

Overview of Landslide Occurrences in Kenya

Causes, Mitigation, and Challenges

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1 INTRODUCTION

Landslides and other forms of ground failure affect communities all across the nation. Despite advances in science and technology, these events continue to result in human suffering, billions of dollars in property losses, and environmental degradation. As the population increases and the society becomes ever more complex, the economic and societal costs of landslides and other mass-wasting processes will continue to rise.

The term ‘landslide’ describes many types of downhill earth movements, ranging from rapidly moving catastrophic rock avalanches and debris flows in mountainous regions to more slowly moving earth slides and other ground failures. In addition to the different types of landslides, the broader scope of ground failure includes subsidence, permafrost, and shrinking soils. This chapter focuses on landslides, the most critical ground-failure problem facing most regions of the country.

Landslides are a significant component of many major natural disasters and are responsible for greater losses than is generally recognized. Landslide damage is often reported as a result of triggering events such as heavy torrential rains, floods, earthquakes, or volcanic eruptions even though the losses from landsliding may exceed all other losses from the overall disaster.

Landslide losses are increasing in Kenya and worldwide as development expands under pressures of increasing populations (Kenvironews, 2007). The resulting encroachment of developments into hazardous areas, expansion of transportation infrastructure, deforestation of landslide-prone areas, and changing climate patterns may lead to continually increasing landslide losses. However, an increase in the cost of landslide hazards can be curbed through

better understanding and mapping of the hazards and improved capabilities to mitigate and respond to the hazards. Being among the most widespread geologic hazards on Earth, landslide losses and damages can amount to hundreds of millions of shillings and hundreds of deaths.

We have the capability as a nation to understand and identify these hazards and to implement mitigation measures. For many years, the Department of Mines and Geology under the Ministry of Environmental and Mineral Resources (recently renamed Ministry of Mining), the Kenya Red Cross Society, numerous universities, and the private sector have been grappling with understanding and reducing landslide hazards, and they have developed an extensive body of knowledge. However, to achieve the goal of significantly reducing losses from landslide hazards, we need a much more comprehensive scientific understanding of landslide processes and occurrence, a robust monitoring programme to warn of impending danger from active landslides, a much greater public awareness and understanding of the threat and the options for reducing the risk, and action at the local level.

A significant, sustained, long-term effort to reduce losses from landslides and other ground failures in Kenya will require a national commitment among all levels of government and the private sector. The central government, in partnership with county governments, must provide leadership, coordination, research support, incentives, and resources to encourage communities, businesses, and individuals to undertake mitigation to minimize potential losses and to employ mitigation in the recovery following landslides and other natural hazard events.

2 TYPES AND CAUSES OF LANDSLIDES

The term 'landslide', by definition, describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil/earth, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing due to gravity. [Figure 1](#) shows a graphic illustration of a landslide, with the commonly accepted terminology describing its features.

The various types of landslides can be differentiated by the kinds of material involved and the mode of movement. A classification system based on these parameters is shown in [Table 1](#). Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief where such landslides occur as cut-and-fill failures (roadway and building excavations), river bluff failures, lateral spreading landslides, collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and

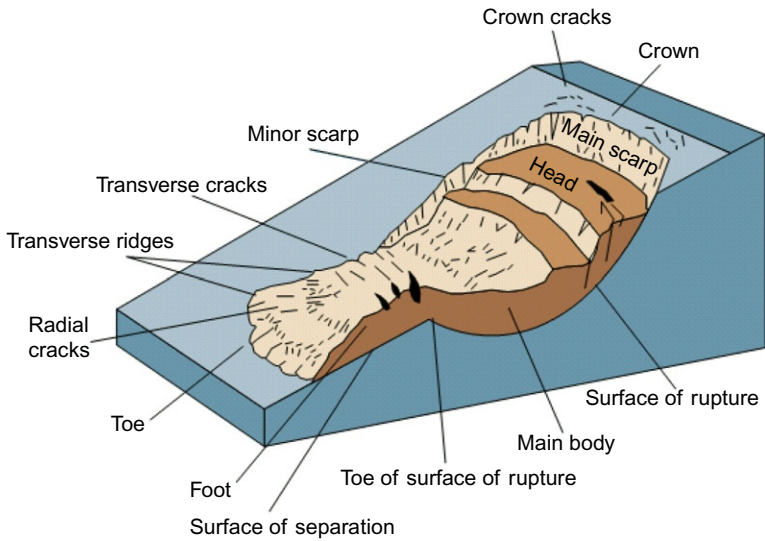


FIGURE 1 An idealized slump-earth flow showing commonly used nomenclature for labelling parts of a landslide. *Source:* <http://pubs.usgs.gov/fs/2004/3072>.

TABLE 1 Types of Landslides

Type of Movement	Type of Material		
	Bedrock	Engineering Soils	
		<i>Predominantly Coarse</i>	<i>Predominantly Fine</i>
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides			
Rotational	Rock slide	Debris slide	Earth slide
Translational			
Lateral spreads	Rock spread	Debris spread	Earth spread
Flows	Rock flow (deep creep)	Debris flow (soil creep)	Earth flow (soil creep)
Complex	Combinational of two or more principal types of movement		

Source: <http://pubs.usgs.gov/fs/2004/3072>.

open-pit mines. The most common types of landslides are described as follows and are illustrated in [Figure 2](#).

2.1 Slides

Although many types of mass movements are included in the general term ‘landslide’, the more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from more stable underlying material. 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 ([Figure 2a](#)). **Translational slide:** In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting ([Figure 2b](#)). 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 downslope as a relatively coherent mass ([Figure 2c](#)).

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 ([Figure 2d](#)). Separation occurs along discontinuities such as fractures, joints, and bedding planes, and movement occurs by free fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water.

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 ([Figure 2e](#)).

2.4 Flows

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

- a. *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 mobilizes as a slurry that flows downslope ([Figure 2f](#)). Debris flows include <50% fines. Debris flows are commonly caused by intense surface-water flow, due to heavy precipitation 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

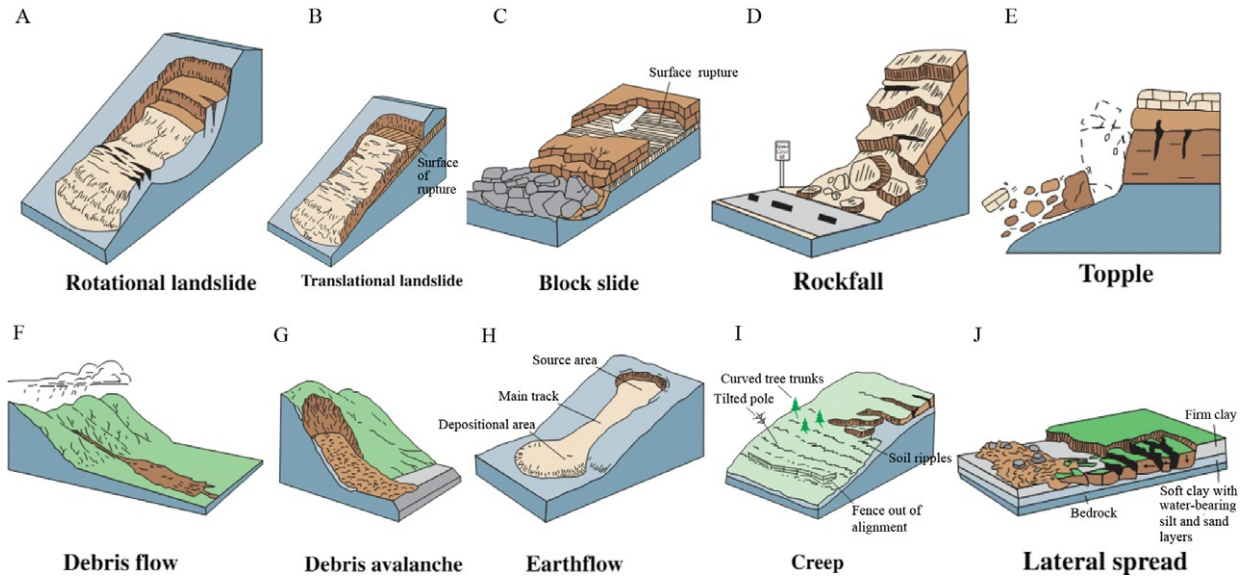


FIGURE 2 Schematic illustrations of the major types of landslide movements. *Source:* <http://pubs.usgs.gov/fs/2004/3072>.

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.

- b. *Debris avalanche*: This is a variety of very rapid to extremely rapid debris flow (Figure 2g).
- c. *Earth flow*: Earth flows have a characteristic ‘hourglass’ shape (Figure 2h). 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.
- d. *Mudflow*: A mudflow is an earth flow consisting of material that is wet enough to flow rapidly and that contains at least 50% 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’.
- e. *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: (1) seasonal, where movement is within the depth of soil affected by seasonal changes in soil moisture and soil temperature; (2) continuous, where shear stress continuously exceeds the strength of the material; and (3) progressive, where slopes 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 (Figure 2i).

2.5 Lateral Spreads

Lateral spreads are distinctive because they usually occur on very gentle slopes or flat terrain (Figure 2j). 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, cohesionless 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 a small area and spreads rapidly. Often, the initial failure is a

slump, but in some materials, movement occurs for no apparent reason. Combination of two or more of the types mentioned earlier is known as a complex landslide.

In Kenya, the characteristics of landslides may be presented in many forms shown in [Figure 2](#) earlier as they result as effects of heavy storms, earthquakes, and volcanic activities.

3 CAUSATIVE FACTORS OF LANDSLIDES IN KENYA

While much research has been done on landslides around the world, the landslides in Kenya have received relatively little attention ([Davies, 1996](#); [Westerberg and Christianson, 1998](#); [Ngecu and Ichang'i, 1999](#); [Ngecu and Mathu, 1999](#); [Westerberg, 1999](#); [Inganga et al., 2001](#); [Knapen et al., 2006](#); [Claessens et al., 2007](#)). Landslides as the most visible mass movements are recognized and well-documented global geomorphic hazards, owing to their major role in slope evolution in mountainous areas and the considerable economic, social, and geomorphological impacts ([Mugagga et al., 2012](#)).

There are multiple types of causes of landslides in Kenya, which can be classified in two categories, namely, inherent and triggering factors ([Kipseba et al., 2013](#)).

The inherent (natural/human-induced) ones comprise the following:

3.1 Geologic Causes

- a. Weak or sensitive materials
- b. Weathered materials
- c. Sheared, jointed, or fissured materials
- d. Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, and contact)
- e. Contrast in permeability and/or stiffness of materials

3.2 Morphological Causes

- a. Tectonic or volcanic uplift
- b. Glacial rebound
- c. Fluvial, wave, or glacial erosion of slope toe or lateral margins
- d. Subterranean erosion (solution and piping)
- e. Deposition loading slope or its crest
- f. Vegetation removal (by fire and drought)
- g. Thawing
- h. Freeze-and-thaw weathering
- i. Shrink-and-swell weathering

3.3 Human Causes

- a. Excavation of slope or its toe
- b. Loading of slope or its crest
- c. Drawdown (of reservoirs)
- d. Deforestation
- e. Irrigation
- f. Mining
- g. Artificial vibration
- h. Water leakage from utilities

The main triggering factors include

1. rainfall
2. earth movements
 - earthquakes, volcanism, faulting, and thunder
3. human activities
 - clearing of vegetation, farming, undercutting, building, quarrying, blasting, construction, and other engineering works

In Kenya, majority of, if not all, the landslides are caused/triggered by water and/or human activities. Slope saturation by water is a primary cause of landslides. This effect can occur in the form of intense rainfall, changes in ground-water levels, and water-level changes along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers. Landsliding and flooding are also closely related because both are related to precipitation, runoff, and the saturation of ground by water (Ngecu et al., 2004). In addition, debris flows and mudflows usually occur in small, steep stream channels and often are mistaken for floods; in fact, these two events often occur simultaneously in the same area.

Though there are no records of landslides that have been caused by volcanic activity, it is suggested that there are landslides whose triggering may be caused by seismic activity. This could be expected in the mountainous areas that are vulnerable to landslides. The occurrence of earthquakes and/or earth tremors in steep landslide-prone areas greatly increases the likelihood that landslides will occur, due to ground shaking alone or shaking-caused dilation of soil materials, which allows rapid infiltration of water. This is expected in most parts of the Rift Valley where there have been increased reports of ground failure with devastating effects. Widespread rock falls also are caused by loosening of rocks as a result of ground shaking.

The distribution of the occurrence of landslides in Kenya as recorded by the Department of Mines and Geology Department, 2012 is shown in [Figure 3](#). It is clear that most landslides recorded are in the central highlands of Kenya, the Rift Valley, and the western region of Kenya. The general elevation of the landscape in Kenya is shown in [Figure 4](#).

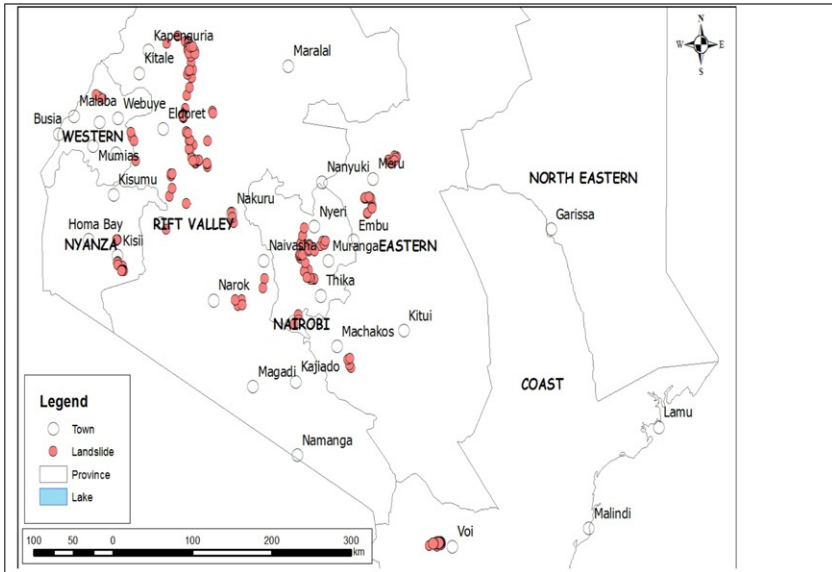


FIGURE 3 Landslide-prone areas in Kenya. *Source: Mines and Geology Department (2012).*

These areas are characterized by high-precipitation regimes of over 1200 mm annually, high population density, and steep slopes of up to 80° as indicated in [Figure 5](#), which shows the rainfall distribution in Kenya.

These areas are also found to have deep volcanic soils that become saturated with water during heavy downpour. In some places, the rocks are highly fragmented due to the effects of tectonic forces that have affected them and also weathered due to the constant presence of water in the area. The escarpment is characterized by stream valleys and ridges, as a result of erosion by small streams flowing downslope. The general drainage of the area is towards the west into the Rift Valley.

Landslides have also been observed in areas covered by rocks of the basement system such as the Yatta Area, Machakos County ([Ogora and Kotut, 2013](#)). In general, the rocks in such areas can be subdivided into four main age groups:

1. Archean—Mozambiquian rocks
2. Tertiary—volcanics and sediments
3. Pleistocene—sediments
4. Recent—soils and alluvial deposits

The metamorphic rocks vary in grain size from fine-grained schists to coarse gneisses and in composition from pure quartzites and marbles to varieties rich in biotite, muscovite, and hornblende, the intrusive being converted to

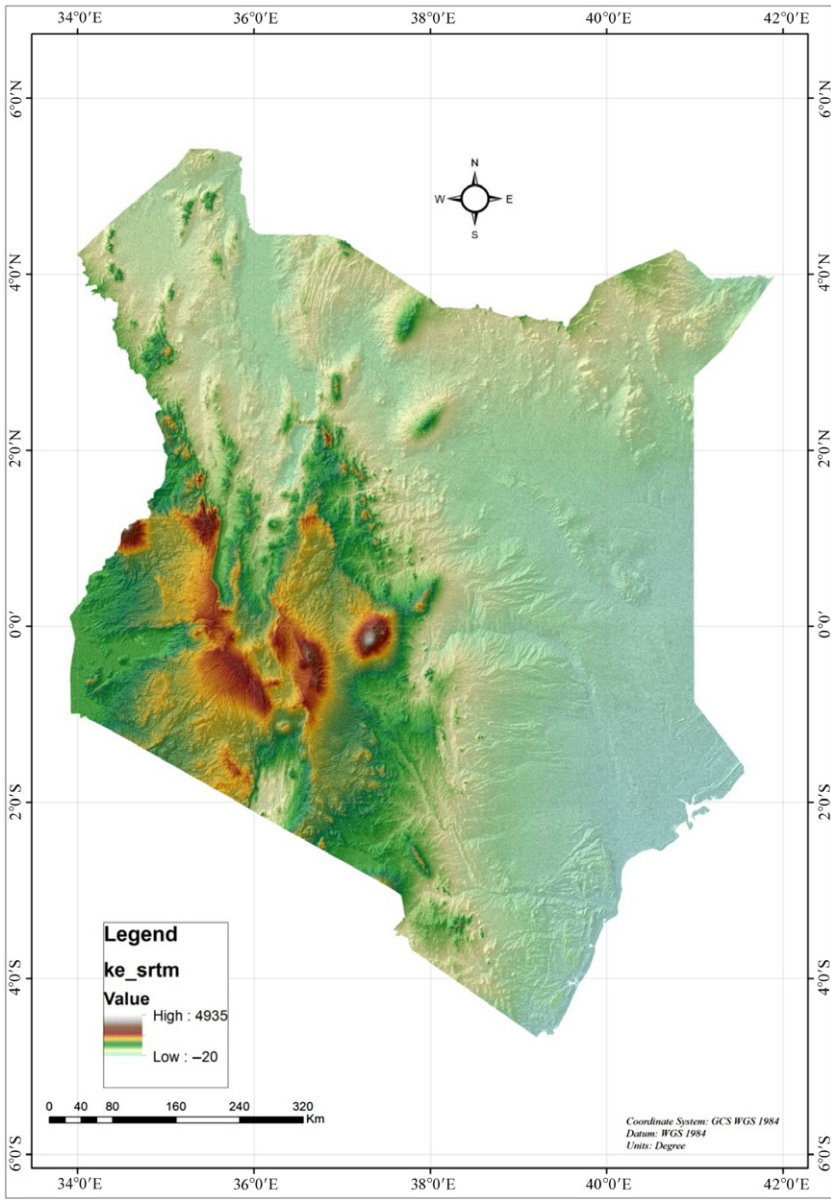


FIGURE 4 Digital elevation model of the landscape in Kenya (Compiled at the GIS lab, Department of Geology, University of Nairobi).

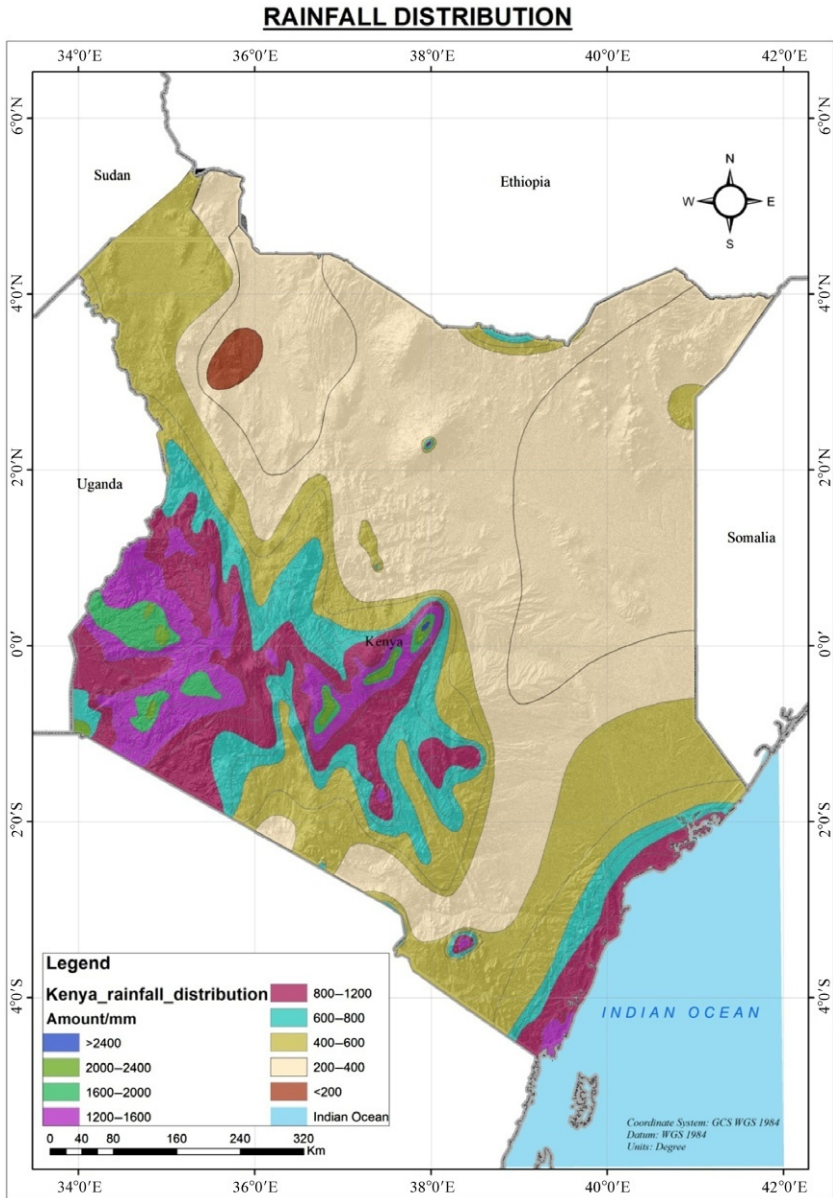


FIGURE 5 Annual rainfall distribution in Kenya (Compiled at the GIS Lab, Department of Geology, University of Nairobi).

TABLE 2 Main Landslide-Prone Areas in Kenya

- Mt. Elgon
- Nandi Escarpment
- Gucha
- Nandi
- Kericho
- Rift Valley Escarpment
- Cherangani Hills
- Tugen Hills
- Nyambene Hills
- Muranga
- Taita Hills
- Nakuru Town

plagioclases. The water that triggers the slides infiltrates through the loose soils and the volcanic sediments before being intercepted by the often impermeous Archean Mozambiquan/basement rocks (Table 2).

3.3.1 Anthropogenic Factors

Land tenure has been identified as the most important anthropogenic factor leading to landslides in the Kenya and the region. A driving force behind unsustainable land-use practices is the population growth and density in the areas bordering the mountainous regions.

3.3.2 Population Growth

The distribution of Kenya's population closely follows rainfall distribution patterns. Thus, areas of high rainfall tend to have high population density reflective of high population growth. Such high populations exert pressure to the land to produce food and other environmental services. This leads to land degradation, which, in turn, renders the land prone to landslides (Rop, 2011).

3.3.3 Land Tenure and Land Use

High population growth is the main cause of pressure on land, forest degradation, and land fragmentation. For example, high population makes families in most areas overcultivate their plots to maximize crop yield. It is generally noted that farming practices that do not allow the land to lie fallow from time to time are among the main causes of landslides. Furthermore, some crops have a better soil-holding capacity than others due to the size of their roots

and also whether they are intercropped with other plants or not. The high population density and number of children per household also result in fragmentation of plot size for many families (see photo below). Once the children grow up and establish families of their own, it is expected that part of the plots of the parents is passed on to them. This means more pressure on the land and inability to lay parts of the land fallow, which is very important for regeneration and improving soil fertility.



Photo showing the patchwork agricultural plots in the hilly terrain of Kisii district, Western Kenya. The plots are further subdivided as the children in a household mature into adulthood.

3.3.4 Deforestation

Deforestation is a common problem in the districts bordering mountainous regions in Kenya and is also closely linked to population pressure. The only type of fuelwood used in the districts is charcoal that is collected from the local forests and produced locally. Historically, there has been a long-standing conflict with the authorities on local population's illegal resource harvest in the forest.

4 SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF LANDSLIDES IN KENYA

Landslides in Kenya have been on the increase in the recent past. This has social, economic, and environmental impacts, mainly loss of life, agricultural land, and crops and destruction of infrastructure. Landslides tend to bury all that is their way, resulting in destruction of life and property. They may bury or sink buildings, rubble and boulders moved to block roads, railways, and lines of communication or waterways. They may destroy all property along



FIGURE 6 A bridge destroyed by the mudslide along Thingitungi stream.



FIGURE 7 Household materials destroyed by the landslide.

their way and render agricultural land unproductive. The casualties of mudflows, massive boulders, rocks, and all that can be moved by the landslides may be thousands of people and animals (Figures 6 and 7).

4.1 Socioeconomic Impacts of Landslides

There has not been any recorded effort to estimate the economic loss of landslides in Kenya despite the high frequency of the occurrence of the landslides. However, economic losses due to landslides can be classified as direct and indirect (Ngecu and Ichang'i, 1999; Ngecu and Mathu, 1999; Schuster and Highland, 2001). Direct costs can be defined as the costs of replacement, rebuilding, repair, or maintenance resulting from direct landslide-caused damage or destruction to property or installations. All other costs of landslides are indirect; examples are the following:

- Reduced real estate values in areas threatened by landslides.
- Loss of tax revenues on properties devalued as a result of landslides.
- Loss of industrial, agricultural, and forest productivity and of tourist revenues, as a result of damage to land or facilities or interruption of transportation systems (Knapen et al., 2006).
- Loss of human or domestic animal productivity because of death, injury, or psychological trauma (Kitutu et al., 2009).

Table 3 illustrates some of the common impacts of landslides in different parts of the country. Some of the impacts previously mentioned are also shown in Figures 8–12.

TABLE 3 Socioeconomic Impacts of Landslides in Kenya

Date	Landslide Location	Impact
April 2013	Kijabe Landslide	Blocked railway line, disrupted services
30.04.2002	Maua Landslide	11 People died
22.04.2001	Kitheu Landslide	4 People died, destroyed water pipes
30.04.1997	Muranga Landslides	11 People died, 7 houses destroyed, 3 cows died
November 2008		1 Child died
2002–2008	Timboiwo	Houses, crops, pasture destroyed Yabsoi's Farm, Kericho whole farm destroyed
2003	Kokwet, Kipkelion	4 People died, pasture lost, arable land rendered infertile
November 2008	Chesegon Landslide, Pokot Central	11 People died, pasture lost, arable land rendered infertile
2002	Kocholwa	Livestock killed
2010	Mt. Elgon, Pokot, Kessup, Subukia, and Timobo (continuous rock falls)	Lives lost Houses destroyed Roads blocked Crops destroyed
April 2013	Yatta Landslide	3 people died, houses destroyed



FIGURE 8 Uprooted plants and trees by a landslide.



FIGURE 9 House destroyed by huge rock boulders down a slope due to a landslide.

4.2 Environmental Impacts of Landslides in Kenya

4.2.1 *Impacts of Landslides on Stream Environments*

The main types of landslides that affect streams are debris flows, which may follow the stream channel for great distances (occasionally 100 km or more). Debris flows provide important sediment transport links between hillslopes and alluvial channels and thus are an important factor in drainage-basin sediment budgets (Schuster and Highland, 2001). In addition, debris flows influence the spatial and temporal distributions of sediment in stream channels,



FIGURE 10 Landslide debris flow in West Pokot County, Kenya.



FIGURE 11 Yatta landslide of April 2013.

either because they deposit sediment in the channels or because the deposits provide a source for accelerated transport of sediment farther downstream. The pollution of rivers and other water bodies adds on to the environmental impact of the landslides and poses a health hazard to local people (Knapen et al., 2006).

4.2.2 Impacts of Landslides on Forest Cover

Widespread stripping of forest and jungle cover by mass movements has been noted in many parts of the world but particularly in tropical areas as a result of large-scale, earthquake-induced landslide activity.



FIGURE 12 Debris flow along River Thingitungi, Magana area, Kijabe, during the April 2013 landslide. *Source: Kipseba et al. (2013).*

4.2.3 Impacts of Landslides on Livestock and/or Wildlife

Although most kinds of wildlife are able to retreat fast enough to avoid injury from all but the fastest-moving landslides, all wild creatures are subject to landslide-caused habitat damage and destruction. Fish are probably most affected because they are dependent on stream access and water quality for their livelihood, both of which are often affected by landslides. In Kenya, a lot of cases have been reported where domestic livestock has borne the brunt of the landslides. Cows have been injured; goats and chicken pens have been destroyed. However, there is little else that is done to quantify the loss. Fish ponds have been reportedly destroyed by debris from landslides, thereby affecting the livelihoods of the directly affected families.

5 LANDSLIDE MITIGATION: HOW TO REDUCE THE EFFECTS OF LANDSLIDES

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local county governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to landslide hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local county governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt.

The hazard from landslides can be reduced by avoiding construction on steep slopes and existing landslides or by stabilizing the slopes. Stability

increases when ground water is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrane, (2) directing surface water away from the landslide, (3) draining ground water away from the landslide, and (4) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/or the weight of a soil/rock debris is placed at the toe of the landslide or when mass is removed from the top of the slope.

In Kenya, mitigation measures that have been suggested in most cases involving landslide hazards include the following:

- Encouraging local communities to plant deep-rooted trees on steep slopes
- Discouraging cultivation on steep slopes
- Discouraging settlement on steep slopes
- Stopping vegetation clearing
- Putting up of soil conservation structures
- Constructing support structures on vulnerable areas
- Encouraging agroforestry in the areas
- Advising on putting up structures in safer areas

Areas that are generally prone to landslide hazards include those on existing old landslides or at the base of slopes, in or at the base of minor drainage channels, at the base or top of an old fill slope, at the base or top of a steep cut slope, and developed hillsides where leach field septic systems are used.

Areas that are typically considered safe from landslides are characterized by being on hard, non-jointed bedrock that has not moved in the past. They may also include those areas on relatively flat-lying areas away from sudden changes in slope angle and/or at the top or along the nose of ridges, set back from the tops of slopes.

Care should also be taken to look for and document any warning signs that may be occurring in an area. According to [USGS \(2012\)](#), such signs include and not limited to the following:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements, or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Sudden decrease in creek water levels though rain is still falling or just recently stopped

- Sticking doors and windows and visible open spaces indicating jams (side posts of doors or windows) and frames out of plumb.

6 WAY FORWARD

Considering the damages so far being witnessed in the country, there is an urgent need to establish a National Disaster Management Authority, which will be tasked with among other activities, developing a comprehensive National Landslide Hazards Mitigation Strategy. Such a strategy would employ a wide range of scientific, planning, and policy tools to address various aspects of the landslide problem to effectively reduce losses from the ground failure. It should have the following major elements:

- i. Carry out research to develop a predictive understanding of landslide processes and triggering mechanism.
- ii. Hazard mapping and assessments. This would be done to delineate susceptible areas and different types of landslide hazards at a scale useful for planning and decision making.
- iii. Carry out real-time monitoring of active landslides that pose substantial risk.
- iv. Loss assessment. This would be achieved by compiling and evaluating information on the economic impacts of landslide hazards.
- v. Establish an effective system for information collection, interpretation, and dissemination.
- vi. Developing guidelines and training for scientists, engineers, and other decision makers.
- vii. Engage in public awareness and education by developing information and education for the user community.
- viii. Implementation of loss reduction measures by encouraging mitigation action.
- ix. Emergency preparedness, response, and recovery geared towards building resilient communities.

In conclusion, therefore, it is clear that landslides are natural phenomena whose causative factors have substantial human contribution. Continuous monitoring, awareness campaigns, and mapping of landslide-prone areas will help to reduce losses resulting from landslides. It is encouraging to note that the government through the Mines and Geological Department has embarked on a programme to map out all landslide-prone areas, which will culminate in the production of a National Landslide Atlas—a useful tool to planners and other stakeholders. Collaboration among the stakeholders is a major factor in the management of landslides.

It has also been observed that at most of the sites of the tragic landslides, the residents live as squatters and/or peasants in highly densely populated area. In a recent landslide at Kijabe, there were 120 families living on about

two acres land, making it overcrowded with homesteads. The land slopes at an angle of about 25°. This resulted in the families excavating foundations for constructing their houses very close to their neighbours, thus rendering the land unstable. In other areas, the fertile volcanic soil has encouraged the residents to practice subsistence cultivation, even on steep slopes. Most of the farms have poorly maintained soil conservation structures, mainly terraces. Many slope failures have occurred on such cultivated land, rendering the already peasant farmers even more destitute.

Population pressure and the need for more food have caused more disturbances in the land, hence the emergence of landslide occurrence. It is recommended that drastic efforts should be made to ensure the following interventions:

1. Deep-rooted trees especially eucalyptus should be planted especially on the slopy areas.
2. Construction of proper soil conservation measures.
3. Cultivation on steep slopes should be discouraged.
4. Detailed mapping needs to be done in the area to zone out susceptibility of the area to landslides since the slope instabilities are a new phenomenon in the area.
5. Sensitization of the local communities should be done through seminars by the Department of Mines and Geology and other stakeholders.

It is also proposed that the proposed National Disaster Management Authority establishes a landslide-reporting database where all the data collected would be stored and analyzed and then the end product be packaged for dissemination. Such integrated landslide-reporting databases have been used successfully in other countries of the world (Rego, 2001; Foster et al., 2008; Van Den Eeckhaut and Hervas, 2011) to provide early warnings and postdisaster activities, thereby becoming an indispensable service to the public.

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