appendix 2). In spite of the different methodologies used, this figure is comparable with a previous record of 157 plant species for the whole of Lake Bogoria Catchment Basin (WWF, 2002). As indicated in the previous section; vegetation cover has declined and this may be as a result of reduced number of plant species in the watershed. There is a possibility that some species have disappeared from the watershed due to the deteriorating soil condition. Some of these species include *Boscia anguistifolia* (Lito), *Acacia drepanolopium* (Ingowe), *Osyris compressa* (Marimarwe) and Lebche. This study also established that Lokuru, Siriande, Kikorwe and Sebeywe species have greatly reduced in the watershed. On average, 7±3 plant species were recorded per plot. This implies that the watershed ecosystem is less diverse and this may be contributing to its inefficiency in withstanding environmental stress and low productivity.

Species composition in the three locations was almost uniform. Kapkechui location recorded species richness of 10**A**, 9**A** for Simotwe and 9**A** for Koibos.

Plant communities differ from place to place due to edaphic factors such as slope, exposure and soils. Determining climax or normal vegetation in ASALs is difficult and almost impossible. However, studies indicate that the climax vegetation in the watershed was probably that of a tropical Savannah (Stoddart *et al.,* 1975 and Bryan, 1994). A typical savannah was characterized by grassland with an open stand of trees spaced approximately as far apart as their height (8-15m). The herbaceous vegetation, mainly grasses, provided a dense ground cover. This probably explained the availability of water and grass all year round as described in the European literature during the 19^{th} century (Sanyu, 2001). Results of this study demonstrate a shift from this 'Savannah' to shrubland and this can be attributed to the current poor soil condition.

Locals believe that the growth of different plant species that were not part of the initial 'climax' vegetation started in the 1970s. Studies have revealed that in 1970s, the *Acacia species* and *Combretum species* constituted the dominant indicator tree species while *Panicum species, Aristida species* and *Hyparrhenia species* were the dominant grasses in Baringo County. This study registered the presence of these species but established that except for the *Acacia species*, all the others no longer constitute the dominant vegetation. Their abundance/ occurrence has greatly reduced (table 14) to the point that some of these species were classified as minor in this study. As for the *Acacias species,* they are largely supported by ground water and have limited sensitivity to seasonal rainfall, which, however, dramatically affects ground/basal vegetation (Stoddart *et al.*, 1975 and Bryan, 1994).

Table 14: Vegetation type/species cover

Type/Species	Cover
Herbaceous (forbs & grasses)	37.4
Shrubs	15. 5
Trees	6.7
Acacia species	60.9
Aristida species	10.9
Combretum species	4.7
Hyparrhenia species	7.8
Panicum species	1.6

Source: Research data

Various explanations can be given for the observed plant species alterations. Historical information indicates that fire was used to enhance the palatable (decreaser) species. This practice might have tampered with the regeneration capacity of the native species through the destruction of seeds and seedlings. Lack of seeds hinders natural regeneration of native/indigenous vegetation (Islam, *et al*., 2001; WWF, 2002 and Kiptanui and Kyalo, 2009). Probably, the current charcoal burning activities may be worsening the situation. The dominance of *Dodonaea viscose* (appendix 2) in the watershed can be attributed to its great powers of withstanding fire as well as its ability to regenerate very freely, even in dry rocky localities (Dale and Greenway, 1961). Inhibiting regeneration of native species increases the chances of invasive species growing in the area. For instance, the dominance of *Lantana camara* cut across the three locations compared with some native flora such as *Rhus species*, *Croton dicogamus* and *Tarconanthus camphoratus* (figure 4.3). Similar observations hold in the perennial stretch of river Loboi watershed which is dominated by *Prosopis juliflora*.

Heavy grazing also contributes to vegetation composition deterioration (Snelder, 1994). This study affirms this notion. As shown in figure 4.3, the current dominant species in the watershed are all less palatable. The most palatable species have been grazed or/and browsed upon to the extent that their natural regeneration capacity has been exceeded. This is a clear indication that soon, pastroralism may no longer be a sustainable livelihood in the watershed and the rare most palatable species like *Cynodon dactylon* and *Balanites aegptiaca* may soon become extinct. The perception of the locals on overgrazing is however different. Like in the charcoal burning phenomenon, only 7.5% of the respondent admitted that overgrazing contributes to land degradation in the watershed.

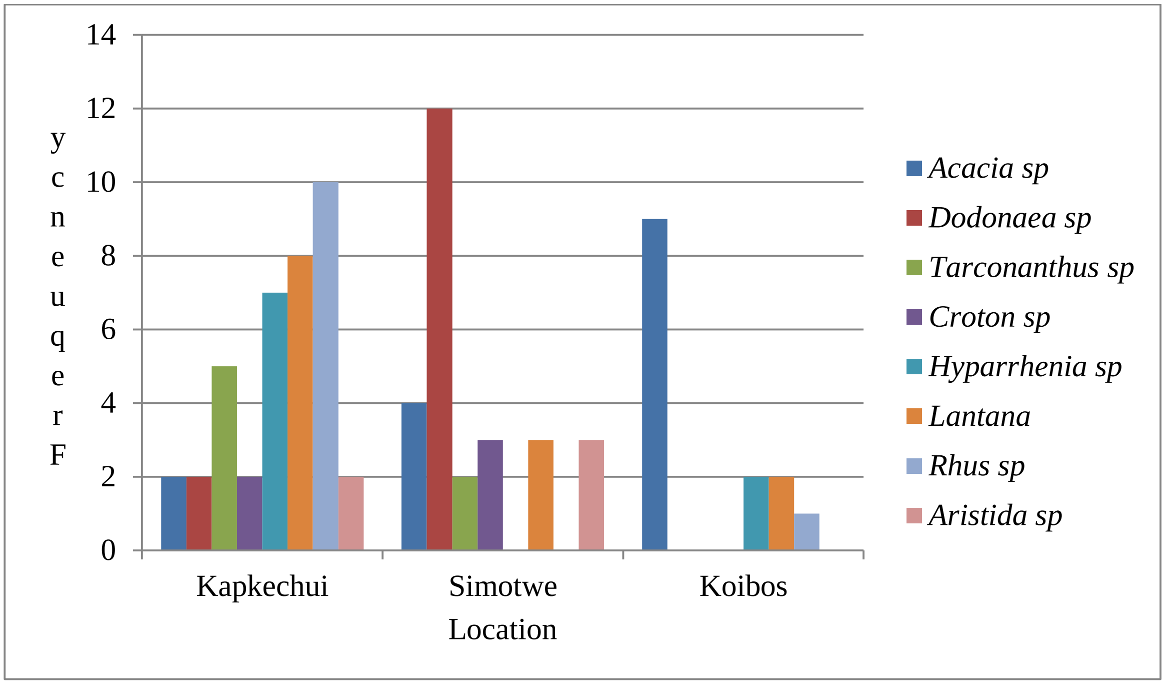

Figure 4.3: Dominant plant species in the river Loboi watershed

This study indicated that there is a strong positive correlation (r=0.87) between cover and vegetation type at 0.01 significant levels. This implies 76% of cover can be explained by the type of vegetation. The findings of this study indicate that the dominant vegetation type is shrubs. This is a shift from the initial herbaceous vegetation particularly the dense grasses. Studies have shown that shrubland in ASALs exacerbates soil erosion (Liu, *et al*., 2003 and Adeel, *et al*., 2005). This is based on the fact that they are not efficient in protecting the soil from the rain drop impact as compared to the herbaceous vegetation, especially grasses. The shrubs recorded are all less palatable and indicators of poor and rocky soil condition especially *Dodonaea viscosa* and *Tarchonanthus camphorates* (Dale and Greenway, 1961) (plate 4&5). The unpalatable shrub species have a wide resprouting capability and are highly adaptable in poor site conditions (Chandrsekaran and Swamy, 1995).

Plate 4: *Dodonaea viscosa* (March, 2013)

Plate 5: *Tarchonanthus camphoratus* (March, 2013)

Acacia mellifera was also considered as dominant with 20.3% cover. Although *Acacia mellifera* is considered a good forage tree, the locals believe that no grass grow underneath it. This was confirmed during field observations. However, the truth in this conviction is yet to be established. Table 15 displays vegetation species that were recorded as sub-dominant and minor in the watershed.

Table 15: Sub-dominant and minor species in the watershed

Sub-dominant species	Minor species
Barleria sp	*Lippia javanica*
Grewia sp	*Indigofera sp*
Acacia senegal	*Albizia sp*
Balanites aegyptiaca	*Combretum sp*
Cynodon dactylon	*Terminalia brownii*
Hyparrenia sp	*Euphorbia tirucalii*
Aristida sp	*Eragrositis superba*
Ipomoea sp	*Panicum sp*

Source: Research data

4.3 Land Degradation Characterization

4.3.1 Visible erosion

Results on the observable erosion in the watershed are as shown in table 16 and figure 4.4. Signs of erosion were recorded during vegetation sampling and household socio-economic survey. The results reveal that no portion of the watershed is free from erosion. Rill erosion is the most prominent type of water erosion in the watershed. The differences in the proportion of erosion recorded in the land cover form and that of the questionnaire can be attributed to the fact that farms/lands near homesteads are taken care of as compared to those further away. One expects to see no/less rills and gullies near homesteads and vice versa. As per the results there were less gullies (25%) observed near homesteads compared to those further in the fields (34.4%). Sheet erosion dominated in the farms (42.5%) while it was least observed in the fields (15.6%). Similar observations have been recorded by Mazzucato *et al*., (2001), Scoones (2001) and Tenge *et al.*, (2004).

Table 16: Visible erosion

Visible erosion	Cover form	Questionnaire
Sheet	15.6%	42.5%
Rill	50.0%	32.5%
Gully	34.4%	25.0%
None	0.0%	0.0%

Source: Research data

Results on the erosion trend in the three locations are as shown in figure 4.4. Sheet, gully and rill erosion were prominent in Kapkechui, Simotwe and Koibos location respectively. There were very few incidences of gully erosion in the upper section of the watershed and this is attributed to the fairly sufficient vegetation cover. Of the three locations, Kapkechui location recorded a slightly higher per cent of grass cover. It has been established that grass protects the soil efficiently.

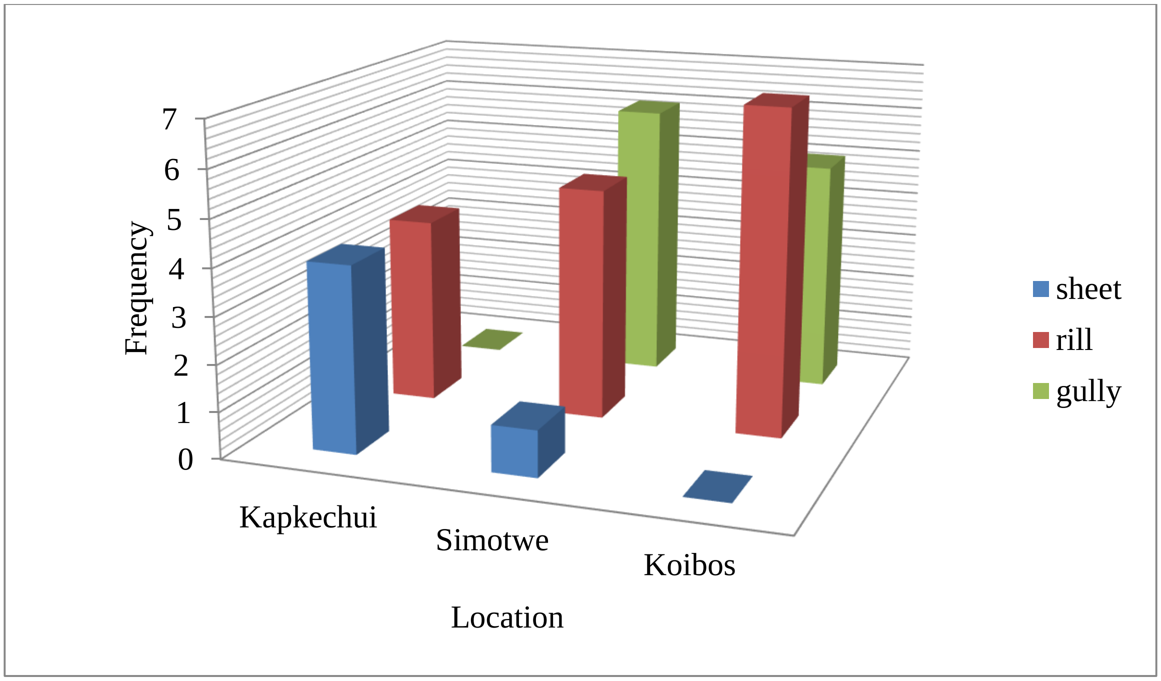

Figure 4.4: Visible erosion in the river Loboi watershed

In Simotwe location serious rills and gullies were observed (plate 6). The erosion scenario in the middle section can be explained by the less vegetation cover hence the soil is exposed to the raindrop impact. The other contributing factor is the low organic matter content which makes the soil aggregates more unstable and susceptible to erosion. It is established that organic matter upon decomposition forms slime that helps to improve and stabiles soil aggregates that enhance plant growth and reduce soil erosion (Wild, 2003 and Mwetu *et al*., 2009). In spite of the good crown cover recorded in Koibos location, rills and gullies are outstanding in the location. Rill and gully formation in the lower section of the watershed can be attributed to the high rock cover and the cumulative effect of increased surface runoff from the upper and middle sections of the watershed.

Plate 6: Gully erosion in Simotwe Location (March, 2013)

4.3.2 Vegetation cover (cover classes).

As shown in figure 4.5, excellent cover (> 70%) dominated the whole watershed with Koibos recording the highest at 18.7% followed by Kapkechui location at 12.5% and Simotwe recording the lowest at 9.4%. On overall, 40.6% of the watershed recorded excellent cover. The results also indicate that 31.2% of the area recorded fair cover (45-55%) and 18.8% good cover. There were no/minimal portions of poor cover in Kapkechui and Koibos locations. Based on this cover class system, vegetation cover in the watershed seems sufficient. The situation is different when using absolute/straight numbers as indicated in section 4.2 above. The cover class system is has the problem of slight errors at the margins of cover classes. For instance, choosing between 30-60% and 60-100% cover classes for a 59.5% cover may lead to huge differences in the overall estimation.

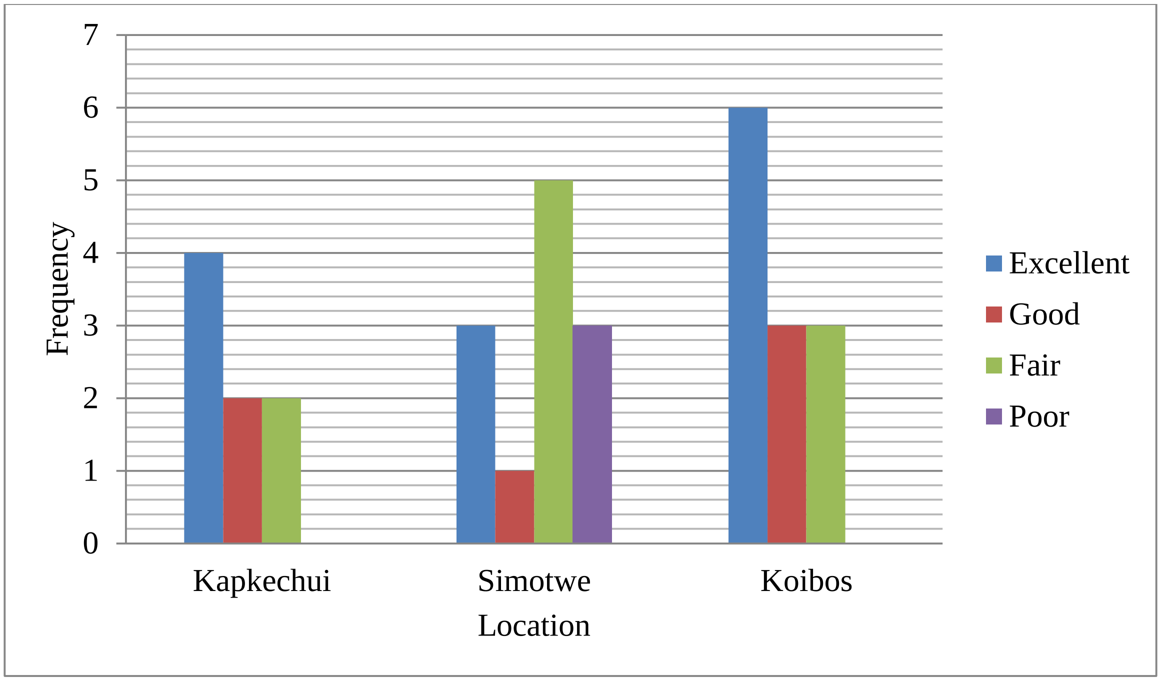

Figure 4.5: Cover in the three locations using the class system

4.3.3 Dominant vegetation

Figure 4.6 illustrates the dominant vegetation type/species in the river Loboi watershed. Most evident from the results is that the dominant vegetation across the three locations is shrub/tree type. As mentioned earlier, there are more shrubs than trees in the area. The results indicate that 84.4% of the watershed is dominated by shrub/tree vegetation. Based on this results the watershed can be classified as a shrubland a deviation from the initial 'savanna'. Grass was found to be the least dominating vegetation with 3.1%. The dominance of herbaceous (forbs) vegetation species was 6.2% twice that of grass. This is a threat to the major livelihood (livestock production) given that most of the dominant shrubs are unpalatable. Similar observations were recorded in Eastern Sudan where less palatable, drought tolerant and annuals were replacing palatable perennials leading to shortage of livestock feed (Akhtur-Schustar *et al*., 2000).

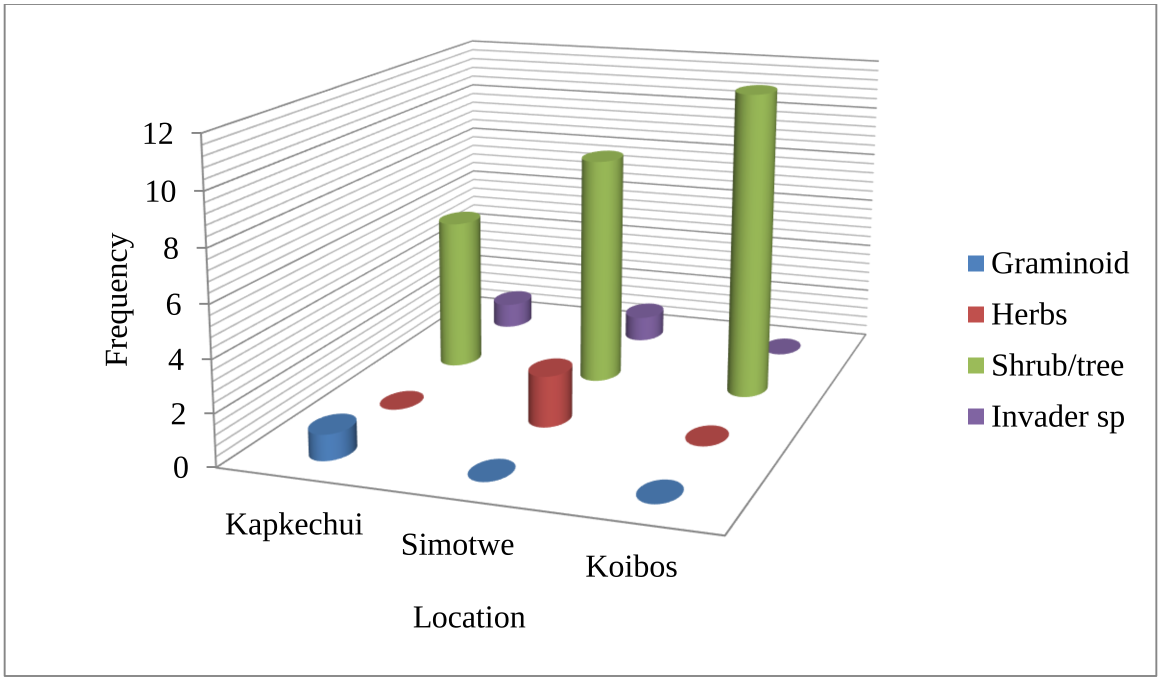

Figure 4.6: Dominant vegetation type in the river Loboi watershed

Based on the analysis of the above biophysical indicators, results reveal that the whole watershed is degraded (table 17). Only 12.5% of the watershed is experiencing moderate land degradation but the rest 87.5% is highly suffering from land degradation. Simotwe location is the most affected region in the watershed (figure 4.7).

Table 17: Extent of land degradation

Level of degradation	**Percent**
Moderately	12.5
High	50
Very high	37.5

Source: Research data

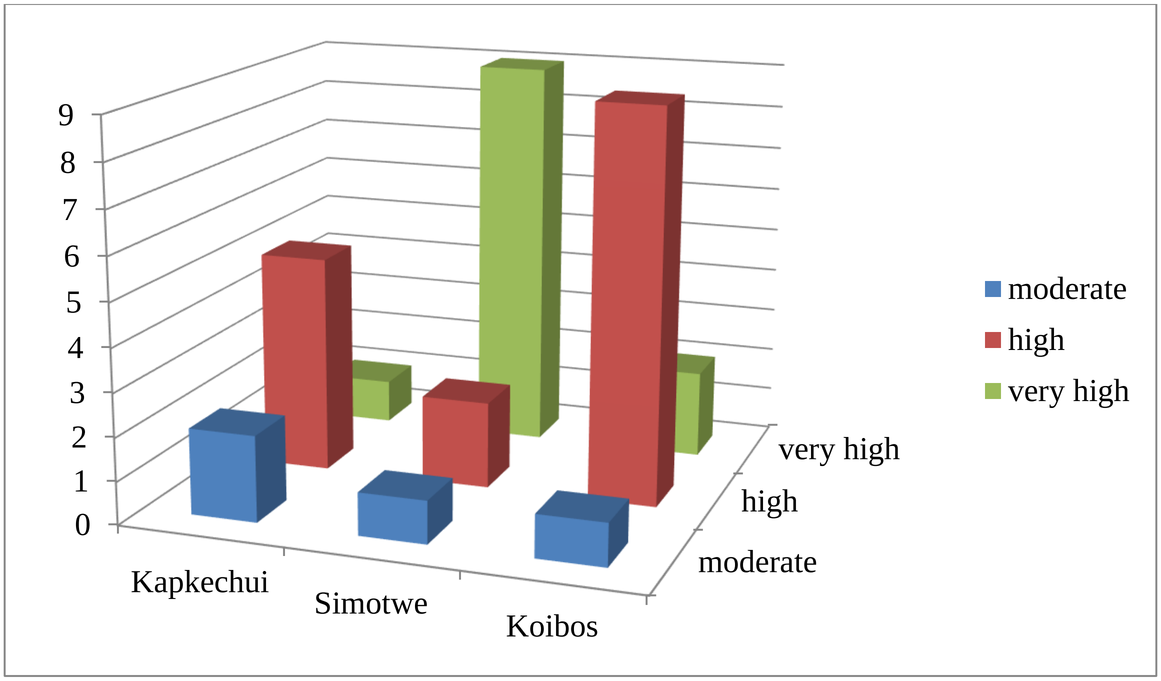

Figure 4.7: Extent of land degradation within the three locations

4.4 Soil chemical characteristics

4.4.1 Soil pH

This study established that the soils in the watershed were slightly acidic with a soil pH of 6.1 (Vanloon and Duffy, 2005). There was no significant variation in the soil pH values in the watershed. Kapkechu location (upstream) recorded a soil pH of 6.1, Simotwe location (middle section) 6.0 and Koibos location (downstream) the soil pH was 6.2. The results also indicated that the eastern side of the river Loboi has more acidic soils (pH 5.8) compared to the western side (pH 6.2). This acidic pH can be attributed to the increased surface runoff of basic cations, especially Calcium (Islam *et al*., 2001). In addition, low soil pH in the watershed can be explained by the extremely high Manganese recorded in the area (Shepherd and Walsh, 2002). Results of this study recorded Manganese levels of 1264.08ppm.

Soil pH influences the amount of nutrient ions stored in the cation exchange sites, the rate of plant nutrient release by weathering and the solubility of all the material in the soil. Therefore, soil pH has a major effect on nutritional status of plants and hence their growth and establishment (Islam and Weil, 2000 and Dougill *et al*., 2002). A near-neutral pH is desirable for most plants and soil micro-organisms. The results reveal that pH has not reached the threshold levels as stated in Landon (1991), (<4.5) and Shepherd and Walsh (2002) (<5.5). Therefore, with careful planning and management, it can be controlled. The alteration or management of soil pH should take into account the fact that different plant species have specific soil pH requirements for their successful growth (Foth, 2006).

4.4.2 Soil organic matter content

The results for organic matter content within the river Loboi watershed are as displayed in figure 4.8. This study established that the soil organic content in the watershed is low. On average it was recorded to be 2.2%. This figure slightly exceeds the 1% organic matter content that agricultural research has identified as a threshold below which focused annual nutrient inputs are no longer capable of maintaining crop yields (Dougill *et al*., 2002). The slightly higher OM levels (2.8%) downstream can be attributed to the fairly higher vegetation cover and deposition of eroded material from the upstream. The other contributing factor is the high rock cover recorded in Koibos location. Rocks assist in maintaining microbial activities such as decomposition (Lahav and Steinberger, 2000).

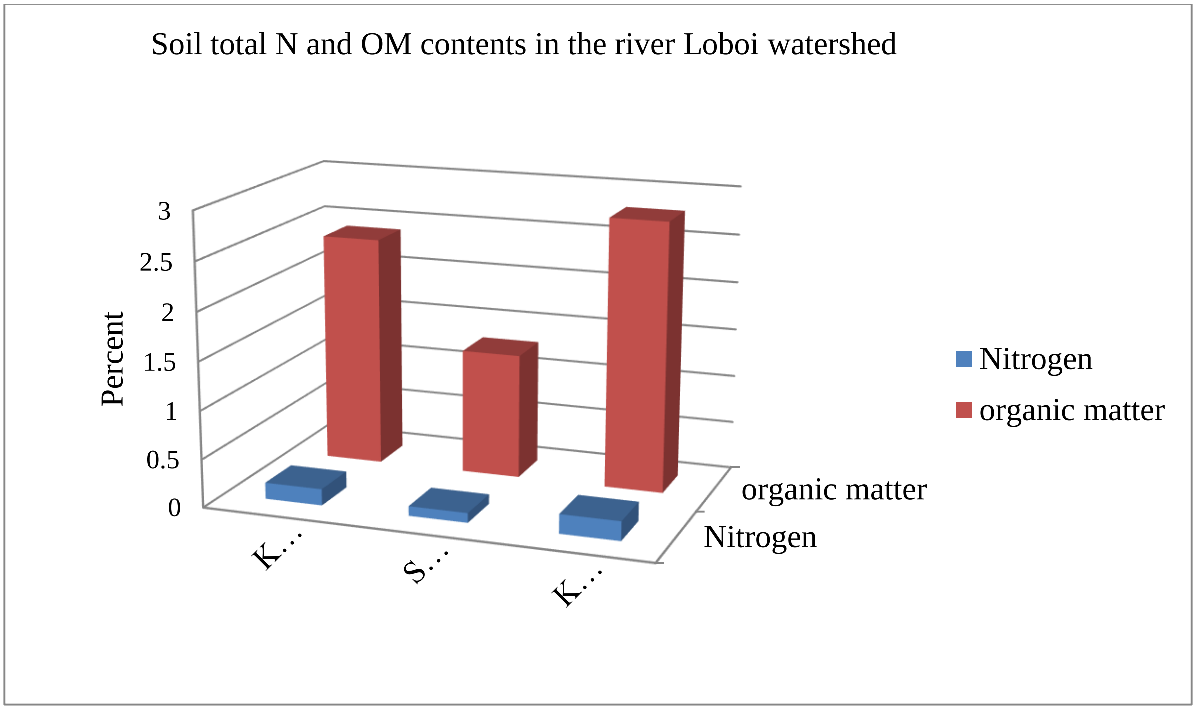

Figure 4.8: Total N and OM content in the three locations

The results also depict a gradual increment in organic matter content as one move further away from the river course (table 18). This can be explained by the change in vegetation cover. This study established that there is less cover nearer the river channel compared to that further away. Therefore, with more cover litterfall increase and hence more organic matter and vice versa. Many studies, among them McDonagh, *et al*. (2001), Islam, *et al*., (2001), Mainuri, *et al*., (2009) and Panda (2011) affirms the positive correlation between SOM levels and litter.

Table 18: OM concentrations on either side of river Loboi

Direction	**Distance from river**	**%OM**
East	2Km	1.73**B**
East	4Km	3.26**A**
West	2Km	1.76**B**
West	4Km	2.05**B**

Means followed by same letters are not significantly different from each other at α=0.05

Source: Research data

The results also indicate a higher organic matter content on the eastern side (2.5%) of river loboi compared to the western side (1.9%). Based on vegetation cover results mentioned earlier this is unlikely. Probably the higher organic matter can be attributed to large amounts of livestock manure given that there are more people settled on the eastern side.

The watershed being a semi-arid region is characterized by high temperatures. The high temperatures coupled with less vegetation cover in the watershed, subjects the organic matter to accelerated oxidation. This reduces the amount available in the soil (Islam, *et al*., 2001 and Mainuri, *et al*., 2009). Increased soil erosion is also a contributing to the low SOM levels. The continuous rapid soil erosion in the watershed washes away a significant amount of organic matter (Gachene, 1995 and Islam, *et al*., 2001). Huge surface runoffs carry large quantities of undecomposed litter plus other large organic debris that erode the river bank.

To some extent the low SOM levels can also be explained by the subsistence crop farming. Organic matter in soils reduces with continuous land cultivation (Islam, *et al*., 2001; McDonagh, *et al*., 2001 and Mainuri, *et al*., 2009). This study established that subsistence crop farming is a livelihood adopted by all the respondents in the watershed which is a testimony to frequent disturbance of soil aggregates. In Ethiopia, crop farming was considered a greater contributor to soil degradation compared to livestock and wildlife grazing (Taddese, 2001).

Organic matter acts as cementing agent to soil properties. It also improves the soil structure, aggregate stability and infiltration capacity of the soil (Hassink, 1996, Wild, 2003 and Mainuri, *et al.*, 2009). Low SOM levels may result in poor soil structural stability that ultimately result in dry and poorly drained soil condition that is unfavourable for seedfall germination and survival and establishment of seedlings (Islam, *et al*., 2001). In addition, under no-fertilizer, no-manure regime, SOM is the source of almost all the Nitrogen, sulphur and a proportion of Phosphorous available to crop plants (Wild, 2003). Consequently, the need to replenish organic matter in the watershed remains essential to prevent further soil degradation.

4.4.3 Soil macro-element concentration

4.4.3.1 Nitrogen concentration

Results show that total soil N in the watershed is deficient (<0.20%) (Courtney and Trudgill, 1992 and Radojevic and Bashkin, 1999) and follows the same pattern as organic matter content (figure 10 above). On average the nitrogen content was recorded to be 0.16%. However, the differences in total Nitrogen within the three locations were not statistically significant ($p=0.13$). The differences in soil organic matter and total N in the watershed were not statistically significant because of the high coefficients of variability (CV values of 53% and 40% respectively). This is usually due to high variability in the area sampled.

Total nitrogen, like SOM, decreases with increased soil degradation. This is based on the fact that soil nitrogen is primarily in the organic fraction of the soil and hence the bulk of soil nitrogen is present in the upper soil horizon where the bulk of organic matter is located. In case of soil erosion, therefore, soil nitrogen is washed away with organic matter (Panda, 2011). Where nitrification readily occurs, most of the mineral nitrogen occurs as nitrate. However, nitrification process is inhibited by low soil pH (Black, 1965; Dougill *et al.*, 2002 and Foth, 2006). The low total N levels may be affecting the utilisation of other macro elements particularly Potassium and Phosphorous (Panda, 2011).

4.4.3.2 Phosphorous concentration

As displayed in table 19 available soil Phosphorus (P) in the watershed is deficient (<20 ppm or mg/kg) (Radojevic and Bashkin, 1999) and this is fairly uniform along the watershed. The 2.7ppm recorded in the watershed is described as very low comparing it with the 20ppm optimal concentration. The low concentration can be attributed to soil pH. Maximum Phosphorous concentration occurs at soil pH range of 6.5 to 7.5. Below 6.5 there is increasing formation of relatively insoluble iron and aluminium phosphates (Foth, 2006). Phosphorous is critical in determining plant growth. It stimulates early root development and growth as well as early maturity of crops (Panda, 2011). In most cases Phosphorous concentrations in the soil solution are low compared to other macro nutrients such as Nitrogen, Potassium, Calcium and Magnesium.

Table 19: Concentration of some macro-elements along the river Loboi watershed

Location	**P(ppm)**	**K(ppm)**	**Ca(ppm)**	**Mg(ppm)**	**Na(ppm)**
Kapkechui	2.5**A**	248**A**	493**A**	500**A**	146**B**
Simotwe	2.6**A**	208**A**	536**A**	443**A**	189**A**
Koibos	3.0**A**	212**A**	674**A**	489**A**	153**B**
Optimum conc.	***20.0***	***150***	***2500***	***150***	***100***
Mean	**2.7**	**222**	**568**	**477**	**163**
LSD(p=0.05)	0.6	94	227	72	30
CV(%)	15.3	38.9	52.8	38.8	35.7

Means followed by same letters are not significantly different from each other at $\alpha=0.05$

Source: Research data

4.4.3.3 Calcium concentration

Available soil Calcium is extremely low (<2500 ppm or mg/kg) (Radojevic and Bashkin, 1999) and does not vary greatly along the watershed. Calcium is a critical nutrient in determining plant growth. It improves the intake of plant nutrients especially Nitrogen (Panda, 2011). Studies indicate that most economic crops yield best in soils where the exchange complex is dominated by Ca^{2+}. A high Ca^{2+} indicates a near-neutral pH which is desirable for most plants and soil micro-organisms. Similarly high Ca^{2+} status is desirable because it reflects low concentrations of other, potentially troublesome exchangeable cations, primarily Al^{3+} and Na^{+} (Donahue *et al.*, 1971). The low levels of Calcium (568ppm) may be as a result of low soil pH recorded in the watershed as well as increased surface runoff.

4.4.3.4 Potassium concentration

Potassium is the third most important macro element after Nitrogen and Phosphorous. Potassium is uniformly sufficient along the watershed. Its concentration (222ppm) is slightly higher than the optimal concentration (150ppm) (Radojevic and Bashkin, 1999). Soil moisture is very important in supplying it to plant roots. Therefore, it may not be available to plants despite its sufficient concentration in the soil due to soil moisture limitations in the watershed. Potassium is important in increasing crop resistance to diseases and for stimulating rooting activity, photosynthesis, translocation of sugar and chlorophyll production (Radojevic and Bashkin, 1999 and Panda, 2011).

4.4.3.5 Magnesium concentration

The concentration of Magnesium was found to be excess in the watershed; 477ppm (Radojevic and Bashkin, 1999). A more than 300ppm of Mg is considered excess. Therefore, its concentration needs to be minimised through the addition of humus and compost. Sometimes, high exchangeable Mg^{2+} is associated with poor physical soil condition. Based on this, the excess amounts of Magnesium may be due to physical degradation of soils in the watershed.

4.4.3.6 Sodium concentration

Sodium is not a requirement by plants but can replace part of potassium ions requirement by some species. Its concentration (163ppm) is higher than 100ppm which is the optimum concentration. This implies that there may be chances of having Sodium toxicity in the watershed. The higher level is due to low SOM. Sodium in the exchange complex can make the soil unstable and impermeable to water (Marshall and Holmes, 1979).

4.4.4 Soil micro-element concentration

Results of the micronutrients are shown in Table 20. Copper (Cu) is deficient (<1 ppm or mg/kg). Zinc (Zn) (>5 ppm or mg/kg) and iron (Fe) (>10 ppm or mg/kg) are sufficient in soil. Manganese (Mn) levels in the watershed are extremely high (>550 ppm or mg/kg) and may be toxic to plants. A 1000-2000ppm Manganese concentration, damages plant growth (Courtney and Trudgill, 1992). The concentration of these micronutrients is almost uniform in the whole watershed except for Zinc. Zinc levels in the upper section of the watershed differ significantly with that in the middle and lower stretches of the watershed.

Table 20: Concentration of micro-elements along the river Loboi watershed

Location	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)
Kapkechui	0.21**A**	16.8**A**	1367**A**	30**A**
Simotwe	0.26**A**	9.80**B**	1233**A**	27**A**
Koibos	0.37**A**	10.1**B**	1192**A**	24**A**
Optimum conc.	***1.00***	***5.00***	***550***	***10***
Mean	**0.28**	**12.24**	**1264.08**	**26.85**
LSD (p=0.05)	0.2	5.4	483.3	6.9
CV (%)	**49.8**	**54.4**	**36.9**	**33.4**

Means followed by same letters are not significantly different from each other at $\alpha=0.05$

Source: Research data

Upon aggregating concentrations of the assessed macro and micro elements, the soil in the river Loboi watershed is of low fertility. This is based on the findings that the soils are low in organic matter content and deficient in Nitrogen, Phosphorous and Calcium. Potassium although sufficient in the soils, it may not be available to plants due soil moisture limitations. In addition the concentrations of Magnesium, Sodium and Manganese may detrimental to vegetation growth in the watershed. The low fertility status is inconsistent with GoK, (1994), Bryan, (1994) and Johansson and Svensson, (2002). This inconsistence can be attributed to the fact that soil erosion menace is constantly washing away the key soil constituents.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has provided important information regarding the nature of land degradation in the river Loboi watershed. Based on the findings, the following conclusions are drawn.

- On average, a household in the watershed holds 33 animals with fairly large land holdings. Most locals lack economic capital and knowledge, making them insufficient in tackling the land degradation menace.
- The vegetation cover in the river Loboi watershed was established to be 59.6%. Based on individual cover, the dominant plant species consisted of *Dodonaea viscosa, Tarconathus camphoratus, Lantana camara, Acacia mellifera, Acalypha fruitcosa* and *Croton dicogamus.* Except for *Acalypha fruitcosa*, most of these species are classified as unpalatable shrub vegetation.
- The soils in the watershed are of low fertility. As for macro nutrients, Magnesium is in excess and Potassium is in sufficient supply but it may not be readily available to plants due to soil moisture limitation. Other macro elements (Nitrogen, Phosphorous and Calcium) are deficient including organic matter. On average their concentration were; N=0.16%, P=2.7ppm, Ca=568ppm, K=222ppm, and Mg=477ppm. Concentrations of most microelements were adequate except for Manganese whose concentration was extremely high (1264ppm).
- The observed soil degradation, particularly the enormous soil erosion, can be attributed to low soil organic matter content, high levels of Sodium, reduced vegetation cover and the shrub vegetation in the watershed.
- The middle stretches of the river Loboi watershed is the worst hit. Ereyon, segondoi and Kapkaunji villages constitute the parts seriously suffering from land degradation.

5.2 Recommendations

As per the research finding, the following recommendations are made:

- Any successful land rehabilitation project in the watershed needs to support the local community by incorporating income generating activities and essential services (for example, education and infrastructure) in their programmes.
- The river Loboi watershed like many parts in the Baringo County has suffered severe land degradation. In order to enhance the adoption of soil and water conservation measures that can curb land degradation peril, there is need for institutional support of extension services. The farmers should be encouraged to constantly seek advice on the integrated use of vital inorganic and organic inputs derived from the livestock sector from the agricultural extension officers.
- Protection of vegetation cover is a major instrument for preventing further land degradation in the area. Maintaining vegetation cover will protect the soil from water erosion and increase the soil organic matter which is key in improving the overall soil quality and hence land potentiality. A >70% cover dominated by native, highly palatable and drought resistant graminoids is recommended. This can be achieved by encouraging locals to practice on farm grass reseeding.
- Passive rehabilitation approaches such as fencing off an area and leaving it to regenerate through natural processes, should be avoided.
- A watershed approach to land degradation control in the watershed is needed so as to promote environmental sustainability. Environmental challenges such as land degradation ignores administrative boundaries therefore planning of rehabilitation programmes should transcend the local administrative boundaries and encourage the locals to work together.

5.3 Further research

Species diversity of vegetation supports both livestock and locals in the watershed. Keystone species that are important for the health and survival of many other native species in the watershed need to be identified and their dynamics understood.

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APPENDICES

Appendix 1: Vegetation cover and composition form

LOCATION…………………………………………………………………….

TRANSECT No………………………………………………………………...

PLOT No……………………………………………………………………..

DATE…………………………………………………………………………

A) STEP POINT METHOD

Point	Hit	Species
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

B) LINE INTERCEPT METHOD

Species	Distance Start(m)	Intercepted End (m)

C) COMMENTS:

Soil erosion (type/signs of accelerated erosion)

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

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

……………………………………………………………………………………

Dominant key species/vegetation type

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

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

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

Appendix 2: Plant list

Botanical name	Local name	Cover	Occurrence		
			Upp	Mid	Low
1. *Dodonaea viscosa*	Tibilikwe	32.8	×	×	-
2. *Tarchonanthus camphoratus*	Lelekwe	23.4	×	×	-
3. *Croton dichogamus*	kelelwe	18.8	×	×	×
4. *Acacia senegal*	Chemanga	10.9	-	×	×
5. *Balanites aegyptiaca*	Ngoswe	10.9	-	×	×
6. *Hyparrhenia species*	Chepnganiante	7.8	×	-	×
7. *Lantana camara*	Kamosgoi	21.9	×	×	×
8. *Rhus natalensis*	-	15.6	×	×	-
9. *Berleria species*	-	14.1	-	×	×
10. *Aloe vera*	-	6.2	×	×	-
11. *Ipomoea species*	-	7.8	-	×	-
12. *Indigoferra arrecta*	Aruo-Ng'wony	3.1	-	×	×
13. *Cissus quinquangularis*	Sung'uruti	17.2	-	×	×
14. *Acacia brevispica*	Kornista	18.8	×	-	×
15. *Acacia mellifera*	Ng'orore	20.3	-	×	×
16. *Acacia tortilis*	Sesiet	6.2	-	×	×
17. *Grewia trichocarpa*	Sitewe	12.5	×	-	×
18. *Lippia javanica*	Mwokyonte	1.6	×	-	-
19. *Acalypha fruitcosa*	lokurwe	20.3	-	-	×
20. *Vebris glomerata*	Chepkorian	9.4	-	×	×
21. -	Kikorwe	12.5	×	×	-
22. -	kilembelie	3.1	-	×	-

23. *Albizia species*	-	3.1	-	×	-
24. *Acacia reficiens*	Barsule	3.1	-	×	×
25. *Combretum hereroense*	Mesketwa	3.1	-	-	×
26. *Heteropogon macrostachyus*	-	6.2	-	×	×
27. *Euphorbia tirucalii*	Kormotwe	1.6	-	-	×
28. *Terminalia browni*	Koloswet	3.1	-	×	×
29. *Combretum apiculatum*	Chepnganiante	1.6	-	-	×
30. *Cynodon dactylon*	Seretik	9.4	×	×	×
31. *Eragrostis superba*	-	1.6	×	-	-
32. *Themeda triandra*	-	1.6	×	-	-
33. *Ozoroa insignis*	Mutung'wee	1.6	×	-	-
34. *Acacia seyal*	Leng'nee	1.6	×	-	-
35. *Ziziphus mucronata*	Noywee	1.6	-	-	×
36. *Sporobolus species*	-	4.7	×	×	-
37. *Vangueria madagascariensis*	Komolwe	1.6	×	-	-
38. Sisal	-	7.8	×	×	-
39. *Cyperus rotundus*	-	1.6	-	-	×
40. *Panicum species*	-	1.6	-	-	×
41. *Tarenna graveolens*	Betwon	3.1	-	-	×
42. *Aristida keniensis*	-	10.9	×	×	×

Appendix 3: Questionnaire

Good morning/afternoon. My name is Alice Bitengo Gwako of Egerton University conducting research on land degradation assessment in the River Loboi watershed. The purpose of this research is to establish the level of land degradation in the watershed. The approach to establish the level of degradation will include collecting data that relates to the soil condition, the vegetation - both indigenous to the area and those that have been introduced and human activities that are anchored to the livelihoods of the people living within the Loboi River watershed. The results will be useful in the planning and establishment of appropriate restoration/rehabilitation measures in the watershed. Your contributions towards this course will be regarded vital and confidential, i.e. answers you provide to the questions asked will be used for research purpose only.

Respondent Name____

Sex__________________ Age_________________

Village____________________________________

Location____

Date of Interview_____________________ Time_________________

Place of Interview____

Name of Interviewer____

PART1: DEMORGRAPHIC DATA

1. Household members

Name of member	Relation to HH Head	Sex	Age	Marital status	Level of education	Occupation

2. (a) Type of housing (observation of main house)

    Mud walled with thatch roof [1]

    Mud walled with iron sheet [2]

    Semi permanent [3]

    Others (specify)________________[4]

(b) Number of rooms in (a) above [1] [2] [3] > [4]

(c) Number of houses in the homestead. [1] [2] [3] > [4]

3. Latrine types available (observation)

Pit latrine [1]

Flush Toilet [2]

Bush [3]

Other (specify) [4] ______________________________

4. a) What is your main source of water?

Pipe water [1]

River [2]

Borehole [3]

Dug well [4]

Sand dam [5]

Other (specify) [6] ______________________________

b) What is the distance to nearest water point/source?

< 100m [1]

100m to 500m [2]

500m to 1 Km [3]

1Km to 2km [4]

>2km [5]

5 Household expenses

Item	Quantity	Cost (kshs)	Duration
Maize/flour			
Beans			
Vegetable			
Fat/oil			
Sugar			

Travel/Transport			
Tea leaves			
Rice			
wheat			
Soap			

6.a) Do you own land and for how long?

i) Yes [1] No [2]

ii) Period: <1yr [1] 1 – 2yrs [2] >2yrs [3]

b) What is the size of your land/farm?

<1 acre ` [1]

1-2 acre [2]

3-5 acre [3]

>5 acre [4]

c) Do you own land elsewhere? Yes [1] No [2] What is the acreage? ___________________

PART 2: CROP AND LIVESTOCK PRODUCTION

7 a) Do you keep livestock?

Yes [1] No [2]

If (yes), give your household livestock composition and numbers

	Animal type	Number
1	Cattle	
	Cow s	
	Heifers	
	Bulls	
	Calves	

2	Sheep	
3	Goat	
4	Donkey	
5	Other (specify)	

b) Give the acreage you have allocated for livestock production (ha)_____________

c) What type of livestock rearing system are you using?

Tethering [1]

Free range [2]

Zero-grazing [3]

Paddocked [4]

Nomadic [5]

Other (specify) [6]_______________________________________

d) Do you experience shortages of forage and when?

(i) Yes [1] No [2]

(ii) If yes, when? (time)________________________________

e) Do you buy any supplementary cattle feeds for your livestock?

i) Yes [1] No [2]

ii) If yes, how much do you buy per week?

1 bag [1] 2-3bags [2] Any other (specify)_____________________________

f) How often do you sell your livestock?

1- **3** months [1] 3- 6 months [2] Every year [3]

Reasons:

i)…………………………………………………………………………………

ii)…………………………………………………………………………………

iii)…………………………………………………………………………………

8a) which crops do you grow?

Type of crop	Acreage	Type of fertilizer/ manure	Production (No of bags)	Unit price
Maize				
Beans				
Water melon				
Vegetables				
Sisal				
Groundnuts				
Millet				
Other (specify)				

b) What type of soil erosion is experienced on the farm? Observe

Sheet erosion [1]

Rill erosion [2]

Gully erosion [3]

Other (specify) [4] ________________________________

c) Do you do any soil and water conservation practices on this farm?

Yes [1] No [2]

d) If yes, which ones?

Stone Terraces [1]

Contours [2]

Fanya juu [3]

Tree planting [4]

Fallowing [5]

Any other (specify) [6]______________________________

9a) Were you trained on soil and water conservation practices?

Yes [1] No [2]

b) If yes, who trained you?

Agriculture extension officers [1]

Forest officers [2]

Church (which one) [3]

Self initiative [4]

Mass media [5]

Other (specify) [6]

c) What difficulties do you experience when carrying out soil and water conservation practices on your farm? Rank them in order of priority.

Labour

Tools and equipment

Time

Land ownership

Knowledge

Cost

Other (specify)

11a) Do you make charcoal

Yes [1] No [2]

b. How often do you make charcoal?

Every day [1]

Weekly [2]

Once in a month [3]

Occasionally [4]

Any other specify [5]_________________________________

c. Name any tree species preferred for charcoal making.

i) ____

ii) ____

iii) ____

12. What do you think has caused land degradation in the area?

i) ____

ii) ____

iii) ____

13. Whom do you think has the main responsibility of controlling land degradation?

____

____

____