A STUDY OF EROSIONAL FEATURES AND ENVIRONMENTAL RESTORATION OF RIVER KALIKUVU CATCHMENT IN KITUI COUNTY, KENYA

BY

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DECLARATION

This research project is my original work and has never been submitted for examination in any other university.

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This research project has been submitted for examination with our approval as University supervisors.

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DEDICATION

To my beloved family, especially my husband, Mr. Frederick William Kinga, who tirelessly supported me throughout the study and fieldwork period.

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Plates

LIST OF ACRONYMS

DANIDA	:	Danish International Development Agency
FAO	:	Food and Agriculture Organisation of the United Nations
GIS	:	Geographic Information System
GoK	:	Government of Kenya
GPS	:	Globe Positioning System
ICRAF	:	International Centre for Research in Afro forestry
KARI	:	Kenya Agricultural Institution
KNBS	:	Kenya National Bureau of Standards
SASOL	:	Sahelian Solution Foundation
UNEP	:	United Nations Environment Programme
UNU	:	United Nations University
USDA	:	United states Department of Agriculture

ABSTRACT

Soil erosion is one of the most significant processes of land degradation that reduces productivity of agricultural land and forms erosional features,. The present study of erosional features and environmental restoration in Kalikuvu river catchment is in a semi-arid area with sparse vegetation cover in Kitui County, Kenya and this has promoted both water and wind erosion.

The objectives were to determine factors that cause soil erosion, investigate geomorphologic landforms resulting from soil erosion, study the impact of soil erosion on crop production, especially maize, and suggest restoration measures used in Kalikuvu catchment to control soil erosion.

A sample of 44 respondents from a total of 1,297 households (KNBS, 2009) was selected. The primary data was collected through direct field survey while secondary data was extracted from existing documents and records from various institutions. For purposes of data collection, the Kalikuvu river catchment was divided into three segments namely youthful, mature and old since there were differences in the extent of erosion and erosional features in the three stages. The resulting data was subjected to statistical and descriptive analysis. The results show that the causes of soil erosion in the study area are due to both human and physical factors. Soil erosion has impacted negatively on the community in terms of relief food dependency and rills and gullies that criss-cross the study area. The restoration responses put in place are "*Fanya Juu*" terraces, planting of trees and gabion construction. The soil erosion was found to be a serious problem in the study area and containing it in the near future seems to be unlikely due to the challenges faced by restoration responses being used, namely the dryness and bareness of the area,

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background to the Study

The changing surface of the earth has attracted a lot of debate over the centuries through the works of Herodotus (458 BC – 425 BC), Ptolemy (54 BC) and Aristotle (382 BC- 322 BC) as reported by Thornbury (1969). Davis (1850-1934) came up with the first geomorphologic concept of cycle of erosion in humid latitudes that tends to explain earth surface processes that begin with an initial uplift of the landmass followed by a long period of tectonic quiescence. The period of tectonic quiescence is characterized by major land forming stages, namely youth, mature and old stage. In this monumental work, Davis maintained that structure, process and time were the most predominant factors and that running water or a river was the major agent of erosion that changed the land surface. This study examines landforms resulting from soil erosion in Kalikuvu River catchment.

Soil erosion and the resultant landforms has for a long period of time been a major issue in a number of semi-arid lands in Africa (Dunne *et al;* 1979). According to Kithiia *et al;* (1993), soil erosion in Kenya is mainly due to surface water run-off from "bare" soil surface. The problem is more pronounced in the marginal lands, as a result of sparse vegetation cover, intensive cultivation and overstocking. Soil erosion if not checked leads to formation of rills, gullies, caves and bare surface ground mainly covered by stones and rocks. These landforms have been noted to lead to soil degradation, which is a global problem today. The soil erosion has negative effects on roads, agricultural land, settlement and livelihood of the people. With the rapidly increasing population of both human and livestock, sustainable land management and conservation of water catchment regions are priority areas of intervention. Rapid population increase within the catchment leads to destruction of vegetation, land use change and destabilization of water infiltration into the soil, thus encouraging increased overland flow resulting to soil erosion by water (Kitheka 1994).

1.2 Statement of the Problem

Soil erosion is one of the greatest causes of land degradation in Africa (Thomas, et al, 2000). Soil erosion as a geomorphological process creates landforms that tend to affect agricultural productivity and .influences stream flow in the water catchment. Water is a necessity for most of the development programmes and is a life sustaining resource which must be studied to establish the underlying processes and inter-linkages (Barrow 1987).

Over recent years, the Kalikuvu catchment in Kitui Central Division, Kitui County has experienced rapid increase in population of both human and livestock. Intensive land use activities on the water catchment have replaced vegetation cover to create room for agriculture and settlements. This has led to disturbance of soil structure and stability, accompanied with rainstorms of high intensity, on steep slopes to form surface runoff which consequently detaches and transports soil particles down slope to streams. The resultant effect is formation of erosional landforms and siltation of water bodies such as rivers, where sediments are deposited.

Soil erosion causes landforms such as rills, gullies, residual hills and caves. that affects physical infrastructure, agricultural land, human settlement and livelihood of the people. Areas along River Kalikuvu are eroded and are characterised by the presence of gullies and rills. Ephemeral streams that drain into the Kalikuvu River transport large quantities of sediment derived from rills and gullies. There is need to study the factors causing soil erosion, identify geomorphologic landforms due to soil erosion, investigate the impacts of soil erosion on crop production and how soil restoration activities in Kalikuvu catchment can be undertaken. The study shall provide planners with vital information necessary for restoration of catchment for sustainable development

1.2.1. Research Questions

The study of soil erosion and landforms in a catchment attempted to address the following research questions:

1. What are the causes of soil erosion in Kalikuvu catchment?

2. What are the geomorphologic landforms resulting from soil erosion in Kalikuvu catchment?
3. What is the impact of soil erosion on crop production especially maize in Kalikuvu catchment?
4. What are the restoration measures used in Kalikuvu catchment to control soil erosion?

Answers to the above questions were meant to achieve the following objectives.

1.3 Study Objectives

In addressing the research questions in the Kalikuvu catchment, the objectives were to determine:

1. Factors that cause soil erosion.
2. Geomorphologic landforms resulting from soil erosion.
3. The impact of soil erosion on crop production, especially maize.
4. Restoration measures used in Kalikuvu catchment to control soil erosion.

1.4. Research Hypotheses

1 H_o -There are no specific factors responsible for soil erosion situation in the Kalikuvu catchment.

2 H_o- There are no landforms in the Kalikuvu catchment due to soil erosion.

3 H_o- There are no impacts of soil erosion on crop production especially maize in Kalikuvu catchment.

4 H_o-There are no specific restoration measures due to soil erosion in the Kalikuvu catchment.

1.5. Justification of the Study

This study critically evaluated and assessed causes of soil erosion and described the associated land forms in Kalikuvu catchment in Kitui County. A review of literature on selected catchments of Kenya (e.g. Ongwenyi *et al;* 1992, Kithiia *et al;* 1993 and Kitheka 1994) indicated that where scientific studies have been carried out on soil erosion, concentration has been in large river basins experiencing humid climatic conditions and in which the major land use activity is cultivation. Little has been done on soil erosion in agro-pastoral areas, characterized by ephemeral streams in semi-arid environments like Kalikuvu catchment in Kitui County. Kalikuvu catchment is a small area with many geomorphologic landforms.

The river basins in the rangelands tend to be inhabited by people that keep livestock and grow crops mostly for subsistence. It was the position of this study that if the factors causing soil erosion in a small river basin were determined, then it would be possible to design appropriate remedial measures that could be applicable in other small drainage basins in the rangelands of Kenya. The expected contribution of this study in the Kalikuvu catchment included:

- Knowing factors causing soil erosion in the Kalikuvu catchment could be useful in designing soil erosion remedial measures
- Identification of landforms due to soil erosion could assist in establishing an early warning system in soil erosion management in any river catchment
- The determination of soil erosion impacts on livelihood such as maize production could be of use in establishing appropriate relief measures
- The soil erosion restoration measures in a river system could be used to develop an evaluation tool for effectiveness of such measures in restoring degraded surfaces due to soil erosion.

The choice of the Kalikuvu catchment was based on the following reasons:

1. Soil erosion being a major problem in the Kalikuvu catchment meant that it was expected to have many types of erosion surfaces and landforms thus affecting livelihoods.
2. Kalikuvu catchment being a small area allow for detailed study of soil erosion, the results of which can be used to model soil erosion in larger areas
3. Kalikuvu catchment is conveniently located and accessible from two major shopping centres namely Itoleka and Katulani and therefore the area was a consideration in terms of data acquisition, especially during rainy season.
4. Previous studies on soil erosion had not specifically dealt with soil erosion problems in the Kalikuvu catchment

The contribution of this study to knowledge was in the field of environmental geomorphology in terms of erosion processes and associated landforms impact on livelihoods. It was also the position of this study that there was need for an evaluation of the impacts of the soil erosion and suitability of the intervention measures in the Kalikuvu catchment with the view of scaling up such experiences.

1.6. Operation Definitions

Basement rock system part of the earth`s crust formed of hard igneous or metamorphic rock that lies beneath the cover of soft sedimentary rock.

Catchment sometimes referred to as watershed, is the area bounded by high relief where rainfall that occurs within the boundary drain streams with a single river mouth.

Cycle of erosion is the modifications of the earth`s surface by erosion from the original uplift of the land to the ultimate low plain, usually through a series of stages referred to as the youthful, mature and old stages.

Geomorphology is the study of landform processes that created such landforms, and the history of their evolution.

Geographic Information System (GIS) is a group of tools used in capturing, storing, manipulating and analyzing georeferenced spatial data to create new spatial information from various perspectives.

Land degradation is the reduction in the ability of the land to produce benefits from a particular land use under specified form of land management.

Landforms are any physical features on the earth`s surface formed as a result of geological and morphological forces.

Soil Erosion is the detachment and transportation of soil particles by the forces of water and wind.

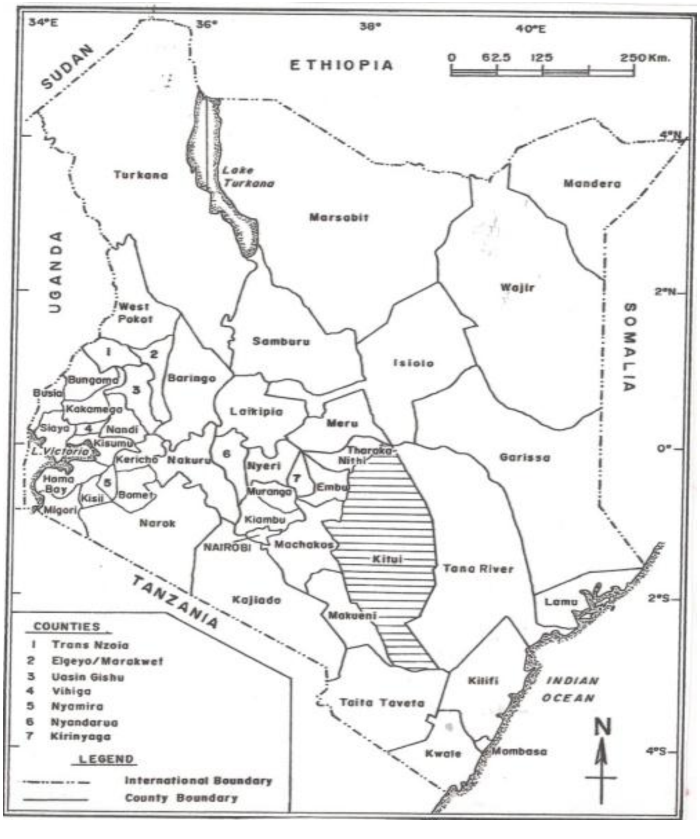
CHAPTER TWO

2.0. THE STUDY AREA

2.1 Location and Size

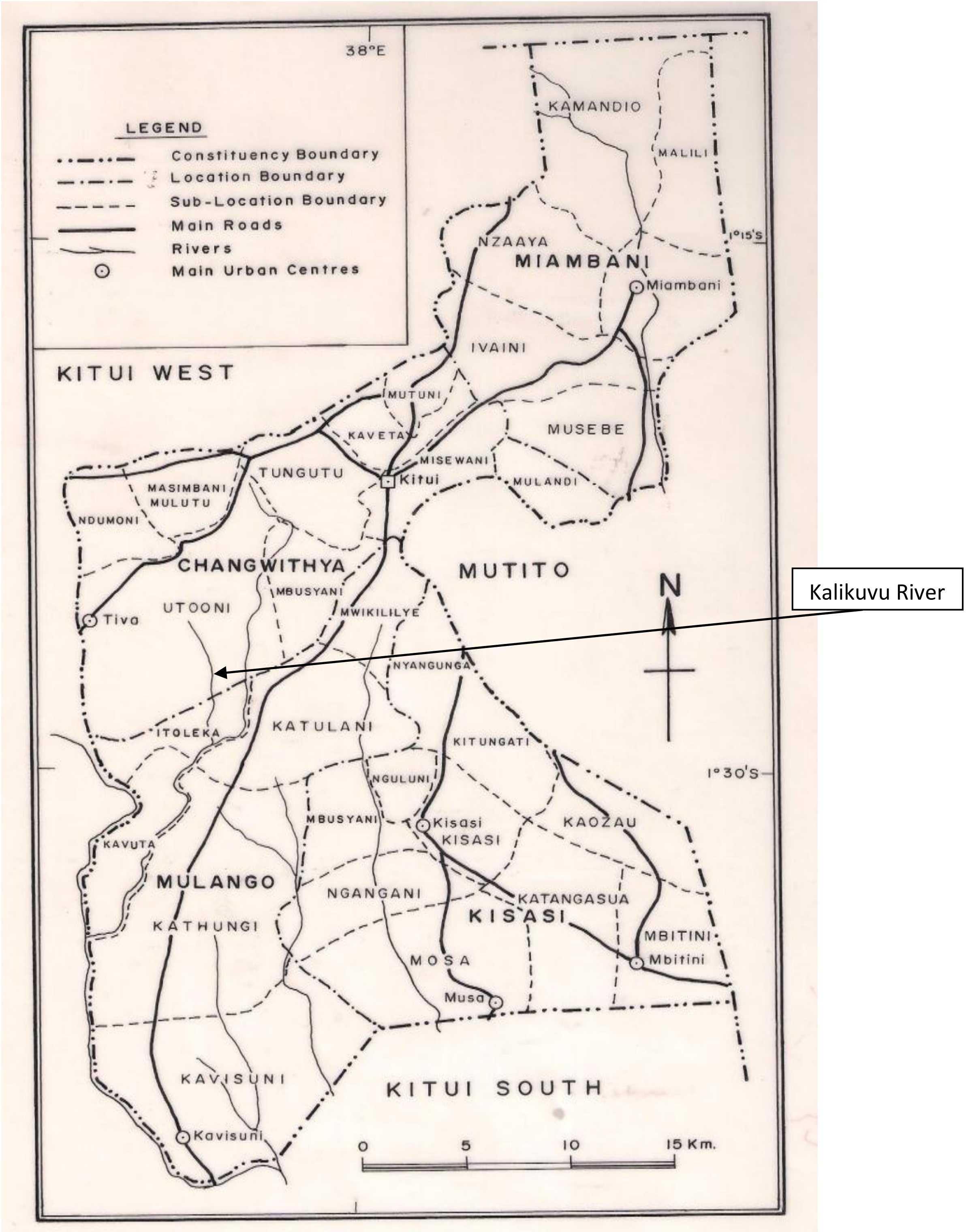
The present study on soil erosion, landforms processes and environmental restoration was carried out on River Kalikuvu catchment in Central Division, Kitui County. Kitui County which lies between latitudes $0^{o}3.7'$ and $3^{o}00'$ south, and longitudes $37^{o}45'$ and $39^{o}00'$ East and therefore within the tropical region (as indicated in figure 2.1). The Central Division covers an area of 809 km^2, it borders Yatta to the West, Matinyani and Mutonguni to the North, Mutito to the East and Chuluni to the Southwest. The division has 8 locations namely Kyangwithya West, Kyangwithya East, Mulango, Township, Katulani, Miambani and Itoleka (Divisional implementation team central division kitui 2009) as shown figure 2.2. River Kalikuvu catchment covers an area of about 53.6km^2 and the river has a length of about 9.4km. It is a tributary of River Muilini, which is part of the Athi river drainage system.

Figure 2.1: Location of Kitui County in Kenya



(Source: District Development Plan, GOK 2002-2008)

Figure 2.2: Locations and sub-Location of Kitui Central Division



(Source: District Development Plan, GOK 2002 – 2008)

2.2 Geology

The bedrock of Kitui County is composed of various gneisses of the Basement System. There are four main rock types in the Kitui County according to Louis Berger International Inc., (1983), namely:

- Quaternary superficial deposits;
- Tertiary rocks;
- Palaeozoic sedimentary rocks;
- Precambrian crystalline rocks.

Table 2.1: Geomorphological Processes and Rocks in Kitui County

Age	**Geomorphic Process**	**Rock types**
Precambrian	Tectonics and metamorphism, Erosion, peneplanation	Gneisses and Schist
Palaeozoic	Forming of basin by tectonic activity and faulting	Shales, sandstones
Tertiary	Tectonic activity	Intrusive and dykes
Quaternary (recent)	Erosion, local sedimentation	Soils, sands, alluvium, limestone, clays, silts

(Source: Schoeman, 1948; Sanders, 1954; Louis Berger International Inc., 1983)

Precambrian crystalline rocks

The Precambrian rocks are generally referred to as rocks of the “Basement Complex”. General rocks show a regional structural North-South trend of foliation. Most of the Kitui County is underlain by gneisses and schist rocks, formed by tectonics and metamorphism processes which took place during Precambrian. These rocks have fractures, faults, joints and weathered zones. The schist is often sealed by the clay resulting from weathering (Borst *et al;* 2006).

Palaeozoic sedimentary rocks

Shale, grits and sandstones rocks are formed by tectonic activity during Palaeozoic period and are found in the South-Eastern corner of the County, Mainly in Tsavo-East National Park (Borst *et al;* 2006).

Tertiary rocks

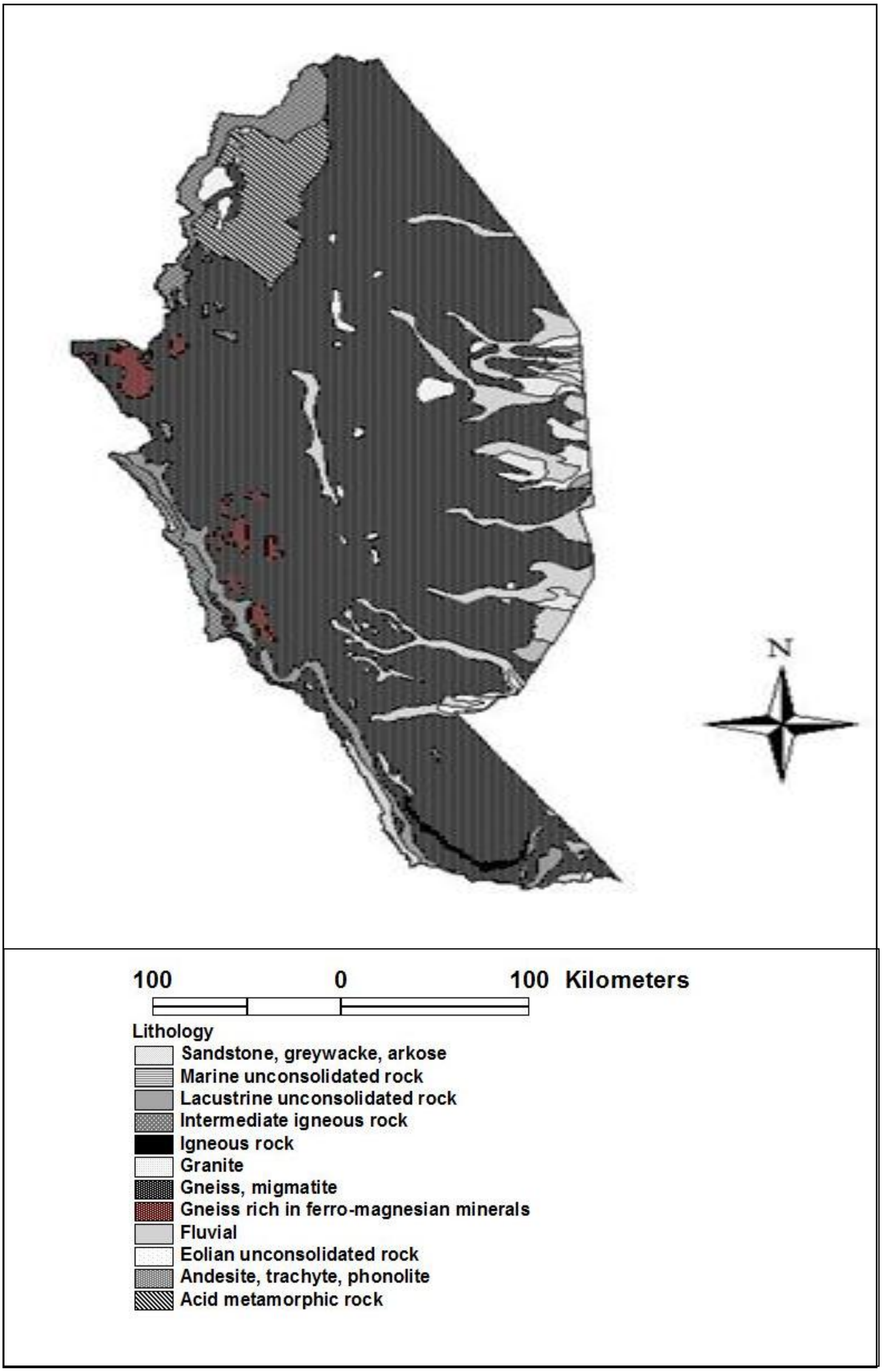
Volcanic rocks, both intrusive and dykes were formed by tectonic activity during the tertiary period. They outcrop in the plains and along the Eastern boundary of the County.

Quaternary rocks

The quaternary superficial deposits consist of sands and gravels along river channels. The other types of quaternary are formed by deposits of talus or loose unconsolidated materials, example, at the edge of steep slopes, such as alluvium and silts. They were formed by processes of erosion and local sedimentation, during quaternary period.

Due to complex tectonic activity most of the primary structures and textures have been lost through crystallization and re-crystallization. However, it is still recognized that sandstones and other sedimentary rocks were metamorphosed to gneisses, which form the lithology at present. The major part of the central County is a non-dissected sedimentary plain (Erhart *et al;* 1983) as shown in table 2.1 and figure 2.3.

Figure 2.3: Geology of Kitui County



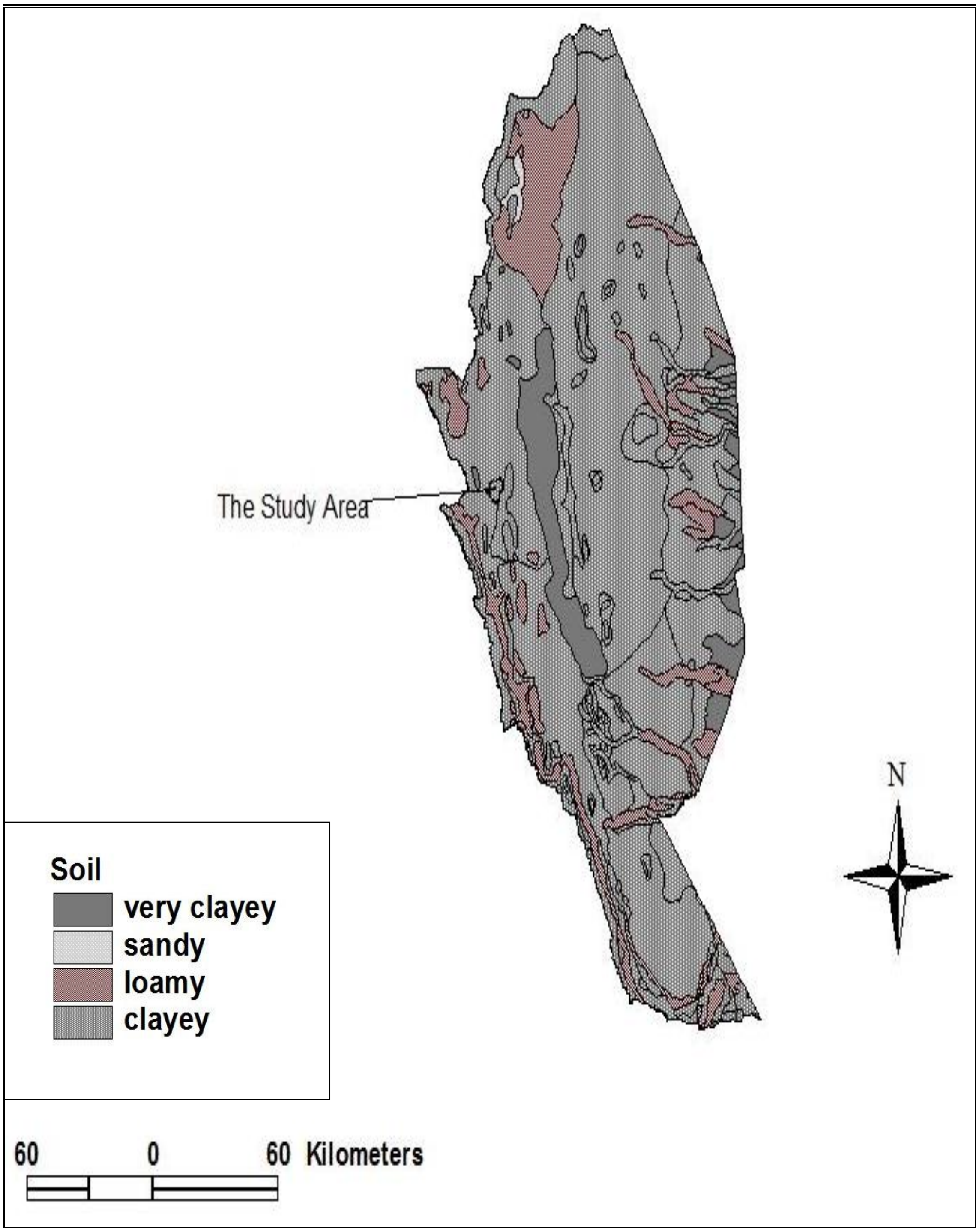
(Source: Department of Geological Survey, 2014)

2.3 Soils

Soil formation has been influenced by the geology and climate of the area. Luvisols and Ferralsols have formed from weathered metamorphic rocks. Luvisols and ferralsols are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay and in many places with topsoil of loamy sand to sandy loam and others with acid humic. Luvisols surface soils with high silt content may be sensitive to slaking and erosion. Luvisols are suitable for a wide range of agricultural uses. Luvisols on steep slopes require erosion control measures.
Ferralsols are characterized by minerals such as glasses and ferro-magnesian minerals and the more resistant feldspars and micas have disappeared completely. Ferralsols are poorly equipped to supply crops with moisture during periods of drought, particularly those in elevated positions.

The central part of the Kitui County has sedimentary plains and the eastern parts of the County both have Ferralsols that are rich in sodium and perceptible to excessive erosion and worsened by comparatively low rainfall in the region. Towards the western part of the County are Vertisols GOK (2002-2008); MoA (1982). The riverbed itself is filled with coarse sand (about 600 µm), which is an erosion product of the different local lithological units, mainly gneisses which has a thickness varying from a few centimetres to more than 2 meters (Erhart *et al;* 1983*)* as shown in figure 2.4.

Figure 2.4: Soil Map of Kitui County



(Source: Field GIS reading, Kenya terrain data, 2010)

2.4 Relief and Landforms

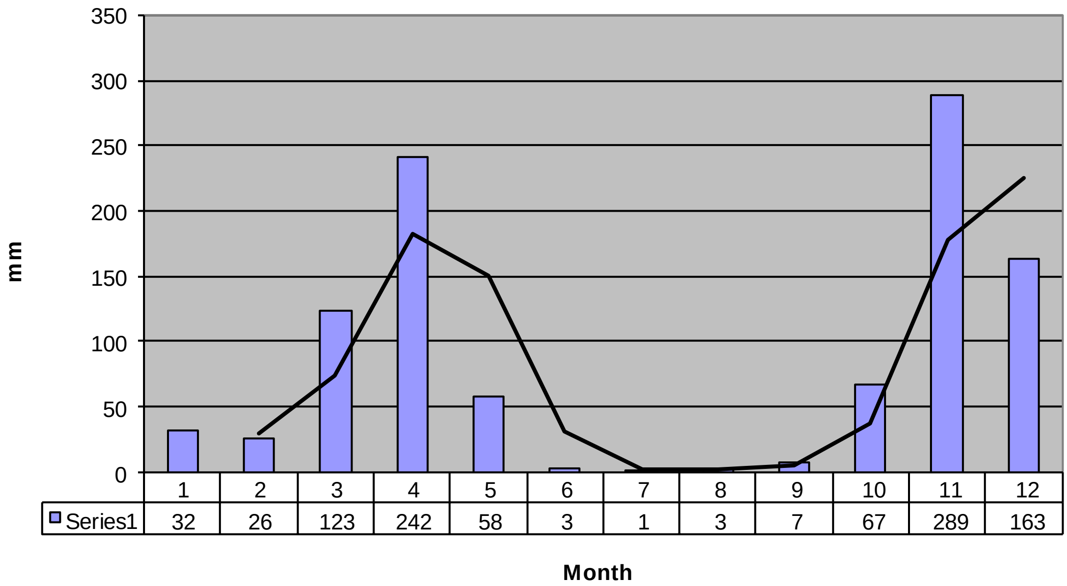
Kitui County has a range of hills in the Central part, to the eastern side of the County there is Yatta plateau which is the main feature, and stretches from the north to the south of the County between rivers Athi and Tana. The plateau is almost plain with wide shallow spaced valleys. The altitude of Kitui central division rises from 400m to the South West and 1700m in the south East above sea level. It is characterised by hilly ridges separated by wide, low lying areas and has slightly low elevation of between 600m and 900m above sea level. The altitude of the catchment, under study ranges between 1168m to 1129m above sea level and generally slopes from West to East. The catchment is characterized by gullies, hilly ridges and rills. It has steep slopes at the youthful stage and gentle slopes at the old stage of the river valley. Erosion increases as the slope length increases due to greater accumulation of run-off. The type and length of slope are critical factors in determining erosion (GOK 2002-2008).

2.5 Climate

The climate of Kitui County can be classified as hot and dry for most of the year and can be characterized as an arid and semi-arid with unreliable rainfall. The rate of evaporation is so high that many reservoirs and rivers dry up when the rains stop. The high rate of evaporation and unreliable rains are characteristic features of the County that cause several limitations to intensive and meaningful land use and other related development activities (GOK 1994-1996).

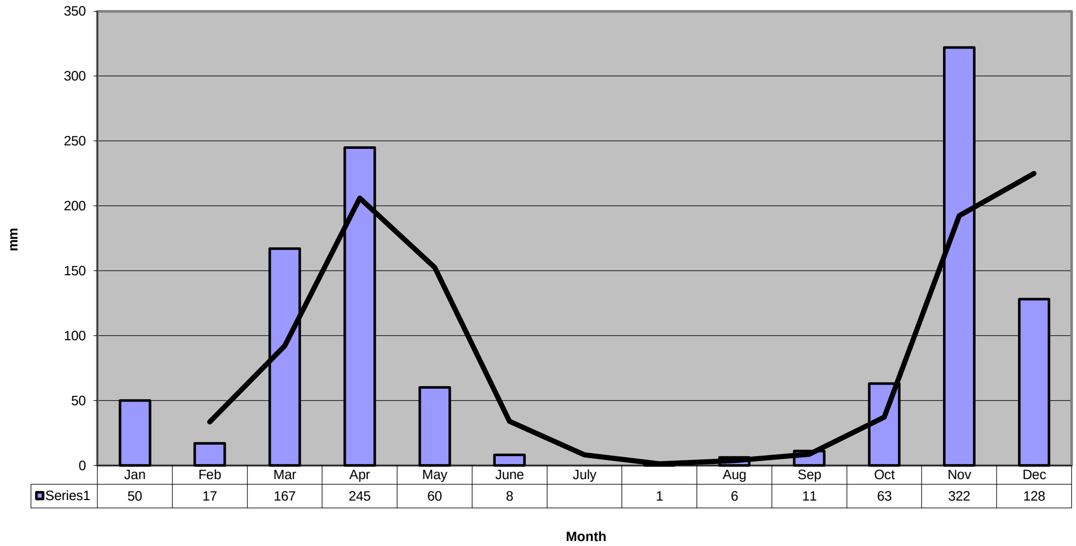
The central division of Kitui receives a bi-modal rainfall with amounts ranging between 300-800 mm per annum. The estimated annual rainfall is 600 mm (Divisional implementation team central division Kitui 2009). The rainfall is seasonal with two rainy seasons: the long rains come in March/April and short rains in October/November. The short rains are more reliable, while long rains are usually unreliable. The short rains are high in amount, (as shown in figure 2.5 and 2.6), leading to sheet erosion. The amount of rainfall fluctuates from year to year. The periods falling between May to September and December to March are usually dry. The seasonality affects erosion in the area. The area falls under agro-ecological zones LM4 and LM5 (Divisional implementation team central division Kitui 2009).

Figure 2.5: Rainfall Regime at Kitui Agr. Office (9138000 Altitude 1152M) for 67 Years up to 1976



(Source: Kitui Agricultural Office, 1976)

Figure 2.6: Rainfall for Kitui Water Supply Dam (9138014 Altitude 1180M) for 12 Years up to 1976



(Source: Kitui, Water Supply (Dam), 1976)

The area experiences high temperatures throughout the year, which range from 16^{o}C to 34^{o}C. The minimum mean annual temperatures in Kitui County vary between 14^{o}C to 18^{o}C in the western parts and 18^{o}C to 22^{o}C in the eastern parts. The maximum mean annual temperatures on the other hand; vary between 26^{o}C to 30^{o}C in the western parts of the County and 30^{o}C to 34^{o}C in the eastern parts (GOK 1994-1996).

2.6 Drainage

Kitui County is dominated by two main rivers, River Tana to the eastern side and River Athi to the western side. The county lies within the water divide of the two main drainage basins of River Tana and River Athi; this affects the drainage and erosion of the County. The River Tana is Kenya's largest river and drains the Eastern flank of the Aberdares and the Southern slopes of Mount Kenya. Both rivers discharge to the Indian Ocean (Borst et al; 2006). River Tana is the only perennial river in the county and most of the ephemeral streams that drain into it generally become dry within one month after the rainy season.

In spite of perennial headwater, the River Athi often runs dry due to high rate of evaporation and infiltration losses (Borst *et al;* 2006). The rivers in Kitui County are strongly characterized by high flows in April to May and November to December and very low or nil flows in the intervening dry periods. Some of the drainage systems which form River Athi are Rivers Tiva, Muilini and Kalikuvu. The source of River Kalikuvu is in Utooni area in Ithiani sub location. River Kalikuvu is a seasonal River and flows during the rainy season and dries up shortly after the rains. It has length of about 9.4km and covers an area of 53.6km^2. The river forms dendritic drainage pattern, at first stage of development. At the youthful stage the valley is deep and narrow forming a v-shape, at the mature stage the channel is deep and forms u-shape and at the old stage the channel forms open u-shape and shallow in depth.

2.7 Vegetation Cover

Vegetation cover has the dual role of stabilising the soil to reduce raindrop impacts that seal the soil porosity and thus reduce infiltration and soil erosion. The vegetation is sparse and predominantly drought resistant. The vegetation consists of mainly of *Acacia spp*. and other thorny bushes. Examples are *Acacia clavigera*, *Acacia seyal*, *Terminalia spp.*, *Commiphora spp*. (Katumo 2001).

2.8 Population

Kitui County has a total Population of 1,012,709 people; the Central Division has an estimated population of 123,742 people with forum families of 17,000 and a population density of 200 people per square kilometre (Divisional implementation team central division kitui, 2009). The Kalikuvu Sub-location has a total population of 5,626 people (KNBS 2009).

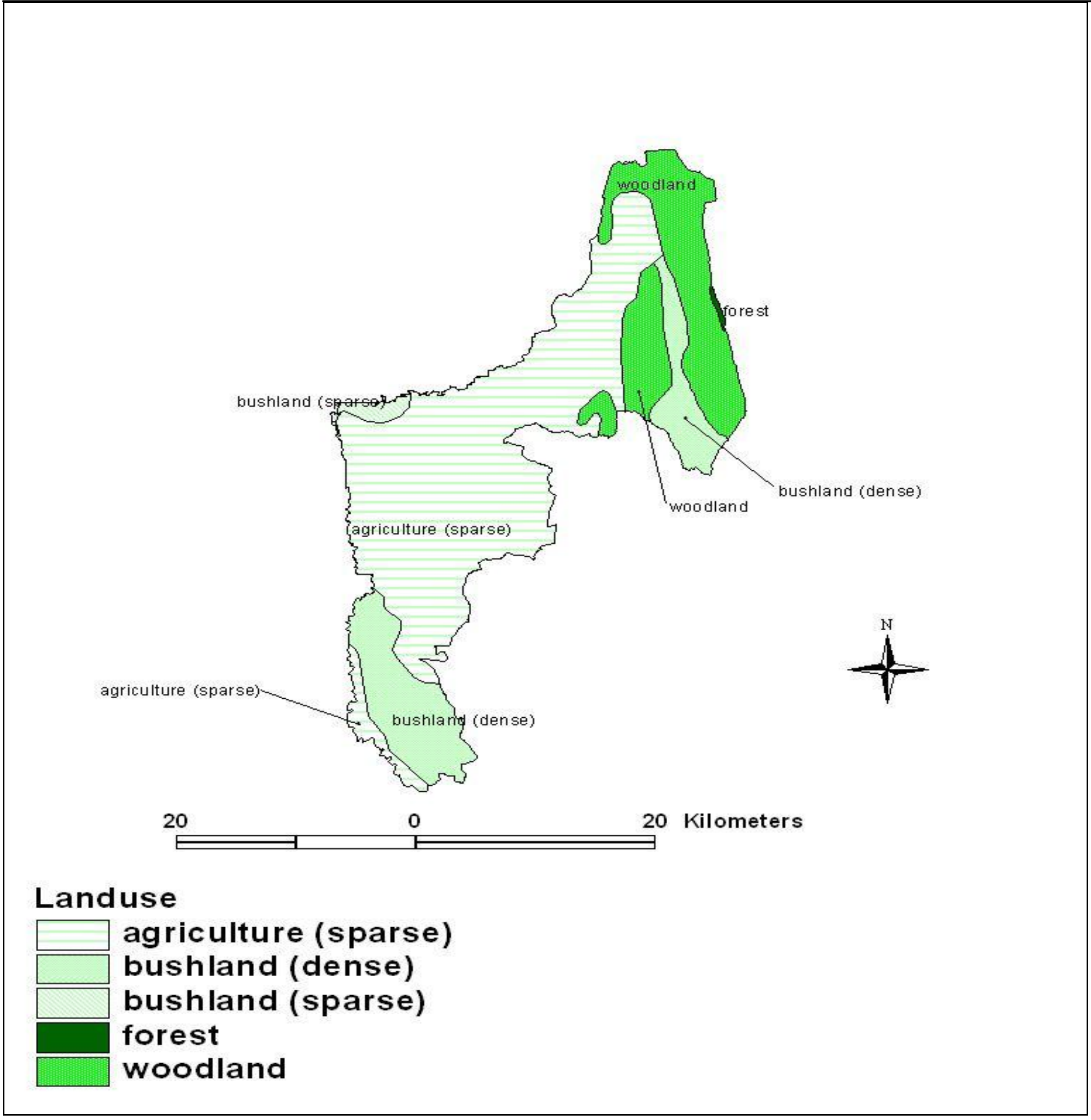
Most of the inhabitants belong to the Kamba tribe and live in communities consisting of small huts and buildings near their fields. Villages are small, consisting of a few shops and other buildings. The social and economic policy direction has an impact on environmental issues (Borst *et al;* 2006).

2.9 Agriculture

The economy of the region is largely rural and more than 95% of the population earns their living from agriculture as shown in figure 2.7 where agriculture covers a large portion of Central Division of Kitui County. Rain fed agriculture is predominant while irrigated agriculture only takes place on small plots on the river banks. Various types of drought resistance cereals, horticultural crops, root crops, oil crops, and creepers are grown. The major cereals are maize, cowpeas, pigeon peas, sorghum, beans and green grams. The horticultural crops grown include fruits, mangoes and paw paw trees; vegetables are normally under irrigation along the large seasonal rivers and vegetables grown are tomatoes, onions, *sukuma wiki*, cabbages and spinach. The root crops and oil crops grown are cassava, sweet potatoes and sunflower. Creepers: Pumpkins, butter nuts and watermelons, the cover crops help in controlling surface run off and soil erosion. Land transformation from natural to different cropping systems has increased cases of accelerated erosion in the study area. The farm units vary in size but mainly small scale, on average they range between 1 to 5 hectares and are privately owned (GOK 2002-2008). During long rains in March/April the farmers have reduced land size due to the biannual crops which are still in the field from the short rains (Divisional implementation team central division Kitui, 2009).

Livestock is the major economic activity in the county. Pastures and water for the animals lasts only a few months leaving the animals with virtually no grazing fields. Traditional livestock keeping is practiced and the main livestock bred are; chicken, goats, cows, donkeys and sheep. There is also Bee keeping. The livestock carrying capacity is 12 acres (GOK 2002-2008).The research carried out by National Environmental Secretariat (1981) indicate that the area has experienced series of drought roughly after every 8 to 10 years (as shown in appendix 11). This is thought to influence soil erosion in the County greatly.

Figure 2.7: Land use Map of Central Division, Kitui County



(Source: Field GIS reading, Kenya Land use data, 2010)

2.10 Other Economic Factors

Besides farming, other economic activities are charcoal burning, basket breading, bee keeping, sand harvesting and brick making (GOK 2002-2008). The local people use firewood as the main source of energy as well as for sale. In this case lots of trees and shrubs are cut down; leaving large areas bare, which become very susceptible to erosion.

2.11 Education

The primary schools in the Kitui County are about 606 and scattered all over the vast area, resulting to long distances between the schools. The teacher pupil ratio is quite low at 1:13. The primary school going population aged 6-13 years representing 27% of the total population. There are both secondary and private secondary schools in the area; however, there are no technical centres of higher learning in the county. Most schools and other training institutions in the county are ill equipped and underutilized. Quite recently, Kenyatta University (KU) established a campus in the town headquarters and soon after the University of Nairobi (UON) established the Southern Eastern University College (SEUCO), (GOK 2002-2008). Environmental education is not currently well taught in the present curriculum. The government however has established the concept of "Green Schools" in the country.

2.12 Health facilities

The county has 92 health facilities, which are inadequate given the vastness of the area. These facilities are unevenly distributed as most of them are found in central and Kabati divisions. Many of these facilities lack the necessary equipments and personnel to enable provide quality services to the people. The most prevalent diseases are malaria, respiratory infections, diarrhoea, Hiv/Aids, skin diseases and eye infections. The doctor - patient ratio is 1:16047. Life expectancy level in the county is 51 years, which is below the national average 55 years (GOK 2002-2008).

CHAPTER THREE

3.0. LITERATURE REVIEW

3.1 Introduction

The objective of this review was to highlight some important scientific works that are available on Soil erosion and its impact in the World, Africa, Kenya, Kitui County, and Kalikuvu sub-location. This was deemed necessary in revealing trends in research activities on causes of soil erosion, its impact on landforms and crop yields and restoration measures, which were considered useful to this study. The review was also meant to reveal restoration measures. The review is organised into topical issues based on the study problems, objectives and hypotheses.

3.2 Soil Erosion

Soil erosion is a naturally occurring process that affects all landforms, by the natural physical forces of water and wind. Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. It involves three distinct actions; soil detachment, movement and deposition. A great deal of research work has been done over the years on soil erosion and its impact on the earth surface. The problem is more pronounced in the marginal lands due to cultivation and overgrazing (Denga *et al;* 2000). Denga *et al;* (2000) citing the UNEP report (1987) noted that the problem of soil erosion as had a long history in Kenya, where by 1935 it had become a major environmental problem, increasing in the 1960s when the nature of approach to soil conservation changed from enforcement to advisory, which led to a temporary breakdown of soil conservation activities but this changed in the 1970s when attention focused on land management and conservation practices, with a view to reducing the problem of soil erosion.

Erosion problem in Kenya has mainly been considered in terms of water movements as shown in the work of Dunne *et al;* (1976), Dunne *et al;* (1978), Ongwenyi (1978, 1979), Edwards (1979) and Waine (1983) where the focus was on erosion by water with a general conclusion that soil erosion rates in Kenya were increasing leading to surface degradation, which they considered as an environmental problem. Stockdale (1937), Sutherland (1990), Thomas *et al;* (1997) all indicated that soil erosion in

Kenya was one of the most serious land problems. The present study was focused on soil erosion problem in the Kalikuvu Catchment in Central Division of Kitui County, Kenya.

3.3 Factors Influencing Soil Erosion

Several studies have examined various factors that influence soil erosion. Wischmeier *et al;* (1965) examined factors that influence soil erosion within a catchment. They developed a model referred to as Universal Soil loss Equation which is important in evaluating the problem of soil erosion within a catchment. Margareta (1982) working on soil erosion by water in different climates found that the major factors which affect soil erosion were climate, relief, soil and vegetation. Kitheka (2000) found important factors accelerating soil erosion to be slope or gradient, ground cover, soil/rock type, land use and climatic factors. Mbuvi *et al;* (2000) found climate, relief, soil erodibility, land use and surface cover to be the main factors considered for erosion susceptibility. This study used Margareta`s classification and grouped factors influencing soil erosion into three categories of physical, geological and human activities.

3.3.1 Physical Factors

Physical factors include rainfall, wind, and vegetation cover. Rainfall is the amount and intensity of precipitation, seasonality, and storm frequency in an area. Rainfall intensity generally refers to the amount of rainfall that is recorded within a given period of time. Rainfall amount is an important factor in causing soil erosion in a catchment. The importance of rainfall amount in causing soil erosion is in connection with storm duration and intensity. Several studies have attempted to define the most erodible climatic environments in terms of annual sediment output from catchments of varying sizes, (Langbein *et al*; 1958; Wilson 1973; Walling *et al*; 1979). The above studies found complex interrelationship between sediment yields and climatic characteristics. Langbein *et al*; (1958) related sediment yields to annual precipitation within a range of climatic zones. Their study found that, high rainfall leads to high runoff in arid regions which causes increased rates of soil erosion. Douglas (1967) in his study also related sediment yields to annual runoff.

Roose (1967) regard the maximum rainfall intensity greater than 60mm/hr for 15 minutes, as an important parameter in causing soil erosion. The study established that the most effective rainfall intensity in causing soil erosion in the catchment was in the range of 45 mm/hr and 77 mm/hr. Wilson (1973) in his review of previous investigations concluded that variations in climatic regimes and land use characteristics make it difficult to come up with a single rule relating sediment yields to rainfall or runoff for a relatively small area. Christianson (1981) assessed the problem of soil erosion in semi- arid Tanzania and analyzed climate, soil type and slope as factors of importance for the initiation and acceleration of soil erosion. The study also discussed the geomorphologic effects of erosion processes in the semi-arid environments. According to Hudson (1981) only storms with mean rainfall intensity greater than 25 mm/hr are effective in causing soil erosion.

Imeson (1983) studied soil erosion thresholds in semi-arid areas in Northern Morocco. The approach adopted was the use of field measurements, to determine rates of erosion and infiltration. The study found that other factors need to be considered if the erratic response of erosion to rainfall in semi-arid areas is to be explained. It was established that potential for erosion reflected in the high erodibility of the soil and low infiltration rates does not necessarily result in high rates of runoff and soil erosion. The difference in soil loss was found to be explained by differences in soil conditions. Investigations by Brandt (1990) in river systems in Sweden have shown that erosion loses from experimental index plots could not be easily extrapolated to large areas. Brandt found that the transportation of sediments in rivers of Sweden to be highly correlated to runoff.

In Kenya several studies have been carried out on the relationship between rainfall and soil erosion in different areas. Quoting the works of Wischmeier *et al;* (1962) and Hudson (1971), Othieno *et al;* (1977) found that little erosion occurred when the rainfall intensity is less than 20 mm/hr in Kericho, Kenya. Ongwenyi (1978) and Nyandega (2008) found that rainfall factor was an important variable in soil erosion processes in the upper Tana catchment. Suthern *et al;* (1990) in their work, established that, suspended sediment yield was high with main sources being fine grained colluviums and a significant relationship between rainfall volume and eroded sediment load for kotiorin catchment in Baringo. Kitheka (1994), citing the work of Dunne (1976) on soil erosion in Kajiado County, found that rainfall amount and intensity is an importation factor in causing soil erosion, especially on bare ground, where rain drops hits the soil with great kinetic energy causing splash erosion and compaction of the upper horizon of the soil, leading to greater erosive power. According to USDA (2001) water erosion is caused by the impact of raindrops on bare soil and by the power of running water on the soil surface. The amount of run-off can be increased if infiltration is reduced due to soil compaction, Ritter (2012). The study also established that, if the rainfall generally comes when fields are being prepared there is a much higher likelihood for soil erosion to occur and special care should be taken to protect these fields. Run-off concentrated by poorly designed or maintained roads or trails can cause accelerated erosion on the adjacent slopes and roadbeds.

Angima *et al;* (2003); Mutua *et al;* (2004) related sediments yield to annual precipitation within a range of climatic zones. Their study found that, as the amount of rainfall and run-off in arid regions increases, the mean rates of soil erosion also increases. It also established that, although the soil erosion caused by long-lasting and less-intense storms is not a spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant especially when compounded over time. Studies on soil erosion suggest that increased rainfall amounts and intensities lead to greater rates of erosion, thus, if rainfall amounts and intensities increases in many parts of the world as expected, erosion would also increase, unless restoration measures are taken. Soil erosion rates are expected to change in response to changes in climate for a variety of reasons. The most direct is the change in the erosive power of rainfall, (Wikimedia Foundation, Inc. organization. 2014). The studies on rainfall as a physical factor contributing to soil erosion were deemed important for the present study, because Kalikuvu sub-location in Central Divisition, Kitui County is a semi-arid area and receives seasonal rainfall which is likely to cause soil erosion.

Many studies have examined wind erosion in different areas. Food and Agriculture Organization of the United Nations (FAO 1994a) carried out study on wind erosion in the arid and semi-arid areas of Asia and Australia. The study found that arid and semi-arid areas are severely affected by wind erosion, and the removal of soil particles by wind action and the abrasive effects of moving particles as they are transported. It occurs when soil is left bare of vegetation as a result of cultivation, and/or overgrazing following overstocking. The study estimated that in Pakistan some 42% of the arable land is affected by wind erosion, in India the figure is 6%, although the total area affected 11 million ha, is the same as for Pakistan. According to work done Ritter (2012), the speed and duration of the wind have a direct relationship to the extent of soil erosion. Wind erosion was found to be taking place during periods of drought, when soil moisture levels are very low, thus releasing the particles for transport by wind. The study also found that, lack of windbreaks (trees, shrubs, crop residue, etc.) allows the wind to put soil particles into motion for greater distances, therefore increasing abrasion and soil erosion. Encyclopaedia (2014) and USDA (2014) quoted water and wind erosion to be the two primary causes of land degradation, with 84% of degraded acreage making excessive erosion one of the most significant global environmental problems. Therefore the above studies on wind erosion were deemed important for the study because in Kalikuvu sub-location wind is very strong during dry season due to absence of vegetation cover and it is likely to cause soil erosion.

Many studies have been carried out to evaluate the influence of vegetation cover on soil erosion (Dunne 1975 and Dunne 1976). It was established that as vegetation cover reduces below 0-30%, the rate of erosion increases drastically. Moore (1978), Angima *et al;* (2003) Mutua *et al;* (2004), Ritter (2012) and encyclopaedia (2014) found that soil erosion potential increases if the soil has no or very little vegetative cover and/or crop residues, this is because plant and residue cover protects the soil from raindrop impact and splash, it also tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. The erosion reducing effectiveness of plant and /or residue cover depends on the type, extent and quality of cover. Jean *et al;* (2006) study found that vegetation affects rainfall intensity through interception of rain drops by branches and leaves. This breaks up the kinetic energy of raindrops and therefore reducing the erosive ability of the storm and Surface run-off can occur whenever the leave storage and ground storage are full. Run-off can occur whenever there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The studies on influence of vegetation cover on soil erosion were deemed important for the study, because the Kalikuvu sub-location being a semi-arid area is covered by sparse vegetation.

3.3.2 Geological Factors

Geological factors include rock type and whether tilted, faulted, folded or weathered, soil types including its porosity and permeability, slope and length of slope. Rock type and structure determines the resistance of the rock to the weathering processes that operate in that particular environment. Each rock type is composed of a particular set of minerals, which are joined together by crystallisation, chemical bonding or cementing. The forces of plate tectonics such as tilting, folding and faulting, form fractures on rocks thus weaken their structure, such rocks erode more easily. Rock strata always form horizontally, so anything not horizontal has been acted upon. If the rocks are bent, they have been folded and if there is a break and movement within the rocks, this is a fault. The highly jointed or faulted rocks present many planes of weakness along which weathering agents (e.g. water) can penetrate into the rock mass, leading to more erosion. Many studies have shown that the susceptibility of soil to erosion is influenced by its physical, hydrological, chemical and mineralogical properties as well as its soil profile characteristics.

Ritter (2012) defines Soil erodibility as an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil texture is the principal characteristic affecting erodibility, but structure, porosity, organic matter and permeability also contribute. USDA (2001) indicated that past erosion also has an effect on soil erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with sub soils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils. Angima *et al;* (2003) and Mutua *et al;* (2004) concur that, Soil properties are very important in determining soil porosity and permeability.

Slope angle and slope length affect runoff generated when rain falls to the surface. The amount of water on a particular hill slope segment is dependent on what falls from precipitation and what runs into it from upslope hill slope segment. As water runs down slope, the water that has accumulated in youthful segment runs off adding to precipitation that falls in to old segments. The amount of water increases in the down slope direction. As a result, the amount and velocity of water, and therefore hence rates of erosion increases towards the base of the slope. Dunne (1978) used tree root exposure method to estimate the rate of soil erosion in Maralal. A linear relationship between the rate of sediment production and slope or gradient was established. The study concluded that gradient and length of slope are critical factors in determining soil erosion by water. Angima *et al;* (2003); Mutua et *al;* (2004) and Ritter (2012) in their study concurred with the work of Dunne. They all established that the amount of runoff and the power of water to erode and transport soil are greater on long and steep slopes due to the greater accumulation of runoff. Therefore the above studies on geological factors which influence soil erosion were deemed important for the study because Kalikuvu sub-location is covered mainly by basement rocks and sandy soils which are likely to contribute greatly to soil erosion.

3.3.3 Human Factors

Geomorphologic processes of weathering and erosion are considered to be environmentally determined; however the rates of these processes are influenced by human activities. Previous studies on erosion were based on the roles of climate, vegetation cover, soil and geology. Many studies have been carried out to examine the influence of human activities on soil erosion. Land use was noted to have a lot of effect on soil erosion, Koyda (1977) reviewed soil erosion and man`s influence on it, and called for an increase in research and application, such as through the creation of an international conservation decade. The loss of protective vegetation through deforestation, over grazing, ploughing, and fire outbreak, makes soil vulnerable by being swept away by water. In addition, over cultivation and compaction cause the soil to lose its structure and cohesion and it becomes more easily eroded. Erosion will remove the top soil first, once this nutrient rich layer of soil is removed; few plants will grow in the soil again. With time the sub soil is exposed to the surface, supporting few plants, the land becomes unable to support plant life, a process called desertification. In area where much of the topsoil is lost, the site may no longer be able to support the historic vegetation according to USDA (2001) and ICRAF (2004).

Deforestation or logging can cause increased erosion rates due to soil compaction, exposure of minerals in the soil, for example road construction and heavy grazing. Roads are likely to cause increased rates of erosion, because in addition to removing the ground cover, they can significantly change drainage patterns, especially if an embankment has been made to support the road. Lootens *et al;* (1986) on his study on some aspects of water and sediment discharge in the upstream section of the Kafubu River (Shaba-Zaire) noted that due to excessive deforestation in the study catchment, the mean annual run-off in the catchment is higher on disturbed catchments than on undisturbed ones. According to Makenzi (2000) deforestation and clearing of vegetation for crop production and livestock pasturage, with consequent heavy losses of soil, have caused serious degradation of most catchments in Kenya. Mbuvi *et al;* (2000) concluded that depletion of soil cover due to overgrazing has adversely affected the soil physical properties. US Academic journal (2014) and USDA (2014) studies established that forests are cleared to get wood and charcoal for sale, the cleared land is used for agriculture and settlement, thus deforestation accelerates soil erosion by leaving large areas exposed to heavy rainfall or wind erosion.

Tillage and cropping practices, reduce soil organic matter levels, cause poor soil structure or result in soil compaction causing increase in soil erodibility. As an example, compacted subsurface soil layers can decrease infiltration and increase runoff. The formation of a soil crust, which tends to "seal" the surface, also decreases infiltration. On some sites, a soil crust might decrease the amount of soil loss from raindrop impact and splash; however, a corresponding increase in the amount of runoff water can contribute to more serious erosion problems. Shifting cultivation is a farming system, which sometimes incorporates the slash and burn method in some regions of the world. This degrades the top soil which supports agriculture and causes it to become less and less fertile.

Studies to monitor the soil erosion within grazing and agricultural catchments of the upper Tana were conducted by Ongwenyi (1980a). The study showed that soil loss under grazing and agricultural lands is an important factor in explaining the difference in the rates of soil erosion in different catchments. The study was limited by the short term data collected in the field which may not be representative of the long-term erosion conditions in the upper Tana.

Downing *et al;* (1985) attempted soil erosion in Kiambu and Murang'a counties. The objectives of the study was to develop a methodology for assessing the susceptibility of different land uses to soil erosion. It was found that fields with annual crops have high soil loss while perennial crops had the lowest. Ritter (2014) established that soil erosion potential is affected by tillage operations, depending on the depth, direction and timing of ploughing and the type of tillage equipment. Human activities remove vegetation from an area making the soil susceptible to erosion. Heavy grazing can reduce the vegetation cover and increase erosion. In this study, focus was on causes of soil erosion in the Kalikuvu Catchment Central Division, Kitui County Kenya, from the residents' point of view and field observation. Therefore the above studies on physical, geological and human factors which influence soil erosion were deemed important for the study. Therefore the above human factors which influence soil erosion were considered important for the study.

3.4 Landforms Due to Soil Erosion

Moore (1978) provided a comprehensive text on soil erosion types and resulting landforms such as rills and gullies. Douglas (1994) examined water erosion from the study on processes such as splash erosion, sheet erosion, rill and gully erosion and mass movement which cause soil erosion. The study established that where runoff becomes concentrated into channels ***rill and gully erosion*** may result. Rills, as compared to gullies, are small rivulets of such a size that can be worked over by ploughing. Gullies are much deeper (often being several metres deep and wide) and form a physical impediment to the movement across the slope. Mutua *et al;* (2004) found that sheet erosion leads to formation of bare land, while rill erosion results to formation of small well defined channels called rills, deepened and enlarged rills form gullies which become a nuisance factor in normal tillage. The present study examined the landforms on the sites that witnessed severe soil erosion and from the residents' point of view in the Kalikuvu Catchment in Central Division, Kitui. Therefore the above studies on landforms resulting from soil erosion were deemed important for the study.

3.5 Soil Erosion and Crop Production

Chakela (1981) examined the problem of soil erosion and sedimentation in Lesotho and found that most parts of Lesotho experience high rates of soil erosion which has consequently affected the design capacities and lifespan of surface water reservoirs. Ongwenyi (1977) examined the problem of soil erosion and water conservation within the upper Tana catchment. The study concluded that, soil erosion has led to loss of the topsoil nutrients resulting to low productivity. Ritter (2012) using UNU`S Ghana-based Institute for Natural Resources in Africa, Concluded that, in Africa, if current trends of soil degradation continue, the continent might be able to feed just 25% of its population by 2025.

Pattan (1987); Denga *et al; (2000);* Bakker *et al;* (2007) and Taylor *et al;* (2008) examined effects of soil erosion on crop productivity. These studies concluded that soil erosion leads to reduction in crop yields. Njenga *et al;* (2000) worked on evaluation of gully control measures in central province, Kenya, and concluded that gully erosion poses a serious threat to agriculture in Kenya especially in arid and semi-arid areas. Imbira (2000) indicated that gully erosion leads to loss of productive land and jeopardizes existing communal facilities such as roads and buildings. The present study was focused on effects of soil erosion on crop yields especially maize in the Kalikuvu Catchment Central Division, Kitui County, from the residents' point of view and field observation. The previous studies on effects of crop production as a result of soil erosion deemed important for the study.

3.6 Soil Erosion Restoration Measures

The problem of soil erosion in catchment has a serious repercussion on water resource management and planning, therefore the area should be evaluated critically with a view of developing strategies for controlling the problem of soil erosion. Environmental restoration can be defined as a process of repairing damaged ecosystem. Many studies have been carried out on restoration measures on different areas and found that restoration measures can reduce soil erosion by both water and wind. The effectiveness of any crop management system or protective cover depends on how much protection is available at various periods during the year relative to the amount of erosive rainfall that falls during these periods. In an undisturbed forest themineral soil is protected by a litter layer and an organic layer, these two layers protect the soil by absorbing the impact of rain drops and keep the underlying soil porous and highly permeable to rainfall. Severe fires can lead to significantly increased erosion if followed by heavy rainfall, in this respect, crops which provide a good, protective cover for a major portion of the year can reduce soil erosion much more than can crops which leave the soil bare for a longer period of time and particularly during periods of high erosive rainfall.

According to Divisional Implementation Team in Central Division, Kitui County (2009), soil restoration in Itoleka location has not been taken by farmers seriously. Generally 40% of the farms in Itoleka location are conserved, with the rest of 60% being unconserved. The soil and water conservation methods evident in the area are; Fanya juu, retention ditches and trash lines. Therefore it was necessary to establish the types of conservation measures, which in this study constituted restoration measures, and their variations.

Management measures are often applied to grazing land in situations where uncontrolled use has led to degradation and where other measures simply do not work without a fundamental change in land management. Protection from grazing, allow regeneration of vegetation cover, such measures are often essential for the rehabilitation of badly degraded areas where technical measures and other interventions are not adequate on their own (but can act in a supplementary way). But there are also examples of intensification of grazing land use where fodder crops are planted and used for cut-and-carry feeding of livestock (WOCAT, 2007). Ritter (2012) indicated that gully formations are difficult to control if corrective measures are not designed and properly constructed. Control measures must consider the cause of the increased flow of water across the landscape and be capable of directing the runoff to a proper outlet. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery.

Tillage and cropping practices, as well as land management practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotation or changing tillage practices are not enough to control erosion on a field, a combination of approaches or more extreme measures might be necessary, such as contour ploughing, strip cropping or terracing may be considered as suggested by Angima *et al;* (2003) and Mutua *et al;* (2004). The problems of water and soil conservation have been examined in the high and medium potential parts of Kenya in detail by Thomas (1977 b) and Ongwenyi (1978b and 1980b). These studies found that the grass provides the best protection for soil and causes minimum loss of water through runoff. These studies failed to address restoration measures in the low potential parts of Kenya, which was addressed by the present study.

Heede (1976) using studies by Renfro (1972) on sediment control in the USA, concludes that gully improvement can be done quickly by working from within the gully rather than from outside, because of the concentration and availability of higher moisture in a defined channel. He argues that catchment restoration measures are only supplemental to gully control. Thomas (2000) suggested that gully control is generally an expensive undertaking and it is important to carry out a systematic analysis of the situation before selecting and designing the control measures. In a study of 40 gullies in central Kenya, Njenga (1991) found that 87% of gullies had been unsuccessfully controlled. Wenner (1984) noted various problems that had arisen in attempts to control gullies and the study observed many instances where control measures have failed, in some of these situations the control measures have involved substantial expenditure on posts, wires, gabions, rocks and labour. Othieno *et al;* (1977) attempted an assessment of soil erosion on a field of young tea plantation under different soil management practices in Kericho. The study established that soil erosion in Kericho is caused by the impact of the energy of rain drops and to control this problem, mulching and canopy methods are important.

In general, many studies generally concluded that the less the disturbance of vegetation or residue cover at or near the surface, the more effective the tillage practice reduces erosion. Pagiola (2000) studied soil conservation measures in Kitui and Machakos Districts in Kenya, the results of the analysis show that terracing is profitable in small-scale farms under a wide range of conditions, the study recommended construction of *fanya juu* terraces as one of the restoration measures to avert soil erosion in arid and semi-arid areas. In this study, very little empirical analysis was carried out on the severity of soil erosion in the areas. The current study has discussed landforms resulting from soil erosion, which indicates the severity of the erosion process. The construction of *fanya juu* terraces was supported by Sigunga (2000) and Stahl (2000). Sigunga (2000) found that *fanya juu* terraces were superior to other methods of conservation in Machakos and Kitui Counties as well as many parts of Central Province.

Thomas (2000) found that terracing increases soil depth and fertility is preserved, that would otherwise be diminished through erosion. Mati (2000) on his work on soil erosion and conservation activities on land affected by road drainage suggests that gabions are suitable method to control large gullies. The study also suggests that the channels should be planted with perennial grass to give a good ground cover. Muhia (2000) supported the method of planting vegetation along the river bank to control soil erosion.

Makenzi (2000) recommended protecting indigenous species as well as introducing new fast growing and drought resistant species in marginal areas. The present study was carried out on a seasonal river Kalikuvu catchment in Central Division Kitui County, which is a semi-arid area. The study dealt with environmental restoration measures to control erosion in the area, such as terraces, gabions, weirs and planted trees for conserving soil. The overall goal of the present study was to determine the factors that cause soil erosion, the geomorphologic landforms due to soil erosion, the impact of soil erosion on crop production especially maize and restoration measures used to control soil erosion in the area. None of the previous studies examined soil erosion in Kalikuvu catchment in detail.

3.7 Conceptual Framework

Since the geographical cycle was proposed by Davis (1909), the structure and development of river drainage networks has been of central concern in geomorphology. Davis viewed the development of stream networks as a necessary consequence of the evolutionary “maturation” of landscapes through the geomorphologic processes of soil erosion. Davis’s framework has been improved in the present study to develop a detailed conceptual model on the evolutionary development of network. The erosion problem is made up of the following variable factors; climate, topography, vegetation, soils and human factors (Baver, 1956). According to this study, soil erosion is a function of geological, environmental and human factors which may be summarised to the descriptive equation as follows;

E = f (G, E, H,…) ....(1)

Where, E = Erosion

G = Geological factor

E = Environmental factor

H = Human factor

Table 3.1 summarizes the factors and elements of erosion.

Table 3.1: Factors that Cause Soil Erosion

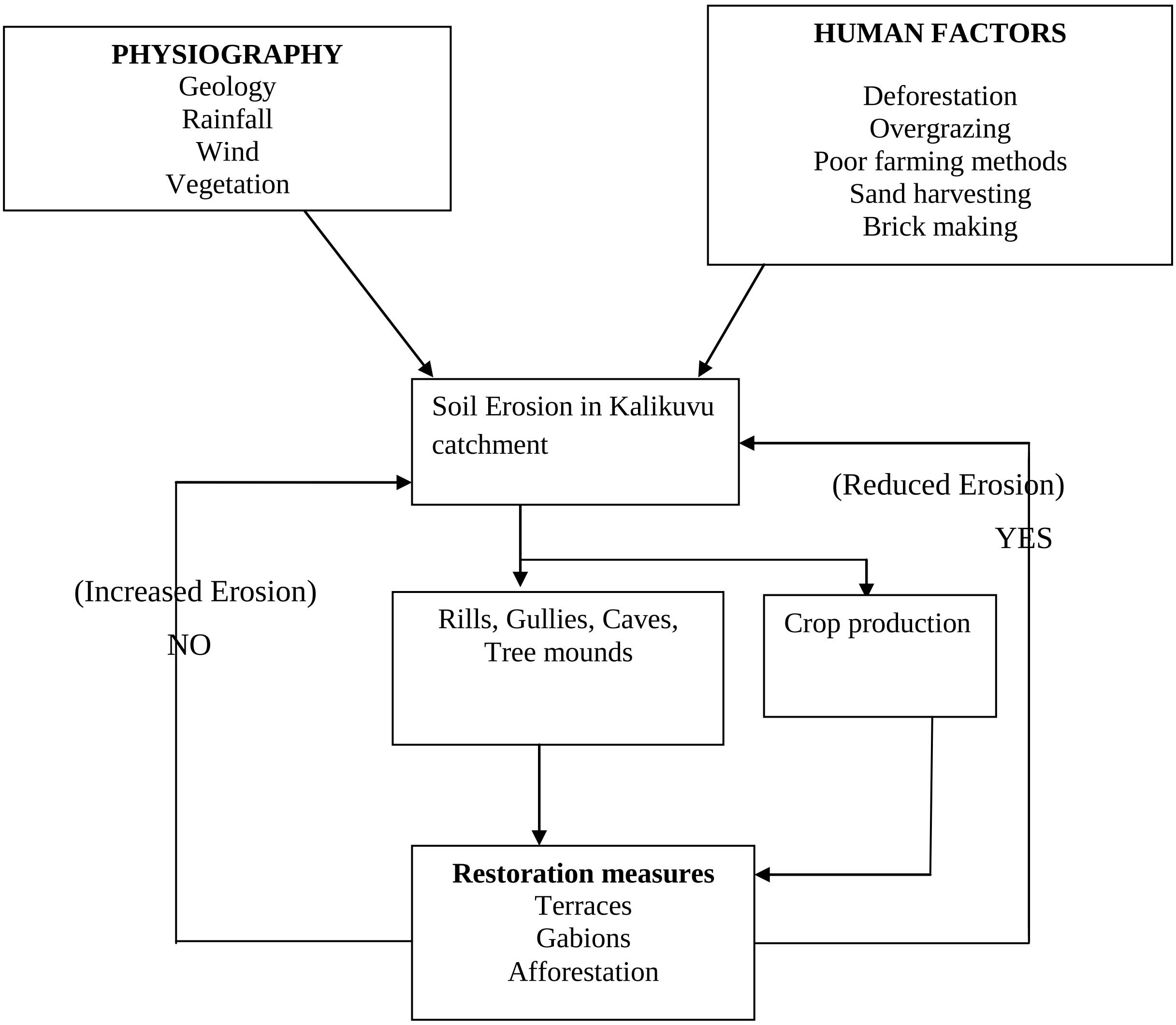
Factors	**Elements involved**
Environmental	Amount and intensity of rainfall, average and range of temperature, seasonality, wind speed, storm frequency, land cover
Geological	Sediments or rock type, slope or gradient and length, silted, faulted, folded or weathered rocks; porosity and permeability of rock or soil.
Human activities	Livestock, land use

(Source: Researcher, 2012)

Quite often these factors act in concert and therefore their relationships become very complex. The impacts of soil erosion include formation of caves, tree mounds, rills and gullies. These landforms in turn discourage movements and reduce maize production. The restoration measures included terraces, gabion and afforestation.

The current study attempted to assess the factors that cause soil erosion in Kalikuvu catchment, geomorphologic landforms due to soil erosion, impact of soil erosion on crop production especially maize and the restoration measures to control soil erosion. This study was carried out to bridge the already existing gap in soil erosion studies in Kenya in terms of knowledge in geomorphologic landforms, effects of soil erosion on crop production especially maize and the restoration measures. Figure 3.1 shows the relationship between factors, processes, effects and restoration techniques of soil erosion.

Figure 3.1: Conceptual Framework of Soil Erosion



(Source: Researcher, 2014)

CHAPTER FOUR

4.0. METHODOLOGY

4.1 Introduction

This study used multistage sampling procedure to acquire the necessary data where the surface area was first covered by transects. Each transect was treated as a stratum. From each transect the erosion surfaces, various land uses were treated as clusters since erosion landforms and land uses are expected not to have continuous coverage in the catchment.

4.2 Data Types and Sources

This study used both primary and secondary data to address the stated problems and meet the study objectives. Primary data was collected directly from the field on erosion occurrence, resulting landforms, topography, land cover and land use, erosion impacts on crop production and restoration measures. The primary data was sourced from the field through observations, measurements and interviews. Terrain data was obtained through measurements using GPS receivers. Data on vegetation cover was obtained through observation and interviews as was the case with human activities. The data on landforms resulting from soil erosion in Kalikuvu catchment was based on inventory of landforms developed during reconnaissance. Additional data was collected through measurements and observation of landforms and by interviewing the residents.

The data on environmental restoration measures to control soil erosion was obtained from both residents and government of Kenya officials. The data were for terraces, planted trees and application of manure in the farms by farmers to mitigate soil erosion and enhancing environmental restoration. The official data was on what the Government and Non-Governmental Organizations were doing to help the residents control soil erosion such as gabion construction and extension services and training. The data on restoration measures was obtained through interviewing the residents as well as soil conservation officers and field observation. The collected data provided information thought to be adequate in assessing the extent and impact of restoration measures being carried out in Kalikuvu catchment.

The secondary data were mainly on geological and environmental data including geology, agro-ecological zones, relief and soils, rainfall, and land use, and socio-economic data including population. Secondary data was sourced from government databases, topographical maps and Remote sensed data based on Radar measurements (The Kenya terrain data 2010), scholarly publications, journals, and statistical abstracts. Rainfall data was obtained from meteorological department of Kenya for stations in Kitui County. Soil type data was obtained from Kenya Agricultural Research Institute (KARI) and from existing soil maps. The data collected has helped to determine factors that cause soil erosion in Kalikuvu catchment.

4.3 Data Collection

4.3.1 Sampling Frame and Sample Size

The present study is a case study in which data were collected from Kalikuvu catchment in Kalikuvu sub-location which has been was severely affected by soil erosion. The catchment has an area of about 53.6km^2, and it is divided in to three stages, namely youthful, mature and old stages, and this was guided by the erosion landforms in the river catchment. Each stage was further subdivided into east and west of Kalikuvu river and covered with transects from which data was collected on major factors that cause soil erosion, landforms resulting from soil erosion, impact of soil erosion on crop production especially maize and restoration measures carried out to control soil erosion in Kalikuvu catchment.

The size and number of transects depended on the surface area of each stage, extent of eroded surfaces, number of erosion landforms, altitudinal variations, settlement, relief, distribution and land use. The sampling flame included all farmers that constitute all the inhabitants of the sub-location to determine the number of interviewees included in the sample data. In addition, the Divisional Agricultural Officer, Water Resources management Authority and Environmental Officers, the Assistant Chief and other opinion holders serving in this county formed part of the study population.

Purposive sampling was employed, whereby first representative sub-zones were sampled, after which farmers were selected. A form of non-probability sampling in which decisions concerning the individuals to be included in the sample were taken by the researcher, based upon a variety of criteria which may include specialist knowledge of the research issue, or capacity and willingness to participate in the research. A total of 44 respondents both males and females were chosen, depending on knowledge and experience. The determining factors were agricultural skills and mature age, which was above 22 years.

However, all the County Heads of the above mentioned departments were interviewed. The advantage of purposive sampling is that the investigator is able to select respondents that are able to be mature and knowledgeable in the area of study who provide information by virtue of knowledge or experience, and the results of purposeful sampling are usually expected to be more accurate, Bernard (2002). Of course the main disadvantage is that the selection of respondents depends entirely on the criteria set by the investigator and therefore the results are as good as the knowledge of the investigator. The investigator ensured that there was internal consistency in the selection process. However despite the disadvantages involved, this study used purposive sampling because the catchment was small and qualitative information was needed.

Borg and Gall, (1996) defines a sample as a small proportion of a target population selected for analysis. The target population for study were the residents of Kalikuvu sub-location, with the total population 5,626 comprising of 1,297 households (KNBS, 2009). A sample of 44 respondents representing households was selected using the formula

$$n = \left(\frac{zs}{d}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where n = the required sample size

s = the standard deviation of the pilot sample data.

d = tolerable margin of error at a specified level of confidence *(0.05).*

z = z-score at the specified level of confidence (1.96).

Out of 65 households, 38(58.5%) questionnaires were received back while 27 (41.5%) were never received back. The researcher carried out purposive interviews on 6 experts including, Agricultural Extension Officers, the Assistant Chief and other opinion holders. Thus, the sample size was 6 custodians on knowledge and 38 households, giving total of 44 respondents. Only the heads of households were interviewed since it is the unit for any decision making in a family. All the landforms resulting from soil erosion in the catchment constituted target erosion landforms, but only erosion landforms within transects marked were studied. The data from each eroded sampled area and their associated landforms were collected and analysed.

4.3.2 Data Collection Instruments

A questionnaire was used to collect data on the impacts of soil erosion on crop production based on the number of 90kg bags of crops harvested. The data was obtained through administering questionnaires to the residents, agricultural officers, Assistant chief and opinion holders

Geographic Information Systems (GIS) software was used to create spatial information on geology, agro-ecological zones, relief and soils from the collected data while Globe Positioning System (GPS) receiver was used to collect the coordinates and heights of erosion sites and associated landforms. The other instruments used in the field were tape measure and meter ruler to measure the depth and width. Camera was used to record pictorial information on the details observed, such as landforms resulting from soil erosion and restoration measures such as construction of terraces and gabions.

4.3.3 Sampling Procedure

Prior to commencement of data collection, adequate preparations were made by conducting an extensive reconnaissance, where contacts were made with people who would facilitate the research work. Such people were local administrators, other researchers, and research assistants, ministry of agriculture officers, conservation team leaders and residents who have lived or worked in the catchment for more than five years. Much background information was obtained from the earlier researches and residents who have lived in the area for a long time. Field reconnaissance survey was also used to identify the sampling sites and clusters in order to determine their suitability.

The sampling along the river profile was determined by the section of the river development as derived from the terrain data and GPS measurements, terms of terrain, vegetation cover, and human activities. Access along the river profile in some cases was limited by slope, vegetation cover, and rough terrain and this was particular so in the youthful stage characterised by steep slope and the mature stage characterised by rugged terrain and thorn bush. Major altitudinal change along the profile marked the stratification boundary in the study sampling process.

This study used multistage sampling procedure to acquire the necessary data, where the surface area was first covered by transects. Each transect was treated as a stratum. From each transect the erosion landforms and various land uses were treated as clusters since erosion landforms and land uses are expected not to have continuous coverage in the catchment. The data was collected using questionnaires, observations and measurements.

During the reconnaissance, a team of 4 research assistants was selected and trained to administer the questionnaire. After the training a pre-testing of the questionnaire was done by administering it to 10 households. The final questionnaires administered were 44 in number. The pre-testing improved the response rates and also helped to create harmony in the research team. Questionnaires were administered to the residents and agricultural officers in the catchment to provide qualitative information based on knowledge and experience. The questions were based on the following:

a) Causes of soil erosion in the catchment.
b) Landforms resulting from soil erosion.
c) Impacts of erosion landforms on human activities.
d) Restoration measures put in place to control soil erosion.

Field observation and measurements were carried out within transects and clusters but what to be observed depended on the geomorphologic characteristics, especially erosion surfaces and this was systematic to ensure spatial representation along the river profile. Observation was based on the following:

a. Distribution, depth and width of landforms resulting from soil erosion such as rills, gullies, residual hills and exposed tree roots.

b. Type and length of the slope.
c. Vegetation cover.
d. Human activities such as farming methods, type of crops grown, types and number of animals reared, settlement density and distribution, types/sources of energy for domestic use and conservation techniques employed.

Erosion features due to natural factors had order which started with sheet erosion followed by rills, which joined to form gullies. Erosion features induced by man or tectonic factors lacked the order mentioned above, man-induced features were bordered by human activities while features due to tectonic factors were noted to be deep steep slopes.

The observed information was recorded on an observation spreadsheet, photographs, base maps and note book sketches. The resulting data was used to have some measure of types of erosions, causes of erosion, extent of erosion, impacts of erosion on the earth surface and human activities and restoration measures put in place.

Field measurements were carried out to provide quantitative information on the observation results as follows:

a) Extent of eroded surfaces;
b) Geographic locations;
c) The depth, width and length of rills and gullies;
d) The depth of exposed roots of trees by sheet erosion; and
e) The type and length of slope.

4.4 Data Processing and Analyses

4.4.1 Data Processing

Data collected from the field were first compiled into a common file from which a code book was generated. The code book information was converted to a digital data file using excel and SPSS software. The resulting data file was edited and cross-checked for errors in data entry by running a frequency distribution. A frequency distribution assists in identifying outliers and missing entries in the database.

Before the questionnaire data were entered, a template was developed based on the coding system prepared from the questionnaire; priority was given to the coding of questions that were not coded during the questionnaire preparation. This was done to ensure that data entry went on without interruption. Data was entered into the computer using Microsoft Office Excel Worksheet. This is a flexible spreadsheet from which data can be easily exported to other programs. From Microsoft Office Excel, it was possible to carry out descriptive statistics to get a broad perspective of the field data. These include measures of central tendency such as means and frequencies. Others, included tables, pie-charts, bar graphs that are used in this report.

4.4.2 Data Analysis Techniques

Once the database files (observation, measurement and questionnaire data) were completed, a preliminary analysis was carried out on all data variables, to get the aggregation (central tendency), and dispersions. The purpose of the measures was to assist in accurate description of the sample data and in determining the appropriate inferential methods to be used in measuring extent, differences and associations on all the variables of concern. Spatial analyses were used to locate erosion surfaces and landforms, their distribution, and impacts. The frequency results were then tested for significance to measure whether the observed occurrences were chance events or significant events in the erosion characteristics of the Kalikuvu catchment. The statistical tool used in this process was the chi-square statistic both as a contingency measure and as a test of independence.

The chi- square is defined using the formula

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where: X^2 = Pearson's cumulative test statistic, which asymptotically approaches a χ^2 distribution.

O_i = an observed frequency;

E_i = an expected (theoretical) frequency, asserted by the null hypothesis;

n = the number of cells in the table.

The expected observation was calculated for the single variable using the procedure of row total times column total divided by the grand total in a test of independence and the row proportion divided by the column total in the single variable contingency measure. The variables used in the chi-square statistical tests were causes (or factors) of soil erosion, soil erosion characteristics and problems, and lastly soil erosion impacts on crop production and restoration measures. The tests in all cases were at α 0.05 (95% confidence level).

4.4.2.1 Determining the Causes of Soil Erosion

One of the focuses of this study was to determine the causes of soil erosion and to do this, it was important to capture information on residents understanding of causes of soil erosion. This was done through first checking if the locals could identify the causes of soil erosion in the catchment and then seeking explanations for such factors. One respondent could provide multiple explanations; therefore the study employed the use of multiple response analysis where it measured how many times a particular response appears for a given variable (what causes soil erosion in this area?) in a survey.

This analysis involved first creating the response groups or categories and then secondly splitting the variables in to sub-variables according to number of categories. From there, a new variable was created by joining the response for each sub-variable for each respondent. The new variable was then subjected to frequency analysis to measure distribution tendencies in terms of aggregations and dispersions. The multiple response analysis of causes of soil erosion in Kalikuvu catchment indicated 177 response groups. The results were then cross-tabulated with sections of the Kalikuvu River Catchment. The results were subjected to inferential analysis to test if the results were different by stages of river Kalikuvu Catchment. The Chi square technique was used to test the hypothesis that there was no difference in soil erosion in the Catchment section.

Table 4.1: Test of Difference in causes of soil erosion by stages of catchment

Causes of soil erosion	v1	v2	v3	v4	Expected				Computed chi-square			Total
Overgrazing	12	8	7	27	11.659	8.591	6.75		0.01	0.041	0.009	0.060
Deforestation/charcoal burning	8	5	7	20	8.636	6.364	5.00		0.047	0.292	0.8	1.139
Steep terrain	10	6	4	20	8.636	6.364	5.00		0.215	0.021	0.2	0.436
Poor farming methods	8	2	8	18	7.773	5.727	4.50		0.007	2.428	2.722	5.155
Lack of conservation measures	8	7	1	16	6.909	5.091	4.00		0.172	0.716	2.25	3.138
Soil type	6	5	2	13	5.614	4.136	3.25		0.027	0.180	0.481	0.688
Ignorance	4	4	0	8	3.455	2.546	2.00		0.086	0.831	2	2.917
High rains in short period	5	1	1	7	3.023	2.227	1.75		1.293	0.676	0.321	2.291
Bare land	5	1	1	7	3.023	2.227	1.75		1.293	0.676	0.321	2.291
High wind speed	4	1	1	6	2.591	1.909	1.50		0.766	0.433	0.167	1.366
high human population	3	2	1	6	2.591	1.909	1.50		0.065	0.004	0.167	0.236
Lack of awareness on soil conservation	2	3	0	5	2.159	1.591	1.25		0.012	1.248	1.25	2.510
Livestock movement	2	2	1	5	2.159	1.591	1.25		0.012	0.105	0.05	0.167
Sand harvesting	2	0	2	4	1.727	1.273	1.00		0.043	1.273	1	2.316
Brick making	2	0	1	3	1.296	0.955	0.75		0.383	0.955	0.083	1.421
Farming on steep slopes	0	2	0	2	0.864	0.636	0.50		0.864	2.922	0.5	4.286
lack of motivation	0	3	0	3	1.296	0.955	0.75		1.295	4.383	0.75	6.429
Climate change	0	0	2	2	0.864	0.636	0.50		0.864	0.636	4.5	6
Dry soil	2	0	0	2	0.864	0.636	0.50		1.495	0.636	0.5	2.632
Laziness	0	1	0	1	0.432	0.318	0.25		0.432	1.461	0.25	2.143
N/A	0	1	1	2	0.864	0.636	0.50		0.864	0.208	0.5	1.571
total	19	14	11	44							chi square	49.190
											critical chi square	28.87
											df =18	

(Source: Researcher 2013)

V1= Youthful Stage V2= Mature Stage V3= Old Stage V4= Total

The responses on causes of erosion were grouped in to two; physical and human factors. The physical factors were further subdivided in to geomorphologic and climatic factors. Human factors were; overgrazing, deforestation/ charcoal burning, poor farming methods, ignorance, high human population, livestock movement, lack of awareness on soil conservation, sand harvesting, brick making, lack of motivation, farming on steep slopes, and laziness. Geomorphologic factors were; steep terrain, soil type, and bare ground. Climatic factors were; high rains in short period, high wind speed, and climate change.

4.4.2.2 Determining Landforms Resulting from Soil Erosion

This study investigated the geomorphologic landforms resulting from soil erosion in the Kalikuvu catchment, and to do this, it was important to capture information on residents' understanding of soil erosion and its types. This was done through first checking if the residents considered soil erosion as a problem and then seeking explanations for their views. The explanations tended to be dualistic where the implication of soil erosion characteristics, landforms on the surface and soil erosion effects was all present.

Since one respondent could provide multiple explanations, the study employed the use of multiple response analysis where it is measured how many times a particular response appears for a given variable (why say soil erosion is a problem in this area?) in a survey. This analysis involved first creating the response groups or categories and then secondly splitting the variables in to sub-variables according to number of categories. From there, a new variable was created by joining the response for each sub-variable for each respondent.

The new variable was then subjected to frequency analysis to measure distribution tendencies in terms of aggregations and dispersions. The results were then cross-tabulated with stages of the Kalikuvu River Catchment. The results of the multiple response analysis above were subjected to inferential analysis to test if the results were different by stages of river Kalikuvu Catchment. The Chi square technique was used to test the hypothesis that there was no difference in characteristics or effects of soil erosion in the Catchment.

4.4.2.3 Determining the Impact of Soil Erosion on Maize Production

One of the objectives of this study was to determine the impact of soil erosion on crop production especially maize in the Kalikuvu catchment, and to do this, it was important to capture information from the residents if the crops are grown in the catchment. This was done through first checking all the crops grown and how many times in a year. Locals indicated that they grow variety of drought resistant crops. Many respondents quoted maize as a common crop grown in the area. The explanations given were that maize is a staple food in the catchment.

Since one respondent could provide multiple crops, the study employed the use of multiple response analysis where it is measured how many times a particular response appears for a given variable (what crops are grown in this area?) in a survey. This analysis involved first creating the response groups or categories and then secondly splitting the variables in to sub-variables according to number of categories. From there, a new variable was created by joining the response for each sub-variable for each respondent.

The new variable was then subjected to frequency analysis to measure distribution tendencies in terms of aggregations and dispersions. The results were then cross-tabulated with stages of the Kalikuvu River Catchment. The results of the multiple response analysis above were subjected to inferential analysis to test if the results were different by stages of River Kalikuvu Catchment. The Chi square technique was used to test the hypothesis that there was no difference in crop production due to soil erosion in the Catchment.

4.4.2.4 Determining Restoration Measures Suitable to control Soil Erosion

Since soil erosion had earlier been noticed as a problem in the Kalikuvu Catchment, it was necessary to establish the types of conservation measures, which in this study constituted restoration measures, and their variations. A multiple response analysis was carried out first to identify the types of conservations using multiple frequency analysis procedure resulting in appendix (1X). The results of the multiple response analysis above were subjected to inferential analysis to test if the results were different by stages of River Kalikuvu Catchment. The Chi square technique was used to test the hypothesis that there was no difference in restoration measures due to soil erosion in the Catchment.

4.5 Scope and Limitations

Soil erosion is a very complex geomorphologic process involving a constellation of factors, many of which also interact with one another. For example the relationship between rainfall and weathering processes, soil formation and vegetation cover are intricately complex. This study therefore focused on factors that were relevant to the study area. Factors of erosion such as deforestation, overgrazing and poor farming methods were estimated to be relevant to the area of study.

There were many factors cited by Agricultural Extension Officers as restoration measures but the major ones that are thought to be culturally acceptable such as afforestation, terraces, cut-off drains, mulching, and zero tillage amongst many were adopted. The data on factors causing soil erosion in Kalikuvu catchment in Kitui County was obtained from the field and local perspective (from social and geomorphology purpose). Observation and measurements was used to collect data on erosion. Landforms observed were rills, swallow-holes, caves, hills and gullies.

The study attempted to do an assessment of the impact of soil erosion on crop production especially maize which is a staple food in the area. All other crops grown in the area such as beans, peas, cow peas, water melons, pumpkin, green grams and cassava were also included in the analysis to measure the ranking of maize growing as an activity in the catchment. The other crops therefore did not form part of the statistical inferential analysis but were tools used to measure the justification of using maize as an erosion impact parameter.

The local opinion was used to find out the impact of soil erosion on the environment and crop production. This knowledge revealed insights in resource and ecosystem management and such insights could be used to develop policies and community awareness programme to restore soil erosion hazards. Impact-locals were interviewed on impacts of soil erosion to the environment. This was to find out if they were blaming the soil erosion on crop production especially maize which is a staple food in the area. Restoration measures dealt with types and depth of methods used in the area to control soil erosion. The study did not try to measure rate of soil erosion and when the features were formed. The study also did not measure the yields because the farming is on small scale basis for subsistence consumption only.

CHAPTER FIVE

5.0. RESULTS AND DISCUSSIONS

5.1 Introduction

This study addressed the causes of soil erosion in Kalikuvu catchment, geomorphologic landforms due to soil erosion in Kalikuvu catchment, impacts of soil erosion on crop production especially maize in Kalikuvu catchment, and restoration measures being used in Kalikuvu catchment to control soil erosion.

Of all the 44 respondents, 59.1% were males and 40.9% were female giving none bias gender representation. This is because males and female have different roles in the Kalikuvu catchment which may affect soil erosion in one way or the other. However in many homesteads the males were likely to be the heads of households and responded to the questionnaires. The two groups were then grouped further into 5(five) groups based on age; 20-24, 35-39, 40-44, 50-54, 55-59 and 60-64 years. The respondents were also grouped according to the occupation of various knowledge, and residency.

The respondents were grouped into five age groups. Persons within the age group between 45 and 49 years old were the highest and constituted 29.5%, those between 55 to 59 years old constituted 18.2%, those between 40 and 44 years and 50 to54 had 13.6% each, and those between 60 and 64 years were 9.1%. Age groups 30 to 34 and 35 to 39 constituted 6.8%. The least was age group 20 to 24, with 2.3% of the population.

Farmers were the majority respondents being 18.2% of the population, followed by house wives 13.6%, professionals including teachers, pastors and shopkeepers 6.8%, while Assistant Chiefs and Agricultural Extension Officers represented 4.5% of the population. The others represented 2.3% of the population. The participants came from diverse occupational background, each from the following categories, farmer, watchman, youth leader, chicken trader, shopkeeper, community service and he last one was a head woman. This was a quite representative sample of the societal mixture of professional ideologies; the stakeholders appeared to be well represented in the sample.

5.2 Factors Causing Soil Erosion in Kalikuvu Catchment

The respondents were asked if the factors that cause soil erosion are present in the area. All the 44(100%) respondents confirmed that the factors that cause soil erosion are observed in the area of study. The following factors were sighted to be causing soil erosion: overgrazing had the highest 15.3%; relatively steep terrain and deforestation were second each with 11.3%, burning of charcoal was observed to be a common activity in the area; poor farming methods 10.2%; lack of conservation measures 9.0%; soil type 7.3%; ignorance 4.5%; bare land 4.0%; high wind speed 3.4%; lack of awareness on soil conservation measures 2.8%; livestock movement 2.8%; sand harvesting 2.3%; brick making 1.7%; and dry soil Farming on steep slopes and climate change each scored 1.1% and finally laziness 0.6%.

The computed chi square was 49.190 while the critical chi-square (χ^2) at α 0.05 is 28.87 and degree of freedom is 18, this indicated that the null hypothesis rejected. The indication therefore was that there is difference in causes of soil erosion in the Catchment. In geomorphology, the implication was that the physical forces affecting soil erosion in the Kalikuvu catchment were different in the stages of the catchment.

The responses given by the residents confirm that human, physical and geomorphologic factors are responsible for causing soil erosion in the three stages of Kalikuvu catchment namely, youthful, mature and old stages. Various types of human activities can be identified as direct causes of land degradation, these can be considered under the following headings; Overgrazing, deforestation, poor farming methods and lack of conservation measures, ignorance, high human population, livestock movement, sand harvesting, brick making, farming on steep slopes , lack of motivation and laziness.

5.2.1 Overgrazing

This study collected data on the type of animal husbandry in Kalikuvu catchment, there was need to establish whether different types of animal husbandry were practiced in the area, which could have contributed to severe soil erosion in the catchment. The respondents were asked the type of animal husbandry practised. All the respondents indicated to be practising animal husbandry. From the 74 multiple responses, 51.4%, confirmed that they practiced free range in dry season and 43.2% indicated that they practice tethering in rainy season, 2.7% indicated zero grazing, while 2.7% indicated otherwise (as shown in table 5.1).

Overgrazing was cited to be the major cause of soil erosion in the three stages of the river catchment with 15.3%; this percentage was noted to be high during dry season. The results from the respondents conform to the field observation where during dry season animals were cited grazing in a free range manner, searching for pasture and water. Tethering and zero grazing were observed to be practiced during rainy season. Geomorphology researches have shown that, free grazing and browsing animals are responsible for gully erosion in many areas. The researcher established that many animals were kept on a small area with a low carrying capacity. Animals were cited grazing on a land with scattered vegetation and much of the bare land. The average number of indigenous cows per household ranged between 4 to 5 and there were extreme cases that had 14 cows. Grade cows, commonly known as exotic breeds are most unpopular in the area, owing to the harsh conditions of the environment.

Overgrazing of grasslands leave bare patches where roots no longer hold the soil together. When this is combined with the action of rain and wind the bare patches become bigger, leading to sheet erosion. The animals especially cattle make tracks, where runoff flow along forming gullies. Besides actual overgrazing of the vegetation by livestock, other phenomena of excessive livestock amounts can be considered under this heading, such as trampling. The effect of overgrazing usually is soil compaction and/or a decrease of plant cover, both of which may in turn give rise to water or wind erosion. From plate 5.1, goats were browsing freely on the scanty vegetation. This surface shows both sheet and gulley erosion caused by overgrazing and road cuts and in plate 5.2, tethering husbandry of indigenous cows has caused overgrazing and sheet erosion in the mature catchment.

Table 5.1: Types of Animal husbandry

Husbandry	Responses	
	N	Percent
Tethering in rainy season	32	43.2%
Free range in dry season	38	51.4%
Zero grazing	2	2.7%
N/A	2	2.7%
Total	74	100.0%

(Source: Researcher 2012)

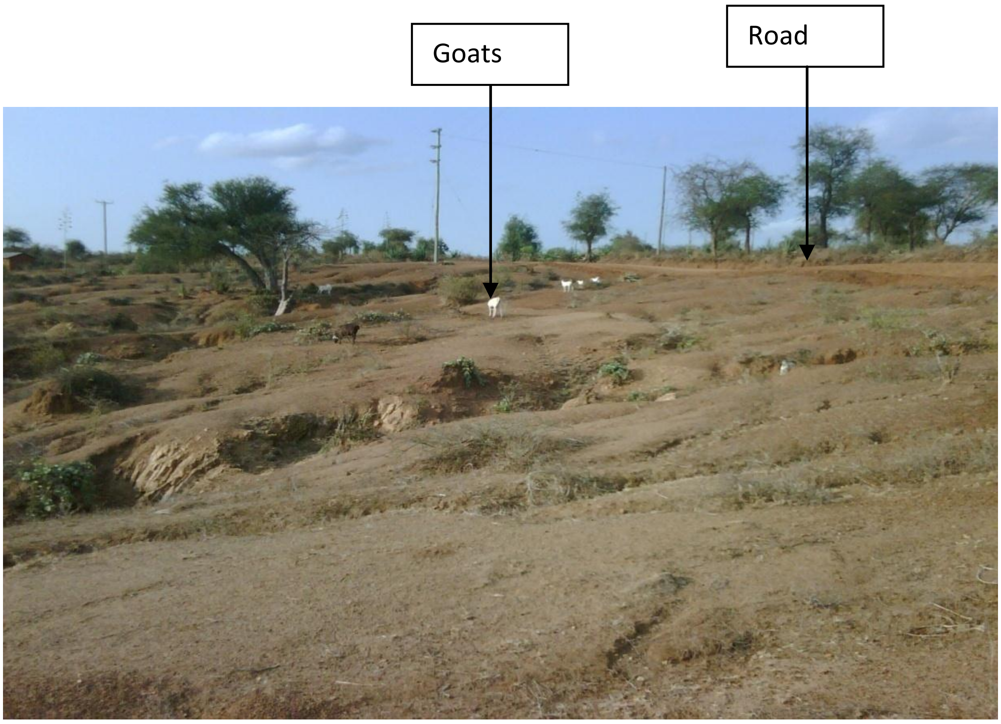


Plate 5.1: Goats browsing and cutting forming rills in the mature Kalikuvu Catchment

(Source: Researcher, 2012)

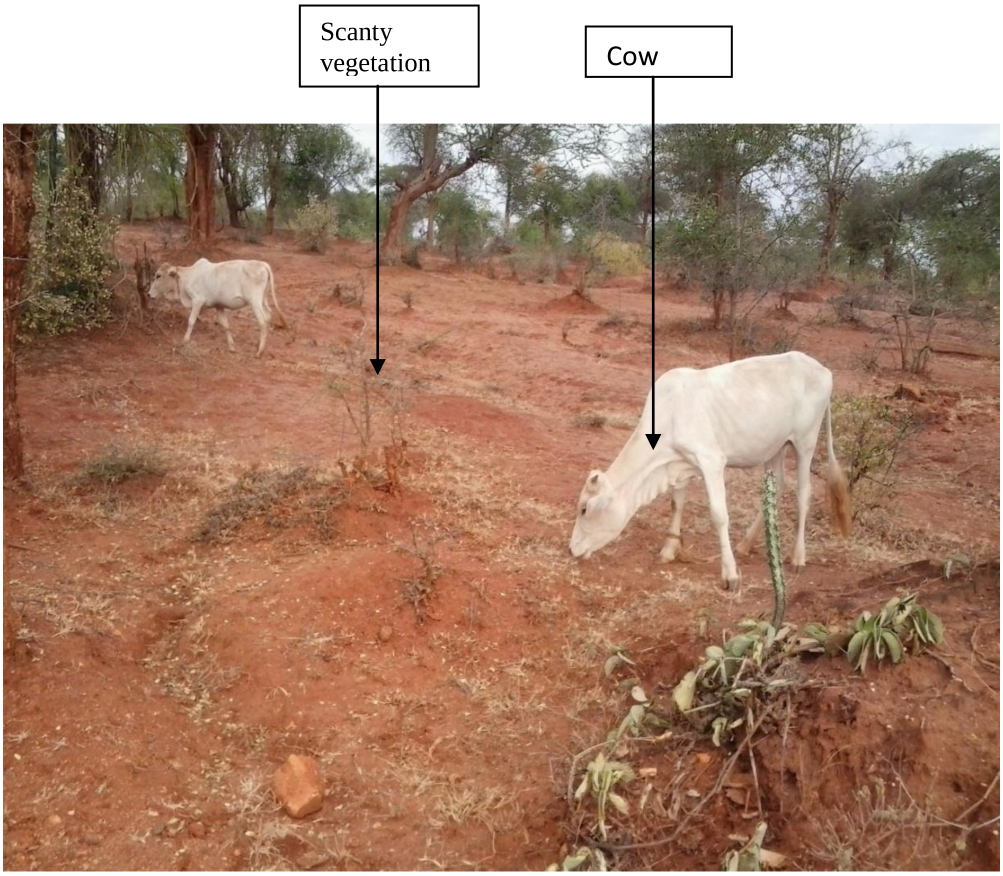


Plate 5.2: Cows grazing on scanty vegetation in the mature Kalikuvu Catchment

(Source: Researcher, 2012)

5.2.2 Deforestation

In every household included in the sample data, residents indicated that they use trees for various purposes, leading to deforestation where 95.5% indicated cutting down trees to get poles for construction and 100% cleared trees to either get room for settlement and crop cultivation, fencing homesteads and farms to protect animals from destroying property or for fuel wood. The use of vegetation products were also investigated in terms of sources and the results showed tendencies to source from the forests 52.6% of the respondents indicated that they use firewood from the forest, while 39.7% use charcoal, only small percentage indicated that they use gas. The implication of the results was that human activities could lead to active decline of vegetation cover if no remedial measure was taken and the final results would be deforestation and possible desertification. Less vegetation cover means high susceptibility to forces of soil erosion.

From the field it was observed that firewood is the main source of energy for domestic use, while charcoal is sold to earn income. The growing human population in the area has led to continued cutting of trees. Deforestation leads to low vegetation cover which aggravates sheet and gully erosion. With time sheet erosion exposes sub soil to the surface. Deforestation and removal of natural vegetation: defined as the near complete removal of natural vegetation, from large stretches of land, for example by converting forest into agricultural land, large scale commercial forestry, road construction, urban development, etc. Deforestation often leads to erosion and loss of nutrients.

Overexploitation of vegetation for domestic use: contrary to "deforestation and removal of natural vegetation", this causative factor does not necessarily involve the (near) complete removal of the "natural" vegetation, but rather a degeneration of the remaining vegetation, thus offering insufficient protection against erosion. It includes activities such as excessive gathering of fuel wood fodder, (local) timber. From plate 5.3, erosion has taken place to a depth of about 0.8metres around the tree stump in the mature catchment.

Plate 5.3: Deforestation in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

5.2.3 Poor Farming Methods

The data was collected on type of tillage carried out in the area as shown in table 5.2, which may have played a major role in causing soil erosion and consequentially lead to the formation of the geomorphologic landforms. 70 multiple responses were received, 50.0% indicated that tillage is done manually by hand, 35.7% said they use oxen, while 14.3% use tractor to plough the land.

Table 5.2: Types of Tillage

Types of tillage	**Responses**	
	N	Percent
Oxen	25	35.7
Manual by hand	35	50.0
Machinery (tractor)	10	14.3
Total	**70**	**100.0**

(Source: Researcher, 2012)

The field observation showed that majority of the residents use oxen to till the land. Tillage by hand is used in rare cases when the oxen are weak or dead after a long drought; tractors are used by few rich residents who have large farms. Most probably the people interviewed misunderstood the question which resulted to the above responses.

The residents also indicated that they plant before the onset of rain; in order to maximize on low rains and farming takes place on steep slopes and along the river banks, this has encouraged both sheet and gully erosion. Farming on steep slope and on river banks was identified during data collection. Poor agricultural activities: defined as the improper management of cultivated arable land. It includes a wide variety of practices, such as shortening of the fallow period in shifting cultivation, unsuitable land use e.g. growing of annual crops on steep hillsides such as pigeon peas, use of poor quality irrigation water, absence or poor maintenance restoration measures, untimely or too frequent use of heavy machinery, improper crop rotations etc. This category would also include the extension of cultivation onto lands of lower potential and/or high natural hazards. Degradation types commonly linked to this causative factor are erosion (water or wind), compaction, loss of nutrients and salinisation. Tillage and cropping practices lowers soil organic matter levels, because of poor soil structure, and result of compacted contribute to increase in soil erodibility, non-tillage therefore has a way of reducing soil erosion. Tillage in the area is done either manually or by using oxen.

5.2.4 High Population Density

The collected data on population showed that there was high population in the area, leading to clearing of vegetation cover. This information conforms to what was observed in the field. There were many settlements on youthful and mature stages of the catchment, some located on convex slopes. The area around the homesteads was noted to have bare ground with exposed sub soil, several rills and others gullies. Kalikuvu sub location has a population density of 169 persons per square kilometres (GOK 2002-2008). Settlements and animal husbandry has caused severe soil erosion on steep slopes in the mature catchment as shown in plate 5.4.

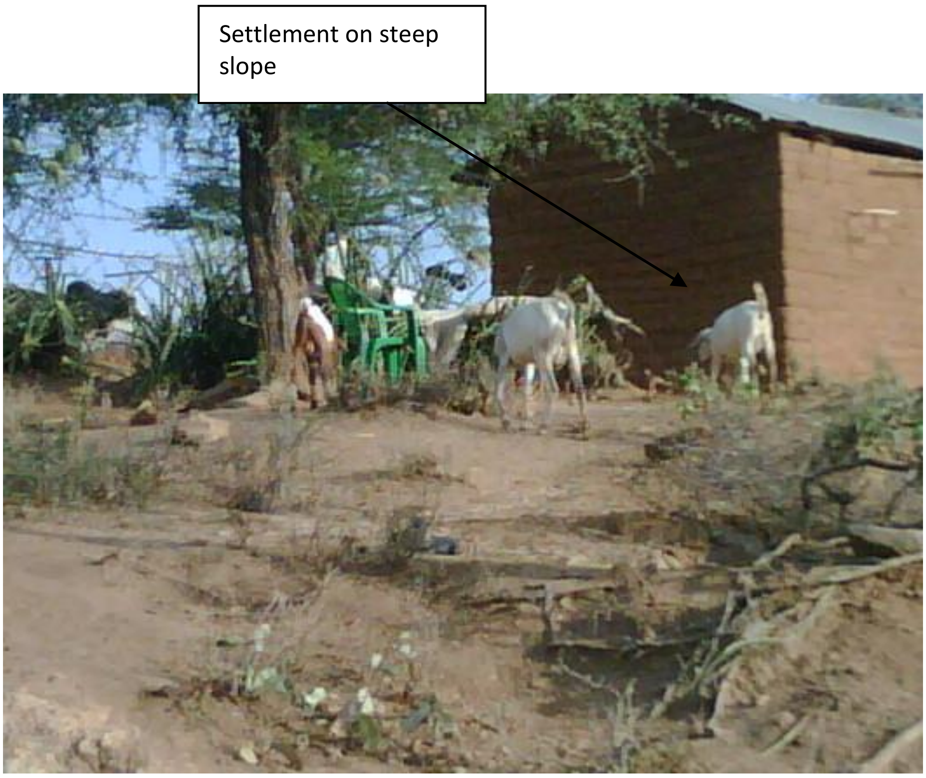


Plate 5.4: Settlements on the steep slope in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

5.2.5 Other Economic Activities Causing Soil Erosion

There are other economic activities that take place in the catchment, such as, brick making, charcoal burning and selling of firewood. Brick making exercise was noted to take place at youthful stage of River Kalikuvu and along the river bank, this activity weakens the soil structure and with time gully and rill erosion take place as illustrated in plates 5.5 where the depression formed 40centimeteres deep. Soil excavation formed depression measuring 2.5 metres deep and 2 metres wide as noted in plate 5.6.

The field observation showed that majority of the residents fetch sand from river Kalikuvu for construction, sand harvesting is an illegal activity because it encourages soil erosion.

Plate 5.5: brick making in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

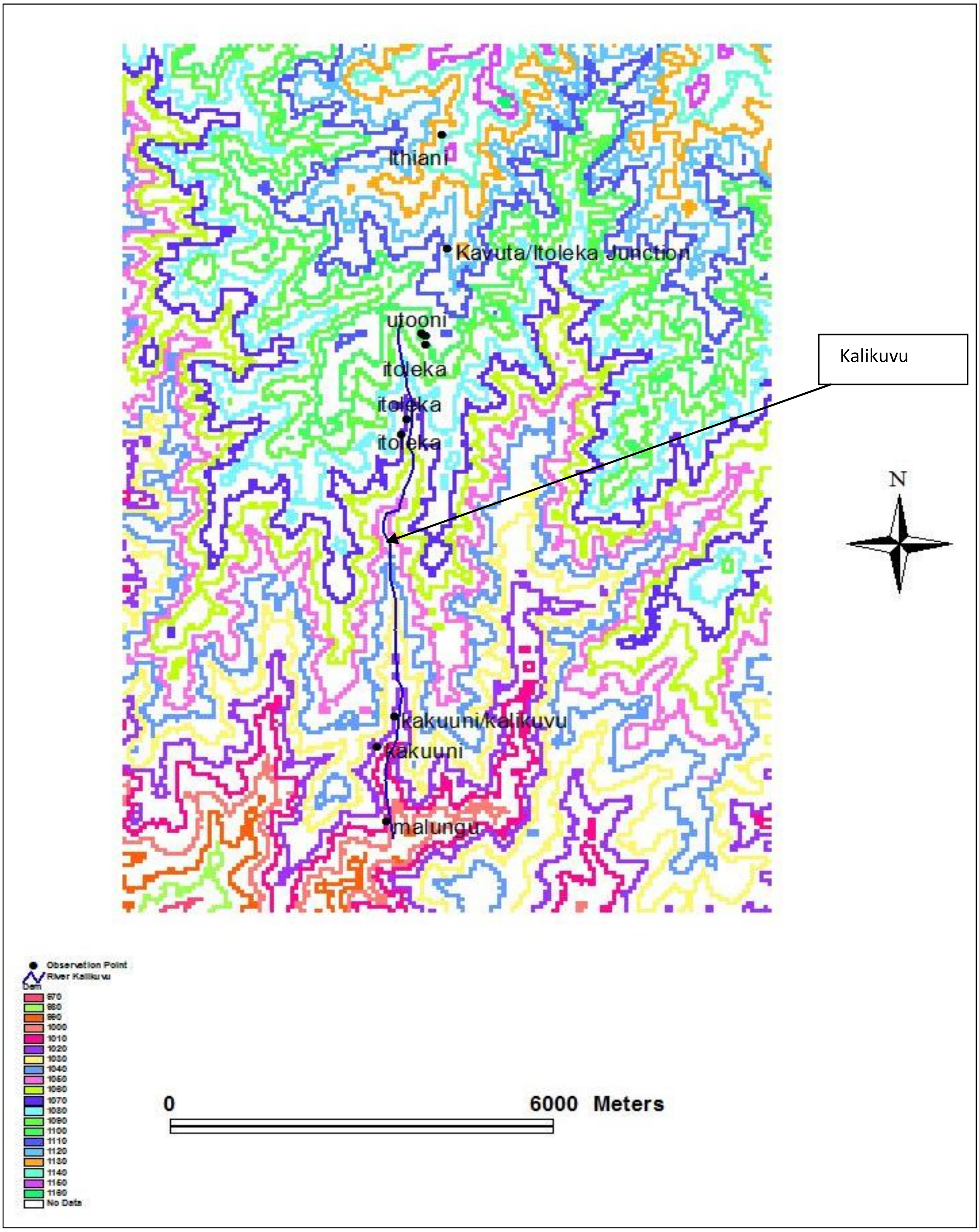
Plate 5.6: An excavated pit in the youthful Kalikuvu Catchment
(Source: Researcher, 2012)

Physical factors responsible for soil erodibility in the area were cited by residents as follows; steep terrain, soil type, seasonal rains and high wind speed respectively.

5.2.6. Steep Terrain

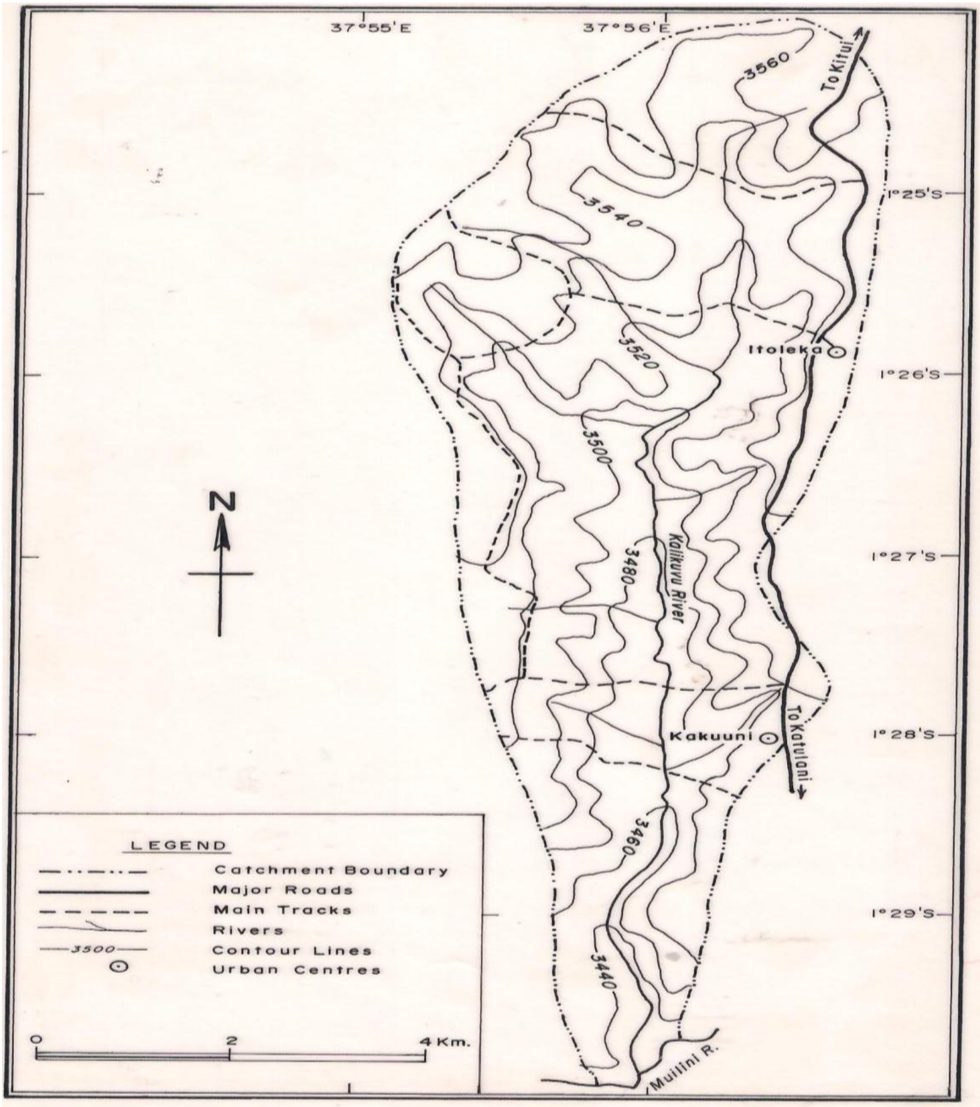
The altitudinal variations along the River Kalikuvu catchment was generated from the GPS readings during the field reconnaissance activity as shown in figure 5.1, 5.2 and 5.3. Multiple responses of 11.3% cited steep terrain to be a major physical factor causing soil erosion in the catchment. This factor conforms to observed data, where the areas with steep slopes were noted to have many gullies and rills. Geomorphologic researches have proved that, the steeper the slope, the greater the erosion, as a result of the increased velocity (swiftness) of water-flow. Soil erosion by water increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment). Steep slope has led to formation of a gully 3meters deep in the mature Kalikuvu catchment as shown in plate 5.7.

Figure 5.1: The Terrain of Kalikuvu Catchment



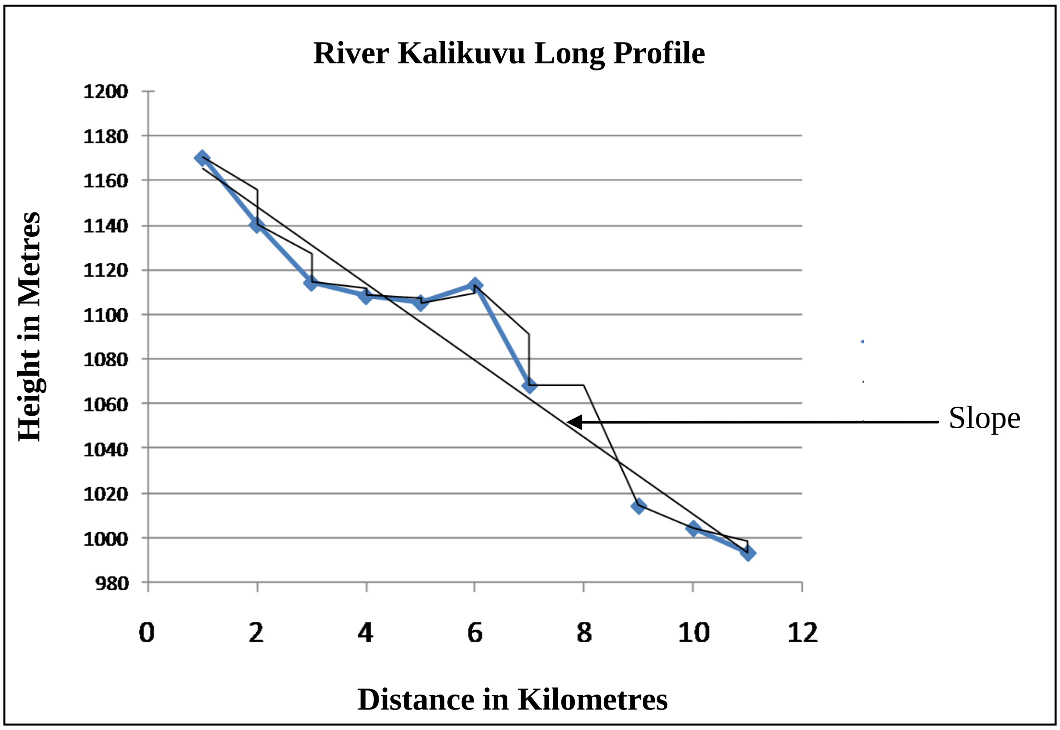
(Source: Field GIS reading, Kenya terrain data, 2010)

Figure 5.2: River Kalikuvu catchment



(Source: Compiled from Topographical map, Survey of Kenya, 2012)

Figure 5.3: A GPS generated long profile of Kalikuvu River catchment



(Source: Field GPS readings 2012)

Plate 5.7: A Gulley in the mature Kalikuvu Catchment

(Source: Researcher, 2012)

5.2.7 Soil Type

A total of 7.3% of the respondents cited soil type to be physical factor encouraging soil erosion in the catchment. This conforms to field observation, where the soils were observed to be mainly sand and gravel. Researchers have proved sandy soils to be easily eroded. Over cultivation in the area, cause the soil to loose its structure and cohesion (ability to stick together) and it erodes more easily.

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Annual crops have a tendency to generate sheet erosion as the rains become less and the ground becomes bare such as Pigeon peas. Table 5.3 shows types of crops grown in the catchment.

Table 5.3: Crops Grown

Crops grown	**Responses**	
	N	Percent
Maize	6	17.6
Beans	7	20.6
Cow peas	6	17.6
Green grams	2	5.9
Pigeon peas	5	14.7
Sorghum	1	2.9
Cassava	2	5.9
Cotton	1	2.9
Sweet potatoes	1	2.9
Tomatoes	2	5.9
Pumpkins	1	2.9
Total	**34**	**100.0**

(Source: Researcher, 2012)

Past erosion also has an effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with sub soils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

5.2.8 Rainfall and Runoff

A total of 4.0% of the respondents indicated that, seasonal rains in the catchment are also responsible for soil erosion. They indicated that they receive rain in two seasons, 50% said March and October. 33.3% said March to June and 50% said October to December. They all indicated that, the area receives two rain seasons and such rains are accompanied by high runoff, especially at the onset of rains. This conformed to data collected from the weather station near the catchment; the disparity in months was noted to be due to unreliability of the rains.

The impact of raindrops on bare soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles. Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration.

It is typical in arid and semi-arid areas to forget about the role of rainfall in causing soil erosion. It can be deemed that the respondents did not consider rainfall as a threat to land degradation. This is typical because lack of or little rainfall is the real cause of degradation and the residents appear not to blame it because rain is a scarce and most needed commodity in the area. The amount and timing of rainfall have great importance in determining the rate of soil erosion, as it has been proved by earlier researchers in geomorphology.

5.2.9 High Speed of Wind

3.4% of the respondents indicated that high wind speed contributes to soil erosion during dry season, when there is scanty vegetation. Researchers have also shown that, the speed and duration of the wind have a direct relationship to the extent of soil erosion. Soil moisture levels are very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind.

5.3 Landforms Resulting from Soil Erosion

Soil erosion being a common process of the Kalikuvu catchment as indicated by the majority of the respondents above, it could not be taken for granted that there were resultant effects. It was therefore important to establish the effects of soil erosion in the catchment as one of the study hypotheses was that soil erosion had no impact on crop production especially maize. When respondents were asked to provide the effects of soil erosion in the catchment the results were in table. The respondents were asked if the soil erosion had effect in the catchment and out of the 44 respondents, 42 confirmed that soil erosion has effect in the area of study.

The main effects sited by the respondents were as follows: reducing crop production had majority of 17.1% respondents; second, increasing the depth and width of rills and gullies hindering people and animal movement 14.7%; eroding the top soil 12.4%; reducing vegetation cover 12.4%; reduced crop health 4.7%; formation of rills and gullies had 3.1% respondents; leading to high poverty levels 3.1% respondents; lack of information on soil conservation 2.3%; presence of wide and deep gullies reduce arable land 1.6%. All these responses were positively observed in the field from the source to the mouth of River Kalikuvu catchment. Only ignorance 3.9% and occurs uncontrollably 1.6% indicated otherwise, per halves they did not understand the question.

From reconnaissance, it was observed that soil erosion is a major problem in the Kalikuvu catchment. About 28.4% of respondents confirmed that soil erosion is severe on steep slopes, 18.3% areas with little/no vegetation, 15.6% along or near river banks. About 8.3% suggested that erosion was severe in many areas including areas with no conservation measures, densely settled and close rivers thus showing the complexity of the erosion phenomenon. Sub-soil is exposed to the surface which is bare or covered by scattered scrubs, cactus and acacia trees as identified in the Kalikuvu catchment. Although erosional features were reported to have negative effect on livelihoods of the locals, on the other hand they can be utilised for tourism purpose.

5.3.1 Soil Erosion Types

This study focuses on the problem of soil erosion in the Kalikuvu catchment and it was deemed important to establish community understanding of soil erosion in the study area. To do this, a number of questions relating to soil erosion in the Kalikuvu catchment were raised with the respondents. About 95.5% of the respondents affirmed that soil erosion is a problem in the catchment. The results conform to the field observations where the transit along the River Kalikuvu catchment from the youthful section to the mouth of the river four types of soil erosion were identified, namely; sheet, rill, gully and bank erosion.

The computed chi square was 27.164 while the critical chi-square (χ^2) at α 0.05 is 27.59 and degree of freedom is 17, this indicated that the null hypothesis of no difference could not be rejected since there was not enough evidence from the sample data. The indication therefore was that difference in soil erosion characteristics and/or effects in the Catchment could be due to chance only. In geomorphology, the implication was that the physical forces affecting soil erosion in the Kalikuvu Catchment tended to be similar and this is usually true of small river catchments erosion problems.

The respondents indicated that soil erosion is a problem in Kalikuvu catchment. Many rills and gullies have been formed on steep slopes and with time they have widened and deepened making it impossible movement of people and animals, especially the areas near the river channel. This is applicable in upper, mature and old stage of Kalikuvu catchment. Areas with gentle slopes have been subjected to sheet erosion and much of the top soil has been washed away exposing sub-soil, such areas were noted to have low vegetation cover and reduced crop yields.

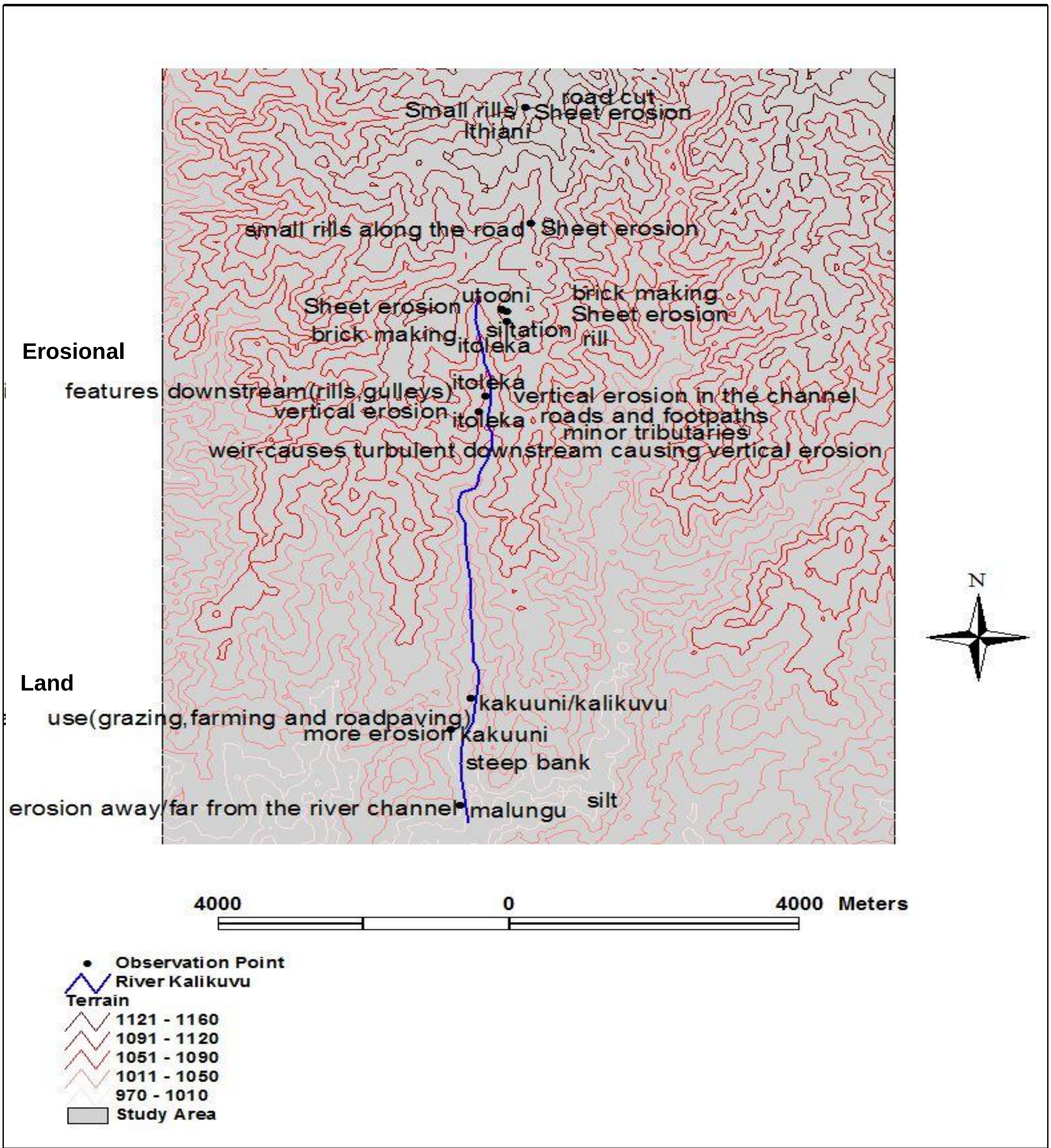
All these responses were positively observed and measured in the field. Youthful section was commonly characterised by many rills and gullies. Large depressions, scarce and poor vegetation cover were evident. At the mature section rills had deepened and widened to form gullies, which were many in number.

Old section, few rills and gullies were evident in areas away from the channel within the catchment. 73.9% of the respondents indicated that people move to Kalikuvu catchment. Newly constructed homesteads were successively identified along the river catchment. The landforms results from soil erosion identified as; sheet erosion, mounds around plants, rills, gullies; deep and wide valleys were successively identified along the river catchment

5.3.2 Soil Erosion and Landforms

There are three types of soil erosion in Kalikuvu catchment namely sheet, rill and gully erosion which has led to formation of erosional features as shown in figure 5.4.

Figure 5.4: Types of Soil Erosion and Associated Landforms



Source: Field GIS reading, Kenya terrain data (2010)

5.3.2.1. Sheet Erosion and Landforms

Sheet erosion is caused by surface runoff, covering large area with uniform slope. Only the fine soil particles are carried away, leaving on the surface smooth and sorted sand and gravel particles as shown in plate 5.8. This is more evident on areas with scanty vegetation. Sheet erosion leads to formation of rills and mounds around plants.

Plate 5.8: A plain with sorted sand and gravel in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

5.3.3 Mounds around Plants

Mounds were reported around *acacia* trees and scattered vegetation such as scrubs and shrubs in Malungu village these are typical vegetation types in arid and semi-arid environments. Mounds around trees are known sometimes to grow at about 10mm/year and can be used to measure the rate of sheet erosion as shown in plate 5.9.where they measured about 15centimetres high.

Plate 5.9: Tree mound in the mature Kalikuvu Catchment

(Source: Researcher, 2012)

5.3.4 Rill Erosion and Landforms

Rills are shallow channels eroded by threads of turbulent flow developed in the sheet flow where entrainment of soil is concentrated. On average rills had depth of about 0.5 metres and width of about 0.5 metres. During storms rills erode head ward on the steepest local gradient at cm/minute or faster. On open slopes, rills tend to form parallel to one another, converging in hillside hollows to form dendritic patterns that are ephemeral, that is, can be destroyed and recreated during major storms. Rills terminate at the base of slopes and thus are not part of the regional drainage network but they demonstrate dendritic drainage pattern. The runoff from the roads was poorly designed thus causing rill to erode the road abutement degenerating into gullies. This is illustrated in plate 5.10.

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Plate 5.10: A rills in the mature Malungu Village
(Source: Researcher, 2012)

5.3.5 Gully Erosion and Landforms

Gullies are the first-order stream channels that develop on slopes at the upper reaches of watersheds. They carry ephemeral stream flow. Narrow and deep sides, the depth and width persist for years or decades, so more persistent than rills but still not "permanent" landforms. Gullies had average measurements of depth about 2.5 metres and width about 2.0 metres. Farm machinery can pass through rills but not gullies. The backward eroding gully shows an abrupt initiation, generally appearing like a hole that quickly collapses. The head cut is discontinuous and the gully flow appears to be relatively flat. The rills soon coalesce to form a wider gully. The gully network is dendritic in character. Road cutting has led to formation of Rills which in turn have formed gullies in the mature catchment of Kalikuvu Village as shown in plate 5.11.

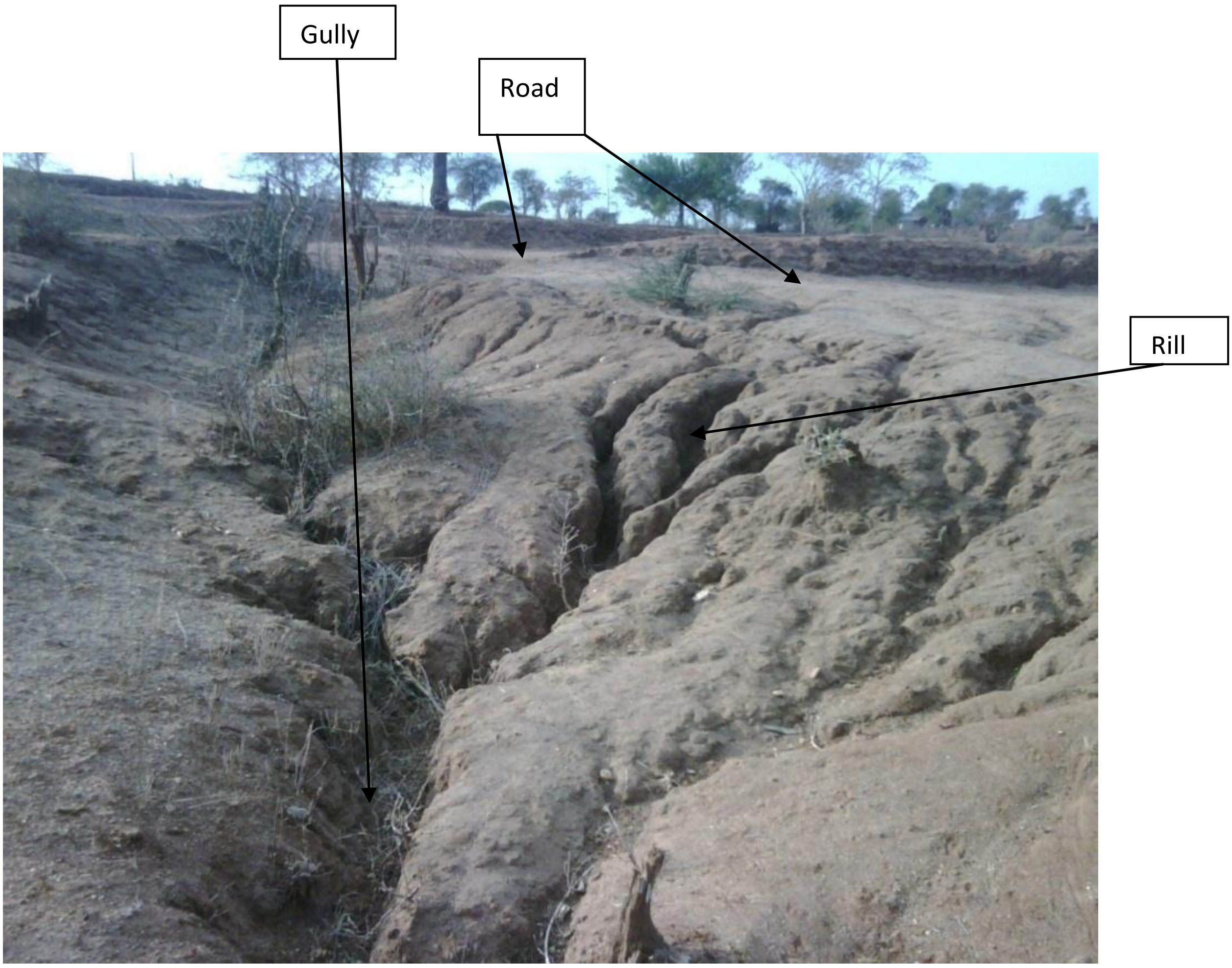


Plate 5.11: A gully in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

5.3.6 Deep and Wide Gullies

Deep and wide gullies have steep slopes of about 3 metres and wide floor of about 9.6 metres and the slopes experience backward erosion leading to formation of caves during rainy season. Such gullies continue eroding vertically until they reach the bedrock. Deep and wide gullies were commonly found at the mature stage of river Kalikuvu new Kakuuni shopping centre. This is illustrated in plate 5.12. Severe vertical erosion has led to formation of deep gullies about 6 metres and about 2.5 metres wide forming Earth Pillar in the youthful catchment within Malungu Village as shown in plate 5.13. Vertical erosion has led to deep gullies of about 3.5 metres and in some areas rocky surfaces have been exposed and horizontal erosion widening the gully to about 7 metres as shown in plate 5.14.

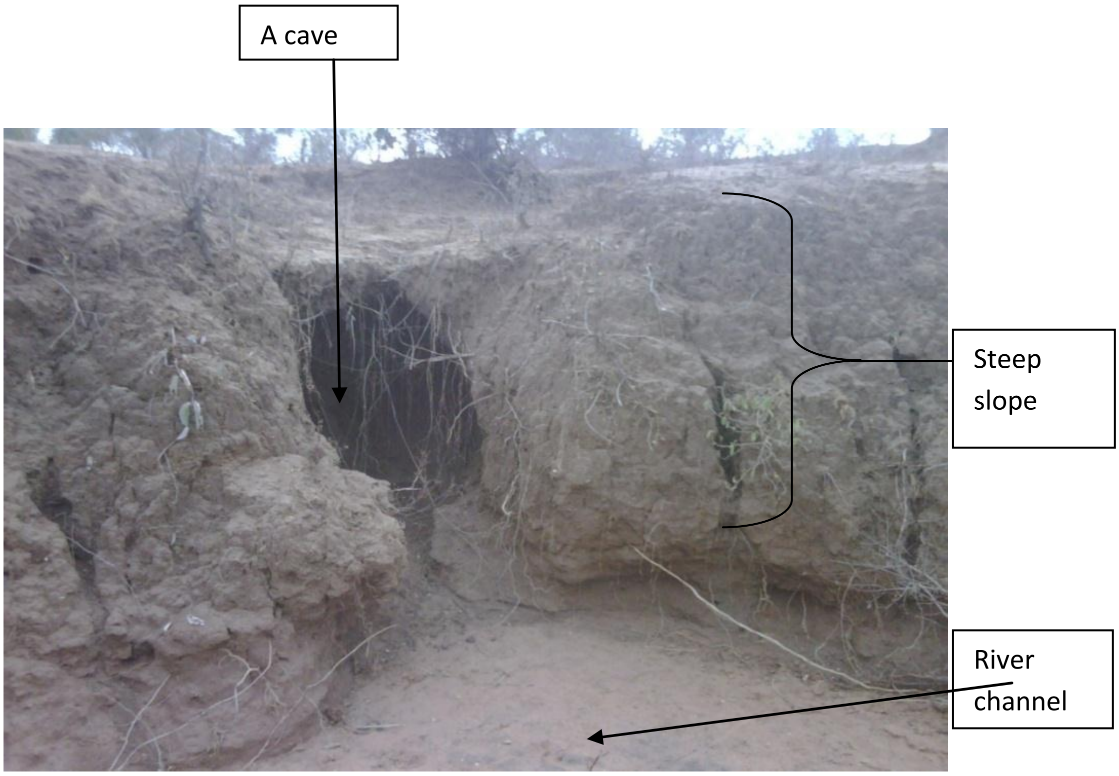


Plate 5.12: A cave in the mature Kalikuvu Catchment

(Source: Researcher, 2012)

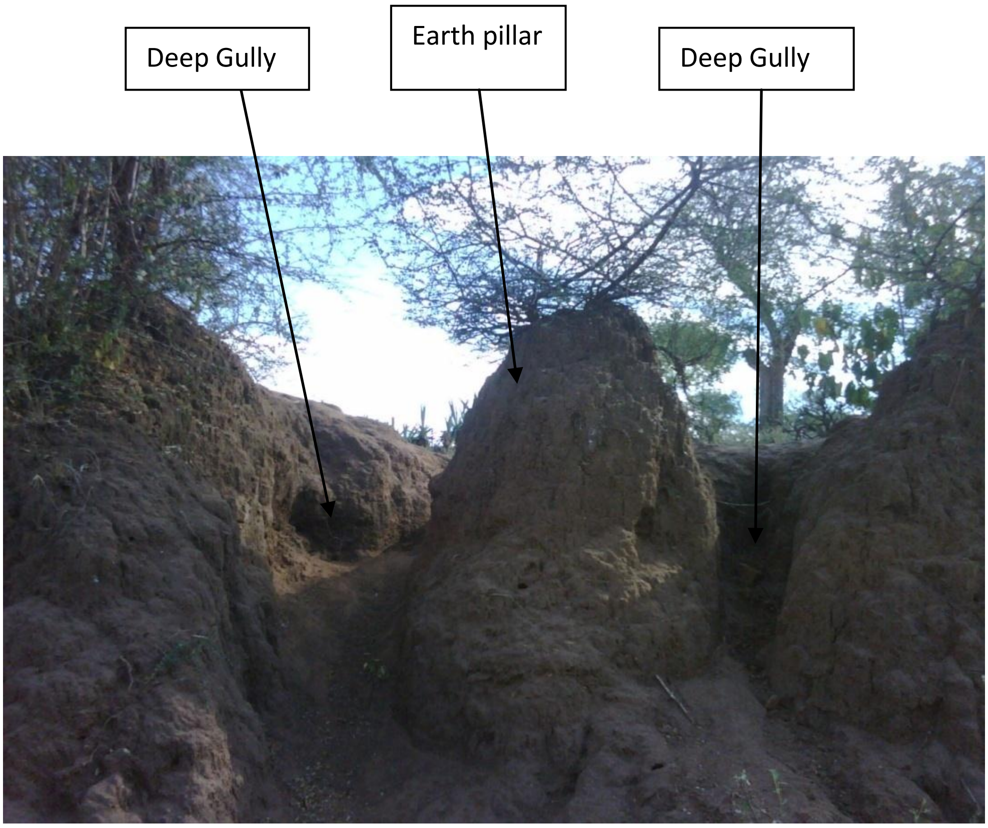


Plate 5.13: A pillar in the mature Kalikuvu Catchment*:*

(Source: Researcher, 2012)

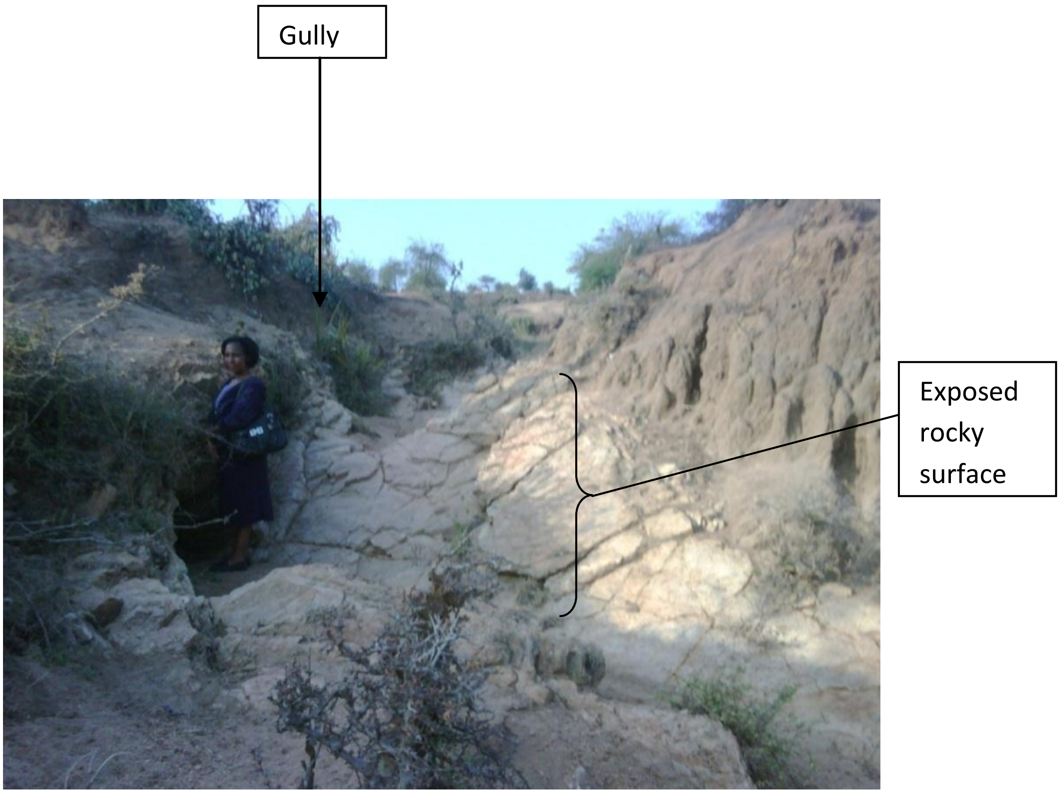


Plate 5.14: Exposed rocks due to vertical erosion in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

The depth of the weathered surface reflects how deep such a gully will be able to erode. Several gullies within the catchment, mainly the mature stage have been deepened by vertical to a depth of about 4 metres and widened to a width of about 9 to 10 metres as shown in plate 5.15.

Plate 5.15: A wide and deep gully in the mature Kalikuvu Catchment
(Source: Researcher, 2012)

5.4 Impact of Soil Erosion on Crop Production especially Maize in Kalikuvu Catchment

This study collected data on major crops grown in the area in order to determine if maize was the main crop grown in the area. All the respondents interviewed indicated that they grow maize. They also indicated that other major crops grown in the area are cowpeas, beans, pigeon peas, green grams, cow peas, green gram and pigeon peas. These are drought-tolerant crops typical in ASAL areas (Arid and Semi-Arid lands) as shown in table 5.5. However the study observed that most of the year, the ground is bare encouraging erosion by wind during dry season and water during onset of rains as illustrated in plate 5.16.

Table 5.5: Crops Grown in Kalikuvu Catchment

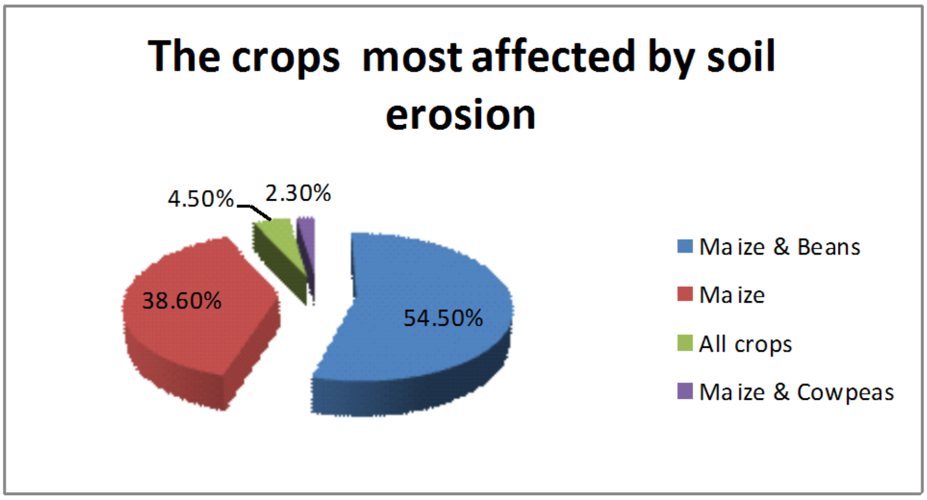
	Responses	
	N	**Percent**
Maize	41	15.5
Beans	35	13.2
Cow peas	38	14.3
Green grams	20	7.5
Pigeon peas	33	12.5
Sorghum	18	6.8
Cassava	10	3.8
Millet	5	1.9
Mangoes	6	2.3
Pawpaw	5	1.9
Sweet potatoes	5	1.9
Tomatoes	9	3.4
Pumpkins	9	3.4
Water melon	5	1.9%
Kale (sukuma)	4	1.5
Spinach	4	1.5%
Others	9	6.8%
Total	**265**	**100.0**

(Source: Researcher, 2012)

The computed chi square was 49.164 while the critical chi-square (χ^2) at α 0.05 is 33.92 and degree of freedom 22, this indicated that the null hypothesis of no difference is rejected since there was enough evidence from the sample data. The indication therefore was that there is difference in maize production in the catchment. In geomorphology, the implication was that the physical forces affecting maize production in the Kalikuvu catchment were different in the stages of the catchment.

All the respondents confirmed that all the crops are affected by soil erosion. Out of 44 respondents, 54.5% quoted the most affected as maize and beans. The second affected is maize supported by 38.6%; 4.5% stated that soil erosion affects all crops. 2.3% supported maize and cowpeas. From the table it can be concluded that maize was quoted by the 100% respondents, the same was observed in the field where in almost every farm there was maize plants. Maize plants in severely eroded areas had short and weak stalks, while less eroded soils had tall and stronger maize stalks with low harvest. Animals may destroy terraces during dry season which in turn encourages soil erosion in the mature Kalikuvu catchment as shown in plate 5.17. Field observation revealed that green grams gave large harvest although planted on a small area; cowpeas had the largest harvest in general, followed by pigeon peas, maize and other crops as illustrated in figure 5.5.

Figure 5.5: The Crops most Affected by Soil Erosion



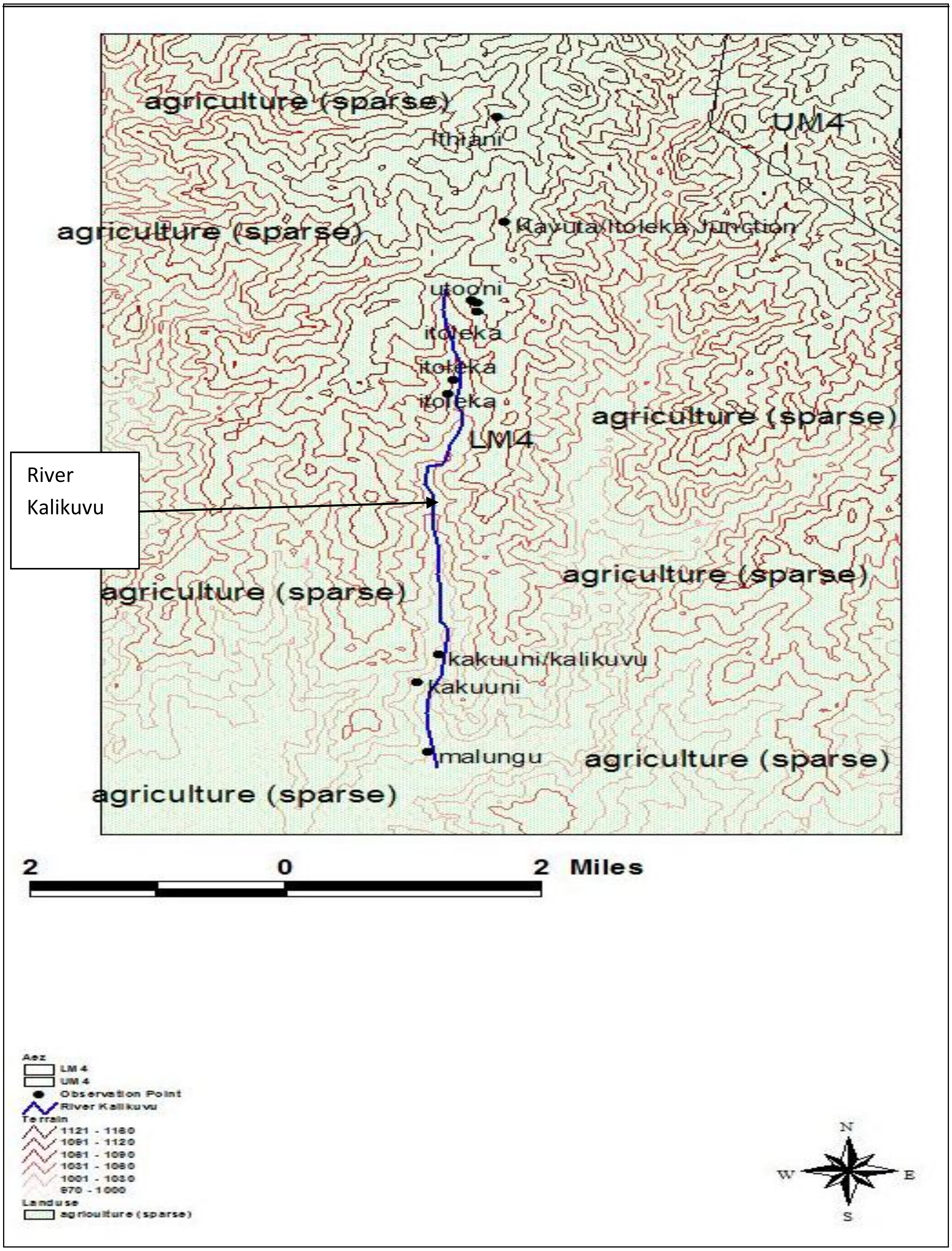
(Source: Researcher, 2012)

Plate 5.16: Pigeon peas in the mature Kalikuvu Catchment
(Source: Researcher, 2012).

The plate above demonstrates that sheet erosion is very rampant in spite of contour ploughing. The farmers adopted contour ploughing because they are aware of the ramification of the steep slopes and pigeon peas are planted as annual crops to control wind erosion during the June-August dry season, but they expose the soil to sheet erosion during the first rains of March.

Plate 5.17: Maize crop, drying prematurely on the farm due to lack of enough rainfall
(Source: Researcher, 2012).

Figure 5.6: Agricultural areas in Kalikuvu Catchment



Source: Field GIS reading, Kenya terrain data (2010)

Apart from the geomorphologic landforms and crop production witnessed on the surface, the vegetation was noted to have been affected by the removal of top soil by erosion, discouraging the growth of young plants in some areas in the catchment. Most of the trees present were deep rooted, sparsed and some were umbrella shaped. Much of the ground lacked vegetation cover, thus encouraging both water and wind erosion. 6% of the residents indicated that, soil erosion has reduced plant cover and plant health as shown in figure 5.6 and table 5.4.

Table 5.4: Effects of Soil Erosion on Plants

Effects of soil erosion on plants	**Responses**	
	No of cases	Percept
Erodes top soil	2	9.5
Reduces crop production	3	14.3
Reduces vegetation cover	2	9.5
Increases rills and gullies hindering movement	3	14.3
Very high poverty levels	1	4.8
Ignorance	2	9.5
Reduced crop health	1	4.8
Others	2	9.5
Total	21	100.0

(Source: Researcher, 2012)

Stunted secondary vegetation was identified in the mature of Kalikuvu catchment as a result of severe erosion. The vegetation controls both water and wind erosion in the catchment as shown in plate 5.18.

(A) Acacia *tortillis* **(B)** Cactus

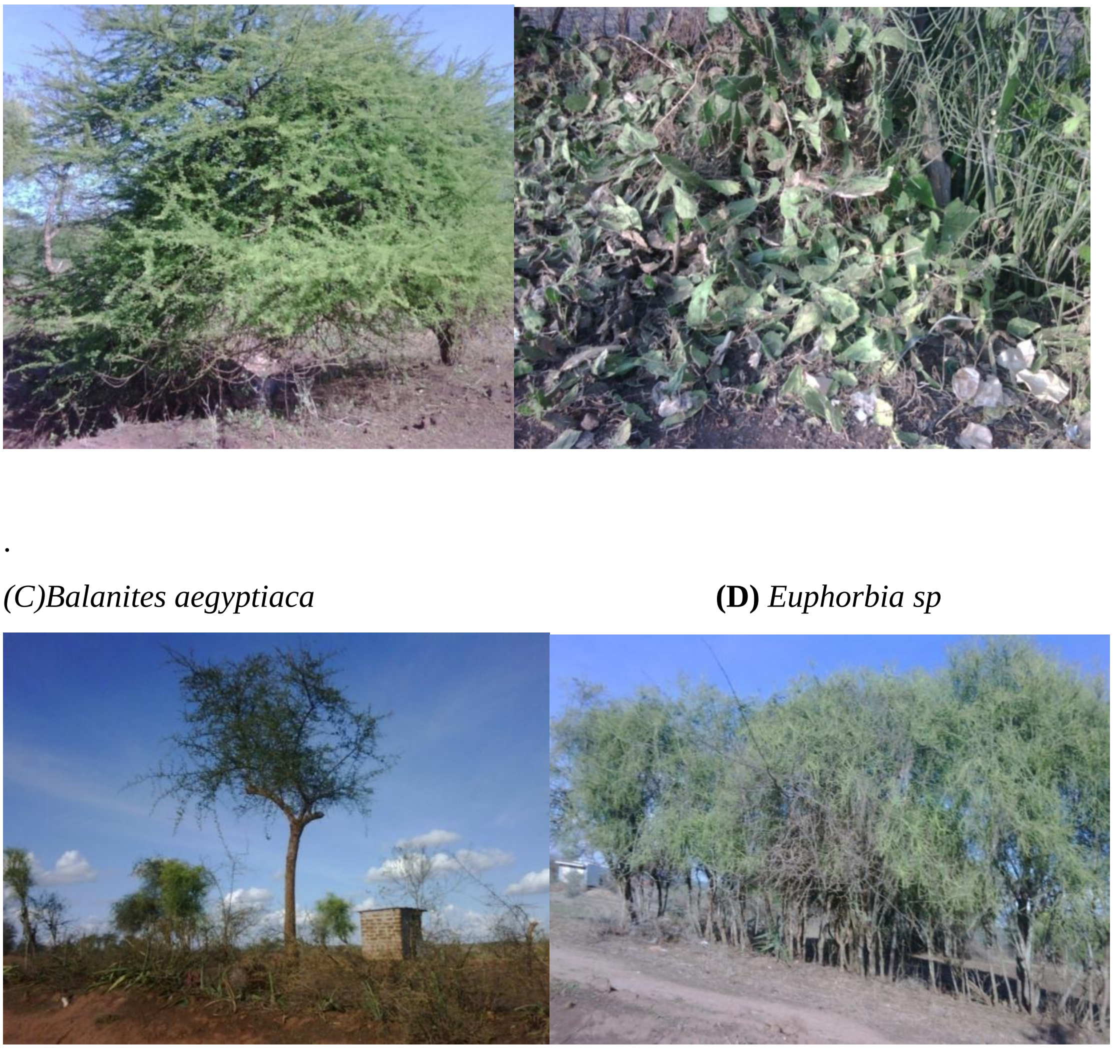


Plate 5.18: Stunted secondary vegetation (A-D) in the mature of Kalikuvu catchment Kakuuni Village (Source: Researcher, 2012)

5.5 Restoration Measures for Soil Erosion Control

Since soil erosion had earlier been noticed as a problem in the Kalikuvu sub-location.

A multiple response analysis was carried out first to identify the types of restoration using multiple frequency analysis procedure. The respondents were asked if restoration measures to soil erosion are present in the area. The residents admitted to be aware and the multiple responses were as follows; terraces had the highest 39.0%; benches second with 23.0%, cut offs 17%; Afforestation 15%; trenches 3.0%; none 2.0% and planting perennial crops 1.0%.

The computed chi square was 15.314 while the critical chi-square (χ^2) at α 0.05 is 9.49 and degree of freedom is 4, this meant that the null hypothesis of no difference was rejected since there was enough evidence from the sample data. The indication therefore was that there differences in soil restoration measures in the Kalikuvu catchment were significant. In geomorphology, the implication was that the restoration measures in the Kalikuvu catchment were different in the stages of the catchment (as indicated in appendix XI). Environmental restoration involved several techniques and approaches to remedy degradation which include the following:

- The use of contour ploughing, zero tilliage, and establishing wind breaks and as “live” fences;
- Establishing terraces or leaving unploughed grass strips between ploughed land;
- Making sure that there are always plants growing on the soil (perennial crops or trees, and that the soil is rich in humus (decaying plant and animal remains). As shown earlier, this organic matter is the "glue" that binds the soil particles together and plays an important part in preventing erosion;
- Avoiding overgrazing and the over-use of crop lands;
- Practising afforestation or agro-forestry;
- Allowing indigenous plants to grow along the river banks instead of ploughing and planting crops right up to the water's edge;
- Encouraging biological diversity by planting several different types of plants together (mixed farming);
- Conservation of wetlands, especially the floodplains.

5.5.1 Crops as Restoration Measures

Concerning the type of crops grown, the respondents indicated that, seasonal, biannual and perennial crops are grown in the area. Biannual are crops which take two seasons and perennial take many years in the *shamba,* both biannual (especially pumpkin which act as ground cover) and perennial such as mango trees, help to control water within the flood plains. This is illustrated in plate 5.19 where mango trees (perennial crops) and pigeon peas (biannual crops) in the old catchment have protected the soil from severe erosion. Many of the seasonal crops, such as cow peas and beans, cover the ground thus controlling soil erosion.

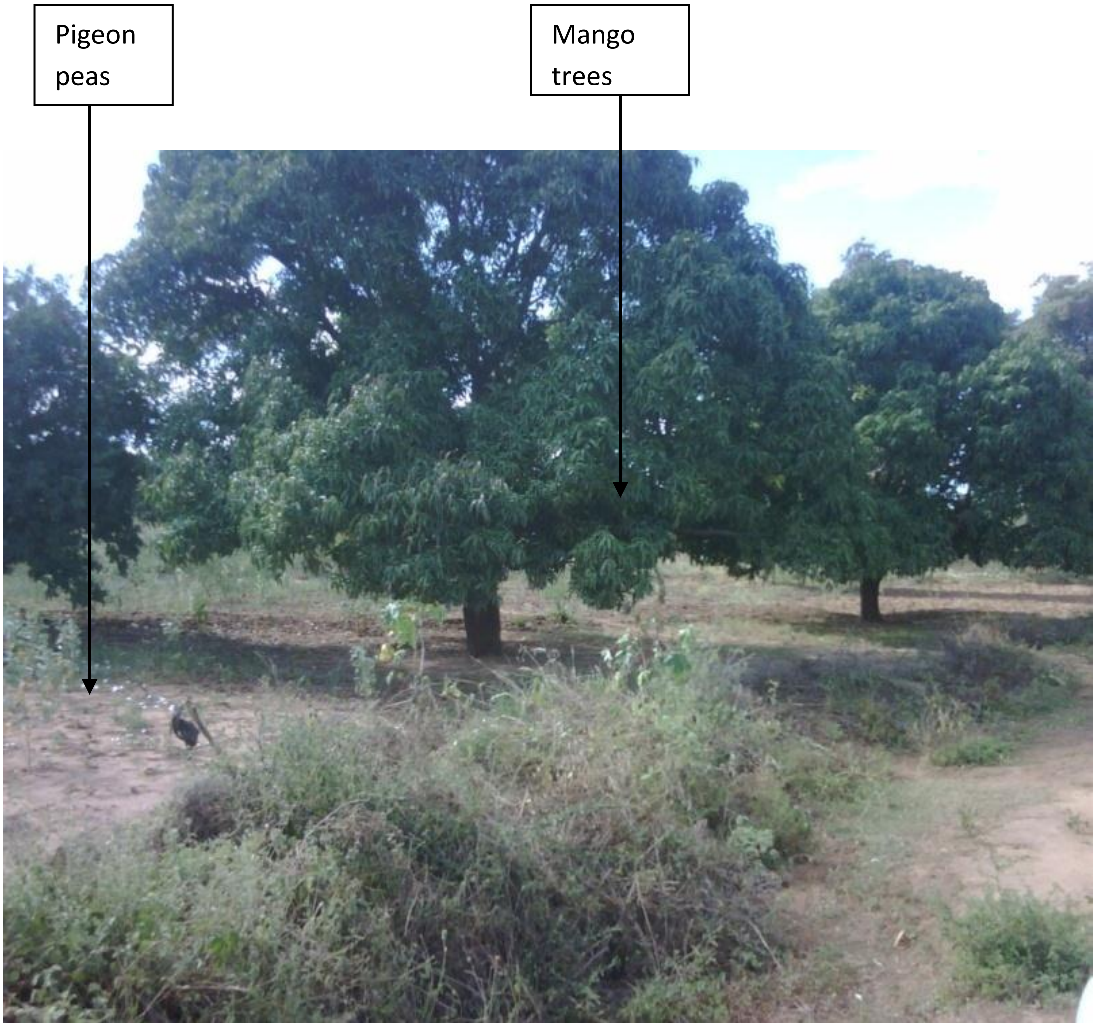
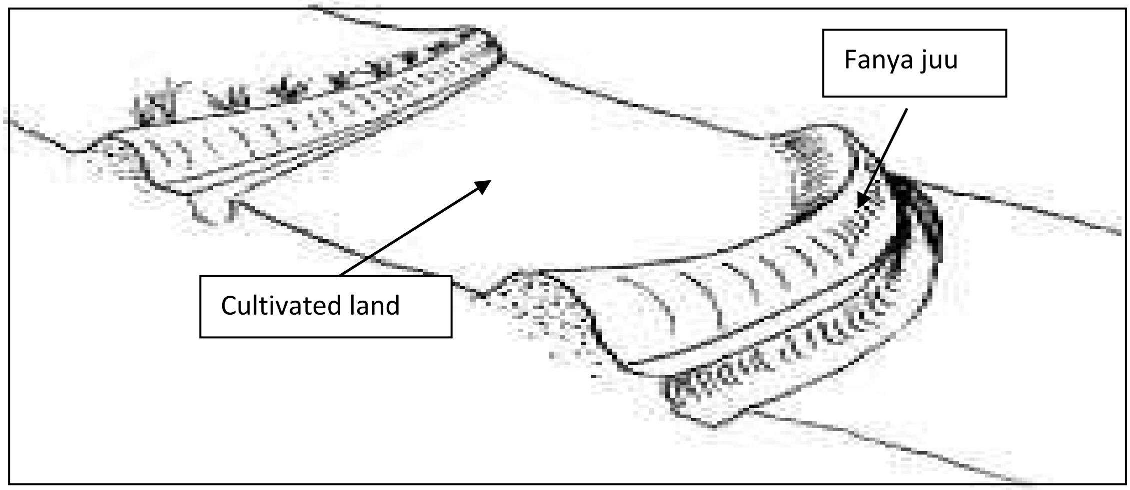


Plate 5.19: Agroforestry farming along the old river bank in the Kalikuvu Catchment
(Source: Researcher, 2012)

5.5.2 Terraces

A series of wide steps on a slope, cut so that they can be used to control surface runoff and for growing crops. A total of 39% of respondents indicated that they dig terraces as a way of controlling soil erosion. The number of those dig benches and cut offs was 23% and 17% respectively. Some farms were cited with well-maintained terraces, especially to the west side of River Kalikuvu. Cut-off drains are dug across a slope to intercept surface runoff and carry it safely to an outlet such as a canal or stream. *Fanya Juu* terraces were common in the farms and were used to protect cultivated land, compounds and roads from surface runoff, and to divert water from gully heads as illustrated in figure 5.7 and plate 5.20, Malungu village near the mouth of Kalikuvu River joins river Muilini at longitude 381227, latitude 9835856 and altitude of 993 metres, western side. *Fanya Juu* terraces are constructed by digging ditches and heaping the soil, forming bunds in the youthful sides of the ditches. Between the ditch and the bund a small edge prevents the soil from sliding back. Spacing depends on slope and soil depth.

Figure 5.7: Fanya Juu Terraces used to Control Soil Erosion



(Source: Researcher, 2012)

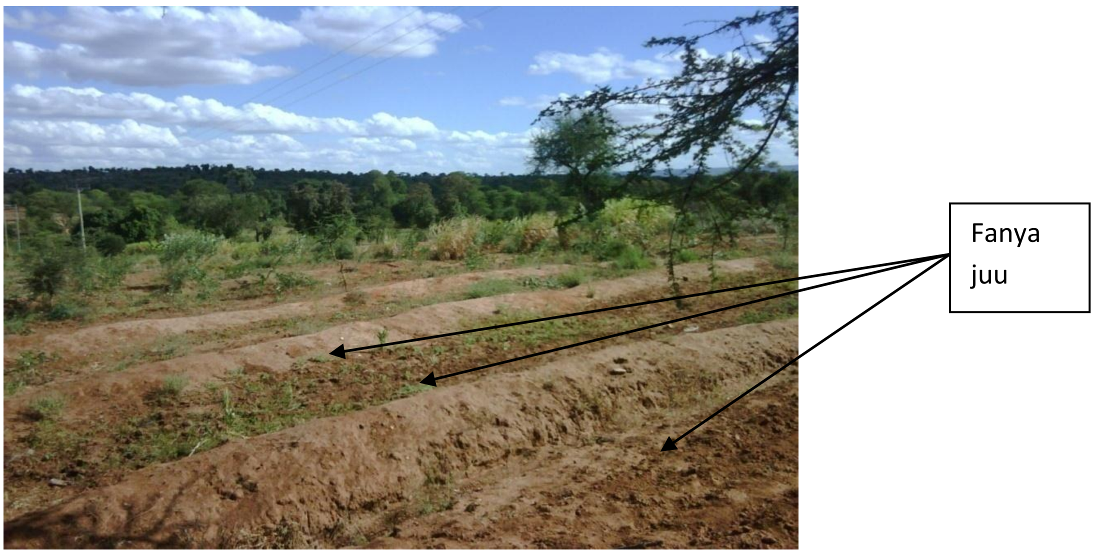


Plate 5.20: ***Terraces used to conserve soil in old Kalikuvu sub-location***

(Source: Researcher, 2012)

5.5.3 Gabions

A Gabion is a cylindrical metal container filled with stones, used in the construction of underwater foundations to control gully erosion. Residents indicated that with the help of the Government and Non-Governmental organizations such as Danish International Development Agency (DANIDA) they have constructed gabions to control gully erosion in the catchment. Several gabions were identified along river Kalikuvu, as shown in plate 5.21, a gabion measuring 0.8metres high and width of 4.8metres, near Kalikuvu shopping centre.

Plate 5.21: Gabion constructed to control gully erosion in Kalikuvu Village
(Source: Researcher, 2012)

5.5.4 Sand Dams

Sand dams are small concrete structures in ephemeral riverbeds that store water from the rainy seasons under a layer of sand. The respondents indicated that several of these sand dams were constructed by locals with the technology and funds from Sahelian Solution Foundation (SASOL), many of sand dams measuring about

2.5meters high and 4.5metres width were cited along the river channel from the youthful to old stage. Ecological restoration was evident behind the sand dams between Kakuuni and Kalikuvu Villages (as indicated in plate 5.22). Sand dams although the main aim for their construction was to raise the water table in seasonal rivers in the area, they also play a major role in controlling the speed of water, which in turn reduce soil erosion in the study area.

The Assistant chief through the act of chief has been holding meetings with the residents to educate them on dangers of sand harvesting in the catchment as a measure of controlling soil erosion.

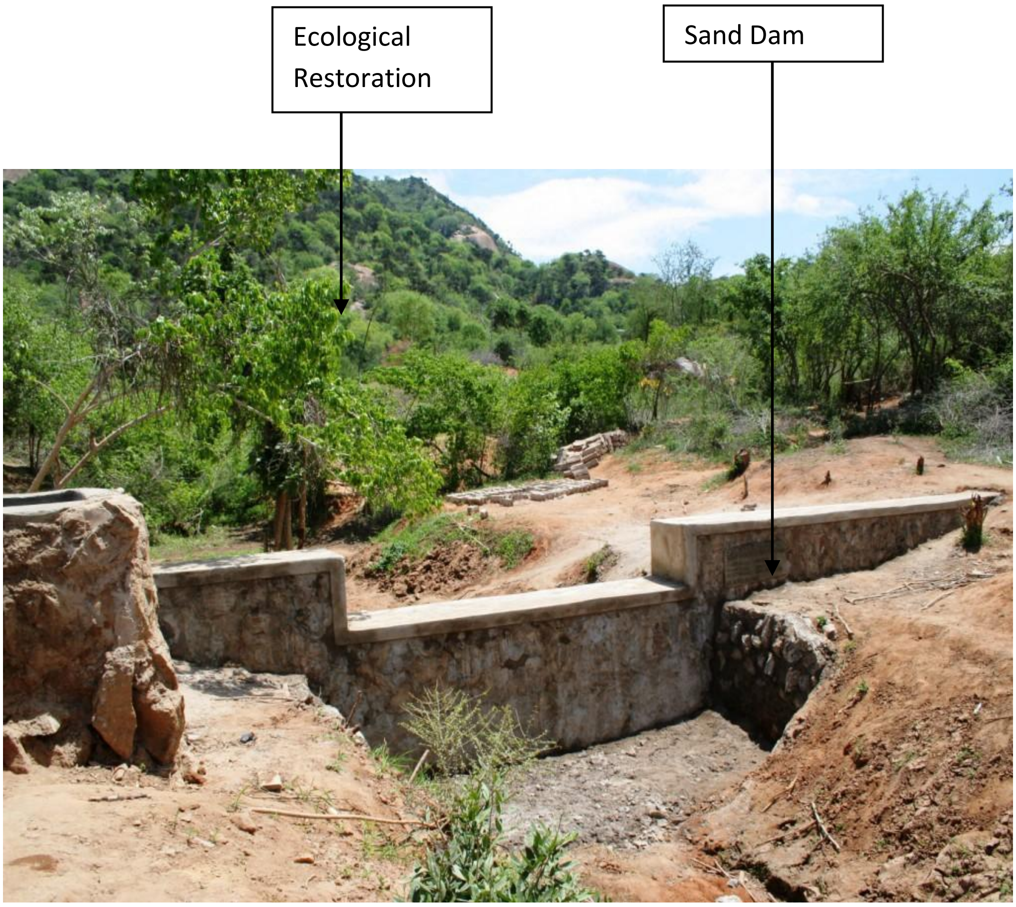


Plate 5.22: *Sand dam along Kalikuvu River*

(Source: Researcher, 2012)

5.5.5 Planting Vegetation along River Banks

The respondents indicated that, planting of vegetation along the river channel controls water velocity which in turn reduces the rate of soil erosion within the catchment. This conforms to work done by Mati (2000) and Muhia (2000). Napier glass was cited along the Kalikuvu channel at the old stage. Preserving river banks is able to reduce bank erosion as shown in plate 5.23.

Plate 5.23: *Napier grass along the old River Kalikuvu.*

(Source: Researcher, 2012)

5.5.6 Afforestation

This is the process of planting many trees on an area of land. A total of 15% of the respondents indicated that afforestation is practised in the catchment; this conformed to field observation and researches by ICRAF (2004). Trees were evident at the edge of the farm to control sheet erosion in the farm. Mixed farming is practised and maize and cowpeas were planted in the same farm as shown in plate 5.24. This was observed to be common in all areas sampled.

Plate 5.24: *Trees planted at the edge of the farm and mixed farming at the old Kalikuvu*
(Source: Researcher, 2012)

CHAPTER SIX

6.0. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary and conclusions

From the study findings it was concluded that soil erosion is a serious problem in Kalikuvu catchment. The summary of the findings were done according to the specific findings obtained in chapter five. The study found out that the factors causing soil erosion in Kalikuvu catchment in Kitui County to be human activities, such as overgrazing, deforestation, Poor farming methods especially along the river bank and on steep slopes, lack of restoration measures, excavation of the steep slopes, Sand harvesting, brick making, the above factors are aggravated by population increase. The study found out the physical factors contributing to soil erosion in the Kalikuvu catchment are soil type, steep slopes, seasonal rains and prolonged dry period.

The study sought to find out the main types of landforms in Kalikuvu catchment formed as a result of soil erosion. The landforms were tree mounds, caves, residual hills, rills and gullies. Wide and deep gullies were found to interfere with human activities such as cultivation and movement of people and animals.

The study also sought to find out the impact of soil erosion on crop production especially maize in Kalikuvu catchment. Crop yields are low in areas severely affected by soil erosion, the areas with thin top soils and areas with many geomorphologic landforms. The farmers in the area are aware that soil erosion in the catchment was caused by both human and physical factors. The chiefs reports show that the local government sends out warnings to the residents indicating that the zone is prone area to soil erosion and therefore people should conserve soil in their farms. Additionally, the local government discourages settlements on steep slopes and carrying out activities such as charcoal burning and sand harvesting, because they would accelerate soil erosion in the area. Soil erosion occurrence in Kalikuvu sub-Location in Kitui County is not related to single factor within the catchment but a combination of human, geological as well as environmental factors.

The main factors which cause soil erosion are human activities such as deforestation, overgrazing, charcoal burning, brick making, sand harvesting, excavation of the slope through road cuts, establishment of settlements on steep slopes, cultivation along the river banks and increased agricultural activities. The study also concluded that physical factors such as low and seasonal rainfall, sparse vegetation cover, shallow sandy soil and steep slope significantly contributed to the occurrence of soil erosion in Kalikuvu sub-location.

Further, it was concluded that soil erosion in Kalikuvu has formed geomorphologic landforms which have adversely affected physical and social-economic environment through land degradation, destruction of infrastructure, and displacement of residents, siltation of rivers and reduced maize yields. The soil erosion restoration measures in the area were established to be many and generally in the form of terraces, planted trees, gabions along gullies and weirs across the river channel to reduce the speed of water and rate of soil erosion. The majority members of the community were aware of the restoration measures necessary to control soil erosion in the Kalikuvu catchment.

6.3 Recommendations

6.3.1 Policy Recommendations

The study makes the following recommendations:

1. Policy makers should ensure that education campaign on soil erosion is embraced by the residents of Kalikuvu sub-location to restore soil erosion in the catchment.

2. The County government should ensure that appropriate extension services for restoration of eroded areas and improving land productivity through increasing budgetary allocation of Kalikuvu sub- sub-location.

3. The County government should take severe measures against destruction vegetation cover by having penalties that are answerable to the law.

6.3.2 Recommendation for Further Research

1. The study recommends that investigation be conducted on rate of soil erosion in the study area. Evidence of increased population and intensive land use may not necessarily result in soil erosion.

2. The impacts of government policies on human activities influencing soil erosion in the study area have not been spelt out correctly. There is need to analyse land use policies and set guidelines for land use according to terrain analysis and other erosion factors as discussed in this project.

3. Some of the landforms described in this project may be beneficial as tourist and research sites.

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APPENDICES

Appendix I: Questionnaire

Introduction

Part one: General information

Q1. Sex of the respondent, (tick the correct one)

Male

Female

Q2. Age of the respondent in years (indicate the correct one)

____

Q3.Occupation

____

Q4. Residency, (tick the correct one)

(a) Local Resident

(b) Occupational resident

Q5. Duration of residence

____

Part Two: Factors causing soil erosion

Q6: Is soil erosion a problem in this area?

1) Yes

0) No

Q7. If Q6 is yes, why is soil erosion a problem in this area?

____

____

Q8. Indicate areas in this place where soil erosion is a major problem

____

____

Q9. For each area in Q8, what are the characteristics of the surface?

Q10. For each area in Q8, what contribute to soil erosion?

a) How has the population density changed in the last 10 years?
b) How has the human activities affected soil erosion in this area?
c) What are your sources of energy for domestic use in this area?
d) Where do you get building/construction materials (sand, stones, timber, water, grass) from?
e) How do the energy sourcing, building materials acquisition and population density relate to soil erosion in this area?

Part Three: Types and extent of soil erosion

Q3: (a) How many types of soil erosion do you know?

(b) What is the most significant type of soil erosion in this area?

(c) What are the main types of soil erosion in this area?

(d) According to you, what are the main factors causing soil erosion?

(e) What are the effects of soil erosion?

(f) How has the soil erosion changed the landscape of this area?

(g) How has the soil erosion changed the soils of this area? To what extend?

Part four: Impacts of soil erosion

Q4: (a) What types of farming do you practice?

(b) Which animal types do you keep?

(c) Do you keep them for commercial or just for subsistence?

(d) How many animals in each category?

(e) What are the most preferred crops in this area?

(f) What types of crops do you grow in your farm?

(g) How do the crops stated above perform in your farm?

(h) What varieties of maize do you grow?

(i) How has soil erosion affected maize productivity in this area?

(j) How many bags of maize do you harvest per acre in your farm?

(k) Are the yields sufficient for your family needs?

(l) How do you address the deficits, if any?

(m) Do you receive any aid relief? If yes, from where?

Part five: Restoration Measures against Soil Erosion

Q5: (a) What do you understand by soil conservation and management?

(b) What conservation measures do you know?

(c) What have you done to control soil erosion in you farm?

(d) Have you succeeded in controlling soil erosion in your farm?

(e) How have your efforts changed productivity from your farm where you have Carried out these initiatives?

(f) What is the local community doing in order to control soil erosion in this area?

(g) Apart from the local community, which other agencies are involved in soil Conservation measures in this area?

(h) What have they done?

Part six: Recommendations on appropriate conservation strategies

Q6: (a) To your opinion, how has your community succeeded or failed in conserving soil and water in this area?

(b) What are the future plans on water and soil conservation in the area?

(c) What external assistance would you recommend to address this problem?

Thank you

Appendix II: History of Famine (yua) in Kitui County

1868 -. Drought and famine known as Yua ya Ngovo

1870- Drought and famine known as Yua ya Ngeetele

1878- Prolonged drought and famine known as Yua ya Kwasa, when many people migrated from Kitui to neighbouring counties in search of food.

1880- Drought and famine known as Yua ya Ndata

1898- Drought and famine known as Yua ya Muvunga, when famine relief rice was brought from Mombasa on the newly constructed railway.

1908- Drought and famine known as Yua ya Malakwe

1953.6-6- Drought and famine known as Yua ya Kalungu

1918- Drought and famine known as Yua ya Imili

1924-5- Drought and famine known as Yua ya Kukwatwa Syua (solar eclipse)

1928-30 - Prolonged famine known as Yua ya Nzalukangye na kakuti due to drought and locust attacks

1942- A great famine that extended to central Kenya, many people relied on cassava for food

1944-7- Prolonged famine known as Yua ya Mwanga due to drought and locust attacks

1949-50- Drought and famine

1959-60- Drought and famine

1961- Famine due to severe drought followed by flooding known as Yua ya Ndeke because relief food was dropped from the air.

1966- Drought and famine

1970-1976- Prolonged Sahelian droughts causing serious famine in Kitui and other dry

Areas of Kenya

1984- Drought and famine

1992- Drought and famine

Source: National Environmental Secretariat (1981)

Appendix III: Factors Causing Soil Erosion

Causes of soil erosion	Responses	
	N	Percent
Overgrazing	27	15.3%
Deforestation/charcoal burning	20	11.3%
Sloppy terrain	20	11.3%
Poor farming methods	18	10.2%
Lack of conservation measures	16	9.0%
Loose soil type	13	7.3%
Ignorance	8	4.5%
High rains in short period	7	4.0%
Bare land	7	4.0%
High wind speed	6	3.4%
high human population	6	3.4%
Livestock movement	5	2.8%
Lack of awareness on soil conservation	5	2.8%
Sand harvesting	4	2.3%
Brick making	3	1.7%
lack of motivation	3	1.7%
Climate change	2	1.1%
Farming on steep slopes	2	1.1%
Dry soil	2	1.1%
Laziness	1	.6%
N/A	2	1.1%
Total	177	100.0%

Appendix IV: Factors Causing Soil Erosion as per Drainage Stage

Causes of soil erosion	Area section			Total
	Youthful Stage	Mature Stage	Old Stage	
Overgrazing	12	8	7	27
Deforestation/charcoal burning	8	5	7	20
Sloppy terrain	10	6	4	20
Poor farming methods	8	2	8	18
Lack of conservation measures	8	7	1	16
Loose soil type	6	5	2	13
Ignorance	4	4	0	8
High rains in short period	5	1	1	7
Bare land	5	1	1	7
High wind speed	4	1	1	6
high human population	3	2	1	6
Lack of awareness on soil conservation	2	3	0	5
Livestock movement	2	2	1	5
Sand harvesting	2	0	2	4
Brick making	2	0	1	3
Farming on steep slopes	0	2	0	2
lack of motivation	0	3	0	3
Climate change	0	0	2	2
Dry soil	2	0	0	2
Laziness	0	1	0	1
N/A	0	1	1	2
Total	19	14	11	44

Appendix V: Test of Difference in Features Formed by Soil erosion by stages

Effects of soil erosion	**V1**	**V2**	**V3**	**V4**		Expected value				Computer chi-square			Total	
Erodes top soil	10	4	2	16		7.168	5.12	3.712		1.119	0.245	0.790	2.153	
Reduces crop production	10	5	7	22		9.856	7.04	5.104		0.002	0.591	0.704	1.298	
Reduces vegetation cover	8	5	3	16		7.168	5.12	3.712		0.097	0.003	0.137	0.236	
Increasedrills andgullies hinders movement	10	6	3	19		8.512	6.08	4.408		0.260	0.001	0.450	0.711	
Formation of rills and gullies	3	0	1	4		1.792	1.28	0.928		0.814	1.28	0.006	2.100	
Very high poverty levels	2	2	0	4		1.792	1.28	0.928		0.024	0.405	0.928	1.357	
Ignorance	1	3	1	5		2.24	1.6	1.16		0.686	1.225	0.022	1.933	
Lack of information	1	1	1	3		1.344	0.96	0.696		0.088	0.002	0.133	0.222	
Reduced crop health	2	2	2	6		2.688	1.92	1.392		0.176	0.003	0.265	0.445	
Reduced arable land	1	0	1	2		0.896	0.64	0.464		0.012	0.64	0.619	1.271	
Occurs uncontrollably	1	0	1	2		0.896	0.64	0.464		0.012	0.64	0.619	1.271	
Area is steep	0	4	2	6		2.688	1.92	1.392		2.688	2.253	0.266	5.207	
Exposed tree roots	2	0	1	3		1.344	0.96	0.696		0.320	0.96	0.133	1.413	
Overgrazing	1	2	1	4		1.792	1.28	0.928		0.350	0.405	0.006	0.761	
Loose soil	0	1	1	2		0.896	0.64	0.464		0.896	0.203	0.619	1.718	
Hardening of ground	1	0	0	1		0.448	0.32	0.232		0.680	0.32	0.232	1.232	
Destruction of land scenery	1	2	1	4		1.792	1.28	0.928		0.350	0.405	0.006	0.761	
High rainfall within short time	1	1	0	2		0.896	0.64	0.464		0.012	0.203	0.464	0.679	
Poor farming methods	1	1	0	2		0.896	0.64	0.464		0.012	0.203	0.464	0.679	
N/A	0	1	1	2		0.896	0.64	0.464		0.896	0.203	0.619	1.718	
Total	56	40	29	125								chi-square	27.164	
												crit-chi	27.59	df=17

Where: V1 = Youthful Stage; V2 = Mature Stage; V3 = Old Stage; V4 = Total

Appendix VI: Crops Grown

	Responses	
	N	**Percent**
Maize	41	15.5
Beans	35	13.2
Cow peas	38	14.3
Green grams	20	7.5
Pigeon peas	33	12.5
Sorghum	18	6.8
Cassava	10	3.8
Millet	5	1.9
Mangoes	6	2.3
Pawpaw	5	1.9
Sweet potatoes	5	1.9
Tomatoes	9	3.4
Pumpkins	9	3.4
Water melon	5	1.9%
Kale (sukuma)	4	1.5
Spinach	4	1.5%
Others	9	6.8%
Total	265	100.0

Appendix VII: Maize Production per Stage of Catchment

Crops	Area section			Total
	Youth Stage	Mature Stage	Old Stage	
Maize	19	11	11	41
Beans	14	12	9	35
Cow peas	17	12	9	38
Green grams	11	7	2	20
Pigeon peas	14	11	8	33
Finger millet	2	1	0	3
Sorghum	9	5	4	18
Cassava	6	3	1	10
Millet	3	0	2	5
Sunflower	2	0	1	3
Cotton	1	2	0	3
Mangoes	2	0	4	6
Paw paw	2	0	3	5
Sweet potatoes	3	1	1	5
Castor seed	0	0	1	1
Tomatoes	2	2	5	9
Pumpkins	5	3	1	9
Water melon	3	0	2	5
Cucumbers	0	0	1	1
Kale (sukuma)	1	0	3	4
Cabbages	1	0	1	2
Spinach	1	1	2	4
Guava	0	0	1	1
Red Onions	1	0	2	3
Sisal	0	1	0	1
Total	19	14	11	44

Appendix VIII: Test of Difference in Maize Production due to Soil Erosion by Stage of Catchment

V1	**V2**	**V3**	**V4**	**V5**		**Expected value**				**Computer Chi Square**			**Total**
Maize	19	11	11	41		18.411	11.140	11.449		0.019	0.002	0.018	0.038
Beans	14	12	9	35		15.717	9.509	9.774		0.188	0.652	0.061	0.901
Cow peas	17	12	9	38		17.064	10.325	10.611		0.000	0.272	0.245	0.517
Green grams	11	7	2	20		8.981	5.434	5.585		0.454	0.451	2.301	3.206
Pigeon peas	14	11	8	33		14.819	8.966	9.215		0.045	0.461	0.160	0.667
Finger millet	2	1	0	3		1.347	0.815	0.838		0.316	0.042	0.838	1.196
Sorghum	9	5	4	18		8.083	4.891	5.026		0.104	0.002	0.210	0.316
Cassava	6	3	1	10		4.491	2.717	2.792		0.507	0.029	1.151	1.687
Millet	3	0	2	5		2.245	1.358	1.396		0.254	1.358	0.261	1.873
Sunflower	2	0	1	3		1.347	0.815	0.838		0.316	0.815	0.031	1.163
Cotton	1	2	0	3		1.347	0.815	0.838		0.089	1.723	0.838	2.650
Mangoes	2	0	4	6		2.694	1.630	1.675		0.179	1.630	3.225	5.034
Paw paw	2	0	3	5		2.245	1.358	1.396		0.027	1.358	1.842	3.227
Sweet potatoes	3	1	1	5		2.245	1.358	1.396		0.254	0.095	0.112	0.461
Castor seed	0	0	1	1		0.449	0.272	0.279		0.449	0.272	1.860	2.581
Tomatoes	2	2	5	9		4.042	2.445	2.513		1.031	0.081	2.461	3.573
Pumpkins	5	3	1	9		4.042	2.445	2.513		0.227	0.126	0.911	1.264
Water melon	3	0	2	5		2.245	1.358	1.396		0.254	1.358	0.261	1.873
Cucumbers	0	0	1	1		0.449	0.272	0.279		0.449	0.272	1.860	2.581
Kale (sukuma)	1	0	3	4		1.796	1.087	1.117		0.353	1.087	3.174	4.614
Cabbages	1	0	1	2		0.898	0.543	0.558		0.012	0.543	0.349	0.904
Spinach	1	1	2	4		1.796	1.087	1.117		0.353	0.007	0.698	1.058
Guava	0	0	1	1		0.449	0.272	0.279		0.449	0.272	1.860	2.581
Red Onions	1	0	2	3		1.347	0.815	0.837		0.089	0.815	1.613	2.517
Sisal	0	1	0	1		0.449	0.272	0.279		0.449	1.952	0.279	2.681
Total	119	72	74	265						Chi square Critical chi square df			49.164 33.92 22

Where: V1 = Crops; V2 = Youthful Stage; V3 = Mature Stage; V4 = Old Stage; V5 = Total

Appendix IX: Restoration Measures

restoration measures	*Responses*	
	N	*Percent*
Terraces	*39*	*39.0%*
Benches	*23*	*23.0%*
Cutoffs	*17*	*17.0%*
Afforestation	*15*	*15.0%*
Trenches	*3*	*3.0%*
None	*2*	*2.0%*
Planting Perennial crops	*1*	*1.0%*
Total	*100*	*100.0%*

Appendix X: Restoration Measures to Soil Erosion per Stage of Catchment

Conservation measures	*Area section*			*Total*
	Youthful Stage	*Mature Stage*	*Old Stage*	
Terraces	*14*	*13*	*12*	*39*
Benches	*9*	*11*	*3*	*23*
Cutoffs	*6*	*9*	*2*	*17*
Afforestation	*7*	*2*	*6*	*15*
Trenches	*2*	*1*	*0*	*3*
None	*2*	*0*	*0*	*2*
Planting Perennial crops	*1*	*0*	*0*	*1*
Total	*19*	*14*	*11*	*44*

Appendix XI: Test of Restoration Measures per Stage of Catchment

	Youthful Stage	Mature Stage	Old Stage	Total		Expected value				Computed chi square			Total
Terraces	14	13	12	39		15.99	14	8.97		0.248	0.077	1.024	1.349
Benches	9	11	3	23		9.43	8.28	5.29		0.020	0.894	0.991	1.904
Cutoffs	6	9	2	17		6.97	6.12	3.91		0.135	1.355	0.933	2.423
None	2	0	0	2		0.82	0.72	0.46		1.698	0.72	0.46	2.878
Afforestation	7	2	6	15		6.15	5.4	3.45		0.117	2.141	1.885	4.143
Trenches	2	1	0	3		1.23	1.08	0.69		0.482	0.006	0.69	1.178
Planting Perennial crops	1	0	0	1		0.41	0.36	0.23		0.849	0.36	0.23	1.439
Total	41	36	23	100								chi-square	15.314
												critical chi square	9.49
												df	4

Appendix XII: GPS RECEIVER