MAKERERE UNIVERSITY

COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

IMPACT OF LANDSLIDES ON SMALLHOLDER FAMERS' LIVELIHOODS IN BUBUKWANGA SUB COUNTY, BUNDIBUGYO DISTRICT

BY

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16/U/2827/PS

216005647

A RESEARCH DISSERTATION SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELORS OF ENVIRONMENTAL SCIENCE, MAKERERE UNIVERSITY

OCTOBER, 2019

DECLARATION

I **AGABA JOHN** declare that this work is original and has never been presented to any institution of higher learning for an award of a degree or any qualification.

Signature..........................

Date.08/10/2019..

APPROVAL

This is to certify that this dissertation has been developed under my supervision and is now ready for submission for undergraduate research at Makerere University.

DR. NAKILEZA BOB

Signature .... Date...05/10/2019

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CHAPTER ONE

INTRODUCTION

1.1 Background

Landslides are among the most damaging natural hazards in mountainous areas around the world (Corominas et al., 2014) and they are expected to occur in future under the same circumstances that caused them in the past (Giuseppe et al., 2016). The natural disaster contributes to some of most devastating impacts including loss of human lives, properties and infrastructure in many parts around the globe (Chen et al., 2018). Although the action of gravity is the primary driving force for a landslide to occur, other factors such as climate change and human activities drive increases in the failures of mounds and may exacerbate this hazard further in the future Luo et al., (2019). These factors have been studied to affect slope stability and hence act as a trigger for landslides. Typically, they (pre-conditional factors) build up specific surface or sub-surface conditions that make the slope prone to failure. A landslide is defined as the movement of a mass of rock, debris or earth down a slope. Landslides are a type of mass wasting which denotes any down-slope movement of soil and rock under the direct influence of gravity. In the world, they exist in the following areas; South West Utah Wyoming, Calabria, British Columbia, Switzerland, Salerno, Amalfi Coast, Longeron, Italy, Poshan Road landslide-Hong Kong among others. Landslides are life-threatening events that can make it seem as though the world we live upon is crumbling around us (Bankoff, 2001).

According to Nsengiyumva et al. (2019), the East African regions have experienced major landslides in the recent years and have caused many fatalities and injuries, loss of many hectares of productive farmlands and destruction to infrastructure such as roads, railways and bridges, the warm and wet climate of the landslide-prone regions causes rapid weathering and produces a regolith weaker than the underlying rock with an interface between the two layers. This interface serves as the most common plane along which landslides are initiated once it becomes saturated. Landslides in the region are associated with steep topography, human activities such as deforestation, overgrazing, and unplanned farming on steep slopes and are induced by earthquakes and high intensity of rainfall. The landslide-prone areas are agriculturally very productive and the inhabitants depend on agriculture for their livelihood. The areas also contribute substantially to the national food reserve. The landslides are therefore a burden to the economies of the individual farmers and national governments of the region

During the period between 1994 and 2000 the East African region experienced major landslides resulting from above average rainfall. The landslides occurred in the mountainous regions of eastern and western Uganda in the districts of Kabale, Kukungiri, Mbarara, Kasese, Bundibugyo, Kabarole and Mbale (Nkunzimana et al., 2019). As a result of these landslides, many people lost their lives, plantations were destroyed and settlements were buried by fast moving loose rock boulders and soil debris. In Kenya, the majority of landslides occurred in Murang'a, Nyeri and Nyandarua districts of central Kenya and in several parts of the eastern Province of Kenya. In these areas, several fatalities occurred, bridges were swept away, surface and subsurface water were rendered unfit for consumption and hydro-electricity generating power stations and reservoirs were clogged with silt.

Most of these landslides occurred in areas of high agricultural potential which are highly populated. These areas are characterized by high rainfall, steep slopes of red-brown nitisols which are derived from volcanic rocks. The soils generally are acidic (pH 4.0 to 6.0) and therefore are favorable for production of tea, Arabic coffee and temperate climate fruits such as plums and subsistence crops such as potatoes and maize (Ngecu et al., 2004)

Heavy rains triggered these landslides on the steep slopes of Mt. Elgon in Uganda on March 1, 2010 as per the Ministry of Disaster and Preparedness in Bududa. As the older scars hint, landslides are common in the region, but the new landslides are much larger than previous slides. The slides affected three villages, leaving 83 dead and more than 300 missing as of March 8, 2010; reported the United Nations Office for the Coordination of Humanitarian Affairs.

This natural-color image, acquired by the Advanced Land Imager on NASA's Earth Observing-1 (EO-1) satellite on March 11, 2010, provides clues that the landslide area had been highly populated. Bright roves reflect light extremely well. Tiny white dots scattered across the western slopes of Mt. Elgon are probably structures. Several structures surround the slides.

Heavy rain caused the slides, but deforestation may have also played a role, said the Ugandan government. Dark green forest grows on the slope above the slide area. A strip of pale green land, free of settlements, separates the forest from the slide. This region had been deforested since 2007, according to the government analysis. On a steep slope, trees anchor the soil. Deforested mountains are very prone to landslides

Human activities have left the land exposed to forces of degradation. Besides, the land has been left bare, getting exposed to both internal and external forces of mass wasting. Within the last three years, about 15 people lost their lives as a result of landslides in areas like Bukonzo and Humya in addition these landslides have displaced more than 20,000 people from their homes and destruction of plantations of cocoa and vanilla (Kervyn et al., 2015). The vegetation has been cleared for settlement and financial purposes like charcoal burning, house construction and firewood. This has intensified the greenhouse effect and global warming. As a result, the snows on the Rwenzori Mountain have constantly melted, leading to mudslides and landslides, especially during heavy rains.

1.2 Problem statement

The problem of landslides in Bundibugyo district has been rampant for many years due to heavy rainfall patterns and heavy deforestation along the slope areas for agricultural production (Nkonya et al., 2002). Landslides have caused destruction of several hectares of farmers' crops such as vanilla and cocoa, death of people while others are often left homeless. It is not yet clear how individual farmers are affected in this area. Despite the fact that farmers have tried to use local measures to reduce the impacts of landslides for example using sacks filled with stones to prevent mass movements along the slopes, a question still stands whether there has been a follow up on the appropriate remains how effective are the measures of controlling the landslides. This research was based on the above information gap to investigate the impact of landslides on farmers land and measures in place to address the problem

1.3 General objective

To investigate the impacts of landslides on smallholder farmers' livelihoods and to provide an information about opportunity to develop natural protection technology and mitigate the effects of natural disasters in the future.

1.3.1 Specific objectives

1) To identify the different types and characteristics of landslides in Bubukwanga sub county
2) To quantify the loss of smallholder's crops and other key property assets due to landslides
3) To establish the strategies adopted by farmers to mitigate the impact of landslide

1.3.2 Research questions

Are the farmers aware of the landslides in the area?
Are the farmers being affected by the landslides?
How often have the landslides occurred in the area?
How have the landslides affected the farmers in the area?
What has been done by the farmers to mitigate the impacts of the landslides?
What are challenges being faced by farmers in attempt to mitigate the impacts of landslides?

1.4 Significance of the study

The study sought to generate the information about the different types of landslides affecting farmers in Bubukwanga Sub County as well as the relevant mitigation practices feasible according to farmers' perspectives. The information can be used to guide farmers, environmental authorities and other stakeholders including NGOs to find the most effective, practical and acceptable ways of reducing the effects of landslide in this area hence improve awareness and resilience of the communities towards the hazard. It can also contribute to information for policy interventions aimed at minimize effects of the hazard in Bubukwanga Sub County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concepts

Geologists, engineers and other professionals' definitions of landslides often rely on unique and slightly differing definitions. This diversity in definitions reflects the complex nature of the many disciplines associated with studying landslide phenomena. Landslide is a general term used to describe the down slope movement of soil, rock, and organic, and materials under the effects of gravity and also the land form that results from such movements. Varying classifications of landslides are associated with specific mechanics of slope failure and the properties and characteristics of failure types; other phrases that are used interchangeably with the term "landslide" including mass movement, slope failure, and so on. One commonly hears such terms applied to all types and sizes of landslide (Highland & Bobrowsky, 2008)

2.2 Landslide classification

According to Cruden and Varnes (1996) landslide are movements of masses of rock, debris, or earth down a slope, under the influence of gravity. Landslides can be classified depending on the type of movement (fall, topple, slide, spread, and flow) and type of material (rock, soil, or their combination) that failed (Varnes, 1978). This research focuses on classifying landslides depending on their known characteristics.

2.2.1 Slides

The two major types of slides are rotational slides and translational slides.

Rotational slide: This is a slide in which the surface of rupture is curved concavely upward and the slide movement is roughly rotational about an axis that is parallel to the ground surface and transverse across the slide

Translational slide: In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting. A block slide is a translational slide in which the moving mass consists of a single unit or a few closely related units that move down slope as a relatively coherent mass

2.2.2 Falls

Falls are abrupt movements of masses of geologic materials, such as rocks and boulders that become detached from steep slopes or cliffs. Separation occurs along discontinuities such as fractures, joints, and bedding planes and movement occur by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water.

2.2.3 Topples

Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit, under the actions of gravity and forces exerted by adjacent units or by fluids in cracks

2.2.4 Flows

There are five basic categories of flows that differ from one another in fundamental ways.

Debris flow: A debris flow is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows down slope Debris flows include <50% fines. Debris flows are commonly caused by intense surface-water flow, due to heavy precipitation or rapid snowmelt that erodes and mobilizes loose soil or rock on steep slopes. Debris flows also commonly mobilize from other types of landslides that occur on steep slopes, are nearly saturated, and consist of a large proportion of silt- and sand-sized material. Debris-flow source areas are often associated with steep gullies, and debris-flow deposits are usually indicated by the presence of debris fans at the mouths of gullies. Fires that denude slopes of vegetation intensify the susceptibility of slopes to debris flows.

Debris avalanche: This is a variety of very rapid to extremely rapid debris flow.

Earth flow: Earth flows have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head. The flow itself is elongate and usually occurs in fine-grained materials or clay-bearing rocks on moderate slopes and under saturated conditions. However, dry flows of granular material are also possible.

Mudflow: A mudflow is an earth flow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles. In some instances, for example in many newspaper reports, mudflows and debris flows are commonly referred to as "mudslides."

Creep: Creep is the imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure. There are generally three types of creep. They include; Seasonal, where movement is within the depth of soil affected by seasonal changes in soil moisture and soil temperature; Continuous**,** where shear stress continuously exceeds the strength of the materia**l** and Progressive, where lopes are reaching the point of failure as other types of mass movements. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges.

2.2.5 Lateral spreads

Lateral spreads are distinctive because they usually occur on very gentle slopes or flat terrain. The dominant mode of movement is lateral extension accompanied by shear or tensile fractures. The failure is caused by liquefaction, the process whereby saturated, loose, cohesion less sediments (usually sands and silts) are transformed from a solid into a liquefied state. Failure is usually triggered by rapid ground motion, such as that experienced during an earthquake, but can also be artificially induced. When coherent material, either bedrock or soil, rests on materials that liquefy, the upper units may undergo fracturing and extension and may then subside, translate, rotate, disintegrate, or liquefy and flow. Lateral spreading in fine-grained materials on shallow slopes is usually progressive. The failure starts suddenly in small area and spreads rapidly. Often the initial failure is a slump, but in some material, movement occurs for no apparent reason. Combination of two or more of the above types is known as a complex landslide (Calcaterra et al., 2014)

2.2.6 Causes of landslides

Water: Perhaps the most common trigger of a landslide, water reduces the friction between the bedrock and the overlying sediment, and gravity sends the debris sliding downhill. In sand and clay soils, a small amount of water may increase stability. You've likely seen this when building a sand castle or working with clay. However, the sediment gets heavier as more water is added and that can cause it to flow downhill. This is why many landslides occur after rains

Earthquakes: If the Earth's crust vibrates enough to disrupt the force of friction holding sediments in place on an incline, a landslide can strike. Seismic activity can also make it easier for water to seep into the soil, further destabilizing the slope.

Wildfires: Plants help keep the soil stable by holding it together like glue with their roots. When this glue is removed, the soil loosens, and gravity acts upon it much more easily. The loss of vegetation after a fire makes the razed land susceptible to slides.

Volcanoes: Several characteristics of volcanoes make them fertile starting points for especially destructive landslides. (Horton et al., 2018)

2.5 Measures and strategies of landslides

Most geotechnical engineers are familiar with methods of geotechnical slope stability analysis, global journal of engineering science and research (2016) which may be applied to both soil and rock slopes. Limit equilibrium methods are still popular and very useful. However, powerful and versatile stress-deformation approaches such as the finite element method Baguley, D. and Hose, D.R. (1994) have been widely available in recent decades. Such methods have particular advantages in significant projects. Due to geotechnical, geological and other uncertainties, probabilistic methods and risk analysis approaches have also been developed. One of the benefits of recent research progress is that methods for dealing with landslides and their impacts can include a variety of perspectives. A prudent selection of one or more approaches and strategies would depend upon the scale of the project, its regional context, site-specific location, the available resources and the time-frame for its operation. Approaches for analysis and understanding may include; deterministic or/and probabilistic methods, regional or/and site-specific investigation, landslide inventory and mapping using GIS (Guzzette,et al, 2000), observational approach or/and modeling and simulation, hazard, vulnerability and risk assessment.

2.5.1 Strategies for minimizing impacts

Early Warning Systems strategic approaches for geotechnical risk and for management of landslides as discussed by Chowdhury et al., (2008), Bednarik et al., (2012) and Rwodzi, (2010), development controls and preventive strategies are adopted during slope assessment and design and remedial actions such as restraining works after landslide occurrence.

Before decisions can be made concerning the management of landslides and the mitigation of their impacts, it is necessary to make careful assessments of the potential for instability of specific sites or regions. The limitations of traditional analytical approaches for slope stability assessment are now widely recognized. Experience has shown that assessing the potential of slope instability based on the conventional factor of safety can be misleading. Because of significant uncertainties concerning geological details, geotechnical parameters, pour water pressures and external triggering factors, an understanding of spatial and temporal variability of different factors is very important. Often a deterministic and predictive approach is not sufficient on its own. Observational approaches are very useful for both site-specific and regional assessment and management. Assessment of landslide susceptibility, hazard and risk may require the application of probabilistic concepts and approaches. (Chowdhury and Flentje, 2014; Chowdhury and Bhattacharya, 2011)

CHAPTER THREE

METHODOLOGY

3.1 Study area

Bubukwanga Sub County is found Bwamba County, Bundibugyo district, is located in western Uganda 284km west of Kampala the country's capital. Like other Ugandan districts it is named after its chief town Bundibugyo where the district head- quarters are located. According to Katutu et al. (2019), this area has been affected by landslides over a long time.

The area is on the foot and slope of the Rwenzori Mountain where the first rains are received from March to May which are short and longer rains from August to November. Annual rainfall ranges from less than 800mm to 1600mm and is greatly influenced by altitude, least amount of rainfall occurs in January. The average in this month is 45mm, most of the precipitation falls in April averaging 137mm.Temperatures are highest on average in March at around 24.6^{o}C, July is the coldest month with temperatures averring from 23.4^{o}C. Rainfall distributions enable agriculture to take place throughout the year. It is also surrounded by swamps, rivers like Humya, Kirumya forest (Semuliki) that harbors wild species like monkeys, chimpanzees, buffalos and others. The communities adjacent to the forest practice subsistence agriculture and use the forests to supplement their livelihoods. Some of the forest products include bush meat, herbal medicines, fruits, vegetables and construction materials such as timber and vines for making ropes as well as providing fuel e.g. firewood and charcoal. Therefore, the forest is of great social-economic importance to the local communities.

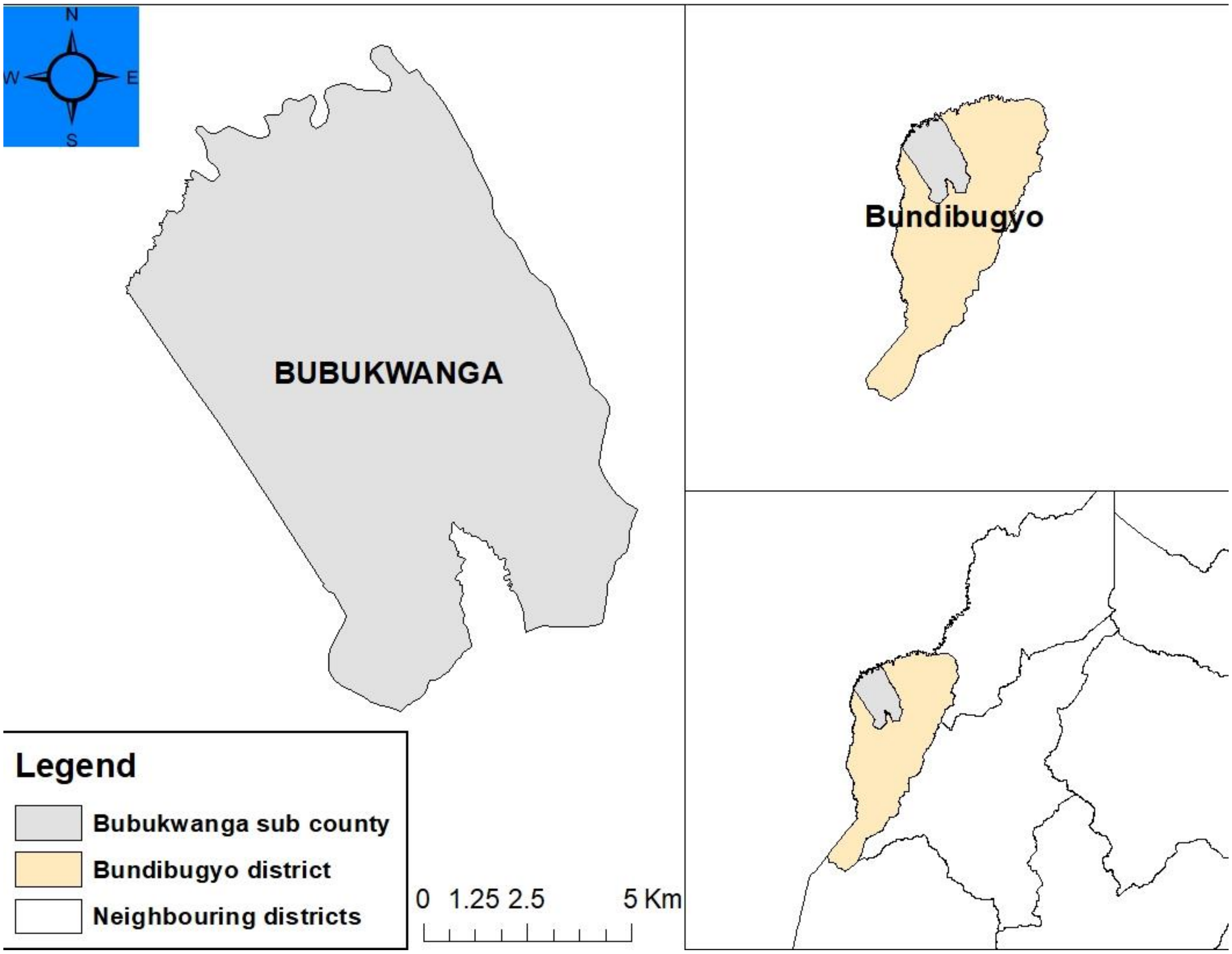

Figure 1: Location of Study area in Bundibugyo district, Uganda

3.2 Research Design

The research data was collected from villages namely Bubulongo, Buhundu 1 and Humya villages. Information from Bubukwanga sub county headquarters indicated that the farmers in these villages were more vulnerable to failures due to presence of very steep areas and inappropriate land management technologies including poor methods of farming that continuously changed the terrain of the area, increasing susceptibility to failures. In this research, 95 respondents were used to act as a sample size based on Cochran's formula for estimation of a sample considering a total of 135 farmers heavily affected by failures. The respondents (farmers) were selected using random sampling technique since the study was more interested in getting a diverse and unbiased information from any of the highly vulnerable farmers in Bubukwanga Sub County.

3.2 Data collection methods

3.2.1 Charactering different landslides

Field surveys were conducted whereby observations and measurements were taken in different areas along selected transects running from lowland to upland. Participatory observations were carried out with the knowledgeable local members to locate where the landslides have recently occurred.

A Global Position System (GPS), Garmin GPSMAP 64s was used to collect data on the locations of landslides. A tape measure was used to measure the widths and lengths of the identified landslides. Types of landslides were identified using local perspectives and classified basing on the McGraw-Hill encyclopedia of science and technology. The slope gradients on which landslides have affected was measured using a clinometer.

3.2.2 Quantifying the loss of small holder farmers

Household surveys were conducted where semi-structured questionnaires were administered to 97 households to identify the type of loss (crops, animals, shelter, trees, number of lives) lost when the landslides happened as well as the size of land affected, type of activity has been conducted on the affected land.

3.2.3 Strategies adopted by farmers to mitigate the impacts of landslides

Household surveys were conducted. Using a random sampling and assignment technique, questionnaires were administered to 95 households due to low finance and limited time, this mostly targeted small scale farmers who had the knowledge about landslide mitigation and management in Bubukwanga Sub County. Review of secondary source of data for example government reports, journals, local leaderships, environmental officers and non-governmental organizations was done to supplement field data.

3.3 Data processing and analysis

Primary data was captured from the field and coded in Statistical Package for the Social Sciences (SPSS), employing both descriptive statistical approach and Microsoft Excel package in which raw data was tabulated and its frequencies, means, percentages and proportions determined. Spatial data on landslides was processed using ArcGIS version 10.4.1. Two-Period Moving averages were used to estimate the relationship between the landslide length, and width.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics of the respondent

A total of 61.1% were male respondents while 38.9% of the respondents were females. Results revealed that 42.1% of the total respondents were employed in other sectors in addition to farming whereas 37.9% of the respondents were only employed in the farming sector. Results also revealed that 43.2% of respondents had primary level of education, 36.8% had attained secondary level of education while 20% had a Diploma.

Table 1. Demographic and socio-economic characteristics of the respondents

Demographic characteristics (N=95)	Frequency	Percentage (%)
Gender		
Male	58	61.1
Female	37	38.9
Employment status		
Employed	40	42.1
Unemployed	36	37.9
Others	19	20.0
Level of education		
Primary	41	43.2
Secondary	35	36.8
Diploma	19	20.0

4.2. Classification of landslides

4.2.1 Characteristics and types of landslides in Bubukwanga Sub County

Table 2 presents the different characteristics and types of landslides identified in number included 31 in number as mud flows, slides, rock flows, debris, lateral spreads, as classified by VARNES (1996) 10 were lateral spreads,15 were mud flows and 6 were slides. For example, 78.9% of the landslides were shallow slides 12.6% of the landslides were small while 8.4% of the landslides were broad. By relating the seasonality of occurrence and type of material affected, results showed that 32.6% of the landslides sweep away or fracture soils, while most of the landslides (46.3%) slump the sloppy areas and 21.1% of landslides cause slight movement of soil and mud.

Table 2. Indicators of the occurrence of landslides in Bubukwanga sub county.

Material affected	**Type**			
	Shallow (%)	Small (%)	Broad (%)	**Total**
Fracturing of soils (%)	25.8	2.7	4.1	32.6
Slumping of slopes	36.6	3.9	5.9	46.3
Slight movement of soils and mud	16.6	1.8	2.7	21.1
Total	78.9	8.4	12.6	100.0

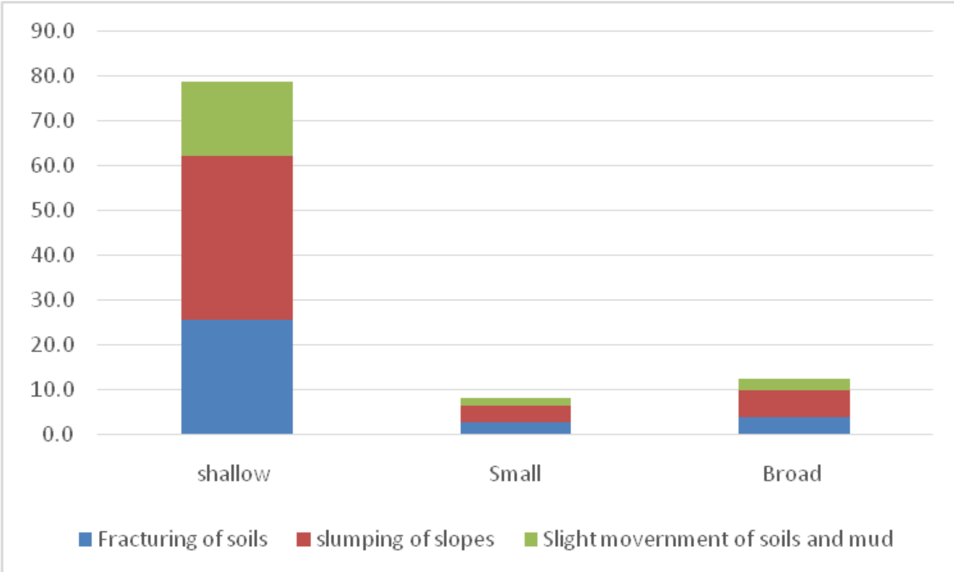

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Figure 2. Types and characteristics of landslides

The landslides were not uniformly distributed as per figure 2 shows where a total of 31 landslides were identified and observed as follows; 15 in Buhundu 1 and appeared to be on a steep slope, a total of 10 landslides in Humya on gentle and flatland and 6 in Bubulongo Villages respectively.

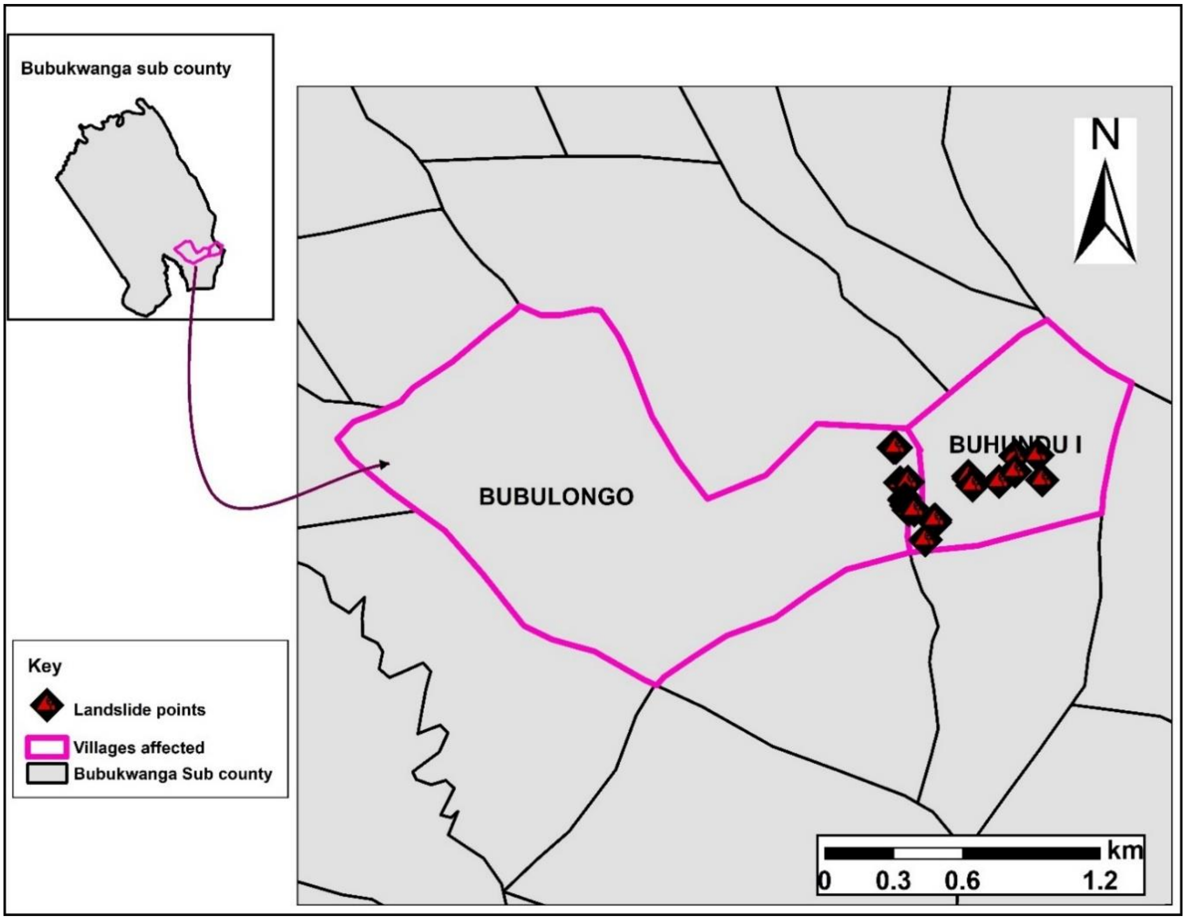

Figure 3. Villages where landslides were recorded

4.2.2 Length and width of landslides

The results also present the length, width and the slope values of landslides recorded in the study area. For example, the maximum length and width recorded were 28.0 meters while the mean values of landslide length and width were 17.9±6.5 and 16.5±5.7 respectively. A 2-period moving average slope gradient revealed a correlational relationship between the length of landslides and slope of the study area.

Table 3. Average mean values of Landslide measurements taken in Bubukwanga Sub County

Landslide measurements	Width (m)	Length (m)	Slope gradient
Max	28	28	0.7
Min	5.8	9.0	0.1
Mean	16.5	17.9	0.4
St. dev	5.7	6.5	0.1

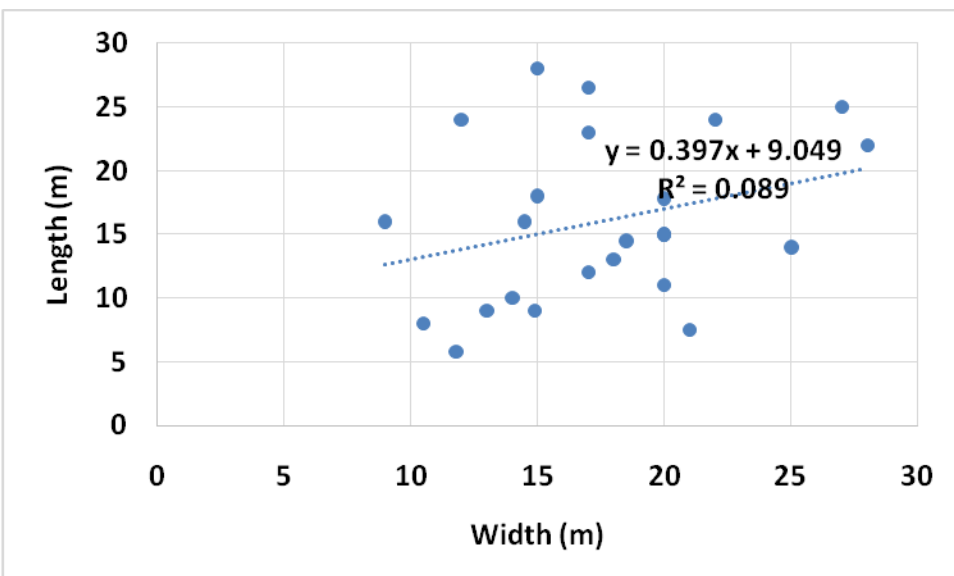

Figure 4. Length and width of landslides recorded in Bubukwanga sub county

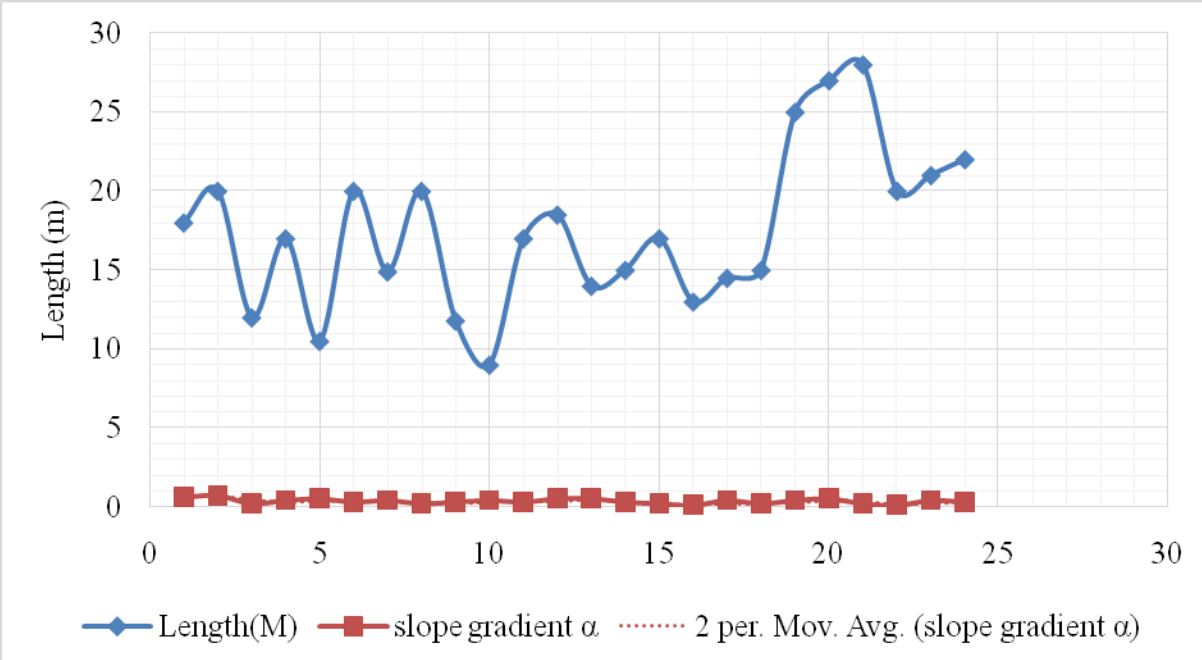

Figure 5. Relationship between length landslides and the slope of landscape in Bubukwanga sub county

4.3 Crop and assets destroyed by landslides

Table 4 presents the response on agricultural and other asset losses due to landslides.

Table 4. Percentage response on major crops and other assets destroyed by landslides

Major crops	**Frequency**	**Percentage (%)**
Cocoa	75	78.9
Vanilla	12	12.6
Cassava	8	8.4
Other assets affected		
Trees	34	35.8
Houses	46	48.4
Others	15	15.8

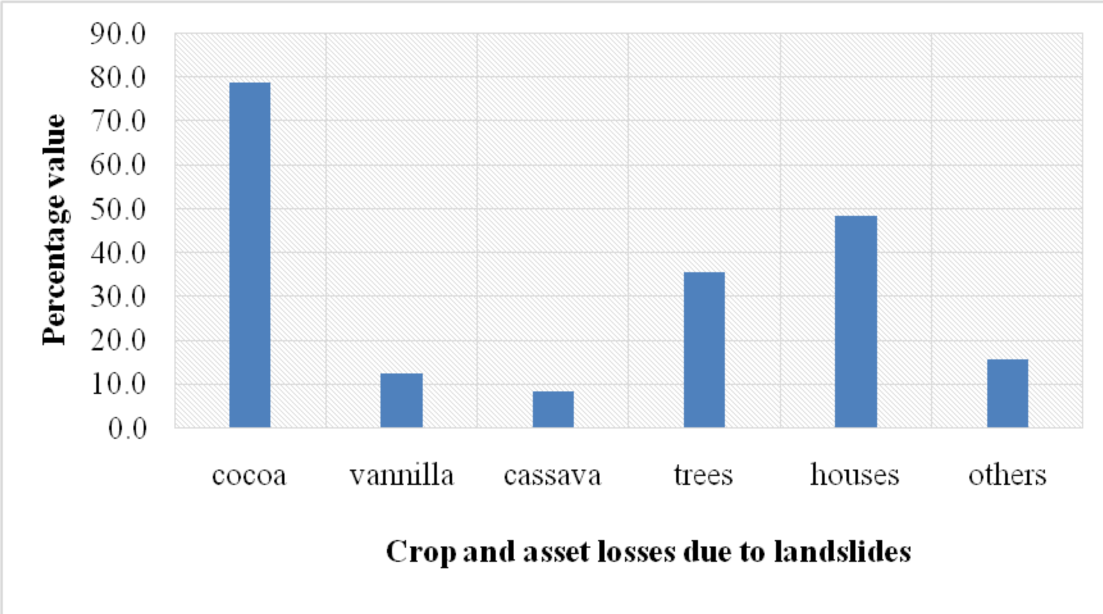

Figure 6. Assets and crop losses due to occurrence of landslides in Bubukwanga sub county

The research also revealed that most of the land hit by landslides (71.6%) had previously been used for cultivation. A total of 52.7% of the total land is individually owned.

Table 5. Use and ownership of land before landslides

Previously activities on the land affected by landslides					
Do you own this Land? (%)		Cultivation	Settlement	Others	Total
	Yes	52.7	15.5	5.4	73.7
	No	18.8	1.9	1.9	26.3
	Total	71.6	7.4	7.4	100.0

Table 6 presents the reported changes in agricultural production due to landslides in Bubukwanga Sub County. For example, on average, a farmer in Buhundu 1 produced about 58.2 kilograms of output and 20.6 kilograms after landslides hence incurring a net loss of 64.7% whereas a farmer in Bubulongo lost about 66.7% of their production due to landslides as compared to 47.8% average losses by farmers in Humya village.

Table 6. Response on average changes in Crop production per farmer due to Landslides (kg)

Village	Before Landslides (kg)	After Landslides (kg)	Net Loss (kg)	Net Loss (%)
Buhundu 1	58.2	20.6	37.6	64.7
Humya	84.7	44.2	40.5	47.8
Bubulongo	106.6	35.5	71.1	66.7
Total	249.5	100.3	149.2	59.8

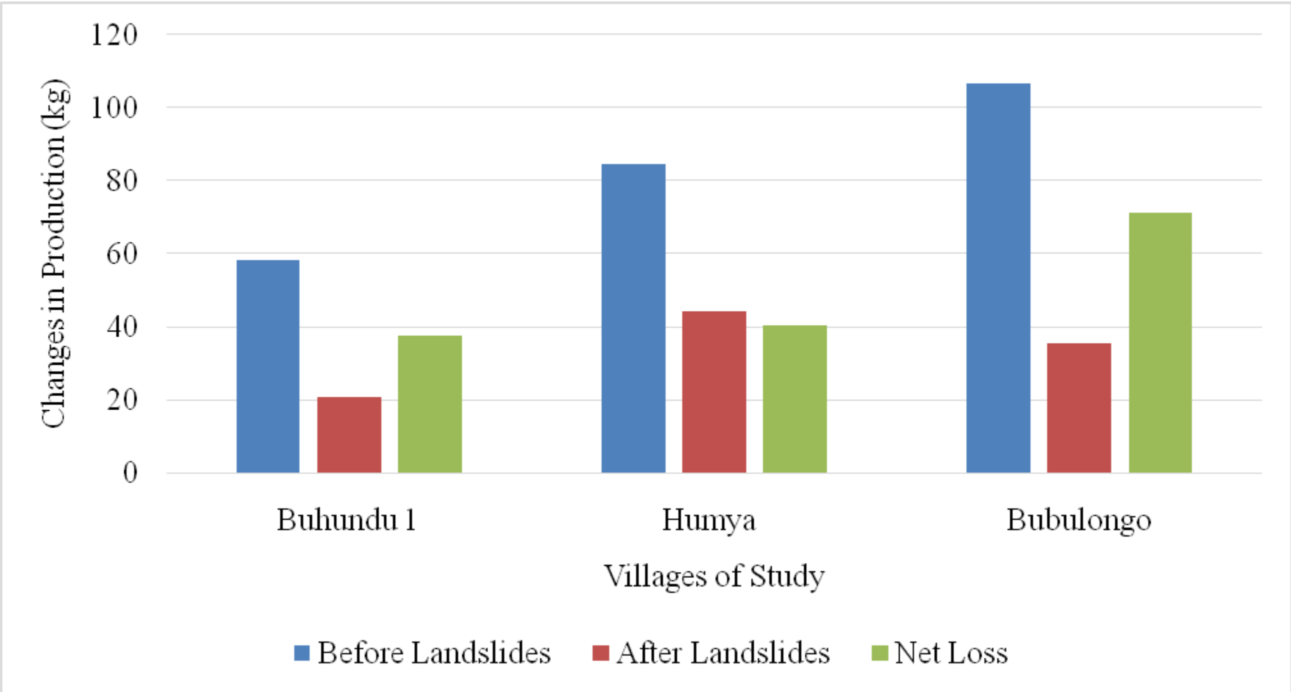

Figure 7. Changes in Production due to Landslides

a)

oils fractured by a landslide in Humya Village

b) A Slump on a landslide scar developing into a gulley due to surface run off on a farmland

Figure 8 : Indicators of landslides

c).An entire farmland swept into a stream in Humya village

d) Numerous crop fields seriously affected or lost on a steep slope in Buhundu 1village

Figure 9:.Farmlands affected by landslides in Humya and Buhundu 1 villages

4.4. Mitigation measures applied in Bubukwanga Sub County

Table 7 and figure 12 presents respondents' knowledge about possible mitigation strategies for landslides in Bubukwanga Sub County. A large percentage (71 %) of the respondents were aware of the different kinds of mitigations measures. Of these, 43% revealed that good mitigation measures can protect the top soil cover by keeping it intact while 28% were of the view that good mitigation measures can help to slow down the speed of water along sloppy areas. However, 30% of the total respondents revealed that they were not aware of the mitigation measures for Bubukwanga Sub County.

Table 7. Respondents' awareness of the importance of mitigation measures in reducing landslide occurrences

Awareness of mitigation measures (%)			
Yes	70.5	Protects the top soil cover	43.1
		Slowing speed of water	27.5
No	29.5	Don't know about mitigation measures	29.5

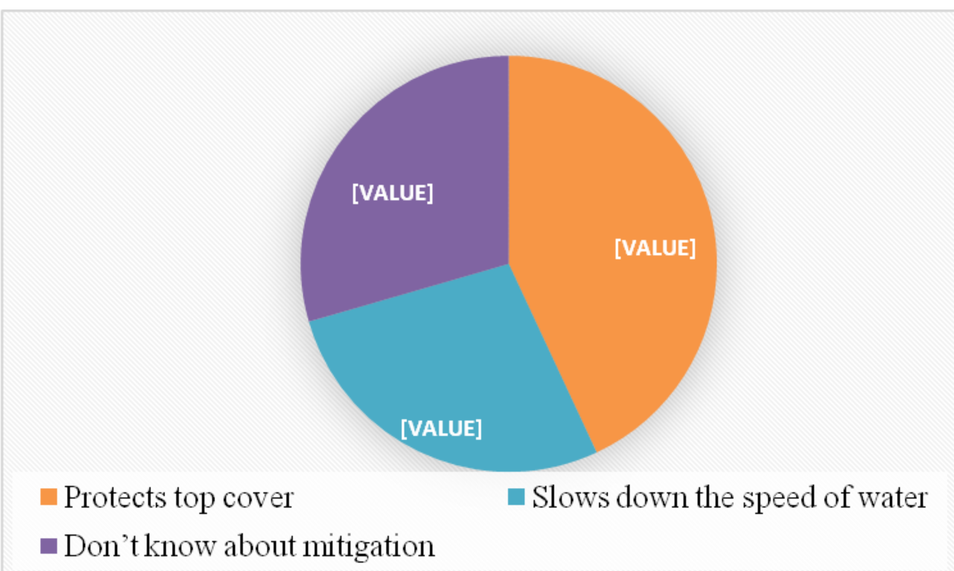

Figure 10: Respondent's knowledge about Mitigation measures

The results further revealed that, afforestation and terracing are most practiced mitigation measures in Bubukwanga Sub County. A total of 81.1% of respondents revealed that afforestation is the most practiced mitigation activity. However, 8.5% of these opined that it is strongly effective while 42.7% of respondents opined that the method is only effective. Also, 18.9% of respondents reported that terracing is one of the major mitigation measures practiced in the study area, with a total of 2.0% of respondents revealing that terracing is strongly effective mitigation measure.

Table 8: Response on level of effectiveness of mitigation measures

Level of effectiveness	**The major mitigation practices used (%)**		
	Afforestation	Terracing	Total
Strongly effective	8.5	2.0	10.5
Effective	42.7	10.0	52.6
Less effective	29.9	7.0	36.8
Total	81.1	18.9	100.0

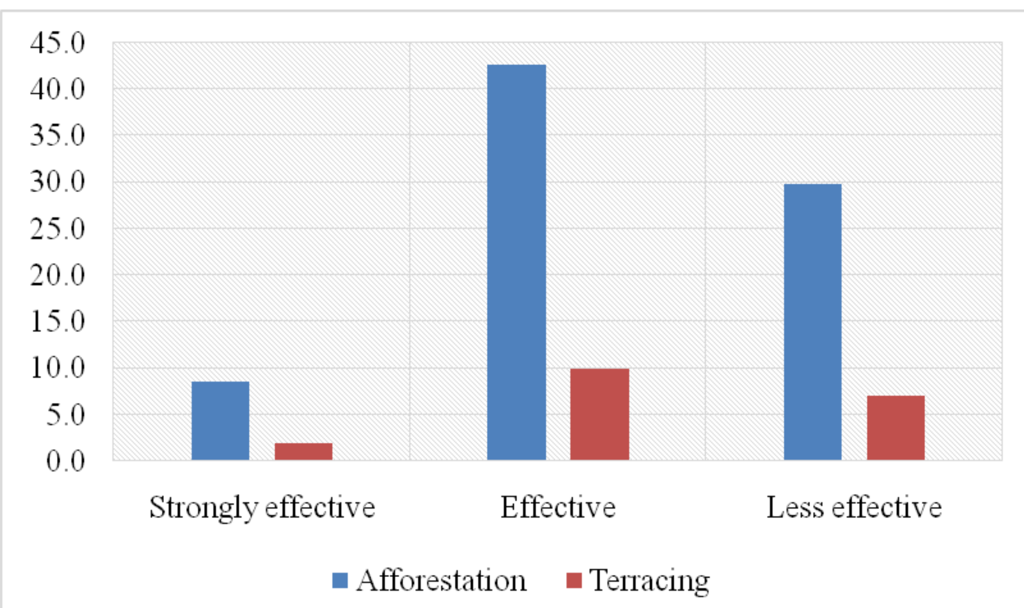

Figure 11: Response on perceived levels of effectiveness of mitigation measures

The results also revealed the different challenges faced associated with different mitigation practices. For example, as shown in Table 7, the majority of respondents (48.4%) revealed that trees take a longer time to mature, while 35.8% revealed that landslides continue to happen despite of mitigation measures applied.

Table 9: Respondents' perception of the challenges faced in mitigation of landslides

Challenges faced in mitigation	**Frequency**	**Percentage value (%)**
Trees take long to mature	46.0	48.4
Limited knowledge in farming practices	15.0	15.8
Landslides continue to happen	34.0	35.8

However, respondents revealed that they often get support from local organizations including but not limited to Esco Uganda limited (58.9%), Semuliki Co-operative (22.1%) and Bundibugyo Local Government (18.9%) (Table10)

Table 10. Organizations that support farmers in Bubukwanga sub county

Organizations approached for support	**Frequency**	**Percentage value (%)**
Esco Uganda Limited	56	58.9
Semuliki Co-operative	21	22.1
Bundibugyo Local Government	18	18.9

CHAPTER FIVE

DISCUSSION

5.1. Classification of landslides based on the identified characteristics

The study revealed that farmers are aware of the landslide indicators and their associated problems. This is evidenced by the farmer's knowledge on the seasonality (78.9%), continuity (12.6%) and permanency (8.4%) of landslides. As per the results of this study, communities were also aware that landslides break soils, cause slight movements of soil masses, crack rocks among others. By comparing the study results with Varnes (1978) and Cruden & Varnes (1996) classification of landslides, the study deduced that Bubukwanga landslides are probably grouped into topples, flows and complex landslides. During rainy periods, the sub county mostly experiences flows and these are associated with rapid mass movement of a mixture of water, soil, rock and moves in shear surfaces which are closely spaced and these are often non-persistent. The topples in Bubukwanga sub county are experienced due to rotations of masses of rocks and/or soil forwards after they are broken or weakened by other forces including water, wind waves, earthquakes among others (Keefer, 2002). The research has also deduced that some failures occur due to a combination of more than one type of movement for example due to topple and flow movements hence forming a complex movement. This conclusion is in agreement with Yilmaz & Ercanoglu, (2019) who recorded complex landslides in the Mount Rwenzori region. The continuous occurrence of landslides is probably explained by the difference in times when different landslides occur. Research by Broeckx, (2018) also recorded slides and rock falls in the Mount Elgon region. According to Nseka et al. (2019), knowledge on landslide occurrence increases the resilience of farmers to the landslide hazards. Using indigenous knowledge and experience, the local communities clearly identified the recently landscape-stricken areas from which length, width and slope measurements were ascertained. The respondents also indicated that landslides normally happen during rainy seasons.

In order to study more characteristics of landslides, community members participated in measuring slope length, width and slope gradient that can be used to ascertain slope angle. The study therefore established that slope gradient is directly related to slope angle which indicates the steepness of the slope. This is the angle formed between any part of the surface of the earth

and a horizontal datum. According to Fan et al. (2019) the slope angle provides the means by which gravity induces stress in the soils, rocks, water and other materials. Gomes & Kavzoglu, (2005) also added that slope affects the velocity of the surface and subsurface flow and hence soil water content and erosion potential. This is in agreement with McDermid and Franklin (1995) who revealed that landslides occur more frequently on steeper slopes and Nseka et al. (2005) indicated that places with a slope angle less than 20° have less landslide occurrences. With gradients lower than 20°c are considered to be safer in terms of failure initiation. Research by Stockton (2019) also indicated that slope failure tends to increase with slope angle but when the slope becomes near vertical, landslides are scarce or nearly absent altogether due to lack of soil development and debris accumulation in such topographic conditions (Selby, 1993). According to Jacobs et al. (2017) slope angle is the
main controlling topographic factor for landslides.

Slope length is also considered as a very important factor in landslide activity since longer slope lengths increase the potential of erosive agents to dislodge and transport of materials downslope. Therefore, longer landslide length indicated that downslope water velocity was greater due to longer slope or/and a greater slope angle which indicates the steepness of the slope. This research has therefore revealed that two factors increasing landslide occurrences in Bubukwanga Sub County that is slope angle and slope length. In addition, Carrara et al., 1995 indicated that slope length is very important in determining the travel distance of materials. In his experiment, Carara et al. (1995) indicated that slide density increases linearly with slope length up to a threshold value of about 500 m.

5.2 Impacts of landslides

Knapen et al. (2006) revealed that the East African highlands are prone to landslides because of their humid tropical climatic conditions, steep topography and high population densities. The research therefore noted that majority of people in Bubukwanga Sub County depend on agriculture established on small farmlands ranging between 0.5 and 2.0 hectares. These values have been confirmed UBOS (2016) which established that there are numerous intensively cultivated plots ranging between 0.5 and 2.2 hectares. Landslides have continuously degraded these farmlands making agricultural productivity exposed and sensitive to landslides with

Vanilla (12.6%) and Cocoa (78.9%) as affected crops in the study area as per the results of this study. The research results are also in agreement with Kato and Mutonyi (2011) who concluded that landslides have degraded farmlands and the environment Uganda's highland areas. According to Katutu et al. (2019) increased intensity of extreme weather events including landslides increases damages of agricultural land by causing erosion of nutrient-rich soils and weakening of soil layers which triggers more landslides causing a positive feedback phenomenon. In the same report Katutu et al. (2019) revealed that landslides had destroyed 95 plantations of food and 180 coffee plantations in the Rwenzori region. Key note respondents indicated that the degradation of farmlands led to heavy losses to farmers with reduced income output and the economy of Bundibugyo district yet in recent years, most of the farmers in villages have focused on cash crop production as they try to keep pace with the increasing costs of changing lifestyles and living expenses (Currenti, 2019). The research therefore determined an average of about 59.7% average losses of agricultural production incurred by each farmer due to landslide strikes in Bubukwanga sub county. Other resources destroyed by landslides include houses (48.4%), tree farms (35.8%) among others. Katutu et al. (2019) also reported that landslides had cracked 234 permanent houses and damaged 19 temporary houses in Bundibugyo district. However, Alexander (2013) has noted that human actions can have a significant impact on ecosystems due to the interdependence of human and ecological systems. Also, NEMA (2014) noted a vivid evidence of land mismanagement as a result of poor methods of cultivation that were associated with catastrophes in the Rwenzori highland region. The current research also found that farmers are inducing changes in the landscape to obtain terrain suitable to farming by modifying the slopes using terraces. However, terraces may be regarded as a human interference with the geomorphic system, which drives the evolution of the terrestrial surface (Sidle et al., 2006) and hence cause unexpected slides and flows and related impacts such as destroying of crops in the gardens.

5.3 Mitigation and resilience practices against landslides in Bubukwanga sub county

Mitigation practices are aimed at increasing resilience of agricultural systems towards the impacts of landslides in Bubukwanga sub county. According to Nseka et al. (2019), resilience to landslides is the ability of a system to anticipate, accommodate, absorb and effectively recover from the effects of a hazard in a timely manner. Maxwell et al. (2015) described resilience as the multiple ways a system can respond to hazard occurrence. It includes ensuring the preservation, restoration or improvement of a system's basic structures and functions (Arbon et al., 2012). This study found that farmers carry out afforestation, reforestation strategies to cope with the increasing occurrence of landslides. The tree woodlots consist mainly of eucalyptus (*Eucalyptus globulus*) and pine (*Pinus leiophylla*). The respondents argued that trees help to hold soil materials against the shear stress forces leading to their stability. The respondents also showed that tree woodlots reduce runoff of water along the slopes. This is in tandem with Katutu et al. (2019) who observed that the dense root system is capable of holding landslides and absorb a significant amount of water in the rainy season and consequently reducing the likelihood of landslide occurrence. Also, Nseka et al. (2019) indicated that slope segments covered by tree woodlots are less susceptible to landslides. The tree planting strategy has also been reported by Kato and Mutonyi (2011) on the slopes of Mount Elgon in Eastern Uganda. It can therefore be concluded that tree planting strategy has increased the resilience of agricultural communities to landslide hazards in this tropical highland environment (Nseka et al.,2019). However, Katutu et al. (2019) observed that in restraining landslides, tree species with very strong root systems should be recommended. These trees should be properly maintained until they are strong enough to have strong roots restrain landslides. At the same time, commercial interest to these trees should be low. Katutu et al. (2019) added that tree species of high commercial value such as eucalyptus, pines after certain period will be cut down for timber or firewood so at end, the purpose is not fulfilled. Hence the most appropriate species to plant could include *Ficus*, *Albizia julibrissin*, *Markhamia lutea*, which are not often used for firewood or building and have of low commercial as compared to pine and eucalyptus tree. According to Selby (1993), tree-covered hillslopes are thought to increase soil shear strength by about 60% depending on the tree type (e.g. podocarps and alfalfa) while Mehrotra et al. (1996) showed that landslide activity increases by up to 15% in those places where the original vegetation cover has been removed or altered

The study also established that farmers have responded to the increasing problem of landslides by adopting better and sustainable farming practices. There is a widespread use of soil conservation practices in Bubukwanga sub county. Such agricultural practices include terracing, crop rotations among others. Personal observations identified different cover crop farms and agroforestry practices. These agricultural practices are important for proper land management in the highlands (Nseka et al., 2019). Cabell & Oelofse (2012) also noted that community resilience to landslides can be improved through practicing agro forestry where crops are grown alongside trees to increase slope stability. Additionally, Barrett & Constas (2014) encouraged reforestation and environmentally sustainable farming practices such as terracing along hill slopes. The research found out that construction of terraces is not very widespread in the study area. However, Katutu et al. (2019) noted that at sites where they have been constructed, it may cause water stagnation and increased infiltration, which can lead to an increased pore water pressure and a higher landslide risk. During long period of heavy rainfall, these places become extremely unstable and landslides can occur.

Therefore, the most effective means of reducing quantity of landslides will be achieved if the population move from dangerous areas along the slope areas and introducing a dense planting of trees. Kitutu et al. (2019)

5.4 Conclusion

The research has identified landslides (flows, topples and complex movements) Bubukwanga sub county by comparing the characteristics revealed by the respondents with Varnes (1978) and Cruden and McGraw-Hill classification of landslides. It is however important to assess landslide risk by concentrating on the understanding of the factors which trigger landslide occurrence such as lithology, rainfall intensity, and human activities among others together with explicit studies of the landslide characteristics based on science. This research has also shown that carrying out forestry activities such as planting trees and shrubs can prevent or reduce the effects of several types of natural disasters by providing soil stability and slowing water speed hence reducing their intensity. This prevents the impact of wind and rain induced storms.

5.5 Recommendation

More scientific studies should be carried out to assess the triggering factors and impacts by different types of landslides. This will provide information for building sustainable resilience mechanisms through designing the most appropriate mitigation measures.

Studies should also be carried out on appropriate plant species that could be grown to regulate landslide impact in this area. Such studies should investigate the characteristics of the species including their growth rate, density of root system, density of crowns, mechanical strength, water absorption ability of the roots among others.

Studies on sustainable agricultural practices such agro-forestry, terracing among others should be done in Bubukwanga sub county. These should aim at identifying and establishing the most appropriate practices to be employed by farmers to reduce on the levels of vulnerability to landslides in the area.

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APPENDICES

Appendix 1: Questionnaire

Dear Respondent,

This is **AGABA JOHN** a third-year student at Makerere University pursuing a bachelor of Environmental Science. The questionnaire is to designed to generate information about the strategies established by farmers to mitigate the impacts of landslides in the affected areas and how these strategies are adopted, how effective are they, and the challenges faced when implementing them. It is strictly for research purposes and the information gathered from the respondent will be kept confidential. I therefore ask for your time to answer some questions and thankful for effective cooperation s

Do you have any questions?

…………………………………………………………………………….

INDIVIDUAL PARTICULARS

PART A GENERAL INFORMATION

Place of residence………………………………………………………………………………

Sex: Male …………………… Female ………………………..

Please circle/tick the correct alternative

1.

Age (circle against the age group you belong to)

A) 18-25 years

B) 26-35 years

C) 36-45 years

D) 46 and above

2.

Occupation: Employed……………. Unemployed………. Others………….

3.

Level of Education

Formal education ……. Informal ……. Others …….

PART B: **Identifying the different types and characteristics of landslides**

What type of landslides do you always experience in your area?

a) How do you identify the landslides in your area?

b)

c) How do you tell the landslides experienced in your area?

d)

e) What are the causes of landslides in your area?

f)

g) Where on the landscape do these landslides occur?

h)

i) How do these landslides move?

A) Fast

B) Slow

Do these landslides occur all of the sudden or they show signs of occurrence?

PART C: **quantifying the loss of small holders crops and other key property assets due to landslides**

1) Have you been affected by the occurrence of landslides in your area? YES …... NO …….

2) If yes, in which season do these landslides occur please specify the month(s)

3) How long do the landslides take place in your area?

4) Where do the landslides mostly occur?

5) In what areas do the landslides occur?

6) What are major causes of the landslides in your area?

7) Do you own the land affected by the landslides? YES ……. NO ……….

8) If yes, how much land has been by affected (in acres?)

a) < 1/2 acre

b) ½ acre

c) 1 acre

d) >1 acre

9) What has the land been used for before being affected by the landslides?

a) Crop cultivation b) settlement c) Livestock d) Building

10) If it was crop cultivation, what was the major crop grown affected by the landslides?

a) Cocoa) vanilla c) potatoes) cassava

11) How much produce were you receiving before the landslides occurred (in kgs.?)

……………………………………………………………………………….

12) How much produce do you get now after being affected by landslides (in kgs.?)

…………………………………………………………………………………..

13) How much money do you get from the produce (in she?)

Before landslides…………………………………. After landslides…………………….

14) To what extent were you affected by the impacts of the landslides in your area? (Tick your appropriate

Strongly impacted	
Moderately impacted	
Not impacted	

15) To what extent have the landslides affected the following classes of people in your area? (Strongly affected, moderately affected, less affected)

Classes of people	Rate of impact
Wealthy	
Middle income earners	
Low income earners	

16) How have you directly been affected by landslides and how much in terms of costs?

Effect	Cost in Gush’s
Loss of crops	
Loss of tress	
Loss of livestock	
Loss of house	
Others specify	

PART D: **Strategies adopted by farmers to mitigate the impacts of landslides**

a)

Are you aware of any mitigation measures to control the impacts of landslides? YES….NO…….

b)

What mitigation measures do you use to control the landslides?

c)

How effective are your measures stated above being applied (measures to be ranked using a scale of (Rank 1=strongly effective; ,2= Effective,3 less effective)

Mitigation measure	Rank

d)

Why rank those mentioned measures in that way?

…………………………………………….

e)

What challenges have you encountered when mitigating the impacts of landslides, please specify

…………………………………………………..

………………………………………………………

f)

What assistance have received to address the problem of landslides

……………………………………….

………………………………………..

g)

Have you approached any organization (s) in mitigating the impact of landslides YES… .NO…?

If yes, please specify the organizations

………………………………………………………………………………………………...

………………………………………………………………………………………………...

……………………………………………………………………………………………….…..

h)

How are these organizations getting involved in mitigating the impacts of landslides?

……………………………………………………………………………………………...

……………………………………………………………………………………………...

i)

What challenges have these organizations faced in mitigating the impacts of landslides

………………………………………………………………………………………………

………………………………………………………………………………………………