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T Suryanarayana
Professor, College of Natural Science, Department of Geology, Wollo University, Dessie, Ethiopia

Dessalegn Gezahegn
Department of Geology, College of Natural Science, Wollo University, Dessie Campus, Ethiopia

Elias Assefa
Department of Geology, College of Natural Science, Wollo University, Dessie Campus, Ethiopia

Addis Seid
Department of Geology, College of Natural Science, Wollo University, Dessie Campus, Ethiopia

Endayen Belay Belachew
Department of Geology, College of Natural Science, Wollo University, Dessie Campus, Ethiopia

Corresponding Author:
T Suryanarayana
Professor, College of Natural Science, Department of Geology, Wollo University, Dessie, Ethiopia

Assessment of landslide hazard in Dessie town

T Suryanarayana, Dessalegn Gezahegn, Elias Assefa, Addis Seid and Endayen Belay Belachew

Abstract
Dessie town is located in a tectonic depression along the western rift margin with a young, high energy relief. Study area is known for numerous landslides in the past. These landslides are of different types, from shallow soil creeping to huge deep-seated landslides with appreciable consequences. Landslides endanger the quickly growing regional centre of Dessie and its infrastructure. Four typical recent landslides have been selected and studied in detail using both remote sensing and field observations from 2013. The described reactivation and new landslide events have been caused by a combination of natural influences and anthropogenic activities. Since seasonal rainfall is the main external triggering factor, precipitation data from Dessie weather station were analysed. The degree of negative human impact on slope instability was also discussed. Endangered zones and the actual risk in the studied localities were identified, and adequate measures were proposed.

Keywords: Tectonic depression, western rift margin, landslides, rainfall

1. Introduction
1.1 Background of the study
Landslides occur when the slope (or a portion of it) undergoes some processes that change its condition from stable to unstable. This is essentially due to a decrease in the shear strength of the slope material. Dessie is an important town in North-central Ethiopia. The study area and its close surroundings are situated in the border zone of the Ethiopian Highlands and the Rift Valley (400 km to the north of Addis Ababa, Regional State of Amhara, Northern Ethiopia) and are characterized by parallel running mountain ranges reaching an altitude of 3025 m a.s.l. The Dessie depression is a hanging valley located along the western rift margin with a young, high energy relief. The elevation of its bottom at the outflow of the Borkena River is at an altitude of 2400 m.a.s.l. The basin is bound by two major parallel faults running in an N-S direction, represented by the steep slopes of Tossa Ridge to the west and by AzwaGedel Ridge to the east. The Dessie graben was produced during the Tertiary- Quaternary extensional phase, which was accompanied by an important regional uplift, raising the Ethiopian plateau by 800–1000m to attain the present altitude (e.g. Almond 1986; Mohr 1986). In the youngest stages of its development, the Dessie graben was a closed basin, which is documented by swampy-lacustrine sediments (Fubelli *et al*. 2008) [7]. Due to advancing uplift, the graben was deeply incised and then re-opened by the backward erosion of the Borkena River (Fubelli *et al*. 2008; Abebe *et al*. 2010) [7]. The outcropping bedrock consists of a sequence of Tertiary Trap Series volcanics (Ashange basalt formation and Dessie basalt formation-e.g. Gregnanin *et al*. 1973). Moderately to highly weathered and densely jointed basaltic rock masses correspond to stratified beds of successive lava flows, inter-bedded with weakly degraded volcanic units and several reddish paleosoil horizons. Vesicular basalt is a highly porous and friable rock type, which is dominant in the central part of the town and is locally overlying stratoid basalt outcrops. These highly weathered rocks associated with unconsolidated materials in steep slope areas represent a high landslide and rock fall susceptibility zone (Ayenew and Barbieri 2005) [2]. The graben floor is filled by sediments up to several tens of metres thick, which consist mainly of colluvial-alluvial deposits (Ayenew and Barbieri 2005; Fubelli *et al*. 2008) [2, 7].

The area of Dessie town has been known for almost half a century for its repeated slope instability problems. The basic predisposition of recent slope movement activity is the tectonic pattern, geological setting (fractured, highly weathered volcanic rocks and loose, unconsolidated deposits) and specific topography (steepness of the area together with river erosion). Loss of human life and damage to infrastructure (roads, bridges, houses, communication facilities, etc.) have been caused by landslides and the related geo-hazard (e.g. Woldearegay 2013) [16]. Soil creeping, debris flows, landslides or rock falling have been described several times since the 1980s (e.g. Eshete 1982; EIGS 1991, 1995; MoWUD 1995; Hailemariam 1995; Tsehayu and Gezehegn 1995; Ayalew and Vernier 1999; Terefe 2001; Ayenew and Geremew 2002; Ayenew and Barbieri 2005; Fubelli *et al*. 2008; Abebe *et al*. 2010 or Beyene *et al*. 2012) [1, 3, 2, 7]. In this study, we have focussed on the most recent landslide activity, which was induced by a combination of specific local conditions and external factors.

Weselected four landslides

1. School_MenbereTshay area,
2. Dessie– Kombolcha road,
3. Kerra area and
4. Doro Mezleyaslope

These represent different types of land sliding in the area but exhibit identical features-frequent reactivation and potential risk for local inhabitants. We have analysed their geometry in detail, documented their evolution and investigated the main triggering factors (with particular emphasis on the impact of human activities). The most frequent landslide types include:-(a) rotational slides, (b) translational slides, (c) rock falls and rock slides (debris avalanches) (Fubelli *et al*. 2008) [7]. The main landslide activity in the Dessie area occurs in silty clay soils and loose deposits of an alluvial and colluvial origin that cover highly weathered basalts (Suyum 2011). Translational slides move along clayey levels of superficial deposits and along the interface between these deposits and the bedrock. Rotational slides mainly occur in alluvial-colluvial and lacustrine deposits. Movement events are commonly restricted to shallow phenomena such as soil slips or mud flows (Abebe *et al*. 2010) [7]. At times, these failures are associated with seasonal earth and soil flows (Ayenew and Barbieri 2005) [2] and very abundant soil creep movements.

1.2. Problem of the statement

Landslides and landslide-generated ground failures are among the common geo-environmental hazards in many of the hilly and mountainous terrains of both the developed and developing world. As defined by Brunsden (1979), landslide is the downslope movement of soil and rock under the influence of gravity without the primary assistance of a fluid transporting agent. Various authors (e.g. Schuster and Fleming, 1986; Schuster, 1995; Glade, 1998) indicated that in many countries the economic losses and casualties due to slope failures are greater than commonly recognized. According to Terlien (1996), although a small percentage of individual landslides are catastrophic, it is essentially the high number which makes the total economic loss due to slope instability (direct damage to agricultural land and infrastructure According to Schuster (1995), world-wide landslide activities are expected to continue in the 21st century for the following reasons: (a) increased urbanization and development in landslide-prone areas, (b) continued deforestation of landslide-prone areas, and (c) increased precipitation caused by changing climatic conditions.

The hilly and mountainous terrains of the highlands of Ethiopia which are characterized by variable topographical, geological, hydrological (surface and groundwater) and land-use conditions, are frequently affected by rainfall-triggered slope failures. Earthquake triggered landslides are little reported in Ethiopia.

In Ethiopia, landslide-generated hazards are becoming serious concerns to the general public and to the planners and decision-makers at various levels of the government. However, so far, little efforts have been made to reduce losses from such hazards. With the on-going infrastructural development, urbanization, rural development, and with the present land management system, it is foreseeable that the frequency and magnitude of landslides and losses due to such hazards would continue to increase unless appropriate actions are taken in the Ethiopia. In order to bring the issue of landslides and associated geohazards into the attention of the academia, decision makers, and concerned organizations this review paper was made. The problem with slope instability in Dessie town is still also acute in other localities and may increase in the future due to the fast expansion of the town. The influence of anthropogenic activities was identified as one of the main triggering factors of reactivation in the observed cases. Fast urban sprawl leads to construction of houses and infrastructure on the outskirts of the city (including the landslide hazard areas) over the last 8 years. It was documented at the selected sites that construction continues in areas where damage by landslides has already occurred. Moreover, remedial and technical measures implemented in the studied areas were found to be partly inadequate or ineffective, which represents a serious issue causing recurring problems.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study is will to carry out Landslide hazard evaluation and zonation in and around Dessie town.

1.3.2 Specific objectives

The specific objectives of the study:

- We will measure that can be reduce effect of landslide in the study areas.
- We will know the possible failure mechanism of the landslide
- We will identifythe landslide active and prone areas.
- We will recommend the area for local government and other researcher
- We will identify the caustic factors of landslide hazard in Dessie town We will understand process and factor leading to slope failure in the area Also we will identify the rock type and geological structure

1.4 Significances of the study

The problem with slope instability in Dessie town is stillalso acute in other localities and may increase in the future due to the fast expansion of the town. The influence of anthropogenic activities was identified as one of the main triggering factors of reactivation in the observed cases. Fast urban sprawl leads to construction of houses and infrastructure on the outskirts of the city (including the landslide hazard areas) over the last 8 years. It was document data the selected sites that construction continues in areas where damage by landslides has already occurred. Moreover, remedial and technical measures implemented in the studied areas were found to be partly inadequate or ineffective, which represents a serious issue causing recurring problems. A long-term landslide hazard will continue to be a significant problem in the area. At least a part of the problem in the future can be prevented by more appropriate urban planning (functional planning and control of housing development) together with investment in functional drainage systems and also by increasing the awareness of responsive authorities and local residents.

Identification of landslide is important to planners, local administrations, and decision makers in disaster planning for reducing the losses of life and property (A balagan and Singh, 1996; Ercanoglu and Gokceoglu, 2003; Bekele *et al*., 2010). Therefore, the present study is very important from the point of view of identifying and understanding the possible causes of the past landslide activities and delineating the areas which are susceptible for future landslide activities.

2. Literature Review

The Dessie basin (ca. 7 km long and 3 km wide; between 2,500 and 2,900 m a.s.l.) is one of the numerous "hanging" grabens located along the western Afar margin. The basin is bordered by two N-S trending steep slopes formed by the action of normal faults: the Tossa escarpment, up to 400 mhigh and up to 80steep, to the west, and the Azwa Gedeleescarpment, lower (ca. 200 m) and more rectilinear, to the east. Both escarpments are topped by gently sloping surfaces, possibly corresponding to relicts of the ancient depositional top of the Trap volcanics before the opening of the Dessie graben (Fubelli *et al*. 2008) [7]. SW-NE trending transfer faults border the basin both to the north and the south. Other faults, ranging in strike from NNW-SSE toNW-SE cross the area exerting a more or less direct control on the local topography.

The area of the Dessie graben is prone to slope failure due to the geological setting, high energy relief and rainfall concentrated into short periods. This article presents four typical examples of recent slope movements in the area. The studied landslide areas have been evaluated in terms of their historical development (especially with the use of remote sensing data), the current status (based on field survey results) and also potential risks in the future. New landslides and reactivations were documented in detail from February to October 2013 (after the above-average rainy period) in all other studied sites. The most significant morphology changes and recurrent problems were reported for the Menbere T shay area. The landslide area is much more extensive and affects not only the visible zone of reactivation but the entire school compound. This locality is not only an example of unsuitable foundations and non-functional remedial works but also currently one of the sites with the highest risk.

2.1 records of landslides in the highlands of Ethiopia

Because of its complex geomorphological, hydrological, and geological setting, the hilly terrains of the Ethiopian landmass have been frequently affected by first time as well as reactivated old landslides. Except for some efforts made by the Ethiopian Geological Survey and Ethiopian Roads Authority, so far, no comprehensive inventory of landslides and their significance (economic, social and environmental) is made in Ethiopia. However, despite multi-facet challenges in landslide research in the country, several authors have reported on slope instability problems in different parts of country. Several authors (e.g. Eshete, 1982; Hailemariam, 1995; Tsehayu and Gezahegn, 1995; MoURD, 1995; Ayalew, 1999; Terefe, 2001; Ayenew, 2002; Ayenew and Barebieri, 2005) [1] have reported on the prevalence of landslides in Dessie town, central highlands of Ethiopia. According to these authors, failure mainly involved unconsolidated materials which overlie the trap volcanics. To mitigate the landslide problems in the town a number of mitigation measures have beenimplemented. Despite these efforts, however, landslides still remain major challenges for the development of Dessie town. in the past (in 1977, 1979, 1988, and 1994), and there are also numerous records of currently active landslides (Eshete 1982; Ayalew 1999; Terefe 2001; Ayenew and Barbieri 2005; Fubelli *et al*. 2008) [1, 2, 7]. The most recently described example of large mass movement is from July and August 2010, when 37 casualties were registered in the Dessie region (Beyene *et al*. 2012). Zonation of landslide risk for the Dessie area has been performed by several authors. Zones of landslide susceptibility for four study localities were defined as being from moderate to very high (Ayenew and Barbieri 2005; Suyum 2011) [2]. Old landslide complexes show current signs of reactivation, as revealed not only by the field survey but also by preliminary inclinometer measurements (Ayenew and Geremew 2002) [3] or by applying the DInSAR methodology (Beyene *et al*. 2012).

2.2 Factors influencing landslide

The primary cause of a landslide is the influence of gravity acting on weakened materials that make up a sloping area of land. While some landslides occur slowly over time (e.g., land movement on the order of a few meters/yards per month), the most destructive ones happen suddenly after a triggering event such as heavy rainfall or an earthquake. Water can trigger landslides and mudslides because it alters the pressure within the slope, which leads to slope instability. Consequently, the heavy water-laden slope materials (soil, rock, etc.) will succumb to the forces of gravity. Excessive water is thought to be one of the most common triggers for landslides. Other factors that weaken slope materials also contribute to the occurrence of landslides. These factors include both natural events such as geological weathering and erosion and human-related activities such as deforestation and changes made to the flow of groundwater. Destruction of vegetation by droughts, fires, and logging has been associated with increased risk for landslides. And if the slope is steeper it will be more susceptible to instability as compared to gentle slope. The gravity pulls which is the main driving force for instability is directly proportional to the slope gradient (Raghuvanshi *et al*., 2014, Bisson *et al*., 2013, Bisson *et al*., 2014, Bisson *et al*., 2010). The slope was extracted from the digital elevation model (DEM). Also, the presence of rain water and ground water decrease the shear strength of slope material by reduces the normal effective stress through the water pressure. These initiates slope instability of the geological material (Lulseged Ayallew, 2004). In addition to the water pressure, it increases weight to slope and increases the stress and leads to landslide to occur in the slope

2.3 Landslide types
Different researchers (Terzaghi, 1950, Varnes, 1978, Cruden and Varnes 1996) [15, 5], classified landslides based on different criteria basically the type of movement was primarily is taken as classification system (Varnes, 1978) [15].

The most accepted landslide classification systems are based on different factors such as, the material being transported (rock, earth, debris), the type of movement (falls, slides, flows, topples, etc.) and movement velocity (high or low) are the major one.

The types of landslides are usually differentiated by the nature of its movement and earth material involved. Here are a few:

2.3.1 Slide
Slides may be translational or rotational. In a translational slide, the earth mass is largely in place after it slides downhill on a plane preface. In a rotational slide, the movement of the earth material is rotational in nature. A slide, in the strictest sense, is characterized by failure of material at depth and then movement by sliding along a rupture or slip surface. If sliding is on a predominantly planar slip surface then the slide is called a block slide. If movement is on a curved slip surface then the slide is called a rotational slide. A lot of rotational slide end up as a mudflow leaving a gaping hole in the ground where the slide began. Debris from the slide is strewn down a torrent track along which the mudflow travelled to the base of the slope or where the flow path widens and dissipates. A rotational slide with one or more curved slip surfaces where the movement of material is incomplete, leaving individual slumped blocks, is referred to as a slump.

2.3.2 Topple
In a topple, the earth mass rotates forward about a pivit. The result is usually a tilt without collapse. It is usually cause by cracks or refracture in the bedrocks.

2.3.3 Fall
These are usually influenced by gravity after large rocks or boulders are detached from their parent rock. They usually fall along steep slopes or cliffs. A rock-fall is the abrupt free fall or downslope movement, (rolling or sliding) of loosened blocks or boulders of solid rock. It differs from a slide in that free fall is the main type of movement and no marked slide surface develops. This type of slope failure occur in caverns and along steep gorges, sea cliffs and steep road cuts through unstable bedrock. The bedding, jointing and fracturing of the bedrock are the important factors affecting slope stability. The effects of weathering, such as the freezing of water in joints (in cold countries), the pressure of water in fissures, and root pressures may initiate failure in the weak rocks. A rock fall, as in most landslides, is usually the result of a combination of factors. On a sea cliff it could be due to a combination of jointing patterns, percolation of surface water, wedging of tree roots and the impact of and undercutting by waves. Thus, a lot of rock-falls along sea cliffs occur during storms when much rain percolates through cracks in the rock and the pressure pushes the blocks over or when heavy surfs strike the cliff causing vibrations and thus causing undercut cliff faces to topple over.

2.3.4 Flow
Flows come in many types, such as Debris flow, Debris avalanche, Mudflow, Creep and Earth flow. Debris flows are fast moving flows of mud and rock and they are the most numerous and dangerous of all the landslides. Debris flows generally occur during periods of intense rainfall or snow melt. They usually begin on the top of steep hills with saturated soil as They are so dangerous because they move quickly, destroy without warning, and obliterate everything in their path. They can destroy homes, knock down trees, and obstruct streets and roadways. Their average speed is 10 miles an hour, but some have been known to exceed 35 miles per hour! Their viscosity ranges from thick, rocky mud to water mud. The following are several types of debris flows. (Talking About Disasters)

2.3.4.1 Earthflow
The wet ground breaks up and falls down the hillside in a rounded shape. It usually occurs on clay or sand and it is the slowest and driest type of flow.

2.3.4.2 Mudflow
Sometimes referred to as a mudslide, a mudflow is when the soil becomes so saturated with water that it speeds down the hill in a muddy river carrying debris. It is the fastest and wettest type of flow. Click on the picture below to see an animation of how fast a mudflow can travel

2.3.5 Creep
Creep occurs mainly in the soil mantle, that part of the soil from the surface to a few centimeters or metres below the surface. It involves the slow downslope movement or the gradual plastic deformation of the soil mantle and/or the fracturing of bedrock at imperceptible rates. There is no single surface along which slippage occurs. The rate of downhill movement or creep can vary from a few millimeters per year for slopes less than 10% to about 10mm per year in steeper terrains. The downward movement involves minute displacement of individual particles that are moving at different rates. It is commonly caused by the expansion of the surface layer due to heating followed by contraction due to cooling. Creep may also be caused be the swelling of certain clays after seasonal rainfalls when their moisture content increases, followed by contraction when their moisture content drops during the dry period.

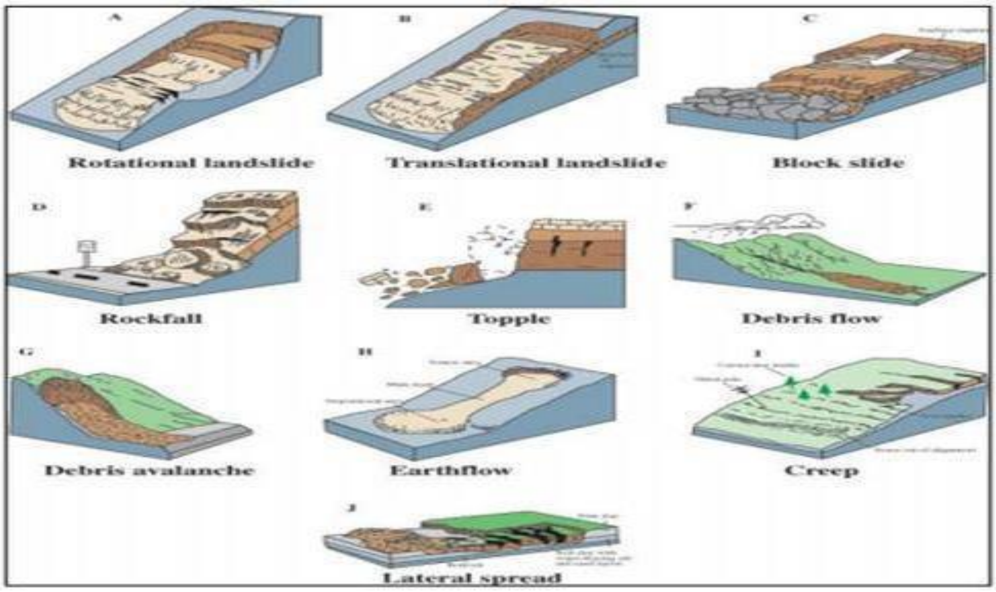

Fig 1: Schematic representation of major types of landslide movements (Source: Keller, 201)

3. Methodology and Materials

3.1 Description of the study area 3.1.1 Location

Dessie is an important town in north central Ethiopia. The study area and its close surroundings are situated in the border zone of the Ethiopian High lands and the Rift Valley. It is about 400km to the north of Addis Ababa, Regional State of Amhara, and Northern Ethiopia. It is geographically located between latitude of 11˚80'N and longitude of 39˚39'E with an elevation between 2470m-2550m above sea level. (Source; Wikipedia, free encyclopedia).

3.1.2 Climate

The Dessie basin climate is characterized by two distinct wet and dry seasons (Gamache 1977; Ethiopian Mapping Authority 1988) [6]. Rainfall data (1974–2004) show a bi-modal rainfall pattern with the heaviest rains in July-August. The climate is warm and temperate in Dessie. In winter, there is much less rainfall in Dessie than in summer. The Koppel-Geiger climate classification is Cwb (humid subtropical climate). The temperature here averages 15.2 °C. The average annual rainfall is 1145 mm.

3.1.3 Physiography

The highlands of Ethiopia are generally characterized by highly variable topography which is a reflection of the past geological and erosion process. A physiographic province characterized by closed basins and mountain ranges produced by Tertiary–Quaternary regional extension (Ukstins *et al*., 2002). The outcropping bedrock consists of a sequence of Tertiary ignimbrites and lava flows with a variable degree of weathering. They are mantled by colluvial and alluvial deposits mainly deriving from the Tosa and AzwaGedel ridges. In the eastern part of the town, swampy-lacustrine sediments, including clays, silts and sands, locally underlie the alluvial–colluvial cover.

3.1.4 Drainage pattern

In the most recent times, the Dessie graben has been first closed with the deposition of the alluvial and swampy-lacustrine sediments (Dessie terrace), and then re-opened by the back-ward erosion of the Borkena and Kelina Rivers with the consequent deep incision of the drainage network and the onset of instability conditions in the basin floor deposits, in the talus belts at the feet of the main escarpments and, locally, also in the bedrock (Fubelli *et al*. 2008) [7].

3.2 Methodology

The present work is relying on office by secondary data from previous works or from satellite image interpretation. In order to develop a landslide hazard zonation map, causative factors were identified after deeply reviewing previous work and literatures. The causative factors for present studies include slope, aspect, land use land cover, lithology and elevation. To fulfill the objectives of this project, the following methods will used:

3.2.1 Pre-Field Work

- A review of previous works in the study area about landscape, geology, hydrogeology and so on will carry out.
- Collection of rain fall, humidity and temperature data from Dessie town water bureau was carried out before going out for field work.

3.2 Material's used

The materials will used for study such as Topographic map of the Dessie Town: - to guide the geotraverse and realize which area should be studied., Geologic Hammer use to take representative sample from exposure by breaking and may be used as scale to take photos of lithological unit and Global positioning system (GPS) used for measure ring the elevation, latitude and longitude. Brunton compass use to measure the orientation of the structures and the strike and dip of the fault block, and also Field notebook used to record the information. Sample bag and Marker pen use for hold representative sample and draw or mark different lithological units respectively.

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