MODELING OF LANDSLIDE OCCURRENCE IN THE HILLY AREAS OF BUDUDA DISTRICT, EASTERN UGANDA

OKELLO NELSON

A project report submitted in partial fulfillment of the requirement for the award of the degree of Master of Engineering (Civil - Geotechnics)

Faculty of Civil Engineering, Universiti Teknologi Malaysia

JANUARY 2015

DEDICATION

All Glory to Almighty God and my daughter Jemimah (RIP)

ACKNOWLEDGEMENT

Firstly, I would like to acknowledge with great thanks the contribution of my supervisor, Associate Professor Dr. Ir. Azman bin Kassim. His credible guidance, continual willingness to help, as well as sparing part of his valuable times, and careful reading of and constructive criticisms and suggestion led to the success of this master project.

I must also send my sincere appreciation to Ugandan Government for the material support in terms of data acquisition, especially the Office of the Prime Minister where Metrological department is found.

I extend my gratitude to Gambu Haruna and course mate during my undertaking of Master in Universiti Teknologi Malaysia for their advice and encouragement.

Lastly, I warmly thank my family and friends, for their love, patience and support during my study period.

ABSTRACT

The purpose of this study was to model landslide occurrence (LO) in the hilly areas of Bududa District taking to consideration the effect of commonly known causative factors and an uncommon landslide causal factor of wind forces on slope with eucalyptus trees. Five different slope models, without and with additional shear strength infrom of tree root cohesion have been use to obtain the final results of LO, with all subjected six (6) different failure criteria (FC). The first four failure criteria (FC1, FC2, FC3 and FC4) assumed were for; group of trees on the slope, tree at the top, tree in the middle and tree at the toe of the slope , while FC5 and FC6 were for slope models with rainfall infiltration only and rainfall plus group of tree weight respectively. Beaufort wind scale 11 was used, and Tree Diameters at Breast Heights (DBH) were varied, commencing with 25cm, 30cm and 60cm for assumed eucalyptus tree height of 25cm. The additional shear strength due to an increased cohesion from the roots ($\Delta c = 5kPa$) was assumed, on the top soil layer of silty clay. Finite element analysis with SEEP/W 2007 was coupled with Limit equilibrium analysis software of SLOPE/W 2007 to achieve expected output or results from different failure criteria. Initial suction of 50kPa at the top of silty clay and 20kPa in the layer of silty gravel, with a total 1044 generated deformed mesh boundary condition were used in transient seepage analysis. Slope model 1 with eucalyptus trees of DBH 25cm yielded an output minimum factor of safety (FOS) of 1.012 for FC3 and value of 1.253 for FC3 (an increase of 23.81% from slope model 4), without and with increased cohesion respectively. With DBH increased to a maximum of 60cm, for slope model 3, safety of the community around this site diminished as the FoS reduced to 0.562 with FC2 and 0.601 with FC3 on day 25, without cohesion, just hours before the fateful day on the 26th June 2012 and remained below 1.0 (from 0.601 to 0.800) with FC3 with roots cohesion, although a gain in the FoS of 33.11% was realized.

ABSTRAK

Tujuan kajian ini dijalankan adalah untuk menghasilkan model (LO) di kawasan Daerah Bududa dengan mengambil kira kesan daripada faktor penyebab utama dan sampingan kepada tanah runtuh. Antaranya, tindakan daya angin keatas cerun terhadap pokok-pokok eucalyptus. Lima jenis model cerun yang berbeza dengan dan tanpa daya ricih tambahan di akar pokok bertanah jelekit telah digunakan bagi mendapatkan keputusan akhir LO, petang berdasarkan kepada enam (6) faktor kegagalan (FC). Empat kriteria kegagalan yang pertama (FC1, FC2, FC3 dan FC4) yang telah dianggarkan adalah untuk pokok yang banyak di kawasan cerun, pokok pada bahagian atas cerun, pokok pada bahagian tengah cerun, dan juga pokok di bahagian kaki cerun. Manakala, kriteria yang kelima dan keenam (FC5 dan FC6) adalah untuk model cerun dengan penyusupan hujan sahaja dan juga penyusupan hujan mengambil kira berat pokok. Angin Beaufort berskala 11 telah digunakan dan pelbagai diameter pokok pada ketinggian aras dada telah dikenalpasti. Pada ketinggian pokok eucalyptus 25cm, ukur lilit 25cm, 30cm dan 60cm telah digunakan. Kekuatan ricih tambahan bergantung kepada peningkatan jelekit pada akar ($\Delta C=5kPa$) telah dianggarkan pada atas permukaan tanah berlumpur yang berkeladak. Analisis unsur terhingga serta SEEP/W 2007, dan analisis had keseimbangan bersama SLOPE/W 2007 digunakan untuk mencapai keputusan yang dijangkakan daripada ciri-ciri kegagalan yang berbeza. Sedutan awal di lapisan atas tanah dan bawah tanah sebanyak 50kPa dan 20kPa dikenakan dengan jumlah 1044 sempadan bersirat telah digunakan di dalam analisis resapan fana. Cerun model 1 bersama pokok eucalyptus dengan ukur lilit DBH 25cm menghasilkan pengeluaran minimum bagi faktor keselamatan (FOS) sebanyak 1.012 untuk FC3 dan sebanyak 1.253 untuk FC3 (peningkatan sebanyak 23.81 peratus (%) daripada cerun model 4), dengan dan tanpa peningkatan jelekit. Apabila DBH ditingkatkan kepada ukur lilit maksima 60cm bagi cerun model 3, keselamatan komuniti disekeliling tapak berkurangan apabila faktor keselamatan berkurang kepada 0.562 bagi FC2 dan 0.601 untuk FC3 pada hari ke 25, tanpa jelekit iaitu hanya beberapa jam sebelum hari malang pada 26 Jun 2012 dan berbaki bawah 1.0 (daripada 0.601 kepada 0.800) dengan FC3 bersama akar berkeladak, walaupun peningkatan faktor keselamatan telah dikenalpasti sebanyak 33.11 peratus (%).

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BS	British Standard
DBH	Diameter at Breast Height
DR Congo	Democratic Republic of Congo
E	Easting
ERDC	Engineer's Research and Development Center
ERRU	Excerpts from Reports by Radio Uganda
FC	Failure Criteria
F o S	Factor of Safety
GeotechNet	Geotechnical Thematic Network
GPS	Global Positioning System
GTS	Global Telecommunication System
HQUSACE	Headquarters' of United State Army Corps of Engineers
IDRL	International Disaster Response Law
KMD	Kenya Department of Meteorology
LL	Liquid Limit
LO	Landslide Occurrence
Ltd	Limited
N	Northing
NEMA	National Environment Management Authority
NMC	National Meteorological Center
PI	Plasticity Index
PL	Plastic Limit

RTH	Regional Telecommunication Hub
SWCC	Soil Water Characteristic Curve
UBOS	Uganda Bureau of Statistics
UDoM	Uganda Department of Meteorology
UiTM	Universiti Teknologi MARA
URCS	Uganda Red Cross Society
US	United States
VSAT	Very Small Aperture Terminal
WMO	World Meteorological Organization

LIST OF ABBREVIATIONS

BS   British Standard

DBH   Diameter at Breast Height

DR Congo   Democratic Republic of Congo

E   Easting

ERDC   Engineer's Research and Development Center

ERRU   Excerpts from Reports by Radio Uganda

FC   Failure Criteria

F o S   Factor of Safety

GeotechNet   Geotechnical Thematic Network

GPS   Global Positioning System

GTS   Global Telecommunication System

HQUSACE   Headquarters' of United State Army Corps of Engineers

IDRL   International Disaster Response Law

KMD   Kenya Department of Meteorology

LL   Liquid Limit

LO   Landslide Occurrence

Ltd   Limited

N   Northing

NEMA   National Environment Management Authority

NMC   National Meteorological Center

PI   Plasticity Index

PL   Plastic Limit

RTH   Regional Telecommunication Hub

SWCC   Soil Water Characteristic Curve

UBOS   Uganda Bureau of Statistics

UDoM   Uganda Department of Meteorology

UiTM   Universiti Teknologi MARA

URCS   Uganda Red Cross Society

US   United States

VSAT   Very Small Aperture Terminal

WMO   World Meteorological Organization

LIST OF SYMBOLS

&	And
C_a	Crown area
C_w	Crown width
H_{CB}	Height to crown base
W_T	Tree weight
ft^2	Square feet
m^2	Square meter
p_a	Wind pressure
$\emptyset$	Phi
°	Degree
°C	Degree Celsius
e	Exponential function
Ft	feet
kN	Kilo Newton
kPa	Kilopascal
m	Meters
mm	Millimeters
lb	Pound
γ	Gamma
ρ	Density
τ	Tao

CHAPTER 1

INTRODUCTION

1.1   Background of the Study

Landslide is one of the most important worldwide landform shaping processes resulting in to minor or major economic consequences (Lepore and Arnone, 2013). It is a major geological phenomenon which includes a wide range of ground movements such as rock falls, deep failures of slopes and shallow debris flows that can bury settled people in the whole village of a particular parish alive with their belongings in just a matter of seconds (Kitutu, 2010 and Hunt, 2007). Landslide occurrence therefore accounts for thousands of sudden global deaths every year (Grity, 2009, and Petley, 2010). Kamal et al. (2011) reported an economic loss of one to two billion dollar per year due to landslide disaster in the United States of America alone. In the year 2010, the gross economic loss from landslides and storms amounted to US dollar Two Million Two hundred and Sixty Two Thousand (Ferris and Petz, 2011).

Furthermore, in the same year in question (2010),the report by Ferris and Petz indicated an overall death toll arising from the Natural disaster to be three hundred ninety thousand three hundred (390,300), in eight different countries, namely; Haiti, Russia, China, Chile, Indonesia, Peru and Uganda. In Europe, living around Mountainous and hilly areas are a real threat (Koehorst et al., 2005). However, people should be aware that landslides can occur even in relatively flat terrain; For example, in areas covered by marine loose clays and or quick clays. European continent has been found to have second highest incidence of landslide casualties with about 16000 deaths recorded over the last 100 years (OFDA/ CRED, 2006). The mechanics behind landslide occurrence varies from region to region depending on the slope vegetative cover as well; with some geological formation having characteristic failure triggered after intense rainfall while others, can fail in a variety of forms which are often complex in nature (Cruden and Varnes, 1996). Soil lithology and gradation have also been found to have adverse effect on landslide occurrence (Kitutu et. al, 2009).

Landslides types commonly occurring in most prone areas throughout the world include deep-seated landslides, debris flow, debris avalanche, earth flow, and shallow landslide; with nature and human beings playing a pivotal role in to the landslide causes. Natural causes of landslides include erosion, groundwater pressure, volcanic eruptions, heavy rain, glacier melting and earthquakes (NEMA, 2010, Ferris and Petz, 2011). Another natural causal factor of landslides is the wind forces (Corcoran and Peters et al., 2011).Wind blowing the tree crown creates pressure on the upper part of the tree which in turn causes a moment loading to the bottom of the tree. Uphill winds acting on well rooted trees will cause a downhill moment, which adds to the driving force in slope stability calculations. On the other hand, downhill winds acting on shallow rooted trees will add downhill shear forces that destabilize the slope. The additional downhill shear forces are mainly derived from the root cohesion from the trees on the slopes. Basically, drag forces caused by trees are

influenced by wind velocity, tree height, crown size, and the slope angle. Man-made causes of landslides include construction, earthwork, blasting, and deforestation (Knapen et.al, 2006).

Published works from most renowned scholars have shown that tropical countries with minimum annual average precipitation of 1800mm have suffered a lot from the rainfall induced landslide of a shallow type, when characterized by both homogeneity and heterogeneity of the slopes materials. Landslide occurrences in heterogeneous slopes are complex in nature and conventional shear strength model cannot critically explain the behavior (Aydin, 2006). The magnitude and forms of heterogeneity of the slopes usually control the mechanism and location failure and deformation characteristics. Conventional slope stability method may end up with stability factor of less than unity but the slope still standing. This phenomenon normally arises as result of suction omission during the analysis and its role in saturated zone located above groundwater table. In the past studies done by Fredlund, the viability of suction in slope stability was brought forward and a model developed to include the suction element (Fredlund, 1978). Further Jamaludin (2010), modified the model to show how suction can realistically influence of water infiltration in slope.

In 2010, Petley, in his report of global death records from landslide occurrence from 2003 to 2010, a total of 6211 deaths in fifteen nations, namely; China, Brazil, India, Uganda, Indonesia, Pakistan, Guatemala, Colombia, Nepal, Peru, Mexico, Burma, DR. Congo, Bangladesh and Taiwan was registered. Geographically, East Asian Countries were found to have suffered most from the horrible disaster, and Uganda, along with DR. Congo were the only countries that emerge from the African contingents that formed the components of fatality graph in figure 1.1 and figure 1.2 below.
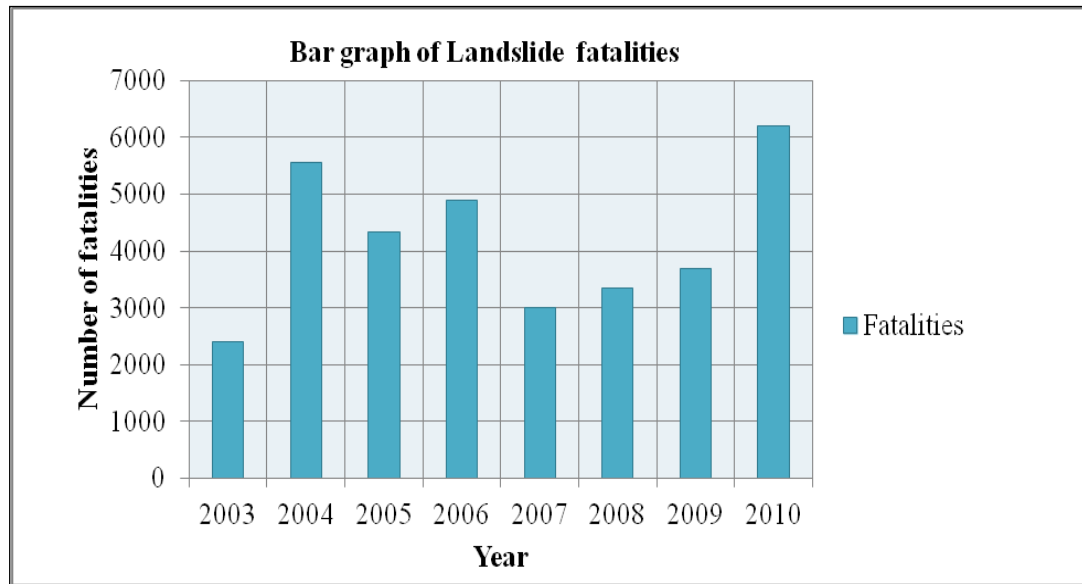
Figure 1.1: Bar graph of Landslide Fatalities from 2003- 2010, (Petley, 2010)

The cyclical trend of the non-seismically induced landslides has therefore been on the rise from 2003 to 2010; with the year 2010 reporting the highest death tolls as show in figure 1.2 below; hence imposing a serious threat all over the globe.
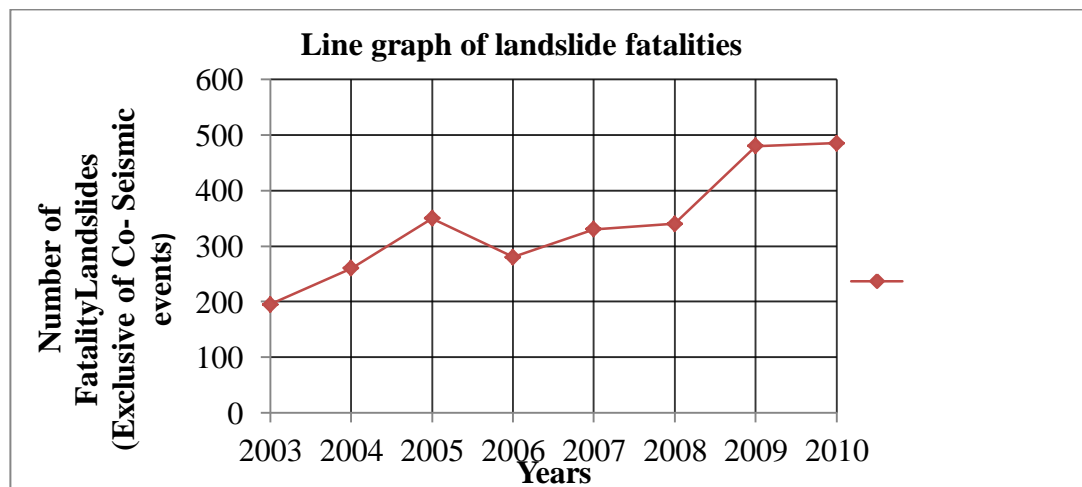
Figure 1.2: Landslide Fatalities from 2003- 2010, (Petley, 2010)

In Africa, compilations from landslide literatures indicated that Kenya, Ethiopia, Rwanda, Zimbabwe, Cameroon and Uganda as countries venerable to landslide disasters (Kitutu, 2010). In Cameroon for example, landslide occurred in Mbonjo area, in the coastal town of Limbe in 2001 and Wambane in 2003 where 21 and 23 people were killed respectively after a severe rainfall that saturated the soil leading to complete loss in the shear strength of the soil (Diko et al., 2012; and Ngole et al.; 2007).

In East Africa, Countries of Kenya and Uganda have majorly faced the tragic actions from landslides since the Twentieth century (Ngecu et al.; 2004). In Kenya, landsides occurred along the Thika – Murang'a highway at Karugia on 10th November 1997 and resulted to totally washing away of a 1 Km section of the highway (Ngecu and Mathu, 1999). Furthermore, on December 26th 1997 severe landslide occurred at Gatara village in Murang'a District in central Kenya after heavy rainfall saturated the tertiary Basalt agglomerates and tuffs (Ngecu *et* al, 2004). The main causative mechanism for this was due to considerable deformation by man, exposing the steep slope surface and down slip was triggered after heavy rainfall as a result of limited contact between the agglomerates and tuff surfaces (Ngecu and Ichang'i, 1999). Another notable landslides in Kenya were also registered around the Western slope area of Mount Kenya in 1997and early 1998 along Embu-Meru Highways due to saturation of andosols soil with variable plasticity index (20 – 22%). The landslide smashed Embu- Meru bridge tunnels over River Mutonga completely, halting several road business and communication between Embu and Meru (Ngecu and Mathu, 1999).

In Uganda, landslides are more frequent in the mountainous regions of Mbale, Kabale, Kisoro, Sironko, Kapchorwa and the districts in the Rwenzori region (IDRL, 2011). Landslides often result from improper land use and management on mountainous slopes, for example, through clearing the slopes of their natural vegetation and over-cultivation due to increase of population. It is estimated that

31% of the total population in Uganda lives in mountainous areas, and is therefore potentially vulnerable to landslides.

In Eastern Uganda, one of the largest and most destructive landslides was a 100,000 m^3 slide that moved the earth material for over 2.5 km down slope, carrying away everything on its course including houses and plantations, killing seven people and injuring several others at Bugobero village in December, 1997 (Erima *et* al, 2004). In addition, several hundred livestock were buried by the speeding debris after raining lightly for the whole day, thereby, the continuous precipitation led to an increased degree of saturation and loading until it was greater than the shear strength of the soil and flowed under the force of gravity. During this year (1997), landslides occurrence were widely distributed in the hilly and mountainous area of Mbale due to exceptional rainfall in the months of October to December, with Bududa area experiencing the most devastating landslides in the Eastern Region of Uganda where more than ten people died, infrastructures were destroyed and agricultural farm land squashed away. Before the sub division of the Mbale District into other smaller Administrative units, another major landslide occurred at Buteza sub-county in Mbale District of eastern Uganda on 27th October 1999, the failure was influenced by mechanical instability of the steep slopes that crop up after saturation of both the deeply weathered tertiary volcanic rocks and humid surface layers on the slope after prolonged rainfall, killing four people from the same family while several others were reportedly displaced or missing (Nyamai, 2004, and Kitutu *et al* 2010).

On 1st March 2010, in Bududa district, Eastern Uganda, severe landslides struck the densely populated Bukalasi Sub County, Nametsi parish in Nametsi village and 385 people were buried alive after it rained heavily and continuously for six days (URCS Report, 2010). This was the most horrible landslide around the mountainous Elgon region since the 20th century. Furthermore, still in Bududa District, another landslide occurred in the afternoon hours on Monday 26th June 2012 in Bulucheke Sub County, Bumwalukani Parish burying the villages of Namanga

and Bunakasala. Surprising, most of the slope were covered by eucalyptus trees which were nearing maturity but all were swept down slope with a huge soil mass (URCS Report, 2012), and Eighteen people were killed. Continuous rainfall coupled with windy storm elements for days are believed to have triggered the landslide. In 2011, Twenty three people were killed by landslides after mounds of mud buried their homes. The Mountainous region of Bududa District has records of heavy rainfall, with cases of strong winds reported in some areas, and landslide occurrence has never dwindled. Scores of people year in year out but detailed systematic geotechnical studies has remained a main concern, specifically to the people of Bududa as well the government of Uganda.

1.2   Problem Statement

Well known scholars have conducted many studies related to the local causes for mass movement in the East African Highlands since the beginning of the 20th century (Muwanga et al., 2001). In Bududa, landslide problem started as early as 1933in Manjiya County killing a total of Twenty five people. The main triggering factor was prolonged rainfall events of low intensity but no systematic geotechnical in-depth studies has been conducted on landslides occurrence to its associated failure mechanisms (Kitutu, 2010, Muwanga et al., 2001). Other landslide causal factors also reported by different researchers include the soil properties, inclination or steepness of slopes, construction activities and geological factors but none of these has triggered landslides in Bududa areas without the elements of rainfall infiltration. Furthermore, the local inhabitants mention the elements of storms coupled with wind of higher magnitude just days before the incident. On 1st March 2010, in Bududa district, Eastern Uganda, landslide of severe magnitude occurred in the densely populated Bukalasi Sub County, Nametsi parish in Nametsi village and 385 people were buried alive by a huge mass of soil carried down the slope after it rained

heavily and continuously for six days (URCS Report, 2010). In lieu to the above, the quest for proper engineering solutions to the continuous occurrence of landslides in the hilly areas of Bududa District has therefore remained wanting.

1.3   Aim of the Project

The main aim of the study was to model landslide occurrence in the hilly areas of Bududa District, Eastern Uganda, through recognition of geological processes, seepage as a result of rainfall infiltration and deformation on the slope due to climatic changes from wind forces that govern failures of slopes.

1.4   Objectives of the study

The objectives of this project were mainly four**:**

i.   To determine the contribution of rainfall infiltration to landslide occurrence in the hilly areas of Bududa.

ii.   To model and ascertain the effects of dynamic forces of wind on landslide occurrence the slope with eucalyptus trees in the hilly areas of Bududa District.

iii.   To determine the factor of safety for the model slope with eucalyptus trees in stable condition and at point of total failure at the landslide site being studied using a coupled analyses.

iv. To determine the contribution of additional shear strength on the slopes as a result of tree roots cohesion

1.5   Scope of the project

The scope of the project will be limited to the development of small scale Geotechnical models of landslide occurrences in the hilly areas of Bududa, Eastern Uganda. The factor of safety of the slopes at selected areas with two or more landslides occurrences using appropriate slope analysis soft ware to aid in drawing conclusions and recommendations.

1.6   Study Area

The study has been in Bududa District situated in Eastern Uganda (lower map). Bududa was formerly Manjiya County in Mbale District (Figure 1.3) and it lies in the south western of part of the Mount Elgon Volcano. It is geographically located between latitude 20 49" N and 20 55" N, longitude 340 15" E and 340 34" (Upper map). Four Land slide sites were visited; namely Bududa 1 in Nametsi village, Bududa 2 site in Bumayoka Sub County, Bududa 3 site in Bulucheke   Sub County, Bumwalukani parish and covering the two villages of Namanga and Bunakasala. The fourth site was named as Bududa 4, in Bukibolo Sub County in Bunamukye parish, Nerondo village. According to the information obtained from the residence, Bududa 4 has never experienced any landslide threat, and therefore believed to be stable. In 2010, a horrible landslide occurred in Bududa 1 site in Bukalasi Sub County, Nametsi Parish in Nametsi village. Soil sample for laboratory

testing obtained from this site was located at N 01° 01.855' and E 034° 25.313' and at an elevation of 1812 m above mean sea level. Failure stretches from the top at an altitude of 1812 m downwards to an elevation of 1749 m above mean sea level where the soil mass was deposited. Bududa 1 landslide site had slope length of approximately 300m, with a slope angle of 12.12 °.

In Bududa 2 Landslide site, no serious death happened but it was worth studying because of the material properties at this site. By visual observation, the sections of the failed slope composed of 200mm thickness of decomposed materials (humus), 1300mm thickness of yellowish brown gravelly sand and the rest of the soil profile up to 3000mm were yellowish brown schist, while other sections had combination of soil with boulders with series of relict joints. Two different soil samples were taken for laboratory testing; and were labeled as Bududa 2 for the normal sample and Bududa 2/1 for the soil sample with boulders. The coordinate of Bududa 2 landslide site was registered as N 01° 02.142' and E 034° 23.588' at an elevation of 1699m above mean sea level. Failure stretches from the top at an altitude of 1699m downwards to an elevation of 1627 m above mean sea level where the soil mass was deposited. Slope distance tracked using the GPS was 203.27m, with a slope angle of 20.74 °.

The 2012 landslide occurred Bududa 3 site in Bulucheke Sub County, Bumwalukani Parish burying the villages of Namanga and Bunakasala. Surprising, most of the slope were covered by eucalyptus trees which were nearing maturity but all were swept down slope with a huge soil mass. Soil sample for laboratory testing obtained from this site was located at N 01° 01.855' and E 034° 25.313' and at an elevation of 1643 m above mean sea level. Failure stretches from the top at an altitude of 1643m downwards to an elevation of 1532 m above mean sea level where the soil mass was deposited. GPS track along Bududa 3 slope gave a slope length of 480 m, with a slope angle of 13.37 °.

Finally, the fourth site was named as Bududa 4, in Bukibolo Sub County in Bunamukye parish, Nerondo village. This site had no records of landslides since the beginning of the 20th century and is believed to be stable. The slope is a bit steeper, and inclined at 27.4 ° to the horizontal. Climbing was a big task and tracking was done only for about 159 meters with the help of the GPS. Soil samples for laboratory analysis were taken from the foot of the slope of elevation 1513 m above mean sea level and the coordinate being N 00 °59.817 ´and E 034 °17.745 ´.
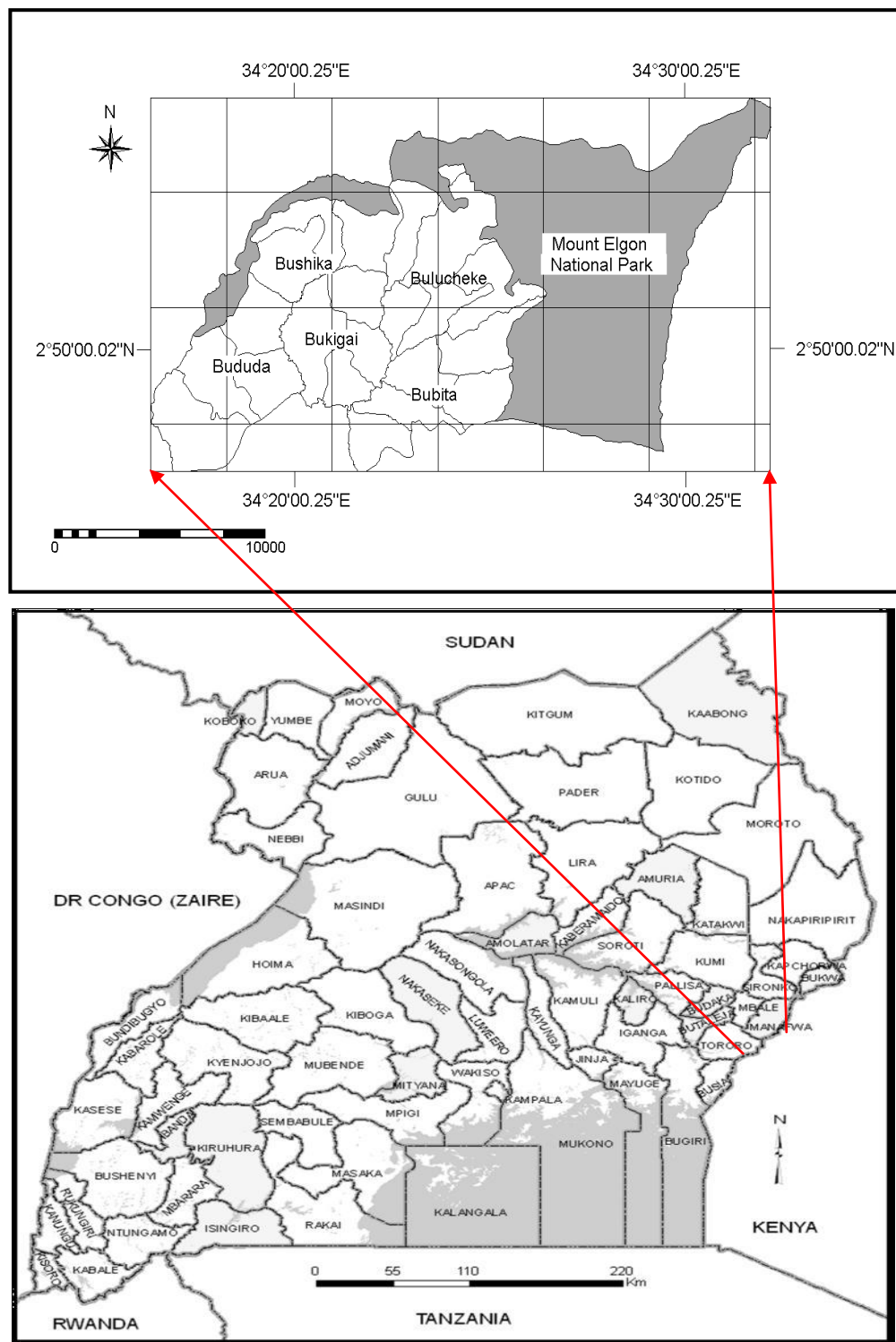
Figure 1.4: Location of Bududa District in Uganda, originally known as Manjiya County in Mbale District (Kitutu, 2010).

REFERENCES

Ayalew, L., (1999): The effect of seasonal rainfall on landslides in the highlands of Ethiopia. Bull. Eng. Geol. Env. 58: p. 9-19.

Aydin, A., (2006): Stability of saprolitic slopes: nature and role of field scale heterogeneities.

Bischetti, G., et al, (2009): Root cohesion of forest species in the Italian Alps. Regular article from the Department of Agricultural Engineering, University of Milan, Italy.

British standards institution (1990). British standard 1377: 1990. Methods of test for soils for civil engineering purposes, London.

Chiaradia. E. et al, (2012): Incorporating the Effect of Root Systems of Forest Species into Spatially Distributed Models of Shallow Landslides, **International Journal of Forest, Soil and Erosion**, 2 (3): 107-118.

Coder. D, (2008): Storm wind loads and Tree damage, Tree and storm series; Warnell School of Forestry and Natural Resources (WSF&NR). University of Georgia, Monograph publication WNFNR 08- 24

Coder. D, (2010): Root strength and Tree anchorage; Warnell School of Forestry and Natural Resources (WSF&NR). University of Georgia, Monograph publication WNFNR 10- 19 (Pp 88)

Corcoran, M. K. and Peters, J.F. et al (2011): Initial Research into the Effects of Woody Vegetation on Levees; ERDC Numerical Simulation TechnicalReport to HQUSACE, Volume III of V; pp 180-219.

Cruden, D.M., Varnes, D. J. (1996) - Landslide types and processes. Transp ResBoard, Spec Rep 247, pp 36-75.

Danjon. F. et al, (2008): Using three dimensional plat root architecture inmodels of shallow slope stability. Annals of Botany 101; Pp 1281- 1293.

De Beats S.; Torri D., Poesen. J., Salvador M., and Meersmans, (2008): Modelling increased cohesion due to roots with EUROSEM. Earth surface, process, landforms Journal, Vol 33, pp 1948- 1963.

Diko, M. and Ekosse G., et al., (2012): Physical and geotechnical characterization of unconsolidated sediments associated with 2005 Mbonjo landslide, Limbe, Cameroon.

Ferris, E. and Petz, D., (2011): A year of living dangerously: A review of Natural Disaster in 2010 (Report); pp 6.

Girty, G.H., (2009): Understanding the process behind Natural Disasters; Version 10.

Historical Weather for 2010 in Tororo, Uganda- http://weatherspark.com/history/29329/2013/Tororo-Eastern-Region- Uganda

Historical Weather For 2012 in Tororo, Uganda- http://weatherspark.com/history/29329/2013/Tororo-Eastern-Region- Uganda

International Disaster Response Law (IDRL) in Uganda (2011): An Analysis Report of Uganda's legal preparedness for regulating issues in International disaster response, pp 20-21.

Jamaludin, M., (2010): The role of curved- surface envelope Mohr- Coulomb in governing shallow infiltration induced slope failure.

Jamaludin, M., (2011): Understanding Rainfall induced landslide. UiTM press, Malaysia.

Kitutu, G., (2010): Landslide occurrences in the Hilly areas of Bududa, Eastern Uganda and their causes, PhD Thesis.

Kitutu, M., et al, (2009). Influence of soil properties on landslide occurrences in Bududa district, Eastern Uganda, African Journal of Agricultural Research Vol. 4 (7), pp. 611-620.

Knapen, A., et al, (2006): Landslides in a densely populated county at the footslopes of Mount Elgon (Uganda): characteristics and causal factors. Geomorphology 73, 149–165.

Koehorst et al., (2005): Work package 6 Determination of socio-economic impact of natural disasters: GeotechNet pp 17- 19.

Konig, O and Kaufmann J, (2014): Report on Wind speed units and wind direction; Addicted to wind, wind finder.com.

Lateh. H, (2008): Effect of vegetation roots for stabilizing gullied slope along the East- West highway, Malaysia.

Leif Nutto, et al (2006): Management of individual Tree diameter growth and implication for pruning for Brazilian Eucalyptus grandis; Hillex Maiden.

Lepore, C. and Arnone, E., (2013): Physically based modeling of rainfall triggered landslides: a case study in the Luquillo forest, Puerto Rico.

Lepore, C., and Kamal A., et al., (2011): Rainfall-induced landslide susceptibility zonation of Puerto Rico, a Journal of Environmental Earth Science.

Michelle. S. et al, (2012): Modeling the influence of Trees on the stability of Levees. Symposium paper from California Levee Vegetation Research Project (CLVRP)

National Environment Management Authority Uganda (2010): Landslide in Bududa District, their Causes and Consequences. State of the Environment Report for Uganda; pp 2-5.

Ngecu, W.; and Mathu E., (1999): The EL Nino triggered landslides and their economic impacts on Kenya: Episodes Vol 22, no 4- pp.284- 288.

Ngole, V.M.; Ekosse, G.; and Ayonghe, S.N., (2007): Physico-chemical, mineralogical and chemical considerations in understanding 2001 Mbeta New layout landslide, Cameroon: Journal of applied science and environmental management, Vol. 11, No. 2, pp.201-208.

Nyssen, J., Moeyersons, J., Poesen, J., Deckers, J and Mitiku H., (2003): The environmental significance of the remobilization of ancient mass movements in the Atbara-Tekeze headwaters near Hagere Selam, Tigray, Northern Ethiopia. Journal of Geomorphology.

Petley, D., (2010): Global death updated Report from Landslides in 2010. Available at **http://blogs.agu.org/landslideblog/2014/04/07/hannover-point/**

Preene. M, (2014): Preene Ground Water Consulting; An article on Hydraulic conductivity. West Yorkshire, UK.

SEEP/W, (2007): Geo-Studio finite element software for Ground water seepage analysis; GEO-SLOPE International Limited.

Selby, M.G., (1993): Hill slope materials and processes, Oxford University Press. New York

SLOPE/W, (2007): Geo-Studio Limit Equilibrium software Slope stability analysis; GEO-SLOPE International Limited.

Uganda Bureau of Statistics (UBOS), 2011: Statistical abstract survey report on socio- economic sectors, Kampala (Uganda).

World Meteorological Organization (WMO), 2012: Severe weather forecasting Demonstration Project (SWFDP) mission to the Uganda Department of Meteorology Entebbe, Uganda.

Wu. T.et al, (1979): Strength of Tree roots and landslides on Prince of Wales Island, Alaska. Canadian Geotechnical Journal; 16(1); Pp 19-33.