LAND USE CHANGE, LANDSLIDE OCCURRENCE AND LIVELIHOOD STRATEGIES ON MOUNT ELGON SLOPES, EASTERN UGANDA.

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ABSTRACT

An investigation of the relationship between the physical, pedological and anthropogenic influences on landslide occurrence on the midslopes within and outside Mt Elgon National Park was carried out. One of the landslides occurred in a protected pristine forest environment within the Park while the other two were located at sites deforested for cultivation within and outside the National Park. Field based surveys, GIS techniques and laboratory tests were used to collect and analyze the data.

A household survey was undertaken to establish the main community livelihood strategies, the drivers of land use change and implications for land degradation on the mid slopes of Mt Elgon. Aerial photographs taken in 1960 and orthophoto maps formed the benchmark for the analysis of the respective land use changes between 1995 and 2006, using 30m Landsat TM and 20m SPOT MS images in IDRISI Andes GIS environment. Landslide sites were mapped using a Magellan Professional MobileMapper^{TM}CX and terrain parameters were derived using a 15M Digital Elevation Model. A hybrid supervised/unsupervised classification approach was employed to generate land cover maps from which the areal extent of three land cover classes (agricultural fields, woodlands and forests) was calculated. Particle size distribution and atterberg limits were used to test the hypothesis that soils at the landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention. Shear strength parameters (internal of friction and cohesion) were used calculate the slope factor of safety to ascertain slope stability at pristine and disturbed landslide sites.

Results from the socio-economic survey revealed that smallholder subsistence agriculture and encroachment on the National Park resources are the main sources of livelihoods for the communities surrounding the Park. The communities also have a strong socio-cultural attachment to the National Park, as it is the source of items used during traditional rituals like circumcision. Encroachment is driven by the high population pressure and the prevalent political climate. Farmers mainly use slash and burn technique to prepare land for cultivation and those close to the National Park are reluctant to adopt appropriate farming and soil conservation practices due to the uncertainties surrounding their future on such plots. Slash and burn

techniques were observed to accelerate various forms of erosion including rills, gullies and sheet. Soil and water conservation techniques were mainly practiced on privately owned farms.

The period 1960 and 1995 was characterized by minimal land use changes and no encroachment into the designated Mount Elgon National Park. Conversely, the period 1995 – 2006 marked a significant loss of woodlands and forest cover particularly on steep concave slopes (36º – 58º) within the National Park. The land use change trends were attributed to the prevalent land politics and exponential population growth in the region. The encroachment onto the critical slopes was noted to have induced a series of shallow and deep landslides in the area. Deforestation on Mt Elgon was reported to have both onsite and offsite climate variability and implications in the form of drought, heat waves, flash floods, economic dislocation, crop failure and associated malnutrition in surrounding low lying areas.

The soils on pristine and disturbed slopes contain high amount of clay (>10 percent), are fine textured (>50 percent of the material passing the 0.075mm sieve) and highly plastic. These soil attributes imply low permeability, excessive water retention and high susceptibility to expansion and sliding. The vertic nature of soils at Nametsi was confirmed by the extremely high plasticity indices (averaging 33percent), while, high liquid limits at Buwabwala (53 percent) and Kitati (59 percent) qualified the soils as vertisols which are associated with landslides. The results point to the fact that soils at landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention. Therefore, the hypothesis that soils at three landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention is accepted. Notwithstanding the fact that the study was focussed on mid-altitude slopes of Mt Elgon, the results are in tandem with investigations carried out earlier on the lower densely populated slopes, thus confirming the widespread nature of problem soils on Mt Elgon.

There is an urgent need to control human population growth and restore forest cover on the heavily deforested steep slopes particularly within the National Park, and restrain communities from encroaching on the pristine slopes of Mt Elgon. This will be achieved if the politicians, Park Authorities and local communities jointly participate in the design and implementation of CFMs. Future research could focus on climate change implications of deforestation of Mt Elgon environments and quantification of carbon loss related to deforestation and soil degradation in the mountain environments.

DECLARATION

I, MUGAGGA FRANK solemnly declare that this thesis was composed and written by me. It has never been presented anywhere for any academic award or otherwise. All materials used from other sources are duly appreciated and properly acknowledged.

13.01.2011

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MUGAGGA FRANK

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LIST OF ACRONYMS

BS – British Standard

CFM – Collaborative Forest Management

DEM – Digital Elevation Model

FAO – Food and Agriculture Organization

FFNC – Faculty of Forestry and Nature Conservation

GCPs – Ground Control Points

GIS – Geographical Information Systems

GoU – Government of Uganda

IPPC – Inter Governmental Panel on Climate Change

KCSZ – Kano Close – Settled Zone

MCEP – Mount Elgon Conservation and Development Project

MENP – Mount Elgon National Park

MoW – Ministry of Works

MUK – Makerere University Kampala

NAADS – National Agricultural Advisory Services

NDVI – Normalized Difference Vegetation Index

NEMA – National Environment Management Authority

NMMU – Nelson Mandela Metropolitan University

NTFPs – Non Timber Forest Products

PMA – Plan for Modernization of Agriculture

SCWG - Soil Classification Working Group

SPSS – Statistical Package for Social Scientists

UBOS – Uganda Bureau of Statistics

UNEP – United Nation Environment Program

USCS – Unified Soil Classification System

UWA – Uganda Wildlife Authority

CHAPTER ONE

General Introduction

1.1 General introduction

Mountain ecosystems are continuously experiencing extensive changes due to natural and anthropogenic processes (Rajan *et al.,* 1998; Klein, 2001; Agarwal *et al.,* 2002; Lui *et al.,* 2003). These changes have led to conversion of land cover with serious environmental implications (Mashalla, 1985; McCall, 1985; Kikula, 1990; Hansen *et al.,* 2001; Lung and Schaab, 2010). Studies on Mt Kilimanjaro (see Maro, 1974; 1998; Gamassa, 1991; Yanda and Shishira, 2001; William, 2002; Soini, 2005) provide evidence of replacement of forests by agriculture and settlements, leading to severe erosion, disruption of water sources and drying of rivers. Mountain forest ecosystems are particularly important from an ecological perspective as they provide goods and services that are essential to maintain the life-support system on a local and global scale. Green house gas regulation, water supply, nutrient cycling, genetic and species diversity as well as recreation are some of the services that forests provide (Whiteman 2000; Beniston, 2003; Nagendra *et al*., 2004; Sivrikaya *et al.,* 2007). 'Mountains also represent unique areas for the detection of climatic change and the assessment of climate-related impacts because when climate changes rapidly with height over relatively short horizontal distances, so does vegetation and hydrology' (Beniston 2003, pg 5).

Mass movements are recognized and well documented global geomorphic hazards due to their major role in the development of hillslopes in mountainous areas and their considerable economic, social and geomorphological impacts (Knapen et *al.*, 2006). However, literature on landslides in East Africa's highlands is rather still restrictive (Ngecu and Mathu, 1999; Knapen *et al.,* 2006; Claessens *et al.,* 2007). Some of the landslide studies that have been conducted in the East African region include, (Ngecu and Inchangi, 1989; Davies, 1996; Westerberg and Christiansen, 1998; Ngecu and Mathu, 1999; Westerberg, 1999; Inganga *et al.,* 2001) in Kenya; (Muwanga *et al.,* 2001; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2004: 2009) in Uganda; (Rapp *et al.,* 1972; Christiansen and Westerberg, 1999a,b) in Tanzania; (Moeyersons 1989, 2003) in Rwanda. These studies suggest anthropogenic factors such as slope disturbance, particularly deforestation related to population pressure as the major causes of landslides in East African highlands (Ngecu and Mathu, 1999; Muwanga *et al*., 2001; Breugelmans, 2003; Knapen, 2003; Glade and Crozier, 2004; Knapen *et al.*, 2006; Kitutu *et al*., 2004: 2009).

Knapen *et al.,* (2006) attribute landslide occurrence on stable, marginally stable and actively unstable slopes of Mt Elgon to a combination of preconditions, preparatory and triggering causal factors. Preconditioning factors including topography (slope angle, length, aspect, gradient, and curvature), lithology, shrink-swell soil properties and annual rainfall receipts act as catalysts to allow other destabilizing factors to act more effectively. On the other hand, preparatory factors including human activities (such as cultivation, excavation for housing, foot paths and deforestation) tend to place slopes in a marginally stable state, making them susceptible to mass movement without actually initiating it. Triggering factors shift slopes from being marginally stable to actively unstable state by initiating movement. Such factors include seismic activity, extreme rainfall events related to the El Niño phenomenon, and concentration of runoff in restricted infiltration zones such as hollows (Glade and Crozier, 2004; Knapen *et al.,* 2006).

There has been growing concern over the human destruction of forests especially in the tropical and subtropical countries' mountain environments and the associated consequences on soil and water quality, biodiversity, global climatic and livelihood systems (Turner *et al.,* 1995; Laurence, 1999; Noss, 2001; Armenteras *et al.,* 2003). East Africa's highlands have a high potential for agricultural production and, until the mid 20th century, were resilient to exploitation (McCall, 1985). The favourable climate with abundant rainfall and fertile soils attracted farmers to the region many centuries ago. The productivity of the land also supported chiefdoms and kingdoms with a stratified social structure. The land adequately supported both subsistence and surplus food production. However, today land degradation is threatening the very basis of the farming communities. The expansion of cultivation on the marginal slopes of Mt. Kilimanjaro, for example, has threatened the existence of its montane forests with considerable climatic impacts ranging from vanishing glaciers, increased frequency and intensity of fires, decreasing water supplies and an overall change in the people's livelihoods (Beniston, 2004; Soini, 2005; Hemp, 2009). According to the East African scenarios, the expansion of cropland and grazing land will continue to replace natural forests by a further 38 percent of its 1995 areal extent till 2032 (UNEP, 2004).

1.2 Statement of the Problem

Land resources form the main asset for the derivation of livelihoods by most rural communities. Nearly 80 percent of the Ugandan population relies on land and agriculture for their primary livelihoods (NEMA, 2007). However, the agricultural resource base has been both shrinking and degrading with the increasing population pressure and marginal lands with very steep slopes increasingly being brought under cultivation (Buyinza and Nabalegwa, 2008). This has led to intense land degradation due to soil erosion on mountain slopes. Resulting from this is low and in many cases declining agricultural productivity. Demographic projections by district suggest that as a country, Uganda will be depleted of agricultural land by 2022, with the Eastern region running out of available agricultural land earlier than the other regions (Jorgensen, 2006). Finding ways to reverse these trends is an urgent need in Uganda and many other developing countries.

Previous studies suggest anthropogenic factors, especially population pressure coupled with slope disturbance and deforestation as the major causes of landslides in East African highlands (Ngecu and Mathu, 1999; Muwanga *et al*., 2001; Breugelmans, 2003; Glade and Crozier, 2004; Kitutu *et al*., 2004; Knapen *et al.*, 2006; Kitutu *et al*., 2009). Landslides have however been reported and observed on pristine gazetted forested slopes of Mount Elgon National park (Claessens *et al.,* 2007). In order to bridge this gap, there is a need to investigate and understand the factors responsible for landsliding in pristine forested environments of Mt Elgon.

Communities on Mt Elgon region derive most of their livelihoods from agricultural activities. However, literature on the socioeconomic factors affecting hill agricultural diversification strategies is rather still scarce (Buyinza *et al.,* 2008). Previous studies including (Muwanga *et al.,* 2001; Knapen *et al.,* 2006; Claessens *et al.,* 2007) have generally focused on developing soil erosion predictive models based on biophysical aspects. However, the socioeconomic conditions, factors and interactions that influence peoples' land management decisions and their implications for sustainable productivity and land degradation are variable and complex (Buyinza *et al.,* 2007). Addressing this information gap therefore requires urgent attention. This study therefore aimed at improving our understanding of the linkage between anthropogenic and biophysical factors and their implications for landslide occurrence on disturbed and pristine slopes of Mount Elgon, Eastern Uganda. In the main, the following were the objectives of the study;

1.3 Objectives of the study

The following were the objectives of the study;

1. To understand the relationship between livelihood diversification strategies, household productivity and land degradation on the slopes of Mount Elgon, Eastern Uganda. To achieve this objective, the socioeconomic factors and conditions affecting household choices regarding livelihood strategies and the implication for soil conservation by the communities adjacent to Mt Elgon National Park (MENP) were investigated.

2. To investigate the relationship between land use change and its implication for landslide occurrence on the slopes of Mount Elgon. This objective was achieved by examining the temporal and spatial trends in land use change for the period 1960 and 2006 and how the observed trends related with

topographic parameters and landslide occurrence on the slopes of Mount Elgon.

3. To characterize soil physical properties and their implications for landslide occurrence on pristine and disturbed slopes of Mount Elgon, Eastern Uganda. In order to test the hypothesis that soils at landslide sites are inherently 'problem soils' where failure can occur even without human intervention, analysis of soil physical properties was done on three recent landslide sites on Mt Elgon. One of the landslides occurred in a protected pristine forest environment within the Park while the other two are located at sites deforested for cultivation within and outside the National Park.

1.4 Study area

1.4.1 Biophysical description

1.4.1.1 Location

Mount Elgon, from which the National Park derives its name, is a large mountain massif in east central Uganda. Most of the caldera of its extinct volcano lies within Uganda, while large parts of the southern and eastern slopes of the massif lie within Kenya, (UWA, 2000). The Ugandan part of Mount Elgon lies in Mbale, Manafwa, Sironko, Bududa and Kapchorwa Districts. The longest north-south distance of the mountain is about 80km and the largest east to west distance is about 50km, exclusive of the extra 20km long spur of the Nkonkojeru ridge sticking out in the west. The highest point of the crater rim is 4321m above sea level, making Mount Elgon the eighth highest massif in Africa and the second in Uganda, after the Rwenzori. The National Park stretches between 0° 52′ and 1° 25N and 34° 14′ and 34° 44′ E (GoU 1996).

1.4.1.2 Geology and vulcanism

Mount Elgon is associated with the Rift valley volcanoes. It is the oldest solitary volcano in East Africa and rests on dissected peneplain of Precambrian bedrock of the Trans Nzoia plateau (Precambrian Basement Complex). Mount Elgon is thought to be of tertiary origin, some 20 million years ago (MCEP, 1997). The base of Mount Elgon covers an area of about 4000 square km, more than the base of Mt Kilimanjaro and is thus thought that at one time, Mount Elgon may well have been higher than Kilimanjaro. Following a major eruption at some time in the past, the summit of Mount Elgon collapsed into a chamber from which volcanic material had been expelled. The resulting caldera is about 8 km in diameter, making it one of the larger examples of this type in the world. The floor of the caldera lies at about 3500 metres, or some 800 metres below the highest point on the crater rim. The highest point is Wagagai at 4321m (UWA, 2000).

1.4.1.3 Climate

The climate of Mount Elgon is dominated by the seasonally alternating moist south-westerly and dry north-easterly air streams (GoU, 1996; MCEP, 1997). The main influences of rainfall on MENP are first the orthographic effect of the mountain itself and secondly the proximity to Lake Victoria. The area receives an approximately bimodal pattern of rainfall, with the wettest period occurring from April to October, while July – August and December to February tend to be relatively dry periods. The mean annual rainfall ranges from 1500 mm on the eastern and northern slopes to 2000 mm in the south and the west. Mid-slopes oriented towards the east and north at elevations between 2,000 and 3000 metres tend to be wetter than either the lower slopes or the summit. On the lower slopes, the mean maximum temperatures increase from 25º C to 28º C and mean minimum temperatures are 15ºC to 16º C (GoU, 1996; UWA, 2000).

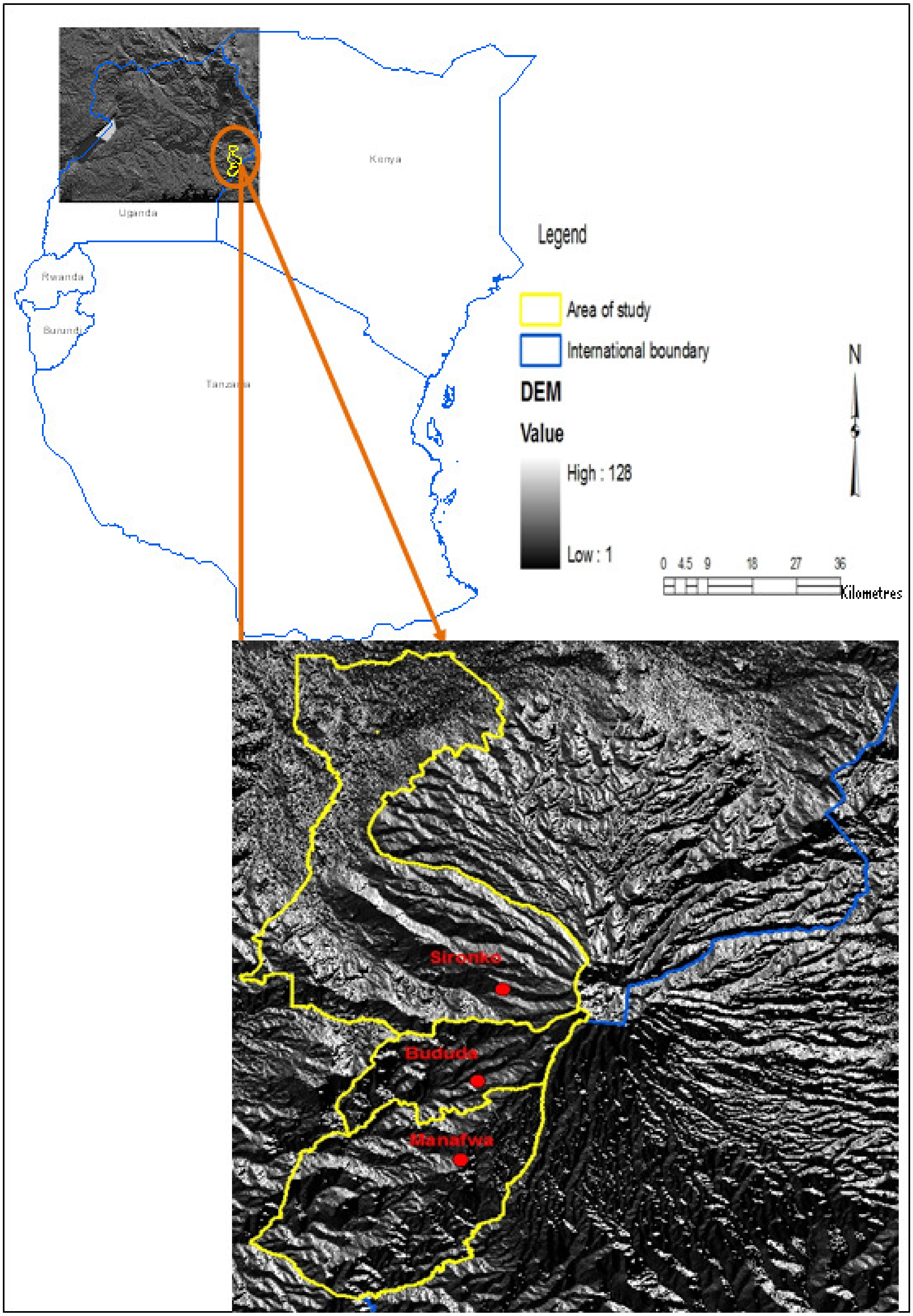


Figure 1.1: Location of Mount Elgon on the Uganda-Kenya border, with indication of the study areas

1.4.1.4 Hydrology

Mount Elgon is a very important water catchment in the area with major and minor rivers cascade from the caldera. The streams which assume a radial pattern cover the entire mountain and flow all year round. Suam, one of the major rivers originating from Mount Elgon passes through the spectacular Suam gorge. Other rivers are Sisi, Simu, Lwakaka, Sironko, Manafwa, Sipi and Bukwa. Together they serve several million people in the upper and lower slope Districts of Mbale, Kapchorwa, Tororo, Butaleja, Pallisa, Kumi and Soroti as well as in Kenya with good quality water (MCEP, 1997).

1.4.1.5 Soils

The relatively young and fertile calcium-sodium-potassium rich soils that cover the slopes are moist, dark humus loams. On the steep slopes in the high altitude moorlands, very shallow soils are found, while red brown, clay loams have formed on the gentle slopes. Under natural conditions, these soils support tropical forest vegetation. Cleared of forest, the soils support a highly productive agriculture (MCEP, 1997).

1.4.1.6 Flora and fauna

The vegetation of Mt Elgon reflects the altitudinally controlled zonal belts commonly associated with large mountain massifs. Howard (1991) recognized four broad vegetation communities namely; mixed montane forest up to an elevation of 2500 metres, bamboo and low canopy montane forest from 2400-3000 metres, high montane heath from 3000 and 3500m and moorland above 3500 metres. The high montane heath and moorland zones are rich in shrub and herb species that are endemic to the higher East African mountains or even to Mount Elgon itself, like the giant *Lobelia elgonensis* and *Senicio elgonensis,* the dwarf shrub *Alchemilla* *elgonensis* and the *Heracleum elgonensis*. The mixed montane forest is made up of tall dense forest dominated by a range of species in a variety of combinations. The main species are *Podocarpus mailanjianus, Afrocrania volkensii, Schefflera volkensii, Hagenia abyssinica, Rapanea melanophloeos* and *Ilex mitis*. Other species found less frequently but over a wide range include *Dombeya goetzenii, Olea africana* and *Xymolus monospora* (Scott, 1991; Van Heist, 1994; GoU, 1996; MCEP, 1997; UWA, 2000).

A total of 30 species of small mammals (shrews and rodents) are known to live on Mount Elgon. These consist of a mix of highland, forest-dependent and open habitat species. In addition, there is a range of larger mammals, which include monkeys (black and white colubus, blue and de Brazza's) leopards, elephants, buffaloes, bush pigs, sitatunga and duikers (GoU, 1996; UWA, 2000). Over 296 bird species, 171 butterfly species and 71 moths normally associated with tropical mountain massifs have been recorded in MNEP (GoU, 1996; UWA, 2000).

1.4.2 Social context

1.4.2.1 Ethnicity

The Bagisu are the predominant ethnic group on the southern and western slopes of Mount Elgon. They are thought to have settled here about 1500 AD. Traditionally, the Bagisu who are of Bantu language stock are crop farmers; limited livestock keeping is also practiced. On the northern slopes of Mount Elgon, the Sabiny are the dominant people. They are a Nilo-Hamitic group related to the Kalenjin of western Kenya. Other Nilo-Hamitic groups include the Pokot in Uganda and Kenya, and the Kipsigis in Kenya. The traditionally pastoralist Sabiny are thought to have migrated to the Elgon from the north and settled in the 17th century. The word 'Elgon' in fact, is thought to be an adaptation of the Maasai word 'El Kony' referring to communities of pastoralists living on the upper part of the mountain (GoU, 1996; UWA, 2000).

1.4.2.2 Mount Elgon as a cultural resource

Within the Park, there are many sites associated with traditional ceremonies, particularly circumcision. Caves are visited by Sabiny women after birth of twins. Mount Elgon as well, has a significant place in the Bagisu folklore concerning the creation and origin of man. Also present within Park boundaries is a significant number of burial sites that are of particular importance to residents of nearby villages. Examples of sacred sites in MENP are the Sayuni area which is sacred to the Bagisu (Bulucheke) and Khauka cave on Wanale ridge (UWA, 2000).

1.4.3 The management of Mount Elgon National Park: A past-present perspective

The history of control of forests by the government for conservation purposes in Uganda dates back to the colonial period. By 1908, the colonial government had put all the major forest areas in the country under the control of the government. The colonial government emphasized that "the public good was best served through the protection of forests and water resources, even if this meant the displacement of the local communities" (UWA, 2000). In 1929-30, a first attempt was made to establish boundaries around Mount Elgon to prevent people from extending the cultivation further upslope. This initiative was however dropped due to community resistance. In 1937, a boundary was finally demarcated and Mount Elgon Crown Forest was gazetted under the authority of the Forest Department (Legal Notice 100 of 1940). In 1948, the area was regazetted as Mount Elgon Central Forest Reserve (Legal Notice 41); it was regazetted yet again in 1951 as a Demarcated Protection Reserve. Changes in District names, excisions and more accurate mapping resulted in further changes of the boundary until 1968 when it was promulgated as comprising 120,000 hectares (Synnott, 1968; GoU, 1996). Working plans (including protection, research and production) for the reserve were prepared and designated between 1954 and 1968.

The Forest Department management however collapsed in the 1980s, due to political instability during that period, resulting in widespread encroachment of all forests in

Uganda. In January 1988, a new Government Forestry Policy was proclaimed, which clarified the role of forestry as not only providing timber, fuel, pulp and poles but to also address broader environmental values. The president announced that forest reserves would revert to their 1963 boundaries, which meant that all encroachers had to be evicted. In 1991 a ban on felling indigenous trees and the production of charcoal in Forest Reserves was imposed but it proved difficult to control the trade in indigenous timber, because there was no regulation of sales (Malpas, 1980; UWA, 2000).

In 1988, a Forestry Rehabilitation Programme was initiated with the support of several donors. The European Community was mostly involved in the natural forest sector to help the Forest Department regain full control over its 1.4 million hectare estate and to rehabilitate encroached areas with fast growing trees. The programme did not aim at total protection, but rather development of management systems to preserve 50percent of the natural high forest whilst allowing controlled timber harvesting in the other half.

In 1987 the idea to designate all natural forest areas over 100 sq.km as 'Forest Parks' was originated. This name was changed to 'Conservation Forests' after a dispute with Uganda National Parks in 1992. Within these conservation forests, total protection areas (including nature reserves and sites of special scientific interest) were to be gazetted and there was a proposal to establish semi-independent Boards for the Conservation Forest. A Park Manager and other staff for Mount Elgon were appointed in 1993. In preparation of an interim management plan for Mount Elgon Conservation Forest, it was proposed to set aside a 'community zone' of 500m from the boundary. Pending longer term management planning, all extractive activities were banned as well as cultivation, hunting and grazing. In the interim management plan for 1992-1994, even the collection of minor forest products for subsistence, including bamboo, was only allowed for permit holders.

Despite efforts to protect the Park boundary and restore previously encroached lands, encroachment continues to be a management problem. Incidences of infringement have continued to occur for a variety of reasons, including a strong community desire for more agricultural land, declining land productivity in some areas, high population pressure, political interference and connivance with National Park Staff. In addition, problems with identifying and marking the correct Park boundary have occurred in a number of areas, with different boundary surveys over the years producing different outcomes, either as a result of lack of information or because of manipulation of the true boundary by the surveyors due to community pressure. The most recent boundary survey carried out between 1993 and 1996 found that land already used for cultivation was in fact within the gazetted park boundary, thus creating conflict with the community who consider the land as theirs (Scott, 1998; UWA, 2000).

1.5 Structure of the Thesis

This thesis is made up of six chapters. Chapter one provides a general introduction to the study. The problem statement and objectives of the study are also presented in this chapter. The chapter concludes with a description of the study area and presents insights into the past-present management perspectives of Mt Elgon. A review of literature relating to the anthropogenic drivers of livelihoods and implications for landuse change and mass movements is presented in chapter two. The chapter also presents literature on the biophysical factors that have been identified to have implications for mass movements. Chapters three, four and five are based on the set thematic objectives. In this regard, chapter three is based on the relationship between livelihood diversification strategies, household productivity and land degradation on the slopes of Mount Elgon, Eastern Uganda. Chapter four presents the relationship between land use change on the slopes of Mount Elgon and its implications for landslide occurrence. A characterization of soil physical properties and their implications for landslide occurrence on pristine and disturbed slopes of Mount Elgon is provided in chapter five. Given the publication format of the three chapters, a number of overlaps and replications are inevitable. A synthesis of all the chapters is presented in chapter six. A conceptual model of the factors responsible for mass wasting on Mt Elgon as identified in this study is also developed and presented in chapter six. The chapter concludes by presenting recommendations and suggestions for future research. A list of references as used in all chapters is provided at the end of the thesis.

CHAPTER TWO

Literature Review

2.1 Introduction

This chapter presents insights into existing literature on the anthropogenic and biophysical drivers of environmental change and their implications for landsliding in mountain environments. It also highlights the human-environment nexus through the various livelihood strategies. A review of the causes of landslides is also presented. It is noteworthy however that some aspects of the literature review presented here appear in the subsequent chapters, which are structured in publishable format.

2.2 Understanding livelihood strategies

'Livelihood' refers to the access that individuals or households have to different types of capital, viz natural, physical, human, financial and social; and opportunities and services (Ellis, 2000). The rules and social norms that determine the ability of people to own, control or claim these resources are varied and complex. Several factors influence the extent to which a household depends on a resource such as a forest. Such factors include distance, infrastructure, wealth, household size, and level of education of members of the household. Distance from the forest will mainly dictate whether a household depend almost entirely on the forest or not for its needs. Some research findings have shown that poorer households depend totally on forest products due to limited access to alternative sources of income, while the more wealthy households mainly use the forest for larger commercial activities (Wass, 1995).

Rural households earn income from diverse allocations of their natural, physical and human capital assets among various income generating activities. Literature offers many reasons why such diversification occurs (see Ellis, 1998; Barrett *et al.,* 2001; Carter and Barrett, 2006). Among these might be diminishing returns on increasing investment in certain activities, synergies (economies of scope) among distinct activities, or missing markets that compel self-provision of goods or services the household desires for own consumption. Similarly, households may wish to diversify as a strategy for coping with an unexpected shock, or to minimize risk *ex ante* by participating in activities that generate imperfectly correlated returns. The presumption throughout the literature is that households choose such patterns of diversification so as to achieve the best possible standard of living, broadly defined. The chosen combination of assets and activities is often referred to as the household's 'livelihood strategy'. A livelihood strategy encompasses not only activities that generate income but many other kinds of choices, including cultural and social choices, that come together to make up the primary occupation of a household (Ellis, 1998).

Communities on Mt Elgon region derive most of their livelihoods from agricultural activities. However, literature on the socioeconomic factors affecting hill agricultural diversification strategies is rather still scarce (Buyinza *et al.,* 2008). Previous studies including (Muwanga *et al.,* 2001; Knapen *et al.,* 2006; Claessens *et al.,* 2007) have generally focused and developed soil erosion predictive models based on biophysical aspects. However, the socioeconomic conditions, factors and interactions that influence peoples' land management decisions and their implications for sustainable productivity and land degradation are variable and complex. Addressing this information gap therefore requires urgent attention.

Land tenure, as pointed by some previous studies is a key factor when it comes to dependence on protected forest resources. The landless and land-poor are often more dependent on forest product collection than the land-rich (Lacuna-Richman, 2002; Pandit and Thapa, 2003). In Orissa (India) dependence on forest income was strongly correlated with size of land holdings, with the landless being most dependent (Fernandes and Menon, 1987). Other social variables may also influence forest use. In one study, Non Timber Forest Products (NTFPs) exploitation was positively correlated with household debt, labour availability and male to female ratios and negatively correlated with income, education, distance to forest, involvement in non-agricultural activities and incorporation into the market (Gunatilake, 1998). Factors such as the size and labour capacity of households (Mamo *et al.,* 2007), migration status (Lacuna-Richman, 2006), opportunity costs of collection and the substitutions of forest products by market purchased goods (Senaratne *et al.,* 2003), and the strength of markets for forest produce may also be important (Bista and Webb, 2006).

2.3 Linking livelihoods and environmental degradation

The discussion on livelihood-environment processes relates closely to the discussion on poverty- environment linkages. Since the 1970s, it has been almost universally agreed that poverty and environmental degradation are inextricably linked. The links between poverty and the environment have also been seen to be self-enforcing (Reardon and Vosti, 1995; Kruseman *et al.,* 1996; Duraiappah, 1998; Ohlsson, 2000). It is therefore futile to attempt to deal with environmental problems without a broader perspective that encompasses the factors underlying world poverty and international inequality. Many parts of the world are caught in a vicious downwards spiral; poor people are forced to overuse environmental resources to survive from day to day, and the degradation of the environment further impoverishes them, making their survival ever more difficult and uncertain (Ohlsson, 2000; Ravnborg, 2003; Soini 2005; Bratt, 2009).

Different people in the same area rely on four different institutions to claim natural capital in order to earn a livelihood. They include the political, legal, economic and socio-cultural institutions that influence and condition the way communities access and utilize resources. It is the diverse institutions that influence the course of ecological change (de Haan, 2000). Local institutional arrangements are underpinned by power relations, and are shaped, in turn, by interactions with regional, national and global-level processes, both environmental and political-economic (Forsyth *et al*., 1998). The relationship between income/poverty and the environment is not static but can be influenced by policies.

While various products are extracted from the environment by collecting natural products (fodder grass, firewood and medicinal plants), the majority of livelihood strategies in an agricultural setting involve reshaping (mainly through deforestation) the environment to accommodate production of commodities that the natural environment would not otherwise provide (cropping). The way the environment is treated in the utilization process determines what livelihood strategies (e.g. what landuse practices) are available for the future, whether the utilization processes are sustainable or not. It is therefore important that any attempts to understanding the biophysical aspects associated with land degradation address the socio/economic drivers that dictate the course of action taken by rural communities in the pursuit of their livelihoods (Forsyth *et al.,* 1998; de Haan, 2008).

2.4 Landuse change and its implications for environmental change

Mountain ecosystems are continuously experiencing extensive land use changes due to natural processes and anthropogenic processes, (Klein, 2001; Agarwal *et al.,* 2002; Lui *et al.,* 2003). These changes have not only led to modifications, but also conversion of land cover with serious environmental implications (Hansen *et al.,* 2001; Lung and Schaab 2010). Studies on Mt Kilimanjaro (see Maro, 1974; 1998; Gamassa, 1991; Yanda and Shishira, 2001; William, 2002; Soini, 2005) provide evidence of replacement of forests by agriculture and settlements, leading to severe erosion, disruption of water sources and drying of rivers. Mountain forest ecosystems are particularly important from an ecological perspective as they provide goods and services that are essential to maintain the life-support system on a local and global scale. Green house gas regulation, water supply, nutrient cycling, genetic and species diversity as well as recreation are some of the services that mountain environment forests provide (Beniston, 2003; Nagendra *et al.,* 2004; Sivrikaya *et al.,* 2007). Mountains also represent unique areas for the detection of climatic change and the assessment of climate-related impacts because when climate changes rapidly with height over relatively short horizontal distances, so does vegetation and hydrology (Whiteman, 2000).

There has been growing concern over the human destruction of forests especially in the tropical and subtropical countries' mountain environments and the associated consequences on soil and water quality, biodiversity, global climatic and livelihood systems (Turner *et al.,* 1995; Laurence, 1999; Noss, 2001; Armenteras *et al*., 2003). East Africa's highlands have a high potential for agricultural production and, until the mid 20th century, were resilient to exploitation (McCall, 1985). The favourable climate with abundant rainfall and fertile soils attracted farmers to the region many centuries ago. The productivity of the land also supported chiefdoms and kingdoms with a stratified social structure. The land adequately supported both subsistence and surplus food production. However, today land degradation is threatening the very basis of the farming communities. The expansion of cultivation on the marginal slopes of Mt. Kilimanjaro, for example, has threatened the existence of its montane forests with considerable climatic impacts ranging from vanishing glaciers, increased frequency and intensity of fires, decreasing water supplies and an overall change in the people's livelihoods (Beniston, 2003; Soini, 2005; Hemp, 2009). According to the East African scenarios, the expansion of cropland and grazing land will continue to replace natural forests by a further 38 percent of its 1995 areal extent till 2032 (UNEP, 2004).

2.5 Landslide occurrence: A review of the causes

Mass movements are recognized and well documented global geomorphic hazards due to their major role in the development of hillslopes in mountainous areas and their considerable economic, social and geomorphological impacts (Knapen *et al.*, 2006). As pointed out by Anthony and Julian (1996) and Knapen *et al.,* (2006), landslide triggering depends on several complex and interrelated variables such as episodes of heavy rainfall, cumulative precipitation prior to failures, snow melt, changes in ground water characteristics and fluid pressure and shearing resistance due to a variety of factors such as sediment loading and compaction, changes in slope geometry and seismic activity. The conditioning and triggering actions of the above variables are reviewed in the subsequent sections.

2.5.1 Topographic factors

The contribution of slope morphological parameters including curvature, gradient, aspect and elevation to landslide activity has been inferred by various scholars (Julian and Anthony, 1996; Jakob, 2000: Zhou *et al.,* 2002; Hong *et al.,* 2005; Istanbulluoglu and Bras, 2005; Begueria, 2006; Glenn *et al.,* 2006). Convex slopes inhibit the storage of moisture over long periods of time, (Winter *et al.,* 2010). As demonstrated by Jakob (2000) and Dai and Lee (2002), the concentration of subsurface drainage within a concave slope, resulting in higher water pressure in the axial areas than the flanks, is one possible mechanism of triggering landslides.

Slope gradient has a great influence on the susceptibility of a slope to landsliding (Jakob, 2000; Ohlmacher, 2000 Dai and Lee, 2002). On a slope of uniform isotropic material, increased slope gradient correlates with increased failure. However, variations in soil thickness and strength are two factors which vary over a wider range for both failure and non failure sites (Dai and Lee, 2002).

The aspect of a slope can influence landslide initiation (Dai and Lee, 2002). Moisture retention and vegetation is reflected by slope aspect which in turn may affect soil strength and susceptibility to landslides. If rainfall has a pronounced directional component by influence of a prevailing wind, the amount of rainfall falling on a slope may vary depending on its aspect (Wieczorek *et al.,* 1997; Dai and Lee, 2002).

Dai and Lee (2002) observed that at very high elevation, mountain summits usually consist of weathered rocks, whose shear strength is much higher. At intermediate elevations, however, slopes tend to be covered by a thin colluvium, which is more prone to landslides. At very low elevations, the frequency of landslides is low because the terrain itself is gentle and is covered with thick colluvium and/or residual soils; and a higher perched water table is required to initiate slope failure.

2.5.2 Pedological factors

In purely practical terms, Baynes (2008), suggest that problem soils are those soils that are somewhat different from normal soils in that they can be unusually difficult and costly to engineer. Such soils have high propensity to expand, collapse, disperse, erode or settle and those that are unusually weak, chemically aggressive or corrosive; they may induce slope failure due to their distinct shrink-swell properties at various moisture contents (Van Der Merwe, 1964; Bell and Culshaw, 2001; Baynes, 2008). A detailed account of the characteristics of expansive soils and their implications for landslide occurrence is described in the subsequent paragraphs.

Following Van Der Merwe (1964), various scholars (Knapen *et al.,* 2006; Yang *et al.,* 2007; Kitutu et *al.,* 2009; Preuth *et al.,* 2010; Wati *et al.,* 2010) have used the clay fraction to explain a given soil's shrink-swell properties hence landslide susceptibility. Beyond certain expansion thresholds, a soil may become problematic, hence prone to landsliding. Accordingly, soils with ≥10percent clay exhibit expansive potential, while, those with >30percent are extremely expansive and prone to landslides (Van Der Merwe 1964; Baynes, 2008).

The dominant clay mineral present in a soil also influences its expansion and sliding potential. Ohlmacher (2000) and Yalcin (2007), associated landslide occurrence to montmorillonite and illite clays belonging to the smectite group. Such clays have lower shear strength and higher swelling potentials, and are more prone to landsliding than shales composed of Kaolinite and chlorite (Ohlmacher, 2000).

Soil texture is yet another pedological factor that can explain landslide susceptibility. As demonstrated by Yang *et al.,* (2007), Jadda *et al.,* (2009) and Wati *et al.,* (2010), fine textured clayey soils have small pores and liberate water gradually. Such properties make soils prone to landslides because of the high water retention. Wati *et* *al.* (2010) observe that the low permeability of fine textured clayey soils exacerbates the vulnerability to landslides.

Positive correlations between high plasticity and fine grained inorganic clays and silts have been observed (see Orazulike *et al.,* 1988; Chartwin *et al.,* 1994; Isik and Keskin, 2008). Highly plastic inorganic soils are prone to sliding especially during rainfall events due to the reduction of shear resistance (Dai *et al.,* 2002). According to Van Der Merwe (1964) and Baynes (2008), plasticity index values above 32percent and >30percent clay, signify extremely high expansive potential, such that soils can be categorised as vertic, which are associated with landslides.

The role of liquid limits in characterizing the problem nature of soils has been noted by various scholars (Van Der Merwe, 1964; Mario *et al.,* 1996; Msilimba and Holmes, 2005; Fauziah *et al.,* 2006; Baynes, 2008). Van der Merwe (1964) and Baynes (2008) categorised soils with ≥25percent Liquid limit as extremely expansive and thus prone to landslides.

The natural stability of slopes has implications for landslide failure. Various scholars have used shear parameters (cohesion and internal angle of friction) to compute the natural slope factor of safety (F_s) (Harris and Watson, 1997; Finno *et al.,* 1997; Tiwari and Marui, 2004; Fauziah *et al.,* 2006; Gonghui *et al.,* 2010), with F_s <1 implying natural slope instability, while F_s>1 implying natural stability. However, Finno *et al.,* (1997) and Gonghui *et al.,* (2010) observe that slope failure often occurs by localised deformation in a thin zone of intense shearing; therefore using overall stress-strain measurements may not be representative of such intense shear behaviour. They caution that care should be exercised before reaching generalised conclusions, owing to the interplay of various factors that may induce slope instability (Sidle *et al.,* 1985; Inganga *et al.,* 2001; Nyssen *et al*., 2002; Knapen *et al.,* 2006; Claessens *et al.,* 2007; NEMA 2007; Kitutu *et al.,* 2009 and Mugagga *et al.,* 2010).

It is noteworthy that despite not being considered in many landslide studies, problem soils are widespread around the world with their prevalence particularly in the tropics favoured by climatic conditions (Williams *et al.,* 1985; Baynes, 2008).

2.5.3 Rainfall as a landslide triggering factor

The central role of rainfall in triggering landslides has been noted by many a scholar (Froehlich and Starkel, 1995; Gonzalez-Diez *et al.,* 1999; Montserrat *et al.,* 1999; Zezere *et al.,* 1999; Zhou *et al.,* 2002; Vanacker *et al.,* 2003; Hong *et al.,* 2005; Istanbulluoglu and Bras, 2005; Knapen *et al.,* 2006; Karsli *et al.,* 2009). Van Beek (2002), observes that depending on the geometry and strength of the slope materials, increasing net rainfall depths are required to induce failure. Whilst such amounts may be delivered by a single rainfall event in some occasions, most soils require more substantial periods of rainfall to attain critical pore pressures. The development of positive pore pressure in soil and colluvium profiles due to infiltration of water during intense and or prolonged rainfall periods is usually considered the main triggering mechanism (Wieczorek, 1987; Van Asch *et al.,* 1999).

2.5.4 Human activities as triggering factors

Human activities and modification of the landscape increasingly play central roles in triggering landslides (Gupta and Joshi, 1990; Julian and Anthony, 1996; Slaymaker, 2000; Bernard *et al.,* 2001; Vanacker *et al.,* 2003; Remondo *et al.,* 2005; Preuth *et al.,* 2010). Available literature suggests a strong historical link between human activities (particularly, deforestation, logging, hillslope cultivation and excavation, forest fires) and landslide activity (Sidle *et al.,* 1985; Zezere *et al.,* 1999; Cannon, 2000; Jakob, 2000: Cruden and Miller, 2001; Dapples *et al.,* 2002; Nyssen *et al.,* 2002; Begueria, 2006; Kamusoko and Aniya, 2009; Lung and Schaab, 2010).

Deforestation is considered one of the main preparatory factors for landslide occurrence on most East African highlands, because it decreases the factor of safety through root decay (Sidle and Kerry, 1992; Inganga *et al.,* 2002; Knapen, 2003; Vanacker *et al.,* 2003; Knapen *et al.,* 2006); thereby enhancing the risk of shallow slope movement (Sidle and Terry, 1992; Vanacker *et al.,* 2003). The loss of vegetation cover on mountain environments inevitably has implications for local and regional climate variability (Beniston, 2003; IPCC, 2007a, b). Such variability is not confined to mountain ecosystems, as populated lowlands depend on mountain water resources. Vegetation change and associated shifts in intra-annual precipitation patterns could give rise to drought episodes (Barnett *et al.,* 2005).

Population pressure forces people to cultivate unsuitable steep slopes, thus contributing to slope instability (Yanda and Shishira, 2001; William, 2002; Soini, 2005; Knapen *et al.,* 2006; Buyinza *et al.,* 2008). The role of cultivation on steep concave slopes in inducing slope instability has been inferred by many a scholar whereby the soil hydrological conditions are greatly altered by way of enhancing saturation and also triggering debris flows under extreme rainfall events (Ian and Flores, 1999; Inganga *et al.,* 2001; Glade 2002; Nyssen *et al.,* 2002; NEMA, 2007).

Excavation of steep slopes for house building, foot path construction, plot levelling, and agricultural terraces causes water stagnation, increased infiltration and reduces lateral support, leading to increased pore pressure and landslide risk (Bhudu, 2000; Knapen *et al.,* 2006; NEMA, 2008). The cracks that develop upon drying in swell-shrink soils form a bypass mechanism for rapid infiltration and over saturation of the zone above the shear plane consequently resulting in slope failure (Van Asch *et al.,* 1999; Knapen *et al.,* 2006).

2.5.5 Vegetation cover as a landslide mitigation factor

Vegetation cover has a very strong influence on the activity of rain-induced landslides (Van Beek, 2002). Besides the effects of direct human-induced action, vegetation cover per see has implications for soil hydrological properties (Julian and Anthony, 1996; Van Asch *et al.,* 1999; Wasowski *et al.,* 2010; Winter *et al.,* 2010). Vegetation provides both hydrological and mechanical effects that are generally beneficial to the stability of slopes (Dai and Lee, 2002). It significantly modifies soil hydrology by increasing rainfall interception, infiltration and evapotranspiration (Begueria, 2006). Interception and evapotranspiration reduce the amount of water that reaches the soil and stored in it. As stressed by Blijenberg (1998), Cannon (2000), Zhou *et al.,* (2002), Istanbulluoglu and Bras (2005) and Winter *et al.,* (2010), the reinforcement and slope loading introduced by vegetation cover have great potential for reducing landslide occurrence. As concluded by Franks (1999), sparsely vegetated slopes are most vulnerable to failure.

2.5.6 Landslides on East Africa's highlands: A review of the causes

Literature on landslides in East Africa's highlands is rather still restrictive (Ngecu and Mathu, 1999; Knapen *et al.,* 2006; Claessens *et al.,* 2007). Examples of some of the landslides studies that have been in conducted in the East African region include, (Ngecu and Inchangi, 1989; Davies, 1996; Westerberg and Christianson, 1998; Ngecu and Mathu, 1999; Westerberg, 1999; Inganga *et al.,* 2001) in Kenya; (Muwanga *et al.,* 2001; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009) in Uganda; (Rapp *et al.,* 1972; Christianson and Westerberg, 1999) in Tanzania; (Moeyersons 1988, 1989b, 2003) in Rwanda. These studies suggest anthropogenic factors, especially population pressure coupled with slope disturbance, inconsiderate irrigation and deforestation as the major causes of landslides in East Africa's highlands (Ngecu and Mathu, 1999; Muwanga *et al*., 2001; Breugelmans, 2003; Knapen, 2003; Glade and Crozier, 2004; Knapen *et al*., 2006; Kitutu *et al*., 2004: 2009).

Knapen *et al.* (2006), attribute landslide occurrence on stable, marginally stable and actively unstable slopes of Mt Elgon to a combination of preconditions, preparatory and triggering causal factors. Preconditioning factors which include topography (slope angle, length, aspect, gradient, and curvature), lithology, shrink-swell soil properties and annual rainfall receipts act as catalysts that allow other destabilizing factors to act more effectively. On the other hand, preparatory factors, particularly human activities such as cultivation, excavation for housing, foot paths and deforestation tend to place the slope in a marginally stable state, making it susceptible to mass movement without actually initiating it. Triggering causal factors shift the slope from being marginally stable to an actively unstable state by initiating movement. Such factors include extreme rainfall events (such as El Niño), and concentration of runoff in restricted infiltration zones of concave slopes (Westerberg and Christiansen, 1999; Knapen *et al.,* 2006).

2.6 Summary

Investigations of the relationship between the anthropogenic, topographic and pedological factors provide a better and holistic understanding of the causes of landslides on mountain environments. On the basis of the above literature, the present study investigates the relationship between livelihood strategies, land use changes and physical properties parameters and implications for landslide occurrence on Mt Elgon. It also tests the hypothesis that soils on Mt Elgon slopes are inherently ‘problem soils’ susceptible to landslides.

CHAPTER THREE

Livelihood Diversification Strategies and Soil Erosion on Mount Elgon, Eastern Uganda: A Socio-Economic Perspective

Abstract

Land resources in Uganda are continuously shrinking and becoming degraded despite being the main livelihood assets for rural communities. This chapter examines the socioeconomic factors and conditions affecting household productivity and land degradation on the slopes of Mt Elgon. Primary data were obtained through household survey conducted in Tsekululu Sub County, Bubulo County, Manafwa District, Eastern Uganda between May and August 2008. The communities around the National Park are generally smallholder subsistence crop farmers, owning small pieces of land acquired through inheritance, privately owned and customary tenure arrangements. Farmers mainly use slash and burn techniques to prepare land for cultivation while those close to the National Park are reluctant to adopt appropriate farming and soil conservation techniques due to the lack of security of tenure. Slash and burn techniques were observed to accelerate various forms of erosion including rills, gullies and sheet. However, soil and water conservation techniques such as mulching were mainly practiced on privately owned farms due to the desire to recoup costs of investment in the land. Moreover there is a general inaccessibility to agricultural advisory and credit services in the area. The National Park is a big source of livelihood for the communities, especially those within the Park vicinity. It is a source of food, building poles, herbal medicine, and fodder. The communities also have a strong socio-cultural attachment to the National Park as it is the source of materials used during circumcision rituals. It also a source of bamboo shoots, a cultural delicacy of the local communities. The Collaborative Forest Management (CFM) put in place by the UWA through which the communities and Park staff share responsibility for the management of the Park ecosystem is abused by the communities by way of illegally accessing restricted zones and not adhering to resource harvesting quotas. This is partly due to the incitement by local leadership and politicians who encourage the communities to access the resources for their selfish political gain and economic interest. There is an urgent need to restore forest cover on encroached land and restrain communities from opening up new farming areas especially within and around the National Park. This however requires all stakeholders including local politicians, the National Park Authorities, the local communities and extension workers to actively participate in the design and implementation of Collaborative Forest Initiatives (CFM). Participation of all affected parties will create a sense of ownership and make CFM sustainable in the long run. Extension and agricultural interventions should focus on agro forestry promotion and sensitization of the farming communities about the dangers of using slash and burn as a farming technique. The communities should also be mobilized to form needs-driven cooperative groups as a way of enhancing their produce marketing abilities.

Keywords: Household productivity; livelihood strategies; soil erosion; soil conservation practices; Mount Elgon

3.1 Introduction

Land resources form the main asset for the derivation of livelihoods by most rural communities. Nearly 80 percent of the Ugandan population relies on land and agriculture for their primary livelihoods (NEMA, 2007). However, the agriculture resource base has been both shrinking and degrading with the increasing population pressure and marginal lands with very steep slopes increasingly being brought under cultivation. This has led to intense land degradation due to soil erosion on mountain slopes. Resulting from this is low and in many cases declining agricultural productivity. Demographic projections by district suggest that as a country Uganda will be depleted of agricultural land by 2022, with the Eastern region running out of available agricultural land earlier than the other regions (Jorgensen, 2006). Finding ways to reverse these trends is an urgent need in Uganda and many other developing countries.

Communities on Mt Elgon region derive most of their livelihoods from agricultural activities. However, literature on the socioeconomic factors affecting hill agricultural diversification strategies is still rather scarce (Buyinza *et al.,* 2008). Previous studies (see Muwanga *et al.,* 2001; Knapen *et al.,* 2006; Claessens *et al.,* 2007) have generally focused and developed soil erosion predictive models based on biophysical aspects. However, the socioeconomic conditions, factors and interactions that influence peoples' land management decisions and their implications for sustainable productivity and land degradation are variable and complex. Addressing this information gap therefore requires urgent attention.

This chapter is based on a study carried out in Tsekululu Sub County, Manafwa District. It aimed at examining the relationship between household productivity and land degradation. To achieve this goal, the socioeconomic factors and conditions affecting household choices regarding income strategies and soil conservation of the communities adjacent to Mt Elgon National Park (MENP) were investigated.

3.2 The modified household economic model

A modified household economic model (Figure 1) was used to investigate the livelihood strategies of households in the study area. This model gives insights into the conditions under which households make choices about which economic activities to pursue. It summarizes the assets available to the household, the options to which the assets can be put in order to generate income and the fate of the income generated from the adopted livelihoods (Vedeld *et al.,* 2004).

A household is defined by sharing the same abode and eating together. It is an appropriate unit for economic analysis because a household typically pools its resources, makes joint decisions and shares incomes. Internal and external factors influence the choice of activities to pursue. External factors are those on which the household has little control and include policies, natural vagaries and availability of social services while internal factors are the various types of assets owned by the household (Barrett *et al*., 2001; Damite and Negatu, 2004). The assets can be broadly categorized as; social, human, natural, financial and physical (Chambers and Conway, 1992; Reardon & Vosti, 1995, Barrett and Reardon, 2000; Ellis, 2000). The assets and the activities to which they are put define the household livelihood (Chambers and Conway, 1992; Ellis, 2000) and any factor limiting the attainment of improved livelihood can be seen as a constraint. The constraints may thus be limited access to various assets and adverse household external factors that affect household ability to convert assets into outputs. The same factors constrain the ability of farm households to invest in proper land management measures.

Based on the decisions made, a household undertakes a given set of activities. These define the household's livelihood and can thus be referred to as livelihood activities (Ellis, 2000). Often farm and non-farm activities are combined (Reardon, 1997; Arnold and Townson, 1998; Vedeld *et al.,* 2005). For households in the vicinity of forest resources, a considerable share of the latter is from collection of forest products for subsistence and/or commercial use (Vedeld *et al.,* 2005; Vedeld *et al.,* 2007).

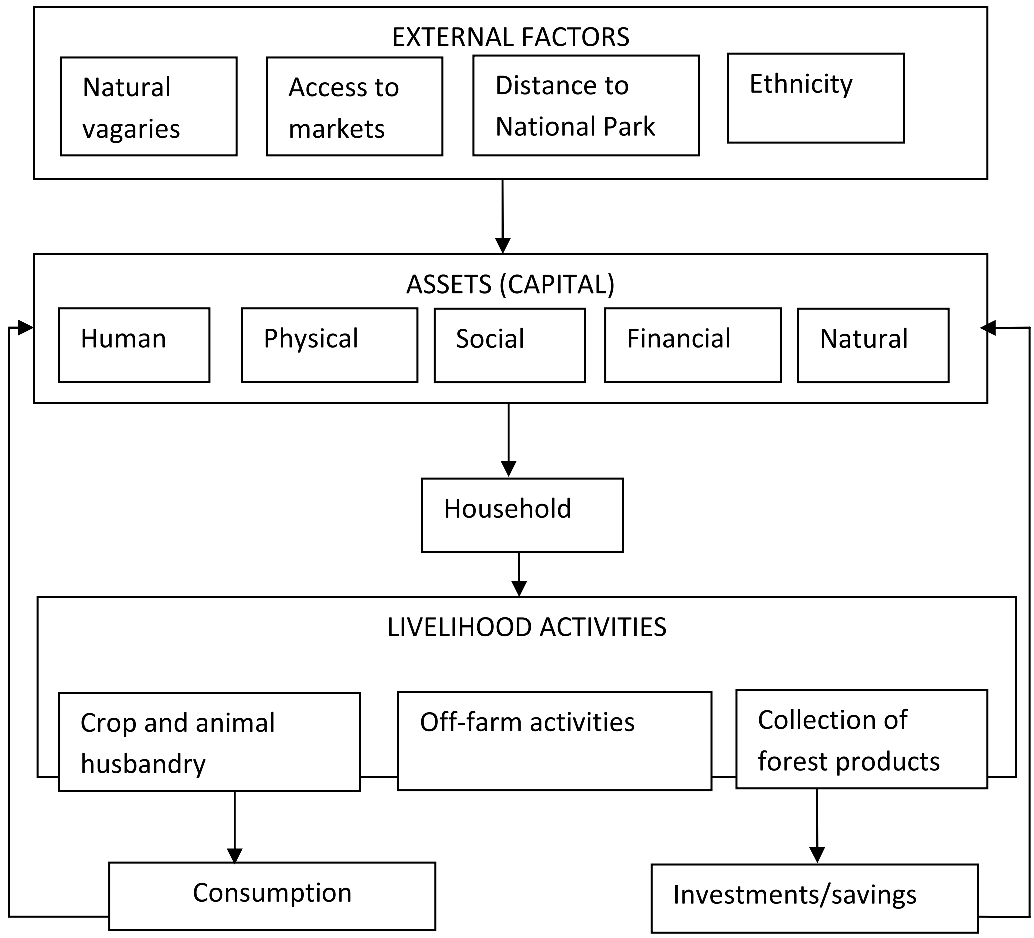


Figure 3.1: The Modified Household Economic Model (adapted from Vedeld *et al.,* 2005)

The selected activities generate income for the household in form of goods and services in kind or in cash. Depending on the existing external factors, the income is either consumed to contribute to the material wellbeing of the household or invested to enhance the household asset base and future incomes. For instance, the prevailing land tenure and access to social services such as agricultural extension services can influence the level of adoption of different land conservation measures. Insecure tenure such as park encroachment does not motivate investment in proper agricultural land management because of the fear of eviction by park authorities, while, lack of access to extension services and information compromises the households' ability to practice good farming practices. These often result in land degradation manifested in different forms of soil erosion such as sheet, rill and gulley erosion as well as shallow landslides.

It is noteworthy that in order for the household to maximise income, a good mix of assets and an enabling external environment are important to choose the most profitable livelihood activities. This is because, access to assets has to be coupled with the ability to put resources to productive use and also the possibility of meaningful asset accumulation in a direction that ultimately leads to more productive assets, (Ellis, 2000; Vedeld *et al.,* 2007). With the modified household economic model, it is possible to investigate the linkage between rural livelihood strategies and land degradation.

Household productivity is depicted in the context of the annual net per capita income that a household obtains from the different livelihood strategies. It is hypothesized that the choice of household livelihood strategies is influenced by the following; human capital (age productivity, education, occupation, gender, marital status); physical capital (ownership and use of land), social capital (participation in programs and organizations), natural capital (biophysical characteristics of the land), financial capital (access to financial services and credit facilities, access to markets and infrastructure), the land management practices used and distance from the Park boundary. This study dealt with all forms of capital apart from the natural and biophysical characteristics of the land. Intra-household resource allocation was also not taken into account.

Most of the factors affecting household livelihood strategies are also likely to influence land degradation and therefore soil erosion. In the present study, farmers were asked about their experiences and observations on the effect of the different soil conservation practices, soil erosion on crop yields and land use in the area. This was coupled with field visits and observations of the evidence of land degradation forms particularly soil erosion and investments that have been made on the farm plots. Measurement of soil erosion was outside the scope of this study.

3.3 Materials and Methods

3.3.1 The study area

The study was conducted in Tsekululu[1] Sub County located on the slopes of Mount Elgon in Bubulo County, Manafwa District, Eastern Uganda. The sub County lies adjacent to MENP (1º25´N and 34º30´E) which is situated approximately 100 km Northeast of Lake Victoria on the Kenya – Uganda border. Mt. Elgon, a solitary volcano is one of the oldest in East Africa. It rises to a height of about 4,320 m above sea level. The region receives an approximately bimodal pattern of rainfall, with the wettest months occurring from April to October. The mean annual rainfall ranges from 1500 mm on the eastern and northern slopes to 2000 mm in the south and the west. Mid altitude slope locations at elevations between 1900 and 3000 metres tend to receive more rainfall than either the lower slopes or the summit. On the lower slopes, the mean maximum temperatures increases from 25ºC to 28ºC and mean minimum temperatures are 15º C to 16º C (Scott, 1994).

A vast area of the mountain is made up from lava debris blown out from a greatly enlarged vent during the Miocene period (12-20 million years ago). The relatively young and fertile calcium-sodium-potassium rich soils are shallow, dark, humic loams that are permanently moist. On the steep slopes in the high altitude moorlands, very shallow soils are found. However, red brown, clay loams have formed on the gentle slopes (MCEP, 1997). The vegetation of Mt Elgon reflects the altitudinally controlled zonal belts commonly associated with large mountain massifs. Four broad vegetation communities are recognized namely; mixed montane forest up to an elevation of 2500 metres, bamboo and low canopy montane forest from 2400- 3000 metres and moorland above 3500 metres (Howard,1991).

[1] The three parishes that make up this sub county (including Bunamulunyi, Bunambale and Bumumali) were until 2007 part of Buwabwala Sub County. Through the decentralization policy, government elevated them to sub county status as a way of improving service delivery in Bubulo County.

According to the 2002 census, the Sub County had a population of 28,836 persons (14,582 males and 14,254 females) with a corresponding population density of 588 persons per square kilometer, compared to the country figure of 126 persons per square kilometer. The mean household size was 4.6 persons per household (UBOS, 2002). The population has been steadily increasing over the years with a growth rate of 3.3percent per annum. This is attributed to the high birth rates and the limited immigration (UBOS, 2002). Up to 95 percent of the population lives in the rural areas. The number of females almost equals that of males with the indigenous population comprising Bamasaba (95 percent). The other tribes include Banyole, Iteso, Babukusu and Sabaot (Manafwa Local Government, 2007).

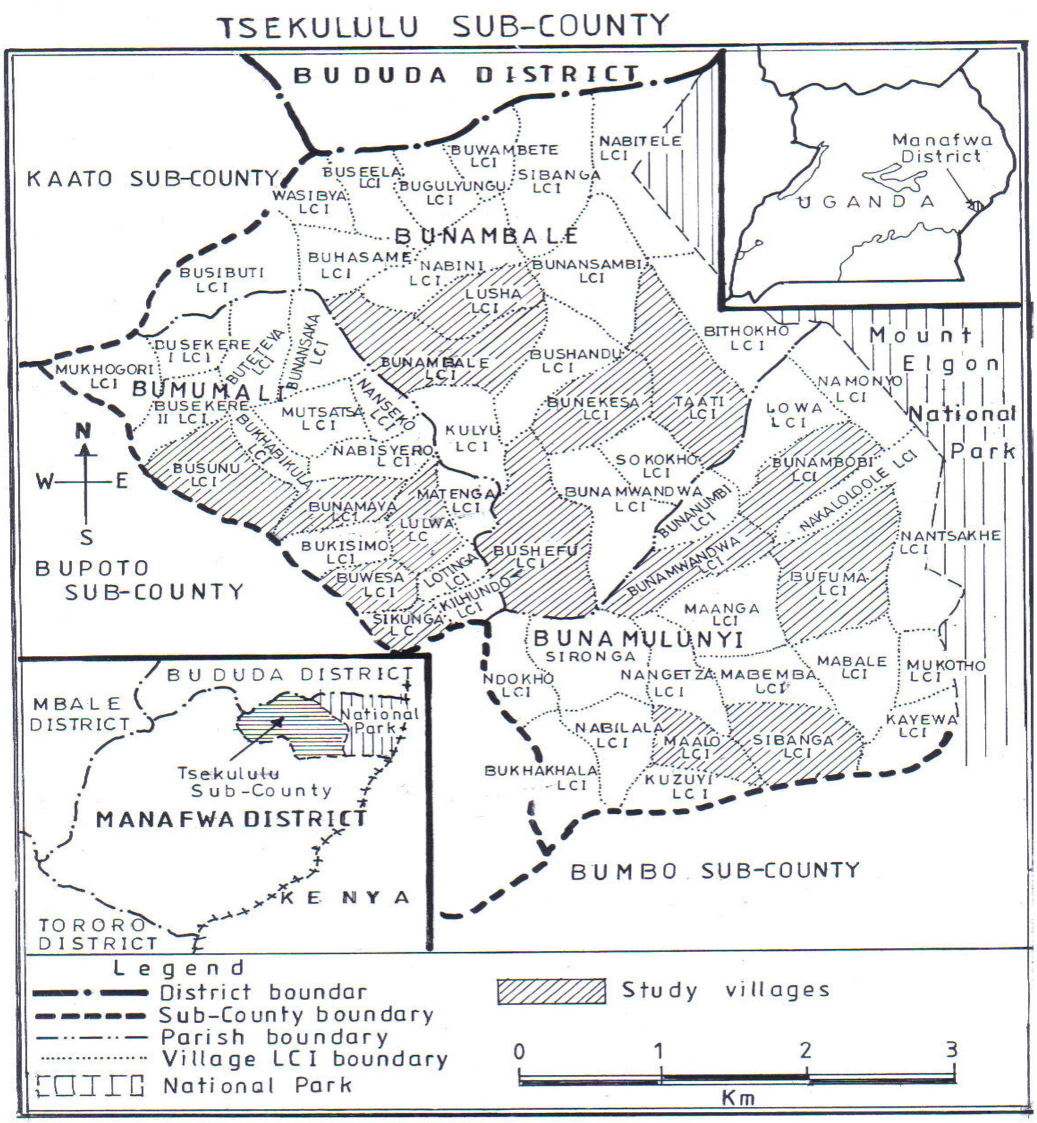


Figure 3.2: The study villages

Land in Tsekululu Sub County is divided between areas designated as National Park and land used for farming. Farmland in the sub county is itself divided between two topographic zones, an upland zone, characterized by intensive coffee and maize farming, and a lowland zone, where beans, yams and onions are grown. Arabica coffee and bananas are traditionally the major cash crop and staple food of the Sub County respectively; however, there is increasing reliance on maize and beans for food, and food crops are also sold for cash. Other crops include Irish potatoes, rice, soybeans, millet, wheat and green vegetables such as cabbages, tomatoes and spinach. Most households also keep livestock, particularly dairy cattle utilizing zero grazing regimes, for sale and own consumption of milk and meat, as well as small stocks of goats, sheep, pigs and chicken.

3.3.2 Data collection

Three study parishes including Bunamulunyi, Bunambale and Bumumali were sampled and stratified according to their distance from the Park boundary. Bunamulunyi and Bunambale parishes were selected because they are adjacent to the Park boundary whereas Bumumali is more than 15 kilometres away from the Park boundary. Five villages or Local Council1 (LC1[2]) were randomly selected from each of the parishes. From each of the villages, 10 households were randomly selected for the interviews, making a total of 150 respondents. Key informants included local leaders, clan elders and Uganda Wildlife Authority (UWA) Staff. The clan elders provided agricultural, land degradation and cultural information that was relevant in explaining environmental resource use and household productivity strategies. The local leaders and UWA staff described their roles and current policies regarding access to Park resources and the relationship between them and Park adjacent communities. The above were coupled with field observation of land degradation particularly soil erosion and landslides in relation to slope angle. Secondary data were obtained from policy documents at the UWA, District Environmental Reports and other relevant documents.

[2] Local Council1 refers to a village executive and is the smallest administrative and decision making unit in Uganda

3.3.3 Data analysis

Primary data collected through the household survey was analyzed using the Statistical Package for Social Scientists computer package (SPSS Version 16). Descriptive statistics such as frequencies and percentages were generated. A linear regression model was run to establish the socioeconomic factors affecting household annual net per capita income. The household annual net per capita income was calculated by subtracting the annual total costs involved in the production of goods and services from the annual gross income.

The following were considered as predictor variables; age, marital status, education level, and occupation of household head, age productivity of household members, type of dwelling, household wealth, size of farm land, Agricultural land use, land tenure systems, access to financial services, participation in social programs and organizations and distance from the Park boundary

Table 3.1: Factors affecting household productivity in Tsekululu Sub County

Variable	*Variable definition*
AGE	Age of Household Head (1 if 20-29; 2 if 30-39; 3 if 40-49; 4 if 50-59; 6 if 60-69; 7 if 70-79; 7 if 80+ years old
MS	Marital status (1 married; 2 single; 3 widow/widower; 77 No response
ED	Education level of household head (1 none; 2 primary one to primary seven; 3 senior one to senior four; 4 tertiary education)
OCC	Occupation of household head (1 farmer; 2 teacher; 3 civil servant; 77 No response)
AGP	Age productivity of household members (1 ≤; 2 if 16-34; 3 if 35-64; 4 if ≥ 65 years old)

TD	Type of dwelling (1 temporary; 2 semi permanent; 3 permanent)
HHW	Household Wealth as ranked by elders (1 rich; 2 well off; 3 comfortable; 4 poor; 5 very poor; 77 no response)
SFL	Size of farmland (1 if < 1; 2 if 1-5; 3 if 6-9; 4 if ≥ 10 hectares of land)
ALU	Land use (1 if all land is used for grazing and cropping; 2 if otherwise)
LT1	Private land ownership (1 if yes; otherwise 0)
LT2	Land inherited from parents (2 if yes; otherwise 0)
LT3	Communal land ownership (3 if yes; otherwise 0)
AFS	Access to financial services (1 if yes; 0 if no)
PSA	Participation in social programs and organizations (1 if yes; 0 if no)
DP	Distance from park boundary (0 ≤ 1 km; otherwise 1

3.4 Results and Discussion

3.4.1 Socio economic and demographic characteristics of the respondents

Seventy seven percent of the respondents were males (Table 3.2). Eighty percent of them were aged between 35- 64 and therefore old and productive. Ninety six percent of the respondents were married. Sixty four percent of them were educated up to primary school level. Ninety five percent were farmers and about eight six percent owned less than 1 hectare of land of which ninety seven percent were cultivating and grazing on all the land. Forty nine percent had inherited the land from their parents, while twenty three percent encroached on the Park for their livelihood. Sixty seven percent were ranked by elders as comfortable households in terms of wealth. Eighty six percent of the dwellings were semi permanent.

Table 3.2: The socio-economic and demographic characteristics of the respondents

Variable	*Frequency*	*Percentage*
Sex		
Male	115	77
Female	35	23
Age group		
16-34	6	4
35-64	130	87
≥65	14	9
Marital status		
Married	145	96
Divorced	4	3
Single	1	1
Educational Level		
None	25	17
Primary	96	64
Secondary	27	18
Tertiary	2	1
Occupation		
Farmer	143	95
Teacher	3	2

Civil servant	3	2
No response	1	1
Size of land owned and tenure		
< 1	129	86
1-5	21	14
Private	36	24
Inherited	74	49
Communal	1	1
Park encroachment	35	23
Rent from neighbor	4	3
Land utilization		
All land used for grazing and cropping	146	97
No response	4	3
Type of dwelling		
Temporary	21	14
Semi permanent	129	86
Household wealth as ranked by elders		
Well-off	13	9
Comfortable	101	67
Poor	23	15
Very poor	12	8
No response	1	1

3.4.2 The main sources of household income and livelihood activities

3.4.2.1 On-farm income

Results indicate that the primary sources of income include the production and sale of agricultural products. The main crops grown include maize, cassava, coffee and beans. Other crops include Irish potatoes, onions, passion fruits, tomatoes and peas. Majority (86 percent) of the respondents own less than 1 ha of land of which 97 percent use all the land for crop and livestock production. The production takes place from owner occupied farms of which 49 percent were inherited from parents, while 23 percent privately own the land. Twenty three percent encroach on the National Park (Table 3.2). Local breeds of chicken, cattle (both indigenous and exotic) and goats are the main livestock owned. Other animals include pigs and turkeys. A mixture of improved and local breeds of livestock is kept by the farmers.

At a region –wide level Buyinza *et al.* (2008), estimated that about 80 percent of the cultivable land in Mt Elgon forest watershed is used for growing cereal crops, 7 percent for cash crops and 3percent for fruit crops. Mt. Elgon forest watershed supplies all the water used for agricultural activities in the region. Two crops are mainly grown in a year. In case of lowland, only a single crop of rice is grown as summer crop and only a few farmers have recently started growing wheat as winter crop after rice. Some farmers have also grown spring maize in lowland before rice. The other crops grown in upland lands are maize, millet, wheat, Soybean and legumes.

Farmers that have adopted and established technologies such as contour hedgerows register positive results on agricultural productivity. However, the inadequate participation of most rural farmers in agricultural technology development is partly responsible for their inability to take full advantage of the improved agricultural technologies. Agricultural technology development among smallholder farmers is still very low. It is therefore imperative that appropriate technology that suits the local economic, cultural and geographical conditions of the region is developed and promoted (Buyinza *et al.,* 2008).

3.4.2.2 Off-farm income

Off- farm income sources such as wage labour on other people's farms were reported by only 3 percent of the respondents. Arrangements such as in- kind payments like harvest share systems and other non-wage labour contracts were not captured by this study. However most landless people do not want to admit that they work for others for fear of being embarrassed, therefore leaving the off-farm income source uncovered, making agriculture, environmental and non-farm activities as the main livelihood strategies in the Mt Elgon area (Buyinza *et al*., 2006; Buyinza and Teera, 2008).

3.4.2.3 Environmental resources

The Park contains a wide range of environmental resources which are of great value to the communities living around it. These resources include; medicinal plants, firewood, fodder for livestock, sticks for hoes, poles for building, vegetables, thatch grass, wild fruits and craft material. About 35 percent of the respondent use the park resources for domestic purposes, 33percent for agricultural purposes and 30 percent are looking for grazing land, while 2 percent seasonally visit the park in search of particular plant species, soil and honey for socio-cultural reasons notably circumcision rituals. Buyinza and Teera (2008) found out 31.3 percent of the total environmental income for Mt Elgon adjacent communities was derived from firewood much of which was from the National Park. Vedeld *et al.* (2004) found out that for households in the vicinity of forests, considerable livelihoods are derived from the collection of forest products for subsistence and commercial uses.

Figure 3.3: Collection of firewood. Due to the clearance of the forests surrounding the National Park, communities resort to Mt Elgon National Park for their wood fuel demands.

Access to Mt Elgon National Park forest resources is regulated through the Collaborative Forest Management (CFM) initiative between UWA and the park adjacent communities through access to certain parts of the forest is allowed during specific periods of the year. Resource extraction quotas are imposed as a way of ensuring sustainability. Under the same arrangement, mechanisms and practices have been put in place by UWA with a view of having communities and Park staff share in the benefits and responsibility for the management of the Park ecosystem. However, illegal access to restricted zones and lack of adherence to resource harvesting quotas are still major management problems posed by the communities. The conflict between resource users and resource conservers has been the greatest hindrance in the conservation of Mt Elgon (Scott, 1998). The ever increasing illegal access to the Park is partly a result of local leaders who are more inclined to tolerate encroachment and exploitation of protected areas due to local political pressures and economic interest than conservation.

Table 3.3: Community dependence on park resources (N=150)

Park Resources	*Frequency*	*Percentage*
Firewood	26	17.5
Wild fruits	6	4.2
Medical plants	39	26.1
Small animals: birds, mice	1	0.1
Thatch grass	8	5.6
Poles for building	13	9.0
Sticks for hoes	16	10.6
Rope materials	1	0.1
Craft material	6	3.7
Fodder	22	14.9
Vegetables	12	8.0

3.4.2.4 Non-farm income

Trade in park environmental resources was reported by 52 percent of the respondents. The trade items mainly included bamboo shoots (31percent), timber (29 percent) and firewood (28 percent). Other minor items included charcoal, bricks and handcraft which collectively accounted for 13 percent. The people engage in trade in order to buy food and other basic items, expand and diversify their income sources, buy seeds and to respond to the demand for goods.

Although the respondents could not attach direct economic costs involved in the extraction and processing of these raw materials, it is obvious that the extraction of these raw materials is labour intensive, restrictive and requires walking long distances inside the Park. For example bamboo shoots can only grow at an altitude range of 2400 and 3000 metres above sea level. Given the fact that most of the settlements lie within 1000 to 1800 metres a.s.l and that most of the slopes are steep ranging between 36° and 68°, it then becomes apparent that accessing these resources requires a lot of energy. Moreover, trade in environmental resources was dominated by the young and productive (16-34) and mature and productive (35-64) age groups taking 36 percent and 94 percent respectively.

Income from school teaching and civil service was accounted for by only 4 percent of the respondents. This could be related to the low level of education of the respondents were by majority (64 percent) had attained just primary school education and therefore could not be formerly employed.

3.4.3 The socio-economic asset profiles and external factors affecting household productivity

Results indicate that the variables age of household head, type of dwelling, amount land owned and size of farm land, land tenure systems (especially the private ownership) and encroachment on the National Park resources significantly affect household productivity at the 95 percent ($P \leq 0.05$) confidence level.

Table 3.4: Factors affecting annual Net Per Capita Income

Predictor variables	*t-ratio*	P-values
AGE	0.90	0.03
MS	- 0.13	0.47

ED	0.38	0.54
OCC	- 1.34	0.80
AGP	- 0.96	0.96
TD	1.76	0.01
HHW	- 1.12	0.49
SFL	2.26	- 0.002
ALU	1.01	0.77
LT2	0.46	0.286
LT1	- 0.48	0.015
LT3	1.03	0.579
AFS	0.39	0.086
PSA	1.26	0.078
DP	0.23	0.48

Standard Error of Estimate = 405.4; R^2= 15.5 percent; R^2 (Adjusted) = 5.5 percent; $P \leq 0.05$; Sample

3.4.3.1 Human capital

Age of household head significantly affects household annual net income. The average age of the household heads in this case was 45, while the range was between 15 and 80. Investments and savings are often long term projects whose benefits take long to be realized. It is therefore understandable that older people will have accumulated bigger savings and investments and therefore bigger return on investments than their young counterparts. In fact, as an investment in human capital, older the people had more children who contributed farm labour, farming being the main stay of the area constituting over 95 percent of the respondents' occupations. With limited income opportunities and higher unemployment, larger families are likely to rely on the labour intensive environmental resources to meet their basic needs, this being made possible by the human capital existing within these families (Buyinza *et al.,* 2004; Buyinza and Teera, 2008).

Marital status, occupation, education level of the household head, age productivity, household wealth as ranked by elders, land utilization and distance from the Park boundary are variables not found to have significant effect on the household's annual net income at the 95 percent confidence level. Similar results were obtained by Buyinza and Teera (2008) where sex, age and educational level of the household head did not yield significant results when regressed against forest income.

3.4.3.2 Physical capital

While the mean land holding was 1.5 hectares the range was 0-6 hectares. Households that own more land are likely to earn more income from working on the land. Land size is therefore expected to have a positive impact on household net incomes. This is because the land can be utilized in the generation of on-farm incomes including crop and livestock production. However, the amount of land owned and size of farmland were found to have negative effects on household productivity. This implies that management, labour and other constraints limit the ability of large farmers to be as productive as small farmers. It therefore suggests that small farmers attain higher productivity from their land than their larger counterparts, conforming to a number of studies which have built upon the ideas of Ester Boserup (1993), about the potential of agricultural intensification under conditions increasing population density and shrinking land holdings. As posted by Adams and Mortimore (1997), increasing population densities have positive consequences and not negative consequences for the economy and environment. Studies in Kano Close – Settled Zone (KCSZ) and nearby areas of Nigeria and Niger and in Machakos District in Kenya reveal that despite population pressure, agricultural intensification can take place while avoiding the land degradation through investment in proper land management techniques (Tiffen and Mortimore, 1984; Mortimore, 1989; Tiffen *et al.,* 1994). Under the right conditions, small scale farmers can and will invest in their land as population rises, thereby enhancing their livelihoods (Blaikie and Brookfield, 1987).

In the linear regression model above (Table 3.4), the variable type of dwelling has a positive effect on the annual net per capita income because households with higher incomes can afford better building materials, hence more permanent structures.

3.4.3.3 Social capital

Participation in agricultural training and extension does not significantly affect household productivity (P=0.086). This can be attributed to the ineffectiveness of such organizations and programs in the study area as reported by the respondents. Notable among these programs are; The National Agricultural Advisory Services (NAADS) and the Plan for Modernization of Agriculture (PMA) both government programs aimed at enhancing and modernizing agricultural productivity in the country. Interviews with the respondents revealed that the majority of the people (95percent) do not have knowledge about the existence of such programs, where to find them and how to benefit from them. Those who expressed knowledge about them complained that the people concerned were inaccessible. Access to such programs and extension services could be enhanced if farm households are mobilized to form needs-driven cooperative groups. Agricultural extension should be focused on promoting agro forestry in the highland areas because of its ecological, economic and social benefits.

3.4.3.4 Financial capital

Results indicate that credit facilities and institutions do not exist in the study area. When regressed against household net per capita income, access to markets did not give statistically significant results ($P = 0.078$). This could be attributed to the subsistence level of production where most households produce items for home consumption. Similar findings were obtained by Buyinza and Teera (2008), where many households adjacent to Mt Elgon depend on social norms to access credit and loans whose collateral property are standing crops such as coffee and maize. The loans are paid back after selling the season's surplus crop harvests. As agricultural modernization and commercialization proceeds in Uganda, access to markets, infrastructure and credit are much more important. Mechanisms should be put in place to ensure that communities access this infrastructure in order to enhance household productivity thereby improving livelihoods.

3.4.3.5 Land tenure

Of all the land tenure arrangements existing in the study area, private land ownership significantly affect household productivity ($P = 0.015$). This can attributed to the fact that private owners are more likely to invest in soil and water conservation measures in order to recoup the costs of their investment in buying the land. This therefore, leads to increased productivity and reduced land degradation. A total and opposite contrast exists for those owning land through inheritance and communal arrangements under the customary tenure system where such initiatives are unlikely to be undertaken since beneficiaries do not have capital investments on the land upon acquisition.

The dominant land tenure system in the study area was customary (49 percent), with the majority of respondents having inherited the land from their parents. This was followed by private lease owners (24 percent). Twenty three percent were landless and therefore were encroaching on the National Park land. Three percent were either renting or borrowing land from neighbours for a specified time period. Crop harvest share systems and non wage labour contracts were the main modes of land rental. More land degradation forms were observed on the encroached land than on inherited and privately owned land. Farmers on encroached plots were noted not to invest in soil and water conservation measures citing the uncertain future and short term periods on rented land. Owners of purchased land may have more incentive to produce cash crops and apply inputs to be able to recoup the costs of their investments. In fact, land management practices including mulching were more pronounced on privately owned land, thus further strengthening the argument that private owners are more likely to invest in land and soil conservation measures.

3.4.3.6 Distance from the Park boundary

Distance from the Park boundary did not have a significant relationship with household annual net income (P= 0.48). This could be due to the fact while it is easier and cheaper for Park adjacent communities to access and trade in Park environmental resources; those far away find it more economical to concentrate on farm, off-farm and non-farm activities. This in return balances the economic benefits that each of these communities accrue from the pursuit of its income portfolio. This argument is reinforced by Buyinza and Teera (2008), where a negative relationship was found between per capita forest income and distance to the forest.

3.4.4 Soil erosion and conservation practices

As observed by Buyinza and Nabalegwa (2008), soil erosion, deforestation and overgrazing are key factors of decreasing per capita income in the Mt Elgon catchment. The small land holdings are as a result of very rapid population growth and inappropriate cultivation techniques. More serious soil erosion problems occur on the marginal slopes ranging between 36º and 58º which dominate the Mt Elgon catchment (Buyinza 2007 *et al.,* 2007). This study did not attempt to measure the intensity of the different soil erosion forms; field observations coupled with respondent interviews were used to elicit information about soil erosion in the area.

Sheet, rill, gulley erosion and landslides are very common in this region. Farming activities take place at very steep slopes which are susceptible to landslides (Buyinza and Nabalegwa, 2008). The relationship between selected slope topographic parameters and landslide occurrence were investigated and the results are presented in subsequent chapters.

The majority of respondents reported that soil was being washed down from their sloping land and 84 percent have attributed the reduction in crop quality and yield to soil erosion. A small number of the farmers that had identified soil quality as the main factor causing declining yields did not know how to improve the soil quality.

Table 3.5: Land use and cover changes in the recent past

Changes	*Frequency*	*Percent*
Reduction in crop quality and yield	126	84
Rapid loss of vegetation cover	9	6.0
Loss of soil fertility	9	6.0
Increased land use due to increased soil conservation	1	0.7
New settlements and Encroachment	1	0.7
NR	4	2.7
Total	150	100

NR= No Response

The main factors influencing the rate of soil erosion include rainfall, runoff, wind, soil, slope, plant cover, population density and the presence or absence of conservation measures (Morgan, 1986). Precipitation levels in the study area are high and intense, slopes are very steep, deforestation is wide spread, population densities are high and few conservation measures are used. On-going farming practices such as slash and burn techniques are also responsible for aggravating soil erosion. Farmers hold the false belief that exposure of land to the sun, rain and air for a long period helps to improve soil fertility (Buyinza *et al.,* 2007).

As environmental conditions in the study area are likely to exacerbate soil erosion, the limited use of soil conservation methods by most farmers is probably a significant factor relating to soil erosion, declining soil fertility and decreasing crop yields. With the exception of contour ploughing and terracing, use of soil conservation methods increases with distance from the National Park boundary. Farmers living far from the Park boundary use a greater variety of soil conservation methods. The low proportion of farmers using soil conservation methods in and around the park is mainly due to the insecure land tenure. There is a widespread fear of eviction amongst people who live in the Park, and until they are certain that they will not be evicted, they are not prepared to invest resources in improving the quality of their land. Scott (1994) concluded that settling land tenure conflicts was of prime importance if sustainable resource use was to be adopted by the communities living around MENP.

The most common land conservation practices used by the people in the study included the use of slash and burn to prepare farm fields (20 percent), application of mulch (16 percent), household residues (15.1 percent), incorporation of crop residue (14 percent), crop rotation (13 percent), and application of manure or composit (12 percent). Use of fallow had declined and the use of organic and inorganic sources of fertility was still very limited, contributing to perceived declines in soil fertility and crop yields in the study area. Of all the land conservation practices, crop rotation and mulching were observed to have a big effect on agricultural productivity. Farmers noted that rotating crops season after season coupled with mulching helped much in restoring soil fertility and reducing problems of pests and diseases.

Slash and burn is a very common and continuously increasing practice in the marginal cultivated uplands of the Mt Elgon catchment area (Buyinza and Nabalegwa, 2008). Various forms of erosion (including rills, gullies and sheet) were observed on fields that had been reportedly prepared using this method. Burning denatures the physico-chemical properties of the soil and therefore exposes it to the agents of erosion. Use of inorganic fertilizers is not very common in the study area. This can be attributed to the costs involved in acquiring these fertilizers, bearing in mind that most of the farming is of subsistence nature. Crop rotation contributes to long term productivity by helping to restore soil fertility and reducing problems of pests and diseases.

This study did not investigate the factors influencing the adoption of different soil conservation strategies by farm households. However Buyinza *et al.* (2007), observed that the adoption of soil conservation strategies varies from one farmer to another, depending on several ecological, social and institutional factors including; availability of extension services, farmers' tribe affiliation, agricultural labour force size, land holdings, farmers' training, schooling period of farm household head, participation in joint soil conservation activities and landslide density in farmlands. With regard to the above, agricultural extension work should be promoted and focused on promoting agro forestry techniques which address the environmental, social and economic needs of the highland areas of Uganda.

3.5 Conclusion

The study has revealed that on-farm agricultural activities and dependence on park environmental resources are the main sources of livelihoods for the communities adjacent to Mt Elgon National park. The communities also have strong socio-cultural attachments to the Park as it is a source of materials used during circumcision rituals as well as the provider of bamboo shoots, a cultural delicacy. Several socio-economic factors such as the age of household head, the type of dwelling, land ownership, private land tenure and encroachment on park resources affect household productivity. While soil conservation practices are more pronounced with communities that are far away from the park boundary, those adjacent to it are reluctant to invest and adopt soil conservation practices owing to the insecure land tenure. The increasing deforestation on the Park and failure of Collaborative Forest Management Initiatives between the Uganda Wildlife and the communities is partly due to the local leadership and politicians who incite people to encroach and even access restricted zones within the Park. However, apart from the prevailing environmental conditions, the wide spread use of slash and burn as the main land preparatory/ conservation practice is a significant factor relating to soil erosion, soil fertility and decreasing crop yields among farm households. There is an urgent need to restore forest cover on encroached land and restrain communities from opening up new farming areas especially within and around the National Park. This however requires all stakeholders including local politicians, the National Park Authorities, the local communities and extension workers to actively get involved in the design and implementation Collaborative Forest Management (CFM) Initiatives. Participation of all affected parties will create a sense of ownership and make CFM sustainable in the long run. Extension and agricultural interventions should focus on promoting agro forestry and sensitization of the farming communities about the dangers of using slash and burn as a farming technique. The communities should also be mobilized to form needs-driven cooperative groups as a way of enhancing their produce marketing abilities.

CHAPTER FOUR

Land use Change on the Slopes of Mount Elgon and Its Implications for Landslide Occurrence.

Abstract

A reconstruction of land use change and its implications for landslide occurrence on the fragile slope of Mount Elgon, Eastern Uganda was undertaken. Aerial photographs taken in 1960 and orthophoto maps formed the benchmark for the analysis of respective land use changes between 1995 and 2006 using 30m Landsat TM and 20m SPOT MS images in IDRISI32 Andes environment. Landslide sites were mapped using a Magellan Professional MobileMapper^{TM}CX and terrain parameters were derived using a 15M Digital Elevation Model. A hybrid supervised/unsupervised classification approach was employed to generate land cover maps from which three land cover classes (agricultural fields, woodlands and forests) were calculated using in Idrisi GIS. A post classification comparison change detection technique revealed different trends in land cover change between the periods 1960 to 1995 and 1995 to 2006. During the 1960 – 1995 period, there were minimal land use changes and no encroachment into the designated Mount Elgon National Park. The period 1995 – 2006 marked a significant loss of woodlands and forest cover particularly on steep concave slopes (36º – 58º) of the National Park. The encroachment onto the critical slopes was noted to have induced a series of shallow and deep landslides in the area. Deforestation on Mt Elgon has both onsite and offsite climate variability and implications. There is a need to restore forest cover on the fragile steep slopes and restrain local communities from opening up new areas for cultivation on critical slopes particularly within the protected area.

Keywords: Land use cover/change, landslides, Mt Elgon, concave slopes, deforestation

4.1 Introduction

Mountain ecosystems are continuously experiencing extensive land use changes due to natural processes and anthropogenic processes, (Klein, 2001; Agarwal *et al.,* 2002; Lui *et al.,* 2003). These changes have not only led to modifications, but also conversion of land cover with serious environmental implications (Hansen *et al.,* 2001; Lung and Schaab, 2010). Studies on Mt Kilimanjaro (see Maro, 1974; Gamassa, 1991; 1998; Yanda and Shishira, 2001; William, 2002; Soini, 2005) provide evidence of replacement of forests by agriculture and settlements, leading to severe erosion, disruption of water sources and drying of rivers. Mountain forest ecosystems are particularly important from an ecological perspective as they provide goods and services that are essential to maintain the life-support system on a local and global scale. Green house gas regulation, water supply, nutrient cycling, genetic and species diversity as well as recreation are some of the services that forests provide (Beniston 2003; Nagendra *et al.,* 2004; Sivrikaya *et al.,* 2007). Mountains also represent unique areas for the detection of climatic change and the assessment of climate-related impacts because when climate changes rapidly with height over relatively short horizontal distances, so does vegetation and hydrology (Whiteman, 2000).

There has been growing concern over the human destruction of forests especially in the tropical and subtropical countries' mountain environments and the associated consequences on soil and water quality, biodiversity, global climatic and livelihood systems (Turner *et al.,* 1995; Laurence, 1999; Noss, 2001; Armenteras *et al.,* 2003). East Africa's highlands have a high potential for agricultural production and, until the mid 20th century, were resilient to exploitation (McCall, 1985). The favourable climate with abundant rainfall and fertile soils attracted farmers to the region many centuries ago. The productivity of the land also supported chiefdoms and kingdoms with a stratified social structure. The land adequately supported both subsistence and surplus food production. However, today land degradation is threatening the very basis of the farming communities. The expansion of cultivation on the marginal slopes of Mt. Kilimanjaro, for example, has threatened the existence of its montane forests with considerable climatic impacts ranging from vanishing glaciers, increased frequency and intensity of fires, decreasing water supplies and an overall change in the people's livelihoods (Beniston, 2003; Soini, 2005; Hemp, 2009). According to the East African scenarios, the expansion of cropland and grazing land will continue to replace natural forests by a further 38 percent of its 1995 areal extent till 2032 (UNEP, 2004).

Mass movements are recognized and well documented global geomorphic hazards owing to their major role in slope evolution in mountainous areas and the considerable economic, social and geomorphological impacts. However, literature on landslides in East Africa's highlands is rather still restrictive (Ngecu and Mathu, 1999; Knapen *et al.,* 2006; Claessens *et al.,* 2007). Examples of some of the landslides studies in East Africa include (Ngecu and Inchangi, 1989; Davies, 1996; Westerberg and Christianson, 1998; Ngecu and Mathu, 1999; Westerberg, 1999; Inganga *et al.,* 2001) in Kenya; (Muwanga *et al.,* 2001; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009) in Uganda; (Rapp *et al.,* 1972; Christianson and Westerberg, 1999) in Tanzania; (Moeyersons, 1989 and 2003) in Rwanda. These studies point to anthropogenic factors, especially population pressure coupled with slope disturbance, inconsiderate irrigation and deforestation as major trigger factors of landslides in East African highlands.

The Ugandan side of Mt Elgon National Park (MENP) was formerly gazetted a natural forest reserve in 1937 with a variety of wild animals. In October 1993, the Government of Uganda declared the area a National Park in an effort to strengthen the conservation status of the ecosystem. Encroachment for cultivation into the National Park is a major threat to the Mt Elgon ecosystem due to the amount of degradation caused by removal of natural vegetation. Encroachment has resulted in the destruction of approximately 25,000 hectares within the past generation, or about one fifth of Elgon's forest. Virtually all of the forest cover below an elevation of 2000 metres has been removed due to encroachment. The breakdown of civil order in the 1970s and

1980s provided a social and economic climate within which encroachment thrived (Malpas, 1980; UWA, 2000).

Despite efforts to protect the Park boundary and regenerate previously encroached lands, encroachment continues to be a management problem. Incidences of infringement have continued to occur for a variety of reasons, including a strong community desire for more agricultural land, declining land productivity in some areas, high population pressure, political interference and connivance with National Park Staff. In addition, problems with identifying and marking the correct Park boundary have occurred in a number of areas, with different boundary surveys over the years producing different outcomes, either as a result of lack of information or because of manipulation of the true boundary by the surveyors due to community pressure. The most recent boundary survey carried out between 1993 and 1996 found out that land already used for cultivation was in fact within the gazetted park boundary, thus creating conflict with the community who considered the land as theirs (UWA, 2000).

This chapter investigates the relationship between land use change and landslide occurrence. The specific objectives of the study are:

1. To examine the temporal and spatial trends in land use change for the period 1960 and 2006.

2. To establish the relationship between land use, topographic parameters and occurrence of landslides on the slopes of Mount Elgon.

4.2 Study area

The study was conducted in Manafwa and Bududa Districts located on the slopes of Mount Elgon, Eastern Uganda. In Manafwa district, a specific area that typifies land use and cover change in the region was chosen. Availability of imagery and particularly 1960 aerial photography of the area was also a basis for the selection. Sites that have experienced frequent landslides in the recent past were chosen for field surveys in both districts. The study area is located on the mid altitude slopes (1900 - 3000m) which receive more rainfall than either the lower slopes or the summit, making it a highly fragile environment (UWA, 2000).

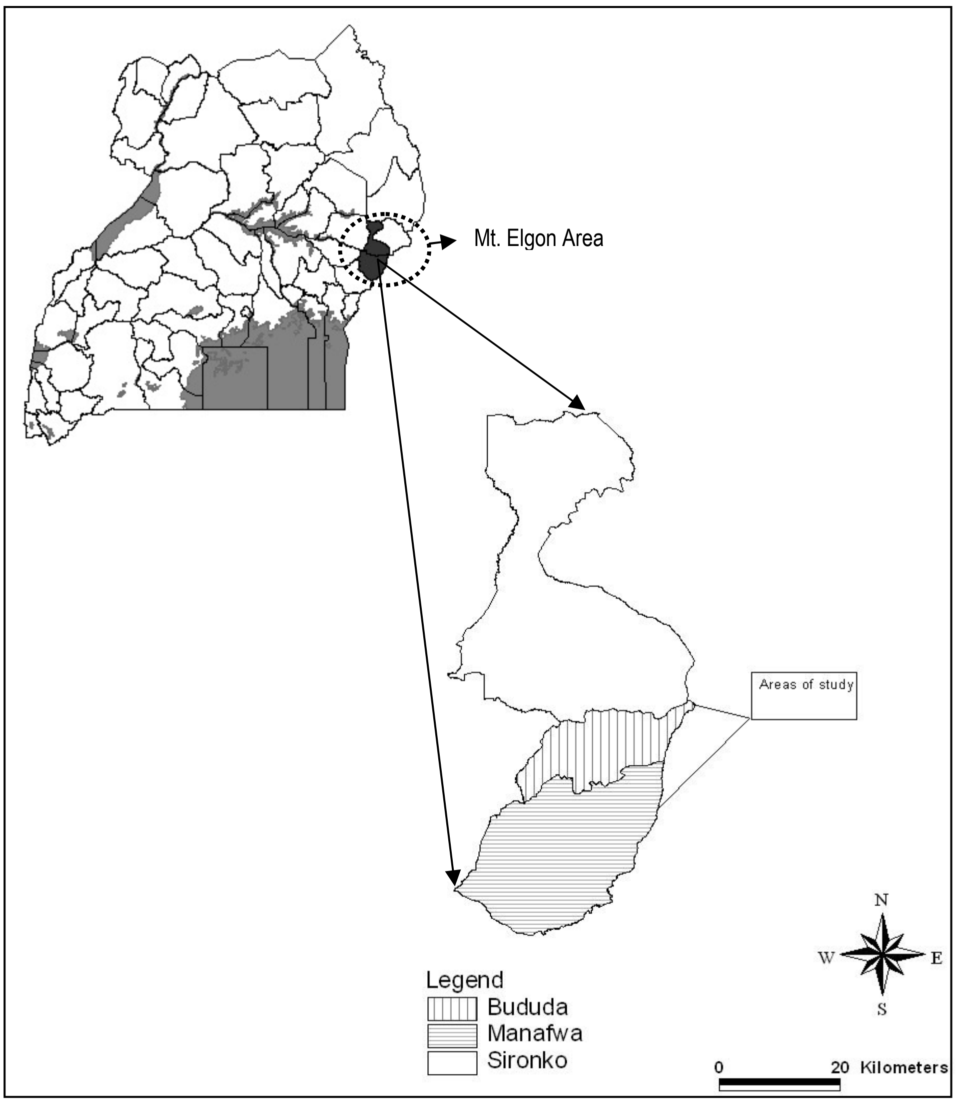


Figure 4.1: The study area indicating the Districts that have recently experienced landslides. Landuse cover/change analysis was restricted to Manafwa District owing to the unavailability of aerial photographs covering the entire area

According to Scott (1994), Mt. Elgon, a solitary volcano is one of the oldest in East Africa. It rises to a height of about 4,320 m above sea level. The area receives an approximately bimodal pattern of rainfall, with the wettest period occurring from April to October. The mean annual rainfall ranges from 1500 mm on the eastern and northern slopes to 2000 mm in the south and the west. Mid altitude slopes oriented towards the east and north at elevations between 2,000 and 3000 metres tend to be wetter than either the lower slopes or the summit. On the lower slopes, the mean maximum temperatures increase from 25º C to 28º C and mean minimum temperatures are 15º C to 16º C. The vast area of the mountain was built up from lava debris blown out from a greatly enlarged volcanic vent during the Miocene period (12-20 million years ago). The relatively young and fertile calcium-sodium-potassium rich soils that cover the slopes are moist, dark humus loams. On the steep slopes in the high altitude moorlands, very shallow soils are found. However, red brown, clay loams have formed on the gentle slopes (MCEP, 1997). The vegetation of Mt Elgon reflects the altitudinally controlled zonal belts commonly associated with large mountain massifs. Four broad vegetation communities are recognized namely; mixed montane forest up to an elevation of 2500 metres, bamboo and low canopy montane forest from 2400-3000 metres and moorland above 3500 metres (Scott, 1994).

Land in the study area is divided between the National Park and farmland. The latter land use is itself divided between two topographic zones; an upland zone, characterized by intensive coffee and maize farming, and a lowland zone, where beans, yams and onions are grown. Arabica coffee is traditionally the major cash crop of the area, and bananas as the staple food. There is however increasing reliance on maize and beans for food, which are also sold for cash. Other crops include Irish potatoes, rice, soybeans, millet, wheat and green vegetables such as cabbages, tomatoes and spinach. Much of the cultivation takes place on steep slopes ranging between 33º and 58º which dominate the landscape of the area. Most households also keep livestock, particularly dairy cattle utilizing zero grazing regime for sale and own consumption of milk and meat, as well as small stocks of goats, sheep, pigs and chicken (Buyinza and Nabalegwa, 2008).

Despite cultivating on steep slopes, there is inadequate use of soil conservation measures in the area, a significant factor that leads to soil erosion, declining soil fertility and decreasing crop yields. The use of soil conservation methods varies with distance from the National Park, such that farmers living far from the Park boundary use far more soil conservation methods than their counterparts in and around the Park. This is explained by the insecure land tenure and the constant fear of eviction by the Park authorities (Mugagga *et al.,* 2010).

4.3 Methods

4.3.1 Aerial photography and Multi-temporal imagery

Remote sensing has shown great potential in land cover mapping and monitoring due to its advantages over traditional procedures in terms of cost effectiveness and timeliness in the availability of information over larger areas (Murthy *et al.,* 1998; Franklin, 2001; Armentaras *et al.,* 2003). In the present study, aerial photographs of 1:24,000 scale taken on 7th February 1960 and Orthophoto maps (1:24,000) of the study area acquired from the Uganda Department of Mapping and Surveys provided a benchmark for analysis of land use and vegetation cover change in the study area. Land use/cover categories ranging from agricultural fields, woodlands to forest cover were mapped from the aerial photographs using a mirror stereoscope. In order to overcome scale distortions inherent to aerial photographs, the mapped details were transposed to transparencies overlaid onto orthophoto maps. The land use and cover maps were captured onto a GIS using Arc GIS 9 Software. Owing to the unavailability of anniversary images of the area, Landsat MS and SPOT imagery taken on 2nd September 1995 and 17th February 2006 respectively were used to assess subsequent land use and land cover changes. The months of February and September are planting and post-harvesting periods in the study area, thus providing a good comparative ground as far as cultivation changes are concerned.

4.3.2 Land use classes

On the basis of a priori knowledge of the study area and the need to consistently discriminate land use/cover classes using images with a different spatial resolution, three broad land use classes were adopted namely; forest cover, woodlands and agriculture. Forest cover consists of a main stratum of continuous and closed canopy broad-leaved ever green trees spread over the area without intervals or breaks. Riparian vegetation, shrubs and bushes were categorized as woodland. All cultivated and fallow land was designated as agricultural fields whose identification was aided by the coinciding planting and post harvesting seasons in the respective images.

4.3.3 Image processing and classification

Despite image pre-processing by Spotimage (suppliers of both Landsat MS and SPOT imagery) that included geo-referencing and orthorecitifcation, geo-rectification accuracy was further improved using 15 ground control points (GCPs) obtained during field visits by means of a Magellan Professional MobileMapper ™ CX. Both the Landsat and SPOT imagery were resampled in IDRISI Andes GIS environment using the nearest neighbour technique and the residual values ranged from 0.0001 to 0.001. Using the 'CALIBRATE' module in IDRISI, radiometric correction of the imagery was carried out. Atmospheric correction was not performed because the post-classification comparison technique adopted for land use/cover analysis also compensates for variations in atmospheric conditions and vegetation phenology between dates, since each land use/cover classification is independently mapped (Coppin *et al.,* 2004; Yuan *et al.*, 2005). The Landsat and SPOT imagery were visually enhanced by processing 8-bit composites with original values and stretched saturation points.

A hybrid supervised/supervised classification approach was used, as the supervised classification was incapable of discriminating the transition between forest cover and woodland. The classification approach therefore comprised; (1) unsupervised classification using CLUSTER algorithm with which eight clusters were created. On the basis of prior knowledge of the study area, the eight clusters were assigned to woodlands and forest cover using the ISOCLUST algorithm in Idrisi environment; (2) a supervised maximum likelihood classification for agricultural fields; (3) fusion of the two classifications using GIS OVERLAY function. Since the two images were acquired by different sensors, the post classification comparison method was used, such that the hybrid classification of the 1996 and 2006 land cover was independently undertaken. This approach has the advantage of compensating for the differences in sensors.

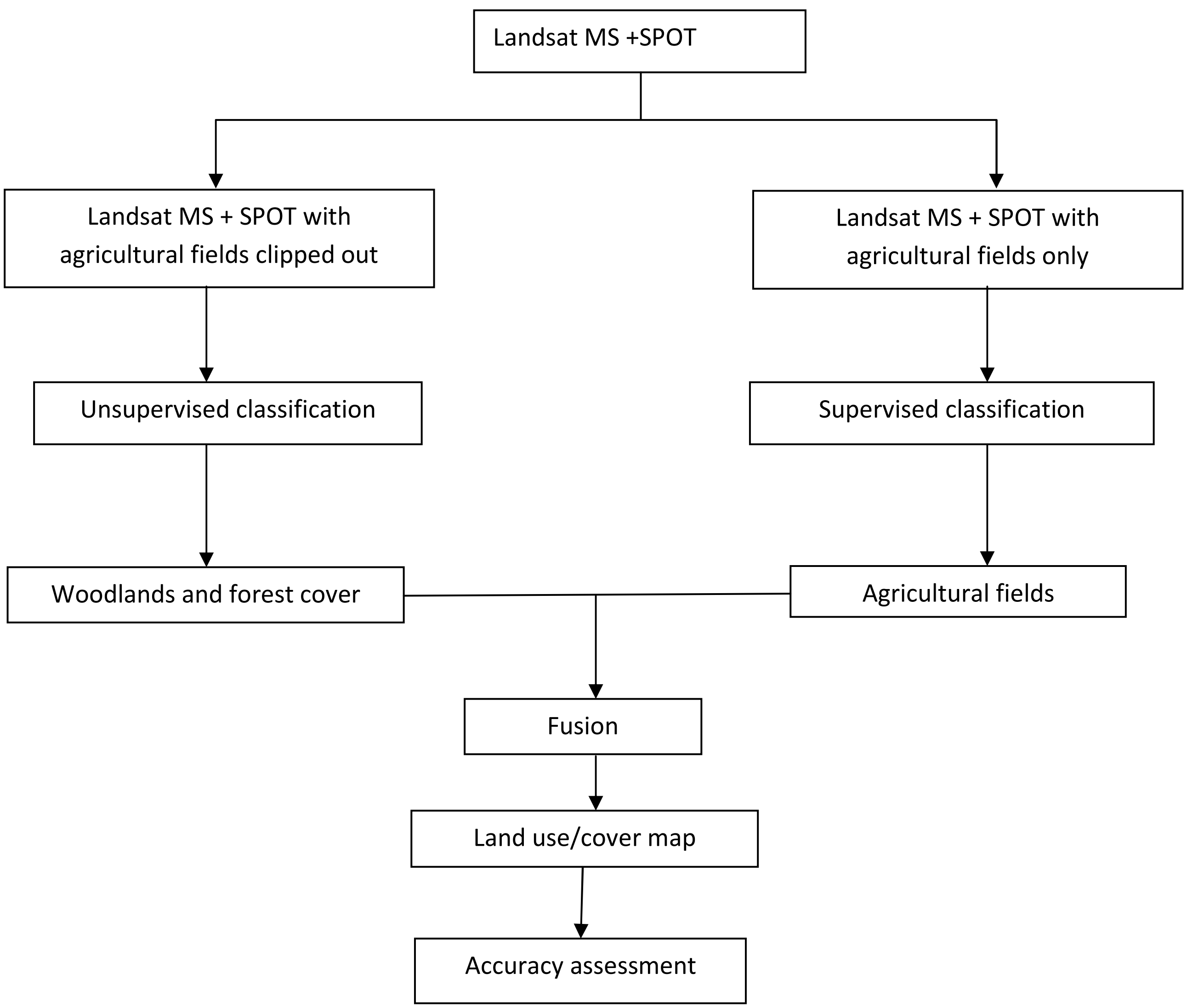


Figure 4.2: Hybrid supervised/unsupervised and post classification comparison scheme

The National Park boundary distinctly marked by thick forest cover was identified using the Normalized Difference Vegetation Indices (NDVI) for both sets of imagery. Among other uses, the NDVI is reliable in monitoring vegetation change (Michael and Graham, 2003; Lillesand and Kiefer, 2004). The upslope limit of the cultivated area was distinctive on both the aerial photographs and satellite imagery; hence, change detection in terms of upslope expansion of cultivated land into the protected forest cover was done by way of overlaying a vector layer marking the 1960 boundary of the protected area on the subsequent imagery. A change detection polygon was delineated and its area calculated in Idrisi Andes database query thus, giving an indication as to the extent of encroachment into the National Park forest between 1960 and 2006.

4.3.4 Classification accuracy assessment

The classification accuracy assessment of remotely sensed data, particularly in developing countries, is greatly compromised by the unavailability of reference ground data or aerial photographs at or near the time of satellite overpass (Skirvin *et al.,* 2004; Kamusoko and Aniya, 2009). In such cases, Congalton and Green (2009), recommend the use of qualitative rather than quantitative accuracy assessments. A qualitative accuracy assessment compares and scrutinizes the differences between a new image and an old data set. In this study, the accuracy for the 1995 Landsat image was qualitatively carried out by comparing it with the 1960 set of aerial photographs. Given that field data acquired in 2008 could not be used to assess accuracy of the 2006 image, qualitative assessment was also used to compare 1995 and 2006 imagery. Distinct land cover features identified during the 2008 fieldwork, which were discernible on the 2006 imagery, were also used as comparison benchmarks.

4.3.5 Landslide surveying and mapping

Field surveying and mapping of landslide sites was undertaken to gain an understanding of the site specific characteristics, particularly topographic attributes of four recent major landslides in the study area. The surveys were conducted from both inside and outside of the Mt Elgon National Park and restricted to recent landslides whose scars are still visible. The fast regeneration of vegetation in this area rendered older landslide scars hard to discern. A Magellan Professional MobileMapper ™ CX was used to map the spatial characteristics of the landslides.

4.3.6 Terrain parameters

The versatility of Digital Elevation Models (DEMs) in terms of deriving macro and micro terrain attributes has been proven in many studies (Band, 1986; Moore *et al.,* 1991; Longley *et al.*, 2001; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kakembo *et al.,* 2007; Sivrikaya *et al.,* 2007; Demirkesen, 2008: Jayaprasad *et al.,* 2009). Local topographic features such as slope, aspect, convexities and concavities play a crucial role in a number of morphological, ecological, and hydrological processes and are thus conditioning factors for landslide occurrence.

In order to establish the relationship between land use, topographic parameters and landslide occurrence, a 15m Digital Elevation Model (DEM) based on Aster imagery was acquired from TTH Earth Observation Consulting Services, France. Using the SLOPE and CURVATURE facilities in Idrisi Andes, slope angle and curvature surfaces were calculated from the DEM. Boolean images for cultivated land and slope angle classes (0-9º, 10-19º, 20-29º and 35º +) were generated using the RECLASS module in Idrisi Andes and overlaid on a slope surface to highlight the extent to which cultivation had expanded into critically steep slopes that form part of the protected area. The slope surfaces calculated from the 15 m DEM were resampled to the 20m SPOT and 30m Landsat MS for overlay purposes using the nearest neighbour resampling technique (Yang and Lo, 2000; Kamusoko and Aniya, 2009). The relationship between landslide occurrence and slope curvature was established by overlaying the mapped sites onto the curvature surfaces of the DEM.

4.4 Results

4.4.1 Land use/cover change between the periods 1960 -1995 and 1995 – 2006

The major land use and cover changes between 1960 and 2006 are illustrated by Figures 4.3 and 4.4.

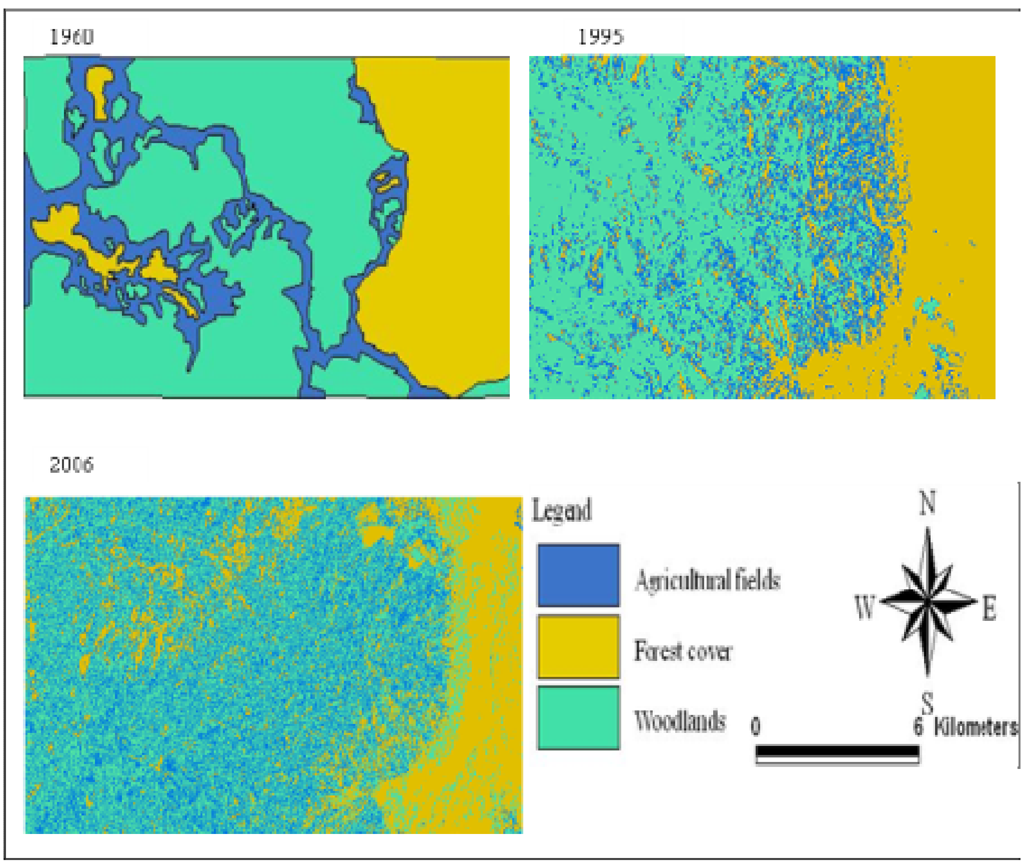


Figure 4.3: Aerial photography details and classified images illustrating landuse/cover between 1960 and 2006

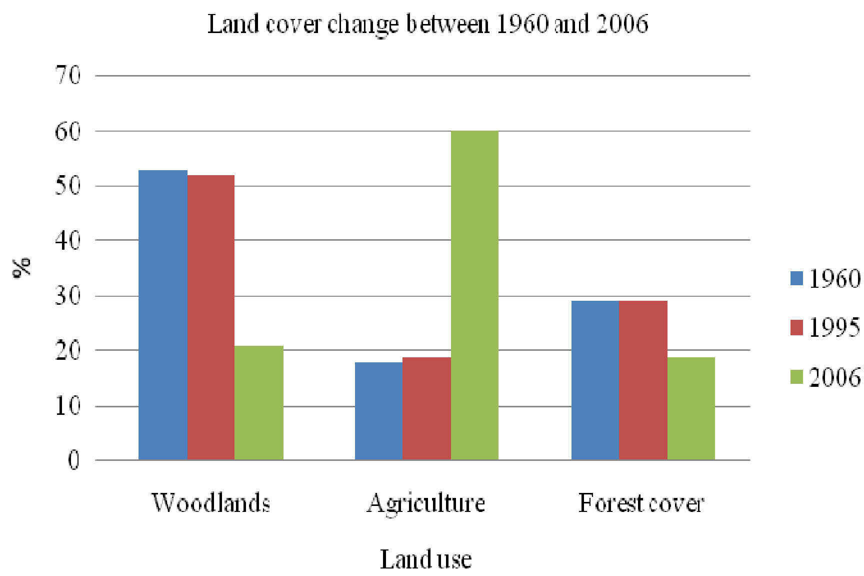


Figure 4.4: Trends in land use change between 1960 and 2006

Woodlands and forest cover were the dominant land use/cover classes between 1960 and 1995. Computed percentages for land use classes show that in 1960, woodlands, forests and agricultural fields occupied 53, 29 and 17 percent of the area, respectively. There were minimal changes in the land use cover between 1960 and 1995. However significant spatial expansion in agriculture and rapid decrease in woodlands and forests were observed during the period 1995 to 2006. The area under woodlands and forest cover was substantially reduced by 58 and 34 percent respectively while agricultural fields increased by 241 percent from 2,024 hectares in 1995 to 6895 hectares in 2006.

4.4.2 Encroachment of cultivation onto critical slopes of the National Park

An overlay of the vector layer marking the 1960 Park boundary onto 1995 Landsat imagery revealed that no encroachment had taken place during this period. However, marked changes in the extent of agricultural encroachment into the National Park forest were detected between 1995 and 2006.

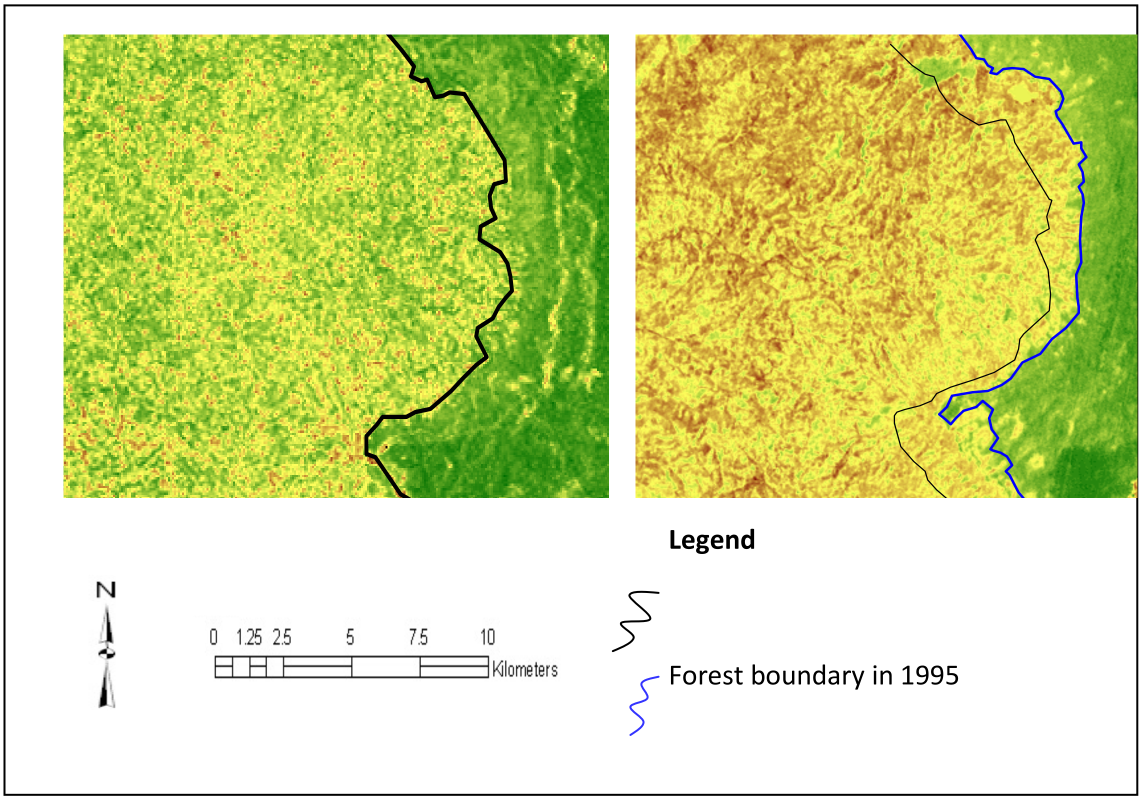


Figure 4.5: Images depicting the extent of forest encroachment between 1960 and 2006

Between 1995 and 2006, 688 ha of National Park forest were lost to illegal expansion of agricultural fields onto critically steep slopes, a phenomenon which is ongoing. Changes in the extent of agricultural fields in relation to slope angle are illustrated by Figure 4.6. The most significant overall trend is the shift from lower and gentle slopes (0-9º) to critically steep ones (10-19º, 20- 29º and 30º +) during the study period. Cultivation on gentle slopes decreased by 19 percent from 1517 hectares to 1231 hectares, but increased by 12, 31 and 61 percent on the 10-19º, 20-29º and 30º + slopes respectively.

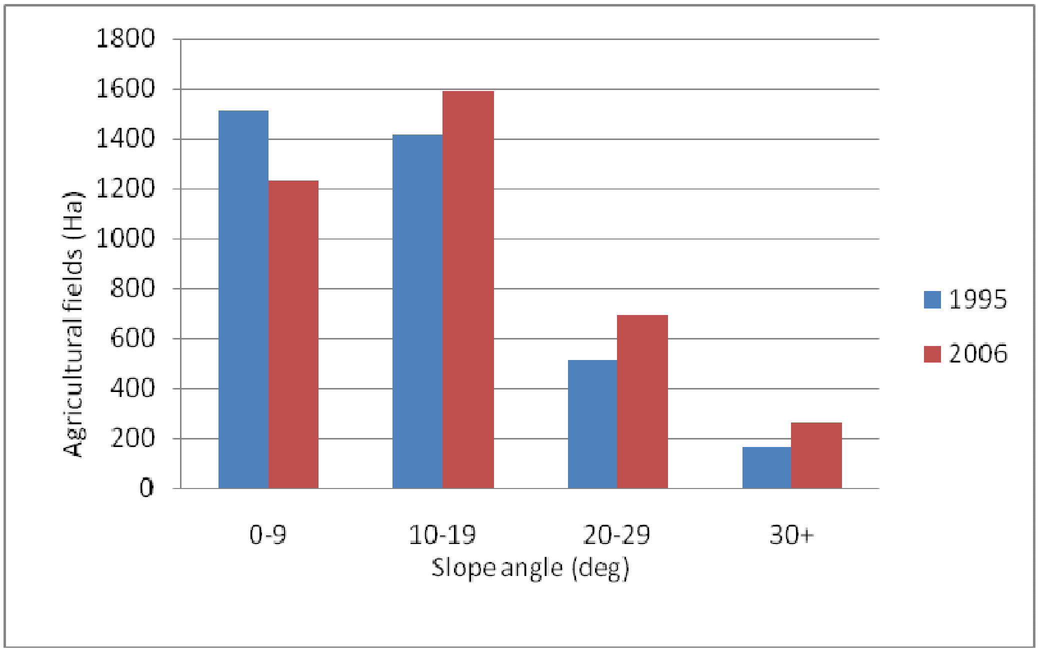


Figure 4.6: Expansion of agricultural fields onto steeper slopes

Similar results were obtained by Buyinza and Nabalegwa (2008) who noted that much of the cultivation took place on slopes ranging between 36º and 58º, which are highly susceptible to landslides.

The role of slope curvature in land slide occurrence has been highlighted by (Knapen *et al.,* 2006; Claessens *et al.,* 2007). In order to determine the relationship between slope curvature and landslide occurrence, curvature surfaces were derived from the DEM and the mapped landslide sites were overlaid. Most of the surveyed landslide sites were found to occur on steep concave slopes (shown with negative indices) which were either under intensive cultivation or were being opened for the same (see Figures 4.7, 4.8 and 4.9).

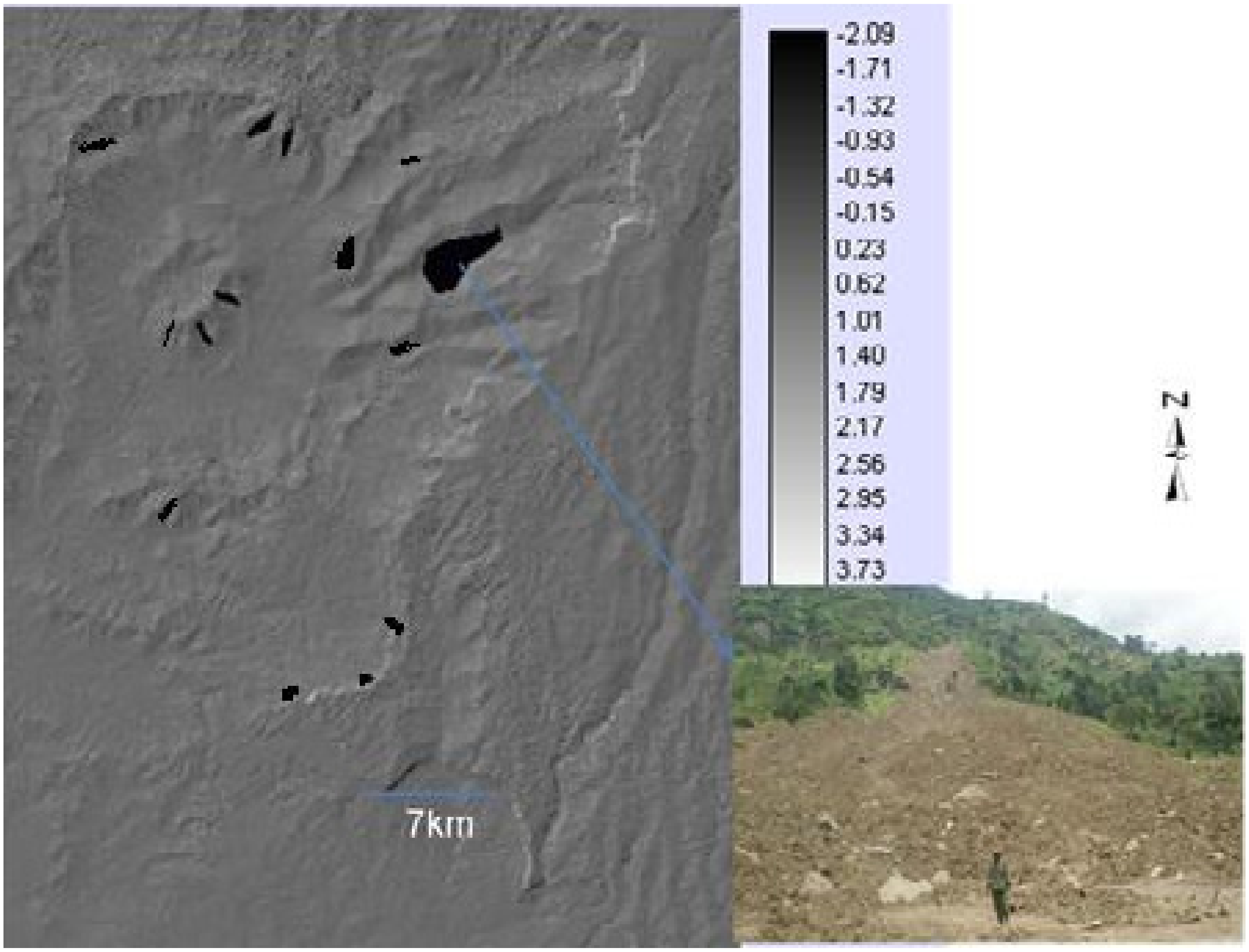


Figure 4.7: Hillshade visualizing the occurrence of landslides on concave slopes. Inset: Photograph of the killer landslide at Nametsi Village that occurred on 1st March 2010. Over 300 people, homes, shops and a community health centre were buried by the debris

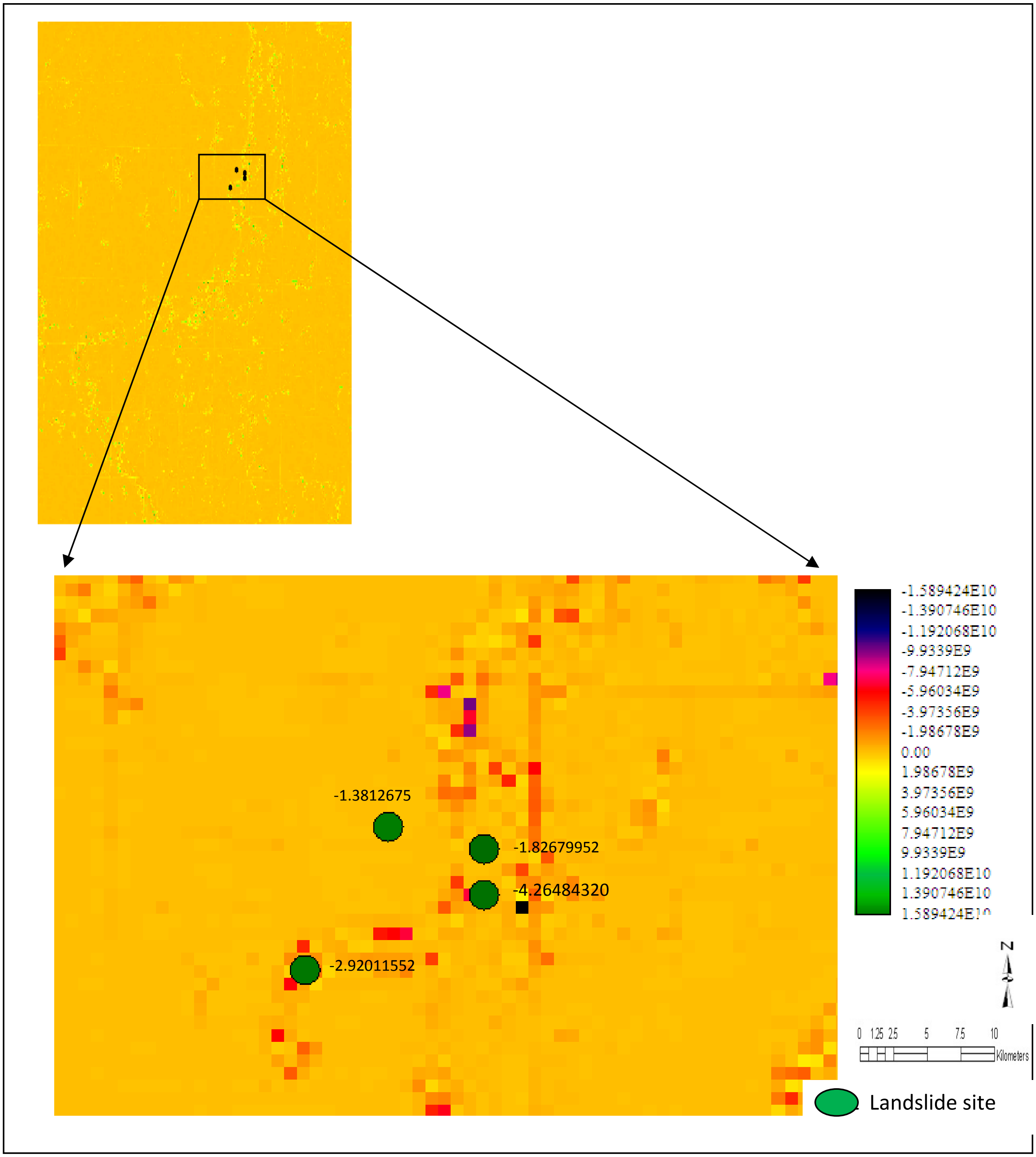


Figure 4.8: Relationship between slope curvature and landslide occurrence. The negative indices depict slope concavity

Figure 4.9: Debris flow site on slopes recently cleared for cultivation

4.5 Discussion

4.5.1 Implications of land use cover change trends

The land use/cover change trends identified above reveal a drastic decimation of forest and woodland cover due to agricultural encroachment particularly into the National Park. This can be attributed to acute land shortages resulting from the exponential population growth in the Mount Elgon region. According to the 2002 Uganda National Census, between 1980 and 2002, the population of Mbale[3] District increased by 82 percent, from 556,941 to 1,012,831 persons. The population density of the area correspondingly increased from 303 persons/km^2 in 1980 to 586

[3] Manafwa, Bududa and some areas of Sironko were then part of wider Mbale District.

persons/km^2 in 2002 (UBOS, 2002). Population pressure and low pa capita income growth account for much of the land cover change (Geist and Lambin, 2001), which are also the main drivers of deforestation in East Africa (FAO, 2003). Coupled with poor farming and subsistence-based agricultural livelihoods, population pressure also compels people to seek farming space from the steep slopes (Buyinza *et al.,* 2008).

Mountain regions are particularly sensitive to anthropogenic impacts. A broad overview of both Landsat 1996 and SPOT 2005 satellite imagery clearly indicates that forest cover for the entire region stretching from the northern slopes (Kapchorwa) to the South Eastern slopes on the Ugandan side of Mt Elgon has been decimated. The loss of vegetation cover inevitably alters mountain hydrology and has implications for local and regional climate variability (Beniston, 2003, IPCC, 2007a, b). Such variability is not confined to mountain ecosystems, as populated lowlands depend on mountain water resources. Vegetation change and associated shifts in intra-annual precipitation patterns could give rise to drought episodes (Barnett *et al.,* 2005). The impacts of climate variability have already in been reported by NEMA (2008) in the low lying areas of Butaleja, Soroti and Pallisa Districts that surround Mt Elgon. These include drought, heat waves, and flash floods, economic dislocation, decline, conflict, crop failure, and associated malnutrition and hunger.

As noted by Knapen *et al.,* (2006), population pressure forces people to cultivate unsuitable steep slopes, thus contributing to slope instability. Similar trends in land use and cover change have been observed in other mountain environments. For example, most bushlands on the slopes of Mt Kilimanjaro are progressively being replaced by agricultural fields (Yanda and Shishira, 2001; William, 2002; Soini, 2005). Lung and Schaab (2010), also identified positive relationships between population pressure and forest clearance in mid altitude tropical forests of Kakamega and Budongo in Kenya and Uganda respectively. Studies in non- mountain environments also show similar trends. Kamusoko and Aniya (2009), found significant positive correlations between population density and the clearance of woodlands for agriculture between 1973 and 2000 on commercial farmlands and communal areas of Bindura District, Zimbabwe.

The tremendous loss of forest and woodland cover between 1995 and 2006 could also be explained by the prevalent political climate. The beginning of land politics in the Mt Elgon region can be traced back to the 1980 General Elections, where several politicians promised parts of the National Park to the Bagisu and Sabiny resident tribes. According to UWA (2000), by 1983, many parts of parts of the National Park forest in Kapchorwa (Benet) and Mbale (Bumbo) were poorly excised, leading to initial encroachment attempts. Against this background, local politicians are reported by UWA (2000) to have incited the local communities to uproot Park boundary markers and grow crops in the Park, besides felling of trees. The contribution of agricultural expansion to slope instability and landslide inducement is explained in the subsequent subsection.

4.5.2 Slope factors and landslide occurrence

An expansion of agricultural fields from lower and gentle slopes to critically steep ones was identified as the most significant land use change trend. The role of this phenomenon in inducing slope instability has been inferred by many a scholar (Ian and Flores, 1999; Glade, 2002). All the landslide sites surveyed were found to occur on steep concave slopes. This is in keeping with Knapen *et al.,* (2006), who identified steep concave slope segments oriented to the north-east dominant rainfall direction as the most favourable precondition for mass movement, especially at relatively large distances from the water divide. The soil hydrological conditions on concave slopes are greatly altered through deforestation and intensive cultivation. This not only enhances saturation, but also triggers a series of debris flows under extreme rainfall events (Inganga *et al.,* 2001; Nyssen *et al.,* 2002; NEMA, 2007). The problem nature of the soils at the landslide sites was identified by Mugagga *et al., (submitted).* In a nutshell, deforestation and cultivation drastically lower the threshold of slope stability in densely populated steep concave slopes of Mt Elgon.

4.6 Conclusion

A drastic decimation of forest and woodland cover by agricultural encroachment particularly between 1995 and 2006 has been identified as the main land use change trend. Population pressure coupled with politicisation of land access was noted as the main driver of the illegal agricultural expansion. Deforestation and cultivation of steep concave slopes alters soil hydrologic conditions within the slope elements by way of enhancing saturation, hence triggering debris flows. Deforestation also has onsite and offsite climate variability implications. It is recommended that forest cover be restored and the local communities restrained from opening up new areas for cultivation on critical slopes particularly within the protected area.

CHAPTER FIVE

The Characterization of Soil Physical Properties and Implications for Landslide on the Slopes of Mount Elgon, Eastern Uganda.

Abstract

Soil properties of major landslides that occurred recently on the mid-altitude slopes of Mount Elgon, Eastern Uganda were analysed. A mudflow, located at the Kitati protected forest site, and two deep debris flows on the Nametsi and Buwabwala deforested slopes (slope steepness between 36º – 58º) were surveyed. In order to test the hypothesis that 'soils at the landslide sites are particularly 'problem soils' and thus prone to landslides', the following analyses were undertaken: particle-size distribution, Atterberg limits, shear strength, and factor of safety (F). Soils at the Kitati and Buwabwala sites exhibited expansive potential, owing to clay content that is well above 20 percent. A clay content exceeding 32 percent was identified at the Nametsi debris flow site implying an extremely high expansive potential of the soil. Furthermore, soils from these sites were generally fine grained with more than 50 percent of the material passing the 0.075mm sieve. High liquid limits at Kitati (59 percent) and Buwabwala (53percent) meant that the soils qualified as vertisols, a type associated with landslides. High plasticity indices (averaging 33percent) confirmed the vertic nature of soils at the Nametsi debris- flow site. These soil attributes imply low permeability, excessive water retention and high susceptibility to expansion and sliding.

Whereas the value of F<1 for the Kitati site signifies an inherently unstable slope, Nametsi and Buwabwala are supposedly stable slopes (F >1). Despite this finding, the stable sites could be described as only conditionally stable because of the interplay of various physical, pedological and anthropogenic factors.

The results point to the fact that soils at the landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention. Therefore, the hypothesis that soils at three landslide sites are inherently 'problem soils' and prone to landslides, is accepted. Despite the focus of the study on the mid-altitude slopes of Mt Elgon, the results are similar to earlier investigations carried out on the lower, more densely-populated slopes, thus confirming the widespread occurrence of problem soils on Mt Elgon. Conservation-based, land-use options need to be undertaken on the mid-altitude slopes.

Keywords: Clay content, atterberg limits, expansive potential, vertic soils, problem soils, Mt Elgon.

5.1 Introduction

Mass movements are recognized and well documented global geomorphic hazards due to their major role in the development of hillslopes in mountainous areas and their considerable economic, social and geomorphological impacts (Knapen *et al.,* 2006). However, literature on landslides in East Africa's highlands is rather still restrictive (Ngecu and Mathu, 1999; Knapen *et al.,* 2006; Claessens *et al.,* 2007). Some of the landslide studies that have been conducted in the East African region include, (Ngecu and Inchangi, 1989; Davies, 1996; Westerberg and Christiansen, 1998; Ngecu and Mathu, 1999; Westerberg, 1999; Inganga *et al.,* 2001) in Kenya; (Muwanga *et al.,* 2001; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009) in Uganda; (Rapp *et al.,* 1972; Christiansen and Westerberg, 1999) in Tanzania; (Moeyersons, 1989; 2003) in Rwanda. These studies suggest anthropogenic factors such as slope disturbance, particularly deforestation related to population pressure as the major causes of landslides in East African highlands (Ngecu and Mathu, 1999; Muwanga *et al*., 2001; Breugelmans, 2003; Knapen, 2003; Glade and Crozier, 2004; Kitutu *et al*., 2004; Knapen *et al*., 2006; Kitutu *et al*., 2009).

Knapen *et al.,* (2006), attribute landslide occurrence on stable, marginally stable and actively unstable slopes of Mt Elgon to a combination of preconditions, preparatory and triggering causal factors. Preconditioning factors including topography (slope angle, length, aspect, gradient, and curvature), lithology, shrink-swell soil properties and annual rainfall receipts act as catalysts to allow other destabilizing factors to act more effectively. On the other hand, preparatory factors including human activities (such as cultivation, excavation for housing, foot paths and deforestation) tend to place slopes in a marginally stable state, making them susceptible to mass movement without actually initiating it. Triggering factors shift slopes from being marginally stable to actively unstable state by initiating movement. Such factors include seismic activity, extreme rainfall events related to the El Niño phenomenon, and concentration of runoff in restricted infiltration zones such as hollows (Glade and Crozier, 2004; Knapen *et al.,* 2006).

Specific soil parameters particularly physical properties such as bulk density, cohesiveness and shear strength have been noted to affect stability on disturbed slopes (Sidle *et al.,* 1985; Zẽzere *et al.,* 1999; Kitutu *et al.,* 2004; Kitutu *et al.,* 2009; Zung *et al.*, 2009). Other scholars (see Van Der Merwe, 1976; Schwartz, 1985; Bell and Maud, 1994; Bell and Walker, 2000; Bell and Culshaw, 2001; Baynes, 2008) have used similar properties to characterize the problem nature and behaviour of soils. According to Bell and Culshaw (2001) and Baynes (2008), problem soils comprise expansive, soft clays, collapsible and dispersive soils. Problem soils may induce slope failure due to their distinct shrink-swell properties at various moisture contents (Van Der Merwe 1964, MoW, 1999; Bell and Culshaw, 2001). The Plasticity Index and clay content percentage within the vertic and melanic top soil horizons can be used to characterize expansive soils (Van Der Merwe, 1964:1976, SCWG, 1991, Green and Turner, 2009). Vertic soils are considered highly expansive with a Plasticity Index of >32 percent, while soils with a melanic A horizon are defined as those which among other attributes, have a Plasticity Index of less <32 percent (Van Der Merwe *et al.,* 2002). Despite not being considered in many landslide studies, problem soils were noted by Williams *et al.,* (1985) to be widespread around the world. Their prevalence in the tropics is particularly favoured by climatic conditions (Baynes, 2008).

Particle size and distribution of pores within the soil matrix were observed by Sidle *et al.,* (1985) to influence slope stability. Knapen *et al.,* (2006) attributed landslide occurrence on East Africa's highlands to rainfall, steep slopes, slope curvature and high clay contents in the soils. More recently, Kitutu *et al.,* (2009) compared soil properties along transects across a series of shallow landslides and zone without landslides within villages on disturbed footslopes of Mt Elgon. Whereas previous landslides studies focussed on the disturbed Mt Elgon footslopes, the present study compares landslides on the midslopes within and outside Mt Elgon National Park. One of the landslides occurred in a protected pristine forest environment within the Park while the other two are located at sites deforested for cultivation within and outside the National Park. In the main, it is hypothesised that soils at three landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention.

5.2 The Study Area

Mt Elgon (1°25´N and 34°30´E) is situated on the Kenya-Uganda border, approximately 100km NorthEast of Lake Victoria. According to Scott (1994), Mt. Elgon, a solitary volcano is one of the oldest in East Africa rising to height of about 4,320 m above sea level. The region receives a bimodal pattern of rainfall, with the wettest months occurring from April to October. The mean annual rainfall ranges from 1500 mm on the eastern and northern slopes to 2000 mm in the south and the west. Midslope locations at elevations between 2,000 and 3000 metres tend to receive more rainfall than either the lower slopes or the summit, (UWA 2000). On the lower slopes, the mean maximum temperatures increases from 25°C to 28°C and mean minimum temperatures are 15° C to 16° C. A vast area of the mountain was built up from lava debris blown out from a greatly enlarged vent during the Miocene period about 12-20 million years ago (Scott, 1994). The relatively young and fertile calcium-sodium-potassium rich soils on the slopes are shallow, dark, humus loams that are permanently moist. On the steep slopes in the high altitude moorlands, very shallow soils are found. However, red brown, clay loams have formed on the gentle slopes (MCEP 1997). The vegetation of Mt Elgon reflects the altitudinally controlled zonal belts commonly associated with large mountain massifs. Howard (1991), recognized four broad vegetation communities namely; mixed montane forest up to an elevation of 2500 metres, bamboo and low canopy montane forest from 2400- 3000 metres and moorland, above 3500 metres .

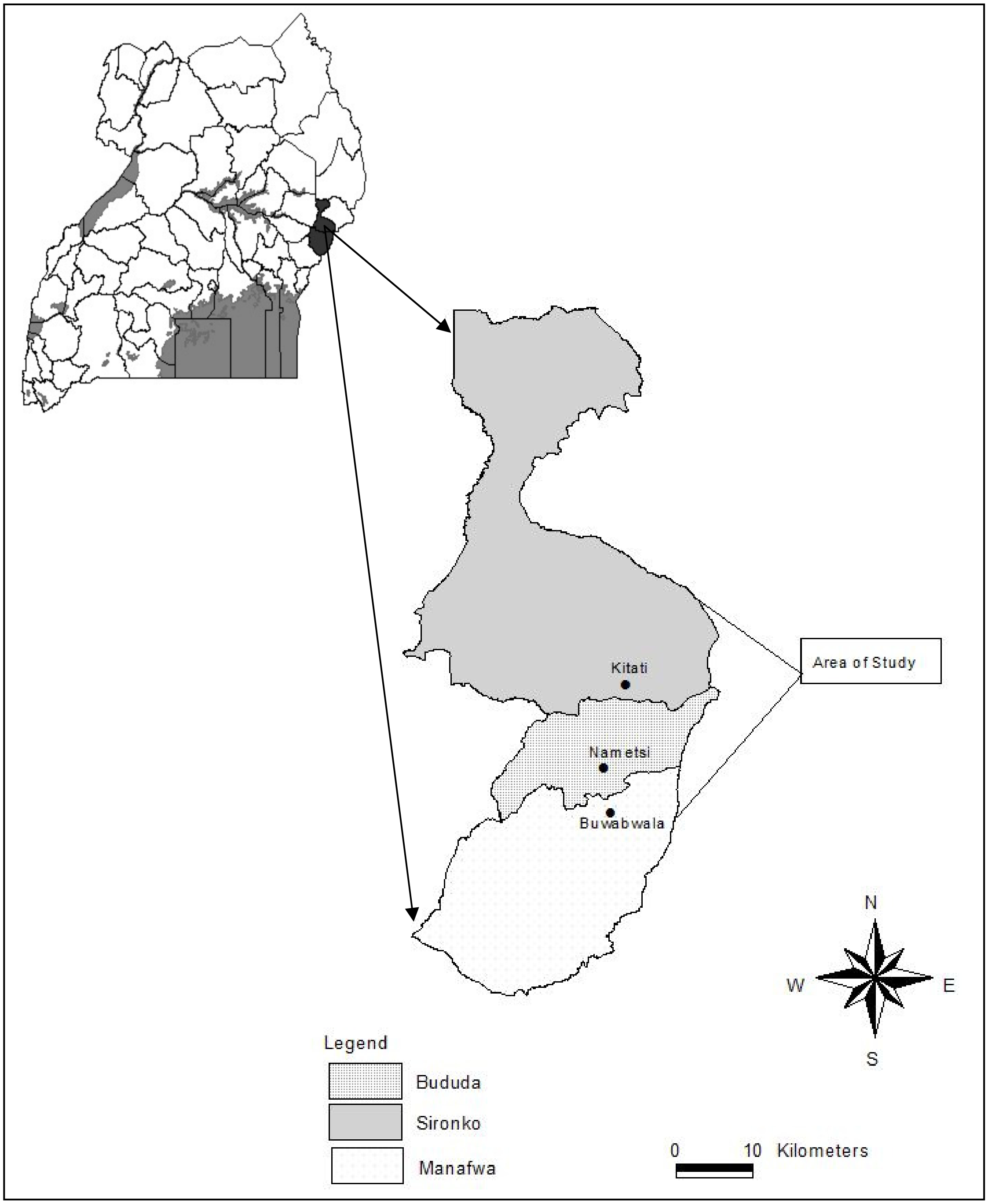


Figure 5.1: Location of the study areas on the Mount Elgon Volcano showing the study sites within the three districts

5.2.1 The study sites

5.2.1.1 Buwabwala site

Buwabwala is found in Tsekululu Sub County on the midslopes (1900 – 2500 m a.s.l, slope angle 36º - 58º) of Mount Elgon in Bubulo County, Manafwa District, Eastern Uganda. Despite being inside the Mt Elgon National Park boundary, this area is heavily encroached for agriculture, grazing, collection of firewood, harvesting of construction materials and poaching of animals. A series of periodical deep and shallow debris flows were reported to have occurred in this area in the past. A deep debris flow reported to have occurred in June 2006 (one of the wettest months in this area) after a spell of torrential rainfall events was surveyed and mapped in the present study.

Figure 5.2: Part of the debris flow site at Buwabwala

5.2.1.2 Kitati site

This is a deep mudflow that occurred during the intense rainfall spell experienced in December 2008. Kitati site is located in Bumulegi village, Budadiri East County, Sironko District. It lies at an altitude of range of 2000 to 2500 metres above sea level and is part of the steep (33º-56º) pristine densely forested slopes of the gazetted National Park. Given that previous landslide investigations in the area (Breugelmans., 2003; Knapen, 2003; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009) had been conducted at sites impacted by human activity, this site presented a unique and intriguing scenario of having occurred in a pristine protected area. There was need to gain an understanding of the underpinnings of landslide occurrence in the area devoid of human impacts.

Figure 5.3: Part of the Kitati landslide site inside the pristine densely forested slopes of Mt. Elgon National Park

5.2.1.3 Nametsi site

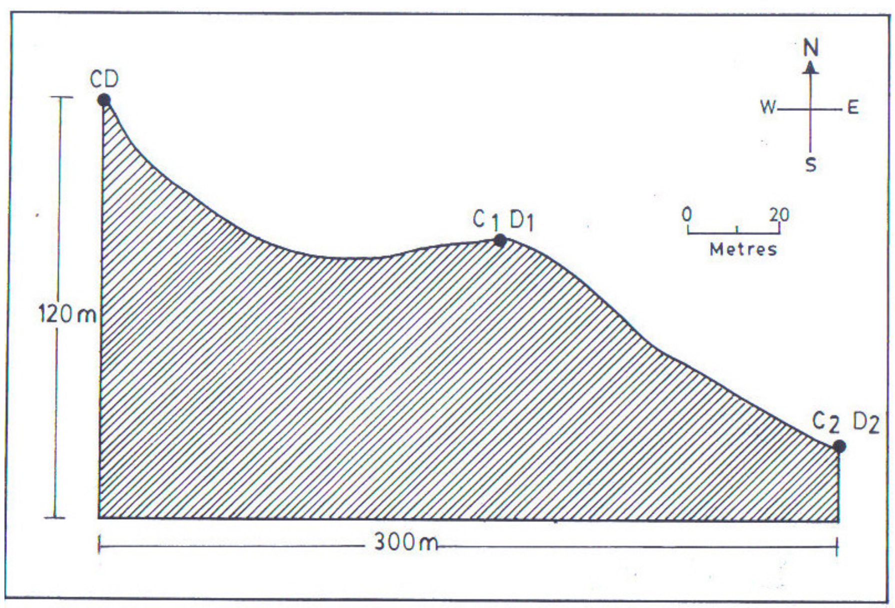
Nameitsi is located on the western slopes of Mount Elgon in Bukalasi Sub County, Bududa District. It is dissected by streams radiating from the Mt Elgon crater flowing over rugged steep slopes ranging between 36º and 56º. Field observations revealed that this landslide was a deep debris flow at an altitude of 1900m a.s.l. It occurred on 1st March 2010 after a series of torrential rains and moved enormous volumes of soil mass and boulders, burying three villages and killing over 300 people who had gathered on a market day.

Figure 5.4: Killer landslide at Nametsi Village. Over 300 people, homes and a community health centre were buried by the debris

5.3 Materials and methods

5.3.1 Landslide surveys

Field surveys entailed mapping the deep landslide complex at Buwabwala using a Magellan Professional MobileMapper ™ CX. One longitudinal and three cross-sectional profiles were undertaken using an abney level and a tape measure. The longitudinal profile was positioned in the centre of the landslide. Two of the cross sectional profiles were positioned within depletion (CD) and debris slide zones (C^2D^2), while the third was in zone of accumulation (C^1D^1) as illustrated by figure 5. The cross-sectional profiles were positioned to highlight variations in slope angle and accumulation of debris within the landslides. Three lobes were identified at the points of intersection between the longitudinal and cross-sectional profiles.



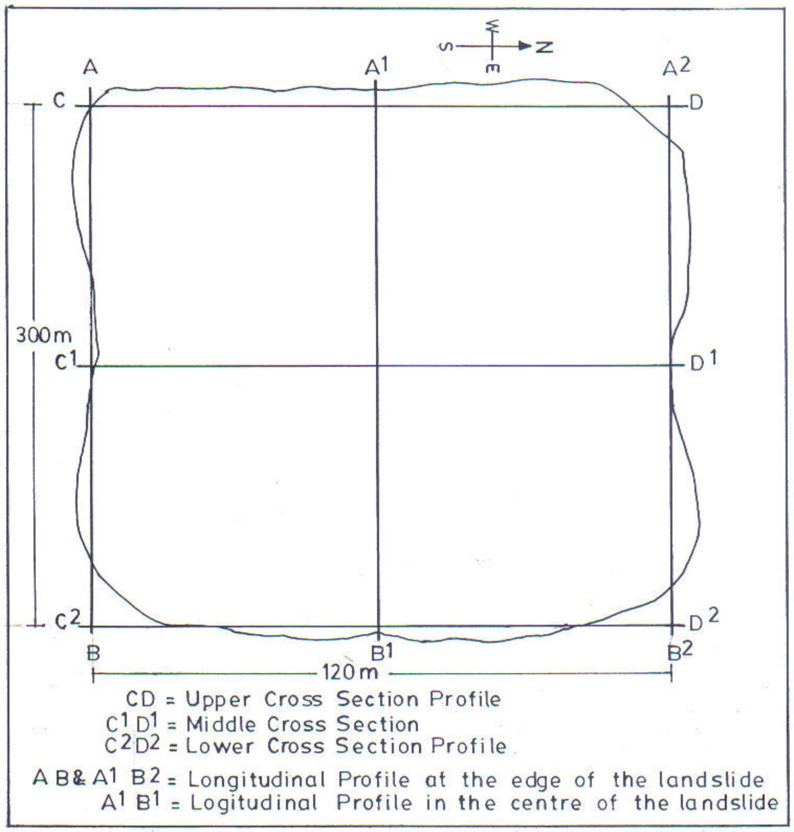


Figure 5.5: Schematic presentation of the Buwabwala landslide complex showing cross sectional and longitudinal profiles within the different zones

At each point of intersection, pits were dug to a depth of 150 cm. Soil samples were obtained at different depths (at an interval of 30 cm) using sampling cores and kept in plastic bags.

Owing to the freshness and highly fragile nature of the moist material at the Nameitsi and Kitati sites at the time of fieldwork, surveying was limited to capturing coordinates using a MobileMapper, and soil sampling at both sites was limited to the top 80 cm. That notwithstanding, the deep and rotational nature of the flows at the two sites provided a reasonable idea as to the soil characteristics at greater depths. Three sampling spots were identified at either site and samples were obtained at an interval of 20 cm. The depth of the debris flow material at the Nameitsi killer landslide was estimated by comparing MobileMapper elevation readings of the different coordinates captured and 15 m DEM of the area.

5.3.2 Laboratory analyses

In order to establish and characterize the problem nature of the slope material in terms of its implications for slope stability, a range of analyses were carried out at the Geotechnical Laboratory, Faculty of Technology, Makerere University and TecLab Limited, Nalukolongo viz; soil particle distribution, Atterberg limits (liquid and plastic limits) and shear strength. Particle distribution was conducted in accordance with British Standard test (BS) 1377: Part 2 sub clause 9.2: 1990. The percentage of clay in particular gives a clear indication as to the problem nature of the soils.

The determination of Atterberg Limits is an important component of soil analysis, as it also points to the problem nature or otherwise of the soil, particularly in terms of its expansiveness at different moisture and clay contents (Selby, 1993). Such behavioural properties can be used to explain the susceptibility of slopes to various slope processes. In the present study, the plastic and liquid limits were determined in accordance with BS 1377: Part 2, sub clause. 4.5:1990. The lower and higher the organic matter and clay content of the soil, the higher the plasticity index respectively (De La Rosa, 1979; Husein *et al*., 1999). The plasticity of the soil samples was further determined using the Unified Soil Classification System (USCS) plasticity chart, which also enabled further classification of the fine material.

Shearing strength in soils is the result of the resistance to movement at inter-particle contacts, due to particle interlocking, physical bonds across contact areas and chemical bonds. Shear strength parameters (cohesion and internal friction) are crucial for slope stability analyses. A Shear Box Test was carried out on undisturbed samples in accordance with BS 1377: Pat7: 1990. This method allows a direct shear test to be made by relating the shear stress at failure to the applied normal stress. It enables the determination of the effective shear strength parameters of the soil namely; the cohesion (C) and the internal angle of friction (φ) values which are then used to calculate the factor of safety of slopes. Theoretically, if the factor of safety is > 1, then the slope is naturally stable, its failure may be due to external factors. Conversely if it is < 1, then the slope is inherently unstable (Berry and Reid, 1988). The factor of safety (F_s) was calculated thus;

$$F = \left[1 - \frac{\rho_w}{\rho_s} \cdot \frac{D_w}{D}\right] \frac{\tan \phi}{\tan \alpha} + \frac{2C}{\rho_s g D \sin 2\alpha}$$

Where; D_w = Depth of landslide, C= cohesion, D= Slip depth, ϕ = Internal angle of friction, α = slope angle, ρ_w = unit weight of water (1 Mg/cm^3), ρ_s = Unit weight of soil, g = Gravitational acceleration (9.81 m/s^2).

5.4 Results

5.4.1 Field Surveys and mapping

Field observations revealed that the Buwabwala and Nametsi landslide sites were rotational debris flows, while Kitati was a mud flow given the enormous amounts of unconsolidated earth and fluid debris (see Figure 5.7). Evidence from pits dug at the Buwabwala site clearly indicated an inversion of materials from the greater depth to the surface and vice versa as illustrated by Figure 5.6. Using a 15m DEM, all three sites were found to have occurred on concave slopes ranging between 36º and 66º steepness (Mugagga *et al., submitted).*

Field measurements revealed that the depletion zone of the Buwabwala landslide covered approximately an area of 208 by 165 m with an average scarp depth of 4.5m. The accumulation zone occupied an area of 125 by 55 m, while the debris slide zone with an average debris diameter of 2.125 m covered 270 by 27.5 m, burying the first maize crop at the freshly cleared. The depth of the Nametsi killer landslide calculated as described earlier was estimated as ≥8 m.

The dimensions of the depletion zone of the Buwabwala landslide site are summarised in Table 5.1.

Table 5.1: Dimensions of the Buwabwala landslide site

		Length (m)	*Width (m)*	*Scarp depth (m)*
Depletion zone	Minimum	15	30	0.5
	Maximum	180	110	8.4
	Average	97.5	70	4.45
Accumulation zone	Minimum	30	40	
	Maximum	220	70	
	Average	125	55	
Debris slide zone	Minimum	40	15	
	Maximum	500	40	
	Average	270	27.5	

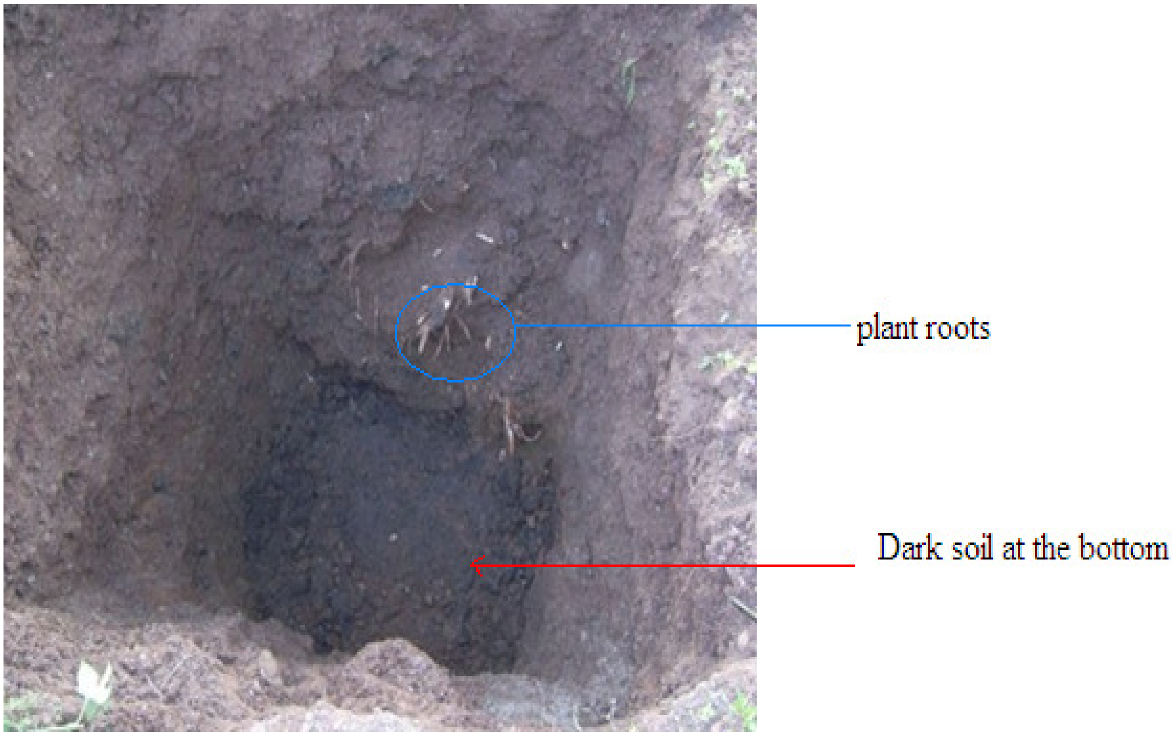


Figure 5.6: Evidence of rotation as shown by dark soil and the plant roots that were found buried at a depth of 2 metres.

Figure 5.7: Mudflow at Kitati landslide site

5.4.2 Soil texture

The soil texture of the three sites is presented in Table 5.2;

Table 5.2: Texture analysis. Take note of the > 10 clay content at the three sites

Buwabwala landslide site					
Profile depth (cm)	Percent OM	Percent Sand	Percent clay	Percent Silt	Textural class
Upper slope profile					
0 - 30	2.4	56	20	24	Sandy clay loam
30 - 60	1.6	60	20	20	Sandy clay loam
60 - 90	1.6	56	20	24	Sandy clay loam
90 - 120	1.2	48	26	26	Sandy clay loam
120 -150	1.4	52	23	25	Sandy clay loam
Middle slope profile					
0 – 30	1.5	44	26	30	Loam
30 -60	0.6	46	32	22	Sandy clay loam
60 – 90	0.7	44	30	26	Clay loam
90 – 120	0.5	56	24	20	Sandy clay loam
120 - 150	1.3	42	27	31	Loam
Lower slope profile					
0 – 30	3.6	56	24	20	Sandy clay loam
30 - 60	1.0	76	10	14	Sandy loam
60 – 90	1.2	56	18	26	Sandy loam
90 - 120	1.2	48	24	28	Sandy clay loam
120 - 150	0.9	52	19	29	Sandy clay loam
Kitati landslide site					
Sampling spot 1					
0- 20	7.1	40	32	28	Sandy clay
20- 40	6.1	64	14	22	Sandy loam

40 -60	8.0	42	30	28	Sandy clay loam
60 - 80	6.8	43	26	31	Sandy clay
		Sampling spot 2			
0- 20	7.1	44	27	29	Sandy loam
20 – 40	6.0	56	18	26	Sandy loam
40 – 60	5.8	62	17	21	Sandy loam
60 - 80	7.0	40	28	32	Sandy loam
		Sampling spot 3			
0 – 20	6.8	44	26	30	Sandy loam
20 – 40	6.4	46	30	24	Sandy clay loam
40 – 60	5.4	41	27	32	Sandy loam
60 – 80	6.6	60	19	21	Sandy loam
		Nametsi landslide site			
		Sampling spot 1			
0 – 20	3.3	6	48	46	Silty clay
20 – 40	4.2	11	43	46	Silty clay
40 -60	2.9	15	46	39	Clay
60 - 80	3.2	7	48	45	Silt clay
		Sampling spot 2			
0 - 20	3.0	9	42	49	Silty clay
20 – 40	2.7	22	36	42	Silty clay
40 – 60	1.7	18	39	43	Silty clay
60 - 80	2.5	19	42	39	Clay
		Sampling spot 3			
0 - 20	1.2	25	38	37	Clay
20 – 40	1.3	28	32	40	Silty Clay
40 – 60	1.4	27	34	39	Silty clay
60 - 80	3.2	14	42	44	Silty clay

As can be noted from Table 5.2, soil samples for Nametsi on average have clay content exceeding 32 percent implying extremely high expansive potential. The soils at Buwabwala and Kitati sites too exhibit expansive potential owing to clay content that is well above 20 percent on average. Such clay content has implications for the shrink- swell properties of the soil. A 10 percent clay threshold has been used as indicator of expansive potential while >32 percent clay content exhibits extreme expansivity (Van Der Merwe, 1964; Baynes, 2008). The particle distribution presented in the subsequent sub-section further characterises the landslide prone nature of the soils.

5.4.3 Soil particle distribution

The particle distribution curves for the three sites are illustrated by Figure 5.8

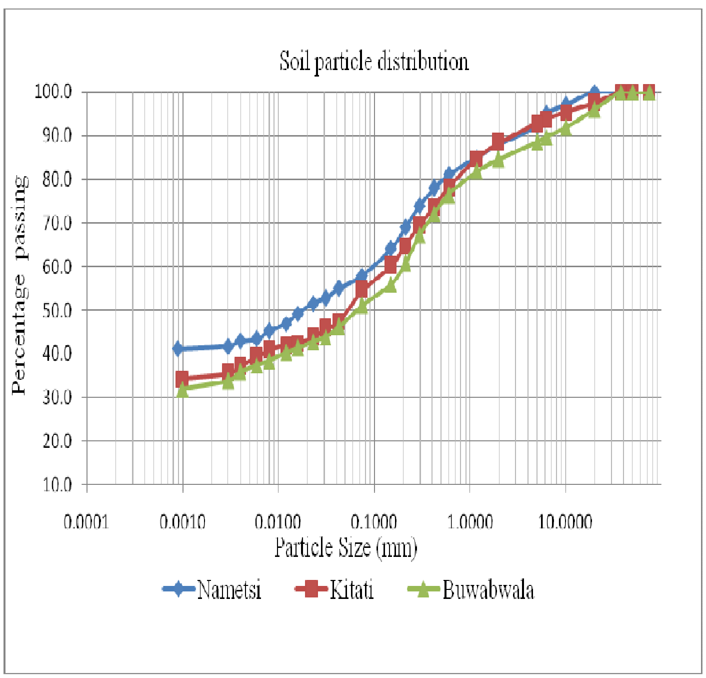


Figure 5.8: Soil particle distribution curves for the three sites

Soils from the respective sites were generally well graded and fine grained with more than 50 percent of the material passing the 0.075mm sieve. However, as can be noted, soils of the Nametsi site are finer than the other two sites. The extremely fine textured nature of the material at the sites also has strong implications for landslide occurrence as will be discussed.

5.4.4 Atterberg limits

In order to gain insights into soil behaviour in response to water content and implications for landslide occurrence, atterberg limits were calculated as are illustrated by Table 5.3.

Table 5.3: Atterberg limits for the respective sites

Atterberg Limits (percentage)	*Buwabwala*	*Kitati*	*Nametsi*
Liquid Limit (LL)	53.5	59.0	47
Plastic Limit (PL)	29.7	38.7	14
Plasticity Index (PI)	23.8	20.3	33

As can be noted from Table 5.3, the Liquid Limit for all the sites is way above the threshold of 25 percent, implying high expansive potential of the soils. The high Liquid Limit and Plasticity Index >32 percent further affirms the extremely high expansive potential for soils at the Nametsi site. This points to the inherently problem nature of the soils. The plasticity index which demonstrates volume change characteristics of the soils is illustrated by the plasticity chart (Figure 5.9).

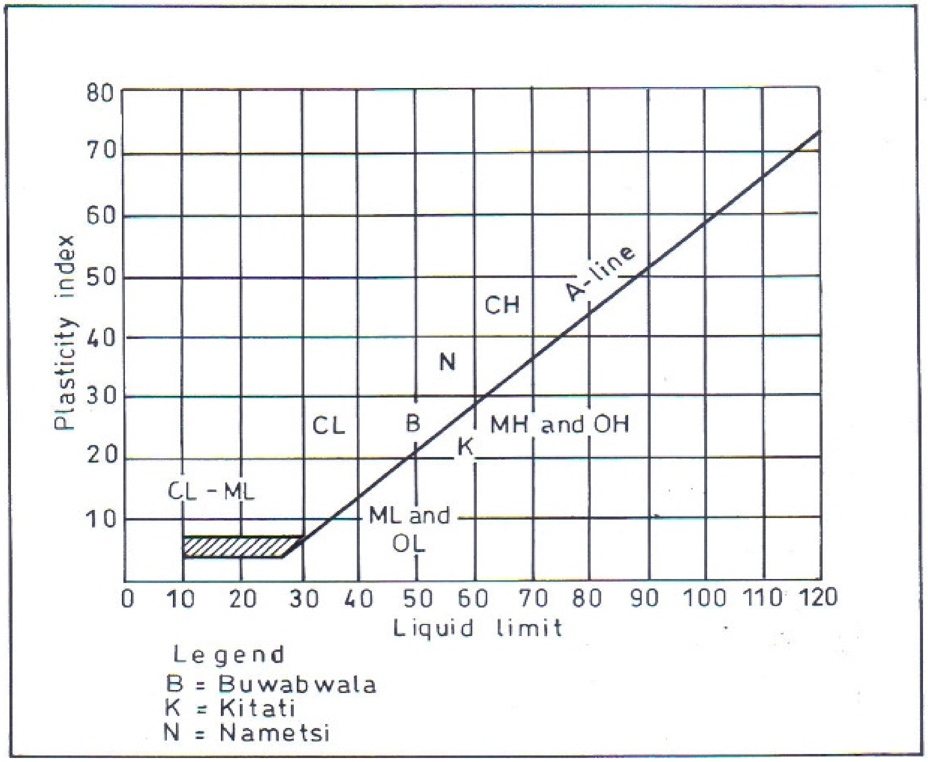


Figure 5.9: USCS plasticity chart for Buwabwala, Kitati and Nametsi soils

The plasticity chart reveals that all the soils at the respective sites contain clay of high plasticity. Specifically, soils from Buwabwala are Blackish sandy clays classified as inorganic clays of high plasticity (MH), while Kitati soils are yellowish brown sandy silts described inorganic silts of high plasticity (CH) groups. The soils from Nametsi are Dark brown sand silt clays classified as inorganic clays of high plasticity (CH). The highly plastic nature of Nametsi and Buwabwala sites is demonstrated by their plotting above the boundary A-line. An idea as to the general natural slope stability at the respective sites, as depicted by the factor of safety was calculated from shear strength parameters as presented below.

5.4.5 Shear strength and factor of safety

Plots of shear strength versus normal stress were used to compute the angle of internal friction and cohesion which were then used to calculate the slope factor of safety for the three sites. Curves for Buwabwala, Nametsi and Kitati sities are presented by Figure 5.10 a, b and c respectively. Table 5.4 presents the shear paramters and the Factors of safety.

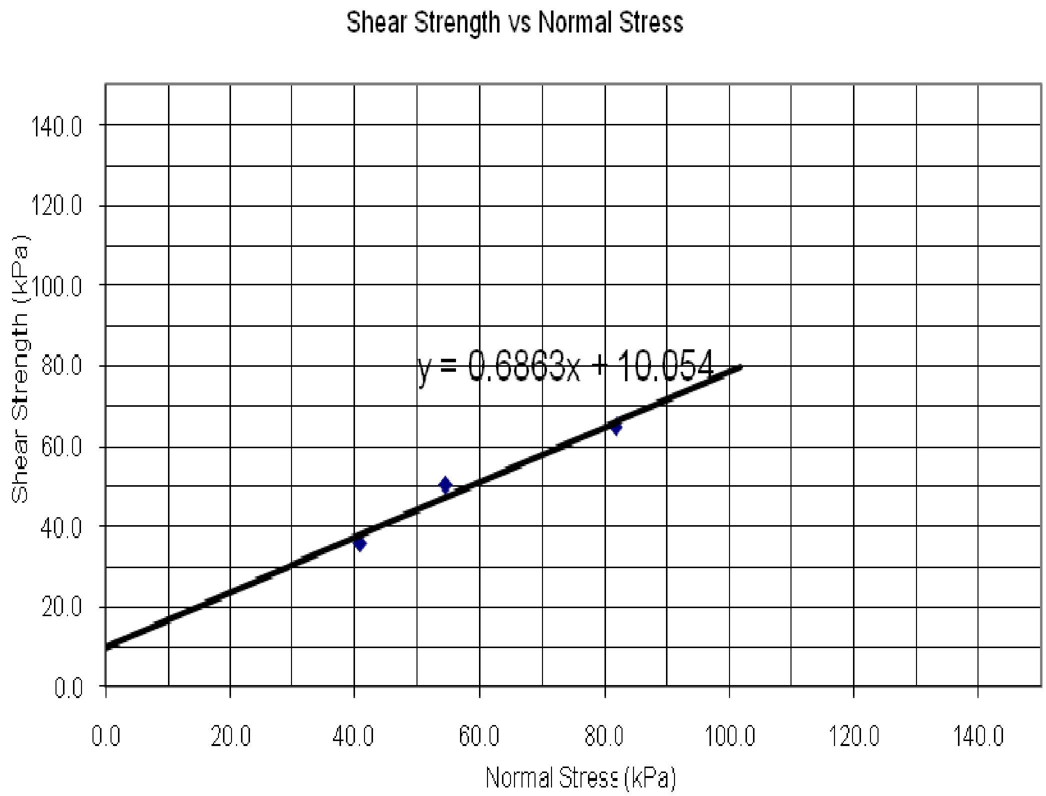


Figure 5.10a: Shear strength versus normal stress curve for Buwabwala site

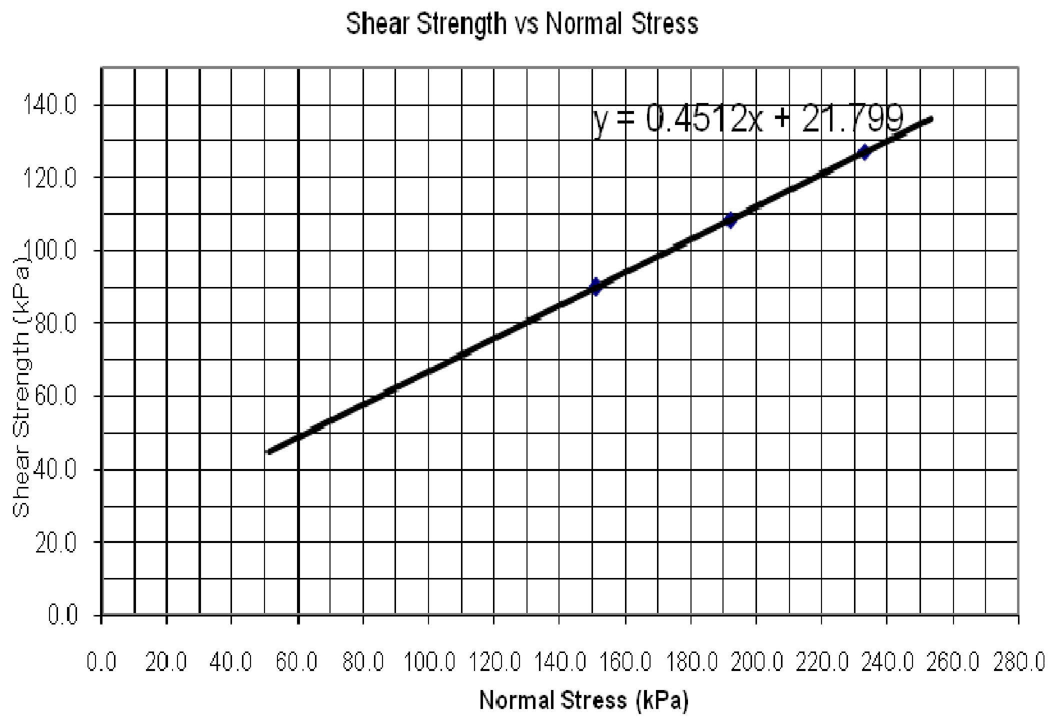


Figure 5.10b: Shear strength versus normal stress curve for Nametsi site

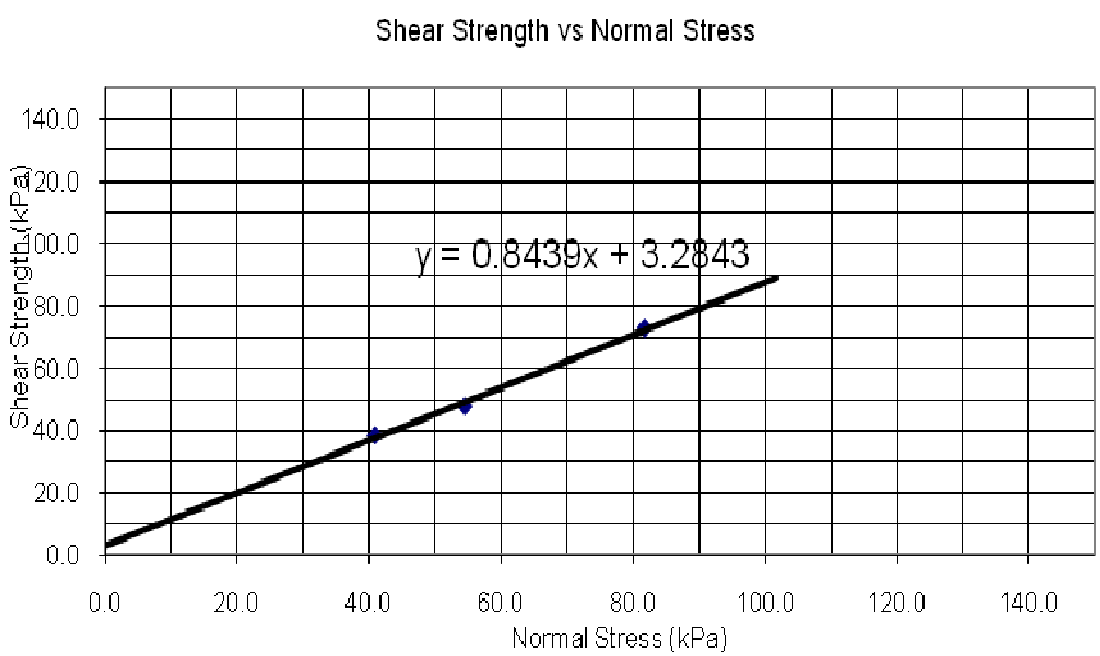


Figure 5.10c: Shear strength versus normal stress curve for Kitati site

Shear strength parameters as calculated from the shear strength versus normal stress curves are presented in Table 5.4.

Table 5.4: Shear parameters and factor of safety at the three sites

	Bulk density *g b* *(Mg/m^3^*	*Normal stress* δ_n *(kPa)*	*Shear strength* t_s *(kPa)*	*Cohesion C (kPa)*	*Angle of Internal friction (f) (Deg)*	*Factor of safety*
Buwabwala		40.9	36.0	10	34	2.16
	2.04	54.5	50.6			
		81.8	65.1			
Nametsi						
		151.0	90.0	22	24	1.88
	2.29	192.0	108.3			
		233.0	127.0			
Kitati						
		40.9	38.7	3	40	0.96
	2.04	54.5	47.9			
		81.8	72.7			

As depicted by the factor of safety which is higher than the critical factor of 1, slopes at Buwabwala and Nametsi sites are supposedly stable while those at Kitati (< 1) are unstable. The Kitati landslide therefore occurred on inherently unstable pristine forested slopes. It is noteworthy however that even slopes with a factor of safety > 1 are conditionally stable. Stability is compromised once external factors exert their influence as will be discussed.

5.5 Discussion

The steep concave nature of the slopes (36º - 58º, mid altitude; 1900 – 2500 m a.s.l) as observed at the three landslide sites has important implications for slope hydrology. According to Ian and Flores (1999); Westerberg (1999); Glade (2002); Knapen *et al.,* (2006), deep rotational landslides on concave slopes can be attributed to the concentration of runoff and sub surface water which reduces slopes shear resistance. Yang *et al,* (2007) and Wati *et al.* (2010), note that steep slopes, particularly those at high elevations are susceptible to failure owing to the increasing shear stress against reducing shear strength. An overlay of several landslide sites on a curvature surface by Mugagga *et al*., (submitted) also revealed the spatial correlation between the landslides and topographic concavity. This highlights the susceptibility of concave elements of Mt Elgon slopes to slope failure, which should be taken cognisance of as restoration and conservation hotspots.

The clay fraction which is well above the 10 percent threshold, identified from analyses of soil samples from the respective sites explains the shrink-swell properties such that the soils exhibit extreme expansive potential, hence susceptible to landslides. The implications of such high clay content for landslide occurrence have been demonstrated by many a scholar (Knapen *et al.,* 2006; Yang *et al.,* 2007; Kitutu *et al.,* 2009; Wati *et al.,* 2010). Kitutu *et al.* (2009) identified the dominant clay minerals on selected slopes of Mt Elgon as highly plastic Kaolinite and illite. According to Ohlmacher (2000) and Yalcin (2007), illite clays are associated with landslide occurrence owing to their low shear strength and high swelling potential. In the same vein, soil particle distribution curves revealed the fine textured nature of the soils at all three sites. Fine textured clayey soils have small pores and liberate water gradually, which renders them susceptible to landslides because of the high water retention (Yang *et al.,* 2007; Jadda *et al.,* 2009; Wati *et al.,* 2010). Their low permeability also exacerbates this vulnerability (Wati *et al.,* 2010).

The plasticity chart revealed that the soils at the respective sites are inorganic clays and silts of high plasticity. Previous studies observed positive correlations between high plasticity and fine grained inorganic clay and silts (Orazulike *et al.,* 1988; Chartwin *et al.,* 1994; Isik and Keskin, 2008). Highly plastic inorganic soils are prone to sliding during rainfall events due to the reduction of shear resistance (Dai *et al.,* 2002). The same scenario plays out on Mt Elgon slopes, where highly plastic inorganic clays become susceptible to sliding even under moderate rainfall events. The soils from the Nametsi site exhibit a higher plasticity index than the other two sites (33 percent, as opposed to 23.8 percent and 20.3 percent for Buwabwala and Kitati respectively). Plasticity index values above 32 percent signify extremely high expansive potential (Van Der Merwe, 1964; Baynes, 2008). Owing to the high clay content (41percent on average) and >32 percent Plasticity Index, the soils at the Nametsi site are categorised as vertisols, known for inducing mass wasting.

The role of liquid limits in characterizing the problem nature of soils has been noted by various scholars (Van Der Merwe, 1964; Mario *et al.,* 1996; Msilimba and Holmes, 2005; Fauziah *et al.,* 2006; Baynes, 2008). The extremely high liquid limits for Buwabwala and Kitati (53 and 59 percent respectively) confirms the problem nature of the soils at the two sites as categorised by Van Der Merwe (1964) and Baynes (2008). The high liquid limits coupled with high clay content and vertic soil properties at the Nametsi site qualify the soils at the three sites as ‘problem soils’ that are susceptible to landslides.

The factor of safety for the Buwabwala and Nametsi suggests slope stability in both instances, while the Kitati slope is not. That notwithstanding, slope failure often occurs by localised deformation in a thin zone of intense shearing; therefore using overall stress-strain measurements may not be representative of such intense shear behaviour (Finno *et al.,* 1997; Gonghui *et al.,* 2010). The stable sites could be described as only conditionally stable because of the interplay of various physical, pedological and anthropogenic factors. As noted by Sidle *et al.* (1985); Inganga *et al.* (2001); Nyssen *et al*. (2002); Knapen *et al.* (2006); Claessens *et al.* (2007); NEMA (2007); Kitutu *et al.* (2009) and Mugagga *et al.* (2010), high rainfall coupled with human intervention through deforestation, cultivation and excavation are external factors that induce slope instability even on hitherto stable slopes. In the same vein, human activity on the slopes of Mt Elgon has drastically decreased the margin of hillslope stability, especially in densely populated and intensively cultivated steep areas. The steep and concave nature of the slopes and the implications for soil hydrology alluded to earlier compounds this interplay. In the present study, two sites with inherently problem soils were deforested for cultivation, rendering them susceptible to failure, despite their ostensible stability. The inherently unstable slopes at Kitati forested site (factor of safety < 1) explain the landslide occurrence even without human intervention.

It is noteworthy however, that the problem nature of the soils as identified in this study is not unique to the mid altitude sites investigated. Similar observations were made by studies that focused on the highly populated lower slopes of Mt Elgon (Breugelmans, 2003; Knapen, 2003; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009). By implication, the problem nature of soils on Mt Elgon slopes is ubiquitous; it is recommended that conservation based land use options are undertaken particularly on the mid altitude slopes.

5.6 Conclusion

This study has characterised the soil physical properties on disturbed and pristine slopes of Mt Elgon and their implications for landslide occurrence. The soil at the sites is of high clay content, fine textured and highly plastic. Whilst high plasticity indices at Nametsi confirm the vertic properties of the soil, the extremely high liquid limit of Buwabwala and Kitati soils signifies their inherent problem nature. On the basis of the factor of safety (< 1), the Kitati landslide is confirmed to have occurred on inherently unstable pristine forested slopes. The conditional stability at Buwabwala and Nametsi sites was compromised by interplay of external human and internal topographic factors. In a nutshell, the hypothesis that soils at three landslide sites are inherently 'problem soils' where slope failure could occur even without human intervention is accepted.

CHAPTER SIX

[4]Synthesis

[4] This chapter brings together all the different strands of the thesis. General conclusions, recommendations and directions for further research are provided.

6.1 Introduction

This chapter brings together the different strands of the respective chapters and provides conclusions based on the findings of the study. A review of the livelihood strategies of the communities surrounding Mt Elgon and the implication for soil erosion is provided. A presentation of relationship between land use change, topographic parameters and landslide occurrence is also given. The chapter concludes by reviewing the character of soils at landslide sites on pristine and disturbed slopes as described in chapter five and the implications for landslide occurrence. A conceptual model which finally integrates all the strands of this work is developed and presented. Recommendations on the basis of the findings and directions for future research are also given.

6.2 Livelihood strategies and soil erosion on Mt Elgon

The communities around the National Park are generally smallholder subsistence crop farmers, owning small pieces of land acquired through inheritance, privately owned and customary tenure arrangements. Farmers mainly use slash and burn techniques to prepare land for cultivation while those close to the National Park are reluctant to adopt appropriate farming and soil conservation techniques due to the lack of security of tenure. Slash and burn techniques were observed to accelerate various forms of erosion including rills, gullies and sheet. However, soil and water conservation techniques such as mulching were mainly practiced on privately owned farms due to the desire to recoup costs of investment in the land. Moreover there is a general inaccessibility to agricultural advisory and credit services in the area. The National Park is a big source of livelihood for the communities, especially those within the Park vicinity. It is a source of food, building poles, herbal medicine, and fodder. The communities also have a strong socio-cultural attachment to the National Park as it is the source of materials used during circumcision rituals. It also a source of bamboo shoots, a cultural delicacy of the local communities. The Collaborative Forest Management (CFM) initiatives put in place by the UWA through which the communities and Park staff share responsibility for the management of the Park ecosystem is abused by the communities by way of illegally accessing restricted zones and not adhering to resource harvesting quotas. This is partly due to the incitement by local leadership and politicians who encourage the communities to access the resources for their selfish political gain and economic interest. Buyinza *et al.* (2007), observed that the adoption of soil conservation strategies on Mt Elgon varies from one farmer to another, depending on several ecological, social and institutional factors, including availability of extension services, farmers' tribal affiliation, agricultural labour force size, land holdings, farmers' training, schooling period of farm household head, participation in joint soil conservation activities and landslide density in farmlands.

6.3 Drivers of land use change on Mt Elgon and implications on climate variability

A general decimation of forest and woodland cover by agricultural encroachment was observed. The exponential population increase in the area over the last few decades has resulted in pressure on the forest and woodland resources as the mainly agro based mountain communities seek farming space, in many instances clearing forests on unstable steep slopes for agriculture, hence contributing to slope instability. Pressure on the forests and woodlands is further exacerbated by the prevalent political climate as people are incited to encroach on the National Park. The relationship between population pressure and land use change has also been established elsewhere (see Yanda and Shishira, 2001; William, 2002; Soini, 2005; Lung and Schaab, 2010; Kamusoko and Aniya, 2009). Mountain ecosystems are particularly sensitive to anthropogenic impacts and the loss of vegetation cover inevitably alters mountain hydrology and has implications for local and regional climate variability (Beniston 2003, IPCC, 2007a; 2007b). Such variability is not confined to mountain ecosystems, as populated lowlands depend on mountain water resources. The impacts of climate variability have already in been reported in the low lying areas of Butaleja, Soroti and Pallisa Districts that surround Mt Elgon. These include drought, heat waves, and flash floods, economic dislocation, conflict, crop failure, and associated malnutrition and hunger (NEMA, 2008).

6.4 Land use change, topographic parameters and landslide occurrence

The expansion of agricultural fields from lower and gentle slopes to critically steep concave ones was identified as the most significant land use change trend. Cultivation on particularly on concave steep slopes has been identified to induce slope instability by many a scholar (Ian and Flores, 1999; Glade, 2002). In the present study, all the surveyed landslides were found to have occurred on cultivated steep concave slopes. Concave slopes were noted as the most favourable precondition for mass movement owing to the alteration of soil hydrological conditions through deforestation and intensive cultivation which enhances saturation thereby triggering debris flows under extreme rainfall (Westerberg, 1999; Inganga *et al.,* 2001; Nyssen *et al.,* 2002; Knapen *et al.,* 2006; NEMA, 2007). Deforestation and cultivation has consequently lowered the threshold of slope stability on densely populated steep concave slopes of Mt Elgon, thereby triggering slope failure especially under extreme rainfall.

6.5 Problem soils and implications for landslide occurrence

The soils at landslide sites investigated were identified as containing high amount of clay, fine textured and highly plastic. These attributes make the soils prone to low permeability, expansion, high water retention and sliding (Dai *et al.,* 2002; Knapen *et al.,* 2006; Yang *et al.,* 2007; Kitutu *et al.,* 2009; Wati *et al.,* 2010). The vertic nature of soils at Nametsi is confirmed by the extremely high plasticity indices, while, high liquid limits at Buwabwala and Kitati qualified the soils as vertisols which are associated with landslides (Van Der Merwe, 1964; Mario *et al.,* 1996; Msilimba and Holmes, 2005; Fauziah *et al.,* 2006; Baynes 2008). As noted by Sidle *et al.* (1985); Inganga *et al.* (2001); Nyssen *et al*. (2002); Knapen *et al.* (2006); Claessens *et al.* (2007); NEMA (2007); Kitutu *et al.* (2009); Mugagga *et al.* (2010), the slopes at supposedly stable sites can be appropriately described as 'conditionally stable' owing to the interplay of various shear reducing factors such as high clay content, texture, concavities, steep slopes, rainfall, deforestation and intensive cultivation, all of which have implications for soil hydrology. Given the above scenarios, the hypothesis that soils at the landslide sites are inherently 'problem soils' where slope failure can occur even without human intervention is accepted. It is also noteworthy that these findings are not unique to mid altitude slopes only; similar observation were made by studies that focussed on densely populated lower altitude slopes of Mt Elgon (Breugelmans, 2003; Knapen, 2003; Kitutu *et al.,* 2004; Knapen *et al.,* 2006; Claessens *et al.,* 2007; Kitutu *et al.,* 2009) implying wide spread problem nature of soils on Mt Elgon.

In summary, the present study has demonstrated the relationship between livelihood strategies, land use and mass wasting around Mt Elgon National Park. Population pressure and political incitement were identified as the main drivers of encroachment and land use change on the slopes of Mt Elgon. The study has further demonstrated the implication of deforestation and cultivation on slope stability and regional climate variability. The study has also demonstrated that soils at landslide sites are inherently problem in nature and prone to landslides with or without human intervention. In conclusion, landslide occurrence on the slopes of Mt Elgon cannot be attributed to a single causal factor, but rather interplay of physical, pedological and anthropogenic factors. A conceptual model that illustrates the interplay of these factors is presented below (Figure 6.1).

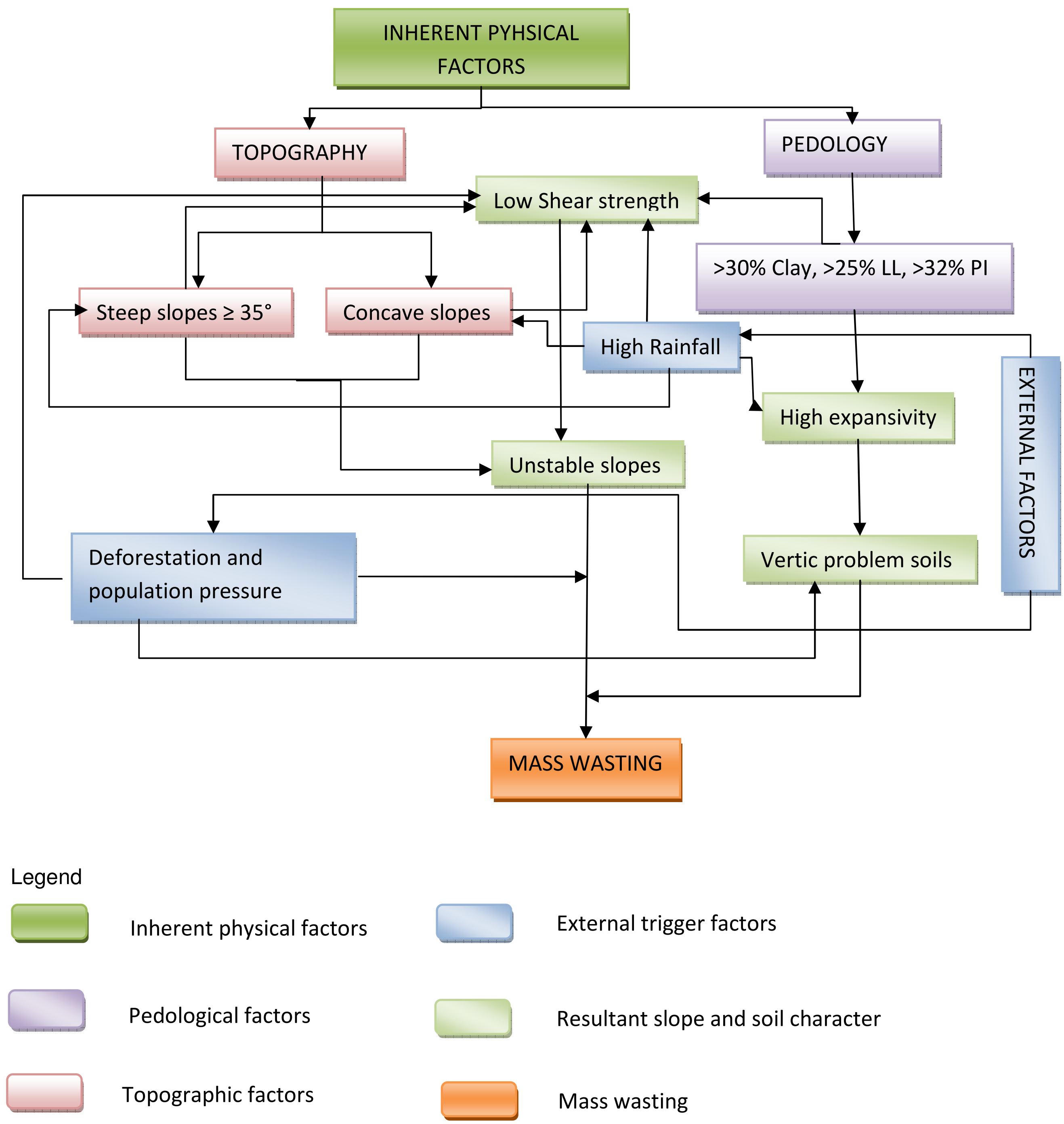


Figure 6.1: A conceptual model of the factors responsible for mass wasting on Mt Elgon as identified in the study. A combination of inherent physical (topographic and pedological) factors are pre conditioning attributes for mass wasting, while the external anthropogenic intervention act as both direct and indirect trigger factors. Steep concave slopes, coupled with the 'problem nature of soils' makes Mt Elgon slopes susceptible to landslides. Deforestation, rainfall and population pressure increase the fragility of the slopes and are responsible for the actual initiation of mass wasting.

6.6 Recommendations

On basis of the above findings, there is an urgent need to restore forest cover on the deforested steep slopes and restrain the communities from encroaching on the pristine mid slopes of Mt Elgon. This however requires the active participation of all stakeholders including local politicians, the National Park Authorities, the local communities and extension workers in the design and implementation of Collaborative Forest Initiatives (CFM). Participation of all affected parties will create a sense of ownership and make the CFM sustainable in the long run. In the same vein, extension and agricultural interventions should focus on promoting agro-forestry and sensitization of the farming communities to the dangers of using slash and burn as a farming technique. The communities should also be mobilized to form needs-driven cooperative groups as a way of enhancing their produce marketing abilities. Dissemination of the research findings to all concerned parties is essential in providing an understanding of the issues surrounding landslide occurrence and how to deal with them.

Secondly, there is an urgent need for population control programmes in the area. The exponential population increase in the last three decades has constrained natural resource conservation with serious onsite and regional climate implications by way of floods, droughts, displacement of people and conflict. Community participation in this initiative is essential, as a safeguard against perceptions that the population control programmes have been imposed on the community.

6.7 Further research directions

The following research directions are recommended:

- A full investigation of the climatic change implications of the deforestation of Mt Elgon environments.

- Quantification of loss of carbon related to deforestation and soil degradation on mountain environments.

The study has revealed that on-farm agricultural activities and dependence on park environmental resources are the main sources of livelihoods for the communities adjacent to Mt Elgon National park. A drastic decimation of forest and woodland cover by agricultural encroachment particularly between 1995 and 2006 has been identified as the main land use change trend. Deforestation and cultivation of steep concave slopes alters soil hydrologic conditions on the slope elements by way of enhancing saturation, hence triggering debris flows. The soil at the sites investigated in this study is of high clay content, fine textured and highly plastic. Therefore, soils on Mount Elgon slopes are inherently 'problem soils' where slope failure could occur even without human intervention. This study has also demonstrated that landslide occurrence is not a product of a single factor but a combination of various physical, pedological and anthropogenic factors.

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Appendices

Appendix A: Introductory letter to Uganda Wildlife Authority

MAKERERE UNIVERSITY

P.O.Box 7062 Kampala Uganda
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WE BUILD FOR THE FUTURE

FACULTY OF FORESTRY AND NATURE CONSERVATION
OFFICE OF THE DEAN

Your Ref: 26th May, 2008

Our Ref: Mr. Wanyama
Research and Monitoring Unit
UWA Headquarters, KAMPALA

Re: PhD Fieldwork Research Permit in Mt. Elgon National Park

This is to introduce to you Mr. Frank Mugagga, a PhD student registered at the Nelson Mandela Metropolitan University, Port Elizabeth of South Africa. Under my local supervision, he intends to conduct field studies on the Topic titled: 'Vegetation change, processes and livelihood strategies on Mt. Elgon and its environs'. His PhD Research Project runs from 2008 - 2010.
The purpose of this letter, therefore, is to request you to grant him a research permit for the said period.

Your Sincerely,

Dr. M. Buyinza
Local Scientific Supervisor

MAKERERE UNIVERSITY FACULTY OF FORESTRY & NATURE CONSERVATION P.O.Box 7062 Kampala -Uganda

In future correspondence please quote the reference number above

Appendix B: Research application approval letter from Uganda Wildlife Authority

UGANDA WILDLIFE AUTHORITY

HEADQUARTERS, PLOT 7 KIRA ROAD KAMWOKYA

P O Box 3530, Kampala Uganda

Your Ref:

Our Ref: UWA/TDO/33/02

6th June 2008

Mugagga Frank
Department of community Forestry and Extension
Makerere University
P. O. Box 7062
Kampala
UGANDA

RE: RESEARCH APPLICATION APPROVAL

I am in receipt of your application dated 26th May 2008 seeking to carry out a study in Mt. Elgon National Park, addressing **"Vegetation change, slope processes and livelihood on Mt. Elgon and its environs"**

I am glad to inform you that your research application has been approved for you to carry out research from 7th June 2008 to 30th October 2009. You will be expected to submit a progress report of your findings by 30th September 2009 to the Monitoring and Research Unit of the Uganda Wildlife Authority.

Should you be unable to work within these dates, please notify me in writing. Note that, any researcher failing to submit the reports at an appropriate time, will not be allowed to come back to wildlife protected areas to do further research.

You will be required to pay a monthly research access fee of Ush 30,000/= to Uganda wildlife Authority. Any other services you may require while in the park will be paid for as per our tariff.

Please report to the Conservation area manager, Mt. Elgon National park upon arrival in the park for registration, payment of fees and further guidance.

Yours sincerely,

Anying Pamela
For: EXECUTIVE DIRECTOR

C.C. Conservation Area Manager, MECA
C.C Monitoring and Research Warden, MECA

Please Warden RGM supervise the research work being done by Mr. Mugagga Frank in Mt Elgon Buwalasi area # Research work supposed to be done
25/6/08

Appendix C: Sample questionnaire for the socio-economic survey

Household Interview Schedule for a PhD study on land use change, landslide occurrence and livelihood strategies on Mt Elgon, eastern Uganda.

Section A: Preliminary information

Date: …………………….. Qnaire No. ……

Parish: ……………

Distance from Park Boundary (in Kms): …………

Name of interviewee (optional)…………………………

Section B: Household characteristics

1)

Respondent	Gender	Age	Marital status	Educ. Level	Main Occupation	Relationship to HH head
Person 1						

2) Age (productivity) distribution by sex in the household

	Productivity (years)	No. of males	No. of females
i	Young unproductive (<15)		
ii	Young productive (15 – 34)		

iii	Old productive (35 – 64)		
iv	Old unproductive (≥65)		

3) Do you seek for additional labour from other people? Yes ☐ No ☐

4) Members of the family not living with you currently?

Number	Residence			Occupation				
	Rural	Urban	Abroad	Students	Civil servants	Private business	Job seekers	Others
None								
1-3								
4-6								
7-9								
10+								

Section C: <u>Household assets and endowments</u>

1) Type of dwelling

(i) Temporary ☐
(ii) Semi- permanent ☐
(iii) Permanent ☐

2) Household wealth (as ranked by the villager elders)

a) Rich ☐ b) Well-off ☐ c) Comfortable ☐
d) Poor ☐ e) Very poor ☐

3). Land ownership and tenure

i) What is the size of your farmland?

Size of land (Ha)

<1
1-5
6-10
>10

ii) Are you cropping or grazing on all the household farmland? Yes ☐ No ☐

iii) If no what is the acreage not being utilized currently and why?

Size of land (Ha)	<1	1-4	5-9	10+

Reasons:

a) It is too far from the home☐

b) It is not productive☐

c) It was lent out to someone☐

d) Lack of enough labour☐

e) Others (specify)………………………. ☐

iv) Type of land tenure

i) Private landholding ☐

ii) Inherited from parent ☐

iii) Communal land ☐

iv) Encroach on park land ☐

v) Rent from neighbour ☐

vi) Landless ☐

vii) Other ……………………………………. ☐

2. Sources of income (subsistence and cash) for the household

a) Crops grown and associated seasonal/annual income

	Qty.	Price per Unit	Total value (Seasonal/annual)	Consumed at home /sold out
Maize□				
Coffee□				
Cassava□				
Bananas□				
Tomatoes□				
G/nuts□				
Beans□				
Peas□				
Passion fruits□				
S/potatoes□				
Millet□				
Irish potatoes□				

b) Livestock production

i) Value of livestock owned

	Qty.	Price per Unit	Total value
Cattle			
Goats			
Pigs			
Sheep			
Chickens			

Rabbits			
Turkey			
Ducks			

(ii) What are the costs (cash) you incur in keeping these animals per month (eg. Vaccines, buying feed, buying stock)?

	Qty.	Price per Unit	Total value
Cattle			
Goats			
Pigs			
Sheep			
Chickens			
Rabbits			
Turkey			
Ducks			

iii) How regularly do you rely on the Park for income?

1. Throughout the year □
2. Seasonally □
3. During drought □
4. Other times □

iv) Reasons why you depend on the park?

5. Grazing □
6. Land for agriculture □
7. Park resources for domestic use □specify………………….
8. Social-cultural reason □ (specify)………………..

v) Park resources extracted for household use?

i	Firewood □
ii	Wild Fruits□
iii	Medicinal plants□
iv	Small animals: birds, mice□
v	Thatch grass□
vi	Poles for building□
vii	Sticks for hoes□
viii	Rope material□

c) Trade

(i) Are you involved in trade (enterprise) in any environmental resources?

i. Yes □ **ii**. No □

(ii) Why do you engage in trade?

a. to buy food and other basic items □

b. to expand income source □

c. to buy seed □

d. to respond to the demand for the goods □

e. Others □ (specify)………………………………….…………

f. (iii) Trade items

Firewood □	Bricks □	Handcraft(specify) □
Charcoal □	Quarry stones□	Building poles□

Timber □	Sand □	Bamboo shoots□

(iv)What is the average production costs and price of the goods you produce?

Environmental resource (trade)	Labour costs Per unit?	Raw material cost (annual)	Price/unit	Average production/yr	Average annual income
Selling firewood					
Selling charcoal					
Timber					
Poles for building					
Handcraft					
Bricks					
Quarry stones					
Sand					
Others (specify)					

d) Other sources of income (entitlements)

(i) What are the other sources of income for your household?

a. Off-farm employment □ (specify)……………………………….
b. Wage labour □ specify)………………………………….
c. Other sources □ (specify)………………………………………

Section D: Support Services

i) Do you regularly seek for support services? Yes □ No □

Nature of support service	Provider	Paid for or free	Comment
Veterinary			

Access to markets			
Access to health services			
Access to extension services			
NAADS			
PMA			
PFA (Prosperity for All)			
Access to credit			
Access to climatic information			
Access to education facilities			

Section E: Socio-cultural activities

i) Socio-cultural ceremonies conducted inside the forest and resources used

Ceremony/ Activity	Resource used	Amount collected	Frequency of collection

ii) Socio-cultural ceremonies conducted outside the forest but need some resources from the Park

Ceremony/ Activity	Resource used	How much is collected	How often collected

Section F: Land degradation and socio-economic impacts

i). What has been the trend in crop production over the past five years?

(Applicable for households that are at least 5 years old)

a. Increasing □
b. constant □
c. decreasing constantly □
d. fluctuating constantly □
e. fluctuating positively □

f. fluctuating negatively □

ii) Are there noticeable land use and land cover changes in the last 10 years in your area? a) Yes □ b) No □

iii). If yes, what have been the trends in land use and cover changes?

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

iv). Has your household experienced any form of land degradation on the farmland?

a) Yes □ b) No □

v) If yes, what socio-economic impacts did you experience as a result of this degradation?

a. Migration to other places □ (specify place)……………..
b. Famine □
c. Floods □
d. Siltation and sedimentation of water sources □
e. Conflicts with neighbours □
f. Others □ (specify)…………………….

Thank you very much for your time

Appendix D: Summary of the socio-economic survey results

Sampled Parishes

Parish	Frequency	Percent
Makutano	8	5.3
Bufuma	39	26.0
Bungati	5	3.3
Maalo	2	1.3
Busulwa	2	1.3
Bunambale	55	36.7
Bumaali	15	10.0
Segululi	3	2.0
Busekere	1	0.7
Bumumali	19	12.7
Total	149	99.3
NR	1	0.7
Total	150	100.0

Distance of parish from the National park boundary

	Distance from Park boundary(Km)							
Parish	**Less than 1 km**		**1**		**4**		**Total**	
	f	percent	f	percent	f	percent		
Makutano	8	5.4	0	0.0	0	0.0	8	5.4
Bufuma	39	26.2	0	0.0	0	0.0	39	26.2

Bungati	0	0.0	5	3.4	0	0.0	5	3.4
Maalo	2	1.3	0	0.0	0	0.0	2	1.3
Busulwa	2	1.3	0	0.0	0	0.0	2	1.3
Bunambale	55	36.9	0	0.0	0	0.0	55	36.9
Bumaali	13	8.7	1	0.7	1	0.7	15	10.1
Segululi	0	0.0	3	2.0	0	0.0	3	2.0
Busekere	1	0.7	0	0.0	0	0.0	1	0.7
Bumumali	0	0.0	0	0.0	19	12.8	19	12.8
Total	120	80.5	9	6.0	20	13.4	149	100.0

Gender

Gender	Frequency	Percent
Male	115	76.7
Female	35	23.3
Total	150	100.0

Age distribution of respondents

Age	Frequency	Percent
20	2	1.3
21	1	0.7
22	4	2.7
23	4	2.7
24	3	2.0
25	8	5.3
26	6	4.0
28	10	6.7

30	8	5.3
31	1	0.7
32	3	2.0
33	2	1.3
34	2	1.3
35	7	4.7
36	4	2.7
37	1	0.7
38	6	4.0
39	1	0.7
40	14	9.3
41	3	2.0
42	3	2.0
43	2	1.3
44	2	1.3
45	3	2.0
46	4	2.7
47	2	1.3
48	4	2.7
49	1	0.7
50	6	4.0
52	1	0.7
53	2	1.3
54	3	2.0
55	2	1.3
56	2	1.3

57	2	1.3
58	1	0.7
59	1	0.7
60	8	5.3
63	1	0.7
64	1	0.7
67	1	0.7
70	3	2.0
75	1	0.7
76	1	0.7
78	1	0.7
80	1	0.7
84	1	0.7
Total	150	100.0

Age range of respondents

Age	Frequency	Percent
20-29	38	25.3
30-39	35	23.3
40-49	38	25.3
50-59	20	13.3
60-69	11	7.3
70-79	6	4.0
80+	2	1.3
Total	150	100.0

Marital Status of respondents

Marital Status	Frequency	Percent

Married	145	96.7
Window	4	2.7
NR	1	0.7
Total	150	100.0

Level of Education

Educn level	Frequency	Percent
None	25	16.7
P1-P7	96	64.0
S1-S4	27	18.0
Tertiary Level	2	1.3
Total	150	100.0

Main Occupation

Main Occupation	Frequency	Percent
Farmer	143	95.3
Teacher	3	2.0
Civil Servant	3	2.0
NR	1	0.7
Total	150	100.0

Relationship

Relationship to HH head	Frequency	Percent
Head	120	80.0
Wife	29	19.3
NR	1	0.7
Total	150	100.0

Productive and nonproductive age groups

Young unproductive(<15) Male No	Frequency	Percent
1	34	22.7
2	31	20.7
3	22	14.7
4	10	6.7
5	8	5.3
6	2	1.3
7	1	0.7
8	1	0.7
NA	41	27.3
Total	150	100.0

Young unproductive(<15) Females	Frequency	Percent
1	34	22.7
2	30	20.0
3	15	10.0
4	16	10.7
5	7	4.7
6	1	0.7
8	1	0.7
9	1	0.7
NA	45	30.0
Total	150	100.0

Young productive(15-34) Males	Frequency	Percent
1	24	16.0

	2	12	8.0
	3	4	2.7
	4	6	4.0
	5	4	2.7
	6	3	2.0
	7	2	1.3
	9	2	1.3
	10	1	0.7
NA		92	61.3
Total		150	100.0

Young productive(15-34) Female No		Frequency	Percent
	1	14	9.3
	2	13	8.7
	3	8	5.3
	4	6	4.0
	5	2	1.3
	6	2	1.3
	7	4	2.7
	8	1	0.7
NA		100	66.7
Total		150	100.0

Productive and nonproductive age groups (cont…)

Old productive(35-64) Male No	Frequency	Percent

	1	35	23.3
	2	2	1.3
	3	1	0.7
	9	1	0.7
NA		111	74.0
Total		150	100.0

Old productive(35-64) Female No		Frequency	Percent
	1	34	22.7
	2	2	1.3
	9	1	0.7
NA		113	75.3
Total		150	100.0

Old unproductive(>=65) Male No		Frequency	Percent
	1	4	2.7
NA		146	97.3
Total		150	100.0

Old unproductive(>=65) Female No		Frequency	Percent
	1	2	1.3
	2	2	1.3
NA		146	97.3
Total		150	100.0

Source of labour

Seek for additional labour from other people?	Frequency	Percent
Yes	26	17.3
No	11	7.3
NR	113	75.3
Total	150	100.0

Number of members of family not living within the household

Rural Resident No	Frequency	Percent
NR	150	100.0

Urban Resident No	Frequency	Percent
1-3	9	6.0
NR	141	94.0
Total	150	100.0

Abroad Resident No	Frequency	Percent
NR	150	100.0

Students No	Frequency	Percent
None	1	0.7
1-3	8	5.3
NR	141	94.0
Total	150	100.0

Civil servants No	Frequency	Percent

NR	150	100.0

Private business No	Frequency	Percent
NR	150	100.0

Job seekers No	Frequency	Percent
None	1	0.7
1-3	9	6.0
NR	140	93.3
Total	150	100.0

Others No	Frequency	Percent
1-3	2	1.3
NR	148	98.7
Total	150	100.0

Type of dwelling	Frequency	Percent
Temporary	21	14.0
Semi-permanent	129	86.0
Total	150	100.0

Household wealth (as ranked by the village elder)	Frequency	Percent

Well-off	13	8.7
Comfortable	101	67.3
Poor	23	15.3
Very poor	12	8.0
NR	1	0.7
Total	150	100.0

Size of farmland (Ha)	Frequency	Percent
<1	129	86.0
1-5	21	14.0
Total	150	100.0

Cropping or Grazing on all the household farmland?	Frequency	Percent
Yes	146	97.3
NR	4	2.7
Total	150	100.0

Type of land tenure	***Count***	***Pct of Responses***	**Pct of Cases**
Private landholding	66	23.8	44.3
Inherited from parent	137	49.5	91.9
Communal land	1	0.4	0.7
Encroach on parkland	64	23.1	43.0
Rent from neighbour	9	3.2	6.0

Total responses	277	100.0	185.9

Crop Quantity harvested

Maize Quantity harvested	Frequency	Percent
1	10	6.7
2	11	7.3
3	6	4.0
4	5	3.3
5	2	1.3
6	1	0.7
7	1	0.7
8	2	1.3
10	1	0.7
11	1	0.7
12	2	1.3
20	6	4.0
30	3	2.0
40	1	0.7
50	15	10.0
60	1	0.7
70	1	0.7
80	4	2.7
100	23	15.3
150	4	2.7
180	1	0.7

	190	1	0.7
	200	12	8.0
	300	9	6.0
	350	1	0.7
	400	5	3.3
	500	7	4.7
	600	2	1.3
	700	1	0.7
	800	1	0.7
	1000	2	1.3
NR		8	5.3
Total		150	100.0

Coffee Quantity harvested		Frequency	Percent
	1	8	5.3
	2	4	2.7
	3	1	0.7
	4	1	0.7
	10	1	0.7
	20	7	4.7
	25	1	0.7
	30	5	3.3
	40	3	2.0
	50	20	13.3
	65	4	2.7

	70	3	2.0
	80	3	2.0
	100	7	4.7
	130	2	1.3
	140	1	0.7
	150	2	1.3
	200	2	1.3
	250	1	0.7
	300	5	3.3
	400	1	0.7
	2000	1	0.7
NR		67	44.7
Total		150	100.0

Cassava Quantity harvested		Frequency	Percent
	10	1	0.7
	80	1	0.7
Total		2	1.3
NR		148	98.7
Total		150	100.0

Banana Quantity harvested		Frequency	Percent
	1	1	0.7
	10	1	0.7

	20	7	4.7
	30	2	1.3
	50	2	1.3
	100	3	2.0
	120	1	0.7
NR		133	88.7
Total		150	100.0

Tomatoes Quantity harvested	Frequency	Percent
NR	150	100.0

Gnuts Quantity harvested	Frequency	Percent
NR	150	100.0

Beans Quantity harvested		Frequency	Percent
	1	6	4.0
	3	1	0.7
	4	1	0.7
	10	5	3.3
	15	2	1.3
	20	15	10.0
	25	2	1.3
	30	9	6.0
	40	1	0.7

	50	30	20.0
	60	4	2.7
	70	1	0.7
	75	2	1.3
	80	6	4.0
	100	11	7.3
	200	2	1.3
	300	1	0.7
	400	1	0.7
	1500	1	0.7
NR		49	32.7
Total		150	100.0

Peas Quantity harvested		Frequency	Percent
	20	1	0.7
NR		149	99.3
Total		150	100.0

Passion Fruits Quantity harvested		Frequency	Percent
	100	1	0.7
NR		149	99.3
Total		150	100.0

Sweet potatoes Quantity harvested		Frequency	Percent

NR	150	100.0

Millet Quantity harvested	Frequency	Percent
NR	150	100.0

Irish potatoes Quantity harvested		Frequency	Percent
	4	1	0.7
	20	1	0.7
	30	1	0.7
	100	2	1.3
	200	1	0.7
	300	1	0.7
	400	1	0.7
	180400	1	0.7
NR		141	94.0
Total		150	100.0

Onion Quantity harvested		Frequency	Percent
	600	1	0.7
NR		149	99.3
Total		150	100.0

Crop Unit Price

Maize Unit Price	Frequency	Percent
1	1	0.7
50	2	1.3
300	4	2.7
400	12	8.0
500	97	64.7
600	2	1.3
700	1	0.7
750	1	0.7
800	11	7.3
1000	2	1.3
1400	1	0.7
2500	1	0.7
2700	1	0.7
3000	1	0.7
5000	2	1.3
50000	4	2.7
NR	7	4.7
Total	150	100.0

Coffee Unit Price	Frequency	Percent
700	1	0.7
1000	7	4.7
2000	16	10.7

2200	4	2.7
2255	1	0.7
2300	5	3.3
2500	26	17.3
2600	1	0.7
2700	11	7.3
2800	1	0.7
3000	1	0.7
5000	1	0.7
7000	1	0.7
25000	3	2.0
140000	1	0.7
300000	2	1.3
700000	1	0.7
NR	67	44.7
Total	150	100.0

Cassava Unit Price	Frequency	Percent
1000	1	0.7
2800	1	0.7
Total	2	1.3
NR	148	98.7
Total	150	100.0

Banana Unit Price	Frequency	Percent
800	1	0.7
3000	1	0.7
3500	1	0.7
4000	2	1.3
5000	4	2.7
6000	4	2.7
7000	1	0.7
10000	2	1.3
300000	1	0.7
NR	133	88.7
Total	150	100.0

Tomatoes Unit Price	Frequency	Percent
NR	150	100.0

Gnuts Unit Price	Frequency	Percent
NR	150	100.0

Beans Unit Price	Frequency	Percent
100	1	0.7
180	1	0.7
250	1	0.7

500	1	0.7
800	1	0.7
1000	52	34.7
1200	2	1.3
1400	3	2.0
1500	24	16.0
1800	10	6.7
2000	1	0.7
5000	1	0.7
15000	2	1.3
300000	1	0.7
NR	49	32.7
Total	150	100.0

Peas Unit Price	Frequency	Percent
1000	1	0.7
NR	149	99.3
Total	150	100.0

Passion Fruits Unit Price	Frequency	Percent
1000	1	0.7
NR	149	99.3
Total	150	100.0

Sweet potatoes Unit Price	Frequency	Percent
NR	150	100.0

Millet Unit Price	Frequency	Percent
NR	150	100.0

Irish potatoes Unit Price	Frequency	Percent
200	2	1.3
350	2	1.3
400	3	2.0
30000	1	0.7
72000	1	0.7
NR	141	94.0
Total	150	100.0

Onion Unit Price	Frequency	Percent
300	1	0.7
NR	149	99.3
Total	150	100.0

Crop Total value

Maize Total	Frequency	Percent

500	1	0.7
2000	1	0.7
5000	2	1.3
8000	1	0.7
10000	3	2.0
12000	1	0.7
15000	1	0.7
20000	1	0.7
25000	13	8.7
28000	1	0.7
30000	1	0.7
32400	1	0.7
40000	7	4.7
45000	1	0.7
50000	25	16.7
60000	4	2.7
75000	4	2.7
80000	2	1.3
90000	2	1.3
100000	16	10.7
105000	1	0.7
120000	2	1.3
150000	13	8.7
160000	1	0.7
175000	1	0.7
200000	8	5.3

240000	1	0.7
250000	9	6.0
300000	3	2.0
350000	2	1.3
400000	3	2.0
500000	3	2.0
550000	1	0.7
600000	2	1.3
1000000	2	1.3
NR	10	6.7
Total	150	100.0

Maize Total	Frequency	Percent
500	1	0.7
2000	1	0.7
5000	2	1.3
8000	1	0.7
10000	3	2.0
12000	1	0.7
15000	1	0.7
20000	1	0.7
25000	13	8.7
28000	1	0.7
30000	1	0.7
32400	1	0.7

40000	7	4.7
45000	1	0.7
50000	25	16.7
60000	4	2.7
75000	4	2.7
80000	2	1.3
90000	2	1.3
100000	16	10.7
105000	1	0.7
120000	2	1.3
150000	13	8.7
160000	1	0.7
175000	1	0.7
200000	8	5.3
240000	1	0.7
250000	9	6.0
300000	3	2.0
350000	2	1.3
400000	3	2.0
500000	3	2.0
550000	1	0.7
600000	2	1.3
1000000	2	1.3
NR	10	6.7
Total	150	100.0

Cassava Total	Frequency	Percent
10000	1	0.7
NR	149	99.3
Total	150	100.0

Banana Total	Frequency	Percent
16000	1	0.7
25000	1	0.7
60000	2	1.3
70000	2	1.3
72000	1	0.7
80000	1	0.7
100000	1	0.7
120000	2	1.3
150000	2	1.3
200000	2	1.3
300000	1	0.7
500000	1	0.7
NR	133	88.7
Total	150	100.0

Tomatoes Total	Frequency	Percent
NR	150	100.0

Gnuts Total	Frequency	Percent
NR	150	100.0

Beans Total	Frequency	Percent
5000	1	0.7
8000	1	0.7
10000	2	1.3
15000	2	1.3
18000	2	1.3
20000	11	7.3
25000	1	0.7
27000	1	0.7
30000	7	4.7
36000	1	0.7
40000	1	0.7
45000	4	2.7
50000	15	10.0
54000	1	0.7
60000	3	2.0
70000	3	2.0
72000	1	0.7
75000	12	8.0
80000	2	1.3
90000	4	2.7
100000	10	6.7
105000	1	0.7

120000	1	0.7
135000	1	0.7
150000	3	2.0
180000	1	0.7
200000	1	0.7
300000	3	2.0
375000	1	0.7
450000	1	0.7
600000	1	0.7
720000	1	0.7
1000000	1	0.7
NR	49	32.7
Total	150	100.0

Peas Total	Frequency	Percent
20000	1	0.7
NR	149	99.3
Total	150	100.0

Passion Fruits Total	Frequency	Percent
100000	1	0.7
NR	149	99.3
Total	150	100.0

Sweet potatoes	Frequency	Percent

Total		
NR	150	100.0

Millet Total	Frequency	Percent
NR	150	100.0

Irish potatoes Total	Frequency	Percent
10500	1	0.7
35000	1	0.7
40000	2	1.3
80000	1	0.7
120000	1	0.7
160000	1	0.7
NR	143	95.3
Total	150	100.0

Onion Total	Frequency	Percent
180000	1	0.7
NR	149	99.3
Total	150	100.0

Crops consumed or sold out

Maize Consumed/Sold out	Frequency	Percent

Consumed	4	2.7
Sold out	4	2.7
NR	142	94.7
Total	150	100.0

Coffee Consumed/Sold out	Frequency	Percent
Sold out	1	0.7
NR	149	99.3
Total	150	100.0

Cassava Consumed/Sold out	Frequency	Percent
Consumed	1	0.7
NR	149	99.3
Total	150	100.0

Banana Consumed/Sold out	Frequency	Percent
NR	150	100.0

Tomatoes Consumed/Sold out	Frequency	Percent
NR	150	100.0

Gnuts Consumed/Sold out	Frequency	Percent

NR	150	100.0

Beans Consumed/Sold out	Frequency	Percent
Consumed	2	1.3
NR	148	98.7
Total	150	100.0

Peas Consumed/Sold out	Frequency	Percent
NR	150	100.0

Passion Fruits Consumed/Sold out	Frequency	Percent
NR	150	100.0

Sweet potatoes Consumed/Sold out	Frequency	Percent
NR	150	100.0

Millet Consumed/Sold out	Frequency	Percent
NR	150	100.0

Irish potatoes Consumed/Sold out	Frequency	Percent
NR	150	100.0

Onion Consumed/Sold out	Frequency	Percent
Sold out	1	0.7
NR	149	99.3
Total	150	100.0

Cattle Quantity owned		Frequency	Percent
	1	74	49.3
	2	32	21.3
	3	3	2.0
	4	4	2.7
	5	2	1.3
	6	1	0.7
	10	1	0.7
NR		33	22.0
Total		150	100.0

Pigs Quantity owned		Frequency	Percent
	1	18	12.0
	2	10	6.7
	3	6	4.0
	4	3	2.0
	5	1	0.7
NR		112	74.7
Total		150	100.0

Sheep Quantity owned	Frequency	Percent
1	3	2.0
2	2	1.3
6	1	0.7
NR	144	96.0
Total	150	100.0

Chicken Quantity owned	Frequency	Percent
1	7	4.7
2	31	20.7
3	17	11.3
4	5	3.3
5	11	7.3
6	10	6.7
7	7	4.7
8	4	2.7
10	11	7.3
11	1	0.7
12	4	2.7
14	1	0.7
20	2	1.3
30	1	0.7
35	1	0.7
40	1	0.7

NR	36	24.0
Total	150	100.0

Rabbits Quantity owned	Frequency	Percent
NR	150	100.0

Turkey Quantity owned		Frequency	Percent
	1	2	1.3
	2	1	0.7
	5	1	0.7
NR		146	97.3
Total		150	100.0

Ducks Quantity owned	Frequency	Percent
NR	150	100.0

Livestock Unit Prices

Cattle Unit Price		Frequency	Percent
NR		34	22.7
	30000	2	1.3
	40000	2	1.3
	50000	1	0.7

60000	1	0.7
80000	1	0.7
100000	1	0.7
200000	1	0.7
250000	1	0.7
300000	23	15.3
350000	7	4.7
380000	1	0.7
400000	9	6.0
500000	8	5.3
600000	17	11.3
650000	1	0.7
700000	23	15.3
800000	16	10.7
1000000	1	0.7
Total	150	100.0

Goats Unit Price	Frequency	Percent
NR	93	62.0
30000	12	8.0
35000	3	2.0
40000	16	10.7
50000	19	12.7
60000	3	2.0
80000	3	2.0

500000	1	0.7
Total	150	100.0

Pigs Unit Price	Frequency	Percent
NR	112	74.7
5000	1	0.7
6000	1	0.7
10000	1	0.7
18000	1	0.7
30000	1	0.7
40000	1	0.7
50000	14	9.3
60000	3	2.0
70000	6	4.0
80000	3	2.0
90000	2	1.3
100000	2	1.3
150000	2	1.3
Total	150	100.0

Sheep Unit Price	Frequency	Percent
NR	144	96.0
10000	1	0.7
20000	3	2.0

70000	1	0.7
90000	1	0.7
Total	150	100.0

Chicken Unit Price	Frequency	Percent
NR	36	24.0
500	1	0.7
700	2	1.3
3000	3	2.0
4000	12	8.0
5000	36	24.0
6000	25	16.7
7000	12	8.0
8000	16	10.7
10000	5	3.3
12000	1	0.7
50000	1	0.7
Total	150	100.0

Rabbits Unit Price	Frequency	Percent
NR	150	100.0

Turkey Unit Price	Frequency	Percent
NR	146	97.3

2500	1	0.7
10000	1	0.7
15000	1	0.7
25000	1	0.7
Total	150	100.0
Ducks Unit Price	Frequency	Percent
NR	150	100.0

Livestock Total Value

Cattle Total Value	Frequency	Percent
NR	36	24.0
30000	1	0.7
70000	1	0.7
80000	1	0.7
100000	2	1.3
120000	1	0.7
200000	1	0.7
210000	1	0.7
250000	1	0.7
300000	16	10.7
350000	2	1.3
380000	1	0.7
400000	7	4.7
500000	5	3.3

600000	14	9.3
700000	16	10.7
800000	19	12.7
900000	1	0.7
1000000	3	2.0
1200000	8	5.3
1400000	6	4.0
1600000	1	0.7
1750000	1	0.7
2100000	1	0.7
2800000	2	1.3
3000000	1	0.7
3600000	1	0.7
Total	150	100.0

Goats Total Value	Frequency	Percent
NR	95	63.3
20000	1	0.7
30000	5	3.3
35000	1	0.7
40000	7	4.7
50000	12	8.0
60000	5	3.3
70000	2	1.3
80000	8	5.3

90000	3	2.0
100000	5	3.3
112000	1	0.7
120000	1	0.7
160000	1	0.7
200000	1	0.7
280000	1	0.7
500000	1	0.7
Total	150	100.0

Pigs Total Value	Frequency	Percent
NR	115	76.7
5000	1	0.7
18000	1	0.7
24000	1	0.7
30000	1	0.7
40000	1	0.7
50000	6	4.0
60000	1	0.7
70000	3	2.0
80000	1	0.7
90000	2	1.3
100000	5	3.3
120000	1	0.7

140000	2	1.3
150000	2	1.3
160000	1	0.7
180000	1	0.7
200000	2	1.3
300000	1	0.7
320000	1	0.7
390000	1	0.7
Total	150	100.0

Sheep Total Value	Frequency	Percent
NR	144	96.0
20000	1	0.7
40000	2	1.3
60000	1	0.7
70000	1	0.7
90000	1	0.7
Total	150	100.0

Chicken Total Value	Frequency	Percent
NR	39	26.0
3500	1	0.7
4000	2	1.3
5000	2	1.3

6000	4	2.7
7000	1	0.7
8000	4	2.7
10000	9	6.0
12000	9	6.0
14000	3	2.0
15000	11	7.3
16000	5	3.3
18000	4	2.7
20000	1	0.7
21000	1	0.7
24000	5	3.3
25000	6	4.0
28000	2	1.3
30000	3	2.0
35000	3	2.0
36000	2	1.3
40000	3	2.0
42000	3	2.0
48000	2	1.3
50000	3	2.0
56000	1	0.7
60000	6	4.0
70000	2	1.3
72000	1	0.7
77000	1	0.7

80000	2	1.3
98000	1	0.7
100000	3	2.0
120000	1	0.7
200000	1	0.7
216000	1	0.7
350000	1	0.7
480000	1	0.7
Total	150	100.0

Rabbits Total Value	Frequency	Percent
NR	150	100.0

Turkey Total Value	Frequency	Percent
NR	146	97.3
15000	1	0.7
20000	1	0.7
25000	1	0.7
250000	1	0.7
Total	150	100.0

Ducks Total Value	Frequency	Percent
NR	150	100.0

Livestock Quantity bought

Cattle Quantity bought		Frequency	Percent
	7	1	0.7
NR		149	99.3
Total		150	100.0

Goats Quantity bought	Frequency	Percent
NR	150	100.0

Pigs Quantity bought	Frequency	Percent
NR	150	100.0

Sheep Quantity bought	Frequency	Percent
NR	150	100.0

Chicken Quantity bought		Frequency	Percent
	5	1	0.7
NR		149	99.3
Total		150	100.0

Rabbits Quantity bought	Frequency	Percent

NR	150	100.0

Turkey Quantity bought	Frequency	Percent
NR	150	100.0

Ducks Quantity bought	Frequency	Percent
NR	150	100.0

Livestock Unit Cost

Cattle Unit Cost		Frequency	Percent
NR		149	99.3
	10000	1	0.7
Total		150	100.0

Goats Unit Cost	Frequency	Percent
NR	150	100.0

Pigs Unit Cost	Frequency	Percent
NR	150	100.0

Sheep Unit	Frequency	Percent

Cost		
NR	150	100.0

Chicken Unit Cost		Frequency	Percent
NR		149	99.3
	4000	1	0.7
Total		150	100.0

Rabbits Unit Cost	Frequency	Percent
NR	150	100.0

Turkey Unit Cost	Frequency	Percent
NR	150	100.0

Ducks Unit Cost	Frequency	Percent
NR	150	100.0

Livestock Total Value

Cattle Total Value		Frequency	Percent
NR		149	99.3
	70000	1	0.7
Total		150	100.0

Goats Total Value	Frequency	Percent
NR	150	100.0

Pigs Total Value	Frequency	Percent
NR	150	100.0

Sheep Total Value	Frequency	Percent
NR	150	100.0

Chicken Total Value		Frequency	Percent
NR		149	99.3
	20000	1	0.7
Total		150	100.0

Rabbits Total Value	Frequency	Percent
NR	150	100.0

Turkey Total Value	Frequency	Percent
NR	150	100.0

Ducks Total Value	Frequency	Percent

NR	150	100.0

How do you regularly rely on Park income?	Frequency	Percent
Throughout the year	136	90.7
Seasonally	4	2.7
Others	10	6.7
Total	150	100.0

Reasons to depend on park	*Count*	*Pct of Responses*	**Pct of Cases**
Grazing	96	30.4	65.3
Land for agriculture	105	33.2	71.4
Park resources for domestic use	109	34.5	74.1
Social-cultural reason	6	1.9	4.1
Total responses	316	100.0	215.0

Park Resources	***Count***	***Pct of Responses***	**Pct of Cases**
Firewood	122	17.5	81.3
Wild fruits	29	4.2	19.3
Medical plants	182	26.1	121.3
Small animals: birds, mice	1	0.1	0.7
Thatch grass	39	5.6	26.0
Poles for building	63	9.0	42.0
Sticks for hoes	74	10.6	49.3
Rope materials	1	0.1	0.7
Craft material	26	3.7	17.3

Fodder	104	14.9	69.3
Vegetables	56	8.0	37.3
Total responses	**697**	**100.0**	**464.7**

Involved in trade (enterprise) in any environmental resources?	Frequency	Percent
Yes	78	52.0
No	50	33.3
NR	22	14.7
Total	150	100.0

Why engage in trade	*Count*	*Pct of Responses*	**Pct of Cases**
To buy food and other basic items	49	46.7	67.1
To expand income source	12	11.4	16.4
To buy seed	42	40.0	57.5
To respond to the demand for the goods	2	1.9	2.7
Total responses	105	100.0	143.8

Trade items	*Count*	*Pct of Responses*	**Pct of Cases**
Firewood	25	27.5	42.4
Charcoal	5	5.5	8.5
Timber	26	28.6	44.1
Bricks	2	2.2	3.4

Handcraft	5	5.5	8.5
Bamboo shoots	28	30.8	47.5
Total responses	91	100.0	154.2

Average Production Costs and Price of goods produced

Selling Firewood Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Firewood Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Firewood Unit Price	Frequency	Percent
NR	150	100.0

Selling Firewood Average Production	Frequency	Percent
NR	150	100.0

Selling Firewood Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Charcoal Labour Unit	Frequency	Percent

Cost		
NR	150	100.0

Selling Charcoal Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Charcoal Unit Price	Frequency	Percent
NR	150	100.0

Selling Charcoal Average Production	Frequency	Percent
NR	150	100.0

Selling Charcoal Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Timber Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Timber Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Timber Unit Price	Frequency	Percent
NR	150	100.0

Selling Timber Average Production	Frequency	Percent
NR	150	100.0

Selling Timber Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Building Pole Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Building Pole material Cost	Frequency	Percent
NR	150	100.0

Selling Building Pole Unit Price	Frequency	Percent
NR	150	100.0

Selling Building Poles Average Production	Frequency	Percent
NR	150	100.0

Selling Building Pole Annual Income	Frequency	Percent
NR	150	100.0

Selling Hand Craft Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Hand Craft Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Hand Craft Unit Price	Frequency	Percent
NR	150	100.0

Selling Hand Craft Average Production	Frequency	Percent
NR	150	100.0

Selling Hand Craft Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Bricks Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Bricks Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Bricks Unit Price	Frequency	Percent
NR	150	100.0

Selling Bricks Average Production	Frequency	Percent
NR	150	100.0

Selling Bricks Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Quarry Stones Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Quarry Stones Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Quarry Stones Unit Price	Frequency	Percent
NR	150	100.0

Selling Quarry Stones Average Production	Frequency	Percent
NR	150	100.0

Selling Quarry Stones Average Annual Income	Frequency	Percent
NR	150	100.0

Selling Sand Labour Unit Cost	Frequency	Percent
NR	150	100.0

Selling Sand Raw material Cost	Frequency	Percent
NR	150	100.0

Selling Sand Unit Price	Frequency	Percent
NR	150	100.0

Selling Sand Average Production	Frequency	Percent
NR	150	100.0

Selling Sand Average Annual Income	Frequency	Percent

NR	150	100.0

Other sources of income	Frequency	Percent
Off farm employment	4	2.7
NR	146	97.3
Total	150	100.0

Do you regularly seek for support services?	Frequency	Percent
Yes	79	52.7
NR	71	47.3
Total	150	100.0

Service Provider

Veterinary Service Provider	Frequency	Percent
Government	143	95.3
Private	3	2.0
Namboole	1	0.7
NR	3	2.0
Total	150	100.0

Access to Market Provider	Frequency	Percent
Government	107	71.3
Private	10	6.7

NR	33	22.0
Total	150	100.0

Access to Health Service Provider	Frequency	Percent
Government	4	2.7
NAADS	1	0.7
NR	145	96.7
Total	150	100.0

Access to Extention Serverces Provider	Frequency	Percent
Government	1	0.7
NR	149	99.3
Total	150	100.0

NAADS Provider	Frequency	Percent
NR	150	100.0

PMA Provider	Frequency	Percent
NR	150	100.0

Prosperity for All Provider	Frequency	Percent

NR	150	100.0

Access to Credit Provider	Frequency	Percent
NR	150	100.0

Access to Climatic Info Provider	Frequency	Percent
NR	150	100.0

Access to Education Facilities Provider	Frequency	Percent
Government	134	89.3
Private	3	2.0
NAADS	2	1.3
NR	11	7.3
Total	150	100.0

Service Payment

Veterinary Service Payment	Frequency	Percent
Paid for	113	75.3
Free	24	16.0
NR	13	8.7
Total	150	100.0

Access to Market	Frequency	Percent

Payment		
Paid for	5	3.3
Free	103	68.7
NR	42	28.0
Total	150	100.0

Access to Health Service Payment	Frequency	Percent
Paid for	1	0.7
Free	4	2.7
NR	145	96.7
Total	150	100.0

Access to Extention Services Payment	Frequency	Percent
Free	1	0.7
NR	149	99.3
Total	150	100.0

NAADS Payment	Frequency	Percent
NR	150	100.0

PMA Payment	Frequency	Percent
NR	150	100.0

Prosperity for All Payment	Frequency	Percent
NR	150	100.0

Access to Credit Payment	Frequency	Percent
NR	150	100.0

Access to Climatic Info Payment	Frequency	Percent
NR	150	100.0

Access to Education Facilities Payment	Frequency	Percent
Paid for	5	3.3
Free	133	88.7
NR	12	8.0
Total	150	100.0

Service Comments

Veterinary Service Comments	Frequency	Percent
Good	28	18.7
Fair	2	1.3
Poor	2	1.3
Delay	1	0.7

NR	117	78.0
Total	150	100.0

Access to Market Comments	Frequency	Percent
Good	1	0.7
Fair	3	2.0
NR	146	97.3
Total	150	100.0

Access to Health Service Comments	Frequency	Percent
Good	1	0.7
Fair	2	1.3
NR	147	98.0
Total	150	100.0

Access to Extension Services Comments	Frequency	Percent
NR	150	100.0

NAADS Comments	Frequency	Percent
NR	150	100.0

PMA Comments	Frequency	Percent
NR	150	100.0

Prosperity Comments	Frequency	Percent
NR	150	100.0

Access to Credit Comments	Frequency	Percent
NR	150	100.0

Access to Climatic Information Comments	Frequency	Percent
NR	150	100.0

Access to Education Facilities Comments	Frequency	Percent
Good	10	6.7
Fair	30	20.0
Poor	1	0.7
Delay	1	0.7
NR	108	72.0
Total	150	100.0

Ceremonies/Activities	*Count*	*Pct of Responses*	**Pct of Cases**
Circumcision	104	72.2	128.4
Burial	30	20.8	37.0
Salt Lich	10	6.9	12.3
Total responses	144	100.0	177.8

Circumcision Resources used	*Count*	*Pct of Responses*	**Pct of Cases**
Sticks	25	25.3	34.7
Soil	36	36.4	50.0
Honey	26	26.3	36.1
Grass	1	1.0	1.4
Bamboo Poles	2	2.0	2.8
Water	6	6.1	8.3
Big leaves	1	1.0	1.4
Fire wood	2	2.0	2.8
Total responses	99	100.0	137.5

How often Circumcision Resource Collected		Frequency	Percent
	1	4	2.7
	2	4	2.7
	3	1	0.7
NR		141	94.0
Total		150	100.0

Burial Resources Used	*Count*	*Pct of Responses*	**Pct of Cases**
Sticks	121	62.7	133.0
Soil	36	18.7	39.6
Honey	34	17.6	37.4

Grass	1	0.5	1.1
Bamboo Poles	1	0.5	1.1
Total responses	193	100.0	212.1

Burial Resource Amount	Frequency	Percent
NR	150	100.0

How often Burial Resource Collected	Frequency	Percent
NR	150	100.0

Crop Production trend over the past five years	Frequency	Percent
Increase	3	2.0
Constant	17	11.3
Decreasing constantly	121	80.7
Fluctuating constantly	2	1.3
NR	7	4.7
Total	150	100.0

Are there noticeable land use and land cover changes?	Frequency	Percent
Yes	143	95.3
NR	7	4.7

Total	150	100.0

Noticeable land use and Land cover changes	Frequency	Percent
Reduction in crop yield	126	84.0
Rapid loss of vegetation cover	9	6.0
Loss of soil fertility	9	6.0
Increased land us due to increased soil conservation	1	0.7
New settlements and Encroachment	1	0.7
NR	4	2.7
Total	150	100.0

Has your household experienced any form of land degradation on the farmland?	Frequency	Percent
Yes	131	87.3
No	13	8.7
NR	6	4.0
Total	150	100.0

Social Economic Impact Experienced	*Count*	*Pct of Responses*	**Pct of Cases**
Famine	2	135	93.8
Floods	3	116	80.6
Siltation and sedimentation of water sour	4	89	61.8
Conflicts with neighbours	5	67	46.8
Total responses	407	100.0	282.6