

Disaster Preparedness and Mitigation Measures of the Kapkese Landslide in Kipkelion District, Kenya

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Abstract – The Kapkese landslide disaster has recurred (December 2015) from the heavy El Nino rainstorms sweeping Kenya. The village is located in Kokwet Location, Kipkelion West Constituency, Kipkelion District, Kenya. This has again caused harmful geoenvironmental hazards to the villagers who have migrated to safer areas, far from their original homesteads. In May 2003, a mother and her three little daughters were killed when their hut was buried in a similar landslide. The existing landslide vulnerability occurrence ratings have been identified and documented using participatory approaches. The adoptive indigenous methods, which helped mitigation against the negative impacts, were useful while determining the slope steepness using Abney level and other inherent factors that triggered the landslide. The geological set up, settlement and climatic factors relating to landslides, revealed that the affected homesteads are on a steep slope of approximately 80%. The underlying Tertiary volcanic rocks (basalts and nephelinites) on the steep escarpment where the landslide occurred, consists of loose debris and unconsolidated thick black cotton soils. The slope has scattered vegetation cover due to extensive farming of mainly maize and coffee plantations. The landslide disaster is a precursor to loss of lives, injuries and damage to property. Natural resources, including water points, suffered siltation. Mitigation measures such as geohazard mapping and zoning, construction of support structures, encouraging agro-forestry on vulnerable steep hill slopes and hazardprone areas resulting from poor land use practices, have been recommended.

Keywords: *Kapkese, Landslide, landuse, slope, mitigation preparedness measures, volcanic rocks, geo-hazards.*

1. Introduction

The Kokwet escarpment areas (where Kapkese Landslide occurred in December 2015) located in Chilchila Division, Kipkelion District, Kipkelion West Constituency, are predominantly occupied by the *Kipsigis* tribe. It borders Tindiret Forest Reserves. The area is sparsely populated with the inhabitants mainly living on the steeper inclined sloppy areas on the top of the ridges or on the lower gentler slopes near the rivers, leaving the steeper middle slopes for cultivation. The population of Chilchila Division was 8,717 according to 1999 census. Its projected population for 2008 was 10,197 (Government of Kenya, 1999).

Farming activities are practiced mainly for economic subsistence. Some tomatoes, bananas, sugarcane and potatoes are grown in small scale. Maize and coffee are cultivated for major family income generation. Large indigenous forest trees at the forest edge have been cleared leaving shrubs and a few patches of thin forests on stony, steeply sloping land (Fig.1, Plates 1-7).

The study area is hilly with the parallel ridges that run in a N-S direction. The steep areas of the ridges dip both toward the east and west. It is at Kapchorua ridge, Kapkese village (Kokwet location) that four persons perished in May 2003 after a landslide buried them in their house. Last year (December, 2015), villagers migrated to safer grounds when heavy rains commenced, thus no casualties were reported as the MP (Hon Jackson Rop) had sensitized the people on the impacts of these geo-hazard prone areas to their lives.

The literacy level in the area is moderate.

The mapped area (Ahmed and Almond, 1983) covered a total area of 15 sq. km (5km long and 3km wide). The geology of the study area,

where the mass movement occurred, is mainly composed of the Tertiary analcite and nephelinite volcanic rocks, which have weathered into black clay cotton soils (Binge, 1962). The slope has scattered vegetation cover due to intensive farming of maize and coffee plantations.

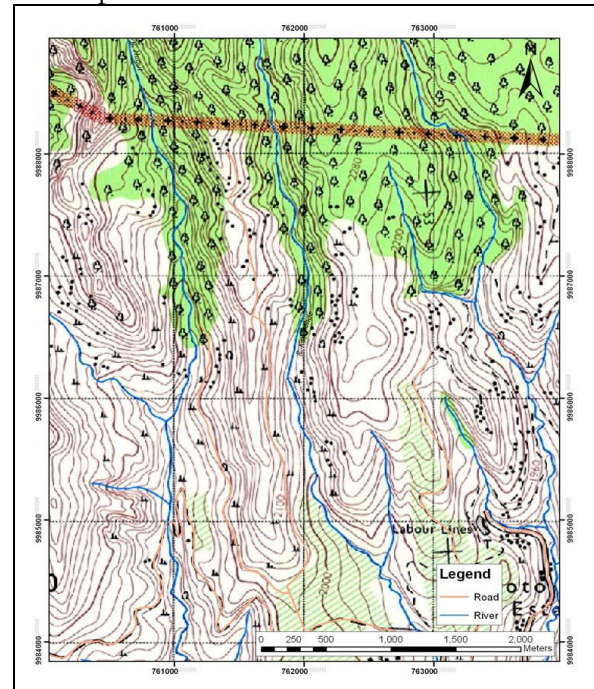


Fig. 1: Map showing the study area affected by landslides

The area was initially under indigenous forest until 1978 when it was sub-divided for settlement purposes. This led to clearance of vegetation to pave way for cultivation and settlement.

2. Materials and Methods

2.1 Definition: A *landslide* or *landslip* is the sliding of a large mass of rock material, soil, etc. (Figs.3, 4), down the side of a mountain or cliff (Allaby and Allaby, 1990; Cunningham and Siago,2001). This takes place on a definite plane, which may be a structural plane, e.g. bedding, joints,

schistosity, etc. Sometimes, because of torrential rains, the pyroclastic material resting on the mountain slopes becomes saturated with water and moves as a *mud flow* or *lahar* (Allaby and Allaby, 1990).

Landslide, also called mass wasting (*mass movement*), is a general term for the transfer of earth material downhill slopes as in the case of the present site (Kapkese village, Kipkelion District). Mass movement includes four main categories: *flow*, *slide*, *fall* (rock fall) and *creep* (Cunningham and Siago, 2001).

Of these, *creep* is the most important if least spectacular. It is the result of gravity acting on material that has lost cohesion typically as a

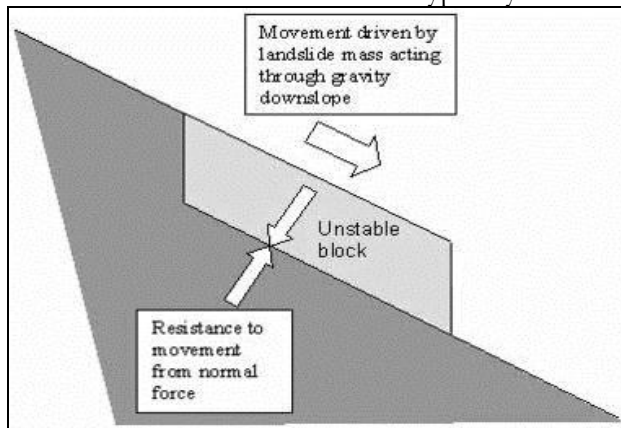


Fig. 2: Diagram illustrating the resistance to, and causes of, movement in a slope system consisting of an unstable block

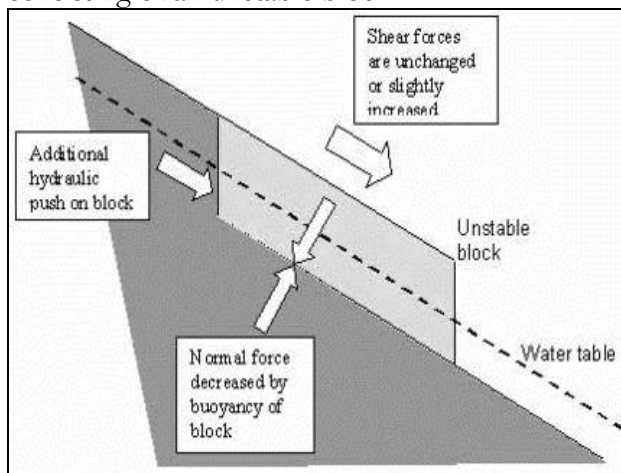


Fig. 3: Diagram illustrating the resistance to, and causes of, movement in a slope system consisting of an unstable block

result of an increase in water content. An avalanche is a rapid and often destructive flow of rock or snow. A slide (or landslide) is a comparatively rapid displacement of Earth material over one or more failure surfaces, which may be curved, or planar (Wikipedia Encyclopedia, 2007):

2.2 Causes of mass movement

Weathered material can move down hill slopes under the influence of gravity, with or without the assistance of running water like the Kapkese's area case (Figs. 2, 3). This movement under the influence of gravity is called mass movement. Gravity exerts a constant pull on all Earth material (stress). Weathered material on slope would immediately slide down to the river (valley) were it not for the fact that it possesses certain strength (Figs. 3, 4), which is due to a number of material properties (Allaby and Allaby, 1990):

1. All particles have rough surfaces, which result in friction between touching particles.
2. The shape of the particles may cause them to interlock like the pieces of a jigsaw puzzle.
3. The clay particles of weathered material attract each other by electric forces, which produce cohesion between particles.

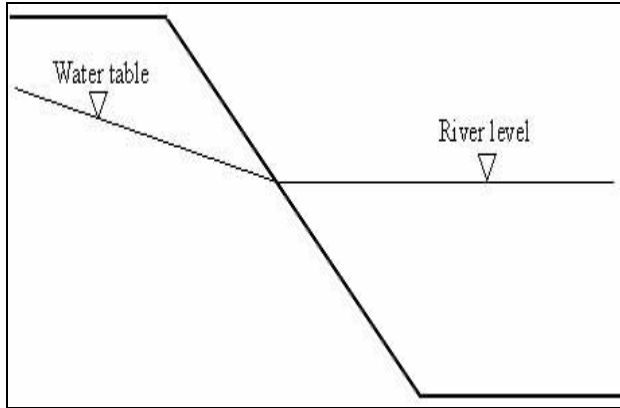


Fig. 4:: Groundwater conditions when the river level is stable.

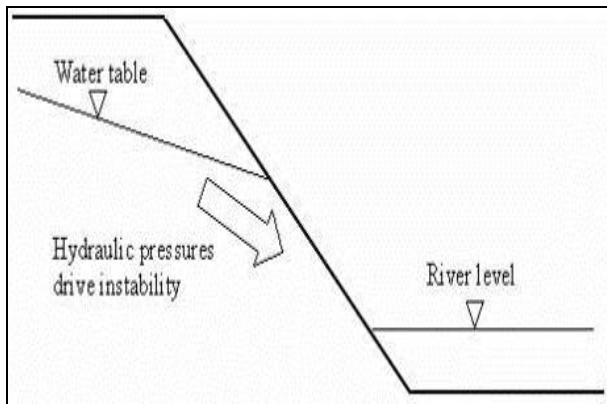


Fig. 5: Groundwater conditions on the falling limb of the hydrograph. If the fall in river levels is sufficiently rapid then the high water levels in the slope can provide a hydraulic push that destabilises the slope, sometimes triggering bank collapse (Siddhartha K. (1999).

Thus mass movement occurs when the stresses acting on the material, exceeds the strength of the material. Alternatively, the strength of the material may be decreased suddenly by a rise in water content, which forces the particles apart. This can be expressed as a factor of safety, F_s .

$$F_s = \frac{\text{Strength of shear resistance of material}}{\text{Magnitude of stress}} \quad (1)$$

Thus, when F_s is less than 1.0 the slope will fail. This is brought about by the application of increased stress due to changes in conditions external to the slope, which increases the denominator, or by the internal processes that weaken the slope material thereby decreasing the numerator. In most cases, failure will result from a combination of both processes, an increase in shearing forces and a decrease in resistance to shear (Allaby and Allaby, 1990; Ahmed and Almond, 1983; Lugens and Tarbuck. 1982)¹.

In simple terms, mass movement can be related to a set of the following five conditions:

1. When the soil and the mantle rock are loose or poorly consolidated and deeply weathered.
2. The angle of repose (depends largely on the shape of the fragments which control the angle at which the fragments interlock while falling) of the regolith and the degree of inclination of the strata (Figs. 2, 3).
3. Presence of thin beds which increase the tendency of movement because there are more bedding planes along which slipping can occur.
4. Moisture content of the soil – movement is greater in very wet weather, particularly after long dry spells (Figs. 4, 5).
5. Conspicuous absence of vegetation cover without which the soil stability is reduced.

2.3 Slope measurement

Since the settlement of the locals in the area, the forest cover has been continuously been cleared to pave way for settlement and cultivation. The wood products have also been a source of building materials (Plate 1). The high demand of wood products from outside the area also contributed to the depletion of the vegetation. This led to bare steep slopes, susceptible to landslides and soil

erosion (Ahmed and Almond, 1983; Kipseba et al., 2008; Ndola, 2005).



Plate 1: Kapchorua area showing over-cultivated areas in steep slopes with the forest area at the background of the first photo.

The slope data in the study were obtained by direct measurements using Abney level (equation 1).



Plate 2: Very steep Kapkese slope where landslide occurred in December 2015

3. Results and Discussion

3.1 Landslides

An old, active landslide was observed between GPS positions 0761185, 9987004 and

0761184, 9987104. This landslide has a width of 106m and a length of 100m. The average slope in the affected area is 30° towards the west. Water flows from an erosional gully from the ridge and disappears at the crest of the landslide resulting in a waterlogged area. This water saturates the soil and causes a slow slumping movement near the scarp of the landslide and consequently a slow creep at the toe of the landslide. This area is at the moment being utilized as grazing area.

Between GPS positions 0761064, 9987740 and 0761075, 9988058, the area is highly prone to landslides. Eight old episodes of landslides were observed in this 200m span, including the fatal 2003 landslide at GPS position 0761096, 9987800. The fatal landslide measured 50m long and 15m wide. Debris of these landslides is mainly black cotton soil laden with rock boulders.



Plate 2: Kapkese's Landslide site with gushing waters on slopes ranging from 60° to 80° , in a

general westward direction (Area MP with inhabitants inspecting the disaster-prone area).

3.2 Debris flows

Debris flows are common in the area. They are normally triggered on the upper slopes of the ridges, flowing through erosional valleys and end up in the rivers. The most serious debris flow happened in 1998 from GPS point 761466, 9987198 and flowed into Mugut River at 0761066, 9987060. Another smaller debris flow occurred in 2005 from GPS point 0761160, 9987830, flowing into Mugut River at GPS point 0761042, 9987650.

There are other numerous, smaller debris flows on other parts of the ridges-Plates 2 &4.



Plate 4: Photograph of Kapkese steep slope (behind Dr. Rop background) and a river valley (December 2015).

3.3 Rock Falls

Rock falls are common on all the slopes below the ridges in the area. They are however more common on the steeper slopes that are under cultivation, especially during or after heavy rains.

This situation is clearly observed on the western slopes of Kapchorua ridge. The boulders are of various sizes which rarely exceeds 2m in diameter. The slope of the ridges on the inhabited area has an inclination angle of up to 60°.



Plate 3: A rock that rolled from the top of the ridge in September 2008

The study established the following in relation to the past landslides/mass movement incidents:

Source1:

Village elders recalled that there have been three incidents prior to this, in 1998, 2003 and 2005; which occurred during the day and there were no fatalities.

Currently, the affected area is approx. 106m x 100m.

3.2 Landscape and geomorphological analysis – Kokwet escarpment at Kapkese village

1. Landscape - Very steep slope of more than 80°. The slope (Ahmed and Almond, 1983; Cunningham and Siago, 2001) increases towards the top of the escarpment (measuring approximately 80m ground distance) - (Fig. 6).

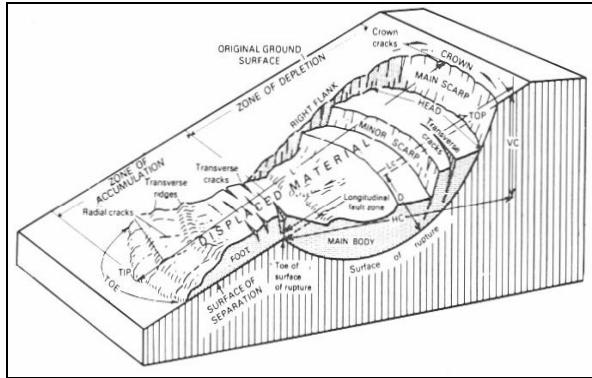


Fig. 6: Nomenclature employed in describing landslides. (Varnes, 1978, in Schuster and Krizek, eds. Landslides - Analysis and Control)

Several cracks filled with water observed a day before the disaster.

Cracks developed after the heavy rains in April – May 2003.

2. Geology and Geomorphology (Fig. 6): The analcite basanite and tephrites overlie the nephelinites. This formation is composed of soft rocks which are easily weathered into black cotton soil. This explains why the area has a thick soil cover of high fertility requiring no fertilizer.

Deep weathering (chemical) has occurred.

- Soaked regolith slumped down the slope at very high speed.
- Soft rock debris, with sticky soils.
- Heavy sludge-like materials rolled to the faults cape toe.

3. Hydrology - Several streams originating from the foot of the forested escarpment. The general drainage of the study area is towards the south. The two main rivers draining the area are Murgut River to the west and Kipsinende River to the east of the study area. Kapkese stream is tributary of Murgut River that drains from the North West. The slopes have some permanent springs which serve as sources of domestic water supply.

Water filled the crack prior to the disaster.

4. Geomorphology (Fig. 6):

The area has its lowest elevation as 1760m near Kokwet market to the south. The highest elevation of 2440m is at the northern part of the area in the forest. The entire area consists of N-S trending ridges that continuously rise northwards.

Escarpment baseline composed of dunes due to soil creek (slow movement of materials); an evidence of potential slope failure.

- Rock boulder/debris found at the escarpment baseline, evidence of the past rock fall.
- Several deep valleys, with stream flows at the escarpment baseline, indication of sub surface drainage.

The Kapkese landslide was probably triggered by removal of trees and other slope vegetations, which subsequently weakened the anchorage holding the overburdens (soils and rocks) on the major Kokwet Escarpment slope or fault zone area (Figs. 6, 8). Thus the weight of the loose soil and rock materials could have increased to the extent that the vertical slope (about 85°) became unstable hence failure, resulting in the mass movement.

5. Rainfall (Fig. 7)

The area receives high rainfall for most of the year. The temperature is generally cool with an average annual temperature of about 20°C and high humidity.

The area receives its highest rainfall in March to June and the lowest in the months of December and January. It has two rainy seasons, long rains between March and June and the short rains between August and October.

Rainfall data for the last six years are shown in the figure below:

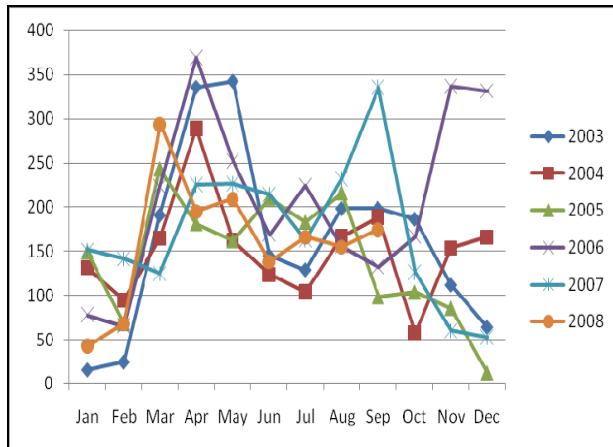


Fig. 7: Graphs of rainfall for the last six years

The highest annual rainfall received in the last six years was in 2006 when 2504mm was received. The lowest rainfall in the same duration was in 2005 with 1711.1mm. In 2003 between April and May, a total of 678mm was recorded (335.6mm in April and 342.4mm in May). This was when massive landslides occurred in the area and killed four family members.

Between November and December 2006, 668.5mm of rainfall was recorded (336.8mm and 331.7mm respectively). Several landslides also occurred in the area.

1. One of the most likely factors that led to the mud flow is inappropriate land use.
2. The slope in question consists of three categories of slope namely (Fig. 8); 80% along the Kokwet escarpment with an east/west aspect with a slope length of 100-200m 20-35% below the above slope for about 50m 20% at the bottom.
3. The steepest slope was deforested and cultivated in some places and some and some with dwellings. These are the structures that were destroyed together with human life on the disaster struck.

4. The cultivated field slopes were planted with maize.
5. The secondary slope of 30-40% was planted mainly with sugar cane.
6. This is the area with very deep soil material it appears over the years, soil masses have been washed to this area.
7. The lower slopes (20-30%) carries most of the residential and farming (maize, millet, bananas) activities.

The greatest risk of mud flow is >80% slope. But again, it is only that slope which had been deforested, and cultivated for maize (annual) crop. Where there were human settlements.

8. The soils are consolidated and appear to hold water hence where there was too much rain; the soil became saturated with water and followed along the slope thereby causing the disaster.

3.3 Geo-environmental Impacts

3.3.1 Impacts (Effects)

All landslides degrade the land in which they occur, rendering the land uneconomical and dangerous to live in. The landslide scars are usually bare and infertile whereas the landslide debris is loose, relatively flat and fertile. The locals settle on these fertile and flat areas regardless of their instability (Kipseba et al., 2008; Ndola, 2005).

The immediate impacts of the landslides in this area are loss of life, crops, trees, pasture and rich soil. Long term impacts include loss of soil fertility and continued erosion (leading to food shortages), trauma from fear of another occurrence or loss of land.

3.3.2 Causative Factors (Analysis)

There are two main categories of factors that influence the occurrence of a landslide. These are inherent factors and triggering factors. Inherent factors create a conducive environment for the occurrence of a landslide

and include geology, slopes, vegetation cover and type of drainage.

Triggering factors: trigger the movement and include rainfall, earthquakes and tremors (vibrations), blasting, machinery, thunder and human activity. The landslides in this area were a result of most of these factors as described below.

I Inherent Factors

a) Slope gradient

It is a very important factor due to influence of gravity. In the area, the slope inclination is generally high along the hill slopes. Some parts are almost vertical (Plates 5, 6).

b) Geological criteria

This includes the type of overburden such as soils and their mechanism and the physical and chemical properties of the underlying rocks.



Plate 5: A homestead constructed on old landslide debris, an unstable ground.

The soils in the study area are black cotton soils with high fertility and support crop cultivation. The area has a thick soil cover.

c) Structural criteria

This refers to the nature of fractures and joints on the underlying rocks or bed rocks. The rock formation in the area is soft and easily weathered.

d) Hydrologic criteria or Moisture content

This accounts for the amount of underground water content or nearness of the water table in the area. Under normal circumstances high

potential areas receive high rainfall whose percolating water is trapped between the overburden and the impermeable rocks. This water lubricates the interface between the two surfaces triggering mudflows or debris flow. This area receives over 1700mm of rainfall annually and therefore the soils are always wet. Permanent water springs are common in the area.

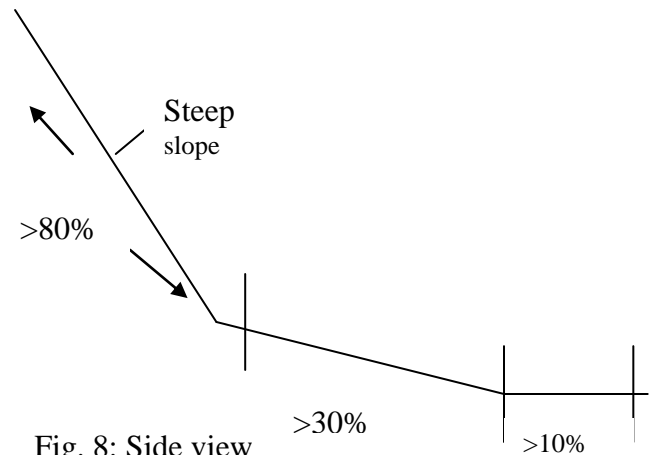


Fig. 8: Side view cross section (Not drawn to scale)

e) Vegetation

Vegetation on steep slopes helps in holding the soils together. The roots system increases the shear strength of the soils hence enhancing cohesion. Vegetation also reduces the surface run off of water during rainy seasons.

On the negative side, mechanical forces resulting from wind blowing vegetation cause instability to the soils. Nonetheless, in general terms, vegetation cover promotes stability of the ground.

In this area, the locals cultivate the steep slopes and are continuously removing the vegetation cover on the upper parts of the slopes (Plates 6, 7).



Plate 6: Steep slopes that have been cleared for cultivation. Note the poor soil conservation measures



Plate 7: Cultivation and settlement on the steep slopes

II Triggering Factors

a) Rainfall

Rainfall increases the water content in the ground. This results in the conditions described in (1, d) above.

b) Human activities

Like natural factors, man's activities such as clearing of vegetation, farming, building, quarrying and blasting, construction and other engineering works trigger landslides. The human activities that have contributed to landslides in the area are as follows:

i. Clearance of vegetation. This started when the locals first settled in the area.

This was done to give way to settlement and cultivation.

ii. Cultivation was observed to have been done on a larger part of the slopes.

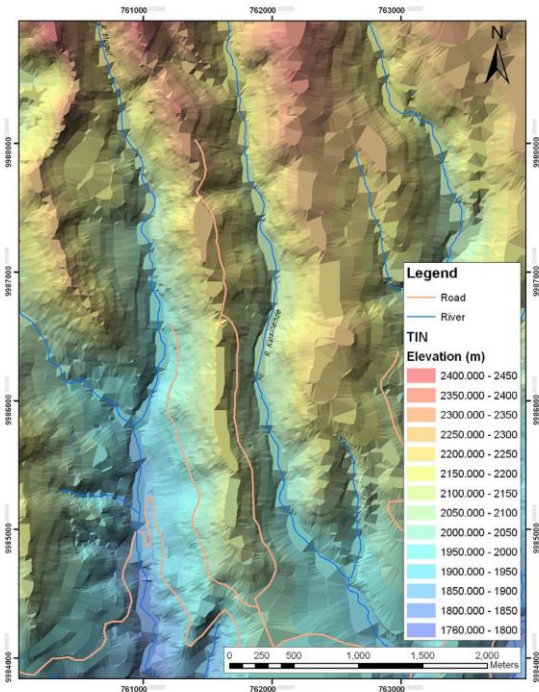
Soil conservation structures are totally lacking in the area.

3.3.3 Risk Analysis

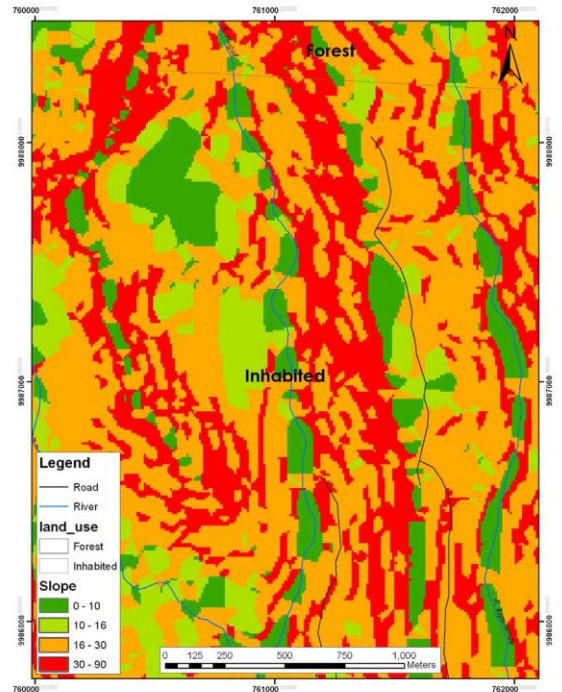
The data which was collected from the field together with the basic (topographic) data was used to categorize the landslide risk in the study area (Maps 1,2,3,4,5). The analysis of the landslide risk took into consideration four parameters (factors) namely slope, population, proximity of old landslides and land use. The results of the slope analysis are illustrated in the maps below.

Areas with a slope of between 0° and 16° were categorized as "Relatively Safe", 16° to 32° as "Moderate Risk" to landslides, and above 32° as "High Risk".

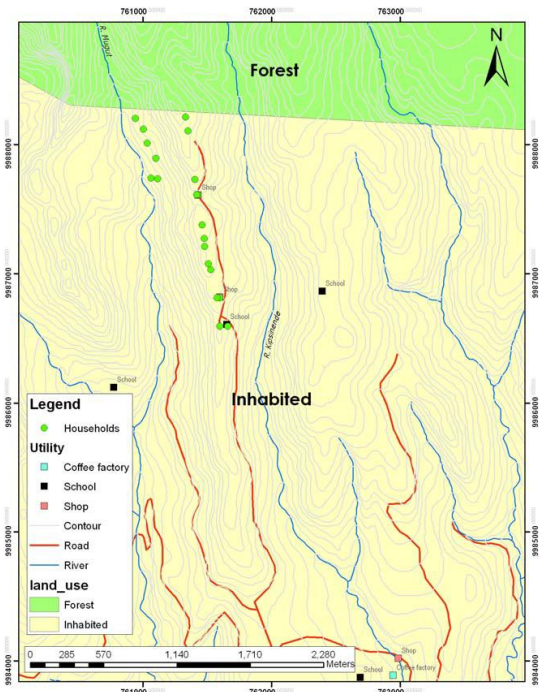
The risk associated with smaller slope is because the slopes have been generally cleared for cultivation. This is mainly due to expansion for more fertile land where artificial fertilizers are not required by the crops.



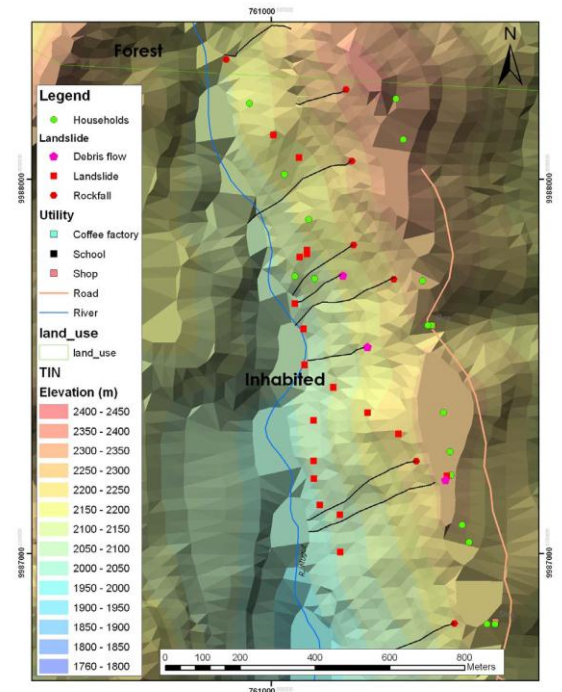
Map 1: 3D map of the area



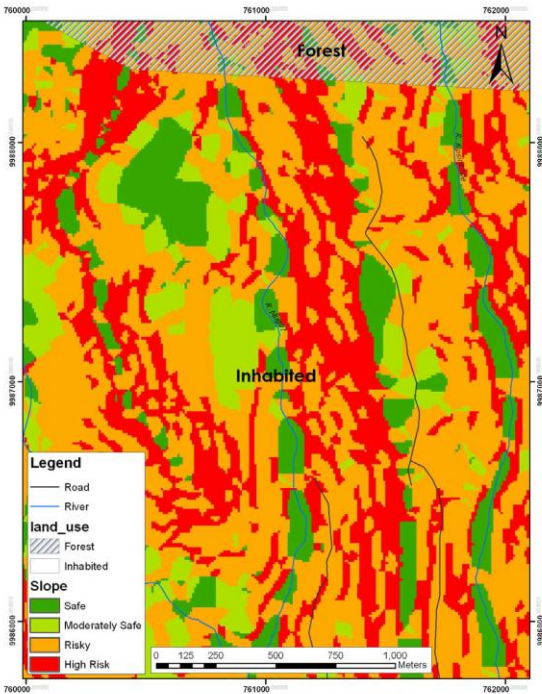
Map 3: Slope map of the area



Map 2: Land use/ Land cover of the area. Note that the households have been highlighted for the area most affected by landslides. Other areas are more populated



Map 4: Location of landslides on the map. Debris flow and rock fall paths are shown by the black lines



Map 5: Landslide Risk map of the area

3.3.4 Land Use – Agriculture & Livestock

The land use in the area includes:

1. Cultivation of subsistence crops e.g. maize, beans, millet, vegetables, sugar cane and fruits
2. Cultivation of coffee as a main cash crop
3. Settlement
4. Exotic trees on the slopes of the hills
5. Livestock and pasture

The top soil on the newly cultivated areas of the slopes is fertile, whereas the eroded areas and those that have been affected by landslides are rocky and not fertile. However areas covered by old landslide debris are very fertile. It also forms a relatively flat ground on which locals build their homesteads. The land-cover on the slopes has been depleted for cultivation, leaving it very susceptible to soil erosion and landslides.

Approx. 0.7 acres of maize, vegetables and some tree stems, a few years old, were destroyed by the mud and debris/rock falls.

Cows, goats, sheep and cats were not affected.

3.3.5 Buildings

One house with common household property in one homestead was buried together with four persons by landslide.

3.3.6 Water Resources

The stream natural water at the lower end of the rivers in the affected area suffered siltation.

3.4 Mitigation Measures

The mitigation measures are proposed as follows:

- ✓ Planting of deep rooted trees on steep slopes.
- ✓ Discouraging cultivation on steep slopes
- ✓ Discouraging settlement on steep slopes
- ✓ Stop vegetation clearing
- ✓ Putting up of soil conservation structures
- ✓ Constructing support structures on vulnerable areas
- ✓ Encouraging agro-forestry in the area
- ✓ The hill slopes should be zoned and the steep areas should be vacated
- ✓ Residents of the area to be moved to less steep areas
- ✓ Plant trees on the steep slopes
- ✓ Introduce bee keeping in order to motivate residents to participate in an income generating activity
- ✓ Educational seminars on public awareness about land use and zonation.

4. Conclusion and Recommendation

The disaster was as a result of regolith slump facilitated by steep slope and infiltrating water in to the deep weathering regolith (Figs. 1 - 8).

Landslides are natural phenomena whose causative factors have substantial human contribution.

In order to avoid such Geo-environmental hazards in future, there is need to map and identify (Patwardhan, 1999):

- The slopes in the study area which are susceptible to landslides; and much effort is needed from all stakeholders in conserving the slopes
- The main triggering factors of the landslides are over saturation of water in the soil due to heavy downpour, depletion of vegetation on the steep slopes and other human activity
- The western slopes of Kapchorua ridge is very unstable and not fit for human settlement

From the observations made, it is therefore recommended that:

- i. There should be no settlement on the steep slopes in the area,
- ii. There should be no cultivation on the steep slopes,
- iii. Reforestation of the entire western slopes of Kapchorua ridge is necessary in order to restore slope stability,
- iv. The residents living on steep slopes should be relocated to safer ground,
- v. Soil conservation structures should be constructed in the area, and
- vi. Sensitization of the local communities should be done through seminars and workshops

Acknowledgements

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