ASSESSMENT OF EFFECTS OF LAND USE PRACTICES ON RIVER CATCHMENTS A CASE STUDY OF NYONGORES RIVER CATCHMENT

BY

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DECLARATION

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Declaration by supervisors

This thesis has been submitted for examination with our approval as the University supervisors.

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DEDICATION

I dedicate this work to my family for their support, love and inspiration

ABSTRACT

Nyongores River is one of the major tributaries of Mara River and is located at the upper catchment of Mara River Basin. Over the years, rising population pressure and intensification of agriculture in the catchment has led to; reduced vegetation cover, poor land use management practices and increased soil erosion. The river is currently one of the major contributors of sediment and agrochemicals in the Mara River and Lake Victoria. The goal of the study was to assess the effects of land use and management practices on sediment concentrations in rivers. The specific objectives were: to map land use types, determine sediment delivery rates from land use types, determine sediment load from the main tributaries and assess the existing land use management practices for soil conservation. GIS mapping, water sampling and interviews of farmers from the catchment were carried out in the month of December 2009, January, February and March 2010. The study revealed that 43.2% of the catchment land use was under maize, 33.6% grasslands, 16.1% tea cover, 4.9% forest cover and 2.2% bare land. Land use under maize cultivation contributed the highest sediment concentration of 0.26g/l, forest (0.024g/l) and tea cultivation contributed the least concentration of 0.0351g/l. Among the tributaries of Nyongores River, Chepkositonik River delivered the highest sediment of 0.493 g/l followed by Kagawet with 0.324 g/l, then Ainopng'etunyek with 0.255 g/l while Kiprurugit was the least with 0.198g/l. The study estimated sediment flow into Nyongores River from the four tributaries at about 0.559Kg/s. The study established that the land use management practices for soil conservation within the catchment were; contour ploughing (24%), terraces (20%), agroforestry (17%), planting of trees (17%), intercropping (12%), mulching (6%), gabions (3%) and sand bags (1%). The study has demonstrated that there exists relationship between land use and sediment delivery rates in the tributaries. The study also shows that various land use management practices influences the rates of sediment concentrations in the rivers. Hence, recommends the adoption of integrated river catchment management for sustainable environment and agriculture.

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ACRONYMS AND ABBREVIATIONS

BCD	Bomet Central Division
EC	European Commission
BDAO	Bomet District agricultural Office
CBO	Community Based Organisation
DLPO	District Livestock Production Officer
DWO	Bomet District Water Office
EMCA	Environmental Management and Coordination Act
ENSDA	Ewaso Ngiro South Development Authority
EPZA	Export Processing Zones Authority
FAO	Food Agricultural Organization
GDP	Gross Domestic Product
GLOWS	Global Water for Sustainability programme
GPS	Global Positioning System
GTZ	GIZ German International Cooperation
HEP	Hydro-Electric Power
ICMP	Integrated Catchment Management Planning
IUCN	International Union for Conservation of Nature
JICA	Japan International Corporation Agency
KM	Kilometres
KNBS	Kenya National Bureau of Statistics
KTDA	Kenya Tea Development Agency
MFC	Mau Forest Complex
MOE	Ministry of Energy
MPND	Ministry of Planning and National Development
MRB	Mara River Basin
MWI	Ministry of Water and Irrigation
NELSAP	Nile Equatorial Lakes Subsidiary African Program
NEMA	National Environment Management Authority
NESK	National Environment Secretariat of Kenya
NLWR	National Land and Water Resources Audit
NRC	Nyongores River catchment
RCMRD	Regional Centre for Mapping of Resources and Development
SPSS	Statistical Package for Social Sciences
SWC	Soil and Water Conservation
TSS	Total Suspended Solids
UN	United Nations
UNEP	United Nations Environment Programme
UNEP	United Nations Environmental Programme
US	United States
USCB	United States Census Bureau
WMO	World Meteorological Organization
WQABAR	Water Quality Baseline Assessment Report
WRMA	Water Resources Management Authority

DEFINITION OF TERMS

Agro-forestry	Is a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit
Appropriate Land use practices	All land management practices that aim at runoff control and/or better soil management.
Catchment area	Area drained by a stream or other body of water. The limits of a given catchment area are the heights of land-often called drainage divides, or watersheds-separating it from neighboring drainage systems.
Discharge	Is the volume rate of water flow, including any suspended solids (i.e. sediment), dissolved chemical species and/or biological material which is transported through a given cross-sectional area.
Erosion	The wearing a way of land by water, wind and general weather conditions. This is a natural process but some land management practices have the potential to greatly increase the rate at which this occurs.
Integrated River Catchment Management (IRCM)	The process of coordinating conservation, management and development of water, land and related resources across sectors within a given river catchment, in order to maximize the economic and social benefits
Land degradation:	The permanent decline in the rate at which land yields products useful to local livelihoods
Land management	The technology, activities and strategies employed by land users to manage their land
River Basin	In this study, the river basin is defined as a large unit of land that drains into the lake
River catchment	In this study, river catchment is the entire geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet (river)
River source	The source or headwaters of a river or stream is the place from which the water in the river or stream originates.
Soil and water conservation	Soil and water conservation (SWC) is the opposite of land degradation, and aims at preventing, reducing or recovering losses of soil, water and plant nutrients.
Soil conservation structures	Constructed earthworks and vegetative controls such as grassed waterways, buffer strips, strip cropping and farm dams
Stream	A flow of water in a channel or bed, as a brook, rivulet, or small river. A steady current in such a flow of water
Surface cover	Vegetation and mulch/stubble cover reduce the impact of rainfall on the soil surface by dissipating the energy of the raindrops (or runoff) and allowing the water to enter the soil.
Tributary	A stream that flows into a *river*, a larger stream, or a lake joins a larger stream, *river*, or glacier, or a lake
Watershed	a smaller unit that contains all lands and waterways that drain to a

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

River catchment environmental issues are becoming an increasing concern in many parts of the world (Wang et al. 2006). The major cause of catchment degradation is the impacts of land use and population changes (which are reported from many countries on earth). The world with a human population of approximately 7 billion (United States Census Bureau, 2011), increasing at an average of 1.7 percent per year, can hardly afford the harmful impacts of land degradation in any form. The rising population requires more food and more space to settle resulting in conversion of more land farming activities. Globally, agriculture is the biggest land use practice in terms of area and is the most significant land use in terms of environmental impacts (Marther, 1986). Agriculture plays a key role in economic development (World Bank, 2005) and poverty reduction (Irz and Roe, 2000). In sub-Saharan Africa 35% of GDP comes from the agricultural sector, which also employs about 70% of the population (World Bank, 2000).

The manifestations of these changes in human population and agricultural land use include increased soil and water degradation as the population encroaches on the forests, hill tops and riverine ecosystems for cultivation and overgrazing (IUCN, 2000). Consequently, this has led to increased sediment and nutrient loads in most stream networks. Since rivers occupy the lowest positions in landscapes, they collect and integrate the impacts occurring over the entire catchments (Naiman et al. 2002). They are excellent indicators of catchment environmental management status.

Kenya has been experiencing rapid population growth in the last four decades, resulting in major changes in land occupation and use (Langat and Mwangata, 1994). The areas that were previously under forest cover have now been cleared and occupied by agriculture (Obando, 2004). Though agriculture is the backbone of Kenya's economy and accounts directly for about 26% of GDP and 27% indirectly through linkages with other sectors, only 20% of Kenya's land is arable and the rest (80%) is a fragile environments (Republic of Kenya, 2006). Yet about 80% of the country's population lives in rural areas and derive their livelihood from agriculture. The increasing population and demand for food is exerting pressure on these fragile environments such as the watersheds, riverine ecosystems and hill tops and have led to increased soil erosion.

Mara River (395 km length) is a trans-boundary river with its basin (13,750 km^2) being shared between Kenya (65 %) and Tanzania (35 %). The River originates from the South West of Mau Forest Complex with high rainfall, (1400 mm/year) and descends from 3000 m in altitude to below 2000 m, criss-crossing Bomet, Narok, Transmara, then through the Mosirori Swamp and in the north-eastern part of Tanzania and into Lake Victoria (NELSAP, 2002). The water in the Mara River is a critical resource not only in terms of support to livelihoods of the communities living around it but also for its use in large scale farming, domestic water supply, hydro power and its important role in the Masai Mara and Serengeti Game ecosystems, both world-famous for their rich wildlife and natural beauty (GLOWS, 2007).

Agriculture dominates the economy of the upper catchment area providing a livelihood to about 80% of the population in the area (Ministry of Planning and National Development, 2008). Mati B.M. et al., (2005) found out that agricultural land within the upper catchment of the basin increased by 55% and forest cover reduced by 23% between 1986 and 2000. The upper catchment, particularly in the Nyongores sub-basin is characterized by sloppy terrain of up to 55% , fertile soils and moderately high rainfall making it more prone to soil erosion by runoff than any other part of the basin (Bomet District Agricultural office, 2009). According to Mati B.M. et al., (2005) soil erosion from farming activities in the Mara River Basin is the greatest challenge to water quality problems. WQBAR, (2007) found out that the upper catchment annually releases tons of sediments that contain nutrients into the Mara River. Hecky (1993) and Mati B.M. et al., (2005) pointed out that the Mara River at its mouth and Lake Victoria are already showing signs of enrichment and attributed this to the increased soil erosion and fertilizer runoff from agricultural practices at the upper catchments. The generation of hydropower at Tenwek mission hospital along Nyongores River in the upper catchment is frequently hampered by siltation of its dam, (Terer, 2005).

1.2 Problem Statement

The sediment and nutrient loads in a stream network are a resource management problem of global significance. In many developing countries, sustainable land use and water resource development are threatened by soil erosion and sediment related problems (Johnson and Lewis, 1985). Water-borne erosion reduces soil fertility in agriculture and increases the supply of sediment to rivers. The high concentrations of suspended sediments in rivers can: reduce stream clarity; inhibit respiration and feeding of stream biota; diminish light needed for plant photosynthesis; eutrophy in rivers and wetlands; make water unsuitable for irrigation; smother the stream bed; increase land flooding and high cost of water treatment for human, (NLWRA 2001).

High population and current farming practices in the Mara River Basin (MRB) of Kenya are primary factors contributing towards the reduction in quality and quantity of water resources in the basin (ENSDA, 2005). Farming, besides degrading the water resources in the basin has also reduced the soil fertility which, in turn, has given rise to poor agricultural yields leading to increased fertilizer application. This clearly shows the extent to which soil erosion is a contributory factor to the basin's and generally to the country's structural food insecurity problem. Soil erosion thus largely remains a problem to be tackled as part of the efforts at ensuring food security, poverty reduction and environmental sustainability in the basin.

The upper catchment has experienced visible symptoms of land degradation in the form of soil erosion and sedimentation of reservoirs and rivers. Increased soil erosion is a concern in the catchment due to its impacts on the water resources and agricultural production. The process of soil erosion in the area is strongly influenced by quality and intensity of surface runoff from rainfall and land use management practices. This combined effect of land use practices and rainfall has accelerated the rates of erosion which is clearly evidenced by sediment deposition along the river channels where the gradient is less steep, siltation of reservoirs and eutrophication in the river downstream.

Though many studies have highlighted the problem, very few studies have been undertaken to address the land use and soil erosion in the catchment. Sediment delivery rates into various tributaries have also not been established and little is known about sediment concentration from different land use types in the catchment. Hence, knowledge of the current sources and quantities of sediment production under various land use types is needed for sound land-use management practices towards erosion reduction.

1.3 Research Objectives

The overall objective of this study was to assess the **effects of land use and management practices on sediment concentrations** in Nyongores river catchment. The specific objectives were to;

1. Establish major land use types within Nyongores River Catchment
2. Determine the sediment delivery rates from land use types to tributaries of Nyongores river
3. Determine the sediment load of the main tributaries draining Nyongores catchment
4. Examine the land use management practices for soil conservation within Nyongores Catchment.

1.4 Research Questions

The study was guided by the following research questions:-

1. What are the major land use types and coverage in Nyongores River Catchment?
2. How is the various land use type affect the sediment delivery rates into the river?
3. What are the sediment concentrations in the tributaries of Nyongores river?
4. What are the existing land use management practices used to control soil erosion in the Nyongores river catchment?

1.5 Justification of the study

Across the globe, water resources and their catchment environments are under threat as never before. In the river basins everywhere, human activities have disrupted the natural hydrological and ecological regimes. The demands on the catchment resources have created a unique set of management issues and environmental pressures that need to be considered together. The impacts in a catchment are felt not only locally, but are transmitted downstream and through land–surface feedbacks that disturbs the climate itself. For instance, water supplies are no longer secure, flood risk is perceptively increasing, and biodiversity is threatened. The challenge is to identify appropriate responses to these threats. Sustainable management options are needed to conserve watersheds and provide water, not only for life, health and development, but to prevent further catchment degradation.

Integrated Catchment Management Planning (ICMP) is considered to be an effective tool for addressing catchment problems in a holistic way, through the integration of social, economic and environmental ideals and objectives. An integrated approach promotes greater awareness and understanding of environmental issues and encourages a more open and cooperative approach to decision-making. This approach allows for the protection of the catchment and its important water resources, while at the same time addressing critical issues such as the current and future impacts of rapid population growth and climate change. ICMP provides a framework to integrate natural resource management with community livelihoods in a sustainable way. It addresses the issues of degradation of natural resources, soil erosion, landslides, frequent droughts and desertification, low agricultural productivity, poor water quantity and quality and poor land use practices from an integrated management perspective. ICMP is therefore vital in achieving catchment management and agricultural sustainability in terms of both production and environmental protection. An integrated approach may also help to reduce the risk of future conflict, or, for some of the more potentially contentious issues, at least identify at an early stage all the key interests. The net result is a more co-ordinate approach to the wise and sustainable use of the catchment land and water resources.

Currently, the water resources and agricultural land use activities in the upper catchment are showing signs that they are not sustainable in the longer term and these are the sorts of trends that need to be reversed. This study was based on the basis of the importance of understanding information related to land use and soil erosion problems in the area of integrated catchment management. Soil erosion besides reducing basin fertility has caused decrease in water quality and quantity and the storage capacity of the downstream reservoirs through silt deposition, which can, in turn, give rise to low biomass production. The major causes of increased soil erosion is attributed to poor land use management practices in the catchment. Some past and existing land uses have resulted in severe degradation of the catchment land and water resources. Planning for and implementation of effective soil and water conservation measures in a catchment require, among other things, a detailed understanding of the contributions from the various sources and particular land use types on soil erosion. This has an immediate significance to conservation agencies, development agents, water users associations and other community environmental groups for a targeted and cost effective conservation intervention by identifying most vulnerable landscapes and setting of priorities.

The study was undertaken within Nyongores river catchment at the upper Mara river basin. This side was chosen for this research because many of the main environmental challenges in the basin originate from this area due to its intensive agricultural activities and high population density. Assessing the impacts of various land uses in relation to soil erosion is useful in order to monitor the use of land and develop appropriate land use plan (Sombatpanit et al, 1999). This is also critical for the management of watersheds to ensure that the transport of sediment, nutrients and other pollutants to the river is minimized. Such information on soil erosion rates in the area will be an essential pre-requisite for the design of an appropriate land use management and monitoring strategies. The farmers' perception on environmental sustainability would give the opportunity to identify the limitations of present management practices and provide recommendations for improvements.

1.6 Study Area

1.6.1 Introduction

Nyongores river sub-basin is one of the two major tributaries of the Mara River and is located at the upper Mara basin. Mara River is a trans-boundary river which traverses the Masai Mara Game Reserve in Kenya and the Serengeti National Park in Tanzania and drains into Lake Victoria. The Mara River basin is located between 33^{o} 47' E longitudes and 0^{o} 38' S latitudes with a total area of 13,504 km^2, of which approximately 65% is located in Kenya and 35% in Tanzania. The two major tributaries (Nyongores and Amalo rivers) forming Mara river receive their recharge from the Mau forest. Mara River flows for about 395 km.

1.6.2 Location

The study area is located at the upper parts of the Mara River basin on Nyongores River sub-basin. The sub-basin drainage cover is 679 km^2. The area covers part of Bomet District in the south Rift Valley province and lies between 0^{0} 29' and 1^{0} 31' south of the

Equator and between longitudes 35^0 05' and 0^0 35' east. Bomet has six divisions of which Bomet Central with an area of 336.6 km^2 is the largest. Bomet is bordered by Narok to the East and Southeast, Bureti to the north, Sotik to the west, and Transmara to the southwest.

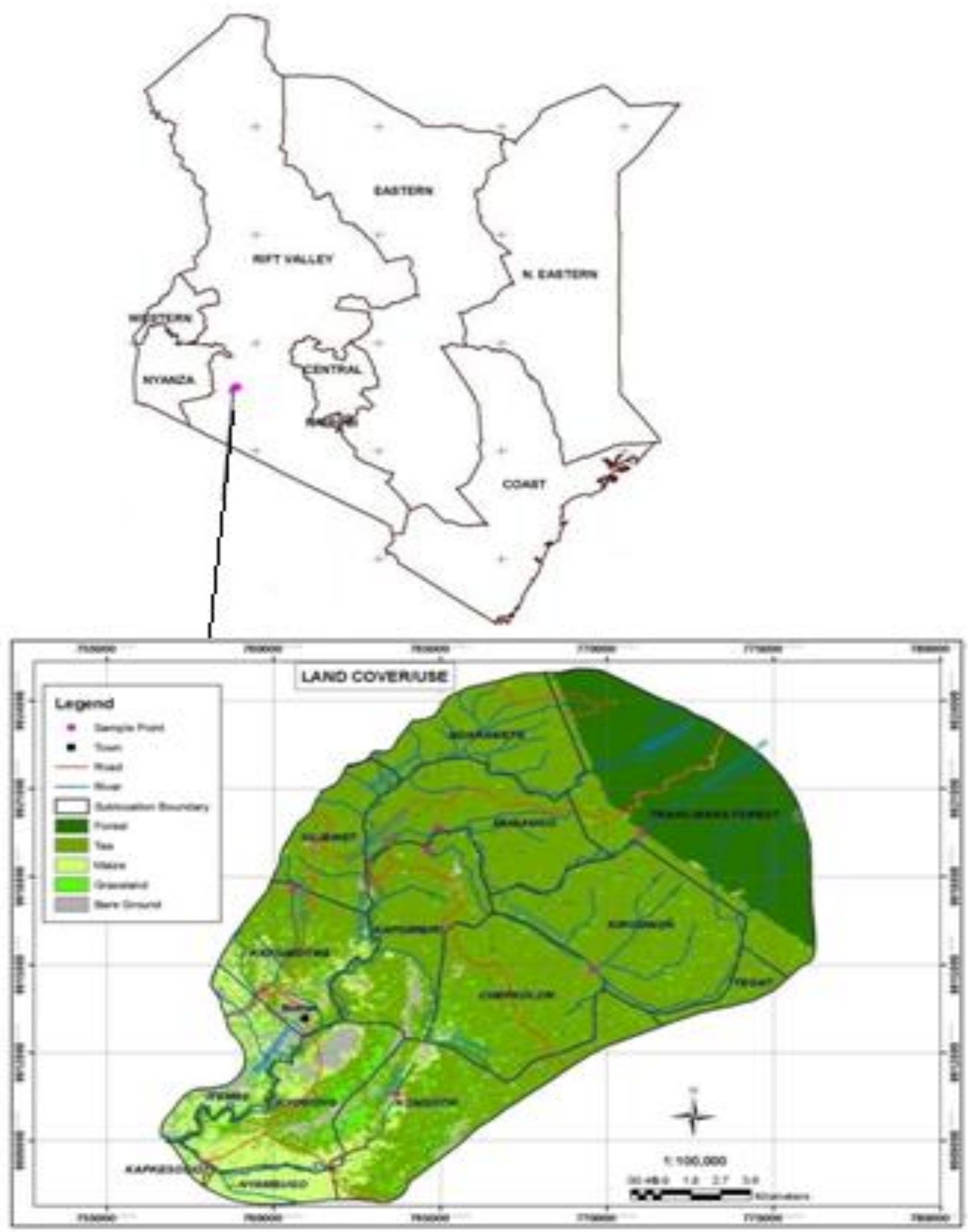

Figure 2.1: Map of Kenya showing the location of the study area (Source: Author, 2010)

1.6.3 Climate and topography

The area has moderate rainfall throughout the year with long rains occurring from March to May and the short rains from August to October. The mean monthly temperature is 18^0C. The topography of the study area is undulating with ridges and valleys slopping southwards and northwards.

1.6.4 Settlement patterns

Bomet Central Division was projected to have a population density of 388 persons per km^2 in the 1999 census. This was the highest population density in the divisions of Bomet District. Further projections indicate that Bomet central had a population density of 453 persons per km^2 in 2008. The distribution of population in Bomet Central is influenced by the Bomet Town which is the centre of business, its proximity to regional road to Nairobi and the soils of the area.

1.6.5 Soils and Agriculture

The soils in the catchment are divided into four main types: the sandy clays that cover a portion of the southern part of the catchment, heavy clay soils that cover about a third of the catchment to the central part, the loam soils that cover the medium zone of the catchment and the lithosols that cover the Northern part of the catchment. The area has high potential for agriculture. The main cash crop grown is tea while maize and beans are the main subsistence crops. The community also keeps dairy cattle.

1.6.6 Drainage patterns

The catchment area has a number of small tributaries that drain into Nyongores River. These includes; Ainap-nge'tunyek, Chepkositonik, Kagawet and Kiprurugit. Others are a number of seasonal streams and springs. All these rivers have their source at Bomet central, Nyongores sub- catchment. Nyongores River has a mean annual discharge of 10.4m^3/sec and drains 679km^2 (JICA, 1987).

1.7 Scope and Limitation of the Study

The scope of this study in terms of geographical area covered Nyongores River at the upper catchment of Mara river basin, specifically at Bomet Central Division. The study was limited to the identification of existing land use types and; determination of the rates of soil erosion from major land use types; the rates of sediment yield from the main tributaries draining the catchments and assess the existing land use management practices and farmers perceptions on soil and water conservation within Nyongores river catchment.

The identified land use types included; forested land, tea, maize and grassland and the tributaries investigated were; Ainopng'etunyek, Kagawet, Chepkositonik and Kiprurugit rivers.

1.8 Layout of the Thesis

The thesis has five chapters with chapter one containing the background information, problem statement, thesis objectives and research questions, rationale for the research, description of the study area and thesis outline. Chapter two covers the literature review while chapter three is the methodology section of the research. Chapter four presents results and discussion in a sequence of the specific objectives. Finally, chapter five contains the conclusion and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Human land use activities impose significant influences on catchment processes. It is well understood that settlement alone can significantly alter the hydrology and sediment supply of streams (Wolman, 1967; Leopold, 1972; Booth, 1991). Accelerated soil erosion caused by rainfall is usually a more rapid process that is largely induced by such human practices as forest clearing, raising crops and domesticated animals, quarrying, and construction. It is this form of erosion by water, which is more detrimental but also amenable to limitation and control, which is the focus of this study.

This literature review focuses upon pressing catchment land use environmental challenges, previous investigations where comparable studies can be drawn on some of the methods for understanding the effects of land use on sediment concentration on rivers and a theoretical review on natural resource use and management.

2.2 Land Use Practices

2.2.1 Agricultural Land use

According to Sheng (1989), land is the pivot of man's absolute existence. The author stressed this by asserting that through the past, in the present, and through the foreseeable future, soil continues to be the foundation of our food supply chain, which is a vital recurrent and capital resource of any nation. The predominant form of global landscape modification is the conversion of natural lands to agriculture (Ramankutty and Foley, 1999). In the rural areas, land use patterns are governed mainly by the requirements of the agricultural practices, which is important for the livelihood of the people. The need for putting land to optimum use through adequate and effective planning has never been greatly felt than at present, when rapid population growth and urban expansion are making available agricultural land scarce.

Kenya's arable land is only 20% and the rest (80%) is fragile environments (FAO, 2008). The increasing demographic pressure has now compelled expansion of crop production to marginal lands. Persistent deforestation for agricultural production is now a form of environmental degradation as crop yields drastically decreased (Oyekale, 2007). Within the upper Mara river basin, agricultural land increased by approximately 55% and forest cover reduced by 23% between 1986 and 2000, (Mati B.M et al, 2005). Local and regional land use changes such as these may cumulatively affect processes over larger scales, such as eutrophication in Mara river and lake Victoria, (WQBAR, 2007 and Hecky, 1993) or global carbon cycling (Foley et al., 2005).

Cultivation on the steep slopes is readily eroding and stripping soil of its natural vegetation cover. The unplanned land use change within and near a fast growing agricultural land in the river basin have led to accelerated soil erosion in the catchments (Karim et al, 2009). In a study reported by Dunne and Leopold (1978), overland flow resulting from saturation developed more frequently on soils used for growing crops. Similarly, exposed soils and increased surface roughness results in greater sediment supply to streams when overland flow occurs (Reid 1993, Woltemade 1994).

2.2.2 Grazing

Over grazing can result in catchment modifications and channel response. Grazing can result in soil compaction, soil erosion, and changes in vegetation communities and abundance. These changes to the catchment can result in reduced infiltration, increased runoff, and increased sediment supply and transport. According to Mulei (1997) up to 50% of the annual rainfall can be lost from eroded slopes, due to decreased infiltration and high surface runoff. The degree to which grazing practices can cause negative impacts is directly related to the degree of over-grazing in the catchment. Tate (1998), found out that overgrazing occurs when the number of livestock per unit area, per unit of time exceeds the carrying capacity of the landscape.

The presence of cattle and the trampling that ensues can lead to a compaction of subsurface soil layers while loosening surface soils (Reid, 1993). Several rangeland studies have found a strong correlation between increased bulk density and water infiltration (Packer,1953, 1963; Rauzi et al. 1966). Given enough precipitation, reduced infiltration resulting from subsurface compaction will increase surface runoff's capability of eroding and transporting loosened surface sediments to nearby streams. Reid (1993), pointed out that changing the longevity of roots through conversion from perennial to annual grasses can play a part in changing soil texture and surface roughness. Reducing soil binding benefits of roots, and exposing more surface area to rain-splash erosion generates more sediment supply to the streams.

According to (Gereta, *et al.*, 2001), grazing pressure in Mara river basin has greatly increased over years resulting in soil degradation and vegetation loss. This overgrazing and poor soil conservation effort has contributed to increased soil erosion and sedimentation, (Obando *et al*, 2006 and Hashimoto, 2008).

2.2.3 Forest

The clearing of forest is one of the most significant forms of catchment degradation. Several forms of land use impacts on the environment operate in the same direction, namely towards loss of ecological diversity. Land use change in developing countries directly affects ecological landscape functions and process with far reaching consequences for biodiversity and natural resources (Karim et al 2009). The greatest threat of unplanned land use changes is the loss and fragmentation of natural habitats. This includes clearing forests for cultivation, overgrazing, and draining wetlands causing habitat alteration usually from highly diverse natural ecosystems to far less diverse (often monoculture) agro-ecosystem. This is clearly most important threat, often related to land use changes on regional scale that involve great reduction in the area of natural vegetation.

Impacts of land use on biodiversity are reported from almost every country on earth. Although the present day forest removal is merely the continuation of a process initiated thousands of years ago, its rate is now probably far greater than at any time in the past. The expansion of agricultural land use has been associated with the loss of environmental amenities, such as biological diversity, ecosystem services, and aesthetic values (James, 1999; Ehrlich, 1988; Wilson, 1992; Wilcove et al., 1998).

On the global scale, the effects of deforestation extend to changes in the reflecting of the earth’s surface and to possible changes in the carbon dioxide balance, and hence on climate. On a more local scale, a major change in land use and cover usually affect hydrology and rates of soil erosion. These effects often extend beyond the locality directly affected, and may give rise to downstream siltation and flooding. The enlargements of fields by the removal of hedge and other boundaries, the drainage of wetlands, and use of fertilizers and pesticides all tend to reduce diversity by eliminating habitats and species.

Deforestation itself is not a problem and in fact may be a necessary condition for economic development. However, when deforestation occurs at rates which set into motion negative feedback effects which jeopardize both the ecological as well as economic systems both at the regional and local level, then it becomes imperative to understand why unsustainable deforestation activities are being pursued. A large number of studies point towards logging as the principal activity responsible for unsustainable deforestation in many parts of Africa. Along similar lines Anderson (1989) asserts in his study that logging was the primary cause of unsustainable deforestation in many parts of Central Africa and Southeast Asia while Repetto (1990) attributes commercial logging as the number one agent for unsustainable tropical deforestation.

Southgate and Pierce (1988), cite the small farmer as the main agent responsible for unsustainable deforestation activities. Southgate (1988) as well as Ives and Messel (1989) went on to cite population growth as the prime contributor to unsustainable deforestation, especially in tropical Africa. The study also highlights the pivotal role government agricultural and pastoral subsidies played in providing the incentives for deforestation to occur. Similarly, Mink (1993), concluded that agricultural expansion driven primarily by population pressures was the principal cause of tropical deforestation in the past.

2.2.4 Population pressure and Settlements

Kenya has been experiencing rapid population growth in the last decades, resulting in major changes in land occupation and use (Langat and Mwangata, 1994 and Schmidt, 1983). The areas that were previously under forest cover have now been occupied by human settlements (Obando, 2004).

Population density is not evenly distributed in most river basins. More humid areas within the basin are the most settled and developed than arid and semi areas. Hence, effects of population pressure are more in some areas than others. This population pressure accelerates deforestation, overgrazing, growth of urban centers and intensive cultivation on fragile areas. This leads to increased soil erosion, sedimentation land degradation and water pollution. Population pressure has also increased demands for food, fuel wood, construction materials and other social- economic needs. In order to meet these demands, vegetation cover has been cleared and agriculture has been expanded to marginal areas with steep slopes. In addition, population pressure has caused land fragmentation to uneconomical size and fallowing is no longer possible (Mather, 1992).

Population growth in the upper Mara river catchment has been consistently high for a number of years since independence and this trend is expected to continue. The population density of Nyongores river basin at the upper catchment was projected to be approximately 453 persons per km^2 by 2008 from 338 persons per km^2 in 1999 census. This population increase will substantially increase the demand for water and land resources in the catchment; hence land use planning is of concern in the control of land use and control of erosion (Kelly, 1996).

2.2.5 Urbanization

Urbanization contributes adverse pressures on the catchment environment. The construction of roads, building of houses, dams and reservoirs, power generation, quarrying, and establishment of industries have led to severe degradation of catchments ecosystems. These have brought about direct and indirect increase in demands on natural resources. Such activities are frequently carried out with political and economic imperatives, overriding technical and environmental considerations (Sichuan, 1985).

2.2.6 Poverty and Environment

Of the world's 7 billion people currently, about 25% of this live in absolute poverty with a further 20% living at subsistence levels (Leonard, 1993) and it is about one in every five children, who live in absolute poverty (UNEP, 1995). Irrespective of the choice of indicator, the absolute numbers of people living in conditions which are deplorable by any standard are rising. People can be easily pushed into poverty when the natural resource sector they depend on for basic needs is being degraded.

Poverty coupled with high population densities is frequently cited as a key cause of land degradation (WCED, 1987). There can be little doubt that the rural population will increase in the future. The evidence, however, suggests that population density in and of itself need not necessarily be a cause of land degradation (Boserup, 1965, Tiffen et al., 1994) and (Templeton and Scherr, 1999). Hence, it must be the context within which dense populations of land users exist that determines whether or not they mismanage land and water.

Studies have shown that poverty causes high population growths which in turn cause environmental degradation. The policy prescription of eradicating the poverty to avert the environmental degradation still holds because by alleviating the poverty, we take care of the population problem which in turn solves the environmental degradation.

Rural poverty cannot be isolated from rural rapid population growth rate and environmental degradation. Poverty is a self sustaining; self generating process that compels people to live in a way that destroys natural resources. Much of the rural environment degradation in Kenya today is as the result of the desperate search of the poor and the landless for such basic needs as fuel, food, shelter and water. Most of the time such poor people have nowhere else to go but go deeper into the forest and further up on the steep slopes to fragile and marginal land. The opening of such areas to arable agriculture often involves the clearing of vegetation cover thus exposing the soil to erosion hence the circle of population growth, rural poverty and resource degradation. According to Thompson (2002), the locally driven degradation has increased the vulnerability of thousands of families who have no alternative income in the Mara river basin.

2.3 Effects of Poor Catchment Land Use Planning and Management

2.3.1 Degradation of Water Sources

The natural availability of water in many river basins is not enough to meet present demands in the surrounding areas (United Nations, 1997). Shortages of water are most prominent in the areas with high population densities and water intensive activities such as irrigation, and too high rates of withdrawal, particularly for irrigation.

The people primarily affected by water shortages are the poor who can ill-afford the expensive and sophisticated technology needed for drawing water from distant sources or from deeper bore holes. Furthermore, most of these farmers are already living on the margin and any slight disruption to their present state could cause them to lose their crops and push them deeper into poverty.

In Kenya, the total annual surface and ground water potential is 19,590 and 619 Mm^3 respectively. However, total annual demand has grown from 2,073 Mm^3 in 1969 to 3,874 Mm^3 in 2000 and was expected to have reached 5,817 Mm^3 in 2010. About 12% of the country has reliable rainfall, while 88% experiences erratic rainfall and have evapo-transpiration rates higher than the amount of rainfall received (Ministry of Water and Irrigation, 2004). Degradation of watershed areas in the country is on the increase, resulting in diminished water resources. The main causes of watershed degradation stems out from the abuse and poor management of forests, soils, overgrazing, extension of settlements into watershed areas, uncontrolled felling of trees for fuel wood and other wood products.

2.3.2 Degradation of Water Quality

Water quality degradation is one of the prime indicators of catchment‘s health (Kelly, 1996). Each day individuals make land use choices that affect the quality and quantity of water in the river. Water pollution is a growing concern for the river basin management, as the basin becomes increasingly farmed, urbanized, industrialized, mined, irrigated and chemically fertilized, etc. People can be affected either directly by water pollution by drinking polluted water, or indirectly by eating aquatic products or irrigated crops that have assimilated water pollutants. Agricultural run-off and surface runoff constitute more diffuse sources of pollutants (Xia, 1998). Catchment soil erosion and pollutant runoff are the main origin of water pollution in the rivers (Wang, 2002).

According to NEMA, (2004), the main water quality threats to human health and environmental safety in Kenya include chemical fertilizers discharge, sewage, nutrients and toxic metals. Run-off from agricultural areas with high fertilizer and chemical contents pollute most surface and ground water sources.

2.3.3 Soil Erosion and Sedimentation

Soil erosion affects everyone, it affects man and its environment and it's as old as the earth itself (OMAFRA Staff, 2003). It is seen as the gradual washing away of soil through the agents of denudation which include, wind, water and man (Abegunde *et al* 2003). Erosion reduces productivity (Craft, 1992). Accelerated erosion as a result of human and animals activities is a major environmental and economical problem throughout the world. It is estimated that 0.3 to 0.5 percent (5-7 million hectares) of total world arable land is lost annually due to land degradation through erosion. Soil erosion impacts are felt on soil quality, agricultural productivity, movement of pollutants, ecological diversity in streams and wetlands, river channel change, infrastructure and building uses, and effects of flooding (Dlamini, http://www.sntc.org.sz/eearticles/soileleg.Html).

Whereas the drier parts of most river basins are slowly transformed into desert-like areas due to desertification, the wetter areas are subjected to heavy rain falls and water erosion. Intensive water erosion over a catchment area causes high volumes of silt to be discharged annually into the main river and its tributaries. The increase soil loss is caused by a substantial reduction in most catchment forest cover, combined with improper land use practices, disorderly reclamation, and denudation (Mou, 1991).

In a study on smaller catchment areas in the gullied hilly loess area of yellow river, Jiang *et al.*, 1981, and Douglas, 1989 found out that farmlands caused splash, rill, and shallow gully erosion over 57 to 67 percent of the catchment area, and thereby contributed to 44 to 59 percent of the total erosion. In Kenya, Mulei (1997), found out that soil erosion and sediment load estimates has increased from 55 000 t a year in 1965 to over 2 Million. Severe soil erosion results from surface runoff caused by the destruction of vegetation for charcoal burning, poor cultivation methods and over-grazing (Ongwenyi *et al.*, 1993). These have profound effects on the sediment loads transported by the rivers.

The combination of land use (that removes protective vegetation), erodible soils, and heavy rainstorms is the main cause of the high erosion rate on the river catchments (Brisma, 1999). The slope degree is also a significant determinant of soil erosion. It has been proposed that 15, 26 and 45 degrees are key threshold angles. For slopes greater than 15 degrees, surface runoff causes soil erosion; at 26 degrees, gravitational processes become more important; and at or above 45 degrees, erosion is most severe (Douglas, 1989; and Yinzhen, 1983). The severity of accelerated erosion is affected by slope, gradient, shape and length and by tillage practices. The soil that erosion carries off now totals 22 billion tons a year worldwide (Hanyona, 2001).

2.3.4 Soil Erosion in Kenya

In Kenya, erosion problems prevail in the highlands where lands are cultivated intensively, the rainfall is sufficiently heavy, and topography is steep (Ahn 1977). The National Environment Secretariat of Kenya(NESK 1976) stated that "erosion is an obvious problem and lack of a substantial remedy taken in the future can be preceded by nothing but a catastrophe." The report indicated that all highlands of Kenya have been experiencing intolerable erosion and that conservation activities are urgently needed. One reason for the problem was stated as the "maximum utilization of land which has left most surfaces completely unprotected by vegetative regeneration apart from the coverage provided by the crops in season.”

The magnitude of erosion in Kenya varies both temporally and spatially depending on the topography, runoff and proportion of basin that is cultivated (Hai et al, 2000). Table 2.1 shows examples of rates of soil erosion in different catchments within Kenya.

Table 4.1: Examples of soil erosion rates in Kenya (Source: Obando, 2009)

Area/ catchment type	**Rates of soil erosion/soil loss**	**Reference**
Semi arid southern Kenya	0.53-1.03cm/year	Wahome, 1992
Undisturbed forest catchments	20-30t/km^2/year	Hai et al, 2000
Agricultural land	10-100t/km^2/year	
Humid areas	0.001-0.02mm/year	Dune et al, 1978
Semiarid	0.01mm/year	
Forested highland drainage basins	0.02-0.03mm/year(20-30t/km^2/year)	Dune et al, 1981
Semi arid cultivated	40t/ha/year	Moore, 1978
Overgrazed	109t/ha/year	
Recently ploughed	6.1t/ha/year	
Old pasture	2.4 t/ha/year	
Forested undisturbed	18-26 t/ha/year	Moore, 1979
Semi arid lightly grazed	50-140 t/ha/year	
Semi arid overgrazed, intensively cultivated	1000 t/ha/year	
Semi arid	0.2-10 mm/year	Moore, 1983

Generally, studies have shown that land use type, soil characteristics, the vegetation cover and the slope aspects influence the hydrology. Rates also calculated from sediment yield (Dune et al, 1979) or using experimental plots (Lewis et al, 1985, Kilewe 1985, 1987, Omwega 1989, Obando 1990) generally indicate high rates of soil erosion and water losses, particularly from agricultural fields.

2.3.5 Soil erosion and Sedimentation in Mara river basin

Soil erosion is a serious problem on farmland particularly in the upper catchment of Mara river basin. Several research studies have been conducted in the area which indicates the problem of poor land use practices as causing increased soil erosion and sedimentation. Terer,(2005) in his study at Nyongores river catchment found out that land use practices in the catchment has led to increased soil erosion and suggested that indigenous knowledge systems can be utilized in the conservation of the catchment. Wamalwa, (2009) found out that, deforestation, pollution and excessive abstraction of water and low level of awareness among the locals are the major concerns in the catchment. The author concluded that, the transition to integrated management in the Mara watershed and other catchments in Kenya may not be smooth and is likely to be hampered, if barriers are not identified and addressed.

According to research by GLOWs (2007), deforestation has led to increased soil erosion and sediment loads in waterways, decreased soil fertility, loss of biodiversity, and change in hydrology. They found out that the degradation at the Mau Forest Complex annually releases tons of sediments that contain nutrients into the Mara River. Mutie et al, 2005 also in his study on the land use land cover changes in the Mara river basin found out that 23% of the forest in the basin has been lost and population has increased by 25% between 1986 and 2002. They pointed out that these land use changes and increased agricultural activities in the catchment are responsible for reduced flow and quality of the Mara River. The nesting sites for spawning fishes in the Mara wetland downstream are under threat by sedimentation resulting from soil erosion upstream (Chitamwebwa, 2007; Sobo, 2002; Bancy, *et al.*, 2008 and Mati, *et al.*, 2005). In addition, soil erosion and run-off from the upper catchment have been associated with sediment build-up at the mouth of the river, increased turbidity, decreased soil fertility, and contamination of the river due to pollutants into the water system (Mati, et al, 2005). Moreover, increased inputs of fertilizers, such as nitrogen and phosphorus, have contributed to the eutrophication of the river and in the Lake Victoria, (Heck, 1993; Muir, 2007).

Although several studies have associated soil erosion and sedimentation with the deterioration of water resources in the upper basin, there is little documentation on the rates of sediment concentration from specific land use types and sediment load on major tributaries. Yet the need for such documentation is acute because it is precisely in the sub catchments in the upper catchment of the basin that most of the human population resides, practices unsustainable farming and clearing of vegetation for agricultural expansion.

Very few studies have attempted to study specific land use type in relation to the amount of erosion or sediment yield contribution. Hence, research on land use impacts on the rates of soil erosion and estimates of sediment contributions from sub catchments will offer information on soil erosion monitoring and control. The rates of erosion and runoff can be used for planning and management of the catchment to improve the quality and quantity of water in the river as well as the productivity of agricultural products in the catchment (Mulei, 1997).

2.3.6 Methods of Estimation of Soil Erosion

Soil erosion may be assessed by applying different methods on various scales. Hudson (1993) made a comprehensive review of most available methods to measure soil loss and runoff from catchment and from plots. The large variety of sediment yield estimating methods can be classified into two broad categories: (i) methods based on direct measurement and, (ii) mathematical methods. Only those methods based on direct field measurements are considered as rigorous approach while mathematical methods are trend indicators at best (U.S. Army Corps of Engineers, 1989).

Direct measurement method is based on direct measurements of hydrologic, hydraulic, and sediment parameters in the study area. There are three major subcategories. These are; stream sampling, reservoir sedimentation investigations, and regional analysis (U.S. Army Corps of Engineers, 1989). For the purpose of conservation- effective land-use planning, there is strong merit in assessing the extent of both existing and potential erosion. The extent of existing erosion may be determined directly by measuring soil losses from fields (catchments) or parts thereof (sub catchments) both of which are defined by specific boundaries or by indirect estimates of soil loss from the sediment loads of rivers (Hudson 1971). Qualitative surface reconnaissance surveys can also yield much information, which, although usually subjective, is valuable for differentiating the several forms of erosion.

2.4 Theoretical Framework

2.4.1 Introduction

The river basin is a closed geographic boundary system which permits various sectors and users in a basin to work together: agriculture, soil and water conservation, industry, settlements, and communities (EC, 1998). Hence, this study is based on the integrated approach that considers the various stakeholders in the riverine management.

The literature on catchment management reveals a comprehensive framework of ideas but which often read as a checklist of options at the river basin, regional and national level. The challenge is to use a flexible approach at the level of the river and tributary system' to create relevant meaningful strategies applicable to the stakeholders at these lower levels. To achieve this, a process of analyzing the situation at hand, selecting a mix of solutions from the comprehensive range of options and then elaborating effective lower level strategies is required. Hence, adaptive resource use management approach is the most appropriate theory this study will be based on.

2.4.2 Adaptive Resource Use Management

Adaptive management can more generally be defined as a systematic process for continually improving management policies and practices by learning from the outcomes of implemented management strategies. Adaptive management has been proposed as a way of dealing with uncertainty and change (Holling 1978). It aims at developing robust and flexible management strategies that perform well under different possible futures and can be modified if necessary. It acknowledges that current knowledge will never be sufficient for future management (Pagan and Crase 2004).

Adaptive management requires a process of active learning by all stakeholders, and continuous improvement of management strategies by learning from the outcomes of implemented strategies and policies (Geldof 1995, Pahl-Wostl 2004, 2007). The learning process is not a matter of random trial and error, but a structured, cyclical process, involving 1) integrated assessment of current problems and possible solutions as perceived by different stakeholders, 2) setting goals, 3) formulation of policies that are hypothesized to contribute to reaching the goals, 4) implementation, to test the hypotheses, through 5) systematic monitoring and evaluation of policy outcomes.

By involving all relevant stakeholders in the assessment and goal-setting stages, an overview of relevant technical knowledge, values, and interests can be obtained. Such an overview allows for designing “experiments” that minimize the risk of degradation of the catchment, in particular irreversible change, and failure of ecosystem services. Furthermore, joint policy formulation, implementation, and evaluation may improve learning and increase support for policy changes.

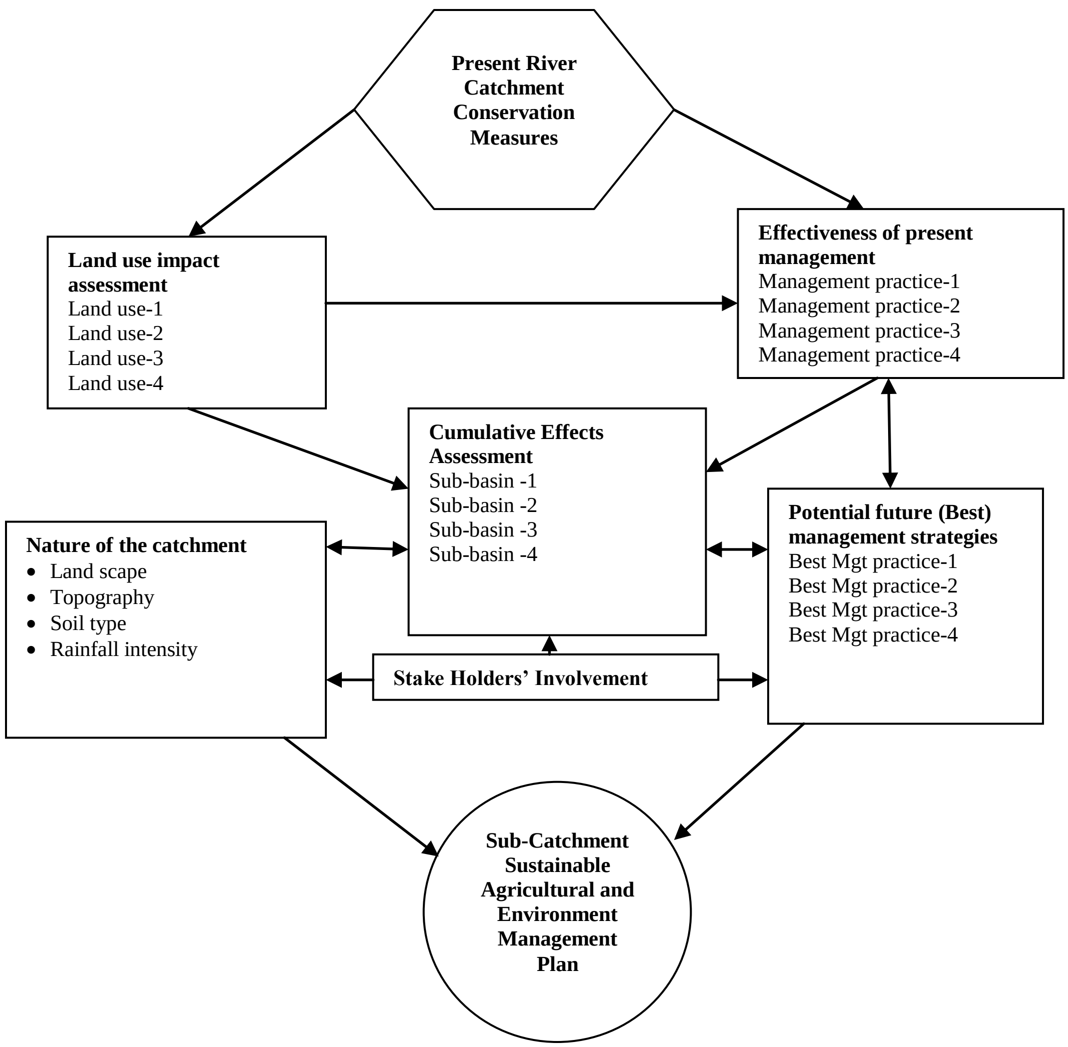

Figure 4.1: Theoretical Framework of Adaptive River Catchment Management (Source: Author, 2010)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Design

The study adopted a case study approach type of research design where both primary and secondary data was collected. First, an intensive reconnaissance survey of the area of study was conducted with the aim of selecting representative sites for sampling. During the reconnaissance; topographical maps were scrutinized, observations, photography and key informant interviews were undertaken. Major land use types, natural features such as forests and rivers confluences as well as roads junctions were marked using a global positioning system (GPS) which was later used as ground control points.

3.2 Sampling Criteria/Design

The major tributary of Nyongores River that drains the upper catchment was purposively targeted for sampling. The upper catchment was selected because of its high population density, slope terrain, fertile soil and intensive cultivation and favorable climate with high rainfall twice a year. Sampling points for collecting water samples were identified at the upstream and downstream of each of the tributaries namely; Ainap-nge’tunyek, Chepkositonik, Kagawet and Kiprurugit. The rivers were sampled weekly during rainy season for a period of four months (December 2009, January 2010, February 2010 and March 2010) for their relative contributions of sediment into Nyongores River.

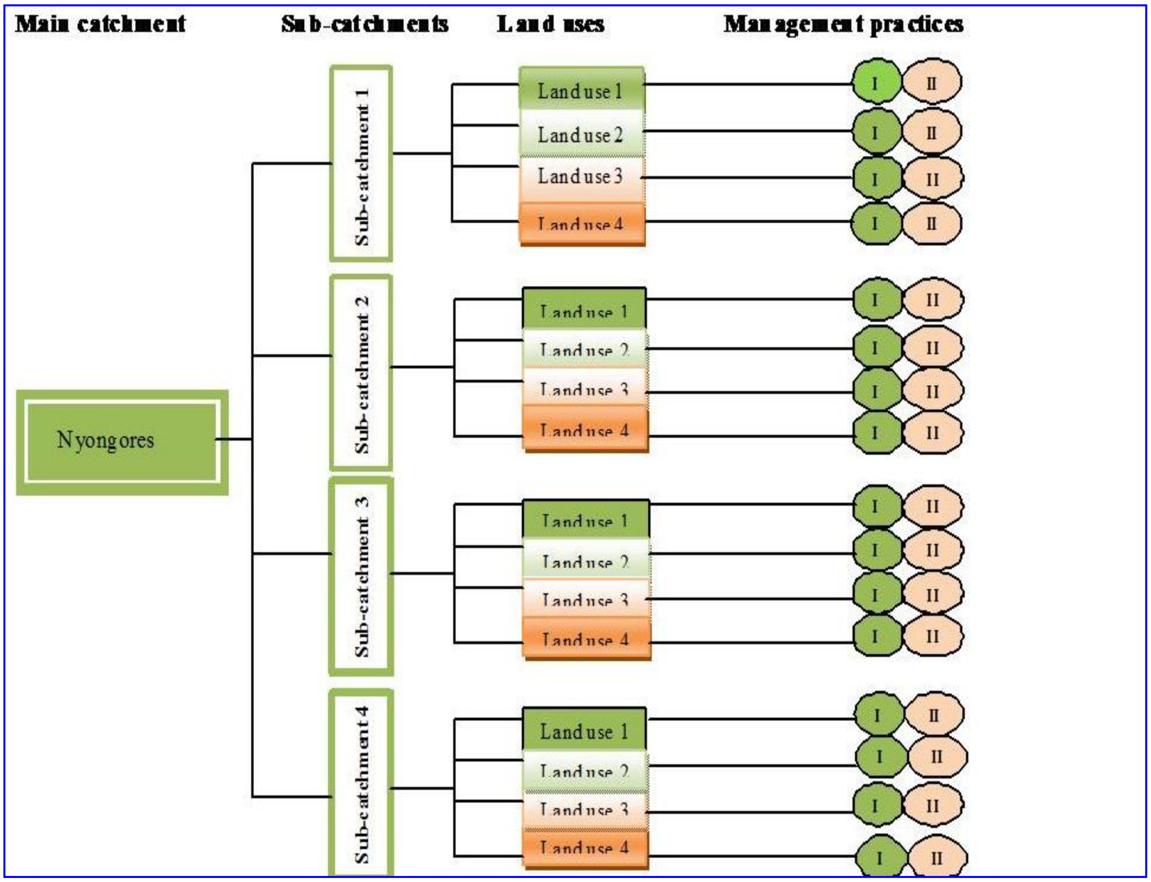

Figure 3.1: Figure Showing the Sampling Framework of the study (Source: Author, 2010)

The study sampling frame work is presented on figure 2.2. where it shows the main river catchment (Nyongores River catchment) its sub catchments 1-4 (Ainopng'etunyek, Chepkositonik, Kagawet and Kiprurugit) and land uses under each sub catchment and their management practices which were either with appropriate management practices (I) or poor management practices (II).

3.3 Data Collection Procedures

During the data collection, both quantitative and qualitative primary and secondary data were collected by employing GIS and water sampling techniques. In addition, survey based interviews, structured questionnaires as well as field observation was undertaken. Each of the technique used is discussed as follows:

3.3.1 Land Use Mapping

The land use types on the catchment were obtained from the Landsat satellite images of November, 2009 acquired from the Regional Centre for Mapping of land resources for development in Nairobi. First, land use/land cover information was obtained during the field visit as part of a ground truthing exercise and it included observation of different land use/cover within the area of study. The exact locations of the different land use types were identified and precisely marked using a Global Positioning System (GPS). The geographic positions of these land use types were input into ArcGIS software to check against the information on the land use types obtained from the classified satellite image.

In addition to Landsat images, field surveys were carried out to observe different existing land use/cover and their associated soil and water conservation practices. Interviews and discussions with stakeholders were also conducted to strengthen the image analyses process.

Four broad classes of land use types were identified in the area of study: Forest, tea cultivated land, maize cultivated land and Grassland.

3.3.2 Water Sampling Procedures

One-liter of water samples were hand-collected from the identified sites of the stream. The samples were drawn from approximately mid-depth of flow. Bottles were rinsed with the stream water, shaken vigorously, and emptied before refilling it for analysis.

A. Materials for Water Sampling

i. stop watch
ii. Tape measure
iii. Meter stick

iv. Water proof note book and pencil

v. Calculator

vi. Collection bottles

vii. Filters and Filtration apparatus

viii. Graduated cylinder (0.5 or 1.0 L)

ix. Flow meter- for measuring river flow velocity

B. Samples Collection Procedures

1. Clean bottles were used to collect the water samples
2. The samples were hand collected from the river
3. The samples were obtained from the upstream of the currents.
4. Sampling from disrupted area were avoided
5. A composite samples were collected and the average taken since sediment may not be uniform

C. Determination of Mean Stream Discharge

To Measure the Discharge of River, the following measurements are required.

- Area of Flow
- Average Velocity of Flow

(i) *Area Flow Measurements and Calculations*

To Calculate Area of Flow, Simple Segment Method was used as follows

The wetted width (whole Width) of the river was measured; recorded and divided into a number of equidistant segments at length, i.e. L_1, L_2, L_3, L_n (Length of segments).

The depth at each segment were measured and recorded as d_1, d_2, d_3, (mean depth of segment). Now, the Area of Flow is the Sum of all Area of Segments.

$(L_1d_1+L_2d_2+L_3d_3.................)$

(ii) *Velocity measurements and calculations*

Velocity measurements were undertaken by use of a current meter. G.O. Environmental Flow meter model 2030R series type was used for flow measurements in the rivers.

(a). Velocity Measurement Procedures

- Select the part of the channel to be measured. The ideal is a stable stream that does not significantly alter course, depth or flow with minor environmental changes. The flow within the channel should run parallel to the stream channel orientation and not be interrupted by backwater flows or structures.
- Develop a cross section of the stream. Measure the width of the stream, extending the cross-section to a point on the opposite bank. Check the depth at every foot and record the reading.
- Stretch a tape across the stream from the near bank to the far, so that one-meter intervals can be read quickly. Cross the stream at the tape and, at each foot mark beginning on the near bank, take a depth measurement and record this information, together with the distance from the near bank.
- Use the depth and width data to draw a rough profile for the stream. Return to the near bank and calculate 60 percent of each depth measured.
- Cross the stream again, lowering the flow meter to the "60 percent of depth" point determined previously. Hold the flow meter in the water for 40 seconds,

then remove the meter and record the measurement. Average the flow data obtained to obtain an average flow.

(b). *Discharge calculation*

The data obtained from velocity measurement and area of cross-section, was then used to calculate the discharge;

Discharge (Q) =Area of Flow (A) × Average Velocity of Flow (V)

Where Q= discharge (m^3/s), V=average velocity (m/s)

D. Determination of Total Suspended Solids (Sediment concentration)

To determine sediment concentration, a known amount of the water sample collected was filtered.

(a). *The Filtration process*

Filtration procedure followed Standard Methods (APHA, 1995). Whatman Glass Microfiber Filters (GF/c) was used to filter the sample. Dry weight was recorded and up to 500ml of sample was filtered using a graduated cylinder, Nalgene hand pump, Millipore filter tower, and a filter flask. The graduated cylinder and filter tower were thoroughly rinsed using de-ionized water to ensure the entire sample was washed through the filter. Using forceps, filters were carefully put into Petri dishes, closed and date and site number marked on them. The Filters were taken to Moi University, School of environmental studies lab where it was oven-dried and reweighed. All masses were measured using AA series Electronic Analytical balance accurate to 0.0001 grams.

(b). *Calculation of TSS*

An equation of total suspended solid was used

TSS (g/l) = (A – B)/C

Where, A – final dried weight of filter in g

B – Initial dry weight of the filter in g

C – Volume of water filtered in L

3.3.3 Estimation of Soil Erosion through sediment concentration

In order to estimate soil erosion from the tributaries, as well as from identified land use within Nyongores river catchment. Water sampling and sediment yields were carried out, where water samples were collected from the stream, filtered and taken for laboratory analysis for sediment load. The river flow velocity, depth and width of the stream were measured for computation of the river discharge.

a) Sediment Estimation from Major tributaries

Four major tributaries were purposely selected to compare their sediment contributions to Nyongores River. Sediment collections were conducted through water sampling on purposely selected points along each tributary. The identified points of water sampling were at the upstream where effects of land use activities were minimal i.e. as it emerges from the source and downstream before it discharges into the main river respectively. Water samples and stream measurements were undertaken weekly during rainy season for a period of four months (December 2009, January 2010, February 2010 and March 2010). This was to enable calculation of monthly and annual sediment yield each tributary delivers into the river. The results obtained was then used as a comparative measure of rates of soil erosion, within a given land use and its management practices.

b) Sediment Estimation under Identified land use types

Four major land use types in the catchment were identified for analysis of its contribution in soil erosion. Intensive surveys were undertaken to identify representative land use types where similar land use type occurring on both sides of a stream was selected. Under each land use type, two categories were selected that is one with best and one with poor management practices as shown in the Table 3.1 below. Water Sampling was undertaken at the river course before and after each land use type.

Table 4.2: Land use classification based on existing management practices

Land Use type	Category	Management Type
Forest	I	Best Management Practices
	II	Poor Management Practices
Tea	I	Best Management Practices
	II	Poor Management Practices
Maize	I	Best Management Practices
	II	Poor Management Practices
Grassland	I	Best Management Practices
	II	Poor Management Practices

3.3.4 Survey on Land use management practices

Primary data from farmers' perceptions and land use management practices were obtained through field survey where interviews, administration of structured questionnaires, observations and photography were applied to obtain information needed.

Information on existing land use types, soil conservation, extent of soil erosion, physical effects of soil erosion and dominant types of erosion were observed and photos taken. Individual farmers views were obtained through structured questionnaires. To ensure representative data was collected, purposive sampling was applied to select farmers and key informants for interviews and administration of questionnaires.

The researcher used semi-structured questionnaires with both closed and open ended questionnaire concerning soil erosion and land use management practices. All the questionnaires were self-administered by the researcher to avoid misunderstanding of the questions by respondents. To obtain the population sample for questionnaire administration and interviews, the table by Glenn D. Israel, 2003 was referred to. Since the population of the study area is 567,415 (KNBS, 2009) and the desired confidence level is 95% with a ± 10% precision then the sample population frame was 100 farmers as shown in the Table 3.2.

Table 4.3: Table Showing Sample Population (Source: Israel Glen 2003)

Sample size for ±3%, ±5%, ±7% and ±10% Precision Levels Where Confidence Level is 95% and P=.5.				
Size of Population	*Sample Size (n) for Precision (e) of:*			
	±3%	±5%	±7%	±10%
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	98
7,000	959	378	198	99
8,000	976	381	199	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	**100**
>100,000	1,111	400	204	100
a = Assumption of normal population is poor (Yamane, 1967). The entire population should be sampled.				

From Table 3.2, 100 farmers were randomly selected within the study area. These population samples were derived randomly based on ratio of area covered by each of the four main sub catchments (Ainopng'etunyek, Chepkositonik, Kagawet and Kiprurugit) the upper catchment of Nyongores River as indicated in Table 3.3.

Table 4.4: Number and Percent Respondents Sampled Per Selected Sub-Catchments (Source: Author, 2010)

Nyongores River Catchment			Percentage (%)	
Sub Catchments	**Sub-locations**	**Number of Respondents**	**% within sub- catchment**	**% of the Total**
Ainopnge'tunyek	Masese	9	31	**30**
	Mugango	12	41	
	Ilyo	8	28	
	Sub Total	**29**	**100**	
Chepkositonik	Kiromwok	13	36	**36**
	Merigi	15	42	
	Motigo	8	22	
	Sub Total	**36**	**100**	
Kagawet	Kyogong	9	43	**21**
	Kipsegon	7	33	
	Goitab Silibwet	5	24	
	Sub Total	**21**	**100**	
Kiprurugit	Silibwet	6	43	**14**
	Chepng'aina	5	36	
	Chepkosa	3	21	
	Sub Total	**14**	**100**	
	TOTAL	**100**	**100**	**100**

Semi-structured questionnaires were administered to the 100 farmers sampled. All the questionnaires were self administered by the researchers to avoid misunderstanding of questions by the respondents. Some questions were translated into the local language (Kipsigis language) for easy understanding by the respondents. The researcher also ensured that respondents had the opportunity to ask questions at the end of the interview. Following the interviews with the farmers and stakeholders, the researcher was able to record causes, effects and signs of increased soil erosion, existing interventions and preferred interventions. A sample of the questionnaires administered is attached as Appendix I.

In addition, key informant interviews were conducted with the purposively selected stakeholders who included Agricultural Extension Officers, District Environmental Officer, Community social workers, water users association representatives, WARMA officers and KFS officers, Community Forest Associations representatives, provincial administration officers of each of the sub-catchments and representative of registered self help groups within the study area. The key informant interviews were aimed at gaining an insight into the agricultural land use history, present management practices and to get explanation on evolving patterns of livelihood activities in relation to land use as well as the interpretations of the reasons for adaption of existing land use practices. This was also done to cross check individual answers on the questionnaires.

3.3.5 Secondary sources of Data

Relevant literature was sought from both published and unpublished sources such as textbooks, journals, newspapers, sessional papers, policy papers, and theses on topics related to land use, soil and water conservation. The materials were obtained from Maseno and Moi University libraries, various websites, Tea Research Foundation and international research and conservation organizations such as GLOWS and WWF Mara River Basin initiative, Mara River Water users association, government organizations and ministries such as National Environment Management authority (NEMA), Water Resource Management Authority (WRMA) and district agricultural office.

The secondary data gave an insight into the research topic and also facilitated the comparisons of a variety of researches on land use effects on soil erosion and catchment conservation strategies. The secondary data also assisted in obtaining rainfall data and river discharge data for Nyongores River.

3.4 Data Analysis

Satellite images of the Landsat 5 ETM image path 169 and row 61 (recorded on 31/12/2009) which was already geo-referenced and corrected for sensor irregularities were used. This was analyzed Using ArcGIS version 9.3 where supervised classification procedures were implemented to classify the Landsat images into the established land use types.

The study adopted the land cover/land use type classification scheme developed by Anderson Land cover scheme (Anderson et al 1979). This scheme was considered because it was found to be compatible with the land use characteristics of the study area. Four land cover classes were considered for this study namely; Forest land, Tea areas, Maize land and Grasslands. Each class was recognized using information obtained from the field consisting of locations of land use/land cover types precisely marked using GPS.

The filters containing sediment concentrations of each of the tributaries were weighed and the results recorded each week for eight consecutive weeks. The sediment weights, river velocity and manually calculated river discharge data were entered into excel sheets for analysis. Data analysis was done by using descriptive statistics such as percentages and mean (averages). The results were presented in the form of tables, charts and graphs.

Questionnaires were first arranged, authenticated and were then classified. The information from each questionnaire was entered into Statistical Package for Social Sciences (SPSS) and Excel sheets for storage and analysis. Descriptive data analysis was done by running the stored data in SPSS sheets using descriptive statistics on computer command options of frequencies and cross-tabulations (cross tabs).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter therefore presents the findings and discussion on: - (i) existing land uses in Nyongores River Catchment, (ii) sediment concentration in streams flowing through identified land use types, (iii) sediment load in the major tributaries to Nyongores River at the upper catchment (iv) existing land use management practices for soil erosion control within NRC and (v) proposed appropriate land use management practices for consideration in the catchment. The results were obtained from GIS mapping, water sampling, questionnaires/interviews, secondary sources of information.

Through the GIS mapping the study determined the existing land use types within the study area. Sampling of streams under the identified land use types and in the main tributaries to Nyongores River enabled the determination of sediment concentration and load into the river. The data collected through questionnaires and interviews gave an insight on the dominant land use types within the study area, causes of soil erosion, effects of soil erosion and existing interventions for controlling soil erosion as well as the perceptions among the farmers towards adoption of integrated catchment management approaches.

4.2 Existing land uses in Nyongores River Catchment

4.2.1 Introduction

GIS land use mapping was employed using Landsat satellite images of November, 2009 to identify existing land use types in the study area. The upper catchment of the

Nyongores River is covered by some parts of Mau forest complex, cultivated land (land under tea and maize crops) and pasture lands for livestock as well as bare lands.

4.2.2 Land use mapping of Nyongores River Catchment

Analysis based on GIS techniques on land use/cover for Nyongores river catchment using Landsat satellite images for November, 2009 indicates that maize covered 43.2% of the catchment, grasslands covered 33.6%, tea lands covered 16.1%, forest land covered 4.9% and bare lands covered 2.2% of the catchment as shown by Figure 4.1 and Table 4.1.

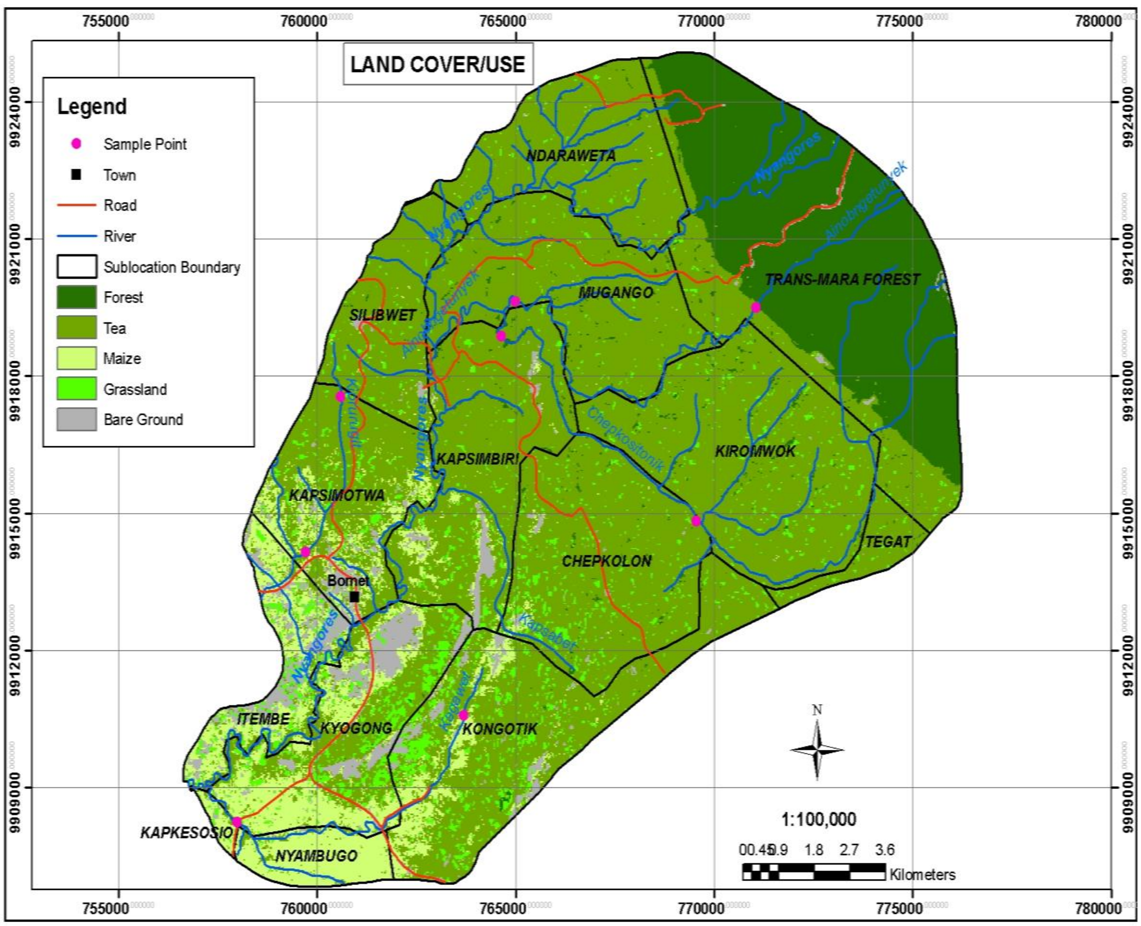

Figure 6.1: Land use/cover Map of Nyongores River Catchment (Source: Author, 2009)

Table 6.1: Area and percentage cover of existing land use type in Nyongores River Catchment (Source: Author, 209)

Land use type	Area (km^2)	% coverage
Maize	145.411	43.2
Grasslands	113.098	33.6
Tea	54.193	16.1
Forest	16.493	4.9
Bare lands	7.405	2.2
Total	**336.600**	**100.0**

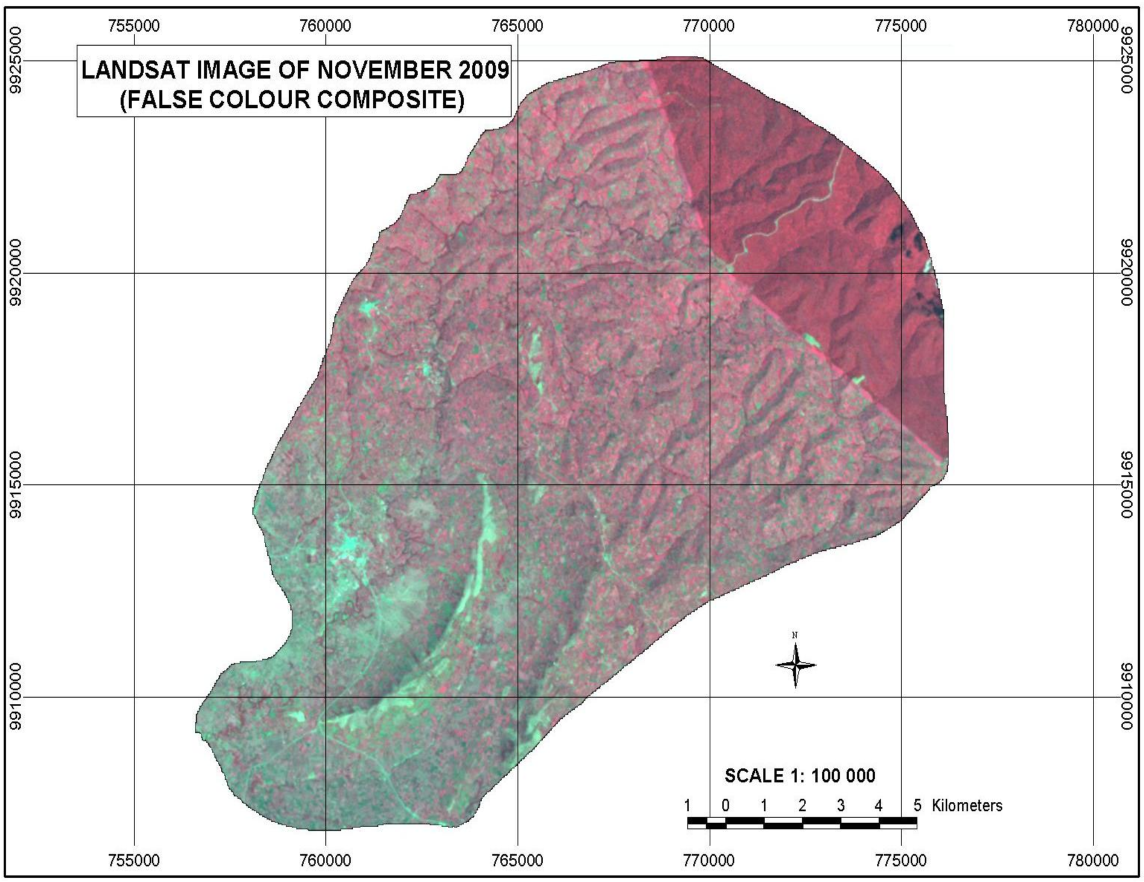

Figure 6.2: Landsat Image – False colour composite (Source: Author, 2009)

4.2.3 Major Land use types in NRC

Table 4.1 indicates that Nyongores River catchment had five land use/cover types namely maize, grasslands, tea lands, forest land and bare lands. Each of the land use type is discussed as follows:

(a) Maize cultivation

Table 4.1 shows that maize growing lands within Nyangores River catchment covers 43.3% of the catchments. Therefore land use on maize cultivation was the dominant land use type within Nyangores river catchment. The results of the study agrees with EPZA (2005) that the bulk of maize production in Kenya is carried out by small scale farmers mainly found in some parts of the Rift Valley Province. Most of the maize growing areas particularly in the southern part of Rift Valley are on fragile ecosystems such as encroached forests, steep slopes, hill tops and along the banks of rivers and streams. The results of the study also agrees with DAO (2010) that NRC has the highest potential for maize production in the Bomet region if farmers overcome the challenges of increased soil erosion, reduced soil fertility and moistures stress.

(b) Grassland/pastures

Table 4.1 shows that 33.6% of NRC was covered by grasslands. The grasslands are used for grazing by livestock kept by farmers such cattle, goats, sheep and donkeys in some households. DLPO (2008) recommended that livestock carrying capacity for Bomet District is one livestock unit per acre in the lower zones of Nyangores river catchment and two livestock units per acre in the upper zones of the catchment. However, interviews with DLPO and Agricultural Extension officers revealed that the current livestock carrying capacity is about five (5) per acre in the upper zone of Bomet and about eight (8) livestock per acre in the lower zones of Nyongores river catchments. This indicates that the area is overstocked and has led to overgrazing in the catchment grassland, foraging on forests and young trees by the livestock.

(c) Tea cultivation

The study established that tea cultivation covered 16.1% of NRC (Table 4.1). According to the EPZA, (2005), tea growing have expanded rapidly since independence in 1963, with 62% of it being produced by the smallholder growers who process and market their crop through their own management agency, Kenya Tea Development Agency (KTDA) Ltd. Bomet is one of the leading districts in production of tea in Kenya by small scale farmers (KTDA, 2006). However, according to Mati et al (2008), tea growing in the upper catchment of Mara river basin has expanded by 214% between 1973 and 2000. The expansion of tea cover was at the expense of forest which reduced from by 32% within the same period.

The study established that tea growing in the NRC mainly covered the upper catchment along the borders of Mau forest complex. The Kenyan government had established planted tea along the border of the forest of approximately 150 metres in width known as Nyayo Tea Zones that was aimed at protecting the forest from further encroachment into the forest besides generating income to the government. This is followed by small scale tea growing farmers. According to Eitzinger et al 2011, on future climate scenarios for Kenya's tea growing areas, the area will remain suitable for tea growing in 2020 and 2050 provided appropriate management practices are put in place.

(d) Forest land

The study established that forest covered 4.9% of NRC (Table 4.1) indicating that it was the fourth dominant land use type in the catchment. Figure 4.1 shows that the forested area in the catchment is part of Transmara forest which is one of the blocks of Mau forest complex. The forest has undergone several stresses as the people living in the area encroaches it for cultivation, charcoal burning, fire woods and indiscriminate logging

(Mati *et al* 2008). This has left the once pristine forest with few stands of indigenous trees some kilometers from its border with the settlement areas.

The study established through interviews with CFA representatives that there existed timber milling industry at Masese area within Bomet central division that contributed to destruction of the forest by removing indigenous hardwoods which were its main raw materials. The CFA representatives also reported that although the industry provided employments to the locals, it led to the degradation of the forest cover within the upper catchment of NRC.

(e) Bare land

Table 4.1 indicates that the bare lands in NRC covered 2.2%. However, this land use type was in very small patches scattered all over the study area. The bare areas included; areas that were ploughed in readiness for planting of crops, roads, footpaths and degraded or eroded areas.

4.3 Sediment concentration in streams flowing through identified land use types

4.3.1 Introduction

The land use types identified by the study namely; maize, grassland, tea and forest were further analyzed to establish their effects on soil erosion. Each of the land use type was each further categorized into two, that is, Land use (I) and (II) based on the existing management practices. Land use (I) represented land use with appropriate management practices while land use (II) represented land use without appropriate management practices (see appendix II for selection criteria). Streams flowing under each land use type were sampled weekly for a period of two months to compare their sediment concentration.

The study purposively selected streams flowing through uniform land use type for water sample collection and analysis to establish sediment concentration. This was done to determine the amount of sediment each land use type contributes into the stream. Both land use type I (with appropriate management practices) and type II (without appropriate management practices) were sampled separately. The sampling was carried out at the upper and lower parts of each stream of approximately similar length. The results of sampling in the streams are as shown in Table 4.2 and Figure 4.2.

4.3.2 Relationship between Land use types and sediment concentrations

Table 4.2 presents results for sediment concentrations from the upper and lower sections of the streams sampled under different land use types for a period of eight (8) weeks. The ranges of sediment concentrations for lower and upper section of each land use are presented in the table below where week 1 to week 8 represents time under different weather conditions and results of sampled sediments concentrations at each sampling points.

Table 6.2 Sediment Concentration of Streams Under Different Land Use Types (Source: Author, 2009)

Land use type	Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Averages
Forest I	Upper	0.411	0.398	0.387	0.394	0.329	0.323	0.317	0.342	0.363
	Lower	0.416	0.434	0.414	0.4	0.364	0.357	0.344	0.363	0.387
	Range	**0.006**	**0.036**	**0.027**	**0.006**	**0.035**	**0.034**	**0.028**	**0.021**	**0.024**
Forest II	Upper	0.465	0.484	0.498	0.532	0.526	0.503	0.512	0.518	0.505
	Lower	0.687	0.932	0.723	0.768	0.714	0.752	0.779	0.715	0.759
	Range	**0.222**	**0.448**	**0.225**	**0.236**	**0.188**	**0.249**	**0.267**	**0.197**	**0.254**
Tea I	Upper	0.392	0.372	0.418	0.392	0.364	0.369	0.361	0.374	0.380
	Lower	0.402	0.435	0.431	0.404	0.424	0.421	0.398	0.402	0.415
	Range	**0.01**	**0.063**	**0.013**	**0.012**	**0.06**	**0.052**	**0.037**	**0.028**	**0.035**
Tea II	Upper	0.446	0.478	0.481	0.518	0.478	0.502	0.47	0.476	0.481
	Lower	0.468	0.485	0.526	0.561	0.643	0.571	0.612	0.643	0.564
	Range	**0.022**	**0.007**	**0.045**	**0.043**	**0.164**	**0.069**	**0.143**	**0.168**	**0.083**
Maize I	Upper	0.453	0.482	0.536	0.475	0.569	0.604	0.593	0.578	0.536
	Lower	0.492	0.548	0.605	0.545	0.659	0.63	0.658	0.636	0.597
	Range	**0.039**	**0.066**	**0.068**	**0.07**	**0.09**	**0.026**	**0.065**	**0.057**	**0.060**
Maize II	Upper	0.648	0.643	0.742	0.779	0.694	0.812	0.707	0.733	0.720
	Lower	0.85	0.922	1.006	1.048	0.945	1.128	0.961	0.972	0.979
	Range	**0.202**	**0.279**	**0.265**	**0.269**	**0.251**	**0.316**	**0.254**	**0.24**	**0.260**
Grassland I	Upper	0.448	0.483	0.479	0.524	0.513	0.733	0.671	0.636	0.561
	Lower	0.479	0.506	0.517	0.594	0.548	0.738	0.695	0.729	0.601
	Range	**0.031**	**0.023**	**0.038**	**0.07**	**0.034**	**0.006**	**0.024**	**0.093**	**0.040**
Grassland II	Upper	0.516	0.632	0.686	0.648	0.649	0.797	0.596	0.621	0.643
	Lower	0.673	0.697	0.745	0.732	0.752	0.928	0.755	0.767	0.756
	Range	**0.158**	**0.066**	**0.06**	**0.083**	**0.103**	**0.131**	**0.158**	**0.146**	**0.113**

Table 4.2 shows that the average sediment concentrations for each of the land use types were as follows:- Forest I were 0.024 g/l, Forest II were 0.254 g/l, Tea I were 0.0.035 g/l, Tea II were 0.083 g/l, Maize I were 0.06 g/l, Maize II were 0.260 g/l, Grassland I were 0.040 g/l and were Grassland II 0.113 g/l. The results indicates that land uses type II had higher sediment concentration than land uses type I. Streams flowing through Forest I had the least amount of sediment concentration compared to any other type of land use while streams flowing through Tea I land use type had the second least amount of sediment concentration. On the other hand, streams flowing through land use type under maize II had highest amount of sediment concentrations than any other land use type.

The comparisons of sediment concentration for each land use type during each of the eight weeks are shown by Figure 4.2.

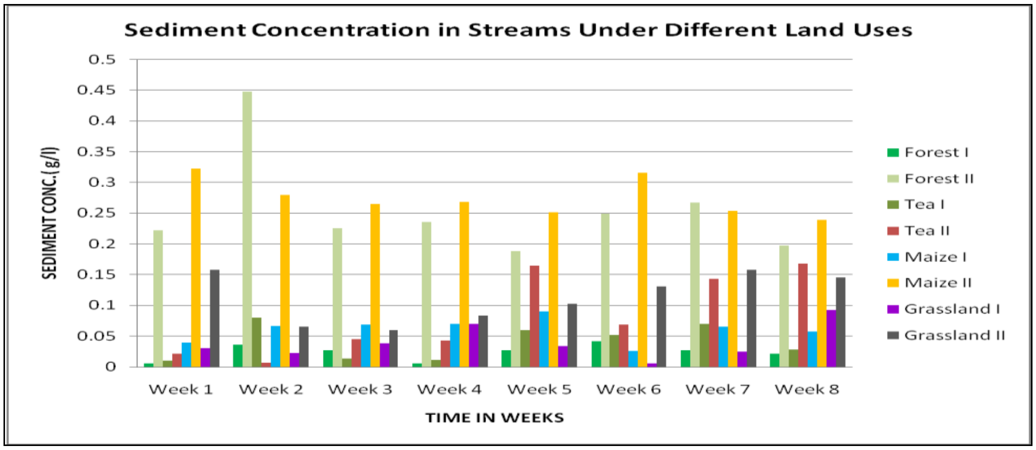

Figure 6.2: Comparison of weekly sediment concentration in streams under all land use types :

4.3.3 Sediment concentration in streams under each individual land use type

a) Forest land use

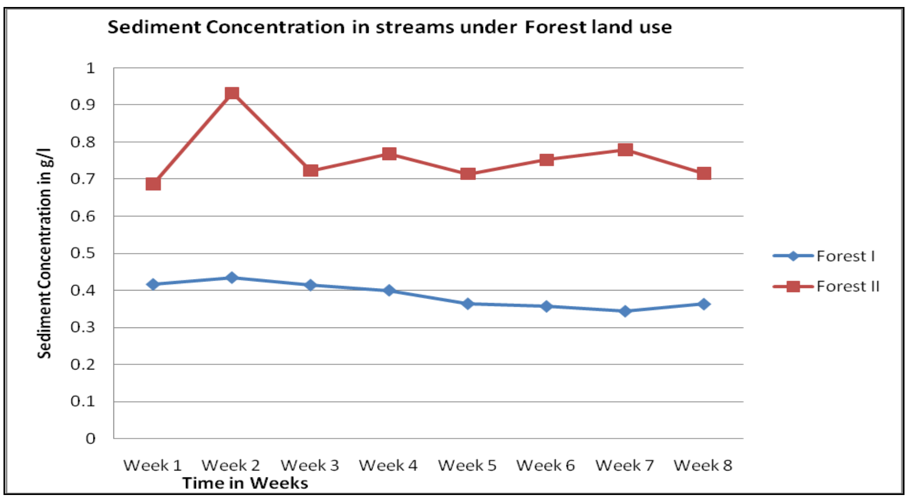

Figure 6.3: Sediment concentration trends for forest land use types for 8 weeks

Figure 4.3 shows that Forest I had a lower mean sediment concentration throughout the the 8 weeks of sampling period than forest II. The results also shows that during the second week of sampling, the sediment concentration for Forest II drastically increased by 50.4% (from 0.222g/l in the first week to 0.448g/l in the second week). The increased was attributed to the land slides that occurred along the banks of steams within the degraded forest having loose soil that could be easily washed away by heavy rainfall during the period.

b) Tea land use type

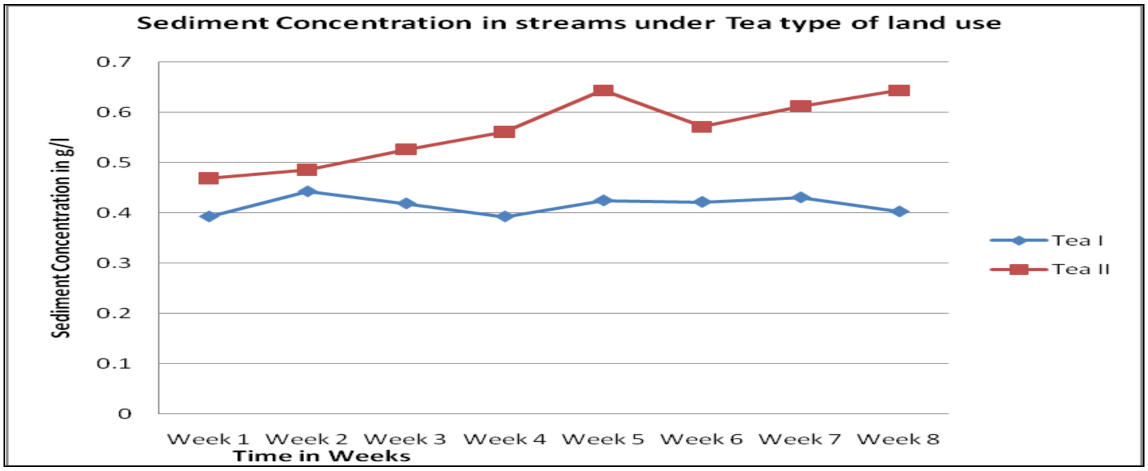

Figure 6.4: Sediment concentration trends for tea land use types for 8 weeks (Source: Author, 2010)

Figure 4.4 indicates that the trends of sediment concentrations in streams under Tea II land use for eight (8) weeks was higher than trends of Tea I type of land use. The range of sediment concentration between Tea I and Tea II land use types as depicted by curves in Figure 4.3 was moderarely lower compared to those of Forest I and II land use types. The curves further indicates that the sediment concentrations under Tea I were moderately constant where as sediment concentration for Tea II were gradually increasing during the eight weeks period. This suggest that tea under poor management practices will continue contributing more sediments if no interventions are put in place.

c) Maize land use type

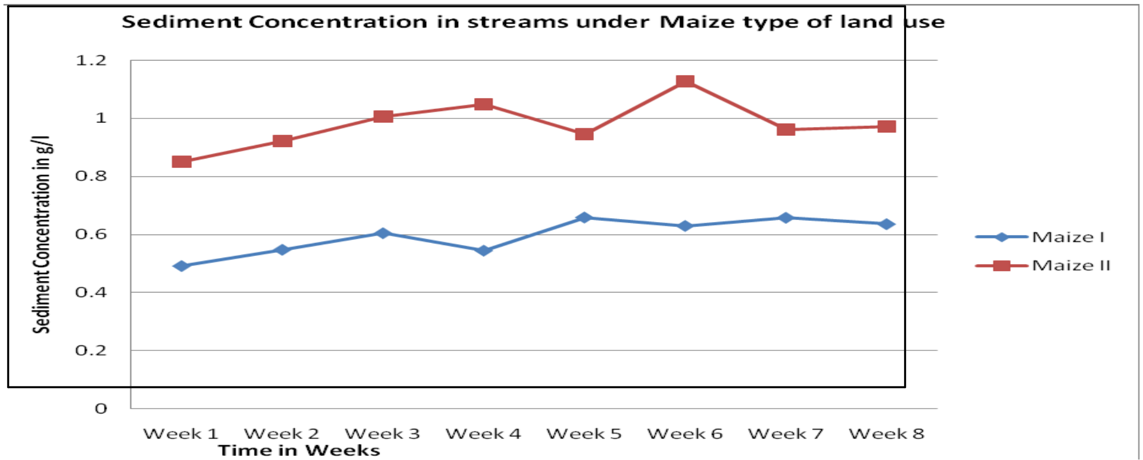

Figure 6.5: Sediment concentration trends for maize land use types for 8 weeks (Source: Author, 2010)

Figure 4.5 shows that maize II recorded a higher sediment concentration than maize I. The results also indicated that the range between maize I and maize II was the highest among the other land use types. This suggested that adoption of best management practices on maize II land use type reduces the soil loss by about 33.3% (that is from average of 0.26g/l to 0.06g/l as shown Table 4.2). Although maize farms with poor management practices produces highest sediment concentrations, best management practices applied on maize farms have a high potential of reducing soil erosion within NRC.The results reveals that land use under maize were the worst contributer of sediment into the streams where maize under management II shows higher sediment concentration than maize I.

d) Grass land use type

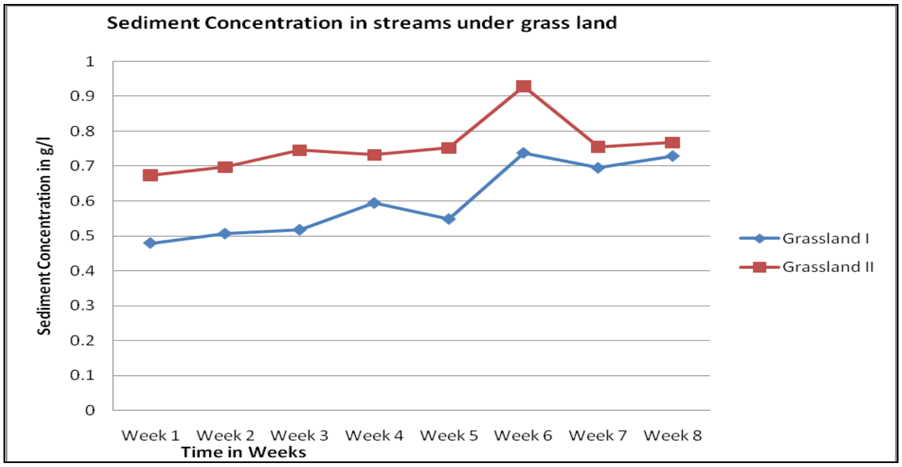

Figure 6.6: Sediment concentration trends for Grasslands types for 8 weeks (Source: Author, 2010)

The sediment concentration trends for grass lands as shown by Figure 4.6 moderately increased from week 1 to week 8. The curves in Figure 4.6 show that grassland I had lower sediment concentration compared to grassland II. The results also indicated the sediment concentration for grassland I and grassland II was almost equal on the eighth week of the study period as indicated by a near convergence of the two curves at that time as shown by Figure 4.6. This could be attributed to the natural rejuvenation of grassland II after a rainy period so as to perform the same functions of sediment sieving as grassland I.

4.4 Sediment load in the major tributaries of Nyongores River

4.4.1 Introduction

The study purposely selected four major tributaries of Nyongores River namely Ainopng'etunyek, Chepkositonik, Kagawet and Kiprurugit rivers. Each of these tributaries drains areas characterized by high population density in the catchment, arable land suitable for both crop cultivation and livestock keeping. Two sampling points on each of the tributaries were selected; one sampling point was located at the upstream where impact from land use activities were minimal i.e. as it emerges from the source and the other at the downstream before it discharges into the main river. Water samples and stream measurements such as depth, width and velocity were undertaken on-site weekly for four consecutive months. The sampling points on each of the four tributaries are shown in Figure 4.7.

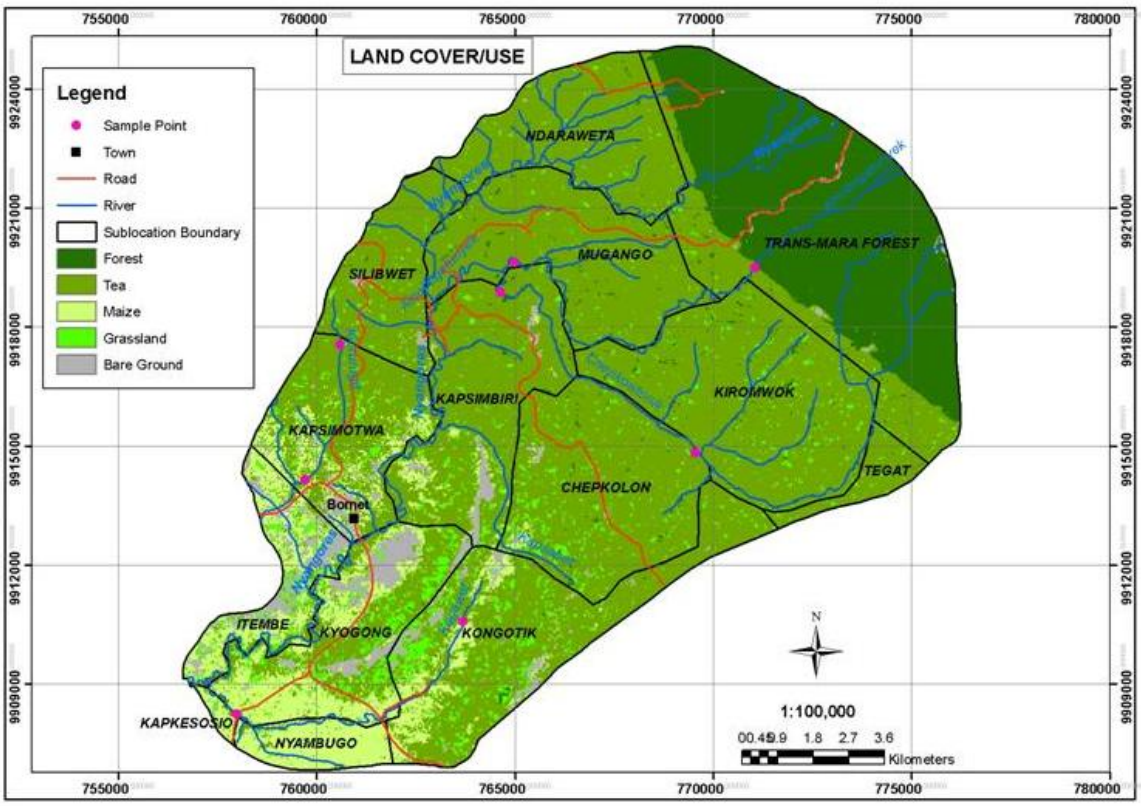

Figure 6.7: Map showing the sampling point on the major tributaries of Nyongores River (Source: Author, 2009)

4.4.2 Average Discharge from the four tributaries (Q=m3/s)

The study calculated the river discharge for each of the four rivers at each sampling point using depth, width (river cross section area) and river velocity. The average discharges are shown in Table 4.3.

Table 6.3: Average discharge for each of the tributaries of Nyangores River (Source: Author, 2010)

Time	Discharge in m^3/s			
	Ainopnge'tunyek	**Chepkositonik**	**Kagawet**	**Kiprurugit**
DEC, '09	0.3241	0.1602	0.0332	0.0297
JAN, '10	0.7825	0.1027	0.0272	0.0981
FEB, '10	1.614	0.6048	0.8341	0.3192
MAR, '10	1.1425	0.5096	0.4094	0.2242
Average	**0.9658**	**0.3443**	**0.3260**	**0.1678**

Table 4.3 indicates that Ainopng'etunyek River has the highest discharge of 0.97 m^3/s followed by Chepkositonik at 0.34 m^3/s, then Kagawet at 0.33 m^3/s and fourthly by Kiprurugit with the least discharge of 0.17 m^3/s. Figure 4.8 shows a graphical representation of discharges of the four tributaries in cubic meters per second for a period of four months (sampling period).

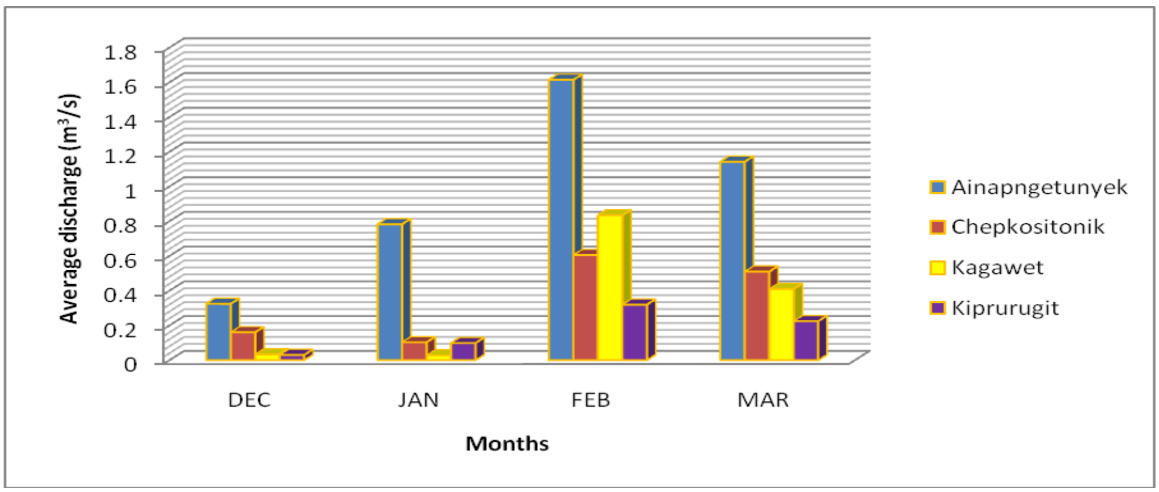

Figure 6.8: A graphical representation of discharge for the four tributaries to Nyongores River (Source: Author, 2010)

The study established that total discharges for the four tributaries of Nyongores river corresponded positively with the average monthly rainfall data obtained from records at Bomet weather station as shown in Table 4.4. The total discharge for the months of

December, 2009 and January 2010 were lower compared with the average discharge for the months of February and March, 2010.

Table 6.4: Average rainfall for the months of December, 2009 to June 2010 (Source: WRMA, 2010. Bomet Water Supply Station Rainfall Data)

Month	Dec	Jan	Feb	Mar	Apr	May	Jun
Average rainfall in mm	6.9	6.2	7.4	9.0	4.2	7.0	1.6

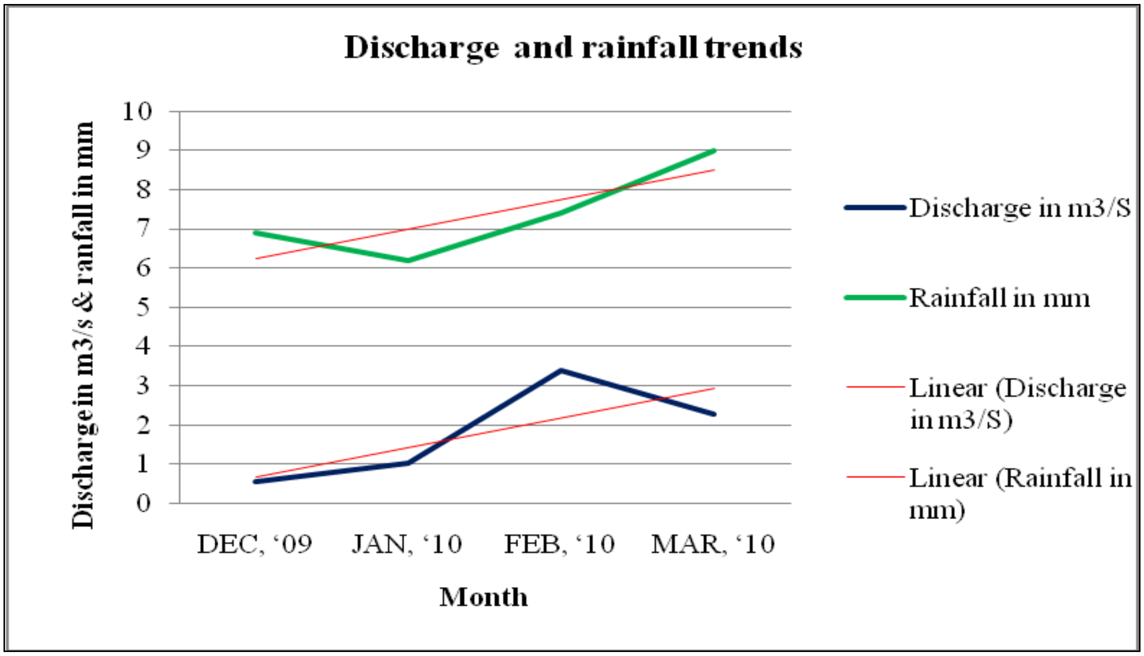

Figure 6.9: Linear trends representation of discharge and average monthly rainfall (Source: Author, 2010)

4.4.3 Average Sediment concentration in the four tributaries (g/l)

Sediment concentrations for each of the tributaries were obtained from water samples collected, filtered, dried and weighed. The results of the sediment concentration for each the tributaries in grams per litre (g/l) are shown in Table 4.4 and graphical presented by Figure 4.10.

Table 6.5: Average sediment concentration for main tributaries from Dec. 2009 to March 2010 (Source: Author, 2010)

	Average sediment concentration (g/l)			
Months	***Ainopng'etunyek***	***Chepkositonik***	***Kagawet***	***Kiprurugit***
DEC, '09	0.257	0.504	0.436	0.37
JAN, '10	0.284	0.479	0.164	0.23
FEB, '10	0.193	0.608	0.522	0.134
MAR, '10	0.286	0.382	0.168	0.057
Average	**0.255**	**0.493**	**0.324**	**0.198**

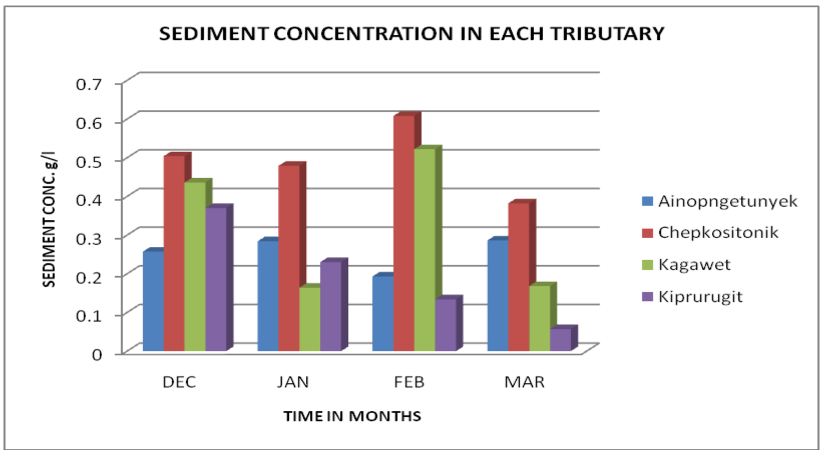

Figure 6.10: Average sediment concentration for the four major tributaries of Nyongores River (Source: Author, 2010)

Table 4.5 shows that the average sediment concentrations for each of the rivers during the four months were as follows: - Ainopng'etunyek (0.255g/l), Chepkositonik (0.493g/l), Kagawet (0.324g/l) and Kiprurugit (0.198g/l). The results indicate Chepkositonik River had the highest sediment concentration while Kiprurugit River had the lowest sediment concentration during the four months period (December 2009 to March 2010). The result also shows that the highest average sediment concentration in the tributaries occurred in December 2009 and February 2010.

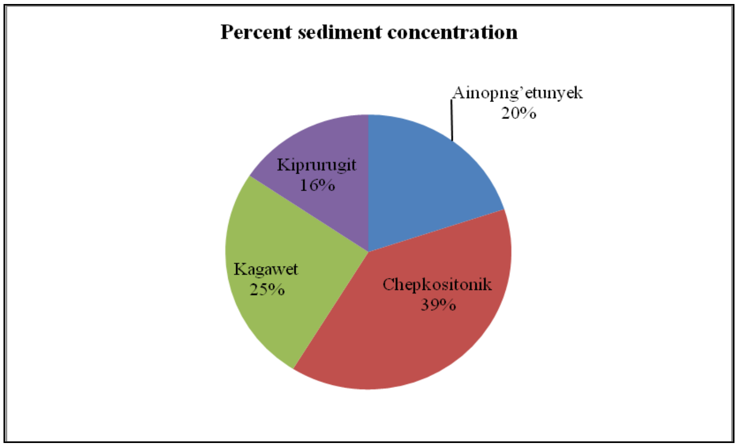

Figure 6.11: Percent sediment concentration ratio in the major tributaries (Source: Author, 2010)

Figure 4.10 shows that Chepkositonik River had the highest percentage sediment concentrations with 39%, followed by Kagawet River with 25%, Ainopng'etunyek River with 20% and the least being Kiprurugit River with 16%. The variation in sediment concentration in each river were attributed to their varying sizes and intensity of land use types and existing management practices shown by Figure 4.2 and effects of slope angles on soil erosion in the sub-catchments as indicated in Table 4.6. Chepkositonik sub-catchment had steep slopes of up to 55% while Kagawet sub-catchment had gentle slopes of about 2%.

Table 6.6: The Sub Catchment and its Physiographic Characteristics (Source: Bomet District Agricultural Office, 2009)

Tributary/Sub catchment	**Slope angles**
Chepkositonik	Steep slopes between 25^{o} and 55^{o}
Ainopng'etunyek	Gentle to steep slopes of between 10^{o} and 35^{o}
Kiprurugit	Gentle slopes of 5^{o}
Kagawet	Very gentle slopes of 2^{o} to flat terrain

Doughlas (1989) support the findings of the study as it states that the slope degree is a significant determinant of soil erosion. It stated that 15, 26 and 45 degrees are key threshold angles. For slopes greater than 15 degrees, surface runoff causes soil erosion; at

26 degrees, gravitation processes becomes more important; and at or above 45 degrees, erosion is most severe.

4.4.4 Sediment load of the four tributaries of Nyongores River

The average discharge and the average sediment concentrations were used to determine the sediment load transported by each of the four tributaries of Nyongores River. This was done by finding the product of average discharge in m^3/s and sediment concentration in kg/l. Table 4.7 shows the average discharge, sediment concentration and sediment load for each tributary of Nyongores River. Figure 4.10 presents a graphical representation of sediment loads of each of the tributaries.

Table 6.7: Average Discharge, Sediment Concentration and Load for Each Tributary

Tributary	**Average Discharge (m^3/s)**	**Average Sediment concentration (g/l)**	**Average Sediment load in kg/s**
Ainopng'etunyek	0.97	0.253	**0.245**
Chepkositonik	0.35	0.493	**0.173**
Kagawet	0.33	0.324	**0.107**
Kiprurugit	0.17	0.198	**0.034**
Total	**1.82**	**0.317**	**0.559**

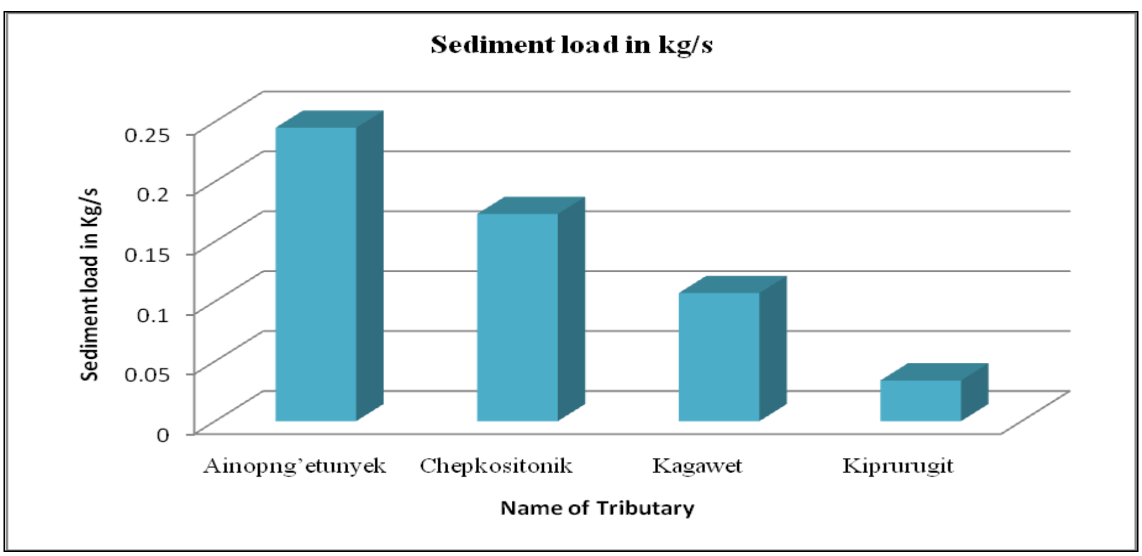

Figure 6.12: Sediment load for each of the tributaries of Nyongores River (Source: Author, 2010)

Table 4.5 shows that the sediment loads for each of the tributaries of Nyongores river were: - Ainopng'etunyek (0.245 kg/s), Chepkositonik (0.173 kg/s), Kagawet (0.107 kg/s) and Kiprurugit (0.034 kg/s). The results indicate that the higher the discharge of the river, the higher the sediment load. For instance, Ainopng'etunyek which had the highest discharge of 0.97m^3/s also had the highest sediment load of 0.245kg/s while kiprurugit river which had the lowest discharge (0.17m^3/s) also had the lowest sediment load of 0.034kg/s. The results further reveals that the more the discharge, the higher the sediment concentration for all of the tributaries except for Ainopng'etunyek River which shows decreasing sediment concentration with an increase in discharge (Table 4.5). The behaviour by Ainopngetunyek River may be attributed to the fact that it drains through some area covered by forest which reduces the effects of runoff into the river. In addition, the sub-catchment had a higher portion of its area covered by tea cultivation compared with the other tributaries like Chepkositonik and Kagawet which drains areas of mostly maize cultivation. It is also possible that the river's high discharge compared to the others enable it to dilute and lower the sediments concentrations.

4.5 Land use management practices for soil erosion control

4.5.1 Introduction

The study sought information on existing land use management practices for soil erosion control within Nyongores catchment through key informant interviews, administration of semi structured questionnaires, perusal of relevant literatures and observations/photography. The study sampled 100 respondents who were mainly farmers from the study area. The number of respondents interviewed from each of the four sub-catchments was randomly selected based on the ratio of the areas covered by each sub-catchment. The number of respondents selected from each sub-catchment is as shown in Table 4.7.

Table 4.7: Number of respondents interviewed in each sub catchment (Source: Author, 2009)

Sub-Catchment	Ratio	No. of Respondents
Chepkositonik	5	36
Ainopng'etunyek	4	29
Kagawet	3	21
Kiprurugit	2	14
Total		**100**

The information obtained from the respondents included: - land sizes, land use types/cover, environmental challenges, trends of environmental changes, existing land use management practices and proposed intervention measures.

4.5.2 Land use and environmental management challenges in the Catchment

The study identified six (6) main environmental challenges within the four sub-catchments of Nyongores River. The challenges were; (i) soil erosion reported by 58% respondents, (ii) water pollution reported by 17% of respondents, (iii) vegetation loss reported by 12% of respondents, (iv) water scarcity reported by 9% of respondents, (v) landslides reported by 3% of respondents and (vi) flooding reported by only 1% of the respondents as shown by Table 4.9.

Table 6.8: Environmental challenges on each of the sub-catchments of Nyongores River (Source: Author, 2010)

Environmental challenges	Percent respondents				Average
	Ainopng'etunyek	Chepkositonik	Kiprurugit	Kagawet	
Soil erosion	51.7	66.7	57.1	52.4	58.0
Water pollution	10.3	16.7	21.4	23.8	17.0
vegetation loss	13.8	11.1	7.1	14.3	12.0
Water scarcity	13.8	5.6	14.3	4.8	9.0
Landslides	10.3	0.0	0.0	0.0	3.0
Flooding	0.0	0.0	0.0	4.8	1.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

The six environmental challenges reported by respondents in Table 4.9 are among the challenges categorized in Water Quality Assessment Report as potential threats in the Mara River Basin (GLOWS and WWF, 2007). The following is a discussion of each of the environmental challenges reported by the respondents:-

(i). Soil erosion

Soil erosion was reported as the greatest environmental challenge across the catchment by an average of 58% of the respondents. The study observed that the worst erosion occurred along the foot paths used by livestock and humans to livestock watering points on most rivers and along the river banks without buffer strips. Plate 4.1 (a) and (b) indicates eroded footpaths leading to Kagawet River at Kipsegon 'Ngeny' livestock watering point. The footpaths have been transformed by erosion to deep gulleys and one of the respondents reported that the footpaths are impassable during heavy rainfall as they turned into 'deep flowing streams'.

Plate 6.1: Two eroded footpaths leading to Kagawet River at Kipsegon (Source: Author, 2010)

Interviews with Agricultural extensions officer and farmers revealed that the causes of soil erosion within the catchment were heavy rains, reduced vegetation cover, overgrazing by animals and land use activities such as cultivation along river banks, on steep slopes and hill tops, quarrying and constructions.

The indicators of soil erosion in the catchment as observed by the study included; deep gullies along footpaths, present of rill and interill on farms and grasslands, exposed roots of old trees, deposits of sediment in areas of low flows along the river channels (shown by Plate 4.1a), highly turbid river water (shown by Plate 4.2 b) and protruding stones that the locals said are ‘growing’ in steep slopes and hills.

Plate 6.2: Sediments deposits on the banks of Kagawet (Above) and turbid water of Chepkositonik River (below) (Source: Author, 2010)

Observations, interviews with the locals and secondary information of the area shows that soil erosion and subsequently sediment transport have not only caused serious environmental and ecological problems, but also economic and engineering problems such as siltation of reservoirs e.g. Tenwek Hospital's hydropower dam and high cost of water treatment. The respondents also reported that soil erosion led to direct damaged of roads and footpaths, reduces soil fertility, loss of arable lands and damage to crops as was reported by one of the farmers;

> "H*eavy rainfall felt in the area immediately after I completed planting maize on my farm and it eroded the farm washing away all the maize seeds and fertilizers down into the stream. I had to sell a cow to purchase more seeds and fertilizers to replant my farm again"* reported the farmer.

Plate 4.3(a) shows part of Bomet-Sigor road which had damaged by water erosion while Plate 4 (b) shows eroded arable land within the catchment.

Plate 6.3: Part of Bomet-Sigor road (above) and eroded edge of a farm (below) damaged by erosion **(Source: Author, 2010)**

(ii). Water pollution

Table 4.9 show that 17% of the respondents reported that water pollution was an environmental challenge of Nyongores river catchment. The study identified sources of water pollution within the catchment to include soil erosion that increased sediment concentration in rivers, runoffs from tea and crops farms with excessive fertilizer to tea and other crop farms, untreated sewage released into rivers from urban areas such as Bomet town, runoffs through open dumpsite located near rivers. Mati et al, (2005); (2008) and WQBAR, 2007) agrees with the findings of the study and states that sedimentation and eutrophication downstream were indicators of water pollution resulting from soil erosion and fertilizers from upstream.

(iii). Vegetation loss

Twelve percent (12%) of the respondents indicated that a reduction in vegetation cover was important challenge in the catchment. Vegetation loss in the catchment had been attributed to increased demand for fuel wood and timber, increased demand for land for cultivation and settlement due to rise in population. Mati et al 2008, supports the findings of the study by indicating that rise in population in the upper catchment of Mara river basin has resulted in continuous vegetation removal. The study established in Figure 4.1 that degraded forests (forest II) generated higher sediment compared with other land use types within the catchment.

(iv). Water scarcity, land slides and flooding

Table 4.9 shows that an average of 9%, 3% and 1% of the respondents identified water scarcity, land slides and flooding respectively as important environmental challenges in the catchment. The study found out that scarcity of water in the catchment had occurred due to contamination of available sources of water such as rivers and streams by agricultural runoffs and untreated sewages from leading to insufficient water for domestic purposes such as drinking. Currently most people rely on roof harvesting and spring waters for drinking. However, a representative of Nyongores Water user’s Association reported that these sources of water are not reliable during prolonged droughts since there is no roof harvesting and most of the springs dries up.

Landslides are not a major challenge as was reported by only 3% of the respondent within the catchment in the catchment but has been reported to have occurred in the catchment during heavy rainfall. Flooding was reported by 1% of the respondents in the Nyongores catchment thus was not a major environmental challenge within the catchment. However, flooding was reported to occur along the banks of some tributaries particularly Kagawet river during heavy rainfall.

4.5.3 Soil erosion control interventions within Nyongores River Catchment

The study found out that several intervention measures to control soil erosion have been put in place in all the four main sub-catchments. The interventions however, varied considerably depending on the location, topography and land use types. The study also found out that each individual farmer could apply one or multiple measures within a given farm. Table 4.11 and Figure 4.15 show interventions techniques for soil erosion control existing in each of the four sub-catchments of NRC. There were eight (8) soil erosion control techniques identified by the respondents within the four sub-catchments namely: - use of sand bags, intercropping, mulching, planting trees, agro-forestry, contour ploughing, construction of terraces and building of gabions.

Table 6.9: Existing soil erosion adoption in the four sub catchments (Source: Author, 2010)

Soil erosion control Interventions Techniques	Number & percentage of respondents in each sub catchment							
	Ainopng'etunyek		Chepkositonik		Kiprurugit		Kagawet	
	No.	%	No.	%	No.	%	No.	%
Use of Sand Bags	3	2.7	1	1.6	0	0.0	0	0
Intercropping	11	9.9	4	6.3	11	20.4	8	11.9
Mulching	6	5.4	3	4.7	4	7.4	3	4.5
Planting Trees	15	13.5	10	15.6	7	13.0	17	25.4
Agro-Forestry	18	16.2	12	18.6	9	16.7	11	16.4
Contour Ploughing	28	25.2	18	28.1	12	22.2	14	20.9
Construction of Terraces	28	25.2	15	23.4	10	18.5	9	13.4
Building Gabions	2	1.8	1	1.6	1	1.9	5	7.5
TOTAL	**111**	**100**	**64**	**100**	**54**	**100**	**67**	**100**

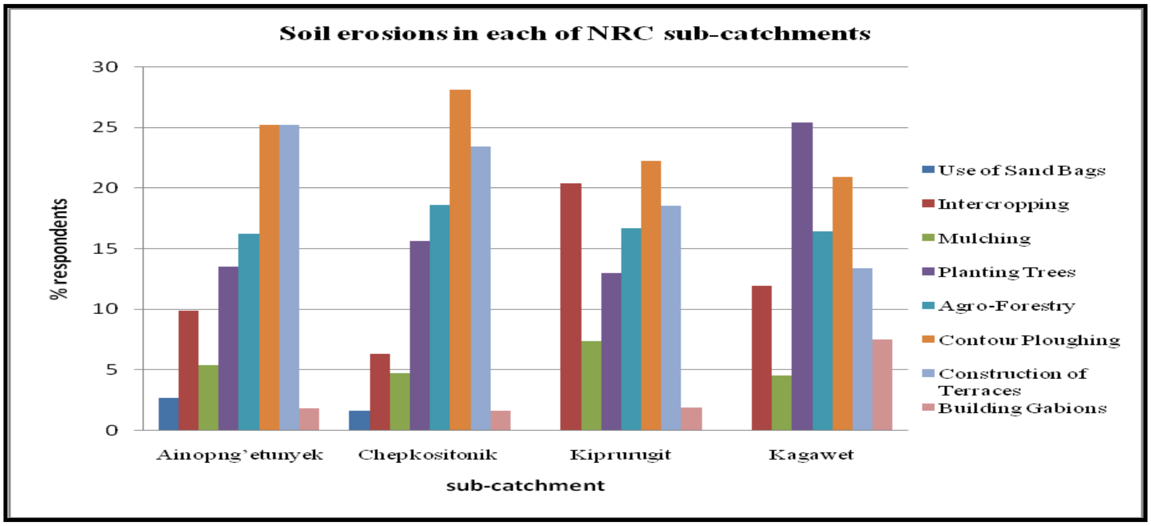

Figure 6.13: Proportion of soil erosion intervention techniques in the four sub catchments (Source: Author, 2010)

The results reveal that most farmers have adopted the construction of terraces and contour ploughing in all the sub-catchments while use of sand bags and building of gabions were the least adopted soil erosion control measures as indicated by Figure 4.15.

Figure 4.16 presents the average percentage of each of the identified soil erosion control techniques applied within Nyongores River Catchment.

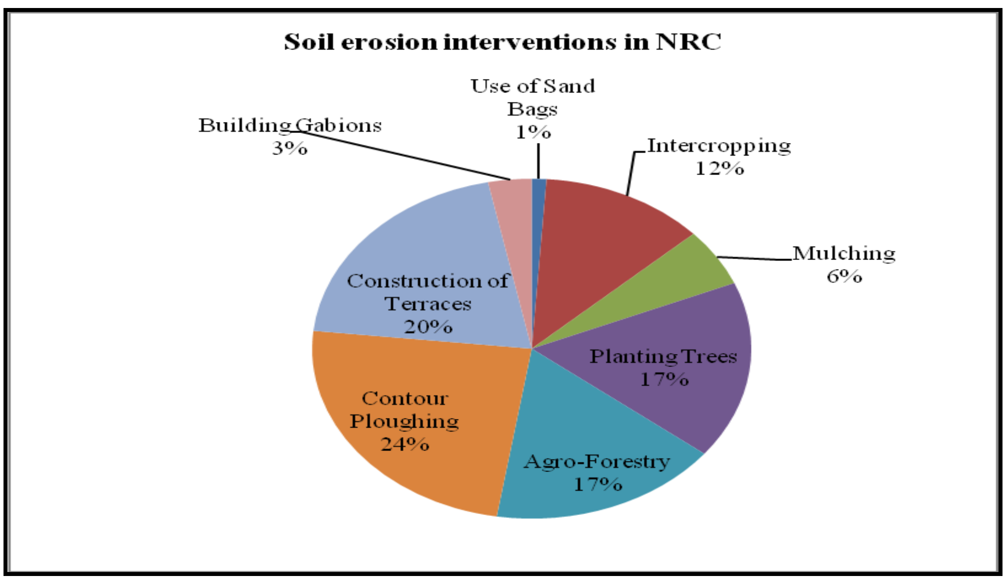

Figure 6.14: Mean percentage of soil erosion techniques applied in NRC (Source: Author, 2010)

Contour ploughing and construction of terraces were the most common soil erosion control techniques used within the catchment as reported by 24% and 20% of respondents respectively. Agro-forestry was reported by 17% of the respondents, planting of trees (17%), inter-cropping (17%), mulching (6%), building of gabions (3%) and use of sand bags (1%). Despite the presence of the eight soil erosion control measures within NRC, the trends of soil erosion for the past 10 years were reported to have worsened. This indicates that the techniques had not been effective in controlling soil erosion. Each of the soil erosion control techniques are discussed as follows:-

(i). Contour ploughing

The study established that contour ploughing was applied by 24% of the farmers within NRC in soil erosion control (Figure 4.16). Contour ploughing involves aligning plant rows and tillage lines at right angles to normal flow of runoff. It creates detention storage in the soil surface horizon and slows down the runoff thus giving the water time to infiltrate into the soil. The effectiveness of contour ploughing in water and soil conservation depends not only on the design of the system but also on soil, climate, slope aspect and land use. The beneficial effect is least marked on compact or slowly permeable soils because these become saturated quickly compared to highly permeable soil.

Most farmers on steep slopes applied contour ploughing but cultivated into the river banks striping the streams of their riparian buffer zone thus increasing soil erosion. Plate 4.4 (a) and (b) shows some farms on contours ploughing but close to the river banks at Chepkositonik sub catchment. During heavy rainfall, the measures are rendered ineffective as runoffs overflows the contours and transport soil to the river.

Plate 6.4: Farm with Agroforestry (Right) and a farm cultivated into the river bank (Right) (Source: Author, 2010)

Roose (1967) recommended that contour bunds could be used alongside contour ploughing to improve soil conservation within farms. The contour bunds are earth banks of 1.5 to 2 m wide, forming buffer strips at 10 to 20 m intervals across the slope. Oblitas and Tammes (1997) in their research indicated that earth bunds on farms have positive effects even after two years of implementation. Therefore earth bunds should be promoted in the catchment to supplement contour ploughing in order to improve soil erosion control.

(ii). Construction of terraces

Terraces were applied by 17% of farmers within Nyongores river catchments to control soil erosion. Oblitas and Tammes (1997) agree with the findings of the study and stated that construction terraces known as 'Fanya Juu' terraces in Kenya have been quite popular. The terraces were used to reduce the velocity of runoff flows on agricultural farms thus reducing the abrasive effects of water the land. Terraces require soil to be moved and the ‘steps’ between the terraces protected from water erosion by vegetation or stonework. However, Terraces which are not maintained may themselves trigger further erosion as mass movements or animals destroy the ‘steps’, or gullies can form at the ‘steps’. Therefore, regular maintenances of terraces on the existing terraces within NRC to make them effective in soil erosion control.

Agro-forestry

Sanchez (1987) defined agro-forestry as growing trees or shrubs on vulnerable slopes or interspersing them between crops cut down runoff and erosion and connectivity. Alternatively, grass cover crops or intercropped vegetables or even weeds can be grown between trees or shrubs, as on coffee or tea plantations. The incorporation of manure or compost into soils so improving soil structure also cuts down runoff and erosion and phosphorus losses in water. According to Nair (1990) agro-forestry has the following characteristics: (i) combines production of multiple outputs with protection of the resource base, (ii) places emphasis on indigenous, multipurpose trees and shrubs, (iii) is particularly suitable for low input conditions and fragile environments, (iv) is more concerned with socio-cultural values than most other land-use systems, and (v) is structurally and functionally complex.

The study established that agro-forestry was used by 17% of farmers in NRC to control soil erosion (Figure 4.16). Tree species used for agro-forestry included trees that are known to consume a lot of water such as eucalyptus hence reducing crop yields. This might have discouraged farmers from applying the agro-forestry measures in most cases. Li *et al* (2001) states that fruit trees intercropped with other crops in agro-forestry practices have shown very good results by reducing soil erosion by 40 to 80% and significantly increasing farmers income. The study therefore recommends that fruit trees be promoted for agro-forestry practices to control soil erosion and increase income to farmers. Nair (1990) stated that fast growing trees and herbs could also be used for agro forestry as it adds fertility to soil and controll soil erosion.

(iii). Planting trees

Tree planting is an extremely important measure in preventing soil erosion and improving the ecological environment. Trees can also provide fuel, forage, plant nutrients, fruits and other products thereby accelerates development of agriculture. Growing trees or shrubs on vulnerable slopes will decrease runoffs velocity and thus reduces soil erosion by water on slopes.

The study found out that 17% of farmers within Nyongores river catchment applied the measures (planting of trees) to control soil erosion. However, most of the trees grown were eucalyptus species which though contributed to soil erosion control have effects on water resources degradation. Therefore the study recommends indigenous species and other environmentally species to be grown.

(iv). Intercropping

The results in Figure 4.16 indicate intercropping is practiced by 12% of the farmers in the catchment. Intercropping a type of farming that alternate contoured strips of intertilled row crops and close-growing crops (for example, a cover crop or grass) aligned at right angles to the direction of natural flow of runoff. The close-growing strip slows down runoff and filters out soil washed from the land in the intertilled crop. Usually, the close-growing and intertilled crops are planted in rotation. Strip cropping provides effective erosion control against runoff on well-drained erodible soils on 6 to 15% slopes. The width of the strips is varied with the erodibility of the soil, and slope steepness (FAO, 1965). Intercropping therefore can be promoted for adoption by farmers to control soil erosion in their farms.

(v). Mulching

Mulching is defined as direct covering the soil with a layer of vegetation such as grass. 6% of farmers of NRC applied mulching in soil erosion control. The farmers affirmed that mulching had other advantages apart from protecting the soil from erosive rainstorms such as retaining soil humidity and increasing soil organic matter. (Aina 1984) stated that mulching improves transmission of water through the soil profile and reduces surface crusting and runoff and improves soil moisture storage in the root zone. These effects have been widely reported that a mulch effectively reduces soil loss has been shown in both field and laboratory studies (Lal, 1976) while Roose (1988) reported drastic reductions in runoff and erosion from a mulched crops on farms on a 20% slope. However, most farmers consider incorporating mulch into the soil as too laborious and thus have not been commonly used.

(vi). Building gabions

Gabions are some of the engineering measures to reduce soil erosion in steep slopes and gullied areas. Gabions are mainly focused on check dams, gully head protecting works and hill side ditches. The study established that were among the least adopted soil erosion measures (3%) within NRC yet there existed deep gullies that requires building of gabions in the area. The study found out that small gullies were generally repaired by means of land leveling while deeper gullies particularly found along footpaths and river banks were repaired by use of stones, tree branches and planting of sisal and *aloe vera* plants. These measures for repairing gullies are not adequate because farmers reported that during runoffs the materials (stones, branches and sisals) are washed away together with soil.

Plate 6.5: Sisal plants used to repair gullies on (a) a footpath and (b) river banks (Source: Author, 2010)

Plate 4.5 shows gullies (Left) on a footpath and (Right) on a river bank repaired by uses of sisal plants. The sisal plants used to repair the gully on the footpath had achieved success but intervention as applied to the gully on the river bank (Plate 4.5 on the right) was reported that to face challenges of being swept away by high flows after rainfall.

Plate 4.6 on the left below shows a gullied footpath was leveled in an attempt to repair. However, such intervention was reported as having worsened the situation soils used for leveling were washed by runoff during heavy rainfall. This made the gulley to expand its width and depth. This was attributed to the lack of lack technical support or appropriate skills by farmers to rehabilitate the gullies. Plate 4.6 on the right shows a gully on which some plants species such as *aloe vera* and grasses have been planted along the footpath to reduce the velocity of the runoff during rainy season.

Plate 6.6: Different types of controlling gully erosion (Source: Author, 2010)

(vii). Use of sand bags

Sacks filled with sand also known as sand bags may be laid to hold up water flowing across the land so that it infiltrates into the soil rather than runs off. When these are put in place, surface runoff will not gain sufficient velocity to incise into the land. The greatest advantage of these type of measures is that such structures can also improve crop yields by trapping rainfall. When sand bags are used in cultivated lands, soil particles are trapped behind the barriers which increase soil depth, and terraces may form, and crop yields in the vicinity of the barriers increase.

Despite the importance of sand bags in soil erosions, increasing crop yields and being simple to implement, very few farmers (1%) had adopted this technique as Figure 4.16. Agricultural extension officer interviewed reported that use of sand bags is a very effective measure of soil erosion control particularly on steep slopes, along footpaths, agricultural fields and along river banks.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

This study was done on Nyongores river catchment with an aim of assessing the effects of land use and management practices on sediment concentrations in its tributaries. The study looked into; the existing land use types, the sediment delivery rates from each land use type as well as sediment load from the tributaries. Management practices for soil conservation strategies were also determined.

The study concluded that Nyongores river catchment has four major land use types namely; forest, tea, maize and grassland types of land uses with maize and tea being the dominant land use covers. Each of the land use types differs in their rates of sediment contributions into the streams based on their existing management practices. Land use with maize cultivation and forest (degraded) without appropriate management practices was the worst sediment contributors, while forest and tea with appropriate management practices contributed minimal sediments into the streams. Chepkositonik tributary had the highest percent sediment concentrations of 39%, Ainopng'etunyek had (25%), Kagawet had (20%) while Kiprurugit were the least at 16%.

The study indicated that soil erosion particularly by water is a widespread problem throughout the catchment which has been triggered by inappropriate land use management practices. The study revealed that there exist soil erosion intervention though they were insufficient and ineffective in most places due to inadequate technical support and motivation by farmers. In addition, the study has shown appropriate land use management practices to reduce erosion should be undertaken in the catchment, not only with regard to the conservation of the soil and its environment but also with regard to the economical and socio-political sustainability of agriculture in the area. The study has demonstrated that there exists relationship between land use and soil erosion and recommended the adoption of integrated catchment management approaches to reduce soil erosion, improve on farming production yields and improve on the quantity and quality of water resources in the catchment.

7.2 Recommendations

The study reveals that the catchment requires measures and strategies which are suitable for adoption to reduce soil erosion and sediment load in rivers. The following strategies are recommended for implementation in the area:

1. Nyongores river catchment requires comprehensive land use planning and environmental management. Land use planning provides an excellent tool for the management of a variety of influential human activities by controlling and designing the ways in which we use land and natural resources, specifically to improve basin management for both human and environmental sustainability and success. The land uses to be considered should include the catchment's forest/vegetation cover, soil cover, river channels, and related aspects such as ground drainage, access roads and river morphology. For soil erosion management these land uses need to be distributed to control the rate of runoff during storm conditions and the rate of flow down the watercourses.
2. There is need to improve existing land use management practices by ensuring proper cultivation techniques, control runoff and soil loss from cultivated areas and

construction of benches on cultivated areas to reduce sediment load in streams. There also the need for the introduction of regular and standardized sediment monitoring programmes in Nyongores River and its tributaries.

3. Areas of steep slopes in the catchment such as Chepkositonik, should consider introduction of measures to increase infiltration rates such as increased plant cover, use of sediment traps e.g. sand bags, digging of ditches among others that will reduce runoff.
4. The district agricultural office and conservation agencies should carry out mobilization and participation of rural communities in soil conservation programmes in the catchment. There is also the need for the establishment of demonstration centres in catchment to educate farmers on best soil conservation practices and use of rural extension workers trained in the importance of soil and water conservation practices.
5. There is need to improve the relationship between upstream and downstream users to improve water and soil conservation in the catchment. The sub-catchments within Nyongores river catchment have different characteristics and there is need to be considered separately. Hence, management/restoration actions to be considered as per each catchment current status by implementing the proposed measures (action plan) on appendix III.
6. This study mapped the existing land use types, determine the sediment concentrations from major land use types, determine the rates of sediment load of the main tributaries draining the catchments and assess the existing land use management practices. This was to give insight into the relationship between the land use and soil

erosion in the catchment and recommended on the approaches for adoption to reduce soil erosion in integrated catchment management. However, for more in depth analysis to understand these relationships and to improve the estimates, the following should be carried out;

a). Study on how can farmers in the Nyongores river catchment can be motivated to adopt soil and water conservation practices on their farming practices

b). More comprehensive catchment studies need to be conducted to identify priority areas to target for management in the catchment.

c). There is need for study on the estimated monetary value of the fertility lost to soil erosion in the in the area

d). The impacts of the declining agricultural productivity in the catchment as a consequence of increased soil loss

e). The effects of current intervention measures on poverty and health of the local residents.

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APPENDICES

APPENDIX I: Rainfall data for Bomet Station; Dec. 2009 – Jun, 2010 (thestudy period) (Source: WRM Kisumu, Kenya 2011)

Bomet Water Supply	12/1/2009	0
Bomet Water Supply	12/2/2009	0
Bomet Water Supply	12/3/2009	2.2
Bomet Water Supply	12/4/2009	6.3
Bomet Water Supply	12/5/2009	0
Bomet Water Supply	12/6/2009	0
Bomet Water Supply	12/7/2009	2.3
Bomet Water Supply	12/8/2009	0
Bomet Water Supply	12/9/2009	0
Bomet Water Supply	12/10/2009	0
Bomet Water Supply	12/11/2009	0
Bomet Water Supply	12/12/2009	0
Bomet Water Supply	12/13/2009	21.8
Bomet Water Supply	12/14/2009	36.5
Bomet Water Supply	12/15/2009	28.4
Bomet Water Supply	12/16/2009	10.9
Bomet Water Supply	12/17/2009	6.9
Bomet Water Supply	12/18/2009	0
Bomet Water Supply	12/19/2009	0
Bomet Water Supply	12/20/2009	0
Bomet Water Supply	12/21/2009	0
Bomet Water Supply	12/22/2009	0
Bomet Water Supply	12/23/2009	5.2
Bomet Water Supply	12/24/2009	0
Bomet Water Supply	12/25/2009	36.9
Bomet Water Supply	12/26/2009	0
Bomet Water Supply	12/27/2009	0
Bomet Water Supply	12/28/2009	0
Bomet Water Supply	12/29/2009	2.1
Bomet Water Supply	12/30/2009	3
Bomet Water Supply	12/31/2009	52.1
Bomet Water Supply	1/1/2010	20.7
Bomet Water Supply	1/2/2010	0
Bomet Water Supply	1/3/2010	69.8
Bomet Water Supply	1/4/2010	8.6
Bomet Water Supply	1/5/2010	0
Bomet Water Supply	1/6/2010	4.3
Bomet Water Supply	1/7/2010	28.5
Bomet Water Supply	1/8/2010	0
Bomet Water Supply	1/9/2010	0
Bomet Water Supply	1/10/2010	5.9
Bomet Water Supply	1/11/2010	16.8
Bomet Water Supply	1/12/2010	0
Bomet Water Supply	1/13/2010	0
Bomet Water Supply	1/14/2010	0
Bomet Water Supply	1/15/2010	0
Bomet Water Supply	1/16/2010	0
Bomet Water Supply	1/17/2010	6.9
Bomet Water Supply	1/18/2010	14.8
Bomet Water Supply	1/19/2010	6.5
Bomet Water Supply	1/20/2010	3.4
Bomet Water Supply	1/21/2010	0
Bomet Water Supply	1/22/2010	0
Bomet Water Supply	1/23/2010	5.1
Bomet Water Supply	1/24/2010	0
Bomet Water Supply	1/25/2010	0
Bomet Water Supply	1/26/2010	0
Bomet Water Supply	1/27/2010	0
Bomet Water Supply	1/28/2010	0
Bomet Water Supply	1/29/2010	0
Bomet Water Supply	1/30/2010	0
Bomet Water Supply	1/31/2010	0
Bomet Water Supply	2/1/2010	0
Bomet Water Supply	2/2/2010	0
Bomet Water Supply	2/3/2010	0
Bomet Water Supply	2/4/2010	0
Bomet Water Supply	2/5/2010	17.2
Bomet Water Supply	2/6/2010	1.3
Bomet Water Supply	2/7/2010	10
Bomet Water Supply	2/8/2010	0
Bomet Water Supply	2/9/2010	0
Bomet Water Supply	2/10/2010	0
Bomet Water Supply	2/11/2010	0
Bomet Water Supply	2/12/2010	0
Bomet Water Supply	2/13/2010	0
Bomet Water Supply	2/14/2010	0

Bomet Water Supply	2/15/2010	1.3	Bomet Water Supply	3/30/2010	0
Bomet Water Supply	2/16/2010	0	Bomet Water Supply	3/31/2010	12.2
Bomet Water Supply	2/17/2010	3.9	Bomet Water Supply	1-Apr-10	0
Bomet Water Supply	2/18/2010	7.8	Bomet Water Supply	2-Apr-10	13.6
Bomet Water Supply	2/19/2010	15.6	Bomet Water Supply	3-Apr-10	0
Bomet Water Supply	2/20/2010	16.5	Bomet Water Supply	4-Apr-10	28.5
Bomet Water Supply	2/21/2010	10.8	Bomet Water Supply	5-Apr-10	0
Bomet Water Supply	2/22/2010	47.6	Bomet Water Supply	6-Apr-10	0
Bomet Water Supply	2/23/2010	2.3	Bomet Water Supply	7-Apr-10	0
Bomet Water Supply	2/24/2010	47.3	Bomet Water Supply	8-Apr-10	8.2
Bomet Water Supply	2/25/2010	15.6	Bomet Water Supply	9-Apr-10	0
Bomet Water Supply	2/26/2010	10.2	Bomet Water Supply	10-Apr-10	0
Bomet Water Supply	2/27/2010	0	Bomet Water Supply	11-Apr-10	0
Bomet Water Supply	2/28/2010	0	Bomet Water Supply	12-Apr-10	0
Bomet Water Supply	3/1/2010	3.8	Bomet Water Supply	13-Apr-10	0
Bomet Water Supply	3/2/2010	20.5	Bomet Water Supply	14-Apr-10	0
Bomet Water Supply	3/3/2010	13.4	Bomet Water Supply	15-Apr-10	17.8
Bomet Water Supply	3/4/2010	36.5	Bomet Water Supply	16-Apr-10	0
Bomet Water Supply	3/5/2010	0	Bomet Water Supply	17-Apr-10	13.1
Bomet Water Supply	3/6/2010	3.2	Bomet Water Supply	18-Apr-10	6.8
Bomet Water Supply	3/7/2010	6.5	Bomet Water Supply	19-Apr-10	9.1
Bomet Water Supply	3/8/2010	28.7	Bomet Water Supply	20-Apr-10	25.6
Bomet Water Supply	3/9/2010	0	Bomet Water Supply	21-Apr-10	0
Bomet Water Supply	3/10/2010	9.1	Bomet Water Supply	22-Apr-10	0
Bomet Water Supply	3/11/2010	0	Bomet Water Supply	23-Apr-10	0
Bomet Water Supply	3/12/2010	0	Bomet Water Supply	24-Apr-10	1.6
Bomet Water Supply	3/13/2010	0	Bomet Water Supply	25-Apr-10	2.8
Bomet Water Supply	3/14/2010	0	Bomet Water Supply	26-Apr-10	0
Bomet Water Supply	3/15/2010	0	Bomet Water Supply	27-Apr-10	0
Bomet Water Supply	3/16/2010	0	Bomet Water Supply	28-Apr-10	0
Bomet Water Supply	3/17/2010	0	Bomet Water Supply	29-Apr-10	0
Bomet Water Supply	3/18/2010	10.6	Bomet Water Supply	30-Apr-10	0
Bomet Water Supply	3/19/2010	0	Bomet Water Supply	1-May-10	5.8
Bomet Water Supply	3/20/2010	0	Bomet Water Supply	2-May-10	16.5
Bomet Water Supply	3/21/2010	5.8	Bomet Water Supply	3-May-10	45.3
Bomet Water Supply	3/22/2010	65.3	Bomet Water Supply	4-May-10	10.7
Bomet Water Supply	3/23/2010	31.9	Bomet Water Supply	5-May-10	15
Bomet Water Supply	3/24/2010	5.9	Bomet Water Supply	6-May-10	0
Bomet Water Supply	3/25/2010	5.9	Bomet Water Supply	7-May-10	0
Bomet Water Supply	3/26/2010	2	Bomet Water Supply	8-May-10	0
Bomet Water Supply	3/27/2010	0	Bomet Water Supply	9-May-10	0
Bomet Water Supply	3/28/2010	10.6	Bomet Water Supply	10-May-10	6.2
Bomet Water Supply	3/29/2010	5.7	Bomet Water Supply	11-May-10	7.2

Bomet Water Supply	12-May-10	21.6	Bomet Water Supply	22-Jun-10	0
Bomet Water Supply	13-May-10	2.6	Bomet Water Supply	23-Jun-10	4.5
Bomet Water Supply	14-May-10	7.5	Bomet Water Supply	24-Jun-10	0
Bomet Water Supply	15-May-10	0	Bomet Water Supply	25-Jun-10	0
Bomet Water Supply	16-May-10	0	Bomet Water Supply	26-Jun-10	0
Bomet Water Supply	17-May-10	25.3	Bomet Water Supply	27-Jun-10	0
Bomet Water Supply	18-May-10	4.4	Bomet Water Supply	28-Jun-10	0
Bomet Water Supply	19-May-10	15.9	Bomet Water Supply	29-Jun-10	0
Bomet Water Supply	20-May-10	3.2	Bomet Water Supply	30-Jun-10	0
Bomet Water Supply	21-May-10	0	Bomet Water Supply	1-Jul-10	0
Bomet Water Supply	22-May-10	0	Bomet Water Supply	2-Jul-10	0
Bomet Water Supply	23-May-10	0	Bomet Water Supply	3-Jul-10	0
Bomet Water Supply	24-May-10	19.9	Bomet Water Supply	4-Jul-10	0
Bomet Water Supply	25-May-10	11	Bomet Water Supply	5-Jul-10	0
Bomet Water Supply	26-May-10	0	Bomet Water Supply	6-Jul-10	0
Bomet Water Supply	27-May-10	0	Bomet Water Supply	7-Jul-10	0
Bomet Water Supply	28-May-10	0	Bomet Water Supply	8-Jul-10	0
Bomet Water Supply	29-May-10	0	Bomet Water Supply	9-Jul-10	0
Bomet Water Supply	30-May-10	0	Bomet Water Supply	10-Jul-10	0
Bomet Water Supply	31-May-10	0	Bomet Water Supply	11-Jul-10	0
Bomet Water Supply	1-Jun-10	0	Bomet Water Supply	12-Jul-10	0
Bomet Water Supply	2-Jun-10	0	Bomet Water Supply	13-Jul-10	0
Bomet Water Supply	3-Jun-10	6	Bomet Water Supply	14-Jul-10	0
Bomet Water Supply	4-Jun-10	7	Bomet Water Supply	15-Jul-10	0
Bomet Water Supply	5-Jun-10	2.2	Bomet Water Supply	16-Jul-10	0
Bomet Water Supply	6-Jun-10	0	Bomet Water Supply	17-Jul-10	0
Bomet Water Supply	7-Jun-10	3.6	Bomet Water Supply	18-Jul-10	0
Bomet Water Supply	8-Jun-10	15.7	Bomet Water Supply	19-Jul-10	0
Bomet Water Supply	9-Jun-10	0	Bomet Water Supply	20-Jul-10	0
Bomet Water Supply	10-Jun-10	0	Bomet Water Supply	21-Jul-10	0
Bomet Water Supply	11-Jun-10	5.8	Bomet Water Supply	22-Jul-10	0
Bomet Water Supply	12-Jun-10	3.2	Bomet Water Supply	23-Jul-10	0
Bomet Water Supply	13-Jun-10	0	Bomet Water Supply	24-Jul-10	0
Bomet Water Supply	14-Jun-10	0	Bomet Water Supply	25-Jul-10	0
Bomet Water Supply	15-Jun-10	0	Bomet Water Supply	26-Jul-10	0
Bomet Water Supply	16-Jun-10	0	Bomet Water Supply	27-Jul-10	0
Bomet Water Supply	17-Jun-10	0	Bomet Water Supply	28-Jul-10	5.8
Bomet Water Supply	18-Jun-10	0	Bomet Water Supply	29-Jul-10	0
Bomet Water Supply	19-Jun-10	0	Bomet Water Supply	30-Jul-10	0
Bomet Water Supply	20-Jun-10	0	Bomet Water Supply	31-Jul-10	0
Bomet Water Supply	21-Jun-10	0			

APPENDICES II: Nyongores River Discharge at Bomet Bridge: Dec. 2009 – Jun, 2010 (Source: WRM Kisumu, Kenya 2011)

StnID	Name	Date	Q(m^3/s)
1LA03	Nyangores	01/12/2009	6.88
1LA03	Nyangores	02/12/2009	6.61
1LA03	Nyangores	03/12/2009	6.21
1LA03	Nyangores	04/12/2009	5.70
1LA03	Nyangores	05/12/2009	4.73
1LA03	Nyangores	06/12/2009	4.27
1LA03	Nyangores	07/12/2009	4.50
1LA03	Nyangores	08/12/2009	4.05
1LA03	Nyangores	09/12/2009	3.84
1LA03	Nyangores	10/12/2009	4.16
1LA03	Nyangores	11/12/2009	4.61
1LA03	Nyangores	12/12/2009	4.73
1LA03	Nyangores	13/12/2009	5.08
1LA03	Nyangores	14/12/2009	5.82
1LA03	Nyangores	15/12/2009	6.34
1LA03	Nyangores	16/12/2009	6.34
1LA03	Nyangores	17/12/2009	6.21
1LA03	Nyangores	18/12/2009	5.82
1LA03	Nyangores	19/12/2009	5.82
1LA03	Nyangores	20/12/2009	5.32
1LA03	Nyangores	21/12/2009	5.20
1LA03	Nyangores	22/12/2009	5.08
1LA03	Nyangores	23/12/2009	4.96
1LA03	Nyangores	24/12/2009	4.84
1LA03	Nyangores	25/12/2009	4.50
1LA03	Nyangores	26/12/2009	4.38
1LA03	Nyangores	27/12/2009	4.61
1LA03	Nyangores	28/12/2009	5.82
1LA03	Nyangores	29/12/2009	8.60
1LA03	Nyangores	30/12/2009	12.02
1LA03	Nyangores	31/12/2009	17.25
1LA03	Nyangores	01/01/2010	21.85
1LA03	Nyangores	02/01/2010	25.16
1LA03	Nyangores	03/01/2010	26.05
1LA03	Nyangores	04/01/2010	23.83
1LA03	Nyangores	05/01/2010	23.22
1LA03	Nyangores	06/01/2010	23.17
1LA03	Nyangores	07/01/2010	22.83
1LA03	Nyangores	08/01/2010	22.54
1LA03	Nyangores	09/01/2010	21.39
1LA03	Nyangores	10/01/2010	20.72
StnID	**Name**	**Date**	**Q(m^3/s)**
1LA03	Nyangores	11/01/2010	20.30
1LA03	Nyangores	12/01/2010	19.32
1LA03	Nyangores	13/01/2010	18.94
1LA03	Nyangores	14/01/2010	16.26
1LA03	Nyangores	15/01/2010	16.64
1LA03	Nyangores	16/01/2010	16.45
1LA03	Nyangores	17/01/2010	15.14
1LA03	Nyangores	18/01/2010	14.57
1LA03	Nyangores	19/01/2010	14.57
1LA03	Nyangores	20/01/2010	13.63
1LA03	Nyangores	21/01/2010	11.33
1LA03	Nyangores	22/01/2010	10.50
1LA03	Nyangores	23/01/2010	9.85
1LA03	Nyangores	24/01/2010	9.22
1LA03	Nyangores	25/01/2010	8.60
1LA03	Nyangores	26/01/2010	8.16
1LA03	Nyangores	27/01/2010	7.15
1LA03	Nyangores	28/01/2010	6.88
1LA03	Nyangores	29/01/2010	6.47
1LA03	Nyangores	30/01/2010	6.74
1LA03	Nyangores	31/01/2010	6.08
1LA03	Nyangores	01/02/2010	4.84
1LA03	Nyangores	02/02/2010	5.08
1LA03	Nyangores	03/02/2010	5.20
1LA03	Nyangores	04/02/2010	5.95
1LA03	Nyangores	05/02/2010	6.21
1LA03	Nyangores	06/02/2010	6.61
1LA03	Nyangores	07/02/2010	6.74
1LA03	Nyangores	08/02/2010	6.88
1LA03	Nyangores	09/02/2010	6.08
1LA03	Nyangores	10/02/2010	6.61
1LA03	Nyangores	11/02/2010	6.74
1LA03	Nyangores	12/02/2010	5.82
1LA03	Nyangores	13/02/2010	5.95
1LA03	Nyangores	14/02/2010	6.08
1LA03	Nyangores	15/02/2010	5.70
1LA03	Nyangores	16/02/2010	6.21

1LA03	Nyangores	17/02/2010	6.88	1LA03	Nyangores	01/04/2010	21.75
1LA03	Nyangores	18/02/2010	7.58	1LA03	Nyangores	02/04/2010	21.54
1LA03	Nyangores	19/02/2010	8.30	1LA03	Nyangores	03/04/2010	21.60
1LA03	Nyangores	20/02/2010	8.60	1LA03	Nyangores	04/04/2010	21.29
1LA03	Nyangores	21/02/2010	8.01	1LA03	Nyangores	05/04/2010	21.44
1LA03	Nyangores	22/02/2010	8.01	1LA03	Nyangores	06/04/2010	21.19
1LA03	Nyangores	23/02/2010	19.27	1LA03	Nyangores	07/04/2010	21.08
1LA03	Nyangores	24/02/2010	18.99	1LA03	Nyangores	08/04/2010	20.98
1LA03	Nyangores	25/02/2010	19.10	1LA03	Nyangores	09/04/2010	20.56
1LA03	Nyangores	26/02/2010	19.21	1LA03	Nyangores	10/04/2010	19.76
1LA03	Nyangores	27/02/2010	19.32	1LA03	Nyangores	11/04/2010	18.99
1LA03	Nyangores	28/02/2010	19.44	1LA03	Nyangores	12/04/2010	18.02
1LA03	Nyangores	01/03/2010	20.35	1LA03	Nyangores	13/04/2010	17.31
1LA03	Nyangores	02/03/2010	20.77	1LA03	Nyangores	14/04/2010	17.01
1LA03	Nyangores	03/03/2010	22.39	1LA03	Nyangores	15/04/2010	16.94
1LA03	Nyangores	04/03/2010	22.59	1LA03	Nyangores	16/04/2010	16.94
1LA03	Nyangores	05/03/2010	22.49	1LA03	Nyangores	17/04/2010	17.37
1LA03	Nyangores	06/03/2010	34.09	1LA03	Nyangores	18/04/2010	18.77
1LA03	Nyangores	07/03/2010	35.10	1LA03	Nyangores	19/04/2010	20.25
1LA03	Nyangores	08/03/2010	32.65	1LA03	Nyangores	20/04/2010	24.02
1LA03	Nyangores	09/03/2010	29.02	1LA03	Nyangores	21/04/2010	21.49
1LA03	Nyangores	10/03/2010	26.00	1LA03	Nyangores	22/04/2010	20.93
1LA03	Nyangores	11/03/2010	24.94	1LA03	Nyangores	23/04/2010	19.65
1LA03	Nyangores	12/03/2010	24.48	1LA03	Nyangores	24/04/2010	19.49
1LA03	Nyangores	13/03/2010	24.02	1LA03	Nyangores	25/04/2010	19.27
1LA03	Nyangores	14/03/2010	21.39	1LA03	Nyangores	26/04/2010	19.21
1LA03	Nyangores	15/03/2010	19.27	1LA03	Nyangores	27/04/2010	19.05
1LA03	Nyangores	16/03/2010	17.37	1LA03	Nyangores	28/04/2010	18.77
1LA03	Nyangores	17/03/2010	12.02	1LA03	Nyangores	29/04/2010	18.54
1LA03	Nyangores	18/03/2010	10.66	1LA03	Nyangores	30/04/2010	18.37
1LA03	Nyangores	19/03/2010	9.69	1LA03	Nyangores	01/05/2010	18.19
1LA03	Nyangores	20/03/2010	9.22	1LA03	Nyangores	02/05/2010	18.60
1LA03	Nyangores	21/03/2010	9.37	1LA03	Nyangores	03/05/2010	19.60
1LA03	Nyangores	22/03/2010	9.37	1LA03	Nyangores	04/05/2010	19.49
1LA03	Nyangores	23/03/2010	10.66	1LA03	Nyangores	05/05/2010	19.71
1LA03	Nyangores	24/03/2010	10.99	1LA03	Nyangores	06/05/2010	19.71
1LA03	Nyangores	25/03/2010	9.85	1LA03	Nyangores	07/05/2010	19.65
1LA03	Nyangores	26/03/2010	13.63	1LA03	Nyangores	08/05/2010	19.44
1LA03	Nyangores	27/03/2010	18.99	1LA03	Nyangores	09/05/2010	19.38
1LA03	Nyangores	28/03/2010	22.29	1LA03	Nyangores	10/05/2010	19.60
1LA03	Nyangores	29/03/2010	23.27	1LA03	Nyangores	11/05/2010	20.88
1LA03	Nyangores	30/03/2010	23.64	1LA03	Nyangores	12/05/2010	20.98
1LA03	Nyangores	31/03/2010	23.41	1LA03	Nyangores	13/05/2010	20.72

1LA03	Nyangores	14/05/2010	22.39	1LA03	Nyangores	07/06/2010	16.39
1LA03	Nyangores	15/05/2010	22.49	1LA03	Nyangores	08/06/2010	18.08
1LA03	Nyangores	16/05/2010	22.74	1LA03	Nyangores	09/06/2010	17.25
1LA03	Nyangores	17/05/2010	23.12	1LA03	Nyangores	10/06/2010	16.70
1LA03	Nyangores	18/05/2010	22.78	1LA03	Nyangores	11/06/2010	16.51
1LA03	Nyangores	19/05/2010	22.59	1LA03	Nyangores	12/06/2010	17.37
1LA03	Nyangores	20/05/2010	22.44	1LA03	Nyangores	13/06/2010	17.43
1LA03	Nyangores	21/05/2010	21.80	1LA03	Nyangores	14/06/2010	17.37
1LA03	Nyangores	22/05/2010	21.70	1LA03	Nyangores	15/06/2010	17.31
1LA03	Nyangores	23/05/2010	21.44	1LA03	Nyangores	16/06/2010	17.25
1LA03	Nyangores	24/05/2010	20.88	1LA03	Nyangores	17/06/2010	17.31
1LA03	Nyangores	25/05/2010	20.46	1LA03	Nyangores	18/06/2010	16.94
1LA03	Nyangores	26/05/2010	20.19	1LA03	Nyangores	19/06/2010	16.70
1LA03	Nyangores	27/05/2010	19.98	1LA03	Nyangores	20/06/2010	16.12
1LA03	Nyangores	28/05/2010	19.65	1LA03	Nyangores	21/06/2010	14.57
1LA03	Nyangores	29/05/2010	19.16	1LA03	Nyangores	22/06/2010	13.63
1LA03	Nyangores	30/05/2010	18.65	1LA03	Nyangores	23/06/2010	13.45
1LA03	Nyangores	31/05/2010	17.79	1LA03	Nyangores	24/06/2010	13.27
1LA03	Nyangores	01/06/2010	17.49	1LA03	Nyangores	25/06/2010	12.02
1LA03	Nyangores	02/06/2010	17.55	1LA03	Nyangores	26/06/2010	12.02
1LA03	Nyangores	03/06/2010	17.49	1LA03	Nyangores	27/06/2010	10.83
1LA03	Nyangores	04/06/2010	17.13	1LA03	Nyangores	28/06/2010	11.16
1LA03	Nyangores	05/06/2010	15.34	1LA03	Nyangores	29/06/2010	12.91
1LA03	Nyangores	06/06/2010	14.38	1LA03	Nyangores	30/06/2010	13.63

APPENDIX III: Questionnaire for Assessing the Impacts of Land Uses on soil erosion in

Nyongores River catchment

Dear Respondent,

My name is Wesley Kiprotich Langat from Moi University, School of environmental studies. I am currently undertaking field data collection for my Masters Degree thesis in environmental planning and management.

I would like to request you to take a few minutes to fill this questionnaire. The information given will be treated with the confidentiality it deserves and will only be use for academic purposes.
Thanks in advance.

Instruction: *Tick where applicable*

Questionnaire serial No…..……

Location/sub location and Village……………………………………………………

……………………………………………………………………………………….

I. Personal Information

1. Name ……………………………………………………age……….…years
2. Sex [ ] Male [ ] Female
3. Level of education [ ] Primary [ ] Secondary [ ] College/ university
4. Occupation …………………………………………………………………….
5. Area of residence: District………………...Division………………Location………

II. General Information regarding the Status of Environmental in the catchment

1. What is the approximate size of your land in acres?
   [ ] 0.1 – 0.9 [ ] 1 – 2.5 [ ] 2.6 – 5 [ ] 5 – 10 [ ] 10 and above
2. What is the main activity (land use) that you undertake in your farm?
   [ ] Crop cultivation [ ] Pasture for livestock farming
   [ ] Forest Cover [ ] Settlement/ Housing
3. In the question above, what is the approximate percentage of your land under each of the activities?

	Land use type	**% cover**
a)	Crop cultivation	
b)	Pasture for livestock	
c)	Forest Cover	
d)	Settlement/ Housing	
e)	Others (specify) …………… ……………………………… ………………………………	

4. How many animals do you have in your farm? Cattle ……., sheep ………….., goats ……, donkeys ……………., any other ……………………….

5. What are the major environmental challenges/concerns in this area?
   [ ] Soil erosion and loss of fertility [ ] Flooding
   [ ] Forest destruction [ ] Riverine vegetation destruction
   [ ] Any other (specify)

…………………………………………………………………….
6. Rate the trend of the identified concerned compared from now and in the past one decade
   [ ] improved [ ] Same [ ] Fair [ ] worsening [ ] very worsening
7. How are the concerns in question 4 above affect you and the community?
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ………………………………
8. What interventions have the stakeholders of this catchment done towards the addressing these concerns?
   ………………………………………………………………………………
   ……………………………………………………………………………………….
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ………………………
9. List the stakeholders concerned and their activities towards addressing the environmental concerns in question 4 above

Name of the stakeholder		**Activity**
1		
2		
3		
4		
5		
6		

III Information on soil, water and riverine conservation

Soil Erosion

1. Have you observed the occurrence of soil erosion in your farm?
   [ ] yes [ ] No
2. What is the main cause of soil erosion in your farm?
   [ ] Water [ ] Wind [ ] Animals [ ] others
3. Where is soil erosion most prevalent within your farm?
   [ ] Cultivated lands [ ] Pasture lands [ ] Forest land [ ] Housing
4. How can you rate the extent of soil erosion in the identified land uses, in question 6 above?
   [ ] Not Significant [ ] Less severe [ ] Severe [ ] Very Severe

5. What are some of the main problems that soil erosion has caused to you and to the community? ……………………………………………………..………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………..
6. What actions have you undertaken to control soil erosion in your farms?
[ ] Building Gabions [ ] Terracing [ ] Planting Grass Cover
[ ] Agro Forestry [ ] Any Other (list)
7. What do you think it can be done in addition to control soil erosion?
………………………………………………………………………………………
………………………………………………………………………………………

Appendix IV: Nyongores River Catchment Land Use Planning and Management Plan (Source: Author, 2010)

Nyongores River Catchment	**Major sources of soil erosion Observed**	**Current Main Existing Interventions**	**Remarks/actions required**
Ainopng'etunyek sub catchment	Forest encroachment, cultivation along river banks, overgrazing and foot paths	Contour ploughing and terracing	• Improve on terracing, agro-forestry, riparian protection and reduce number of stocks to 2 per acre
		Clearance of vegetation	•
		overgrazing	•
			•
Chepkositonik sub catchment	Foot paths, Poor farming methods particularly maize cultivation e.g. hill top cultivation	Contour ploughing, terracing, tree planting	• Improve on terracing, consider the use of sand backs, furrow digging, increase agro-forestry, avoid cultivation on steep slopes and hill tops • Reforestation of hill-slopes, Planting dense woodlands in gullies, Blocking artificial drains, Restoring wetland features, Restoring river channel meanders, Controlling excessive erosion and Management of large woody debris in watercourses
		open hill tops/slope which are steep, steep gullies	• Growing trees or shrubs on vulnerable slopes (agro-forestry) • grass cover crops, or tea plantations (intercropping) • Incorporation of manure or compost into soils so improving soil structure also cuts down runoff and erosion and phosphorus losses in water.
			•
Kagawet sub catchment	Poor maize cultivation practices, overgrazing, foot paths	Agro-forestry, gabions,	• Improve on construction of gabions, improve on agro forestry, practice terracing and protect riparian strips
		Absence of riparian strips	•
Kiprurugit sub catchment	Cultivation along river banks, foot paths and overgrazing	Terracing, agro-forestry	• Improve on terracing, avoid over grazing, protect wetlands and riparian strips
			• Agrodiversity to indigenous soil conservation farming eg planting of sweet potatoes as cover crops
			• Use of diversion ditches
			• Application of live-barriers