EFFECTS OF GEOMORPHIC PROCESSES AND LAND USE ACTIVITIES ON SLOPE STABILITY IN MOUNT ELGON REGION, EASTERN UGANDA

TURYABANAWE LOY GUMISIRIZA (BA.A, MA.LURD)
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DECLARATION

“This thesis is my original work and has not been presented for a degree in any other University or any other award”.

Turyabanawe Loy Gumisiriza
Signature……………………………
Date……………….……

Supervisors:

“We confirm that the work reported in this thesis was carried out by the candidate under our supervision”

Dr. Shadrack K. Murimi (Ph.D)
Kenyatta University
Department of Geography
P.O.Box 43844
Nairobi Kenya
Signature…..……………………….
Date………………………………….

Prof. Joy Obando (Ph.D)
Kenyatta University
Department of Geography
P.O.Box 43844
Nairobi Kenya
Signature…..……………………….
Date………………………………….

DEDICATION

This work is dedicated to my dear parents Petero Rwekishaija (RIP) and Jeneti Kairagwire Rwekishaija, and my dear children Daglous, Derrick, Edith and Elizabeth who should always strive and inspire others to make education their pillar of success.

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LIST OF ABBREVIATIONS AND ACRONYMS

DEM:	Digital Elevation Model
ETM:	Enhanced Thematic Mapper
FAO:	Food Agriculture Organisation
GIS:	Geographic information systems
GLCF:	Global Land Cover Facility
GPS:	Global positioning systems
GSM:	Geological Survey and Mining
ILWIS:	Integrated Land and Water Information System
LC:	Local Council
MAAIF:	Ministry of Agriculture, Animal Industry and Fisheries
NEMA:	National Environmental Management Authority
NFA:	National Forest Authority
NGO:	Non- Governmental Organization
RDC:	Resident District Commissioner
SRTM:	Shuttle Radar Topographic Mission
UBOS:	Uganda Bureau of Statistics
USA:	United States of America

ABSTRACT

This study assessed the effects of geomorphic processes and land use activities on slope stability in Mount Elgon region, in Eastern Uganda. The main objective was to assess the stability of slopes in Mount Elgon so as to map the instability prone areas. To achieve this, the study investigated geomorphic processes and land use practices taking place on slopes and the role of geomorphic processes and land use activities in rendering such slopes unstable. In addition, zonation and mapping of slope instability risk areas, assessment of peoples' perception and attitude towards slope failure as well as response to evacuation programmes put in place by government were assessed. Data was collected through field surveys as well as interpretation and analysis of aerial photographs and Landsat imagery. Interaction with land users, planners and local authorities was conducted through questionnaire administration, conducting interviews, and focus group discussions. Data analysis involved both qualitative and quantitative techniques. Qualitative analysis involved computation of non-arithmetic relations. Descriptive statistics and percentages were used while correlation coefficients and chi- square tests were computed to determine the forms and strengths of underlying relationships. The study established that Mount Elgon is a naturally unstable environment with regard to slope stability. Geomorphic processes especially weathering and undercutting of slopes by rivers was found to contribute directly and indirectly to slope instability experienced in the region. Land use activities such as cultivation, construction and associated clearance of forests have aided natural processes to destabilize the already unstable slopes triggering slope failure. The study classified the slopes in the area into slope instability hazard areas according to when slope failure was last experienced and slope instability risk areas based on slide potential as seen from slope gradient. Even though majority (70%) of the respondents expressed awareness of the unstable and landslide prone environment they are living in, they have over time developed an attitude that has led them to ignore landslides even though they disrupt their life when they occur. The coping mechanisms adopted as well as the people's response to evacuation programmes following slope failure were established to be popularly in favour of staying (84.5%) rather than evacuation (15.5%) from the risk areas. The study concludes that although natural prerequisites for slope failure are ample and of overruling importance in Mount Elgon, human activities need to be regulated or better still prohibited in order to address the situation. The study provides a landslide inventory and slope stability database upon which policies regarding use of land in slope instability hazard areas can be formulated. The intervention strategies recommended by this study could also offer practical short term and long term remedies where ever a similar problem is experienced. Following such a study, studies on landslide vulnerability assessment, resilience and coping mechanisms related to landslides need to be conducted in the area and other areas that face similar hazards.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter introduces the problem that was studied. Specific aspects covered include background of the problem, statement of the problem, objectives of the study, questions that guided the research, hypotheses, justification of the study, its significance, and the major problems met while executing the study.

1.2 Background to the Study

Slopes are a remarkable feature of the landscape not only true of mountainous and hilly areas but also of many plains. However their pronounced nature in the mountainous and hilly areas makes them dynamic landscapes that are often referred to as high energy landscapes of vast instabilities (Westerberg 1999, Bruce 1989, Plummer 2003, NEMA 2007, and NEMA 2009). The high altitude, steep slopes, extreme climatic conditions and above all gravity combine to make these areas a dy’namic mechanism where geomorphic processes are often rapid and at times reach catastrophic extents. This is thus a suitable environment where the role of geomorphic processes in shaping slopes as well as creating slope instability could be successfully conducted.

Slopes in particular, exist in varying degrees of steepness ranging from those that are almost level (0^{O}- 2^{O}) to those that are vertically inclined (above 45^{O}). Whereas some slopes are covered by parent rock, most have a cover of weathered materials called regolith (soil and saprolite). It is however important to note that both parent rock and regolith covering the slope is not static but its composition as well as quantity are being changed by continued weathering. It is at the same time being carried down slope by processes of denudation. It therefore becomes clear that slope steepness is a balance between geomorphic processes that destroy the parent rock to create regolith and those that transport it down slope.

Regolith on level surface requires an agent or medium of transportation while regolith on slope simply moves by the force of gravity which a function of slope steepness and slope length. Due to the influence of gravity, regolith becomes subjected to shear stress. The mechanism is at the same time balanced by shear resistance to counter the effects of shear stress introduced by forces of gravity and thus attain slope stability. It is at this point that a slope is believed to be in equilibrium or balance. However if shear stress from any source exceeds the shear resistance of the material on the slope, the slope will have become unstable. Consequently slope failure or movement will occur in form of rapid down slope movements of differing rates **(APPENDIX 1.1**).

Slope instability therefore is a problem of either increased shear stress on a slope or reduced shear resistance of material covering a slope and its climax is shear failure manifested as slope failure. This kind of situation is a reflection of destruction of natural slope stability which is as a result of both natural as well as human inducing factors (Ramli *et al;* 2005). Although slope instability can occur on any inclined surface, the physical conditions as well as human activities in the hilly and mountainous areas make them susceptible to rapid movements which are often disastrous. This leaves a great imprint on the landscape that can be measured accurately over a given period of time. It also explains the common occurrence of slope failure in settled mountainous areas of the world such as Himalayas in Nepal (Laurie 2004), Andes in Peru (Wemple *et al;* 2000) and in Mount Kenya and Aberdares in East Africa (Ngecu and Nyamai 2004).

Uganda like other parts of the world experiences problems of slope instability in densely settled mountainous areas of the country. Mount Elgon is such an area that has continuously experienced rapid mass movements. These mass movements are reported to have been disastrous but not yet scientifically investigated and documented to bring out technical information to be used in finding appropriate adaptive and adjusting strategies (Kitutu 2002, Knapen et *al*; 2006). Although mountains in western Uganda particularly in Bundibugyo district and Kigezi highlands in south western Uganda have been affected by landslides; Mount Elgon has registered the highest intensity of landslides (Muwanga 2001, NEMA 2009). This area also has the highest population of people living in landslide prone areas. Being a rural area a variety of land use activities are practiced here but the most outstanding ones are settlement and agriculture. All this characterizes it as a potentially high risk area. Research related to slope instability in the area aimed at assessing the role of geomorphic processes and land use activities in destroying natural slope stability was necessary. The current study addresses the underlying issues contributing to an increase in shear stress as opposed to those reducing shear resistances in some slopes in Mount Elgon region in Uganda. To achieve this, the study analysed the characteristics of slopes in Mount Elgon area which have continually been affected by landslides in the past. This was done in order to generate and document information that can be adopted so as to devise effective strategies of coping with slope instability.

1.3 Statement of the Research Problem

Slope instability in Mount Elgon is reported to have occurred for the last forty years and of all areas that have suffered landslides in Uganda, it is this area that has registered the highest intensity (Kitutu 2002). Studies conducted in the area reveal that the mountainous nature of terrain, deforestation, high population densities, and high intensity rains have been the reasons behind slope instability (Knapen *et al;* 2006). Kitutu further reveals that of all areas affected by landslides in Uganda, it is Mount Elgon which has the highest population of people living in areas affected and that this characterizes it as a high risk area. The consequent trend of events has been that the intensity of landslides has increased over the last forty years and more areas initially seemingly safe from landslides currently rank high among the slope instability prone areas of the country.

It is against this background that this study was conducted seeking to map and document some landslide prone slopes of Mount Elgon in order to establish the effects that geomorphic processes and land use activities have had in rendering these slopes prone to slope failure. The elements at risk of these slope failures, the perception and attitude of the local people towards slope failure incidences and coping /evacuation strategies that are put in place by the Government were also another concern for the study.

Landslides in Mount Elgon have put many elements at risk such as human life, productive farmland and infrastructure such as buildings, roads and bridges. Effective coping strategies aimed at reducing the level of vulnerability can therefore be put in place following documentation and mapping of some slope instability risk areas.

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of the study was to assess the stability of slopes in Mount Elgon region so as to map the instability prone areas.

1.4.2 Specific Objectives

Specifically, the study was guided by the following objectives:-

1. To assess the influence of geomorphic processes on slope stability on some slopes of Mount Elgon.

2. To evaluate the influence of land use activities on slope stability on some slopes of Mount Elgon.
3. To characterize the slope instability risk areas using risk zonation mapping.
4. To examine people's perception and attitude towards slope instability risk.
5. To evaluate people's willingness to participate in intervention programmes put in place by government.

1.5 Research Questions

The study was guided by the following questions;

1. What is the impact of geomorphic processes on the stability of slopes in Mount Elgon region?
2. How have land use activities contributed to instability of slopes on Mount Elgon region?
3. What is the extent and vulnerability to slope instability risk areas in Mount Elgon region?
4. How do people perceive and respond to risks from slope instability?
5. How do people respond to any interventions put in place by the government?

1.6 Hypotheses

This study was guided by the following null hypotheses (H_O):

1. Slopes covered with cultivated crops on shallow soils do not fall at lower angles as those covered with cultivated crops on deeper soils but at higher angles.
2. Land use activities do not lead to increased incidences of slope failure in Mount Elgon area.
3. People’s willingness to modify land use on unstable slopes is not influenced by the size of land a person owns.
4. There is no difference between the perception and attitude towards evacuation by land users whose land has experienced slope failure and those that have not.

1.7 Justification and Significance of the Study

Slope instability in Mount Elgon is common in the steep densely populated slopes (Knapen *et al* 2006). It is a natural as well as a human induced phenomenon that has over the years increased in intensity and areal extent. A number of slopes have become risky habitats even though people continue to inhabit them. This has put a number of elements at risk. It was therefore inevitable that mapping and documentation of the vulnerable areas be done so as to provide information that can help to devise effective coping and evacuation strategies. Perception and attitude of the people towards the dangers of slope instability and government efforts to evacuate people from the slopes that are prone to slope instability also needed to be established so as to assess people’s awareness of the dangers of the environment they are living in.

The significance of this study is that decision makers both at national and local levels will base their policies on information that this study has provided to put in place effective adaptation and adjustment strategies. The resultant landslide risk map has for instance revealed the slope failure risk zones that may require having people evacuated so as to reduce the number of elements at risk.

The relationship between geomorphic processes and land use activities that has been established will guide decision makers in devising appropriate land use plans and policies. The findings should for instance serve as an a guide to the local governments or central government concerning the importance of bye-laws governing use of slope failure prone areas such as river banks, road reserves and very steep slopes.

The study has also created a data base upon which the local governments and central government can base to regulate land use activities on slopes that have been established to be slope instability risk zones. Basing on the slide potential zones indicated by this study the authorities will be able to devise appropriate intervention measures that should help to reduce on the degree of loss to each of the elements occupying a given slope.

1.8 Limitations

Language barrier to oral communication with the local community was one of the limitations experienced during data collection. To overcome this, research assistants conversant with the local "Lumasaba" were recruited. These research assistants administered questionnaires and also consulted the local people and local leaders in cases where some observations required clarifications.

Determination of accuracy of information about perceptions of the respondents was another challenge that faced the study. This arose from the fact that slope instability hazard was perceived in a variety of ways by different people. The researcher minimized this by considering the various perception filters so as to determine accuracy of the information given by each respondent.

Some respondents were reluctant to give information on grounds that they had previously given out such information but the victims were never assisted as they expected. Such people indicated that they willingly give information hoping the victims would be given relief items but this was more often never fulfilled. Consequently, the researcher in such cases chose the next target respondents on the list raised by the parish leader.

1.9 Assumptions

The following assumptions were made at the various stages of the study.

- Slope failure occurs more during the rainy season than in the dry season.
- Some geomorphic processes operating on some slopes of Mount Elgon either cause or trigger slope failure.

- Some land use activities carried out on some slopes of Mount Elgon are responsible for the occurrence of slope failure in the area either by causing or triggering it.
- Land users had lived long enough in the area to be well conversant with the occurrence or non- occurrence of slope failure on the slopes they are utilizing and elsewhere in their parishes of residence.
- All the selected study respondents were assumed to be owners of the land they were using.

1.10 Operational terms

The following terms were used in reference to what has been indicated;

1. **Adaptation**: A long term arrangement of activity that take account of the threat of natural extremes.
2. **Adjustment:** All intentional actions taken to cope with the risk and uncertainty of natural events.
3. **Elements at risk:** The population, properties, human and economic activities at risk of an impending damaging event in a given area.
4. **Geomorphic processes**: A natural or human induced land forming activity.
5. **Hazard zonation:** Defining the tendency towards a damaging phenomenon.
6. **Landslide:** The downslope gravitational movement of earth material as a unit owing to failure of the material.

7. **Land user:** A person utilizing land for a specific production to meet his/her livelihood needs.
8. **Regolith:** A layer of unconsolidated material mantling the surface of intact unweathered bed rock.
9. **Risk:** The potential of losing something of value.

   Saprolite: Unconsolidated in-situ weathered rock overlying firm bedrock.
10. **Shear resistance:** Ability of a soil to hold together against detachment and removal.
11. **Shear stress:** A tangential force that pulls material down slope.
12. **Slope stability:** A situation on a slope when either rock or regolith has sufficient strength to withstand stress.
13. **Slope failure:** Collapse of a slope when maximum resistance of a material is overpowered by the force tending to tear a material apart.
14. **Stream:** A body of water with a current confined within a bed and stream banks.
15. **Vulnerability index:** A measure of the degree of loss to a given element or set of elements at risk resulting from occurrence of a landslide of a given type.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Studies on slope stability have been conducted in different parts of the world (Abbot 1999, Cunningham and Cunningham 2004, Alcantara-Ayala 2004, Jasmi 1997, Carara 2005, Gaillard 2007, Rafi 1999, Ngecu 2004, and Nakileza et al; 1998. These are studies carried out both in the developed and developing parts of the world, and some were actually conducted in Mount Elgon itself (Kitutu 2002, Obua et al; 2004, Kitutu 2006 and Knapen et al; 2006). The significant aspects investigated by these studies include forms of slope instability, causes of slope instability, people's perception and response towards slope failure incidences, effects of slope failure and slope instability hazard zonation. The issues that are of relevance to the current study are reviewed in this chapter according to sub-headings depicting the aspects stressed. The chapter also presents the relationship that was conceptualized to exist between the variables of the study.

2.2 Conceptual Framework

The conceptual framework illustrates the link between causes or triggers of slope instability, effects and people's perception and response to slope instability hazards as shown in **Figure 2.1**.

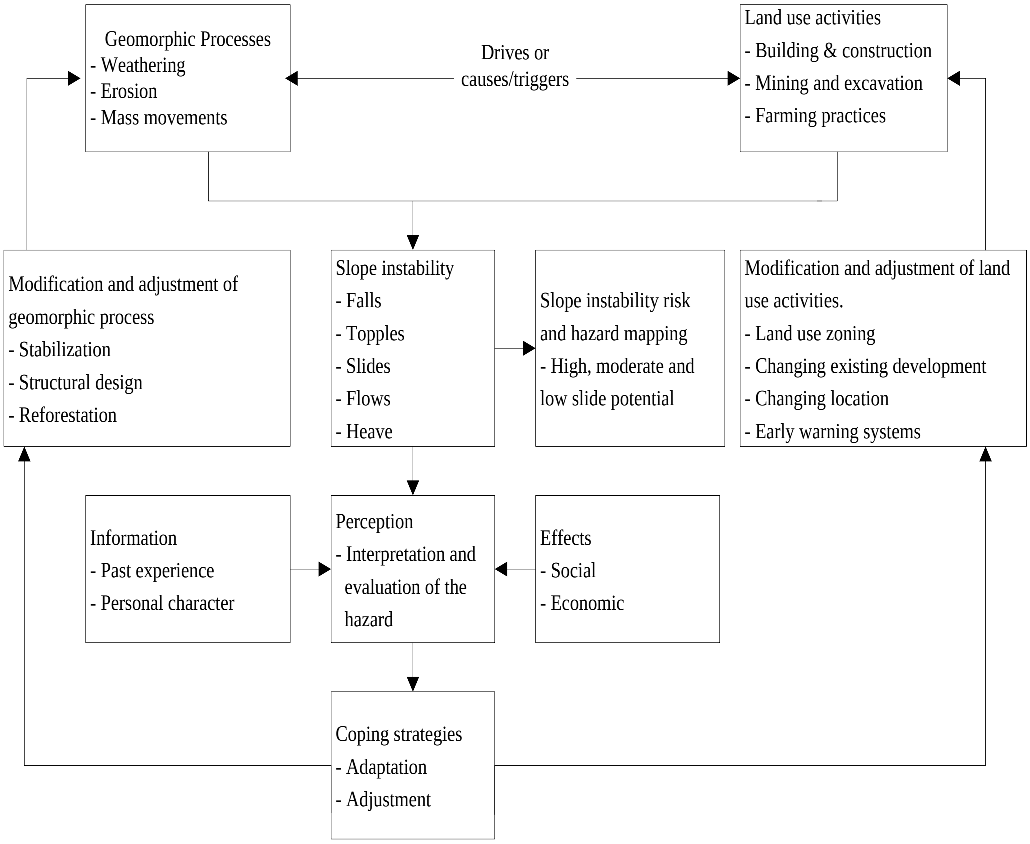

Figure 2.1: Conceptual Framework flow chart

(Morgan 1982, Muthoka *et al;* 1998)

It was formulated by the researcher by adopting and modifying the concept of (Morgan 1982) shown in figure 2.2.

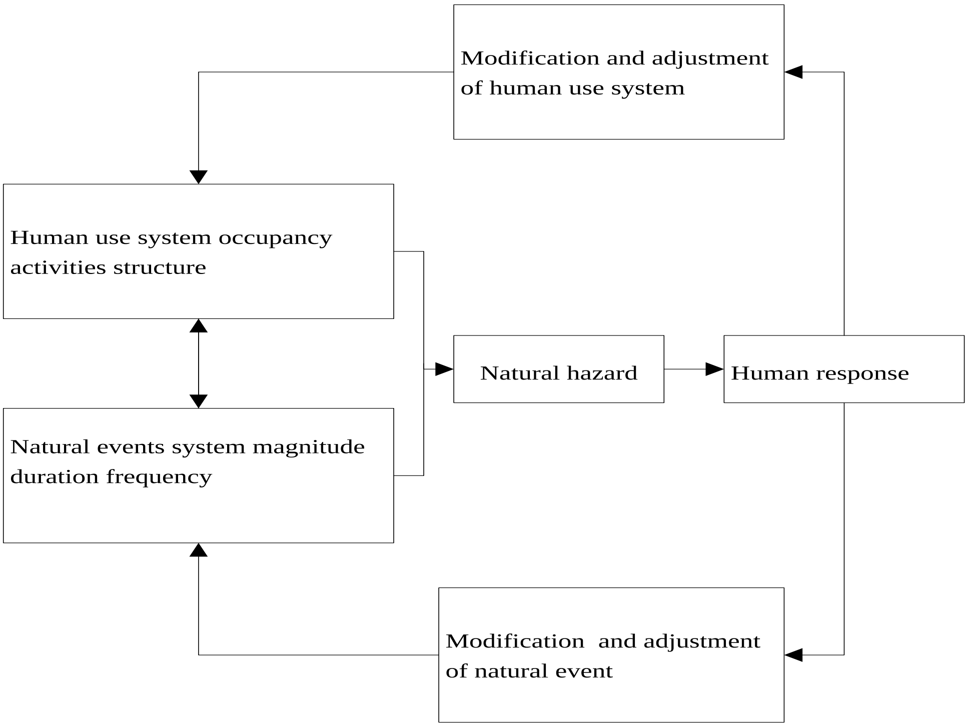

Figure 2.2: Forms of human adjustment to natural hazards (Morgan 1982)

The framework contains four major components which in turn relate to the objectives of the study. The first component is causes or triggers which may be either natural or human induced factors. For purposes of this study geomorphic process such as weathering, mass movement and erosion were the natural factors of study while land use activities such as building and construction, excavation, and farming were the human induced factors considered in this study.

Whereas a cause pushes the slope to the brink of failure, a trigger leads to or initiates the act of slope failure which puts a number of elements at risk and also renders others vulnerable. This component encompassed both the first and second objectives of the study which were to assess/evaluate the influence of geomorphic processes and land use activities on slope stability in Mount Elgon.

The second component is slope instability risk and its zonation. The state of slope instability is when shear stress on either rock or soil on a slope exceeds its shear resistance. It is usually manifested in form of movements of different rates ranging from slow movements to rapid ones – **Appendix 1.1.** In the case of this study slope movements conceptualized were falls, topples, slides, flows, heave and slips. The state of slope instability that involves rapid mass movements has rendered some areas risky thus necessitating efforts directed towards their zonation according to their slide potentials, degree of steepness, and height above sea level. This component of the conceptual frame work formed the third objective of the study.

The third component is perception which is the mental interpretation and evaluation of slope instability risk. It is usually influenced by personal experience, characteristics and sources of information available to the affected person. It is upon these that decisions are made regarding coping strategies in favour of adaptation or adjustment. People have for instance adapted by relying on relief aid and rehabilitation, practicing agro-forestry and short term retreat from the areas affected. Adjustment on the other hand has been by re-forestation, changing land use and stabilization structures.

Coping strategies are the fourth component which covers the different strategies that are devised either to prevent or mitigate the full impact of slope instability hazards to residents. Such strategies are conceptualized to involve modification and adjustment of land use activities and/or modification and adjustment of geomorphic processes.

2.3 Factors Affecting Slope Instability

2.3.1 Geomorphic Process

Abbot (1999) notes that many mass movements are reported with descriptions of events that triggered their movement. The triggers noted include earthquakes, volcanic eruptions and major rainstorms. Though earthquakes and volcanic eruptions were noted to be a common mass movement trigger by Abbot, no seismic activity has been reported in the area of study (Nakileza and Biryabarema 1998). Volcanic activity is commonly noted as being responsible for the formation of Mount Elgon, a volcano that is however believed to be extinct and highly degraded by exogenic forces (NEMA 2009).

According to Don (2007) the decrease in material strength associated with weathering is a slow but steady trigger. However, it’s argued that this triggering mechanism may not be easily determined but at some point material becomes so weak that failure must occur. In line with this, Stathan (1977) asserted that through time, weathering processes reduce the factor of safety of a slope until the critical value is reached. To him these are a kind of steady increase in the susceptibility to failure which is never the cause of a slide. This is an indication that it is rather difficult to determine weathering as a trigger of slope failure than a cause of slope instability.

Sthapit and Tennyson (1993) asserted that the cold climate experienced in the Himalayas favors physical weathering which has led to slow development of soils that are in turn stony in texture. Their study indicated that this was a phenomenon in sparsely populated areas and that rockslides are quite common here in the high mountain region. While their study was conducted in a sparsely populated area, the current study has been conducted in a densely and moderately populated mountainous area. Some parts of the study area are indeed stony like what was observed of the Himalayas.

Ngecu and Nyamai (2004) in their study on extent and significance of mass movements in Abadares observed that the warm and wet climate of the landslide-prone regions causes rapid weathering and produces a regolith weaker than the underlying rock. They further asserted that weathering causes an interface between the regolith and the underlying rock and that it is this interface that serves as the most common plane along which landslides are initiated once it becomes saturated. This observation is indeed true in parts of

Mount Elgon especially those where weathering has resulted into formation of deep red soils.

Berry (2006) noted that a rock avalanche/rockslide possibly initiated by toppling of a 15 metres overhanging limestone cliff engulfed slums in Duwaqua district of Cairo Egypt. A similar incident was indicated to have occurred at Al - Dhafur Yemen in December 2005 when a sandstone cliff failed and a rock avalanche descended on a mountain side village. The cause of both failures was however indicated to have been unknown. Such incidences where hanging rocks simply collapse down the scarp or bare rock faces without any other trigger other than lack of enough support are indeed a common occurrence in parts of Mount Elgon dominated by ridges with scarp faces inclined above 45^o.

According to Kitutu (2006), steep slopes, high rainfall, soil properties and stratification have turned Manjiya into an inherently unstable area. Though Manjiya was part of the current study area, this study unlike the former engaged in demarcating slope instability risk zones basing on physical slope characteristics.

According to Knapen, *et al;* (2006), Mount Elgon area in eastern Uganda has suffered from landslides because of the mountainous nature of terrain, deforestation, high population densities, intense rains and other factors not yet clearly established. Since the outcome of population pressure is deforestation of slopes for specific land use requirements one would need to analyse utilization of land by various land use activities in order to understand the problem of slope instability. Geomorphic processes also needed to be analysed because they are a natural process continuously shaping the land.

According to Obua *et al*; (2004), soil erosion resulted into incidences of landslides on the steep slopes of Mount Elgon between 1997 and 1999. They further noted that this resulted in loss of human life, degradation of agricultural land, destruction of property and displacement of people. This is an indication that there were indeed some elements at risk that required be established and computed.

2.3.2 Anthropogenic Controls

Ives and Mersserli (1980) in their study on Himalayan environmental degradation, related deforestation of steep slopes and construction of agricultural terraces to rapid acceleration of gullies and landslide increase. They noted that in some instances landslides were deliberately triggered by water diversion in order to facilitate new terrace construction. In a related incident Ramsey (1986) asserted that in large areas of failure in the Himalayas, the influence is to some degree by human intervention in the form of mismanagement of land for agricultural purposes. Terrace farming is however not a common practice among the people of Mount Elgon except for a few who employ shallow terraces that have actually been blamed by earlier researchers to facilitate slope instability (Kitutu 2002). Most cultivators in the area just grow crops without employing any form of soil conservation techniques.

Laban (1979) carried out an airborne reconnaissance of most of Nepal and observed that 75% of landslides here in terms of occurrence were due to human induced land use change. He observed that landslides and other catastrophic slope failures throughout Himalayan system have not only been widely reported but viewed with alarm because it is assumed to be the direct consequence of human land use changes over recent decades. Although land use change especially that involving change from a denser land cover to bare ground would indeed create slope instability, land use in densely populated areas tends to be fixed.

Wemple, *et al;* (2000) carried out a study on forest roads and geomorphic processes interaction in the western Cascade Range of Oregon in USA. The authors found out that roads functioned as both production and depositional sites for mass movements as well as fluvial processes. They further noted that debris slides from mobilized road fills were a dominant process of sediment production from roads. Their study found out that road-related sedimentation features were concentrated on a portion of the study area that was characterised by the oldest roads and steep slopes underlain by unstable, highly weathered bedrock. Roads in Mount Elgon are mostly murram coated and their embankments are bare where they cut deep into the slope. This makes such roads vulnerable to slope failure incidences.

Using remote sensing data and GIS techniques, Jasmi (1997) studied slope instability in Cameroon highlands and found out that construction of roads on steep slopes was the most important causative factor. Classified information from infrastructure and land use units revealed a high risk area with several main roads on slopes. Although Mount Elgon is served by one main road that connects Mbale and Kapchorwa towns, there are also a number of feeder roads existing in the area that cut across steep slopes and are indeed likely hot spots for slope failure.

According to Sthapit and Tennyson (1993), slope instability in Nepal as a product of human activities is caused by deforestation in hills and mountains. Studies conducted in various parts of East Africa suggest that slope disturbance particularly by deforestation related to population pressure is the major cause of landslides in the highlands (Ngecu and Mathu 1999, Muwonge *et al;* 2001, Kitutu (2006), and Kitutu 2010). Concerning the situation in Uganda Nakileza and Biryabarema (1998) indicated that landslides have been reported in mountainous areas of the west and east of the country and that in almost all these areas slope failure occurs where there has been deforestation. The New vision (4thOctober 2009:18) also expressed a similar view that deforestation as a result of population pressure was the cause of the landslide that hit Kyokyezo village in Rubanda County, Kabale district in October 2009. It was argued that intense population pressure caused environmental degradation and when heavy rains came the landslide occurred because there was no barrier to check runoff.

Kitutu (2002) in her study in Manjiya County observed that the intensity of land sliding had increased over the years because the area had been cleared off the original forest cover and turned into farmlands. Results of her study noted that high demand for land for farming and settlement had forced people to settle on steep slopes. A common practice in Mount Elgon therefore is that when forests in such densely populated areas are cut down, new land use activities occupy the land. Utilization of land on steep slopes without any soil management practices and engineering works of construction on steep slopes has greatly contributed to slope instability in the area. It is thus reasonable to relate slope instability in such areas to land use that would be currently occupying the land than the act of deforestation itself unless land at the time of failure was unutilized.

Deforestation and cultivation were also indicated by Knapen *et al; (2006*) and NEMA (2007) to have consequently lowered the threshold of slope stability on densely populated steep concave slopes of Mount Elgon thereby triggering slope failure during heavy rains. Whereas this observation was made in the densely populated slopes, the current study focused on slopes of both the most and least affected areas which maybe densely or sparsely populated.

2.4 Slope Instability Risk Zonation

Borga, *et al;* (2004) conducted a study on shallow landslide hazard assessment in northern Italy and delineated areas most prone to shallow land sliding due to surface topographic effects on hydrologic response. Their delineation was based on shallow sub-surface run off and infinite slope failure measurements. The current study in Mount Elgon likewise sought to delineate slope instability risk areas through geomorphic mapping, measurement and monitoring of geomorphic processes as well as infinite slope failure measurements of all forms of slope instability.

Carrara (2005) conducted a study on factors that control slope instability phenomenon in southern Italy. The study found out that geologic and geomorphic variables can be mapped to discriminate rather successfully between stable and unstable slope units. The current study likewise engaged in discriminating between stable and unstable slopes in parts of Mount Elgon by mapping linear structures.

Alcantara-Ayala (2004) asserted that landslides are of major significance in the Sierra Norte Mountains of Puebla in Mexico which is an area with isolated communities. By use of field observations and analysis of satellite images, the study concluded that highly weathered limestone is a source of structural weakness which decreases the strength of slope materials making it highly susceptible to slope failure. Alcantala-Ayala (2004) conducted her study in an area that was sparsely populated. The current study was conducted in an area that is relatively densely populated and with diverse land use activities. Such land use activities are expected to render slopes susceptible to failure.

Espizua and Bengochea (2002) carried out landslide hazard and risk zonation mapping in Rio Grande basin of central Andes. Using topographic maps, geologic maps, satellite images and close monitoring in the field, they came out with a hazard and risk zonation map showing active and inactive slopes. Whereas their study was conducted in a temperate environment where humid conditions prevail throughout the year, the current study was conducted in the tropics where humid conditions are seasonal. Unlike the former the latter also engaged the local community and other stake holders in discussions which were useful in devising some strategies for sustainable land use of landslide prone slopes.

Claessen's *et al;* (2007) used LAPSUS landslide model and digital terrain analysis of topographic attributes as a tool to simulate recent shallow landslides in Manjiya County on the Ugandan slopes of Mount Elgon. The model was tested in Manjiya study area for its ability to delineate zones that are prone to shallow land sliding and to categorize recent landslides into specific landslide hazard. Although the current study was also aimed at landslide hazard mapping, it unlike the former covered both the past and recent forms of slope instability. All landslide scars in the sample parishes whether shallow or deep were mapped and classified as active, intermediate and inactive slope instability risk areas.

According to Knapen *et al* (2006) and NEMA (2007), deforestation and intensive cultivation on concave slopes alters soil hydrological conditions through enhancing saturation thereby triggering debris flows under extreme rainfall conditions. Their study however did not indicate the steepness of the slope as was done by the current study.

According to Wati *et al;* (2010), Knapen *et al* (2006) and Kitutu (2010) 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. Knapen *et al;* (2006) goes ahead to refer to slopes in Mount Elgon as stable, marginally stable, and actively stable according to preconditions preparatory and triggering causal factors. Such factors include topography, lithology, shrink-swell properties and rainfall received as a catalyst.

2.5 People’s Perception of Slope Instability

According to Rapoport (1977) perception is the direct sensory experience of the environment or situation for those who are in it for a given time. He further argues that it may be explained as the way in which people understand structure and learn the environment and use their interpretations to negotiate it. The people living in Mount Elgon indeed have their ways in which they view and negotiate the problem of slope instability experienced in the area and how it affects their livelihoods.

Rapoport (1977) further asserts that people’s perception of their environment is not only influenced by culture and previous experience but also by expectations which these events generate and consequent mental set which may affect how various specific objects are perceived. According to him, perception involves the present stimulus information, present contextual information as well as stored information. The perceiver’s current and stable characteristics, previous experiences as well as hopes, ambitions, fears, values and various other ‘real’ and imagined elements also constitute perception. In line with this, Waugh (2000) asserts that the people’s views are often dependent upon their knowledge and experience of the event in order to make decisions. According to Morgan (1982), the greater the exposure to the hazard and experience of the hazard the accurate and discriminating the perception. Interpretation and evaluation of slope instability in Mount Elgon is likewise determined by filters emanating from the people’s past experiences, present circumstances and their future expectations.

According to Cunningham and Cunningham (2004), people are often unaware of the risks they face in locating on or below unstable hillsides. They further note that people sometimes simply ignore clear and obvious dangers. They cited the case of Southern California where people often build expensive houses on steep hills and narrow canyons that appear quite stable in a dry environment, yet vegetation burns frequently and fiercely during late summer wild fires. This exposes soil to mudslide and debris flows during heavy winter rains. Whereas these findings were made in the developed part of the world where information is effectively disseminated and superior technology sometimes entices people to stay in hazardous areas, Mount Elgon lies in the developing world where people are still largely environment dependent and therefore vulnerable to hazards.

Rafi *et al;* (1999) conducted a study on landslide loss reduction in Kingston metro-politan area of Jamaica and found out that landslides are not as spectacular as a hurricane or an earthquake when they affect a small section of population at any locality. They noted that public interest is aroused only in cases of spectacular landslide events that make headlines because people are killed, injured or buried under debris. Although the cited study was conducted in an area that is prone to other more spectacular hazards than slope instability, Mount Elgon is an area where landslides are a major natural hazard. Nevertheless, landslides indeed arouse national concern whenever they cover a large cross sectional area of a slope and therefore affect a big section of the population.

According to Mitchell (1989), Morgan (1982), and Alcantara–Ayala (2004), people interpret disasters as an act or will of God. Morgan (1982) noted that such people are happy to leave action to what they perceive to be an omnipotent and benign God. In line with this, Rafi *et al;* (1999) noted that in some cases hazardous events are regarded as mysteries like the case of the 1986 Preston landslide that left the village a ghost after residents were forced to abandon their homes and farming lands. The cited authors observed that the overall public reaction to this event described it as “St. Mary Mystery”. More still the same view is shared by Borja – Baeza *et al;* (2005) who observed that to the people of Sierra Norte de Puebla in Mexico, the marginality and impact of disasters is commonly considered as part of the duality between good and bad or natural and unnatural worlds that is attributed to the god’s. These people know that during some moments they can be involved within the blameless and then at some others within evil. The people of Mount Elgon likewise have their various explanations regarding the problem of slope instability and these have been established by the current study.

Roman *et al;* (2001), and Ives and Messerli (2005) noted that the indigenous subsistence farmers in middle mountains of Nepal perceived a landslide to be a beneficial occurrence because the more easily worked earth of the landslide scar actually facilitates terrace construction. Carmen and Kilbun (1999) asserted that vulnerable communities in the Barranco de Tirajan basin on Gran Canaria which is one of the active zones of Canary Islands are generally aware that landslides occur in the basin and can be dangerous, but they rarely consider slope movements as a potential hazard to themselves. Consequently they are also uncertain about the most effective response during an emergency. On the contrary occupants of Mount Elgon are not only aware that landslides can occur anywhere on the mountain but they also know that slope movements are a potential hazard to them.

Obua *et al;* (2004) in his study on the local people's perception of landslides in Manjiya in eastern Uganda reported that the people believe that landslides occur mainly in the wet season and are triggered by frequent cultivation of the same piece of land, prolonged heavy rains, highly permeable soils and steep slopes. They noted that people indicated that land fragmentation, removal of tree cover and shallow terraces accelerate soil erosion and increase the risk of landslides. They further noted that people could actually predict occurrence of landslides and identify areas with landslide risks using indicators like concave slopes that trap rainwater, low tree cover, and stony soils. Whereas Manjiya County which is the current Bududa district forms one of the steepest and densely populated areas of Mount Elgon, other areas covered in the current study such as Manafwa, Mbale, and Sironko are rather moderately populated. The current study partly engaged in establishing the ways in which people in such areas perceive slope instability.

2.6 Coping Strategies Towards Incidences of Slope Instability

Ehsan-Haq (2007) conducted a study on community response to climatic hazards in Pakistan and concluded that there has been collective action by local communities through grass root institutions and local support organizations in effective tackling of problems of a fragile environment. He notes that communities now know it is useless to wait for public institutions to address emergency situations. Contrary to the above, Clark *et al;* (1987) noted that the flood plain dwellers in Shrewsbury England believed it was someone else's responsibility to carry out hazard control measures, organize warning system or set up programmes for evaluation and relief. To Clark *et al;* (1987), such expectation of a centralized or collective adjustment appeared to be common place in most world societies. The situation in Mount Elgon needed to be analysed in order to establish the coping responses that are taken following slope instability incidences.

Gaillard and Le Masson (2007) noted that the volcanic eruption of Mount Pinatubo on the main Island of Luzon in Philippines led to a change in the indigenous cultural fabric of the Aetas. It is doubtable as to whether there could have been such an impact among the Mount Elgon dwellers following slope failure incidences since a number of respondents indicated that they usually vacate an area once a landslide has occurred only to return in a short while.

According to Butler (1976) people generally tend to be reluctant to alter their daily patterns of living unless disaster has already struck. Clark *et al;* (1987) share the same view for they also noted that there appears to be a marked reluctance of individuals to heed hazard warnings or move away from a risk prone area. Similarly Plummer *et al;* (2003:210) in their study of a Los-

Angeles landslide cited the following comments of a resident whose home was moved down slope;

> *"It's no problem. Esther and I figure if we slide down too far, we will just pick up and go back to the top of the hill, and start all over again; that is if the hill is still there after the earthquake".*

Such an individual comment clearly reveals the level of reluctance and consequently the interpretation that one will make out of a hazardous event. Such interpretation is however a possibility in the developed part of the world where individuals are more socially and economically empowered. The socio-economic conditions pertaining in the study area would not easily favour such an interpretation to be made.

A local daily (New Vision 5/3/2010) reported following a landslide that swept three villages in Bududa district three days before, that people occupying villages that were identified to be unsafe were reluctant to relocate. In line with this a local daily (Monitor 5/3/2010) reported that one resident of Nametsi (one of the affected villages) said that although he accepted that the place was apparently dangerous to live in, he did not want to live his ancestral home where his parents were buried. The local daily (Monitor 5/3/2010:4) quoted the resident to have observed; "I know it is not safe for us to live here. Our great grand Parents lived here; we cannot leave the graves of our ancestors." Such was the response of a resident who had just experienced an incident that was still fresh in one's mind. Although this was one individual's opinion, it depicts the views of many other people in the same community.

2.7 Strategies for Sustainable Land Use Activities in Hazardous Areas

Morgan (1982) observed that hazards produce hazard effects which in turn lead to multifaceted adjustment processes. He further noted that adjustment may incorporate adjustment of either the human use or where feasible of the natural event, or both. Another form of response that Morgan (1982) noted is that there may be no adjustment in response to hazard occurrence. In line with this Rafi *et al;* (1999:4) argues that;

> *"If human activities can cause or aggravate the destructive effects of landslides, they can also be used to eliminate or reduce them". This implies that slope instability that is caused or triggered by human activities can be reduced or altogether eliminated by modifying the same activities."*

Although Morgan's observation concerned all hazardous events, slope instability hazard in the study area has also been followed by adjustments in either geomorphic processes or land use activities while on some occasions there has not been any adjustment done. Road induced instability has for instance been followed by lining the road embankments with stones or covering them with concrete. Cracks that develop in the embankments are in turn regularly filled with concrete to reduce the rate of weathering. Shallow terraces have also been employed following incidences of agriculture induced slope instability while tree planting has been the common remedy in most of the areas.

Norman and Smith (1997) argued that to cope with hazards people can adapt or adjust. According to them, Adaptation involves arrangement of land use to accommodate extreme events while Adjustment includes measures like avoidance, control, removal and protection taken to cope with events. Even though some people in Mount Elgon claim that they can be able to tell the likelihood that a landslide will occur, adaptation to slope instability still remains very difficult. A form of adaptation would ideally require that people vacate the slopes the moment they sense an eminent failure danger or when early warning has been raised yet this has never been done before. Even where people at times attempt to vacate the unsafe slopes, it is usually either too late for them to escape or they will move to a more unsafe slope where they end up being buried in the slide. The few measures employed are aimed at adjustment in the form of avoidance and control.

Zimmerman (2004) conducted a study on managing debris flow risks on a hazard prone resort in Switzerland and found that disaster prevention and management have a long tradition in Switzerland. He noted that through integrated approach, disaster reduction measures were implemented at local level in the form of solutions directed to recent disasters, long-term solutions at village level, structural measures and emergency planning. Unlike the case cited above, disaster prevention in the study area could hardly become a tradition amidst a people that are utilizing densely populated slopes. To such a people disaster prevention is sensible and appreciated as long as one does not have to set aside some land for it. Disaster management here is on the contrary management by crisis since both internal and external efforts and concern are shown after a tragic landslide has struck.

Ehsan-Haq (2007) found out that following climatic hazards in Pakistan, people have been mobilized and organized into village organizations to formulate village level plans, prepare emergency situations and respond to emergencies at the right time. On the contrary, the remedy in the study area largely hangs on the initiative of a few concerned individuals with the assistance of civic leaders. According to Muthoka *et al;* (1998), people make a wide range of adaptive and coping adjustments in response to a hazard. The authors argue that the adaptations and coping adjustments made may retard or reverse destruction and enhance productivity.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines methodological details used to execute the study objectives. It involves a description of the study area, research design, sampling techniques and sample size, research instruments and their construction, pilot study, data collection, analysis and computation techniques and logistical as well as ethical considerations.

3.2 Description of the Study Area

The study was conducted on Mount Elgon in eastern Uganda. The area covers four districts namely Bududa, Mbale, Manafwa and Sironko. This area initially formed two districts of Kapchorwa and Mbale but was fragmented with the era of decentralization in 2003 whose aim was to take services closer to the people. All the six districts have experienced incidences of slope instability though not at the same rate of intensity and magnitude.

3.2.1 Physical Location of the Study Area

The study area is nestled among the lofty peaks of Mount Elgon in the eastern part of Uganda at the border with the republic of Kenya (**Figure 3.1**). It is located between latitudes $0^{O}83'$N and $1^{O}33'$N and longitudes $30^{O}8'$E and

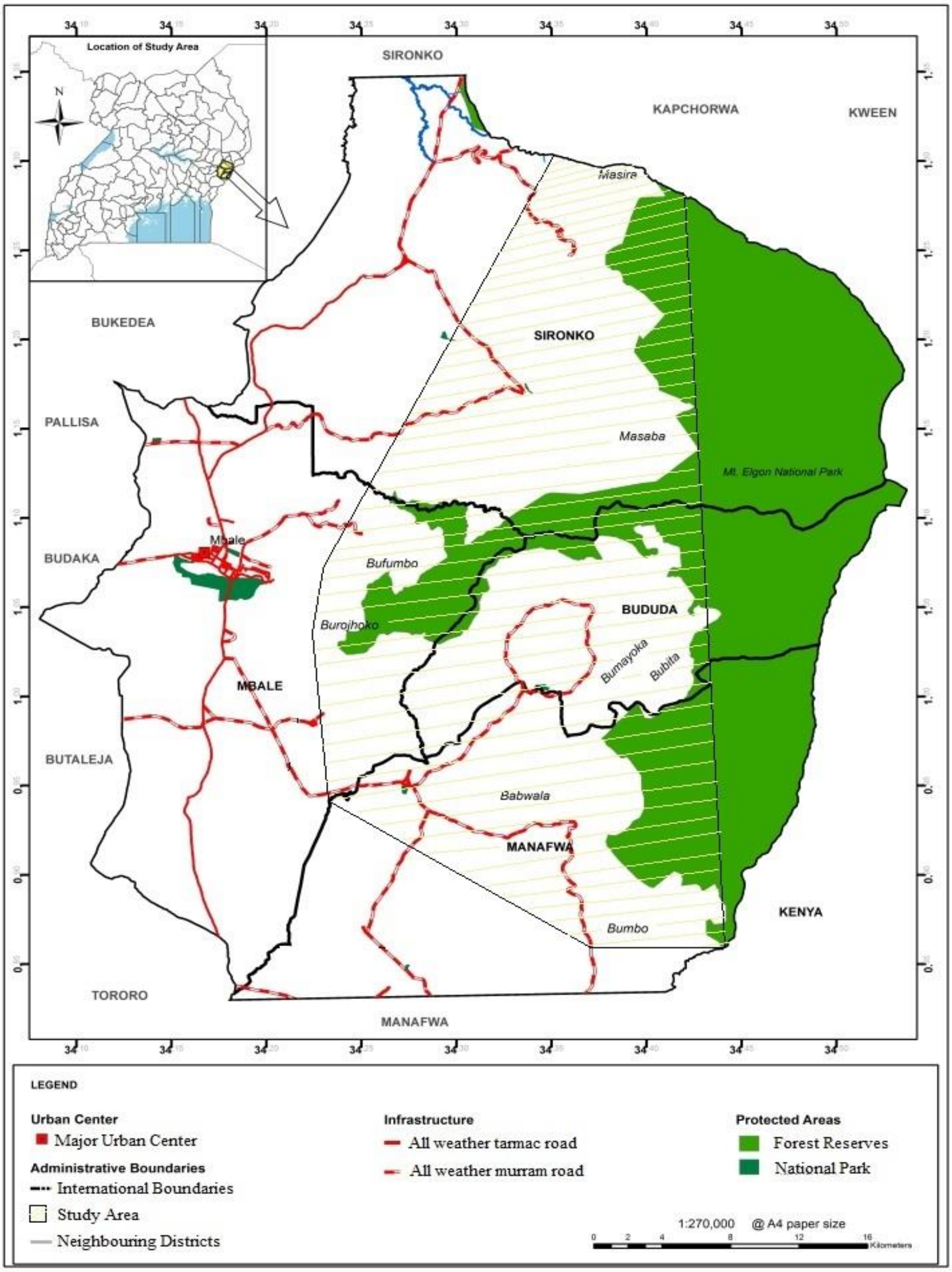

Figure 3.1: Location of the study area on Mount Elgon

(UBOS 2010, NFA 2005, Fieldwork 2009-2010)

34^{O}54′E. It stretches northwards into Sironko district, westwards into Mbale district, and eastwards into Bududa district and Southwards into Manafwa district.

3.2.2 Topography and drainage

Mount Elgon is a solitary volcano that is the fourth highest mountain in East Africa and the second highest in Uganda, rising up to 4320 metres above sea level (Scott 1994). It is one of the oldest volcanoes in East Africa and judging from its base, a common belief has emerged among geological experts that it was once the highest mountain in Africa (Scott 1994). Such geologists assert that it is erosion which played a significant role in reducing the height to its present level.

It is characterized by long steep slopes in most areas of Manafwa and Bududa while gentle and long slopes intercepted by scarps and some rivers such as Namatala, Sisi, Simu and Sironko characterize most areas of Mbale and Sironko (**Figure 3.2**). Slopes in the area of study are associated with a variety of slope angels ranging from the less sensitive 5^{O} slopes to the highly sensitive 40^{O} inclination (Uganda Atlas 1985). The mountain generally has varied altitude and slope angles, length and aspect all of which influence geomorphic processes, land use practices and consequently affects slope stability.

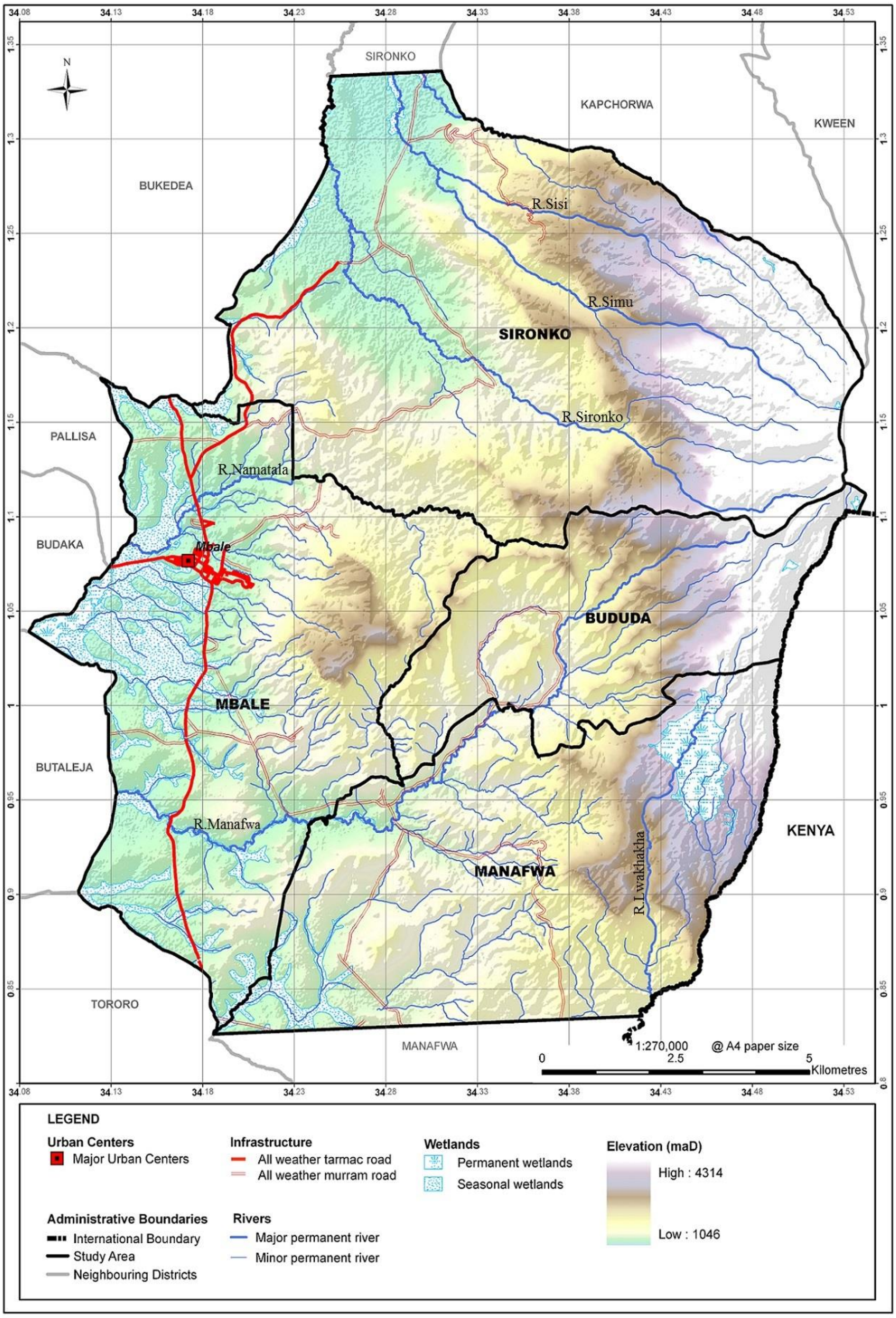

Figure 3.2 Relief and Drainage on Mount Elgon

(GSM 2000, SRTM DEM March 2011)

The steep slopes of Mount Elgon were for instance observed to increase the velocity of overland flow and down slope displacement of soil particles detached by rain splash (Nakileza 2004), while high incidence of erosion and mass movement was observed in Sironko (Nafuna 1993 and Mukholi 1998) and Bududa as well as Wanale Ridge foot slopes (Kitutu 2002).

Mount Elgon is a watershed of international importance feeding waters of Lake Victoria, the Nile and Lake Turkana. A number of rivers drain down the slopes of the study area into Lake Kyoga which is on the plains and is part of the Nile watershed. Such rivers include Sironko, Manafwa, Malikisi, Namatala and Lwakhakha (Figure 3.2). Numerous streams draining the peak area feed their waters into rivers that flow down the mountain. Rivers have consequently dissected the mountain and contributed to the rugged topography depicted. The consequent dense dissection of the landscape by rivers makes it more susceptible to slope failure. In addition, the rivers through undercutting undermine slopes there by creating slope instability. Head ward erosion which is associated with some of the rivers also renders some slopes unstable.

3.2.3 Climate

Mount Elgon experiences humid subtropical climate which is influenced by the south east and north easterly pressure belts (NEMA 1996). It is a moist and moderately dry climate whose elements vary greatly with altitude. Its high altitude associates it with high rainfall and relatively low temperatures. Its altitude and proximity to Lake Victoria influences the rainfall patterns through increasing total rainfall and reducing the severity of the dry season. Rainfall ranges from 1250 mm – 3000 mm annually while temperatures reduce with increase in altitude up to freezing point at the summit area (NEMA 2009). Maximum temperature is 29.3^OC while minimum is 16.2^OC. The region experiences a bimodal rainfall distribution with the wettest months occurring from April to October (Figure 3.3).

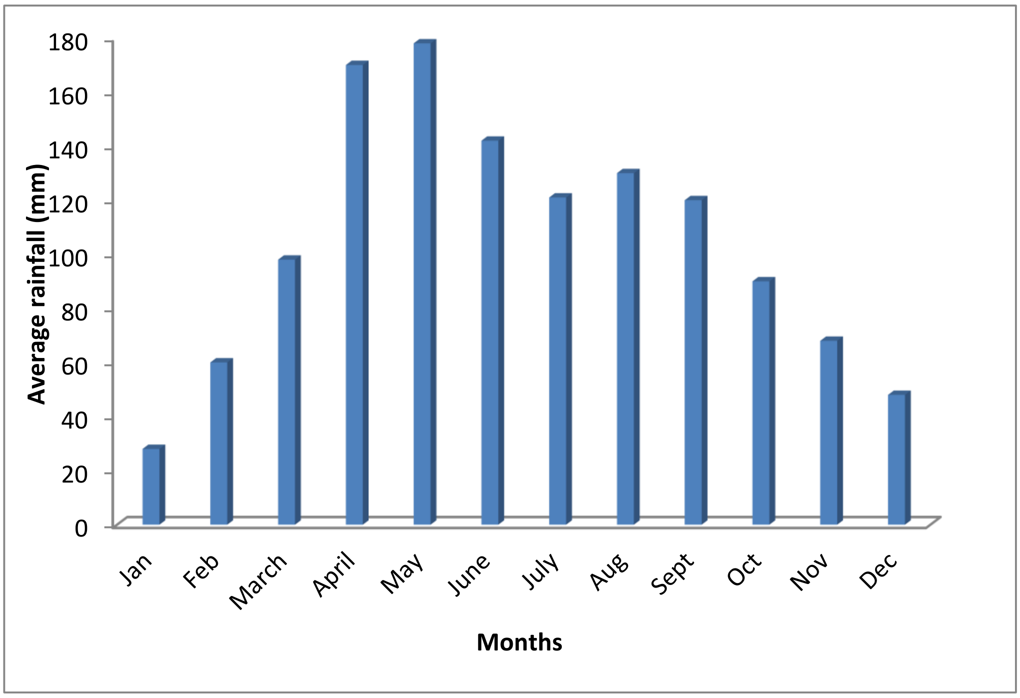

Figure 3.3: Annual rainfall pattern of Mount Elgon zone

(NEMA 2009)

Rainfall reduces on the foothills and slopes from south (1250mm – 1500mm) to north (1000mm) with the northern slopes falling with in the rain shadow of the mountain (Atlas of Uganda 2009). Rainfall received here is usually of high intensity and long duration. It is at times in form of extreme rainfall events such as El Nino rains of 1997-1998 which serve as a lubricant to slope material even when slope would have remained naturally stable (NEMA 2004). Such variations in climatic elements namely rainfall and temperatures that range from a maximum of 29.3^{O}C to a minimum of 16.2^{O}C has greatly influenced the operations of geomorphic processes as well as land uses in the area. This has also in turn influenced the spatial and temporal distribution of incidences and possibilities of slope failure.

The most tragic incidences of slope instability that have been experienced in Mount Elgon have for instance occurred in Bududa, Manafwa, Mbale and Sironko which form the southern slopes of the Mountain. According to earlier studies conducted in Sironko (Mukholi 1998, Nafuna 1993), frequent heavy rainfall or light prolonged rainstorms received at the peak of the wet season lead to mass movement. The relatively low temperatures of 15^{O}C average maximum and evaporation rate of these areas are also noted to bring soil close to field capacity yet this contributes to high runoff rates whenever moderate to heavy rain falls (Nakileza 2004). Besides this, rainfall is a well-known trigger of slope failure incidences world over.

3.2.4 Geology and soils

According to the Mining Journal Uganda Supplement (1996) Mount Elgon is a Strato Volcano of the early Miocene period. It dates with rocks to Miocene origin. Uganda Atlas (2009) indicates that much of the southern and western slopes of the Mountain lie in a zone of tertiary volcanic rocks and associated sediments. It’s depicted to be a zone of volcanic formations comprising generally soda rich agglomerates, lavas and tuffs extruded by the central volcanoes. It also comprises of sediments which underlie some of the slopes especially the Bugisu series. Smaller pockets of undifferentiated gneisses and granulite facies are indicated to exist in the western slopes and northern slopes, while Sediments, alluviums, black soils and moraines of Pleistocene to recent are also indicated to exist on the western and north eastern outskirts in Sironko District.

Such variations in the basement rock have resulted into variation in resistance to geomorphic processes according to rock strength, jointing, permeability and material contrasts. It is for this reason that areas in the southern slopes of the Mountain that are underlain by fenitized oldest tertiary rocks are commonly associated with landslides while those underlain by agglomerates and tuffs suffer from rock falls. Tertiary age cabonatites on the other hand have been found to be unfavourable to landslides (Kitutu 2004).

According to the FAO classification, the soils on Mount Elgon are from the Andisol order “developed in volcanic ejecta” (NEMA 1996). Basing on this classification, the northern slopes which are underlain by Pleistocene to recent rocks consist of gleysols while those elsewhere that are underlain by granite facies consist of Vertisols, red clay loams (nitisols) and non-laterized brown sandy clay loams (lixic and acric ferralsols). The steepest slopes of the Mountain are covered by shallow black-very dark brown soils while the apex is covered by the Masaba series. These soils vary in cohesiveness according to texture, structure and mineralogical composition and hence yield differently to detachment and removal forces. The volcanic nature of soils in Mount Elgon has made it attractive to human activities like settlement and subsistence agriculture despite the fact that its relief makes it a difficult as well as fragile environment.

Another aspect of geology and soils in the area that is of relevance in as far as slope instability is concerned is soil depth and nature of underlying rocks. Slopes that are covered by shallow soils and are underlain by impermeable rock layer are easily affected by slope failure inform of earth or mudflow. Slopes covered by deep but easily detached soils (especially iron oxides) are prone to slope failure (Kitutu 2002).

3.2.5 Vegetation

Mount Elgon is a zone of afromontane vegetation that is a manifestation of the altitudinal climatic differences experienced in the mountain environment. Naturally, vegetation here is classified into four general altitudinal zones namely; mixed montane up to an elevation of 2500 metres above sea level, Bamboo and low canopy montane forest from 2400 to 3000 metres above sea level, high montane heath from 3000 to 3500 metres above sea level and moorland at altitude above 3500 metres above sea level (Howard 1991, NEMA 2009). Basically plant species in the forest zone above 2000 metres above sea level are evidence to the afromontane region.

Apparently, this kind of natural altitudinal vegetation distribution on Mount Elgon has been modified by human interference. The only remaining part lies in the core ecosystem of Mount Elgon area which is characterised by montane forest landscape. This covers the protected area named Mount Elgon National Park. The rest of the area lies in the vast populated agricultural landscapes of the Montane Agro-ecological zone where there are farmlands that are intensively cultivated with Bananas and coffee, annual crops such as sweet potatoes, cassava, onions and Irish potatoes (MAAIF, 1995). Some farmers have planted trees alongside agricultural crops or woodlots but this kind of vegetation does not effectively keep slopes stable like natural vegetation would. Natural vegetation cover unlike semi natural vegetation keeps slopes stable for long (Muhwezi et al; 2007).

The remnant forest zone is a result of the 1989 evictions of the local people from the forest reserve and its consequent conversion into a national park which however still causes conflicts between conservation agencies and the local communities. Human interferences have generally modified the vegetation cover and this has in turn affected the rate of geomorphic processes. Some land use activities such as agriculture significantly change vegetation throughout the year. The vegetation varies for instance from bare ground when fields have just been cleared to partial cover as crops germinate and finally to complete cover when crops have fully grown.

3.2.6 Population and Land Use

Mount Elgon region is a densely populated area that possesses high rural population totals and densities considering the nature of the slopes. The districts selected for this study are among the densely populated areas of Uganda. Population density here according to the Uganda population and housing census was 287 pple/ km^2 compared to the national density of 124 pple/ km^2 (UBOS 2005). The most densely populated district is Bududa whose average population density was 950 pple/ km^2 then (UBOS 2005).

With such high population densities a lot of pressure has been imparted on land resources in terms of subsistence agriculture, building and construction, quarrying and forest resources exploitation. Currently land has become scarce in these districts of Bududa, Mbale, Manafwa and Sironko due to high population density. High population pressure and land scarcity has forced people in such areas to settle and cultivate on steep slopes that are naturally prone to mass movement. Knapen *et al;* (2006) indicates that slopes steeper than 40^0 in some areas are also cultivated yet according to him these are very steep.

3.3 Research Design

The study assumed a quasi-experimental design involving both the experimental and non- experimental methods to assess the phenomena that was on going and that which had already taken place. The study by the diverse nature of its primary data sources assumed both the cross- sectional and the before - and - after studies designs. The non-experimental study assumed a cross- sectional design to decide the study population, select samples, contact respondents, collect and analyse the corrected information concerning community's perception and response to slope instability (**Figure 3.4**.)

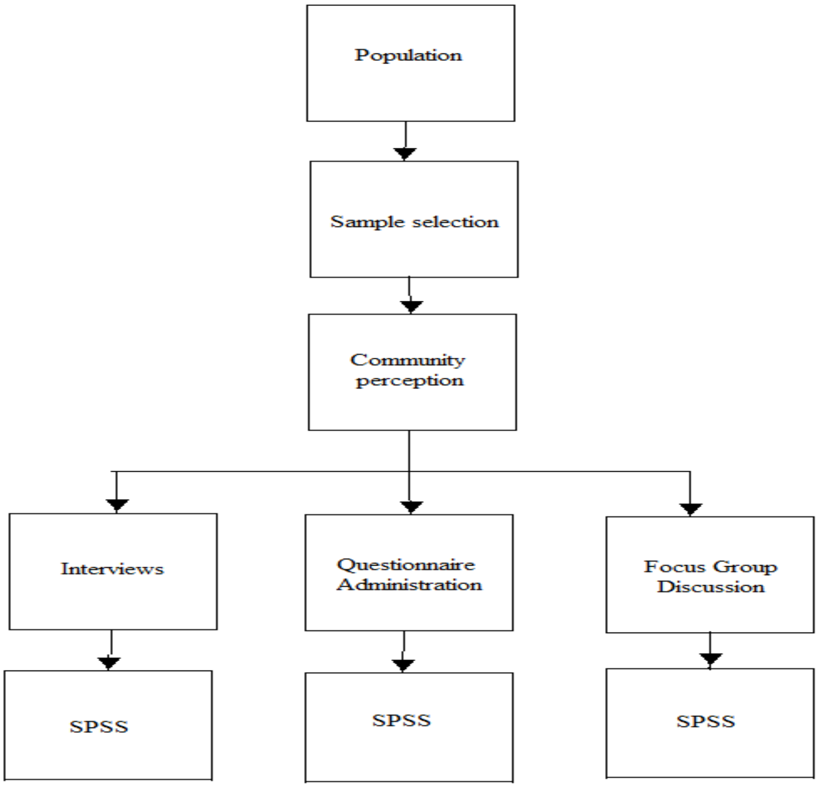

Figure 3.4: The cross-sectional study design followed in gathering and processing data on people's perception of slope instability

The Before- and -after studies design formed the experimental study that was used to carry out two phases of mapping, document geomorphic processes and land use activities on slope instability prone slopes and analyse the consequent observations and measurements taken **(Figure 3.5).**

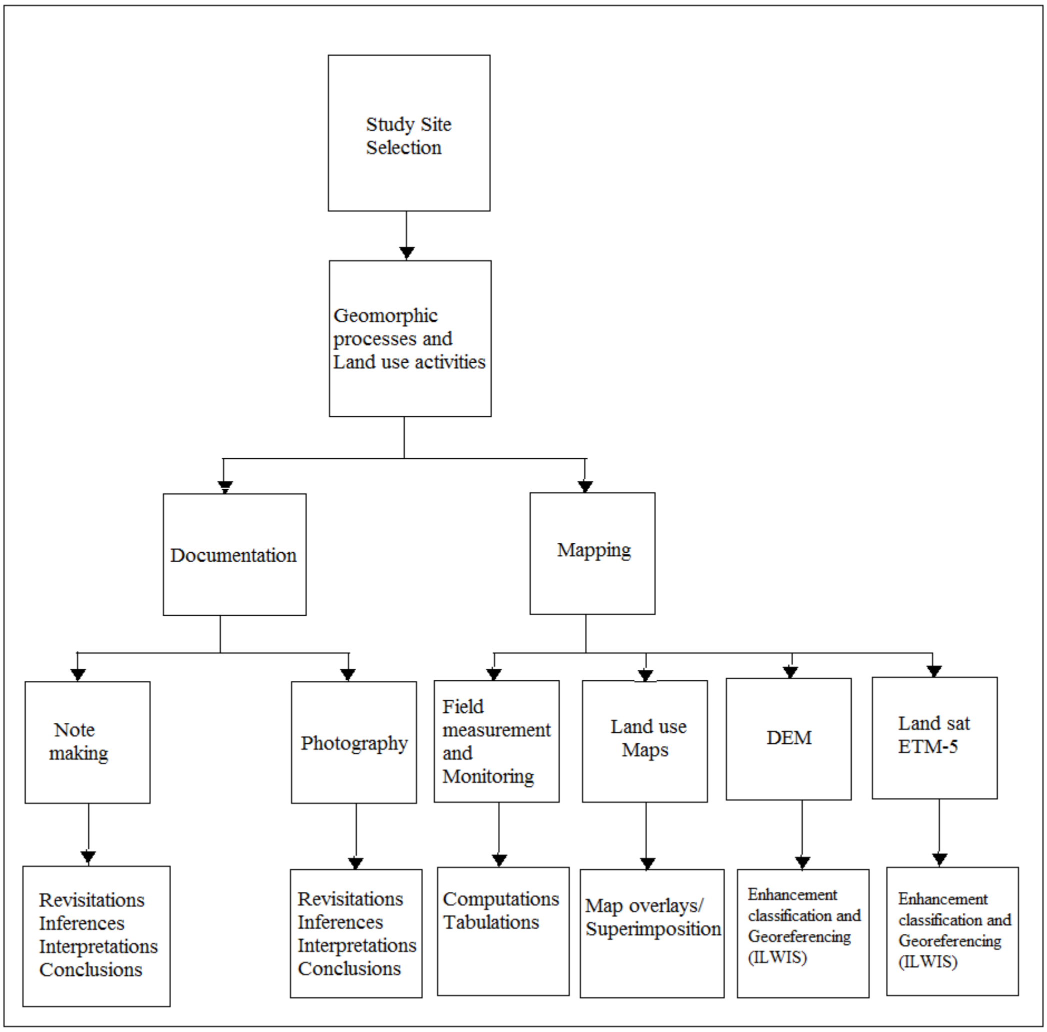

Figure 3.5 The Before- and- after studies design followed to gather, map and process data on geomorphic processes, land use activities and the associated slope instability

The first mapping and documentation phase was done during the dry season while the second was done during the rainy season. Other sources of data that complemented the two phases were maps (topographic, relief, land cover and land use) and LANDSAT ETM- 5 imagery.

3.4 Sampling techniques and sample size

3.4.1 The sample Area

As noted earlier, Mount Elgon extends into six districts within which slope instability in varying intensities and magnitudes has been experienced. Four districts namely; Bududa, Manafwa, Mbale and Sironko were purposively sampled by the researcher for study. The choice of the four districts depended on the intensity of occurrence of landslides in each district and the length of persistence of the problem as expressed in **Table 3.1**.

Table 3.1: Districts and recorded dates when landslides occurred

District	Year when landslide occurred	Intensity of occurrence
Bududa	2012, 2010,2006, 2003, 2002,1999, 1998,1997,1972,1970,1967,1960,1944, 1942,1933,1927,1918,1900,1818	Frequent occurrence
Manafwa	2006, 2005, 2003, 2002, 1999, 1997, 1970, 1967, 1942, 1927	Occasional occurrence
Mbale	2008, 2007, 2001, 1997, 1986, 1972, 1963, 1950	Occasional occurrence
Sironko	2008, 2007, 2002, 2001, 2000, 1999, 1997, 1995, 1988, 1983, 1968, 1948	

Obua, Nakileza and Okello-Ogwang (2004), NEMA (2007), NEMA (2009)

The districts chosen for study are depicted to have experienced the problem of slope instability for quite a long period of time. The four districts are composed of the southern slopes of Mount Elgon. Specific areas of study were systematically sampled from each of the selected districts according to intensity of the problem, namely the most affected and the least affected areas in terms of sub-counties and parishes. This criterion was used to select study areas to enable analysis of the differences in perception of respondents in the two categories. The sub - counties and parishes used represented slopes that steeply inclined above 10^{O} and at the same time densely or moderately settled so that the study could be able to compute the elements at risk. The areas also represented slopes where geomorphic processes as well as land use activities were taking place and were hence ideal for such a study intended to document and map aspects of slope instability.

3.4.2 Target Population

All the land users, district leaders, and local council leaders of the four districts of Mount Elgon commonly affected by landslides namely Bududa, Manafwa, Mbale, and Sironko formed the target population for the study. The accessible population comprised of district leaders, local leaders and land users in the eight sub counties that were selected for study. The target population of land users was reflected by the number of households available in the study districts according to the most recent national population census report of 2005. Each household was therefore taken to represent a land holding and consequently a land user who was a potential respondent for this study as summarized in **Table 3.2**;

Table 3.2: Target population of the study

District	Target population	Accessible population
Bududa	27,909	7,354
Manafwa	58,251	12,441
Mbale	76,358	16,089
Sironko	67,349	5,567
TOTAL	229,867	41,451

(UBOS 2005)

3.4.3 Sampling techniques

A multistage sample design was adopted and sampling was done at several levels as follows:-

The first stage involved selection of sample sub-counties. At this stage representatives from different district administrations were requested to help the researcher rank sub-counties in each district according to the frequency of occurrence of slope failure. Using this information, each of the highest ranked and lowest ranked sub-counties in a district was chosen for study. This yielded a total of 8 sub-counties which were selected (**Figure 3.6).**

The second stage involved selection of sample parishes. With the help of the sub-county leaders a list of parishes where slope failure had occurred in each sub-county was generated. The leaders were then requested to help rank these parishes according to the frequency of occurrence of slope failure. The first and last ranked parishes were then selected for inclusion in the study yielding a total of 16 parishes (**Figure 3.6).**

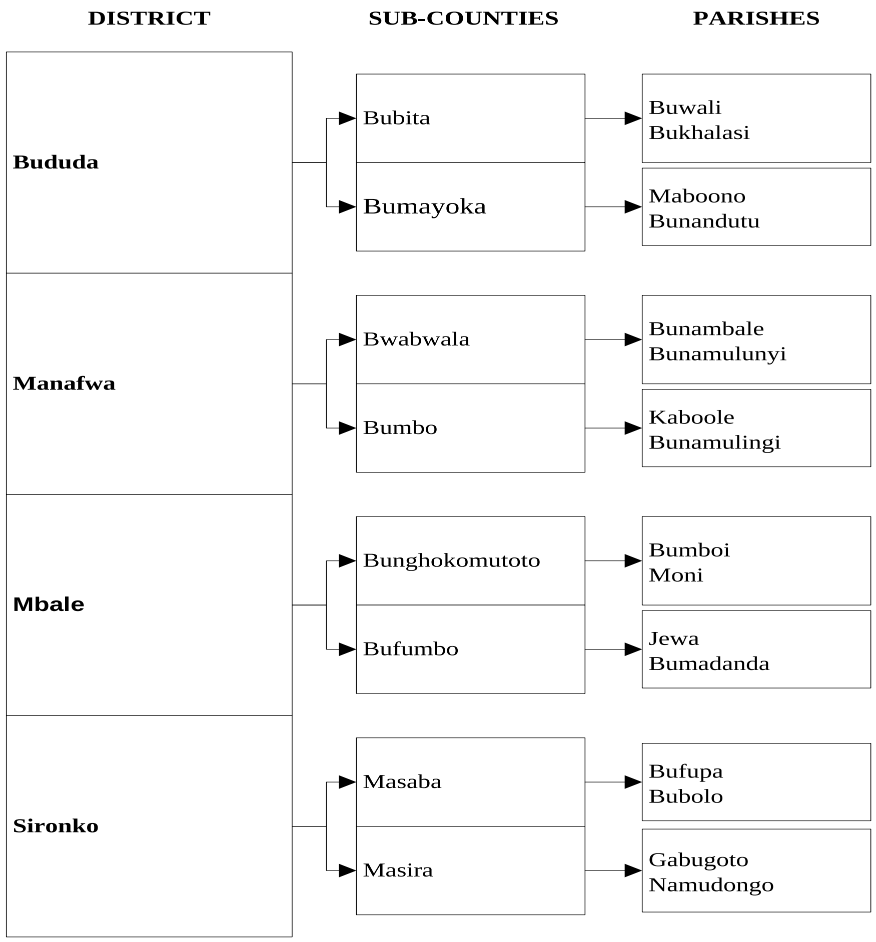

Figure 3.6 Flow chart of the multistage design of selecting study Sub-counties and parishes

The third stage involved selection of study respondents. At this stage a list of land users whose land had experienced slope failure was generated for parishes that were first in rank while the one for the last ranked comprised land users whose land had not experienced slope failure. This exercise yielded a total of 16 lists each with land users ranging from 10-25 altogether. This yielded a sampling frame of 266 people. A total of 10 respondents were selected from each list through simple random sampling using the fish bowl draw method (Kumar 1996). Consequently a sub total of 80 respondents representing land users whose land had experienced slope failure and another 80 respondents representing those whose land had not experienced slope instability were selected. This yielded a total of 160 land users.

Through purposive sampling the Resident District Commissioners, Local council five (LC 5) chairpersons, Local council three (LC 3) chairpersons, Local council one (LC 1) chairpersons, an elder and a landslide victim per affected parish were selected. This yielded a total of 48 respondents. The same procedure was also followed to select civil servants yielding a total of 16 respondents.

3.4.4 Sample Size

Basing on the nature of the problem which required respondents that had experienced slope failure or were in leadership positions, the number of respondents investigated was 224. The categories of respondents were as follows;

- 160 household heads/ land users on whom the questionnaire was administered. These were arrived at by using a formula for sample calculation for small population (Yamane 1967) in Kothari (2004) thus;

  $$n = \frac{N}{1+N(e)^2}$$

  Where; n is the sample size (160),

N is the sample population (266),

e is precision at (0.05) and level of confidence is at 95%.

- 48 purposively sampled key informants who participated in interviews.
- 16 purposively sampled civil servants at district level who participated in focus group discussions.

3.5 Research Instruments

A number of instruments were used to collect data namely questionnaire, interview schedule, proforma checklist, images and maps.

3.5.1 Household Questionnaire

A questionnaire was developed by the researcher seeking to find out the perception people have about slope instability, their attitude towards its dangers, and their willingness to participate in programmes aimed at mitigating the problem. The questionnaire consisted of a set of questions together with their guiding instructions about the information required from respondents in written form. It contained a mixture of multiple choice questions and open ended questions. In designing the questionnaire the researcher tried as much as possible to ensure that every question was consistent with the variable definitions. The questionnaire used is attached (**Appendix 3.1).**

3.5.2 Interview schedule

An interview schedule developed by the researcher was used to aid the recording of interview responses. It was a record of questions administered orally to some of the respondents deemed to be key informants. Both semi-structured and unstructured interviews were conducted. Semi-structured interviews consisted of guiding questions prepared to help the researcher and the research assistants to be logical in asking questions during the interview. It was designed in such a way that it was the interviewer to manage the recording of the responses. The schedule that was administered to selected elders, local council officials and environmental officers is attached (**Appendix 3.2)**. Unstructured interviews were conducted with the top district authorities.

3.5.3 Proforma Checklist

A proforma checklist **(Appendix 3.3)** developed by the researcher was also used in data collection. It was designed to enable the researcher record and also evaluate some of the details of landscape properties and historical accounts studied through observation and documentation. It was aimed at helping the researcher to be systematic in observation of phenomena and to ensure that behaviour was put in context.

3.6 Images and Maps

Aerial photographs (Land’s and survey 2000), Survey topographic sheets (UBOS 2010), land cover and land use maps (NFA 1990 and 2005) LANDSAT image ETM-5 (GLCF 2003), and SRTM DEM (March 2010) were also used in analysis of the study phenomena so as to aid orientation, field checks and ground truthing. They were also incorporated in data collection and analysis for instance to determine spatial extent and size of slope instability risk areas.

3.7 Pilot Study

Pre-field visits were conducted so as to deliver study permits obtained from Uganda National Council for Science and Technology to the different districts where the study was conducted. The Resident District Commissioners of the study districts were visited so as to introduce oneself and also get acquainted with officials that were involved in conducting the study. Sampling of sub-counties of study and visits to sub-counties as well as parishes that were sampled out were conducted during this period.

The researcher also used the pilot visits to identify and induct field assistants. With the help of the local leaders, the researcher selected one person in each sub-county to help in the administration of study instruments and also monitor some of the field experiments conducted in their respective local areas. To reduce on hostility and suspicion to strangers by some study respondents, field assistants were selected on the basis of their knowledge of the local languages (Lumasaba), English language and the geography of the study area. Each of the selected assistants underwent three days of training on instrument administration. They were trained on use of the questionnaire and interview schedules so as to minimize variations in data collection procedures which were likely to bias the results. Those operating in areas where field measurements were conducted were later trained on how to monitor the progress. On the whole, the training process inducted field assistants to become familiar with the instrument so as not to appear unsure or confused.

It was also during such visits that the researcher surveyed the area so as to determine land slide scars that were used as study sites. Land slide scars were identified for study according to their accessibility by foot and ascent of slope. To choose the most appropriate study sites the researcher in company of the field assistant in each area familiarized as much as possible with the Geography of the study area. Two reconnaissance surveys were conducted before the commencement of data collection exercise.

The pilot visits were also used to administer a sample questionnaire on eight sample respondents which was 3.8% of the sample population so as to determine whether the instrument made appropriate, correct and meaningful inferences and therefore measured what it was meant for. This depended on whether questions asked were clear, logical and relevant. Following this exercise, some items that were discovered to be making no contribution to logical conclusions about people's perception of slope instability were either rephrased or discarded.

3.8 Data Collection

The study involved data collection techniques that enabled the researcher to gather both primary and secondary data. These included field observations, photograph and satellite imagery survey, geomorphic mapping, questionnaire administration, interviewing and focus group discussions.

3.8.1 Direct Field Observations and Documentation

Field observations, recording of some observations in note form and documentation through photographing was carried out. This was done to establish the kinds of processes in operation and land use activities carried out in the study area. All the indicators of slope instability as a hazard were recorded on the proforma checklist.

3.8.2 Aerial Photo and Satellite Imagery Analysis

Visual and digital analysis of aerial photographs of each district and a Landsat satellite imagery covering Mount Elgon area was done to identify areas that reflected the impact of geomorphic processes or land use activities on slope stability. This was done to aid field observations in addressing processes and land use issues that were clearly observable. Extent and size of slope instability risk areas was also determined using aerial photographs and LANDSAT ETM-5 imagery.

3.8.3 Geomorphic Mapping

Using survey topographic maps of Uganda (Bubulo sheet 64/2, Budadiri sheet 54/4, Mbale sheet 54/3) and LANDSAT ETM-5 (GLCF 2003) of Mount Elgon region, areas with visible lineament structures associated with steep scarps were identified and mapped using Integrated Land and Water Information

Systems 3.6 software. This was in a bid to compile an inventory of slope instability prone slopes in the study area. ETM- 5 was used because it has the widest stretch of bands that can help discriminate the different features of interest. This helped to identify and document information concerning the extent of slope instability risk areas and their distribution in the study area.

3.8.4 Questionnaire Administration

The questionnaire **(Appendix 3.1)** containing both structured and unstructured questions were administered on the selected 160 land users residing in the study area. The respondents who did not understand English language were assisted by the field assistants to internalize and record their responses in the questionnaires. Whereas some questionnaires were administered and collected on delivery, others were delivered to the respondents and collected at an agreed later date.

3.8.5 Interviews with the Key Informants

Interviews were conducted so as to get over all views concerning people’s beliefs and attitude towards slope instability, their willingness to participate in problem solving programmes, and viable intervention strategies. The interview proceedings were recorded electronically by visual/audio recording.

Interviews with district officials namely the resident district commissioners, local council five (LC5) chairpersons, were conducted by the researcher. On the other hand, the victims of previous landslides, elders, local council one

(LC1) chairpersons and local council three (LC3) chairpersons were interviewed by the field assistants.

3.8.6 Focus Group Discussion

Focus group discussions were conducted to collect qualitative data on issues relating to suited management strategies and intervention needs. A focus group discussion guide containing key questions on issues raised was used to allow free discussion among members. Participants in each group ranged between 6-12 members who were homogeneous in composition in terms of occupation. They included district environmental officers, district agricultural officers, district land officers and district engineers.

Participants selected venues of discussions that were deemed convenient to all of them. Discussions were steered by the moderator and the person who recorded the discussion results and also observed the discussion period which lasted between 30-45 minutes. The results were also recorded by audio recorder to avoid loss of some information which may have been crucial.

3.8.7 Field Measurements and Monitoring

Field measurements and monitoring was done to determine actual positions of slope instability risk areas, role of geomorphic processes and land use activities in accelerating instability of slopes, and slope variables enhancing operation of geomorphic processes and land use activities in destroying slope stability. The following were the measurement and monitoring procedures followed.

3.8.7.1 Mapping Actual Positions of Slope Instability

Geographic coordinates of the location of past and recent evidences of slope instability were recorded using a GPS 76. This yielded measurements of 35 landslide scars and 2 tensional cracks which formed the sample sites. Slope angles of sites below the landslide scars were measured and recorded using a dumpy level theodolite while those above and around the scar were by a Santos clinometer **(Plate 3.1)**. The computed measurements were recorded as part of item number three of the proforma checklist **(Appendix 3.3)**.

Plate 3.1: Measurement of slope angle below a landslide scar
(Bukhalasi- Bududa, May 2010)

3.8.7.2 Soil Profiling

Soil profiling was done in different areas so as to determine regolith depths at different slopes confirmed to be vulnerable to slope failure. Soil profile pits ranging from a minimum of 50 centimetres to a maximum of 300 centimetres depths were dug near each of the studied scars so as to establish the existing soil layers and consequently determine their successive depths **(Plates 3.2, 3.3)** and **Appendix 3.4**. Measurements taken were recorded in the proforma checklist **(Appendix 3.3)**.

Plate 3.2: A one and a half metres deep soil profile pit
(Baaya-Manafwa, December 2009)

Plate 3.3: **A three metres deep soil profile pit**
(Maboono- Bududa, October 2009)

3.8.7.3 Rock Traps

Rock fall rates were determined by assessment of frequency and magnitude of the process. This was measured by placing a trap made of a carpet and a wire netting of 10mm mesh at the foot of a free face **(Plate 3.4)**. The amount of debris that was trapped every 28th day of the month over a period of one year from March 2009 to February 2010 was respectively measured, recorded and then later plotted against cumulative dates so as to be able to determine the rate of movement and periods of relative slope stability.

Plate 3.4: A wire mesh trap placed at a cracked scarp face on Nkokonjeru ridge
(Bumboi – Mbale, 28th December 2009)

3.8.7.4 Slope Profiles

Surveying of slope profiles was also conducted so as to determine the interactions between geomorphic processes and land use activity. This involved measuring of slope length and slope angle, together with observation of associated land use, vegetation and micro relief between two profile stations. A Santos Clinometer was used to measure slope angle and a tape measure used to measure the corresponding length between two successive profile stations marked with two ranging rods. Measurements of slope angle, slope length, together with observed geomorphic processes (micro relief features), land use activities and vegetation were recorded.

3.8.7.5 Slope Movement Analysis

Slope stability analysis was done so as to allow the likelihood of slope movement to be determined. This involved measurements aimed at determining fast movements. This was done by hammering stakes and pegs into areas prone to movement and their displacement measured in relation to some fixed point **(Plate 3.5)**. High displacement rates were interpreted to be an indication of imminent danger of failure. Visual monitoring of rocks was also conducted so as to determine if failure was likely to occur. This was done by inserting bolts on road cuttings and monitoring their position. Detection of high levels of movement was an indication that imminent failure was in the offing and this was a call for laying strategies to mitigate the looming danger. Measurements were taken during two consecutive seasons of dry and wet weather conditions so as to accommodate the effects caused by weather changes.

3.8.7.6 Slope Angle Measurement

Further stability analysis was done by determination of distribution of areas subject to slope instability. A Clinometer was used to make slope angle measurements as well as the equivalent percentage gradient. This was done by measuring slope angles whose slope gradient was computed according to three categories of likelihood of hazard occurrence namely; less than 30%, between 30-60% and greater than 60%. This helped to predict hazard occurrence by rating areas with low, moderate, or high slide potential.

Plate 3.5: Peg displacement measurement to detect likelihood of slope failure
(Bukhalasi – Bududa, March 2009)

3.9 Data Analysis and Computation

3.9.1 Geomorphic processes

Computed data were revisited and inferences made so as to reach logical conclusions about geomorphic processes and their influence on slope instability. Materials collected in traps were measured and results tabulated so as to compute periods of active as well as relative stability of geomorphic processes. Past landslides were characterized according to the measured depth, length, and area so as to give an insight into the types of movements experienced in the area **(Appendix 4.1)**. Characterization of forms of slope instability experienced in the area was done according to Varnes (1978) slope movement characterization displayed in **Table 3.3**.

Table 3.3: Classification of mass movement types

Type of movement			**Type of materials**		
			Bedrock	Engineering Soils	
				Predominantly coarse	Predominantly fine
Falls			Rock fall	Debris fall	Earth fall
Topples			Rock topple	Debris topple	Earth topple
Slides	Rotational	Few units	Rock slump	Debris slump	Earth slump
	Translational	Many units	Rock block slide	Debris block slide	Earth block slide
			Rock slide	Debris slide	Earth slide
Lateral spreads			Rock spread	Debris spread	Earth spread
Flows			Rock flow	Debris flow	Earth flow
Complex Combination of two or more principal type of movement					

Source: Westerberg (1999)

3.9.2 Land Use Practices and their Influence on Slope Stability

Trends in land use were computed from analysis of land use/land cover maps taken in 1995 and 2005. A comparison was then made with the established trends in slope instability occurrence computed by analysis of recorded past landslides. The 35 landslide scars, whose GPS coordinates were recorded, were characterized according to the period when slope failure was experienced. Consequently, the scars were categorized into three slope instability risk zones **(Table 3.4)** which were superimposed on the land use and land cover maps so as to show the effect of changes in land cover on slope instability.

Table 3.4: Characterization of slope instability trend

Period of landslide occurrence	**Slope instability risk category**
Less than 5 years ago	Active
5- 20 years ago	Intermediate
Over 20 years ago	Inactive
Over20 yrs ago – < 5yrs ago	Very Active

Source: Field work 2009-2010

3.9.3 Slope Instability Risk Mapping

The recorded soil profiles measurements were revisited to assess soil depth of various weathering profiles near each of the landslides scars studied. Analysis was based on the weathered regolith depth that is, the depth of the top soil and sub soil to tell whether the soil was shallow or deep. Soil depth was classified following a classification developed by Arsyad (1989) - **Table 3.5**.

Table 3.5: Classification of soil depth

Class	**Depth in cm**
K_o	> 90 cm (deep)
K_1	90-50 cm (moderate)
K_2	50-25cm (shallow)
K_3	<25cm(very shallow)

Source: Arsyad (1989)

Documented data on landslide scar positions and slope angle recorded in the proforma check list was computed to show the effect of various slope characteristics on slope instability. This helped to assess the influences of elevation, slope steepness and slope form on rendering slopes unstable. A characterization of slope instability risk areas was done basing on classification of slope angles by Young and Anthony (1983**) Table 3.6.**

Table 3.6: Characterization of slope steepness

Slope angle (^{O}C)	**Steepness class**	**Applied purpose**
0^{O} -2^{O}	Level or almost level	No practical limitations except poor drainage
2^{O}- 5^{O}	Gentle	Slight practical limitations
5^{O}- 10^{O}	Moderate	Precautionary erosion measures are necessary
10^{O}- 18^{O}	Moderately steep	Substantial 3 practical limitations considerable
18^{O}- 30^{O}	Steep	Land to be left for pasture and forest
30^{O}- 45^{O}	Very steep	Low economic value land
Over 45^{O}	Precipitous to vertical	Normally formed by a free face

Source: Anthony and Young (1983)

The Analysis procedures of the data gathered and documented using the proforma checklist is located in **Appendices 5.1 and 5.2.** Using ILWIS 3.6 and LANDSAT image ETM 5, the recorded Geographic coordinates were transformed into map points of slope instability. ETM 5 image was used because it has the widest coverage of bands and can thus give a better differentiation of the landscape features. The 35 landslide scars whose Geographic coordinates were recorded were characterized according to the slope gradient of the study landslide scars as rated under item (f) of **Sub-section 3.8.7.** Consequently, three categories of slope instability risk zones were identified **(Table 3.7)** and depicted on a slope instability risk zonation map.

Table 3.7: Characterization of slope instability risk areas in Mount Elgon

Slope gradient of study scar	Resultant Slope instability risk category
Above 60%	High landslide potential
Between 30% - 60%	Moderate landslide potential
Below 30%	Low landslide potential

Major lineaments in the area were identified and plotted on LANDSAT ETM 5 image and on Mount Elgon topographic sheet and the transformed Geographic coordinates mapped into this area to assess the geomorphic relationship existing. Results were presented in map form **(Figure 5.6)**.

3.9.4 People's perception and attitude towards slope instability and coping strategies

Primary data about people's perception and attitude towards slope instability which was collected through administration of questionnaires **(Appendix 3.1)** and conducting of interviews was edited, coded and then analyzed using Statistical Package for Social Scientists (SPSS). This was in a bid to find answers to some of the research questions and to draw conclusions concerning the related study objectives.

Through analysis, computation of statistics depicting some phenomenal relationships such as frequencies, totals, percentages, tabulations and cross tabulations were done. Descriptive statistics such as frequency and percentages generated were presented in tables, charts and diagrams to depicted phenomenal relationships existing. Through the analysis, data was subjected to significance tests using the chi-square test while Spearman's rank correlation coefficient was computed in order to determine the degree of association existing between variables. Spearman's Rank Correlation coefficient was also computed to determine the degree of association between people's willingness to modify in land use and size of land owned. Size of land is the independent variable while willingness of people to modify in land use is the dependent variable. The formula for Spearman's Rank Correlation Coefficient according to Gregory (1978) states as follows;

$$r_s = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

Where: d is the difference in rank of each pair of values pairs.

n- Number of pairs

A chi-square test was done to determine the significance of the relationship between perception and attitude of land users who have experienced slope failure and those that have not and then towards evacuation programmes. The formula according to Gregory (1978) states as follows;

$$x^2 = \sum \frac{(O-E)^2}{E}$$

Where: O is the observed frequencies

E is the expected frequencies

3.10 Logistical and ethical considerations

Research ethics were upheld at every stage of the research period. Honesty and objectivity prevailed when collecting analyzing interpreting and presenting data. The researcher obtained a study permit from the Uganda National Council for Science and Technology so as to maintain Ethical standards **(Appendix 3.5**). Information obtained from respondents was treated with great care and confidence. It was only used for purposes of compiling the thesis submitted to Kenyatta University and none of the respondent’s identities were revealed.

CHAPTER FOUR

GEOMORPHIC PROCESSES AND LAND USE ACTIVITIES INFLUENCING SLOPE INSTABILITY ON MOUNT ELGON

4.1 Introduction

This chapter is a presentation and discussion of findings of the study that address the first two study objectives focusing on the influence of geomorphic processes and land use activities on slope stability in Mount Elgon. The findings presented have been subjected to different forms of analysis so as to be able to make logical interpretations and conclusions. The presentation covers descriptive results of analysis, hypothesis tests and accompanying interpretations, explanations and discussions. It is arranged according to sections and sub-sections that were derived from the study objectives and the related hypothesis. The study findings were presented in both pictorial and text format while interpretations and consequent discussions are entirely in text format. The pictorial formats used include tables, graphs, bar diagrams, photographs and maps.

4.2 Characterization of forms of slope instability experienced in Mount Elgon

The forms of slope instability experienced in Mount Elgon were as earlier mentioned in data section 3.9 characterized according to the classification of Varnes (1978) who classified slope movement according to type of material moved and its rate of movement. Consequently (Varnes 1978) classified slope movement into falls, topples, slides, lateral spreads, and flows.

The characterization of the forms of slope instability in Mount Elgon was similarly based on observable parameters such as material moved and consequently deposited depth of the scarp at the head of the scar and toe characteristics. The type of movement was thus inferred from the above observed patterns **(Appendix 4.1).** The distribution of the forms of slope instability that were established to have occurred in the area is summarized in **Table 4.1.**

Table 4.1: Characterization of forms of slope instability experienced on the studied slopes of Mount Elgon

Form of instability		**Material moved & deposited**	**Depth of scar (m)**	**Slide type**	**Where it was experienced**
	Rock fall	Boulders, Pebbles	0.8	Surficial	Mbale, Sironko
	Debris fall	Rock fragments	0.5	Surficial	Mbale, Sironko
	Earth fall	Soil	0.2	Surficial	Bududa
Slides	Earth slump	Soil	7-20	Rotational	Bududa
	Earth slides	Soil	1-6	Translational	All districts
	Debris slide	Rock fragments	4-5	Translational	All districts
Flows	Debris flow	Rock fragments	1.7	Translational	Sironko
	Earth flow	Soil	2	Translational	Bududa, Sironko
Others	Tension crack		0.3-0.8 wide	Gap	Manafwa,Bududa, Sironko
	Pot hole		0.4 - 0.7	Sinking	Manafwa

Table 4.1 indicates that slope instability experienced on some slopes of Mount Elgon is characterized into falls, slides, flows, and other recently noticed uncommon forms of instability. Specific forms of falls, slides, and flows were noted in different areas of Mount Elgon and were named according to the type

of material that was moved hence boulders, pebbles, rock fragments and soil mentioned in descending order of particle size.

4.2.1 Falls

Materials of different shapes and sizes were noted and also reported by the study respondents to have fallen down some slopes in Mbale, Sironko and Bududa districts. **Table 4.1** indicates the categories of falls noted to have been experienced in the area which include rock falls, debris falls and earth falls.

Rock falls of boulders and pebbles were noted and also reported by some study respondents in Mbale and Sironko to commonly occur on Wanale ridge in Mbale district and Zesui - Ulugulu ridge in Sironko district. Existing evidences included boulders and pebbles that had accumulated on the pediment slope and fresh scars that were visible on the scarp faces from where material had recently collapsed- **Plate 4.1**. This form of instability affected the slope directly beneath the scarp where the boulders and pebbles passed and eventually settled.

Debris falls were noted to occur in Mbale and Sironko where rock fragments that had accumulated in rock crevices and cracks and at the top of the scarp face were observed and also reported by residents to often fall onto the debris slope. This was associated with rock fall on ridges where deforestation had taken place at the top for instance Nkokonjeru ridge in Bufumbo- Mbale district, Gabugoto and Zesui ridges in Sironko district.

Earth falls involving soil were observed to frequently roll down the scarp faces of the disturbed ridge tops, river banks as well as along cuttings created during construction of roads and buildings in Bududa, Manafwa and Sironko districts - **Plate 4.2**. All the three categories of falls that have been experienced in Mount Elgon were established to be surficial because they affected the upper most layer of the regolith (0.2-0.8 metres depth) on the debris slope where the boulders, pebbles, rock fragments or soil passed and eventually accumulated.

Plate 4.1: Rocks from a collapsed rock face on Wanale scarp (Mbale 2009)

Plate 4.2: An earth fall experienced on a road side cutting in August 2009
(Bufupa 24th November 2009)

4.2.2 Slides

Slides were noted to have occurred in all the four districts where the study was conducted. Specific forms of slides that have been experienced in the area are earth slumps, earth slides and debris slides -**Table 4.1**.

Earth slumps involving movement of mainly soil were noted to have occurred in different parts of Bududa district. The earth slumps experienced here are categorized as rotational slides because they left behind scars with deep head scarps ranging from 7-20 metres and also deposited a lot of material at the toe of the landslide. Judging by their shape, it was evident that the slumps involved movement of a portion of a whole slope although most of the scars were smaller at the top but wider down slope- **Plate 4.3.**

Debris slides and earth slides were noted to have occurred in Bududa, Mbale, Manafwa and Sironko districts. Judging by the depths of the remnant head scarps evident at the land slide scars and the toe characteristics, the debris and earth slides experienced in the area were of shallow translational nature **(Plate 4.4)** with head scarp depths ranging from one metre to six metres (1m-6m). The slide scars of this category were noted to lack toe material. Debris slides involved movement of broken rocks while Earth slides involved movement of soil.

Plate 4.3: A rotational slump of 2nd March 2010 (Namesti 23rd March 2010)

Plate 4.4: A translational slide of August 2008
(Bukinyale 23rd November 2009)

4.2.3 Flows

Flows were established to have occurred on some slopes in Sironko and Bududa districts. The flows experienced were debris flows and earth flows. Debris flow scars of 1.7 metres depth head scarps were noted in Sironko district while earth flow scars of 2 metres depth head scarps were noted in both Bududa and Sironko districts.

4.2.4 Tension Cracks and Pot holes

Tension cracks were noted and also reported by respondents in Manafwa, Bududa and Sironko. The cracks which existed inform of lateral openings into the ground were observed at 00°54′25.2″N, 034°21′41.4″E in Buwere village, 00^{O}55′08.3″N, 034^{O}22′43.5″E in Bukwapa village and 00^{O}57′35.9″N, 034^{O}22′24.9″E in Tsekululu and Bumbo in Manafwa district **(Plates 4.5a, 4.5b and 4.5c)**. The crack at Buwere was 80cm wide on 28th May 2010 while the one at Bukwapa was 30cm wide on 30th May 2010**.** These cracks are believed to be part of a continuous crack that cuts across Mount Elgon westwards from River Lwakhakha at the border with the republic of Kenya through the districts of Manafwa, Bududa, Mbale, Sironko and North West words through Kapchorwa.

Plate 4.5a: A tension crack cutting across the top of Namisindwa ridge (Buwere 28th May 2010)

Plate 4.5b: A tension crack cutting through Namisindwa ridge Scarp (Bukwapa 30th May 2010)

Plate 4.5c: A tension crack cutting across Tsekululu hill (Bunambale May 2010)

A tension crack occurs into a soil surface as a result of two opposing forces that are associated with saturated soil immediately above the saprolite and that at the surface. This happens when water that infiltrates into the ground saturates the saprolite as well as part of the soil directly above. As a result the saturated material above the saprolite moves down slope yet the unsaturated one at the surface tends to hold firmly thereby opposing the down slope movement. As a result some of the unsaturated material at the surface sunk to occupy the space created underneath consequently creating a crack. When such a process of opposing forces continues, it results into slow slips that eventually worsen into fatal slumps as has been the case in parts of Bududa and Manafwa.

Pot holes which are sunken parts of the ground associated with the same kind of tensional forces were also spotted in Bumbo sub-county in Bwandhiambi village Manafwa district located at 00°53′21.4″N, 034°21′46.6″E and 00°53′22.2″N, 034°21′46.7″E. The former was established to be 0.7 metres deep while the latter was 3.8 metres as of 28th May 2010- **Plates 4.6 and 4.7.**

Plate 4.6: A sunken spot (pot hole) in a cultivated field planted with beans (Buwandiambi 28th May 2010)

Plate 4.7: Part of a sunken spot in a banana plantation (Buwandiambi 28th May 2010)

A summary of the categorization of the sample landslide scars into categories of slope instability and their overall distribution according to districts is depicted in **Table 4.2**

Table 4.2: Categories of slope instability and their distribution by district

Forms of instability	District Name						Over all %
	Bududa	Manafwa	Mbale	Sironko	Total	%	
Rock fall	0	0	1	0	1	2.7	8.1
Debris fall	0	0	0	1	1	2.7	
Earth fall	1	0	0	0	1	2.7	
Earth Slump	9	0	0	0	9	24	73
Debris Slide	1	4	1	1	7	19	
Earth Slide	1	5	2	3	11	30	
Debris flow	0	0	0	1	1	2.7	10.7
Earth flow	1	0	0	2	3	8	
Tensional Crack	0	1	0	0	1	2.7	2.7
Pothole	0	2	0	0	2	5	5
Total	13	12	4	8	37	100	100
Percentage (%)	35	32	11	22	100		

Table 4.2 indicates that slides are the most common form of slope instability experienced on some slopes of Mount Elgon. This was accounted for by 73% of the landslide scars studied. Earth slides which accounted for 30% of all the landslide scars studied were the commonest form of instability experienced in all the districts with majority occurring in Bunambale sub-county, Manafwa

district. Earth slumps which accounted for 24% of the scars studied were indicated to be another major form of slope instability experienced in the area commonly in Bududa district. Debris slides accounted for 19% of the scars studied and were likewise also experienced in all the districts.

Flows accounted for 10.7% of the landslide scars studied and majority of these were earth flows which accounted for 8% of the scars while the rest accounting for 2.7% were debris flows. Falls accounted for 8.1% of the scars studied and each of the forms of falls studied namely; rock falls, debris falls, and earth falls accounted for 2.7% of the scars studied. Pot holes (sunken spots) accounted for 5% while tension cracks accounted for 2.7%.

Bududa district registered the highest number of landslide scars studied representing 35% of all the scars studied and majority of these were the deep seated rotational earth slumps. Manafwa district was also indicated to be highly affected by slope instability representing 32% of landslide scars studied which were majorly the shallow translational earth slides and debris slides respectively. Slide scars in Sironko accounted for 22% of the scars studied and majority of these were slides and falls respectively. Mbale district with 11% of the landslide scars studied is indicated to be the least affected of all the four districts studied.

4.3 Geomorphic processes and their influence on slope stability in Mount Elgon region

Geomorphic processes are the physical processes that shape landforms in a given area. It is in the process of shaping these landforms that slopes are as well rendered unstable as the following discussion unfolds.

4.3.1 Weathering

Field observations and consequent inferences established that physical disintegration of rocks occurred where cracks were noticed on rock out crops and on scarp faces. If such cracks developed on rocks with cross joints, they were noted to have with time resulted into rock fragments of different shapes and sizes ranging from blocks of boulders to small debris that gradually collapsed freely down slope under the influence of gravity.

To assess the rate of material destruction and the consequent slope instability experienced in form of rock fall, a wire mesh trap was placed at the foot of a scarp face and materials were collected on a monthly basis for a period of one year (March 2009-February 2010**.** Materials collected were measured and results tabulated according to months when it accumulated as depicted in **Table 4.3**.

Table 4.3: Material trapped from a scarp face on Wanale ridge in Bumboi - Mbale district

Date of material Collection	Amount collected (g)	Rank Order
March	400	7
April	1100	2
May	1500	1
June	720	3
July	540	4
August	500	5
September	450	6
October	360	8
November	300	9
December	250	10
January	220	11
February	200	12

Table 4.3 shows that the largest amount of material was collected during the month of May indicating that this was the month of maximum destruction of the rock face by weathering process. The lowest amount of material was collected during the month of February indicating that this was a month of minimum rock destruction by weathering on the scarp face. It should be noted here that the largest amount of material collected tended to coincide with the wettest month of the year while the lowest amount coincided with the driest month of the year.

For further analysis of the influence of weathering, **Figure 4.1** depicts the intensity of rock fall under the influence of weathering over a one year period.

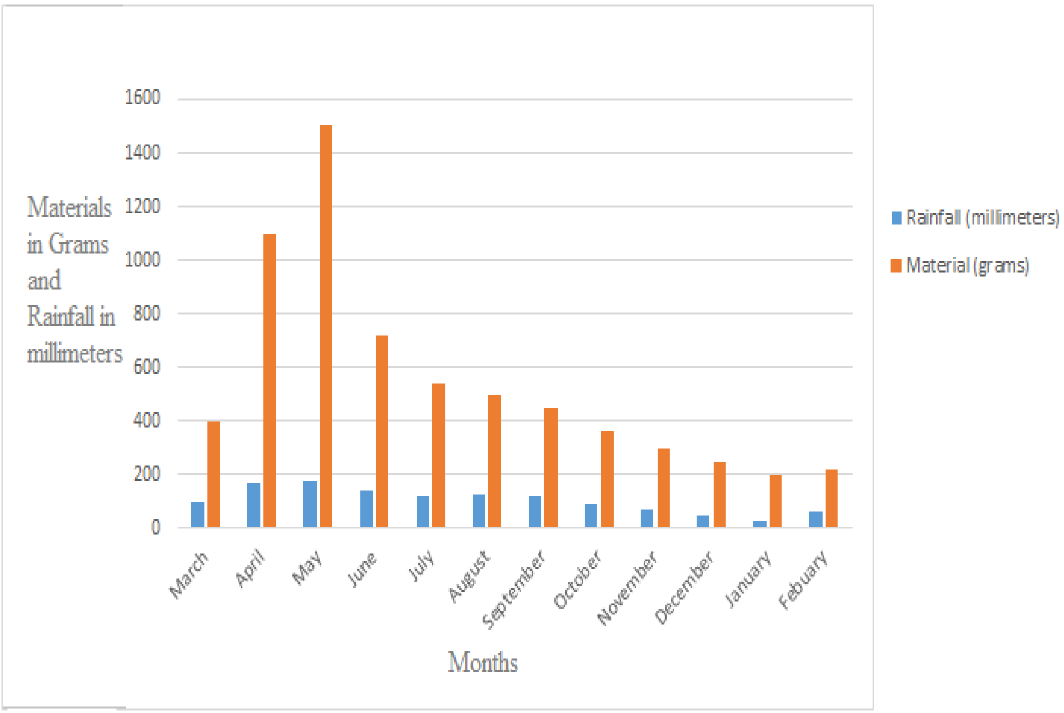

Figure 4.1: Annual weathering intensity on Wanale Scarp face in Mbale and rainfall pattern of Mount Elgon zone

From **Figure 4.1** the highest amount of material was collected during the month of May which is the peak rainfall month. The period of destruction was April-September while the period of calm was October – March. Weathering is revealed to be a continuous process which however varies in intensity over the year. The period April to August is depicted to be a period of rapid physical disintegration and decomposition of the scarp face as reflected by the high values of material that fell from the scarp face - **Table 4.3**. The trend began with increasing amounts of material trapped at the onset of rains and later steadily reduced though still maintaining relatively high values of more than half a kilogram. However the months of October to March are depicted as a period of relative calm as reflected by low and declining amounts of material collected of less than half a kilogram per month-**Table 4.3**. This therefore implies that rainfall is a key factor in the destruction of the scarp face.

The observation above is a clear indication that water plays a big role in influencing the intensity of weathering and the resultant rock fall from Wanale scarp face. Whereas weathering serves to disintegrate rocks during the dry months of the year, rain water serves to exert pressure on the already loosened rocks which simply collapse down slope. This was an indication that rainfall is indeed a trigger of slope failure in Mount Elgon like in other mountainous areas as already noted in Mount Kenya (Westerberg 1999) and in Norway where Terzaghi termed such an effect of rain water on slope instability as “high cleft-water pressure” (Rice 1977).

Weathering was further still established to be influencing slope instability in Mount Elgon through creation of an unstable deep weathering profile. Following the physical disintegration of the parent rock, the rock blocks and pieces are further decomposed into smaller particles that eventually become soil. According to soil pits dug in order to analyze soil depth at different landslide scars, most of the spots affected by landslides were established to possess regolith of more than 90 metres depth. This soil depth according to

Arsyad's classification **(Appendix 4.2)** is of deep soils. Out of the 35 landslide scars that were studied, 71.4% were of regolith depth above 90 centimetres while 28.6% were of regolith depth below 90 centimetres. Soil depth below 90 centimetres was composed of moderate, shallow and very shallow soil. It was therefore evident that deep weathering profiles in Mount Elgon tend to favour slope instability than the shallow weathering profiles. Another indicator of the vulnerability of deep soils to slope failure in Mount Elgon was the existence of deep head scarps where more permanent deep seated rotational scars were identified.

Specific areas where deep weathering has resulted into slope instability include Bufumbo in Mbale district, Bunambale in Manafwa district, Bumayoka and Bubita in Bududa district and Bufupa in Sironko district. Areas where the weathering profile is shallow but still associated with debris slides and flows include Bumbo in Manafwa district, Bunamulunyi in Manafwa district and Gabugoto and Namudongo in Sironko district.

4.3.2 River Undercutting

River undercutting was noted to have been a cause of slope instability in some parts of Mount Elgon. As rivers cut deep down into the channel bed, Steep River banks are created yet every time the river cuts deep it removes the toe material of the slope base. This is a condition that undermines stream bank material which is at the same time material at the base of the slope. This eventually leads to collapsing of slope material starting with that at the river banks followed by that upslope.

Associated with undermining of slope material by river undercutting is the effect of river bank wetting. The river at bank full discharge wets a larger perimeter of the channel than that wetted when discharge is at its lowest. These different bank wetting levels make the bank material heavy and it eventually collapses into the channel yet this removes support for the rest of material upslope which may also slide down slope into the river valley. Such incidences were noted to have occurred in Bumadanda and Jewa in Bufumbo-Mbale district – **Plate 4.8**. Evidence of such effects was landslide scars located along river valleys.

Plate 4.8: A Landslide scar of August 2008 cutting along Nabuyonga stream channel

(Jewa 6th August 2009)

4.4 Land use activities and their influence on slope stability on some slopes of Mount Elgon

A variety of activities were noted on slopes of Mount Elgon and these included cultivation, construction of houses and road excavation, and forest conservation. Survey of areas with landslide scars revealed the existence of a relationship between land use and slope instability by virtue of land use activity or activities that occupied land by the time slope failure occurred- **Figure 4.2**.

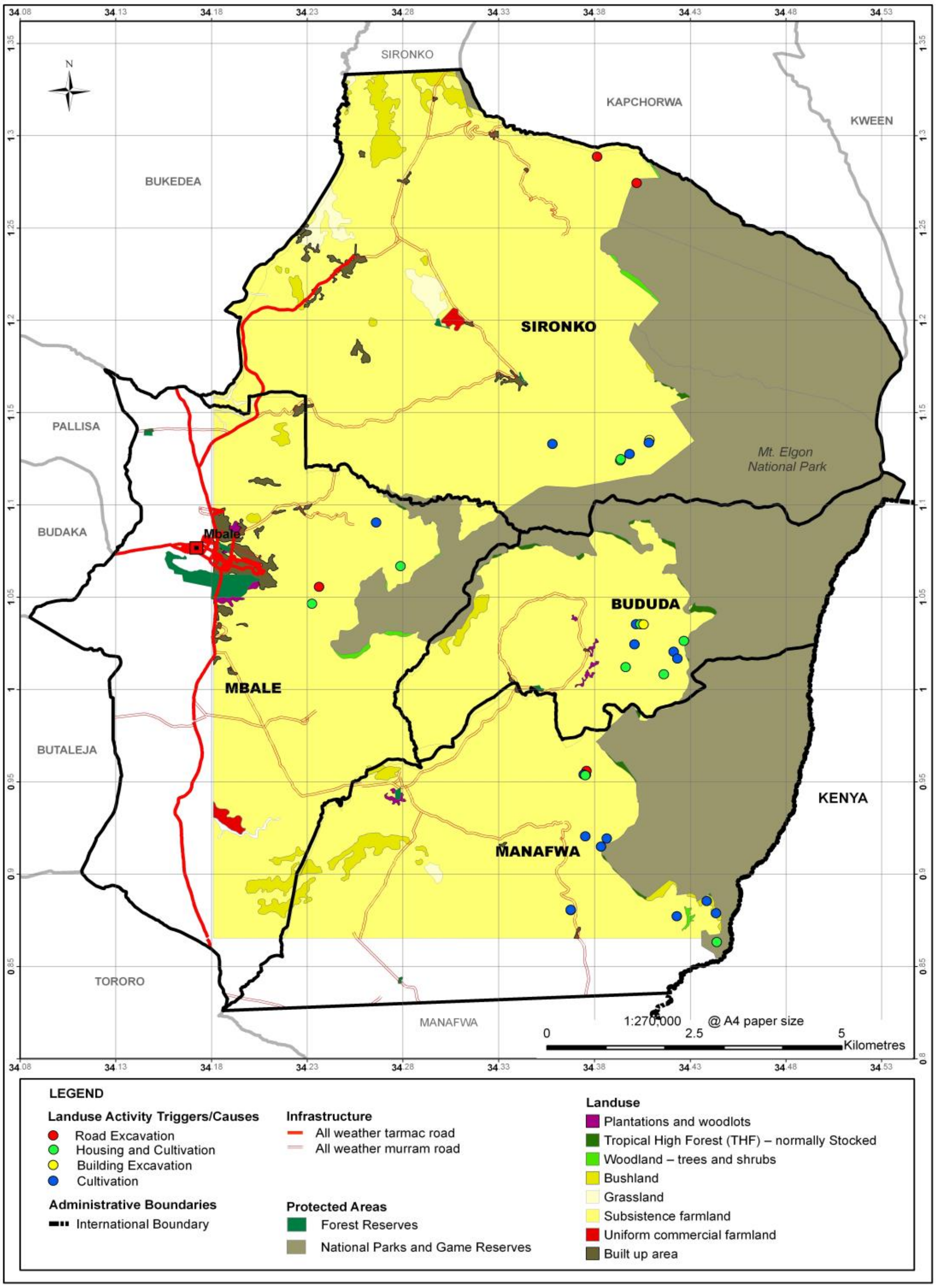

Figure 4.2: Land use activities and associated slope instability in Mount Elgon

(NFA 1990, NFA2005, GLCF 2003, Fieldwork 2009-2010)

Analysis of the 36 landslide scars surveyed revealed that 18 occurred on cultivated fields, 11 occurred where there was housing and cultivation, and 5 took place along road cuttings while 2 were exclusively on excavated housing grounds. The distribution of land slide scars according to land uses that were being practiced by the time the landslides occurred is depicted in **Figure 4.3.**

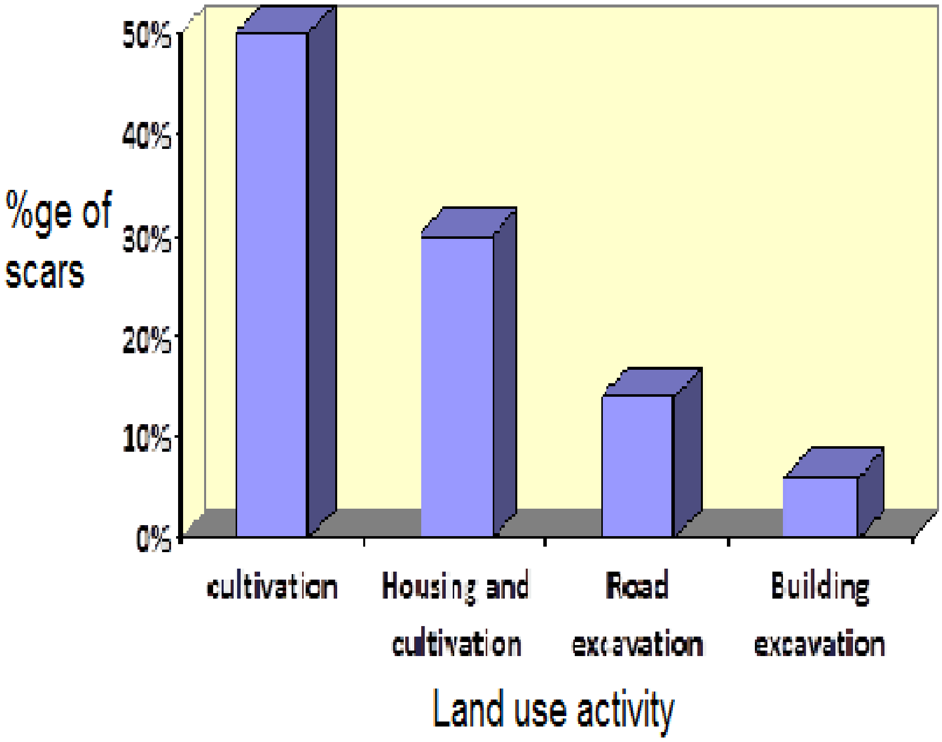

Figure 4.3: Slope instability associated with different land use activities practiced in Mount Elgon

50% of the landslide scars studied is depicted to have occurred where there was cultivation, 30% where there was cultivation and housing, 14% occurred where there was road construction and 6% occurred where land was excavated for building. This implies that cultivation is the leading cause of slope failure experienced in Mount Elgon followed by a combination of cultivation and housing, road excavation building excavation respectively.

4.4.1 Cultivation and slope stability

Cultivation was observed to be the major land use activity carried out on slopes of Mount Elgon. Farm plots were observed to cover most slopes extending right from the valley bottom to the hilltops irrespective of the very steep inclination of most of the slopes. Cultivation was established to be carried out on slopes inclined beyond 30^{O} yet according to Young (1983) 24^{O}- 35^{O} is a limiting angle for landslides on slopes with consolidated rocks while 8^{O} - 10^{O} is a limiting angle for landslides on slopes with clay soils.

Analysis of documented data and slope angle measurements taken from the various sample landslide scars revealed that 72% of the 18 landslide scars established to be associated with cultivation were experienced on slopes steeper than the consolidated rocks threshold while the remaining 28% were situated far above the clay soils threshold. Whereas the lowest inclination at which slope failure was established to have occurred on cultivated land was $15^{O}$the highest inclination was at 40^{O}. Regolith on slopes inclined at 15^{O}- 40^{O} when cultivated therefore becomes more vulnerable to slope failure than when it is left intact. Regolith depth was also established to be influencing stability of soil on cultivated slopes in the study area. The relationship between cultivation, slope angle, soil depth and slope instability was analyzed in **Appendix 4.2** and summarized in **Table 4.4**.

Table 4.4: Land slide scars experienced on cultivated slopes of varying steepness and soil depth

Slope steepness	**Slope angle category**	**Soil depth class**	**Number of scars**	**Percentage**
Steep- very steep	high angle	Deep	12	66.6
Steep- very steep	high angle	Shallow	4	22.2
Level- moderate	low angle	Deep	1	5.6
Level – moderate	low angle	Shallow	1	5.6
Total	-	-	18	100

Table 4.4 indicates that of the 18 sample land slide scars established to be associated with cultivation, 66.6 % were experienced at higher angle slopes with a deep soil cover while cultivated slopes at higher angles with a shallow soil cover registered 22.2% of the scars. This also reveals that cultivated slopes at lower angles with a deep soil cover registered 5.6% of the scars while those at lower angles with a shallow soil cover also registered 5.6% of the scars. This is therefore an indication that steep slopes with deep soils when cultivated easily give way to slope failure when compared to steep slopes that are covered with shallow soils. Low lying areas on the other hand whether with deep or shallow soils do not easily give way to slope failure. The research finding above are in line with the research hypothesis (**H_0**) which stipulates that;

“Slopes covered with cultivated crops on shallow soils do not fall at lower angles than those covered with cultivated crops on deeper soils but at higher angles.”

The research hypothesis is therefore upheld while rejecting the alternative hypothesis **(H_1)**;

> “*Slopes covered with crop cultivation on shallow soils fall at lower angles than those covered with cultivated crops on deeper soils but at higher angles.”*

Regarding elevation, cultivation on most slopes was noted to be extending above 2500 metres above sea level which was the initial ecological boundary of Mount Elgon forest reserve. Related to this is the realization that most landslide scars were established to be situated at an altitude closer or slightly beyond 2500metres above sea level as shown in **Figure 4.4.**

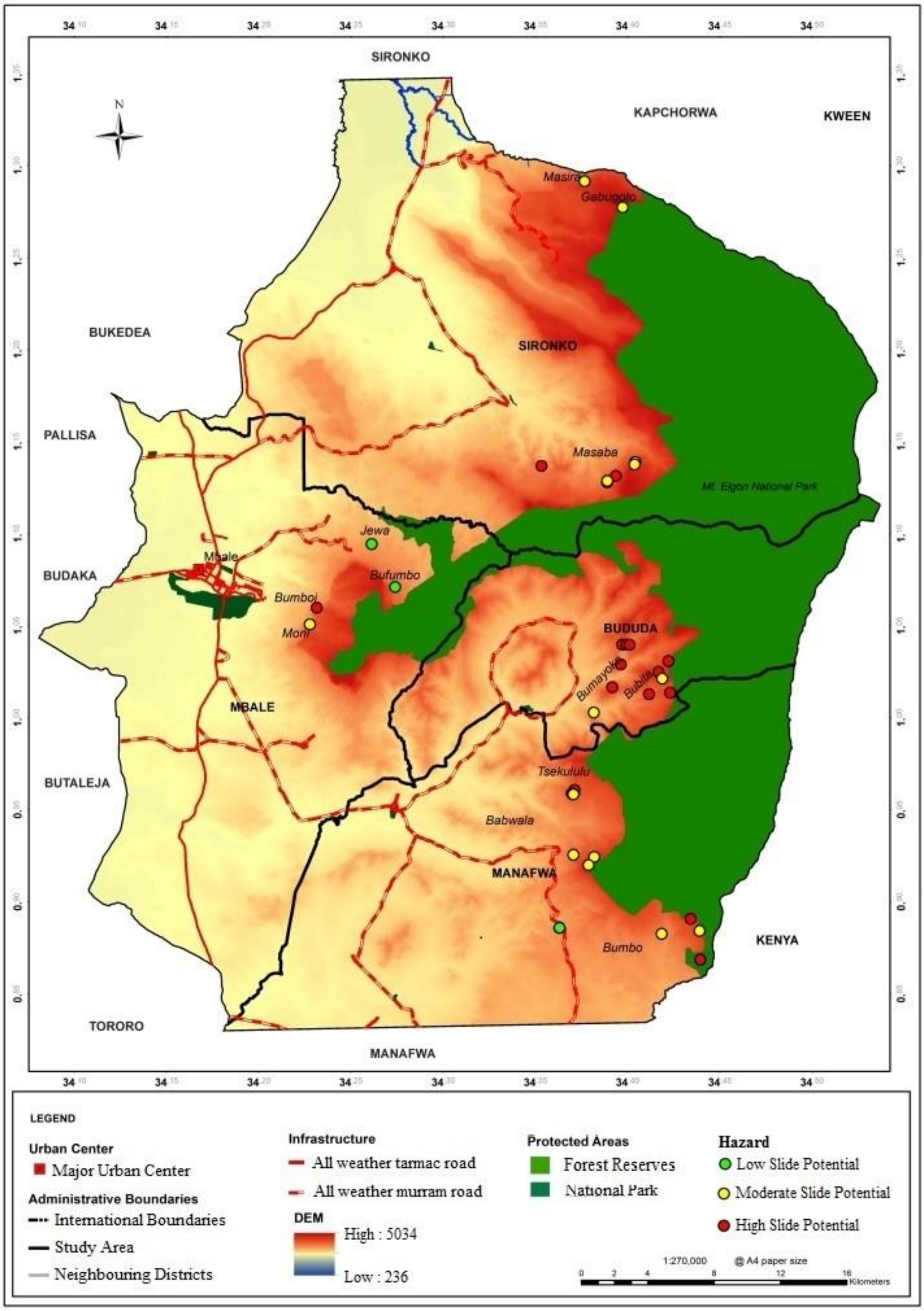

Figure 4.4: Relief, land use and slope stability in Mount Elgon

(SRTM DEM 2010, UBOS 2010, NFA2005, and Fieldwork 2009-2010)

Notably, cultivation was noted to cause slope instability through stripping the slope off its natural vegetation and planting it with crops yet natural vegetation is more effective in keeping slopes stable through binding soil particles and controlling infiltration. Land becomes more susceptible to slope failure during the time it is still bare or even when planted with crops which do not afford soil enough protection. Crops grown on the cultivated slopes include both perennials and annuals like Arabic coffee, bananas, beans, sweet potatoes, Irish potatoes, onions, cabbages, tomatoes, maize and green vegetables. Moreover the rate of plant growth in these highlands was indicated by Nakileza (2004) to be relatively slow due to low temperatures averaging 18^0centigrade during the wet season. Even though farmers usually cultivate land that is suitable for cultivation, such land is at times inherently sensitive to instability owing to its soil depth, physical characteristics or moisture conditions. Such land if left under natural vegetation such as forest cover is less prone to slope instability.

4.4.2 Construction of houses and road excavation

Human activities involving excavation of slopes for construction of houses and excavation of slopes for roads were noted to be responsible for some of the slope instability that has been experienced in Mount Elgon. Besides being mountainous, the area is densely populated and this has forced some people to construct some buildings far uphill even on slopes steeper than 70%. This is an indication that engineering activities are carried out at higher and sometimes steeper reaches that are naturally very unstable. Documentation and analysis of landslide scar data reveal that 69% of the 13 landslide scars studied and which had occurred on the roadsides were located above 24^{O}-35^{O} which is the landslide limiting angle on slopes with consolidated soils (Young 1983). The remaining 31% of the 13 landslide scars were located above 8^{O}-10^{O} which is the landslide limiting angle on clay soils (Young 1983).

Construction was established to be a trigger of slope instability where it involved cutting deep into a naturally steeply inclined slope. This kind of engineering work undercut the slope leaving behind hanging walls that eventually triggered landslides. The cuttings in the slopes were commonly inclined at 90^{O} and incised into slopes measured to range from 45%-73% steepness. Such cuttings were noted to be triggering spots of earth slumps in fenitized oldest rocks of Archean age covered by Nitisols commonly found in Maboono in Bududa district, Bunambale in Manafwa district, and Bufupa in Sironko district.

Besides triggering landslides, such slope undercutting associated with construction activities in Mount Elgon was established to have a short run effect of decreasing hill slope stability. The cuttings were noted to form spots at which a slope is undermined consequently driving the stabilized material upslope into slope failure- **Plate 4.9.** Likewise the hanging walls created during road construction on steep slopes were also observed to trigger or increase hill slope instability. A number of landslides were observed to have been initiated by the hanging walls along the roads that had not been protected by concrete or given any other form of protective cover. This was commonly observed on feeder roads that cut through the steeply inclined parts mostly at 70% and above in Bunandutu in Bududa district and Moni in Mbale district.

Plate 4.9: Slope failure experienced along Bukhalasi-Namesti road on 4th March 2010
(Bukhalasi 23rd March 2010)

Some buildings were further observed to have caused the ground upon which they are constructed to crack due to overloading of the steeply inclined slopes. This was found common on slopes inclined at 30° and covered with shallow loam-clay soils. Such buildings exert a lot of pressure on the shallow and often saturated regolith which developed cracks and eventually assumed a down slope flow as shown in **Plate 4.10.**

Plate 4.10: Slope failure triggered by undercutting by housing construction
(Maboono July 2010)

In some instances the stress imparted by the building onto the slope forces water to ooze out of the ground through the cracks or holes developed into building foundations. Such instances were cited in Bufupa in Sironko, Bumbo and Bupoto in Manafwa and Maboono in Bududa.

4.4.3 Deforestation and slope stability

Mount Elgon is a conservation area with a montane forest ecosystem that was initially a Natural forest reserve gradually elevated into a National Park. This was done so as to save the forest ecosystem that initially extended up slope above 2500 metres above sea level. According to focus group discussions, the only alternative that people have taken following scarcity of land is moving upslope into the forest which they moreover consider to be their free land. This in turn rhymes with what 82.6% of the study respondents expressed, that the government should allow them settle on their land currently covered by the National park rather than expecting them to relocate to Kiryandongo.

As the people moved into higher and steeper slopes looking for land for farming and settlement big chunks of forest were cut. This was mostly experienced during the 1990- 1995 lapse in control policies. This led to deforestation of part of the land initially under Mount Elgon forest National Park. Despite its clear demarcation, the National Park has been encroached mostly for cultivation. Cultivation on some higher slopes was observed to be taking place within the National Park as evidenced by the boundary pillars that were manifest in farm plots depicted in parts of Bumbo in Manafwa district and Bukhalasi in Bududa district **- Plate 4.11**.

Plate 4.11: Cultivated fields and banana plantations carried out on a slope partly falling in Mount Elgon National park whose boundary is indicated by two adjacent white pillars (Bunamulingi August 2009)

Forest soils though fertile are not fully grown and are weak loam-clays that get easily washed down slopes by any slight disturbance. This partly explains the closeness to the park boundary of most landslide scars especially majority of the intermediate and active landslide scars studied. Some forest parts that were encroached during the 1990s had been recovered by 2005 when they are depicted to have regenerated into bush land. Such areas are depicted closest to the landslide scars in Manafwa, Bududa, Mbale and Sironko. There was therefore some recovery of the forest parts that had been encroached in the 1990s. A number of landslide scars in Bumbo, Maboono and Masira were within the forest /National park **(Figure 4.5)**.

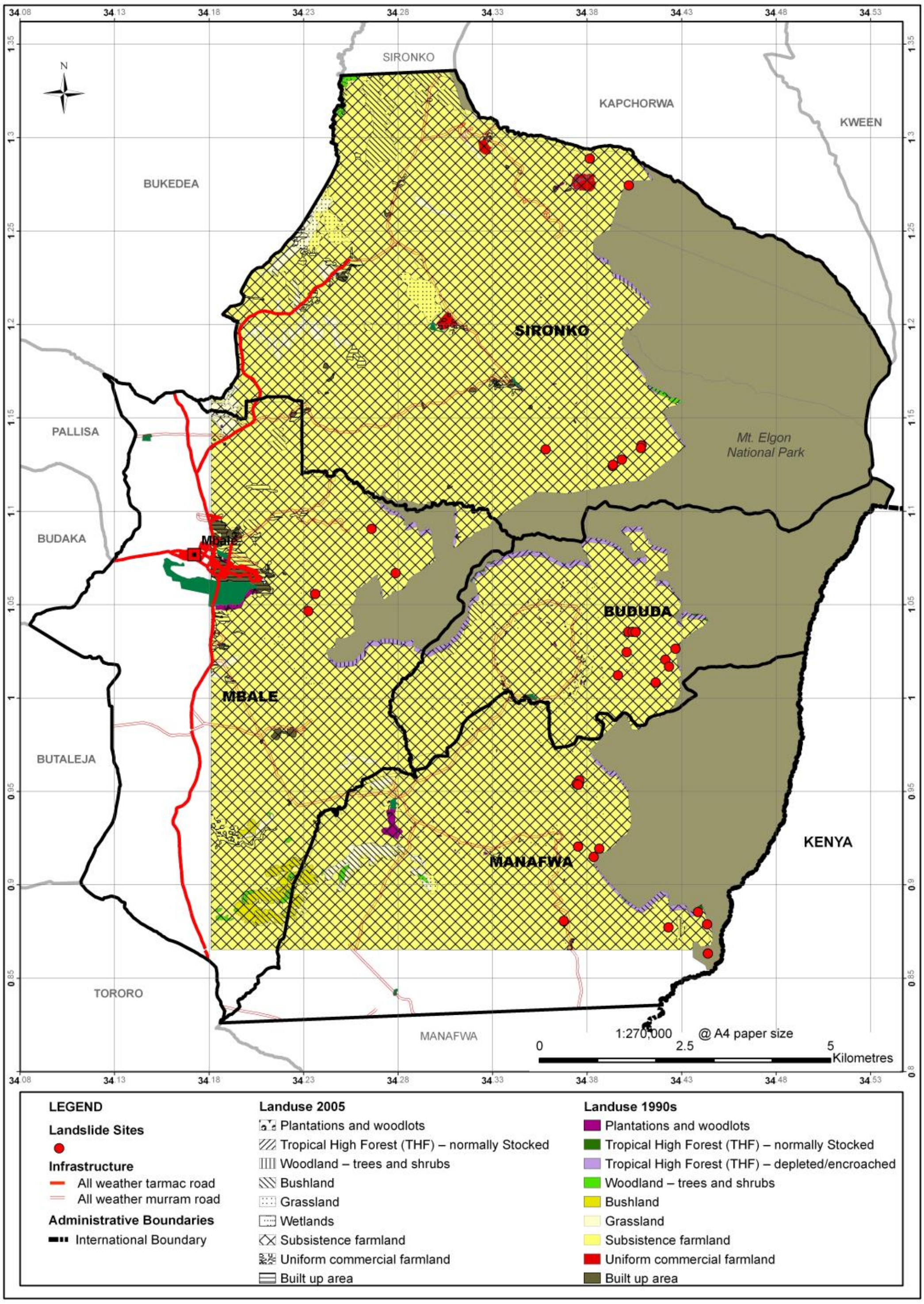

Figure 4.5: Changing forest cover between 1990- 2005 and slope stability in Mount Elgon

(NFA 1990, NFA 2005, UBOS 2010, and Fieldwork 2009-2010)

CHAPTER FIVE

SLOPE INSTABILITY RISK ZONATION AND VULNERABILITY ASSESSMENT

5.1 Introduction

This is a chapter that provides findings of the study revealing slope instability risk areas of the surveyed slopes of Mount Elgon. It particularly addresses findings about objective three which was aimed at determining slope instability risk areas using risk zonation mapping. Through documentation and mapping, some areas found to be at risk of slope failure were identified and categorized into different classes of slope instability risk by considering slope characteristics that made them susceptible to slope failure. The elements at risk due to slope instability in these risky areas as well as vulnerability to landslides are also analyzed in this chapter.

5.2 Slope Instability risk zonation

Documentation and mapping of slope instability risk areas was conducted by use of the following methodology. Specific areas were categorized as risky by analysis and consideration of slope characteristics that made them susceptible to slope failure namely elevation, slope steepness and slope form. The trend of slope instability incidences on slopes where the sample landslide scars were located which was established using some items in the questionnaire and the proforma check list was used to determine the sensitivity of the problem.

5.2.1 Spatial and temporal distribution of slope instability prone areas

Considering the year when slope failure was last experienced at each of the sample landslide scars, specific areas were categorized into active, intermediate, inactive and very active categories. The active areas were those where slope failure was experienced in a period of less than five years ago, intermediate ones were those where slope failure occurred between five to twenty years ago, while inactive ones were those where slope failure occurred over twenty years ago. If on the other hand an area had a history of occurrence of slope failure ranging from over twenty years ago to less than five years ago, such an area was categorized as being very active. Categorization of slope instability risk areas documented and mapped by this study is summarized in **Table 5.1** and **Appendix 5.1.**

Table 5.1: Summary of temporal distribution of slope instability risk areas according to trend

District	Sub-county	Risk Category					
		Very Active	Active	Intermediate	Inactive	Total	%
Bududa	Bubita	1	2	4	0	7	18.9
	Bumayoka	0	4	0	0	4	10.8
Manafwa	Bwabwala	0	3	3	0	6	16.2
	Bumbo	0	4	3	0	7	18.9
Mbale	Bufumbo	0	2	0	0	2	5.4
	Bunghoko Mutoto	0	2	0	0	2	5.4
Sironko	Masaba	0	3	3	0	6	16.2
	Masira	0	2	0	1	3	8.2
Total		1	22	13	1	37	100
Percent		2.7	59.5	35.1	2.7	100	

Table 5.1 reveals that majority (59.5%) of the land slide scars studied had been experienced in a period of less than five years ago hence they were active slides, 35.1% had been experienced in a period between 5-20 years ago so they were intermediate slides while the inactive scars where failure was experienced over twenty years ago accounted for only 2.7%. The very active scars where failure had continually re-occurred since 20 years ago also accounted for 5.4% of the scars studied.

The sensitivity of slope instability in Mount Elgon is also revealed by the fact that there has been a tendency of landslide to re-occur on the same localities. It deserves to be mentioned that active landslide scars did not only form the majority of the scars studied but they were established to have mostly re-occurred on the same spots. This is reflected in the fact that 13 out of 22 active landslide scars studied were found to have re-occurred on the same locality where by seven re-occurred twice while six re-occurred once. The first occurrence of the seven slides that re-occurred twice was either in 1997 or 1999 during the El-Niño rains while the six that re-occurred once were not associated with El-Nino rains. It is only nine active landslides that were found to have occurred once during the recent past five years – **Figure 5.1.**

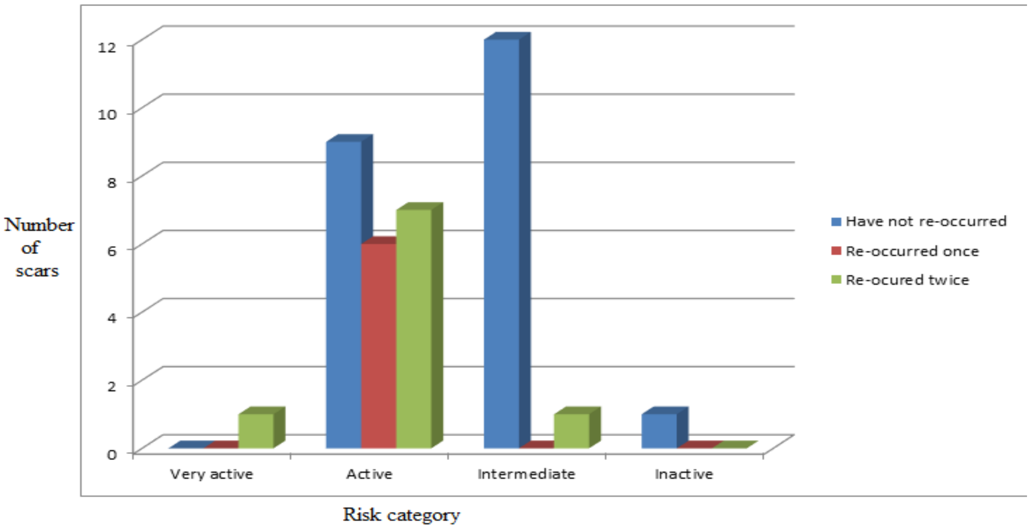

Figure 5.1: **Slope instability risk category by trend**

The very active landslide scar studied was found to have re- occurred on the same spot twice with the second occurrences being experienced during the 1997 El-Nino rains. Areas of intermediate scars on the other hand are depicted not to have experienced re- occurrence of landslides except only one out of 13 scars where slope failure re- occurred twice following the 1999 El-Nino rains in 2000, 2002 and 2003 respectively. The only inactive landslide scar studied on the other hand is depicted to have occurred only once in 1988 and the slope has since then become stable. There is therefore indication that there has been an increasing tendency of re- occurrence of slope instability on the same spots in Mount Elgon in a period of less than ten years ago. Apart from the El- Nino rains triggered occurrences, some landslides are attributable to a combination of geomorphic processes and land use activities.

Figure 5.1 further reveals that the most sensitive areas are located in Bududa which possesses landslide scars of all categories. Slope instability was established to be an old time hazard in Bududa dating far back beyond twenty years ago. Most landslides here were found to have re-occurred on same spots and a case in point is the Namesti landslide of March 2010 which occurred in an old scar of 1932 and 1997. It is for that matter the only scar which has been categorized as a very active land slide scar by the current study. Elsewhere, slope instability is depicted to have intensified in Manafwa where it is however not as old as it is in Bududa and Sironko districts. The spatial and temporal distribution of the sample land slide scars depicting the sensitivity of slope instability in Mount Elgon was computed into a slope instability hazard map - **Figure 5.2**.

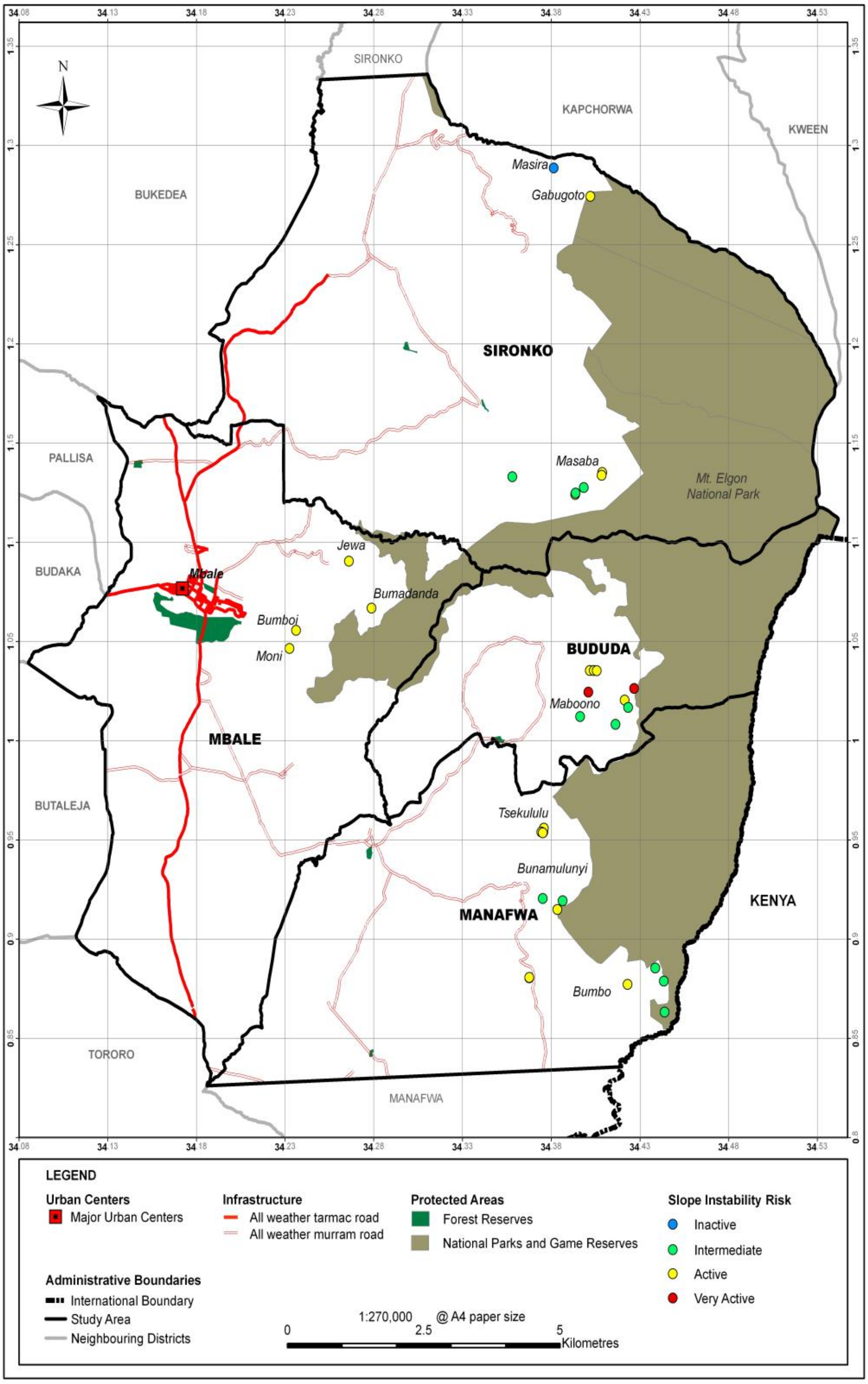

Figure 5.2: Slope instability risk map

(UBOS 2010, Fieldwork 2009-2010)

5.2.2 Elevation and distribution of slope instability prone areas

Slope instability prone slopes represented by the mapped landslide scars (Appendix 5.1) were established to be situated between 1379 - 2531 metres above sea level. Slopes that were found to be mostly prone to slope instability were however located between 1500 – 2500 metres above sea level.

This is an area that a Study conducted earlier in Sironko categorized as the cultivated area of Mount Elgon region (Obua et al; 2004). A total of 32 landslide scars out of the 35 studied were situated in the area extending from 1500 - 2500 metres above sea level, 2 were situated above 2500 metres above sea level, while 3 were situated below 1500 metres above sea level-**Table 5.2.**

Table 5.2: Spatial distribution of sample land slide scars according to elevation levels

Elevation in Metres	**Number of Scars**	**% Distribution**
Above 2500	2	5.4
1500-2500	32	86.5
Below 1499	3	8.1
Total	37	100

As indicated in **Table 5.2**, majority of the landslide scars studied representing 86.5% were situated at elevation between 1500-2500 metres above sea level, followed by 8.1% representing scars situated above 2500 metres above sea level while 5.4% were situated below 1500 metres above sea level. The landslide scars situated above 2500 metres above sea level were located on slopes that were either once covered by Mount Elgon forest but were deforested due to population increase or on the scarp slopes. Such slopes are located in Bududa district where the most recent landslide occurred in March 2010 at Nametsi, Bumbo in Manafwa and Masira in Sironko district. Landslide scars on slopes below 1500 metres above sea level were located in Bufumbo sub-county Mbale district in Jewa and Bumadanda on the long pediment slope below Nkokonjeru ridge. Slopes between 1500-2500 metres above sea level were located in all the districts studied where the natural land cover has been long cleared and replaced with the human created cover.

5.2.3 Slope Steepness and Spatial distribution of areas prone to slope failure

Landslide scars mapped (**Appendix 5.1)** revealed that the steepest slope that had registered slope instability incidences was inclined at 40% while the least steep was inclined at 9%. This finding is in consonant with what Kitutu (2010) established in a study conducted in Bududa district that areas sensitive to landslides range from 14^{O} to 41^{O}. Basing on Young’s classification of slopes (Young and Anthony 1983), the slopes that are most prone to slope failure in the area studied are those that are very steep (30^{O}- $45^{O)}$ being represented by 25 landslide scars followed by steep slopes (18^{O}-30^{O}) represented by 9 landslide scars. Moderately steep slopes (10^{O}-18^{O}) and moderate slopes (5^{O}-10^{O}) were represented by 2 and 1 landslide scar respectively. **Table 5.3** shows the distribution of landslide scars studied according to slope steepness.

Table 5.3: Summary of the spatial distribution of sample landslide scars according to slope steepness category

District	**Steepness Category and associated number of scars**				
	Scars on very steep slopes	**Scars on Steep Slopes**	**Scars on Moderately Steep**	**Scars on Moderate Slopes**	**Total**
Bududa	9	4	0	0	13
Manafwa	8	3	1	0	12
Mbale	2	0	1	1	4
Sironko	6	2	0	0	8
Total	25	9	2	1	37

Table 5.3 reveals that very steep slopes are the areas that are most prone to slope failure in Mount Elgon. Steep slopes are also relatively affected by slope instability while moderately steep and moderate slopes also experience some landslides. According to **table 5.3**, 25 out of 37 sample landslide scars were located on very steep slopes, 9 were located on steep slopes, and 2 were located on moderately steep slopes while only 1 was located on moderate slope.

Overall, Bududa district emerged to be an area with slopes that are most prone to slope instability represented by 9 out of the 25 landslide scars located on very steep slopes and 4 on steep slopes. None was found on moderately steep or moderate slopes. Manafwa district is also depicted to possess very steep slopes that are prone to slope instability represented by 8 landslide scars, followed by Sironko district with 6 landslide scars also located on very steep slopes. Bududa, Manafwa and Sironko possess steep slopes that are prone to slope instability reflected by presence of 4, 3 and 2 landslide scars respectively under this slope category. Mbale district was the least prone of the four districts studied as depicted by only 2 landslide scars that were located on very steep slopes while 1 was located on moderately steep slopes and 1 was located on a moderate slope.

Analysis of slope stability basing on the gradient of slopes where past and recent landslide scars occurred revealed that slopes in Mount Elgon are of differing slide potentials. Measurements guiding the stability analysis are summarized in **Appendix 5.2**. The analysis revealed that majority of the slopes studied were of high slide potential by virtue of being at gradient greater than 60%. This was represented by 49% of the scars studied. Slopes of moderate slide potential at gradient 30-60% also tended to dominate as represented 43% of the scars studied. A few areas were rated to be of low slide potential due to the fact that they are of gradient below 30%. Such areas were represented by 8% of the scars studied. **Table 5.4** depicts the distribution of sample landslide scars according to the rated slide potentials.

Table 5.4: Sample landslide scars arranged according to their slide potentials

District	**Slide potential rating and associated scars**				
	Low < 30%	**Moderate 30-60%**	**High > 60%**	**Total**	**% of scars**
Bududa	0	3	10	13	35
Manafwa	1	7	4	12	32
Mbale	2	1	1	4	11
Sironko	0	5	3	8	22
Total	3	16	18	37	100%
Percentage	8%	43%	49%	100%	

Table 5.4 indicates that majority of slopes with a high slide potential are located in Bududa district represented by 10 out of the 18 sample landslide scars rated to be of high slide potential. Slopes of this category were located mostly in Bumayoka and Bubiita sub-counties in Maboono and Buwali areas respectively. Manafwa and Sironko also exhibited a number of Slopes with high slide potential represented by 4 and 3 scars respectively of the 18 landslide scars rated to be of high slide potential. Such slopes in Manafwa were located in Bunambale and Taaso while in Sironko they were located in Bufupa and Gabugoto. Mbale district also possessed cases on slopes with high slide potential represented by only 1 out of 18 high slide potential sample landslide scars. This was located in Moni on the short debris slope below Wanale ridge scarp face.

Manafwa district on the other hand unlike Bududa registered all kinds of slide potential ratings and actually emerged with majority of slopes having moderate slide potential. This was represented by 7 out of 16 sample scars rated to be of moderate slide potential. Areas of such rating were located in Bunambale, Bunamulunyi and Bunamulingi slopes. Sironko, Bududa and Mbale districts also possessed slopes of moderate slide potential represented by 5, 3 and 1 scar respectively out of 16 sample scars rated to be of moderate slide potential. Slopes of this category were located in Bubolo and Namudongo areas in Sironko, Bukhalasi in Bududa and Bumboi in Mbale. The moderate slide potential areas on the slopes in Bukhalasi and Bumboi were mostly road cuttings initiated by road construction.

Slopes with low slide potential are located mostly in Mbale and Manafwa districts. They were represented by 2 and 1 landslide scar respectively out of 3 sample scars rated to be of low slide potential. Slopes of low slide potential in Mbale were located in Bufumbo in Bumadanda and Jewa where landslides were experienced on the pediment slope below Nkokonjeru ridge. The landslides were initiated by rivers undercutting into the long pediment slope. The low slide potential slopes in Manafwa are located in Bumbo where cracks and potholes were spotted to have developed on the long pediment slope below the scarp on Namisindwa ridge. The slide potential assessed above was compiled into a slope instability risk map depicted in **Figure 5.3**.

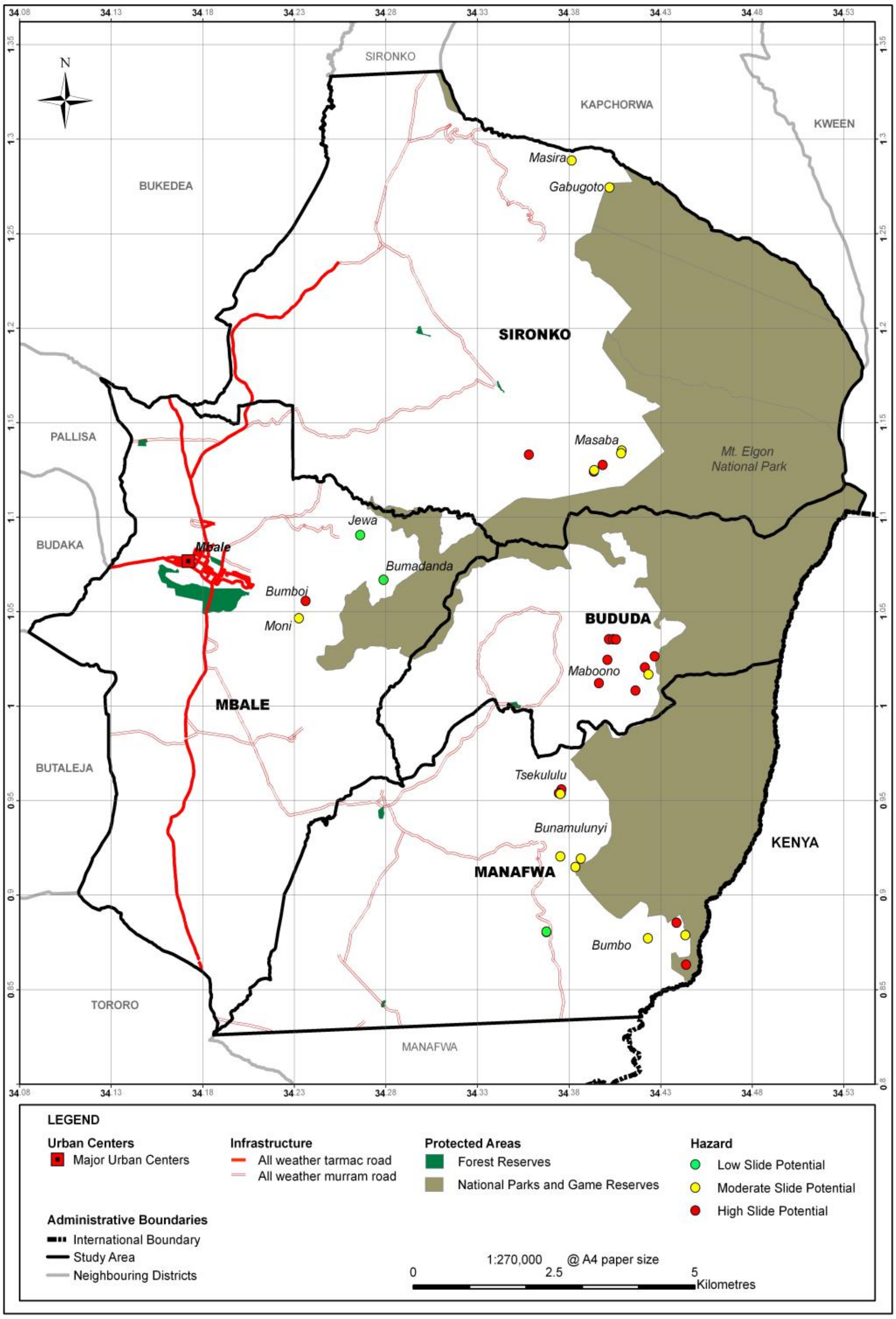

Figure 5.3: **Slope Instability hazard map of Mount Elgon**

(UBOS 2010, NFA 2005 and Fieldwork 2009-2010).

The magnitude of slope instability risk in Mount Elgon is also depicted by the results obtained by monitoring the displacement of pegs and stakes inserted in the ground on different slopes- **Figure 5.4**. The distance between the peg and the soil level on the upper side of the peg was measured on a monthly basis and. The results recorded were later analysed to assess the trend between each measurement made and that of the previous one.

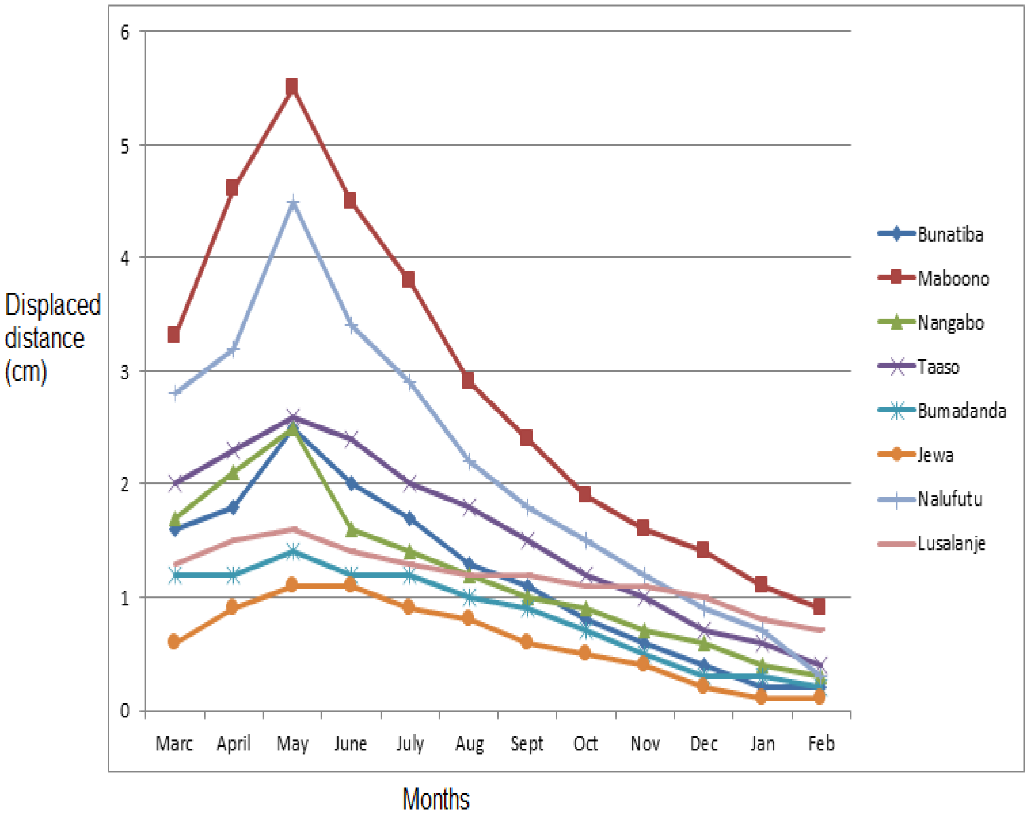

Figure 5.4: Summary of peg displacement measurements to determine likelihood of Slope movement

According to **figure 5.4** slopes in Bududa specifically in Maboono and Nalufutu in Sironko depicted high displacement rates indicating that there is eminent danger of slope failure in such areas. The slopes in Jewa and Bumadanda both in Mbale district and Lusalanje in Sironko district depicted relatively low rates of displacement indicating that there is relative calm in such areas. The situation in other areas such as Taaso and Nangabo both in Manafwa and Bunatiba in Bududa which depicted relatively high also have looming dangers of slope instability risk.

5.2.4 Slope form and distribution of slope instability risk areas.

Field documentation and analysis revealed that segmented slopes and rectilinear slopes with long concave slopes are more prone to slope instability than those with an even curvature. The segmented slopes possess scarp faces alternating with a short debris slope directly beneath the cliff and a long pediment slope at the bottom **-Plate 5.1**. The rectilinear slopes on the other hand have a long concave part extending from the valley bottom towards the summit which is climaxed by a short steep slope-the convexity **-Plate 5.2**.

In all the sample landslide scars and other slope instability risk areas studied, the upper steep concavities were established to be more affected by slope failure than the convexities –**Plates 5.3a and 5.3b.**

Plate 5.1: A slope segmented into the scarp, debris slope and the pediment slope at the bottom (Bumbo August 2009)

Plate 5.2: Rectilinear slopes composed of lower concavities and upper convexities (Maboono December 2009)

Plate 5.3a: **A land slide scar initiated at a spot on the upper steep concave slope in 2010**
(Bukhalasi March 2010)

Plate 5.3b: **A landslide scar initiated on the steep upper concavity of a slope in 1998**
(Buwali December 2009)

Majority of the landslide scars studied which totalled up to 32 out of 37 were found to have been initiated at the upper steeper reaches of concave slopes while only 5 were found to have been initiated on convex slopes . The distribution of sample landslide scars according to slope form is depicted in **Appendix 5.2** and **Figure 5.5** respectively

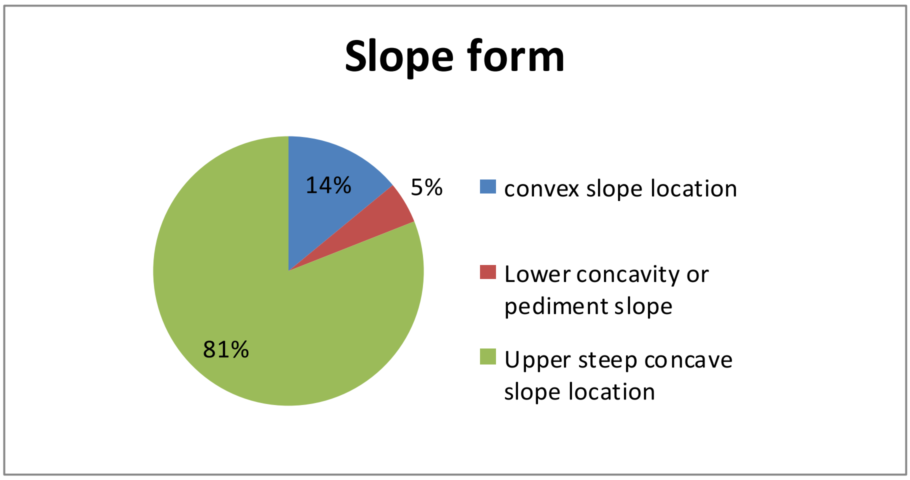

Figure 5.5: Distribution of study sites according to slope form

Figure 5.5 shows that 81% of the landslide scars surveyed were initiated on the upper steep concave slopes, 5% were initiated on the pediment slope (concave), while 14% were initiated on convex slopes. The convex slopes affected by slope failure were mostly those where man's excavation activities of building and road construction had been carried out such as Bunatiba road side scar in Bukhalasi, Bumboi roadside scar in Mbale and Baaya scar in Bunambale – **Plates 5.4a and 5.4b**.

Plate 5.4a: A land slide scar by the road side initiated on the upper convexity of a slope

(Bukhalasi December -2009)

Plate 5.4b: A land slide scar initiated by the road side on the upper convexity of a slope

(Bufupa - November 2009)

Field analysis further revealed that proximity to the scarp faces makes the slope directly beneath the scarp (the debris slope) vulnerable to slope instability. All the material that collapses from the scarp face as well as the top of the ridge usually finds its way on the debris slope and at times the pediment slope beneath it. Depending upon the repose angle of the slope and the size of the collapsed material, the smaller and lighter particles settle on the steeper debris slope while the larger heavier materials roll further down onto the gentler pediment slope **- Plates 5.5a and 5.5b**. The location of sample land slide scars with relation to scarp faces is depicted in **Figure 5.6**.

Plate 5.5a: A debris slope vulnerable to rock fall from an adjacent scarp face
(Namudongo- December 2009)

Plate 5.5b: Pebbles that collapsed from the scarp face in the right middle ground heaped on the pediment slope
Namudongo- November 2009)

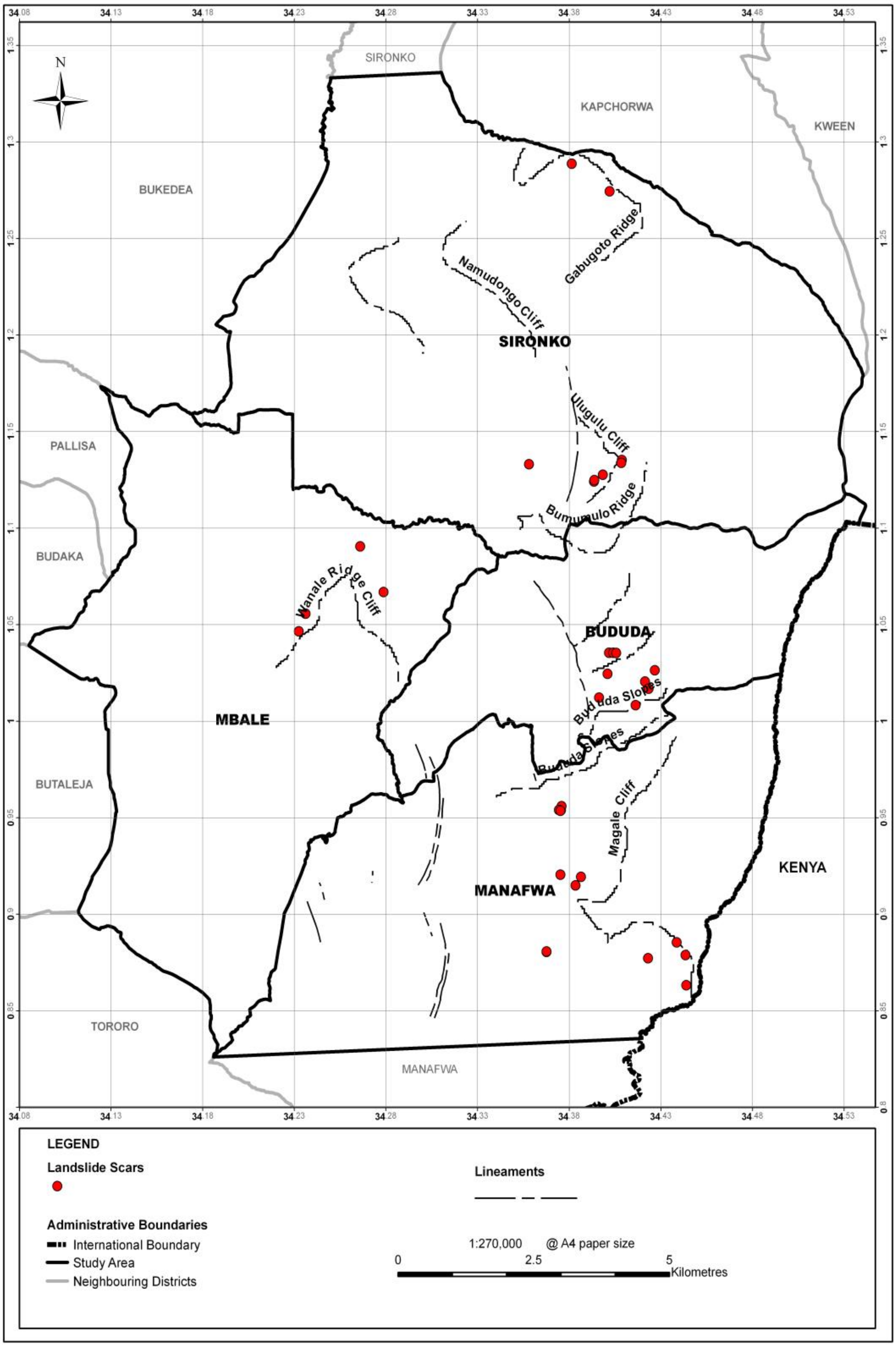

Figure 5.6: Lineaments and associated landslides

(GLCF 2003, Fieldwork 2009-2010)

5.3 Elements at risk due to slope instability hazard in some slopes of Mount Elgon

The study engaged in analyzing the elements at risk of slope instability hazard on some slopes of the study area. Much of the area is generally densely settled and extensively cultivated despite the steeply inclined slopes and this puts a lot of people as well as property and associated social services at stake. The slopes covered in this analysis were those that depicted indicators of likelihood of occurrence slope failure as well as those that have ever experienced slope failure such that population, property, social services and infrastructure likely to be affected could be established using item (6) of the proforma checklist- **Appendix 3.3**. Results of the survey are depicted in **Table 5.5.**

Table 5.5: Elements at risk due to slope instability hazard on some slopes

District	**Sub County**	**Population, property and infrastructure located on risky slopes**						
		People	Buildings	Home-steads	Roads	Foot paths	Schools	Health centres
Bududa	Bubita	2300	490	230	2	16	3	1
	Maboono	1110	225	111	1	8	1	1
Manafwa	Bwabwala	700	105	50	1	6	1	1
	Bumbo	528	90	44	1	4	1	1
Mbale	Bumadanda	336	56	28	2	3	1	0
	Bunghoko	96	18	8	2	3	0	0
Sironko	Masaba	410	68	34	2	4	1	0
	Masira	288	50	24	1	3	1	0
	Total	5758	1102	529	12	47	9	4

According to **Table 5.5,** people, buildings, homesteads, footpaths, schools and health centres stand the risk of being affected by slope instability likely to occur on some slopes in Mount Elgon. This is depicted by a total of 5758 lives that were settled on risky slopes. Equally at risk were 1102 buildings, 529 homesteads, 12 roads, 47 footpaths, 9 schools and 4 health centres. Most of the elements at risk were depicted in Bududa which recorded the highest numbers of elements at risk with Bubita Sub - County registering 3042 and Mabono Sub –County 1447 respectively. The most endangered occupant of the risky slopes is human beings. This accounted for the highest percentage of 77% of the elements at risk of slope failure. 15% of the elements at risk were buildings, 7% were homesteads, 0.6% were footpaths, 0.2% were roads while 0.1% were both schools and health centres respectively - **Figure 5.7**.

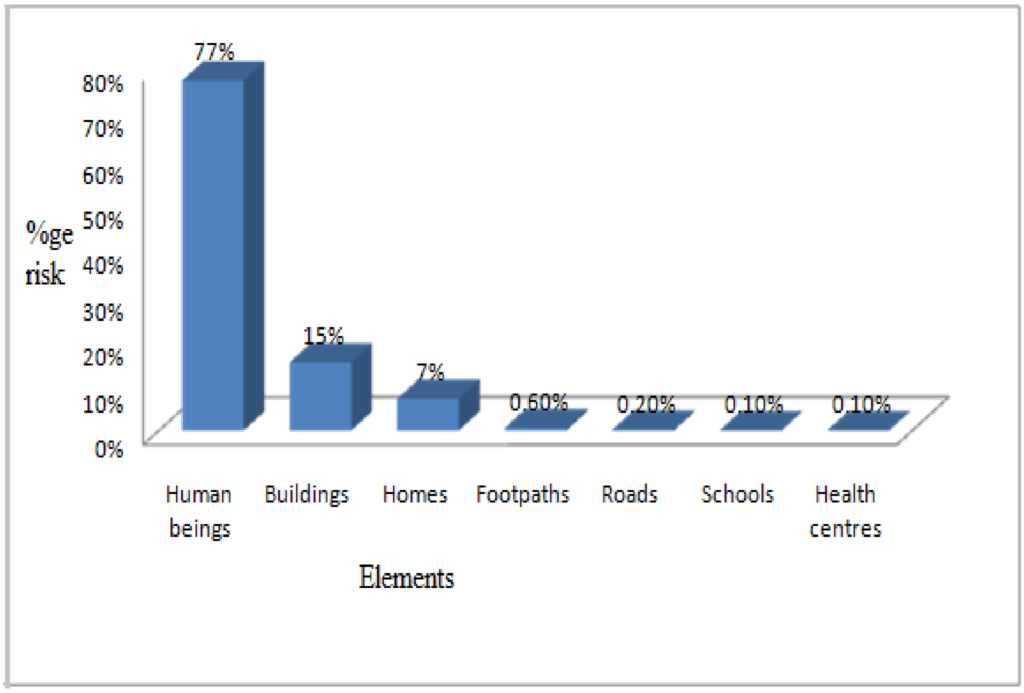

Figure 5.7: Elements at risk of slope instability hazard on some slopes of Mount Elgon

The revelation of the highest recorded values for human beings - **Table 5.5 and Figure 5.7** indicates that the elements at risk of slope instability in the area are still large as depicted by the presence of 529 homesteads still occupying the slope instability prone slopes studied. The magnitude of this looming danger is depicted in **Figure 5.8.**

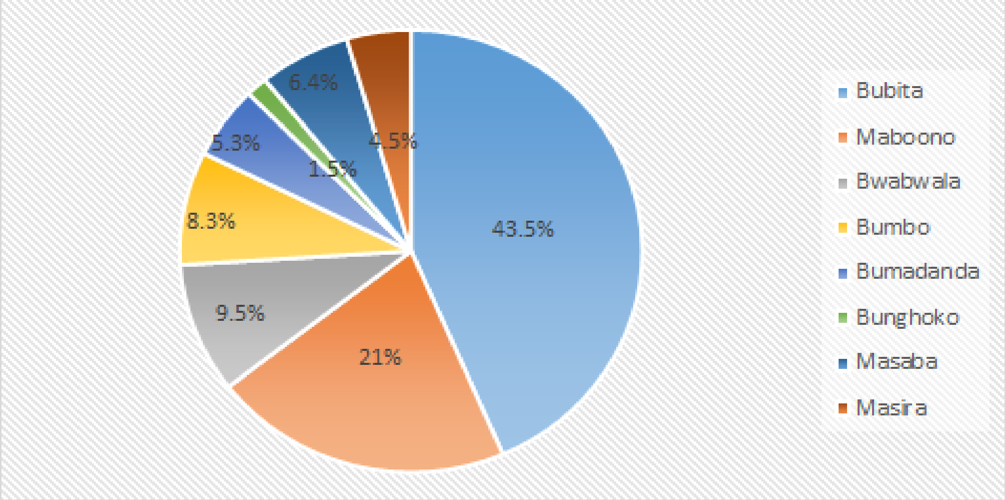

Figure 5.8: Distribution of homes at risk of slope instability hazards

Figure 5.8 indicates that the biggest dangers of people who are at a risk of slope instability hazard are in Bududa particularly Bubiita where 43.5% of the homes located were found and Maboono which has 21% occupants. Elsewhere the vulnerable people are in Bwabwala (9.5%), Bumbo (8.3%), Masaba (6.4%), Bumadanda (5.3%), Masira (4.5%) and Bunghoko (1.5%).

5.4: Vulnerability Assessment

The study engaged in analyzing the elements at risk of slope instability hazard on some slopes of the study area. Much of the area is generally densely settled and extensively cultivated despite the steeply inclined slopes and this puts a lot of people as well as property and associated social services at stake. The slopes covered in this analysis were those that had ever experienced slope failure incidences so that the amount of loss and damages caused by a slide could be easily established using item (7) of the proforma check list - **Appendix3.3**. Results of the survey are depicted in **Table 5.6.**

Table 5.6 Vulnerability due to slope instability hazard on some slopes

District	Sub County	Life loss	People displaced	Ani. loss	Road damage	Bridge damage	Sch loss	H/centre loss	Church damage	Crop loss	House damage
Bududa	Bubita	470	985	170	8	10	4	2	3	942	42
	Maboono	8	48	36	4	5	1	1	0	38	35
Manafwa	Bwabwala	6	22	22	3	2	0	0	0	36	8
	Bumbo	3	15	40	6	1	4	1	1	45	10
Mbale	Bumadanda	3	6	5	4	2	1	1	0	27	6
	Bunghoko	1	12	20	3	1	1	0	0	13	9
Sironko	Masaba	2	14	35	5	2	1	1	0	18	6
	Masira	0	2	3	3	2	0	0	0	6	3
	Total	493	1104	331	36	25	12	6	4	1125	119

According to **Table 5.6** the most vulnerable occupant of the slope instability prone slopes of Mount Elgon are human beings who stand the risk of loss of their only lives or being displaced temporarily or permanently following damage or worse still loss of their homes. This is depicted by a total of 493 lives reported to have been lost during the incidences of the landslide scars surveyed, 1104 families indicated to have been displaced and 119 houses indicated to have been damaged. Other than this direct effect, the other vulnerable occupants of some slope instability prone areas of Mount Elgon were indicated by loss of 125 gardens, 331 domestic animals, 12 schools, and damages to infrastructure and social services such as 36 roads 25 bridges, 6 health centers and 4 schools. **Table 5.6** indicates high vulnerability indices for all categories of elements occupying risky slopes in Bududa district in both sub-counties of Bubita and Maboono.

CHAPTER SIX

PEOPLE'S PERCEPTION AND ATTITUDE TOWARDS SLOPE INSTABILITY

6.1 Introduction

This chapter provides findings concerning people's perception and attitude towards slope instability in Mount Elgon. In particular, the chapter addresses findings focusing on the fourth objective of this study that sought to examine people's perception and attitude towards slope instability risk and evaluate their willingness to participate in coping strategies. The presentation on people's perception and attitude towards slope instability risk covers perceived causes of slope instability, perceived indicators of slope instability, and perceived determinants of the way people react to landslides. The findings on willingness to participate in coping strategies on the other hand covers perceived strategies that would help reduce slope instability, perception and attitude towards evacuation programs and response towards evacuation programs. The study respondents drawn from the four districts were of diverse socio-economic backgrounds and contributed to the findings of this study either by responding to the questionnaire or by being interviewed.

6.2 Questionnaire respondents

The selected districts included Bududa, Manafwa, Mbale and Sironko from which 40 respondents each participated in the questionnaire survey. **Table 6.1** shows the response rate per district.

Table 6.1: Response rate per district

District	Frequency of responses	% response
Mbale	40	25.0
Manafwa	40	25.0
Sironko	40	25.0
Bududa	40	25.0
Total	160	100.0

A total of eight sub-counties were selected from the districts to enable the study capture various views of people living around Mount Elgon. **Table 6.2** reveals the response rate per sub-county.

Table 6.2: Response rate per sub-county

Sub-county	Frequency of responses	% response
Bufumbo	20	12.5
Bunghoko Mutoto	20	12.5
Bwabwala	20	12.5
Bumbo	20	12.5
Bumayoka	20	12.5
Bubita	20	12.5
Masaba	20	12.5
Masira	20	12.5
Total	160	100.0

6.2.2 Interview respondents

The interviews were conducted among 47 respondents selected from four districts of Bududa (10), Manafwa (12), Mbale (13), and Sironko (12 **(Table 6.3).**

Table 6.3: Representation of interview respondents by districts

District	Frequency	% response
Bududa	10	21.3
Manafwa	12	25.5
Mbale	13	27.7
Sironko	12	25.5
Total	47	100

6.2.3 Level of Education

The results indicate that 3.8% of the respondents were of university level of education, 50.6% were of secondary level of education, 41.9 % were of primary level of education and 3.1% were of non – formal education. **Figure 6.1** portrays the education levels of the respondents.

Figure 6.1 indicates that majority of the respondents (92.5%) had attained some level of formal education up to secondary school level while the minority (6.9 %) were both those who had attained University education (3.8%) and those that had no formal education (3.1%).

6.2.4 Size of land holding

The distribution of land size of the study respondents was summarized in **table 6.4**.

Table 6.4: Size of Land holdings of the respondents

Land holding size	Frequency	Percent	Valid Percent	Cumulative Percent
15 hectares	4	2.5	2.5	2.5
12 hectares	5	3.1	3.1	5.6
9 hectares	1	0.6	0.6	6.2
6 hectares	3	1.9	1.9	8.1
5 hectares	8	5	5	13.1
4 hectares	12	7.5	7.5	20.6
3 hectares	5	3.1	3.1	23.7
2.75 hectares	1	0.6	0.6	24.3
2.5 hectare	1	0.6	0.6	24.9
2 hectare	8	5	5	29.9
1 hectares	3	1.9	1.9	31.8
5.75 acres	1	0.6	0.6	32.4
5 acres	1	0.6	0.6	33.0
4 acres	2	1.3	1.3	34.3
3 acres	4	2.5	2.5	36.8
2.5 acres	4	2.5	2.5	39.3
2 acres	20	12.5	12.5	51.8
1. 5 acres	10	6.3	6.3	58.1
1.2 acres	1	0.6	0.6	58.7
1 acre	34	21.3	21.3	80.0
0.75 acre	3	1.9	1.9	81.9
0.5 acre	25	15.6	15.6	97.5
0.3acre	1	0.6	0.6	98.1
0.25acre	2	1.3	1.3	99.4
Invalid	1	0.6	0.6	100.0
(Total) 342.85 hec)	160	100.0	100.0	

The findings above indicate that the largest size of land held by the questionnaire respondents was 15 hectares owned by only 2.5% of the respondents while the smallest was 0.25 of an acre owned by 1.3 % of the respondents. The rest of the respondents (96.2%) therefore owned land ranging from 15 hectares to 0.25 acres. Majority of these (21.3%) however owned 1 acre. It deserves to be mentioned that all land owners interviewed indicated that their land was fragmented into pieces that were located on different slopes on average with the smallest owner possessing two fragmented pieces of land while the largest owner possessed four pieces of land. Going by **Table 6.4,** the total area of land owned by the 159 respondents who gave valid responses about their land holding size was 342.85 hectares. Consequently the average land holding size of the questionnaire respondents was 2.16 hectares.

6.3 People's perception and attitude towards slope instability risk.

Issues to do with slope instability that were of concern to this study were perceived causes of slope instability, indicators of slope instability, and determinants of the way people react following slope failure.

6.3.1 People's perception of the causes of slope instability in Mount Elgon

Responses on people‘s perception about slope instability in Mount Elgon is depicted in **Table 6.5.**

Table 6.5: People's perception about slope instability risk

Responses	**Frequency**	**% response**
Naturally occurring	112	70.0
Both due to natural and human induced	48	30.0
Human induced	0	0
Total	160	100.0

The findings of the questionnaire survey presented in **table 6.5** indicate that 30% of the respondents perceived slope instability as being both a natural and human induced occurrence. This was on the basis that it is natural conditions and human activities which combine together to render some slopes of Mount

Elgon unstable. On the contrary, 70 % of the respondents perceived slope instability to be solely a natural occurrence on the basis that slope instability in Mount Elgon is influenced by natural circumstances. None of the 160 respondents on whom the questionnaire was administered however perceived slope instability to be solely human induced. Findings on perceived causes of slope instability were summarized in **table 6.6**.

Table 6.6: Perception of the causes of slope instability

Perceived cause of instability	**Frequency of responses**	**% response**	**Cumulative % response**
God ordained accident	30	19	19
Steep slopes & heavy rain	82	51	70
Steep slopes, heavy rain & human activities	48	30	100
Total	160	100	

Table 6.6 shows that 19% of the respondents interpreted slope instability to be a natural occurrence on the basis that it is only God who ordains the occurrence of landslides. 51% viewed it as natural in that it is God who created the steep slopes and the heavy rainfall that trigger slope failure. This group of people was generally of the opinion that it is God alone who determines when and where slope instability occurs. The remaining 30% who interpreted slope instability to be both a natural and human induced occurrence attributed it to steep slopes, heavy and prolonged rainfall, over cultivation and deforestation on steep slopes.

Following such diverging opinions about the causes of slope instability, it was deemed necessary establish the role played by people's previous experiences of landslides in perceiving their causes and results were computed in **Table 6.7.**

Table 6.7: chi-square test for significance of one's previous experience on perception and attitude towards slope instability hazard

Item	**Value**	**Df**	**Asymp. sig. (2-sided)**
Pearson Chi-square	4.669[a]	2	.097
Likelihood Ratio	4.927	2	.085
Linear-by-Linear Association	3.381	1	.066
No. of Valid cases	159		

A 2-tailed chi-square value of 0.097 which is greater than the probability value (p=0.05) is an indication that there is no significant relationship between the perception and attitude of land users whose land has experienced slope instability and those whose land had not experienced slope instability. This relationship is further expressed in **Figure 6.2**.

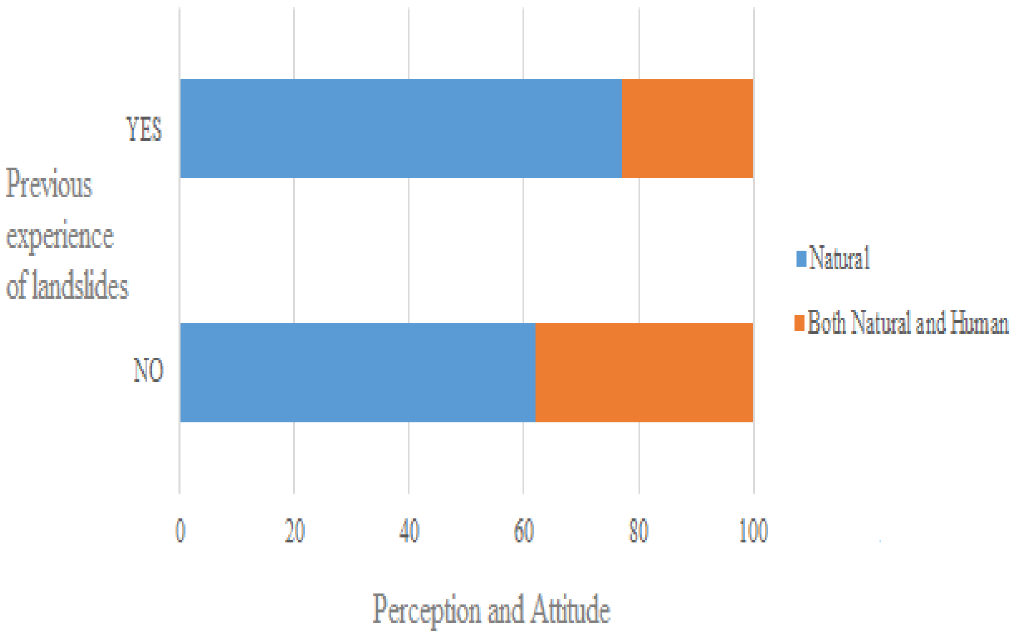

Figure 6.2: Comparison of perception and attitude of land users whose land had experienced slope failure and that of those whose land had not experienced slope failure

Figure 6.2 indicates that 38% of the respondents whose land had never experienced slope failure viewed it as being both a natural and human induced occurrence while 62% viewed it as a natural phenomenon. On the other hand, only 23% of the respondents whose land had ever experienced slope failure viewed it as being both a natural and human induced phenomenon while 77% viewed it as a natural occurrence. It is therefore evident that slope instability in Mount Elgon is strongly perceived as a natural phenomenon both by the people who have previously experienced it and those that have not.

6.3.2 Perceived indicators of slope instability

Findings of the survey indicated that people in Mount Elgon have got different ways of detecting that slope failure is likely to occur on a given slope.

Indicators of eminent dangers of slope failure as expressed by the study respondents are summarized in **Figure 6.3**.

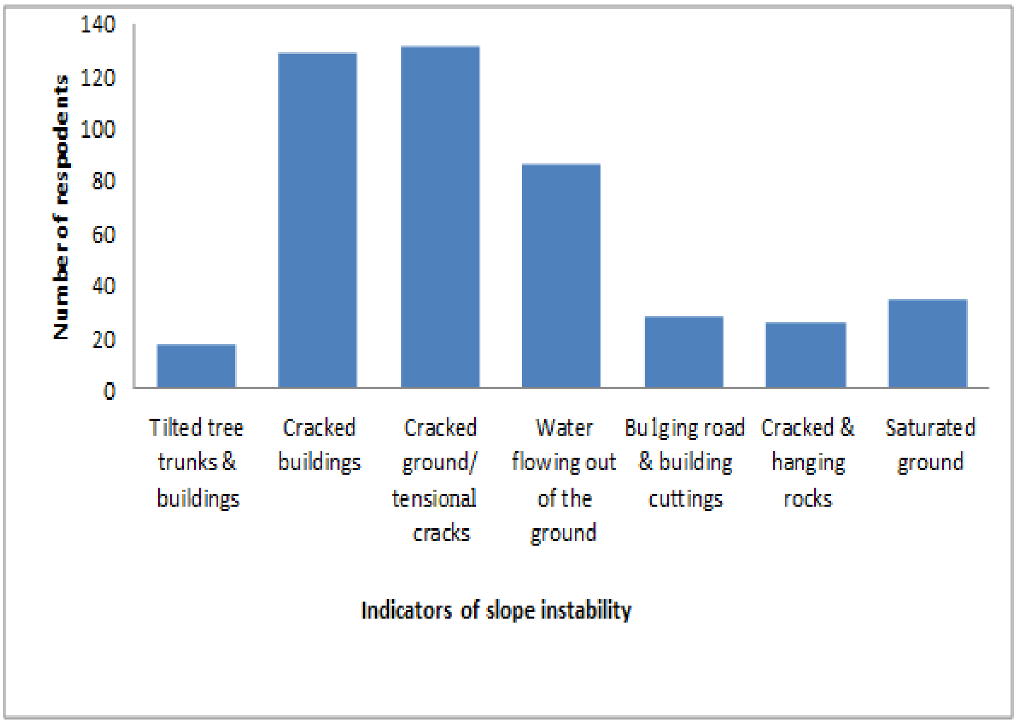

Figure 6.3: Perceived indicators of slope instability in Mount Elgon

As shown in **Figure 6.3**, cracking of the ground or tensional cracks/joints and cracking of buildings were the major indicators of eminent danger of slope failure respectively **(Plates 6.1, 6.2a, 6.2b)**. Other indicators mentioned in their order of ranking were water suddenly flowing out of the ground, saturated ground, bulging road and building cuttings, cracked and dangerously hanging rocks and tilted tree trunks and buildings **(Plates 6.3a, 6.3b, 6.4, 6.5).**

Plate 6.1: Cracked ground associated with tension within regolith on a slope
(Masira-April 2010)

Plate 6.2a: A cracked house veranda

(Kibooko-August2009)

Plate 6.2b: **A cracked house floor Sironko (August 2009)**

Plate 6.3a: **spot where groundwater emerges on to the surface (Maboono-April 2010)**

Plate 6.3b: A hole through which groundwater oozed out to the surface (Bukhalasi 2010)

Plate 6.4: Cracked and dangerously hanging rocks on Zesui ridge that continuously roll down the scarp onto the debris slope (Sironko September 2009)

Plate 6.5: Tilted tree trunks due to large scale creep in Bumbo (Taaso August 2009)

6.3.3 Perceived determinants of the way people react following a landslide

The survey results indicated that people's reaction following a landslide event was determined by a number of factors depicted in **table 6.8**.

Table 6.8: Perceived determinants of the way people react following a landslide

Perceived Determinant of reaction	Number of respondents	% respondents
One's previous experience	115	72
Lack of alternative areas to relocate to	27	17
Comfort got from relief aid	9	5.6
Cultural obligation to stick to ancestral land	9	5.6
Total	160	100

Table 6.8 shows that 72% of the questionnaire respondents indicated that the magnitude of the damage and loss that is experienced during a previous landslide event determines the way people react to the next one. 17% of the respondents are depicted to have indicated that people react the way they do following a landslide because they lack alternative areas to where they could relocate. 5.6% of the remaining respondents attributed the reaction to one's cultural obligation to stick to the ancestral lands while another 5.6% attributed it to the comfort derived from relief aid that the victims got or were promised by government and NGOS.

It was revealed that people usually panic and some of them move away from an area if a devastating landslide was experienced. If on the other hand the landslide experienced was less destructive, people remained and carried on with their normal activities. It was however indicated that people who moved away following a destructive landslide would eventually return and re- occupy their land after some time. Their return period according to the interview responses and focus group discussions differed as illustrated in **Table 6.9**.

Table 6.9: Duration before re-occupying land after a landslide has occurred

Duration before re-occupying land (years)	**Frequency of responses**	**% responses**
0-1	14	30
1-5	21	45
6-10	7	15
Above 10	5	10
Total	47	100

From the results in **Table 6.9**, 30% of the opinion leaders interviewed indicated that land which had experienced slope failure was re-occupied in a period of one year, 45% indicated a period of one to five years, 15% a period of six to ten years and 10%) a period of more than ten years. It is therefore evident that majority (90%) of the people who experienced slope failure re-occupied their land in less than ten years yet this was deemed to be inadequate time for a slope to have regained stability.

Opinion leaders expressed varying opinions when asked whether such a period of less than ten years was enough time for a slope to have regained stability after being affected by a landslide. 80% of the leaders expressed that the period was enough for a slope to have regained stability while 20% expressed that the slope would not have regained stability - **Figure 6.4**.

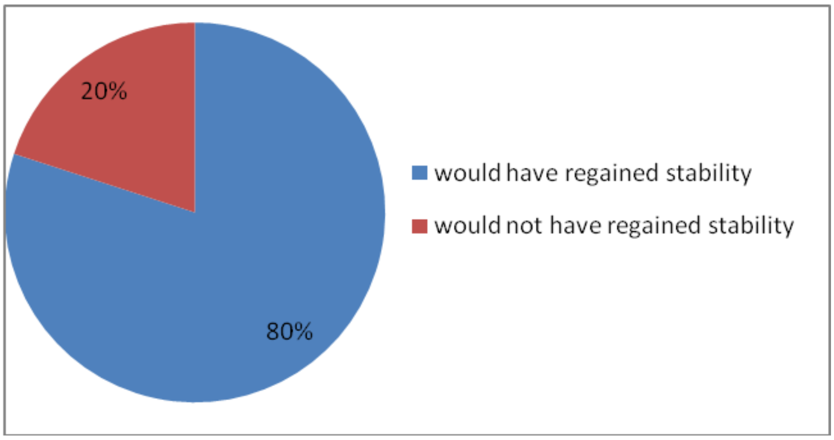

Figure.6.4: Opinion leader's perception of slope stability following land slide occurrence

Residents were of the opinion that at least a period of 10 years would if possible be given a landslide scar to regain relative stability. The opinion leaders interviewed and the various officials who participated in focus group discussions emphasized that it would be better for people to vacate such slopes for good but the problem was that population pressure could not allow that to happen. People therefore only end up temporarily vacating the land to later re-occupy it even in less than a year. The expression of the opinion leaders above fits well with the response of 17% of the questionnaire respondents who indicated that people react the way they do following landslides due to lack of alternative areas where they could relocate.

From the foregoing, the study revealed that perception of slope instability risk in Mount Elgon is governed by a number of filters namely amount of destruction experienced by the victims, lack of alternative areas to relocate to, cultural ties and relief aid that is promised or given to the people affected.

6.3.4 Perception of Strategies that would help reduce elements at Risk

According to the questionnaire survey results, respondents expressed varied opinions concerning what they thought were the strategies that would help reduce loss of lives, displacement of people, destruction and damage of property and infrastructure occupying slopes that were prone to slope failure. The strategies expressed by the respondents are illustrated in **Figure 6.5**.

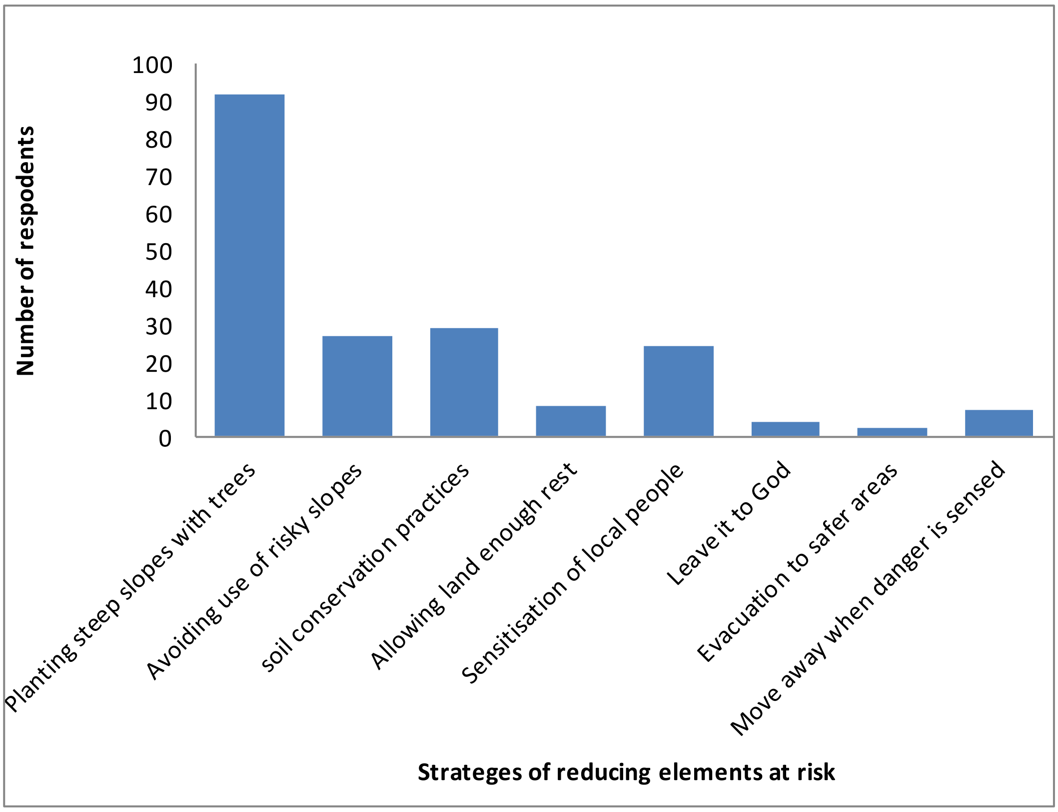

Figure 6.5: Perceived strategies to reduce elements at risk

According to **Figure 6.5,** ninety two (92) out of one hundred and sixty (160) respondents indicated that planting trees on steep slopes would be the most efficient method of reducing elements at risk on slopes prone to slope failure in Mount Elgon. Other strategies indicated and the number of respondents in their support included; avoiding use of risky slopes (27), using soil conservation practices (29), allowing land enough rest (8), sensitization of the local people (24), leave it all to God (4), move away when danger is sensed (7) and evacuation of people to safer areas (2).

Focus group discussions and interviews indicated that the most efficient ways of reducing elements at risk on the slopes prone to slope failure are frequent sensitization of the people on what should be done and what should not be done, relocating people occupying risky slopes to safer areas of the country, and planting trees on steep slopes.

6.4 Mechanism of coping with slope instability incidences in Mount Elgon

Results indicated that people occupying landslide prone slopes of Mount Elgon cope with landslides in varied ways. The mechanisms indicated from those that necessitated vacating ones land or hanging on even when one had been severely affected by a previous landslide. A summary of responses concerning mechanisms of coping with slope instability is depicted in **Table 6.10**.

Table 6.10: Summary of coping mechanisms

S.N	Coping mechanism	Frequency	%	Cumulative %
1.	Vacate the land only for a short while	51	31.9	32.1
2.	Stay and continue with their normal activities	33	20.6	52.9
3.	Either vacate the land only for a while or stay and continue with their normal activities	31	19.4	72.4
4.	Modify on ways land is used	22	13.8	86.2
5.	Totally vacating the land	14	8.8	95.0
6.	All the above	8	4.9	100.0
Sub-total		159	99.4	
Invalid response		1	0.6	
Total		160	100.0	

Table 6.10 shows that minority of the study respondents (8.8%) indicated that people in Mount Elgon cope with slope instability by totally vacating the land, a mechanism that involved relocating to safer areas while the majority (86.2%) indicated mechanisms that involved either remaining on one's land or vacating the area only for a short while. This therefore indicates that most people occupying slope instability prone slopes of Mount Elgon are not willing to relocate to other areas most especially out of Mountain Elgon region. This was depicted by the responses of 32.1% of the respondents who indicated that they would vacate land only for a while, 20.8% who indicated that they would stay and continue with their normal activities, and 13.8% who were in favour of modifying the way land was being used and 5% who indicated all the mentioned mechanisms.

The coping mechanisms above indicated to be taken by the people occupying slope instability risk areas of Mount Elgon are in line with the modes of coping with natural hazards indicated by Morgan and Muthoka- **Figure 6.6.**

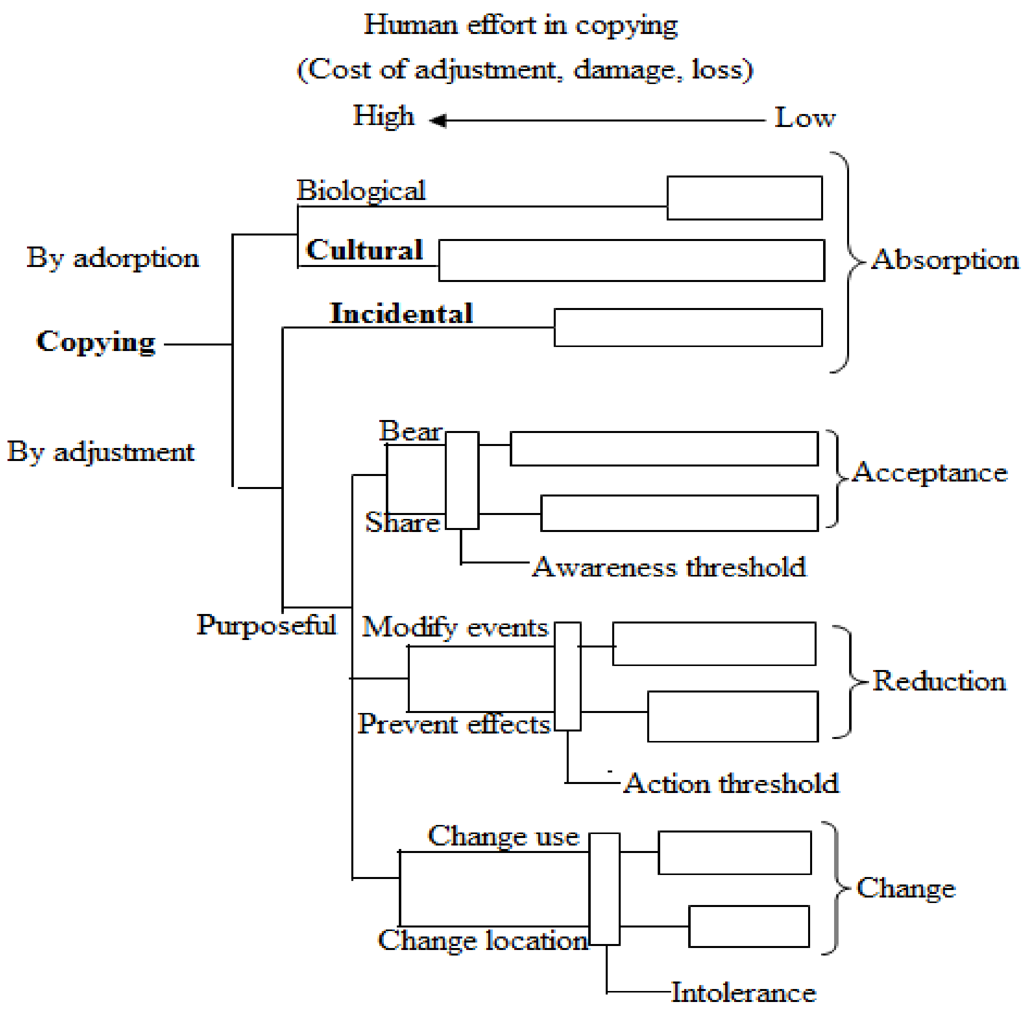

Figure 6.6: Modes of coping with Natural hazards

(Morgan 1982 and Muthoka *et al*; 1998)

The trio argued that by choosing to vacate the land for good, people would have adjusted purposefully through change of location. In the same way, those who choose to vacate the land only for a while would have either purposefully adjusted by accepting to bear and/or share the consequences or they would have adapted by incidental absorption. The other groups of people who choose to stay but modify in the way they use their land would have purposely adjusted by trying to prevent the effects while those that simply stay and continue with their normal activities would have either purposefully adjusted by acceptance or adapted by incidental absorption of whatever consequences.

The willingness of the people to participate in coping strategies is expressed by the given responses towards specific adaptation and adjustment strategies summarized in **Table 6.11**.

Table 6.11: Participation in adaptation and adjustment strategies

Coping mechanism	**Coping mode**	**Frequency of responses**	**%**	**Cumulative %**
Totally vacate	Adjustment	14	8.8	8.8
Vacate for a while	Adjustment & Adaptation	41	25.6	34.6
Stay as usual	Adaptation	82	51.3	86.2
Modify in land use	Adjustment	22	13.8	100
Invalid response		1	0.5	
TOTAL		160	100	

Table 6.11 indicates that adaptation is the most popular mode of coping with slope instability in Mount Elgon whereby the people that have been affected by a landslide stay around and continue with their normal activities. This was represented by 51.6% of the respondents. Adjustment was another mode of coping with slope instability represented by 22.6% of the respondents. This is where people affected by a landslide cope by either vacating the land without ever reoccupying it or staying but modifying the way they are using the land. **Table 6.11** also shows that some people cope by both adjustment and

adaptation if they choose to move away soon after the landslide has occurred to later return to their land after some time. This kind of coping mode was represented by 25.8% of the respondents.

It was established that the people who chose to totally vacate their land felt that they wanted to live in an environment that was safe from landslides hence purposive adjustment through change of location. Such people would be some of those that would have narrowly survived a slope failure incidence in which they lost their entire livelihood. This according to **Table 6.11** was represented by 8.8% of the study responses. Those that vacated only for a while and later returned to their land chose to adjust by accepting to bear or share the consequences of the landslides and this is represented by 25.8% of the responses. Some of these indicated that they eventually got back ready to adopt to the situation on the ground following the landslide occurrence hence incidental absorption of the outcomes of a landslide disaster. The 51.6% respondents who indicated that they chose to stay and continue with their normal activities chose to accept or absorb whatever consequences that was associated with slope instability. This is further reflected in the views of the respondents who equated landslides to any other accidents that happen to people elsewhere. 13.8% of the respondents on the other hand clearly indicated that they coped by staying and carrying out some modifications in the way they used their land. Modification in land use was done so as to reduce or prevent the effects of slope failure hence purposive adjustment as categorized by Morgan (1982) and Muthoka *et a*l;(1998).

Modification in land use though fairly unpopular would yield successful results if undertaken by the majority of the people who opted to stay following a landslide occurrence in an area. It is for this reason that this study attempted to establish the willingness of the people to modify the way they were using their land and the results of the survey are summarized in **Table 6.12**.

Table 6.12: People's willingness to carryout modifications in land use

Responses	**Frequency**	**Percent**	**Cumulative %**
Yes	122	76.3	76.3
No need	34	21.3	97.5
Already done	4	2.5	100.0
Total	160	100.0	

Table 6.12 indicates that 76.3% of the people were willing to carry out modifications in the way they were using their land while only 21.3% were not willing and only 2.5% indicated that there was no need since they had already carried out the necessary modifications. The researcher endeavoured to establish the association that exists between size of land and the ease with which people consider modifying in the way they used their land. The survey therefore engaged in establishing size of land holding for an average person in the area and going by the land holding sizes of the 159 respondents who attended to the questionnaire item, the average land holding size of people in

the area was established to be 2.16 hectares. In a bid to understand the divergence in willingness to modify in land use by the different residents of the area, the study also established the different forms of modification that would be undertaken according to the sizes of land holding that these people own or use and results of the survey are summarized in **Table 6.13.**

Table 6.13: Forms of modifications in Land use and average land holdings

Form of modification	**Frequency of responses**	**% of responses**	**Average land holding (hec)**
Construction on gentle slopes	37	23.1	1
Limit creation of artificial slopes	23	14.4	1.18
Protect artificial slopes	22	13.75	1.21
Avoid cultivating on steep slopes	10	6.25	2.2
Intensive agriculture & agroforestry	68	42.5	0.8

According to **Table 6.13**, the most popular form of modification in land use among the people of Mount Elgon was intensive agriculture and agro-forestry. This was popular among 42.5% of the respondents who were utilizing plots of 0.8 hectares on average. The least popular form of modification in land use was avoiding cultivation on steep slopes. This was popular among 6.25% respondents utilizing larger pieces of land whose average size was 2.2 hectares. This is an indication that people with large pieces of land that can afford to spare some of their land on the steeper slopes for conservation purposes while those with smaller plots would rather carry out a land use modification that entails intensification of use.

In summary, **Table 6.13** depicts that the smaller the size of land, the more willing are the owners to carry out some modification in land use that enables them to make maximum use of their small plots of land. On the contrary, the bigger the size of landholdings the less willing are the owners to carry out modification in land use, after all they can afford to leave some of their land unused if it is not rented out to those with inadequacy. The relationship between willingness of the people to modify land use on landslide prone slopes and the size of land they were utilizing has been depicted on the regression curve – **Figure 6.7**.

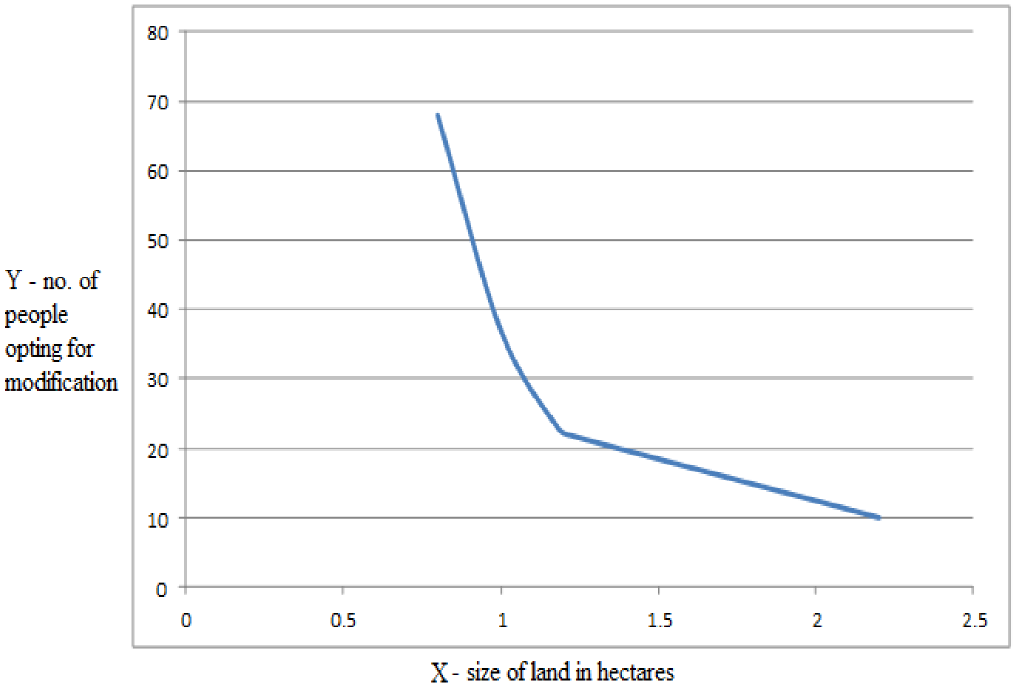

Figure 6.7: Showing the curvilinear relationship between people's willingness to modify in land use and size of land owned

According to **Figure 6.7** the smaller the size of land, the more willing are the people to carry out modifications in land use and the larger the size of land the less willing are the people to modify land use. The regression curve is however a negative one because Y values reduce as X values increase. For purposes of establishing the degree of association existing between the willingness of the people to modify land use and the size of land owned, data in **Table 6.13** was used to compute a Spearman's Rank Correlation Coefficient. The study hypothesis of analysis **(H_0)** postulates that;

> *"The people's willingness to modify in land use on unstable slopes is influenced by the size of land owned".*

The computations of Pearson's moment correlation coefficients between the people's willingness to modify in land use on slopes that are prone to slope instability risk in Mount Elgon and the size land holdings of the people is summarized in **Table 6.14**.

Table 6.14: Computation of Spearman's Correlation

Item		Size of land holding	Do you think it is necessary to carry out some modifications in the way you are using your land?
Size of land holding	Pearson correlation Sig.(2-tailed) N	1.000 159	-0.9^{xx} .005 159
Do you think it is necessary to carry out some modifications in the way you are using your land?	Pearson correlation Sig.(2-tailed) N	-0.9^{xx} .005 159	1.000 160

From the computation above, $R_S = -0.9$

$r^2 = 0.81$

$R_d = 8$

Sig. = 0.005

The results indicate that there is a high degree of inverse correlation between the size of land a person owns and willingness to modify in land use. As stated by Theakstone et al; (1978), since the Spearman Rank Correlation Coefficient has a high negative value ($R_S = -0.9$) with a level of significance of 0.005 which is less than the required 5% (0.05), it is assumed that despite chance elements, the correlation has significance. As shown by the coefficient of determination value, 81% of the variation in willingness to modify in land use is explained by the size of land owned while 19% is explained by other factors such as level of education, steepness of slope and permanency of land use being practiced. This kind of relationship suggests that as size of land increases, willingness to modify in land use reduces. The postulated hypothesis is therefore rejected while upholding the alternative hypothesis **(H_1)** that; “There people’s willingness to modify in land use on unstable is not influenced by the size of land owned.” Therefore, the larger the sizes of land holdings, the less willing the owners are to modify in land use while the reverse is also true.

6.5 People’s perception, attitude and response to evacuation programmes

The people of Mount Elgon were established to have ways in which they interpret programmes that have been put in place to evacuate land slide victims and this has consequently affected the way the victims have responded to such efforts.

6.5.1 People's perception and attitude towards evacuation programmes

Results of the survey indicated that majority of the people (84.5%) in the area have got a negative attitude towards efforts to have people occupying slopes prone to slope instability relocated to safer areas while the minority (15.5%) have a positive attitude. A summary of the results is presented in **Table 6.15**.

Table 6.15: People's perception and attitude towards evacuation programmes

Indicated evacuation response	**Frequency of responses**	**Percent**	**Cumulative %**
Intervention is good so long as it solves problems	24	15.0	15.5
Alternative areas are too far from our ancestral land	13	8.1	23.9
Not used to lowland areas	6	3.8	27.7
Lowland is scarce	19	11.9	40.0
Forest land is free land for peoples well being	4	2.5	42.6
Consensus should be reached over usage of steep slopes	8	5.0	47.7
No external assistance has been given	33	20.6	69.0
Reliance on local authorities	9	5.6	74.8
People find their own solutions	5	3.1	78.0
Authorities should provide relief items instead of evacuation	30	18.8	97.4
Use sensitization workshops instead of evacuation	2	1.3	98.7
It's not good to expect help	2	1.3	100.0
Total	155	96.9	
Missing system	5	3.1	
Total	160	100.0	

Majority of the residents with a negative attitude towards evacuation felt that the alternative areas where government wanted to re-settle the affected people were always lowlands which were more over too far from their ancestral home. These people argued that they have lived on the Mountains all their lives and are therefore not used to such lowlands. To them, however close to the Mountain is lowland, it could never be a suitable substitute for people who have lived on the Mountain all their life time. To them, a more viable alternative would be holding sensitization workshops through which people could be made aware of which slopes should be used and which ones should be avoided. If this cannot be done, they felt they should be given the liberty to find their own way out or even be given forest land at higher elevation which is after all their ancestral land.

The people who were in favour of evacuation programmes were of the opinion that any intervention is good as long as it solved people's problems. These were a minority (15.5%) who viewed evacuation as the only intervention strategy that could help the people who would have been displaced by landslides. This wide variation in the perception and attitude of the people where majority expressed bias towards evacuation called for testing the study hypothesis **(H_0)** which postulates that;

> *"There is no difference between perception and attitude towards evacuation of land by users whose land has experienced slope failure and those who have not."*

The chi - square test for the significance of land users' previous experience and attitude towards evacuation programmes is depicted in **Table 6.16.**

Table 6.16: chi-square test for the significance of one's experience of landslides on their perception and attitude towards evacuation

Item	**Value**	**DF**	**Asymp.sig.(2-sided)**
Pearson Chi- Square	17.781	24	841
Likelihood Ratio	19.785	24	709
Linear-by-Linear Associations	286	1	593
No. of Valid cases	154		

The 2-tailed chi-square value (0.841) in table **6.17** is greater than the probability value (p=0.05), so this means that the postulated hypothesis **(H_o)** is up-held while rejecting the alternative hypothesis **(H_1)** which postulates that; "There is a difference between perception and attitude towards evacuation by users whose land has experienced slope failure and those who have not."

The study therefore suggests that there is no significant difference between perception and attitude of land users whose land has experienced slope failure and those who have not. This implies that even people who have not been affected by landslides hold a negative attitude towards evacuation like those that have been affected. Equally true is also the fact that among the people with a positive attitude towards evacuation were those that had not experienced landslides before.

6.5.2 People's response towards evacuation programmes

Results indicate that majority of the study respondents (76.9%) were against government initiative to relocate people who were affected by landslides to safer areas away from Mount Elgon. These were instead in favour of efforts to sustain the people where they were while a few of them (23.1%) were in favour of the evacuation programmes. A summary of the results is presented in **Table 6.17**.

Table 6.17: People's response towards evacuation programmes

Item	**Frequency of responses**	**%**	**Cumulative %**
Relocating is like being robed	34	21.3	21.8
Cannot just vacate ones land	18	11.3	33.3
Resettlement areas are far away	11	6.9	40.4
Promised relief was never given	24	15.0	55.8
Willing to follow government advice	36	22.5	78.8
Sustain people with relief aid	9	5.6	84.6
People devised their means of survival	14	8.8	93.6
Reliance on local assistance	10	6.3	100.0
Total	156	97.5	
Missing system	4	2.5	
Total	160	100.0	

According to **table 6.17** majority of the respondents who were not in favour of evacuation that is 21.3%, equated relocating to being robbed of one's inheritance, 11.5% indicated that people cannot just vacate their inheritance for some unknown place, 15.4% felt that relocating people may end up like relief which has often turned out to be empty promises, 9% believe that the people can find their way out as usual, 7.1% felt that resettlement areas were very far, 6.4% felt local government is more reliable, while 5.8% are in favour of being sustained where they were rather than asking them to relocate.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter presents a summary of the major findings established by the study on assessment of the effects of geomorphic process and land use activities on slope instability in Mount Elgon in Eastern Uganda. The findings are summarized according to the objectives that guided the study. The chapter also makes conclusive remarks concerning the overall achievements of conducting this study in view of the overriding purpose. It highlights the significance of the study in terms of providing a way forward to the problem of slope instability in Mount Elgon region. Finally policy implications and recommendations that should be undertaken to address the problem of slope instability in Mount Elgon are presented. The suggested approaches include both actions and viable research gaps that still need to be filled in order to lessen the magnitude of problem even in other vulnerable areas of the world.

7.2 Summary of major findings

The problem of slope instability and its associated forms of slope failure were established to be an old time occurrence in Mount Elgon which has only intensified with increased population. Slope instability was for instance documented to have occurred in Bududa as far back as 1818 yet the same area has actually been established by this study to be the most susceptible district.

According to perception of the respondents and the researcher’s own inferences, slope instability in Mount Elgon is both a natural and human induced phenomenon**.** The common forms of slope failure experienced in the area were established to be both in the form of deep seated rotational slides and shallow translational slides. The landslide scars mapped in the area were evidence that falls, slides and flows encompassing different kinds of materials have been experienced in the area. Earth slides and debris slides were the forms of slope instability established to have been experienced in all the districts of the Mountain studied. Earth slumps were exclusively established to have occurred in Bududa district because of the nature of the deep regolith contained on the slopes.

Weathering was established to be the major geomorphic process that directly and indirectly influences slope instability on some slopes of Mount Elgon. The direct influence of weathering is experienced through physical disintegration of rocks forming the scarp faces and other exposed rock outcrops. This has resulted into falls commonly experienced on ridge faces such as Nkokonjeru in Mbale, Namisindwa in Manafwa and Gabugoto and Zesui in Sironko. It was established that such falls were experienced both during the rainy and the dry seasons though they were found to be more rampant and fatal during the rainy season. This was an indicator that water triggers falls during the rainy season while weathering causes falls by gradually breaking down rocks whose shear strength reduces as compared to that of once intact rock. During the dry season weathering acts as a trigger while slope steepness is the major cause.

Weathering on the other hand indirectly causes slope instability through chemical decomposition of the saprolite that is either deposited by other geomorphic processes or remained in situ. This has resulted into formation of a deep soil layer covering the concave slope segments which were established to be the common spots favourable to slope failure in the form of the very common deep seated rotational landslides.

Cultivation and man’s engineering works associated with housing and road construction were the most striking land use activities that influenced slope instability in Mount Elgon. Construction mainly on slopes inclined at 30^0 and above was noted to undermine slopes by undercutting a slope at 90^0 consequently triggering slope failures. Cultivation was noted to be a cause of slope failure mostly through stripping the land off its natural protective vegetation cover thereby exposing it to erosion and landslides.

The questionnaire survey findings revealed that people in Mount Elgon whether those that have experienced slope instability or those that have not are aware that they are occupying a slope instability risk zone that is naturally unstable according to 70% of the respondents and both naturally and human induced according to 30% of the remaining respondents. Despite such awareness, these people insisted on remaining on the slopes however dangerous they may be. These people revealed that they have learnt to ignore landslides despite their occurrence. They believed that landslides have been occurring and will continue to occur as long as the mountain exists. Besides, they have learnt to regard landslides as mere accidents like any others such as motor vehicle ones that can occur elsewhere and either kill, inflict injury on people involved or do not. Most of these people also believe that once a landslide occurs in an area, it cannot occur again in one’s life time even though amidst them are some elders and survivors who indicated that they had survived landslides more than once. Such a perception is thus deemed to be dangerous though it somehow enables the people to carry on with their normal life.

7.3 Conclusion

In conclusion it is important to note that natural conditions of extremely fast geomorphic processes coupled with high rainfall events make mountainous areas such as Mount Elgon an area which is extremely prone to slope instability. Land use activities however indeed also trigger or cause slope instability in some cases but it must be noted that natural prerequisites for slope failure incidences are ample and are of over ruling importance. Land use activities in the area therefore combine with the natural attributes of highly inclined slopes, high rainfall and extreme geomorphic activities to undermine the stability of some slopes that would have been otherwise stable.

It is hoped that the results of slope instability hazard and risk mapping provided by this study will serve as an important data base for Environmental

Impact Assessment to guide policy makers regarding the slopes that should be avoided or used with precaution.

7.4 Recommendations

The findings of the study form a basis upon which to draw recommendations for interventions that are geared towards reducing human induced incidences of slope failure and associated risks in Mount Elgon and other highland areas. Some of the recommended strategies have been employed elsewhere in the world and have indeed proved successful in addressing the problem.

7.4.1 Short term strategies

Most urgently, government should put in place some early warning systems that can guide people to know where and when to avoid danger. This can be done following an evaluation of slope failure hazard potentials of different slopes conducted by government specialists such as engineering geologists, geo-technicians, or civil engineers. The evaluation would help identify areas with visible indicators of eminent danger of slope failure. The immediate response should be evacuation of slopes indicated to be unsafe by these specialists so as to avoid tragic fatalities.

Areas with deep cuts into the slopes following man’s engineering activities should be stabilized by the people using them. This will in addition to reducing costs of maintenance of infrastructure reduce slope failure risks associated with land use activities. Stabilization measures to use could be covering cut faces with vegetation or concrete, directing water way from the landslide or draining it away.

Since the problem of slope instability in Mount Elgon has been accelerated by land use activities aggravated by population pressure on land, people should be sensitized on the need to control population growth and the ways of controlling it. Local governments can achieve this by providing cheaper antenatal services at their health centres at every sub county where husbands would be encouraged to escort their pregnant wives. It is on such occasions that couples would be talked to about advantages of raising small families and where necessary the need to apply family planning methods. In line with this early marriages and polygamy should be discouraged in a bid to reduce the rate of population growth and the resultant pressure imparted on slopes. Programmes targeting education of the youth so that they can get occupied in schools and also in future get alternative jobs rather than relying on livelihood from land can also be helpful in reducing population growth and improving people’s standards of living.

Local government should design and sensitize people on appropriate land use strategies that mitigate slope instability catastrophes associated with some land use activities. Terracing should for instance be emphasized because it helps reduce slope angle yet it has not been popularly used by farmers in Mount Elgon mostly because it has been perceived to be costly in terms of having to sacrifice part of the land. Furthermore local government should intervene to reduce landslide effects through development and enforcement of by-laws on management of slopes prone to failure. Such by-laws could prohibit people from using slopes beyond steepness and elevation that are proved sensitive to failure in different localities depending on soil and hydrological characteristics. People should for instance be prohibited from utilizing slopes above 2500 metres above sea level so that forest can be allowed to regenerate while those cultivating at altitude above 1500 metres above sea level must practice intensive farming involving sound soil conservation techniques. Still in line with this, Government should put in place by-laws prohibiting people from clearing the forest whether natural or planted woodlots.

To reduce on the incidences and the effects of slope failure on people and structures, total avoidance of slopes that have been repeatedly affected by landslides should be emphasized. Land use on such slopes can be restricted or totally prohibited and slopes planted with trees only.

To reduce on elements at risk, people should be educated to avoid settling in areas of high risks such as those close to lineaments that are associated with rock fall, concave slopes that are water logged and areas where landslides have ever occurred.

7.4.2 Long term strategies

In line with this, intensive agro forestry should be promoted on the slopes prone to slope failure. This should involve growing of economical trees such as fruit trees because other than providing fruits for home consumption and some for sale, they would help to provide a more permanent cover than the other trees that are often logged because of their multiple uses. Deep rooted trees such as Cordia Africana locally known as “Kamukikhili” in the area should also be emphasized.

Another land use strategy that needs to be promoted is agricultural intensification as an adjustment to slope instability. This practice would help farmers reap enough produce on their smaller pieces of land that would be intensively utilized with application of manure and fertilizers rather than having to cultivate extensively yet reaping little. Agricultural intensification is a kind of practice that is environmentally friendly and suited to such Mountain slopes confronted with slope failure risks.

Government can help to improve on people’s standards of living by helping them to form self-help projects that can help them rely less on cultivating the sensitive slopes. Alternative means of livelihood that are not focused on land can be introduced and people encouraged to join for instance cultural dance groups that would engage the youth and promote tourism for communities neighbouring Mt. Elgon forest National Park.

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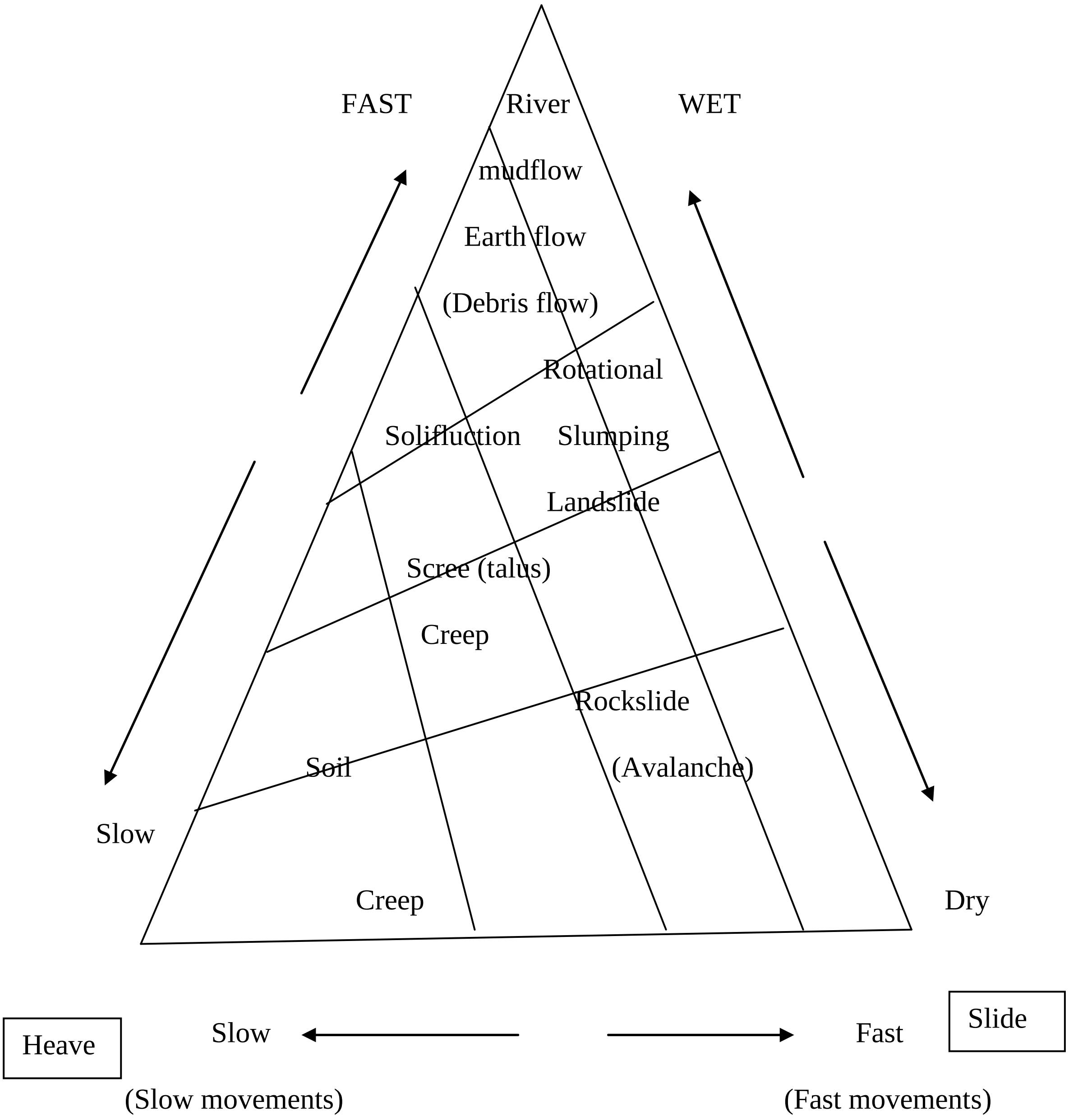
APPENDICES

Appendix 1.1: Classification of Mass Movement Processes



Source: Waugh (2002)

Appendix 3.1: Questionnaire to Selected Land Users Utilizing Slopes that are Prone to Slope Instability in Mount Elgon

Dear Sir/Madam,

I am undertaking a research on effects of geomorphic processes and land use activities on slope instability in Mount Elgon. To accomplish this task, I do hereby seek your assistance by answering the questions that follow below. All information will be treated with maximum confidentiality and will only be used to devise measures to address the problem of slope instability faced by people living in mountainous areas. Your cooperation is highly appreciated.

Section A: Background Information

1. Name of district: ………………………………………………………………
2. Name of Sub county ……………………………………………………………..
3. Name of Parish ……………………………………………
4. Name of Village ……………………………………………

Section B: Personal Information

5. Level of Education…………………………………….
6. Size of land holding ………………………..
7. Slope position of land holding (tick the appropriate).

(a) Upper slope ☐

(b) Middle slope ☐

(c) Lower slope ☐

8. Land use activity/activities practiced by the land user (tick the appropriate).

(a) Crop growing ☐

(b) Animal rearing ☐

(c) Settlement ☐

(d) Quarrying ☐

(e) Forestry ☐

(f) Transport and communication ☐

(g) Others (specify) …………………………………………………………...

………………………………………………………………..

9. Has your land ever experienced slope failure?

(a) Yes ☐ (b) No ☐ (c) Not aware ☐

10. If yes under what land use activity/activities was your land when slope failure occurred?

…………………………………………………………………………………..

………………………………………………………………………………….

11. Do you think it is necessary to carry out some modifications or adjustments in the way you are using your land?

(a) Yes ☐ (b) No need ☐ (c) Already done ☐

12. In case you do, indicate the form/forms of modification or adjustment in land use that you would be willing to undertake.

(a) Restricting construction practices to gentle slopes ☐

(b) Limit creation of artificial slopes ☐

(c) Protect artificial slopes whenever they are created ☐

(d) Others (specify)…………………………………………………………………

Section C: Perception and awareness of slope instability risk

13. Are you aware of slope instability risks on the land that you are utilizing?

(a) Yes ☐ (b) Somehow ☐ (c) No ☐

14. In case you are aware, indicate the way or ways in which you sense that there is such slope instability risk.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

15. In your opinion, is slope instability a natural occurrence or a man-made phenomenon?

….. …………………………………………………………………………...

16. Give reasons why you say it is a natural occurrence.

…………………………………..…………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

17. Give reasons why you say it's a man-made phenomenon…………………

………………………………………………………………………………….

…………………………………………………………………………………..

…………………………………………………………………………………

………………………………………………………………………………

18. Are you taking any precautions to safeguard your land against slope failure?

(a) Yes ☐ (c) No need ☐

(b) Not aware of the need ☐

19. Explain what you do in order to safeguard your land from collapsing down slope.

…………………………………………………………………………….

……………………………………………………………………………

……………………………………………………………………………

20. How often have slopes you are utilizing been involved in slope failure incidences?

……………………………………………………………………………….

………………………………………………………………………………

21. How do people react after slope failure has occurred?

(a) Vacate the land for good ☐

(b) Vacate the land only for a while ☐

(c) Stay and continue with their normal activities ☐

(d) Modify on ways land is used ☐

(e) Others (specify) ………………………………………………………

22. In your opinion, what is the most effective response following slope failure occurrence?

....

………………………………………………………………………………

……………………………………………………………………………….

23. In your opinion, what determines the way people react following a landslide?

………………………………………………………………………………

………………………………………………………………………………

24. In your opinion, what do you think needs to be done in order to reduce elements at risk?

………………………………………………………………………………

………………………………………………………………………………

25. What has been the reaction of the Ministry of disaster preparedness following Slope failure incidences in this area?

………………………………………………………………………………

………………………………………………………………………………

26. What has been the reaction of National Environmental Management Authority (NEMA) following slope failure incidences experienced in this area?

………………………………………………………………………………

………………………………………………………………………………

27. What has been the reaction of the local community towards intervention Measures devised by the Ministry of Disaster preparedness and NEMA following slope failure?

28. What is your opinion about the intervention measures devised by the Ministry of Disaster Preparedness and NEMA to help people cope with slope failure?

29. What has been the reaction of Non-Governmental Organisations (NGO's) Following slope failure incidences in this area?

…………………………………………………………………………………

…………………………………………………………………………………

30. What role have the local authorities played following slope instability in the area?

…………………………………………………………………………………

…………………………………………………………………………………

Thank you very much

Appendix 3.2: An Interview Schedule on the Study of Effects of Geomorphic Processes and Land Use Activities on Slope Instability in Mount Elgon

District of residence …………………………………………………..

Sub county of residence …………………………………………….

Parish of residence ……………………………………………………

Village of residence …………………………………………………..

In your opinion are landslides experienced in this area a natural occurrence or a human created phenomenon? Elaborate on your opinion.

Are landslides in this area a recent or an old time event?

How far back can you date them?

Are there any indicators that people can be able to use to tell that slope instability is likely to occur on a given slope? Elaborate.

How long does it roughly take for a landslide to re - occur in this area?

How do people utilizing landslide prone slopes react following landslide occurrence?

What intervention strategies have been devised to enable people cope with slope instability incidences?

What has been the reaction of the people towards the intervention strategies devised to enable the people to cope with slope instability?

Give suggestions of what you think would be successful coping strategies following slope failure in this area.

Comment on the future of landslide occurrence in this area.

Thank you very much.

Appendix 3.3: Proforma Checklist for Slope Instability Hazard Assessment in Mount Elgon region -Eastern Uganda

Parish…………………………………………………………………………….

Village…………………………………………………………………………

1. Observe and document evidences of dominant geomorphic processes over the slope profile

Above the landslide scar area…………………………………………………

Below the landslide scar area…………………………………………………

Around the landslide scar area……………………………………………..........

2. Observe and document land use practices carried out along the slope profile

Above the landslide scar area…………………………………………………

Below the landslide scar area…………………………………………………

Around the landslide scar area………………………………………………..

3. Map and record existing landslides i.e.

GPS coordinate of landslide scar……………………………………………..

Category of land slide depending on;

Depth of landslide scar………………………………………………………….

Length of landslide scar…………………………………………………………

Area of landslide scar…………………………………………………………...

4. Slope form i.e. concavity, convexity, or rectilinear

Above the landslide scar…………………………………………………………

Below the landslide scar…………………………………………………………

Around the landslide scar………………………………………………………

5. Steepness of slope

Above the landslide scar……………………………………………………………

Below the landslide scar……………………………………………………………

Around the landslide scar……………………………………….. ………………

Probable slope steepness prior to the landslide…………………………………

Soil depth close to the scar…………………………………………………………

6. Observe and record hill slope parameters that determine whether or not failure is likely to occur i.e.

Signs of large scale creep…………………………………………………………..

The opening of joints or tensional cracks………………………………………

Frontal or toe bulges. ………………………………………………………………

Remnant head scarps……………………………………………………………

Titled or disturbed structures. …………………………………………………

A history of instability……………………………………………………………..

7. Observe and record amount of loss or damage likely to be experienced in case a landslide occurs

Number of people residing along the slope ………………………………….....

Number of buildings found along the slope ……………………………………

Number of roads and footpaths existing on the slope…………………………

Number of homesteads existing in the area……………………………………

Number of schools situated on the slope………………………………………

Number of health facilities located on the slope………………………………

8. Inquire and record amount of loss or damage experienced when a land slide occurred on the slope:-

Year of landslide occurrence……………………………………………………….

Number of people residing in the area at the time of the landslide……………

Number of people displaced/lost…………………………………………………….

Number of buildings damaged/destroyed……………………………………..

Number of domestic animals lost……………………………………………………

Number of roads or foot paths rendered impassable……………………………

Number of homesteads damaged/destroyed……………………………………

Number of schools damaged/destroyed…………………………………………

Number of churches damaged/ destroyed………………………………………

Number of bridges damaged /destroyed…………………………………………

Health facilities damaged/ lost………………………………………………………

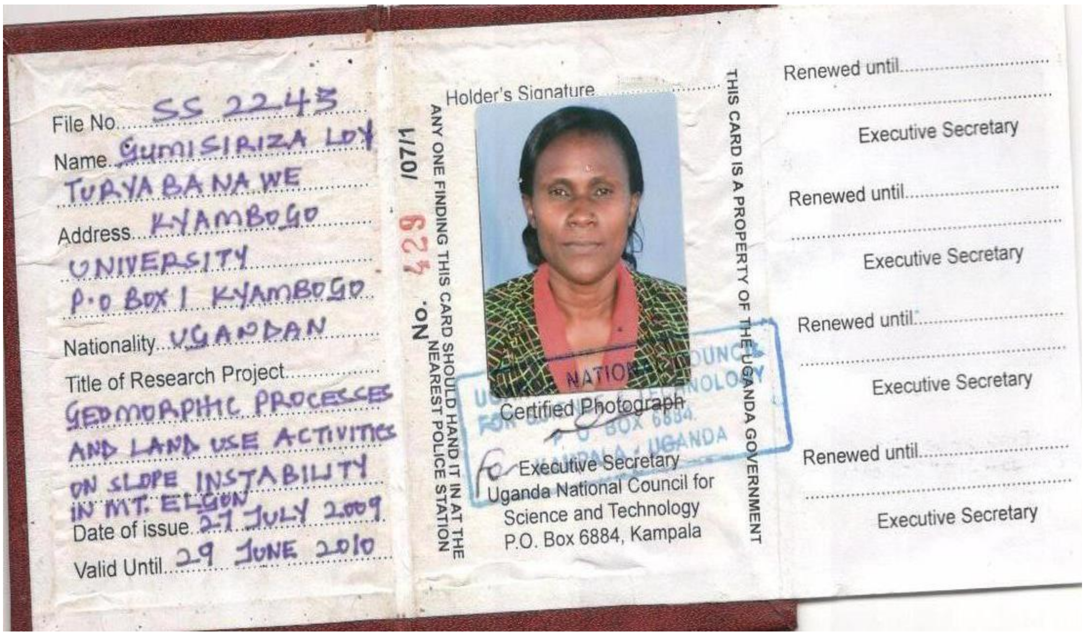
END

Appendix 3.4: Slope profiling procedures

A fifty centimetres deep soil profile pit in Moni, Mbale District

A ninety centimetres deep soil profile pit in Maduwa, Sironko District

Appendix 3.5: Research clearance Permit



File No. SS 2243

Name. GUMISIRIZA LOY TURYABANAWE

Address. KYAMBOGO UNIVERSITY P.O BOX 1 KYAMBOGO

Nationality. UGANDAN

Title of Research Project. GEOMORPHIC PROCESSES AND LAND USE ACTIVITIES ON SLOPE INSTABILITY IN MT. ELGON

Date of issue. 27 JULY 2009

Valid Until. 29 JUNE 2010

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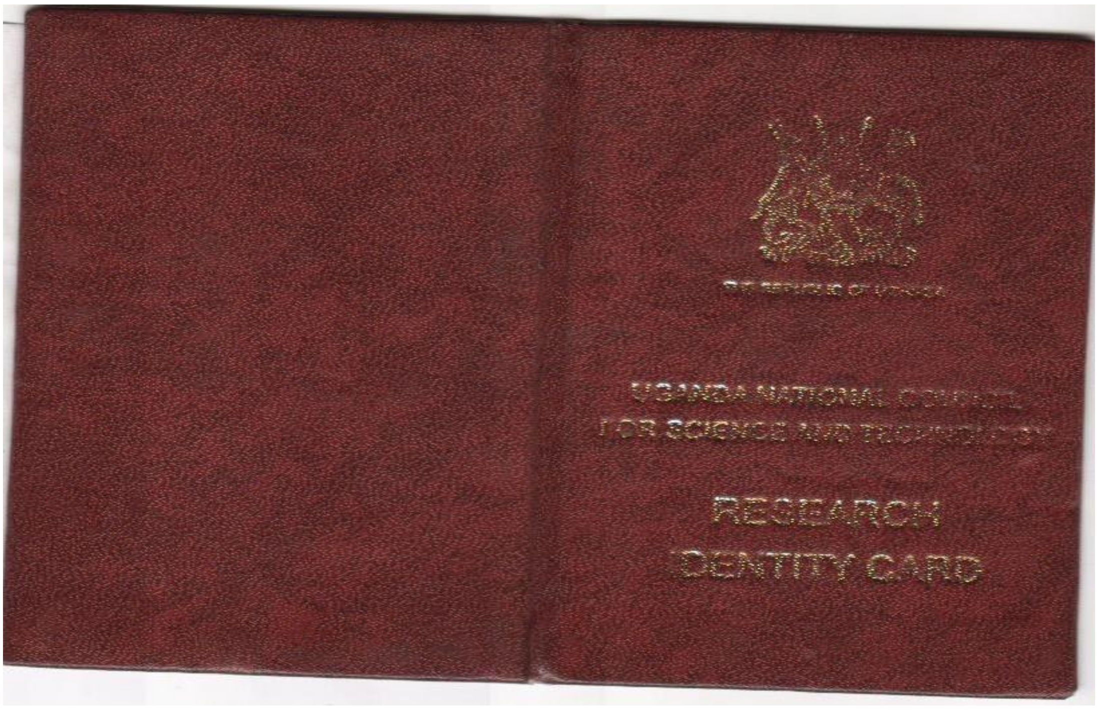

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Appendix 4.1: Exploratory Slope Instability Inventory Sheet

Name	GPS Coordinates	Altitude m.a.s.l	Slope angle (degrees)	Scar Depth (metres)	Soil depth (metres)	Land use activity	Form of Instability
Namesti	N01^{0}01'49.5" E034^{0}25'19.5"	1818	20	63	2.35	Road excavation Settlement Cultivation	Earth slump
Mwerwerwe	N01^{0}01'28.4" E034^{o}25'00.1"	1828	32	8	1.5	Cultivation	Earth slump
Basubizi	N01^{o}01'15.2" E034^{o}25'07.2"	1847	28	3	1	Cultivation	Earth slump
Timbwa	N01^{o}00'47.1" E034^{o}25'230"	1724	39	3	1.2	Cultivation	Earth slump
Lwanda	N01^{o}00'44.4" E034^{o}24'41.6"	1689	37	3	1.4	Cultivation Settlement	Earth slump
Bunatiba	N01^{o}00'08.5" E034^{o}22'539"	1379	27	0.2	0.7	Road excavation	Earth fall
Buwali	N01^{o}00'58.5" E034^{o}23'29.8"	1485	35	10	1.9	Cultivation Settlement	Earth slump
Nangoba| Mukyoma	N01^{o}01'42.9" E034^{o}23'46.5"	1522	36	10	1.2	Cultivation	Earth slide
Maboono Upper	N01^{o}02'22.2" E034^{o}23'49.4"	1780	40	10	3	Cultivation	Earth slump
Mabono Middle	N01^{o}02'22.0" E034^{o}23'57.6"	1733	35	12	2.5	Cultivation	Earth slump
Maboono Lower	N01^{o}02'21.6" E034^{o}24'03.6"	1726	34	14	2.8	Cultivation Settlement	Earth slump
Musole	N00^{o}57'28.7" E034^{o}22'15.0"	1749	30	6	1	Cultivation Settlement	Earth slide
Bunambale	N00^{o}57'36.1" E034^{o}22'16.2"	1729	34	6	1.1	Road excavation	Earth slide
Baaya Lower	N00^{o}57'28.8" E034^{o}22'11.0"	1713	35	6.5	1	Cultivation	Earth slide
Baaya Upper	N00^{o}57'27.4" E034o22'14.0"	1755	30	5	1.5	Cultivation Settlement	Earth slide
Nangabo	N00^{o}55'28.2" E034^{o}22'14.0"	1813	27	5	1.9	Cultivation	Debris slide
Nanseke	N00^{o}55'24.3" E034^{o}22'54.4"	1799	20	5	2	Cultivation	Debris slide
Taaso Lower	N00^{o}52'58.6" E034^{o}26'19.8"	1908	23	4	1	Cultivation	Debris slide
Taaso Upper	N00^{o}52'02.3" E034^{o}26'21.2"	1914	40	5	1.5	Cultivation Settlement	Debris slide
Kigangali	N00^{o}53'22.2" E034^{o}26'02.4"	1940	36	1.5	3	Cultivation	Earth slide
Bukhokho	N00^{o}52'52.6" E034^{o}25'05.9"	1834	31	4	1	Cultivation	Earth slide
Bumadanda	N01^{o}04'15.5" E034^{o}16'26.4"	1618	15	4	1.5	Cultivation Settlement	Earth slide
Jewa	N01^{o}05'40.3" E034^{o}15'40.4"	1457	9	2.7	0.6	Cultivation	Earth slide

Bumboi	N01o03'35.0" E034^{o}13'53.3"	1499	30	3	1	Road excavation	Debris slide
Moni	N01^{o}03'02.1" E034^{o}13'40.1"	1515	40	0.5	0.5	Cultivation Settlement	Rock falls
Bukwapa	N00^{o}55'08.3" E034^{o}22'43.5"	1925	23	30cm wide	0.9	Cultivation	Tension crack
Buwandiambi	N00^{o}53'4.4" E034^{o}21'46.6"	1551	22	2.5	0.4	Cultivation	Pot hole
Buwandiambi	N00^{o}53'4.9" E034^{o}21'46.7"	1564	12	2.8	0.7	Cultivation	Sunken spot
Lusalanje	N01^{o}08'21.5" E034^{o}24'14.7"	2123	25	4	0.98	Cultivation Building excavation	Earth slide
Busalabi	N01^{o}08'16.4" E034^{o}24'13.4"	2118	25	7	1.3	Cultivation	Earth slide
Namagoye	N01^{o}08'13.8" E034o21'12.1"	2114	37	1.7	0.5	Cultivation	Earth slide
Nakiwole	N01^{o}07'54.0" E034^{o}23'37.1"	2012	40	2	0.4	Cultivation	Earth flow
Kikobero	N01^{o}07'41.6" E034^{o}23'19.9"	1992	32	1.6	0.5	Cultivation Building construction	Earth flow
Bukinyale| Gibisi	N01^{o}07'44.2" E034^{o}23'20.4"	2016	30	3	0.5	Cultivation	Earth flow
Maduwa Lower	N01^{o}16'41.4" E034^{o}33'46.9"	2520	38	2	0.5	Cultivation	Debris flow
Maduwa Upper	N01o16'42.4" E034^{o}23'50.4"	5229	31	1.5	0.3	Road excavation	Debris flow
Nalufutu	N01^{o}17'34.0" E034^{o}22'36.1"	1675	24	5	1.2	Road excavation	Debris slide

Source: Field work 2009-2010

Appendix 4.2: Slope Instability Incidences on Cultivated Slopes of varying Slope Steepness and Soil Depth

Scar Name	District	Slope angle (degrees)	Steepness category	Soil depth (metres)	Soil depth class	Form of instability
Mwerwerwe	Bududa	32	Very steep	1.5	K_0	Earth slump
Basubizi	Bududa	28	Steep	1	K_0	Earth slump
Timbwa	Bududa	39	Very steep	1.2	K_0	Earth slump
Mukyoma	Bududa	36	Very steep	1.2	K_0	Earth slide
Maboono 1	Bududa	40	Very steep	3	K_0	Earth slump
Maboono 2	Bududa	35	Very steep	2.5	K_0	Earth slump
Baaya lower	Manafwa	35	Very steep	1	K_0	Earth slide
Nangoba	Manafwa	27	Steep	1.9	K_0	Debris slide
Nansenke	Manafwa	20	Steep	2	K_0	Debris slide
Taaso lower	Manafwa	23	Steep	1	K_0	Debris slide
Kigangali	Manafwa	36	Very steep	3	K_0	Earth slide
Bukhokho	Manafwa	31	Very steep	1	K_0	Earth slide
Jewa	Mbale	9	Moderate	0.6	K_1	Earth slide
Busalabi	Sironko	25	Steep	0.98	K_1	Earth flow
Namagoye	Sironko	25	Steep	1.3	K_0	Earth flow
Nakiwole	Sironko	40	Very steep	0.4	K_2	Earth flow
Bukinyale	Sironko	30	Steep	0.5	K_2	Earth flow
Maduwa lower	Sironko	38	Very steep	0.5	K_2	Earth flow

Source: Field work 2009-2010

Appendix 5.1: Slope Stability Analysis for Slope Instability Risk Mapping

Name	GPS Coordinates	Altitude m.a.s.l	Slope angle (^{0})	Regolith Depth (metres)	Plan Form	Year of Occurrence	Risk Category
Namesti	N01°01'49.5" E034°25'19.5"	1818	32	20	Concavity	1932, 1997 2010	Very active
Mwerwerwe	N01°01'28.4" E034°25'00.1"	1828	32	8	Concavity	2002, 2007 2010	Active
Basubizi	N01°01'15.2" E034°25'07.2"	1847	28	15	Concavity	1997	Intermediate
Timbwa	N01°00'47.1" E034°25'230"	1724	39	18	Concavity	2010	Active
Rwanda	N01°00'44.4" E034°24'41.6"	1689	37	22	Concavity	1997	Intermediate
Bunatiba	N01°00'08.5" E034°22'539"	1379	27	6	Concavity	1997	Intermediate
Buwali	N01°00'58.5" E034°23'29.8"	1485	35	10	Concavity	1997	Intermediate
Nangoba/ Mukyoma	N01°01'42.9" E034°23'46.5"	1522	36	13	Concavity	1997, 2007 & 2010	Active
Maboono Upper	N01°02'22.2" E034°23'49.4"	1780	40	20	Concavity	1997 & 2010	Active
Maboono Middle	N01°02'22.0" E034°23'57.6"	1733	35	23	Concavity	2010	Active
Maboono Lower	N01°02'21.6" E034°24'03.6"	1726	34	25	Concavity	2010	Active
Musole	N00°57'28.7" E034°22'15.0"	1749	30	12	Concavity	2002	Intermediate
Bunambale	N00°57'36.1" E034°22'16.2"	1729	34	11	Concavity	1997, 2005 & 2010	Active
Baaya Lower	N00°57'28.8" E034°22'11.0"	1713	35	10	Concavity	2010	Active
Baaya Upper	N00°57'27.4" E034o22'14.0"	1755	30	5	Concavity	1991 & 2010	Active
Nangabo	N00°55'28.2" E034°22'14.0"	1813	27	5	Concavity	2000, 2002 & 2003	Intermediate
Nanseke	N00°55'24.3" E034°22'54.4"	1799	20	8	Concavity	2002	Intermediate
Taaso	N00°52'58.6" E034°26'19.8"	1908	23	4	Concavity	1999	Intermediate
Taaso	N00°52'02.3" E034°26'21.2"	1914	40	5	Concavity	2003	Intermediate
Kigangali	N00°53'22.2" E034°26'02.4"	1940	36	8	Concavity	2006	Intermediate
Bukhokho	N00°52'52.6" E034°25'05.9"	1834	31	6	Concavity	2008	Active
Bumadanda	N01°04'15.5" E034°16'26.4"	1618	15	7.5	Concavity	1997 & 2007	Active
Jewa	N01°05'40.3" E034°15'40.4"	1457	9	13	Concavity	1997, 2008 & 2010	Active
Bumboi	N01°03'35.0" E034°13'53.3"	1499	30	6	Concavity	2008	Active
Moni	N01°03'02.1" E034°13'40.01"	1515	40	3	Concavity	2007	Active

Name	GPS Coordinates	Altitude m.a.s.l	Slope angle (^{0})	Regolith Depth (metres)	Plan Form	Year of Occurrence	Risk Category
Bukwapa Crack	N00°55'08.3" E034°22'43.5"	1925	23	30cm	Concavity	2009	Active
Buwandiambi Pot hole	N00°53'4.4" E034°21'46.6"	1551	22	2.5	Concavity	2009	Active
Buwandiambi Sunken Spot.	N00°53'4.9" E034°21'46.7"	1564	12	2.8	Concavity	2009	Active
Lusalanje	N01°08'21.5" E034°24'14.7"	2123	29	4	Concavity	1995 & 2008	Active
Busalabi	N01°08'16.4" E034°24'13.4"	2118	25	7	Concavity	1997, 2001 & 2008	Active
Namagoye	N01°08'13.8" E034°21'12.1"	2114	37	6	Concavity	1999	Intermediate
Nakiwole	N01°07'54.0" E034°23'37.1"	2012	40	2	Concavity	2006	Intermediate
Kikobero	N01°07'41.6" E034°23'19.9"	1992	32	8	Concavity	2007	Active
Bukinyale| Gibisi	N01°07'44.2" E034°23'20.4"	2016	30	3	Concavity	2001	Intermediate
Maduwa Lower	N01°16'41.4" E034°33'46.9"	2520	38	2	Concavity	2008	Active
Maduwa Upper	N01°16'42.4" E034°23'50.4"	2529	31	2.5	Concavity	2007	Active
Nalufutu	N01°17'34.0" E034°22'36.1"	1675	24	5	Concavity	1988	Inactive

Source: Field work 2009-2010

Appendix 5.2: Slope Stability Analysis for Slide Potential Hazard Mapping

Name	District	Sub-county	Coordinates	Slope gradient (%)	Landslide potential
Namesti	Bududa	Bubita	N01^{0}01'49.5" E034^{0}25'19.5"	63	High
Mwerwerwe	Bududa	Bubita	N01^{0}01'28.4" E034^{o}25'00.1"	63	High
Basubizi	Bududa	Bubita	N01^{o}01'15.2" E034^{o}25'07.2"	53	Moderate
Timbwa	Bududa	Bubita	N01^{o}00'47.1" E034^{o}25'230"	81	High
Rwanda	Bududa	Bubita	N01^{o}00'44.4" E034^{o}24'41.6"	74.5	High
Bunatiba	Bududa	Bubita	N01^{o}00'08.5" E034^{o}22'539"	51	Moderate
Buwali	Bududa	Bubita	N01^{o}00'58.5" E034^{o}23'29.8"	70	High
Nangoba	Bududa	Bumayoka	N01^{o}01'42.9" E034^{o}23'46.5"	73	High
Maboono 1	Bududa	Bumayoka	N01^{o}02'22.2" E034^{o}23'49.4"	82	High
Maboono 2	Bududa	Bumayoka	N01^{o}02'22.0" E034^{o}23'57.6"	70	High
Maboono 3	Bududa	Bumayoka	N01^{o}02'21.6" E034^{o}24'03.6"	68	High
Musole	Manafwa	Bwabwala	N00^{o}57'28.7" E034^{o}22'15.0"	58	Moderate
Bunambale	Manafwa	Bwabwala	N00^{o}57'36.1" E034^{o}22'16.2"	68	High
Baaya upper	Manafwa	Bwabwala	N00^{o}57'28.8" E034^{o}22'11.0"	70	High
Baaya lower	Manafwa	Bwabwala	N00^{o}57'27.4" E034o22'14.0"	58	Moderate
Nangabo	Manafwa	Bwabwala	N00^{o}55'28.2" E034^{o}22'14.0"	51	Moderate
Nanseke	Manafwa	Bwabwala	N00^{o}55'24.3" E034^{o}22'54.4"	35	Moderate
Taaso lower	Manafwa	Bumbo	N00^{o}52'58.6" E034^{o}26'19.8"	43	Moderate
Taaso upper	Manafwa	Bumbo	N00^{o}52'02.3" E034^{o}26'21.2"	84	High

Kigangali	Manafwa	Bumbo	N00°53'22.2" E034°26'02.4"	71.2	High
Bukhokho	Manafwa	Bumbo	N00°52'52.6" E034°25'05.9"	60	Moderate
Bumadanda	Mbale	Bufumbo	N01°04'15.5" E034°16'26.4"	28	Low
Jewa	Mbale	Bufumbo	N01°05'40.3" E034°15'40.4"	14	Low
Mooni	Mbale	Bunghoko	N01°03'02.1" E034°13'40.01"	57	Moderate
Bumboi	Mbale	Bunghoko	N01°03'35.0" E034°13'53.3"	84	High
Bukwapa	Manafwa	Bumbo	N00°55'08.3" E034°22'43.5"	41	Moderate
Buwandiambi	Manafwa	Bumbo	N00°53'4.4" E034°21'46.6"	40	Moderate
Buwandiambi	Manafwa	Bumbo	N00°53'4.9" E034°21'46.7"	26	Low
Lasalanje	Sironko	Masaba	N01°08'21.5" E034°24'14.7"	56	Moderate
Busalabi	Sironko	Masaba	N01°08'16.4" E034°24'13.4"	47	Moderate
Namagoye	Sironko	Masaba	N01°08'13.8" E034°21'12.1"	73	High
Nakiwole	Sironko	Masaba	N01°07'54.0" E034°23'37.1"	84	High
Kikobero	Sironko	Masaba	N01°07'41.6" E034°23'19.9"	63	High
Bakinyale	Sironko	Masaba	N01°07'44.2" E034°23'20.4"	58	Moderate
Maduwa A	Sironko	Masira	N01°16'41.4" E034°33'46.9"	79	High
Maduwa B	Sironko	Masira	N01°16'42.4" E034°23'50.4"	60	Moderate
Nalufutu	Sironko	Masira	N01°17'34.0" E034°22'36.1"	45	Moderate

Source: Fieldwork 2009-2010