

# CAUSES & REASONS OF LAND SLIDING IN LAGA GABA HIGHLAND AREA, GIMBI TOWN, WEST WOLLEGA ZONE, ETHIOPIA



## Original Research Article

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## ABSTRACT

The study area is located in Gimbi Town, West Wollega Zone, Ethiopia at a distance of 441 Km from Addis Ababa capital city. Its location is 9° 10' N latitude and 35° 50' E longitude with an elevation between 1845 and 1930 meters above mean sea level. The focuses of the study is to assess the problem of landslide & the causes of landslide. To identify this problem the writer uses filed observation, primary, & secondary information for data collection. The main landslide types affect Gimbi Town is sliding landslide due to inherently unstable geological structure. This study assesses the factors that enhance landslide occurrences in Gimbi Town and their impacts on to the livelihood of the people. The main reason of landslide in Gimbi Town are; geomorphology (Topography & steep slope), geology of Gimbi Town, Climate (rainfall & temperature), Erosion Processes, Rock and soil types. The goal, therefore, is to reduce vulnerability and exposure to landslides. The problems in the study area were categorized in to drainage problem leading to deep erosion, degradation, triggering landslide & bottom slope landslide. Therefore, all of them require special attention and specific solutions, accordingly,

- ✓ Drainage problem associated with lack of proper drop and discharge structures have to be provided with proper drop and discharge structure
- ✓ Drainage triggering landslide will be provided with proper channelling and guiding structures and the bottom slope of the slide will be stabilized.
- ✓ The bottom slope landslide will be provided with massive concrete retaining structures will be embedded to the toe rocks and upstream of these will be stabilized with moderated masonry and gabion structures.

## Key words:

Degradation,  
 Erosion,  
 Geomorphology,  
 Landslide,  
 Sliding,  
 Triggering

## I. INTRODUCTION

### Background of the Study

The study area is located in Gimbi Town, West Wollega Zone, Ethiopia at a distance of 441 Km from Addis Ababa capital city. Its location is 9° 10' N latitude and 35° 50' E longitude with an elevation between 1845 and 1930 meters above mean sea level. Landslides, as one of the major natural hazards, account each year for enormous property damage in terms of both direct and indirect costs. The term, landslide is the down slope movement of soil and rock under the influence of gravity without the primary assistance of a fluid transporting agent. The landslide activities are expected to continue for the following reasons are given, (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 Gimbi Town is located on unstable ground formation and is experiencing natural disaster in the form of landslide that has increased in intensity, frequency and severity in recent years. The hilly and mountainous terrains of the highlands of Gimbi Town which are characterized by variable topographical, the local drainage gullies and streams tends to be swampy, geological, hydrological (surface and groundwater) and land-use conditions, are frequently affected by rainfall-triggered slope failures. In Gimbi Town, landslide-generated hazards are becoming serious concerns to the public and to the planners and decision-makers at various levels of the government. In order to bring the issue of landslides and associated geo-hazards into the attention of the academia, decision makers, and concerned organizations; this seminar paper was made.

From the field observation & data of city municipality of Gimbi Town, the scope of the problem is very high; as the landslide has caused significant damage to environment and private properties: homes destroyed, land eroded through slide, and flora destroyed. The problem is distributed throughout the town in all corners and is severe in low-lying areas the slope and storm drainage discharge points. In general, the series problem in Gimbi Town is sliding landslide. This problem is induced by natural factors and could be aggravated by human intervention.

Landslides, as one of the major natural hazards, account each year for enormous property damage in terms of both direct and indirect costs. Landslides can be triggered by a variety of external stimulus, such as intense rainfall, earthquake shaking, water level change, storm waves, or rapid stream erosion that cause a rapid increase in shear stress or decrease in shear strength of slope-forming materials. In addition, as development expands into unstable hill slope areas under the pressures of increasing population and urbanization, human activities such as deforestation or excavation of slopes for road cuts and building sites, etc., have become important triggers for landslide occurrence. There are two main objectives are, Laga Gaba was Identified site in the high risk of land sliding in Gimbi town and the main reasons of land sliding in Gimbi Town were identified as, geomorphology (Topography & steep slope), geology of Gimbi Town, Climate (rainfall & temperature), Erosion Processes, Rock and soil types. Here by, in this section, the researcher would explore, interpreted & discussed what has been researched & documented on the assessment & reason of landslide in previous works. Landslide activity is very common particularly in the Highlands of Ethiopia. In the northern, western, and southern highlands of Ethiopia, the resulting damage due to landslides has been increasing due to various natural and manmade factors. Several studies have been conducted following various qualitative, analytical, and empirical approaches to assess the causes and factors that trigger landslides in different parts of the highlands of the country. Shiferaw Ayele (2009) utilized remote sensing

and GIS approach to delineate Landslide Hazard zones in Abay Gorge (Gohatsion-Dejen), Central Ethiopia. The various causative factors considered for this study were, geology, groundwater condition, drainage, slope, structures, aspect and land use/ land cover. In this study, comparison of the landslide hazard map was made with actual landslide events of the study area and found that 67% landslides lie within the maximum hazard zone delineated by the study. Getachew, Lemmesa *et al.* (2000) conducted mass movement hazard assessment in Betto, Goffa district, North Oromia Zone, Southern Ethiopia. The study identified that the main cause of landslide was the existence of old landslides on steep slopes that was covered by deeply weathered, closely jointed, or sheared basaltic rocks.

### Topography of Study area

The highlands of Ethiopia are generally characterized by highly variable topography, which is a reflection of the past geological and erosion process. The landscape includes plateaus, steep hill slopes, and deeply incised valleys and gorges. Much of the elevation of the highlands ranges from about 1500 to 3500 m: with some of the gorges within the highlands having elevations up to 1000 m while some mountains rising over 4600 m above sea level. The topography of Gimbi town is varies from 1744 to 2113 m above sea level as per Digital Elevation Model (DEM-30 m resolution). Many of the hill slopes are steep enough to reach the limit equilibrium state, whereby external factors such as rainfall infiltration and/or excavations (artificial or natural) could trigger slope failures.

## II. MATERIALS & METHODS

The following materials and methods have been employed to achieve the objectives of the present study. Preliminary reconnaissance survey of the study area to have information on the topographic features, availability of information, accessibility, the main data sources are, Ethiopian Geological Survey, from where the regional Geological map and geological description was acquired and processed, Ethiopian Meteorological Service Agency-the source of meteorological data, Satellite images, the source of information on slope angle, elevation data, and land use land cover of the study area.

### Method of Data Collection

- Representative rock and soil samples were collected from the slopes that are identified as potentially unstable
- Delineation and creation base maps of the study area from topographic and Geological maps to carryout field mapping
- After the background work as desk study has completed, additional actual data were collected and mapped from the field to fill the gap between the available existing data on the map and the present data in study area using GPS onto the base maps, including taking photographs
- Generation of the main contributive factor maps for the area with the use GIS techniques
- preparing a Landslide Hazard Map which comprises the information of the relative susceptibility of the area to landslides
- Evaluations of some general Engineering Geological properties of the representative rock and soil samples and interpretations were made from unstable slopes in the laboratory for future slope stability analyses.

III. DATA ANALYSIS AND INTERPRETATION

Topography of study area

The topography of study area is varies from 1744 to 2113 m above sea level as per Digital Elevation Model (DEM-30 m resolution).

Table 1- Topographic Elevation of Gimbi Town

| No. | Parts of the study area in direction   | Elevation above mean sea level |
|-----|--|--------------------------------|
| 1   | Southern part of the town              | Above 2000 m                   |
| 2   | Central & south- west part of the town | 1900 m-2000 m                  |
| 3   | Large part of the town                 | 1800 m-1900 m                  |
| 4   | North part of town                     | Below 1800 m                   |

Source: Gimbi Town Municipality Office

The data in the table -1 above was analyzed & interoperated as follows:

- The topography elevation above 2000 m is found southern part of the town. In general, landslide site is not observed in this elevation range, since the area is covered by forest and moderately vegetated area, low drainage problem and low man made activities for slope instability.
- The topographic elevation from 1900-2000 m is found central and south west part of the town. About twelve sites were identified related to landslide in this elevation range area. This is mainly due to the land use of the area covered by developed part of the town (there is large man made activities carried due to road and house construction), scarcely vegetated and poor drainage system.
- The topographic elevation between 1800 m-1900 m is large part of the town area. About seven sites were identified related to landslide in this elevation range area. Similarly, these sites are found within the developed part of the town and poor drainage area.
- Below 1800 m is elevation found at the north periphery of the town at the riverbeds.

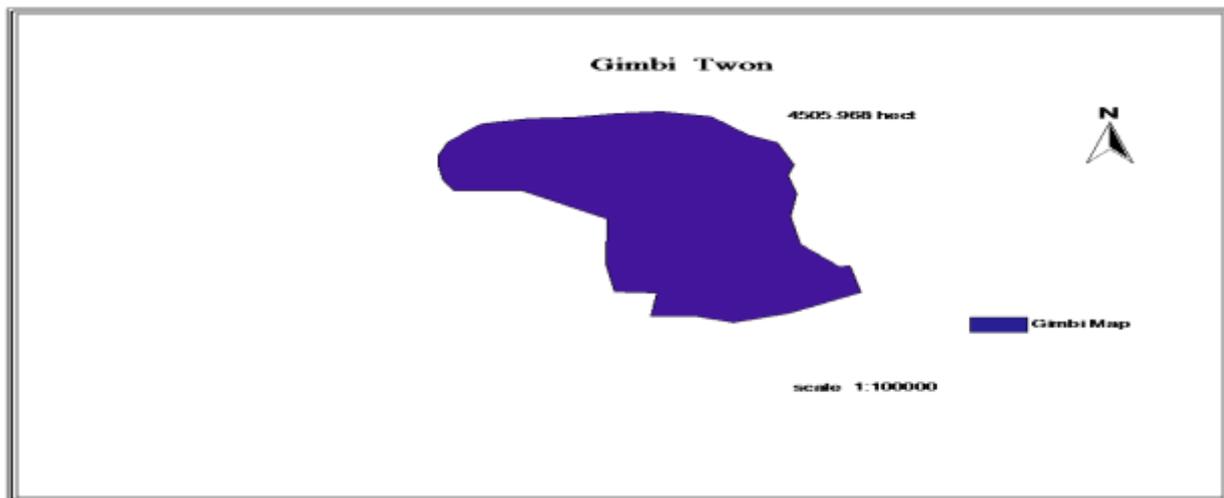


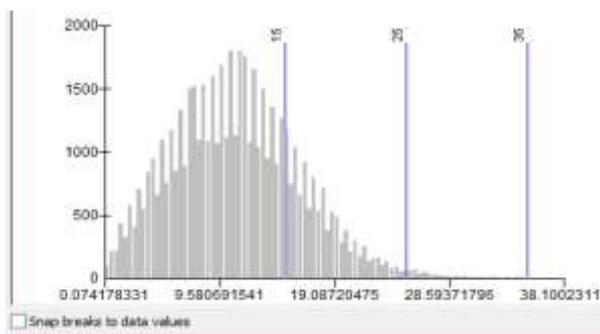
Figure-1: Topographic Elevation Map of study area



Figure-2: Topographic Elevation Map of study area

### Slope of the study area

Relief is a principal factor in the determination of the intensity and character of landslides. It has direct as well as indirect influences. Direct influences encompass slope, steepness, river valley morphology, and thawing gradients. The most important relief characteristic is the steepness, which affects the mechanism as well as the intensity of the landslides. The greater the height, steepness and convexity of slopes, the greater the volumes of the landslides. The stability of the slope against sliding is defined by the relationship between the shear forces and the resistance to shear. The main force responsible for mass wasting is gravity (UNESCO/UNEP, 1988). The slope of Gimbi town is fall in to four categories. The minimum slope is observed is 0 and maximum slope is 38 and the average slope of the town is 11. The detail is presented as shown in figure-3.



**Figure-3:** The Number of Cells Vs Slope

- ✓ **Very gentle slope (0-15°):** this category covered more than 70% of the Gimbi town and only two landslides sites were identified on this slope.
- ✓ **Gentle slope (15-25°):** this category covered about 20% of the Gimbi town and only 17 landslides site were identified on this slope.
- ✓ **Moderately steep (25-35°) and steep (35-38°):** this category covered about 5% of the Gimbi town and only no landslide sites were identified on this slope.

### Geology of Study area

There are many associations of mass movements with certain rock types (UNESCO/UNEP, 1988). Hard intact rocks have strengths controlled by their internal cohesive and frictional properties. Existence of areas of weakness such as faults and joints may lead to rock failures and these are more common in granites and sandstone (Selby 1993). The inherent weakness of these zones increases the deep percolation of water into bedrock and subsequent weathering of crushed rocks into clay rich soil susceptible to failures. The existence of a relatively impermeable layer in the bedrock promotes the formation of a perched water table during storms or heavy rainfall, increasing the risk for slope failures (Sidle *et al.*, 1985). The susceptibility of the whole mass to sliding is determined by the weakest link. During rains, drainage of water through the soil profile is stopped at the point of discontinuity thereby causing water to accumulate. These phenomena results in a semi-solid sub soil material that will easily flow or slump under pressure from the top soil (Kitutu *et al.*, 2009).

The major rock types in the highlands of Ethiopia include

- Metamorphic rocks (mainly Meta sediments and Meta volcanic) and associated intrusive rocks (Mohr 1983),
- Paleozoic sediments which include glacial, tillites and post-glacial sediments (siltstone/sandstone units) (Mohr 1962, 1967, 1983; Kazmin 1972),

- Mesozoic sediments that include sandstone, shale, and limestone units (Assefa 1981, 1991; Russo *et al.*, 1999),
- (4) Cenozoic volcanic (basalt flows of the trap series) which are often associated with pyro-clastic and lacustrine deposits (Mohr, 1988)
- Trachytes and Intrusive rocks (like dolerites) (Mohr 1962).

These rock formations are often affected by different geological structures. The main soil types found in the highlands of Ethiopia are unconsolidated recent sediments which include colluvial /debris materials, residual soils and alluvial deposits. With regard to the influence of rock types on landslides, Gezahegn (1998) and Ayalew (1999) have indicated the presence of soft and low permeability nature of materials (shale) in the Abay Gorge as factors controlling landslides in the area. Ayenew and Beriberi (2005) have reported the presence of loose unconsolidated deposits, which overlie the highly weathered basalt as factors influencing landslides. According to Woldearegay (2005), the presence of soft and low permeability sediments (glacial tillites and shale) which underlie the unconsolidated deposits influence debris/earth slides in northern Ethiopia. Particularly, there are four types of rocks in Gimbi Town.

### Reddish Silt Clay Residual Soil

The residual soil is covered large part of the area in the Gimbi town. The soil in the area is characterized by red in color with silt clay soil by testing with sieving analysis test. It is clay loam soil type. This soil has a thickness from few cm to 50 m thick soil and it easily erodible when it exposed for runoff and with poor drainage system. The land degradation by erosion, landslide, and earth fall is related to this soil in Gimbi town. Therefore, proper drainage system, retaining well, and outfall structure is very important to protect land degradation in the area.

### Residual Gravel Sand Soil

The residual gravel sand soil is found below the residual soil and it is found in the test pits, borehole-drilling logs and in the trench excavated for road and pipe work. This soil has characteristics of hard, dry, gravel sandy texture and yellowish and whitish in color. The soil is found between reddish clay soil and basement rock formation. The thickness of the sediment is varies from few cm to 10 m depending on the location. This soil also a characteristic to erode, when it is exposed to the runoff water.

### Alluvial Sediment

The alluvial sediment is found in the western part of Gimbi town in the river valley. The alluvial sediment is characterized by silt sand with gravel, firm, moist, and whitish in color as observed in the field observation. This sediment is not having relation with landslide problem. It can be used this sediment as construction material source for sand.

### Fault Deposit

This sediment is found in the Western and Northwestern part of Gimbi town boundary in the shear zone. Fault deposit is a section of rock separated from another rock one or more faults. This site found in fault zone metamorphism, the metamorphism that acts on rock girding past one another along a fault and is caused by direct pressure and frictional heat. The material type of the rock is composed of fragmented rock material and regolith. From the previous investigation done by Geological Survey of Ethiopia and field observation the geology of Gimbi town was classified in to three major categories (Jamal Mohammed. 2015).

### Gabbros- amphibolites

The Gabbros- amphibolites is one of the most important rock types occurring over a wide area from small pods to continuous outcrops. The meta-gabbros commonly exhibits a wide range of mineralogical composition and texture from rocks which show magmatic features to rocks in which the primary mineralogy and texture is completely obliterated by deformation and alteration. It also invariably contains amphibolites, dolerite and meta-ultra-mafic.

### Granitoid Orthogenesis

This unit is the second most extensive part of the gneissic unit, and forms rugged terrain and prominent topographic features. They are uniform in outcrop and preserve relict granitic texture. They are usually gray, medium to coarse grained, well foliated and banded. However, a transition from foliated and banded rocks to massive varieties is common. Granite gneiss is the dominant rock type in this unit, and composed of 30-45% K-feldspar (mainly microcline), 20-35% quartz, 20-25% plagioclase (oligo-clase), 5-15% biotite and minor amounts of opaque, Epidote and traces of zircon, sphene, orthite and apatite. Thin sections show that the quartz in these rocks is highly strained and finely re-crystallized, and feldspar twin lamellae are bent and larger grains are broken forming aggregates of angular grains, indicating a high rate of strain. Granodiorite gneiss is the next abundant rock type in this unit. It is dominantly observed east of Gimbi town on the main Gimbi-Nekemte highway, and forming discontinuous hilltops.

### Granite and Granodiorite

This unit forms the dominant part of the Syn-to-late-tectonic intrusive. They are circular, sub circular and elliptical in outline and form the outstanding Cho chi, Grenache, Bronchia and Kalisi Mountains. Five separate plutons; Grenache, Tulu Lencha, Borchicha, Haroji and Wanke represent the unit. They are dominantly monzo-granite and granodiorite, though with a broad compositional spectrum from gabbros/diorite to sye-nogranite. The monzo-granite is grayish white and grayish pink, medium grained, foliated and sheared. The rock is variably sheared and recrystallized, in which large por-phyro-clasts of K-feldspar, quartz, and plagioclase lie within recrystallized matrix of quartz and K-feldspar; however, in less deformed rocks hype dimorphic granular texture is common. Biotite is the characteristic mafic mineral, and is bro-vnto reddish brown and chloritized. In sheared varieties it is deformed (kinked) and partly reduced to the aggregates of sphene and opaque's. Epidote is commonly observed as separate anhedral to euhedral crystal that is in contact with most other phase but in much smaller amounts as secondary minerals in limited alteration of mafic minerals and plagioclase. The euhedral and anhedral Epidote may possibly be a primary (magmatic) phase. This Epidote also contains core of orthite.

### Stratigraphic (geology)

The geology of the site is characterized by overburden residual sediment and basement rock formation. **Overburden Residual sediment:** this sediment is characterized by reddish, silty clay soil, moist, not compacted, and firm. The thickness of the sediment is about 3-10 m. Construction Design SCO excavated the test pit. and the test pit depth is up to 2 m. This sediment is eroded at the bank of the river due to there is no outfall structure and the reset the sediment slide towards the river. **Basement rock:** the basement rock were exposed at the river bed and it is found below the sediment layer. The rock is very massive, moderately weathered, hard and impermeable rock formation.

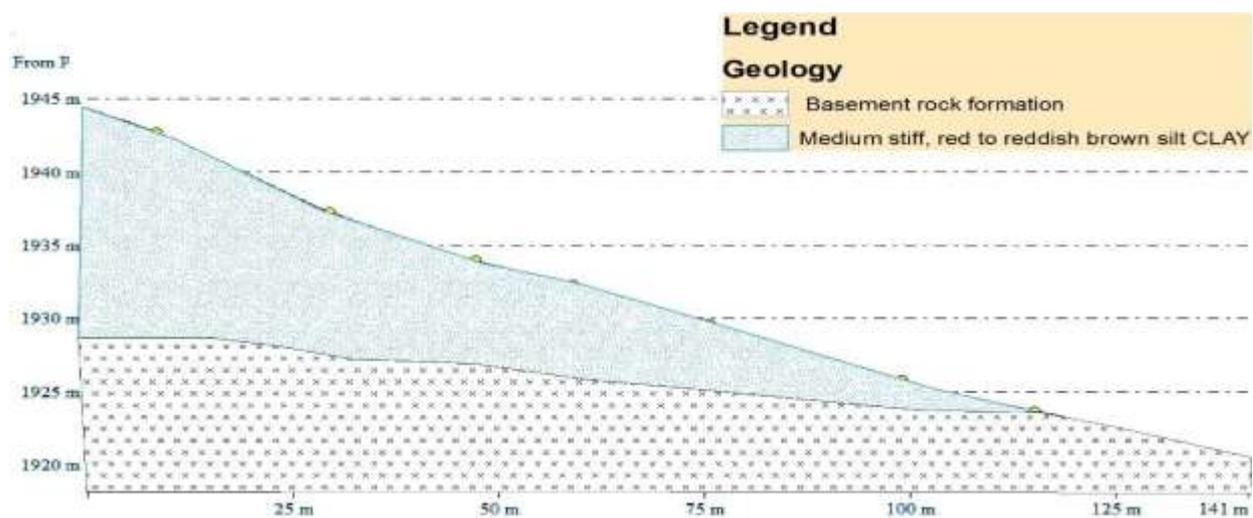


Figure-4: Geological section from fall existing retaining well to downstream

### Climatic Condition of the Study area (Rainfall & Temperature)

The Ethiopian highland is characterized by variable climatic conditions. The fact that the region is located in the tropics combined with the existing high range of altitude and air pressure difference determines the variation in climate that prevails in different areas (Chernet, 1993). Atmospheric temperature, of the highlands, varies from about 30<sup>0</sup> C to 50 C during the seasons October to January. According to the National Atlas of Ethiopia (1981), climatic conditions in the equatorial regions are strongly influenced by their altitude. The Gimbi town is lies in semi- temperate 1500- 2300 mean sea level with annual mean temperature of 15 to 20° C. The climate in Gimbi is warm and temperate. Gimbi is a city with a significant rainfall. Even in the driest month, there is a lot of rain. The average annual temperature is 14.7 °C in Gimbi. The driest month is December, with 13 mm of rain. Most of the precipitation here falls in August; averaging 269 mm. March is the warmest month of the year. The temperature in March averages 16.1 °C. August is the coldest month, with temperatures averaging 13.6 °C in table -2 given below.

Table-2 Monthly Temperature & Rainfall of Study area

| Months of the Year | Temperature Per Month in <sup>0</sup> c | Rainfall Per Month in mm |
|--------------------|---|--------------------------|
| January (01)       | 15                                      | 20                       |
| February(02)       | 25.4                                    | 40                       |
| March(03)          | 16.1                                    | 65                       |
| April (04)         | 15.2                                    | 95                       |
| May (05)           | 15.3                                    | 115                      |
| June (06)          | 13.9                                    | 160                      |
| July (07)          | 13.8                                    | 263                      |
| August (08)        | 13.6                                    | 268                      |
| September (9)      | 13.9                                    | 283                      |
| October(10)        | 14.1                                    | 56                       |
| November (11)      | 14.5                                    | 17                       |
| December (12)      | 14.9                                    | 13                       |

Source: Gimbi Town Meteorology Station

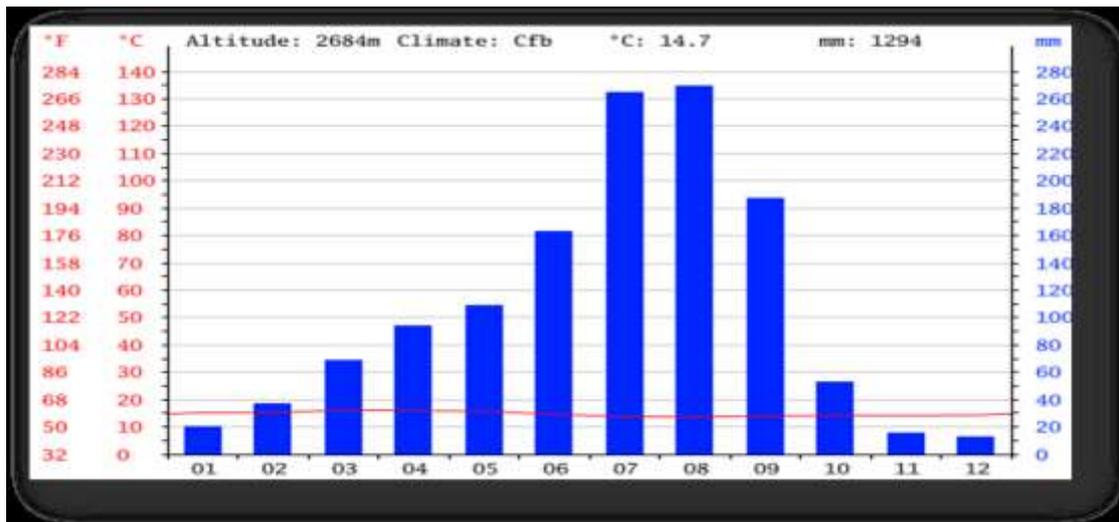


Figure-5 Rainfall Distribution of Study area

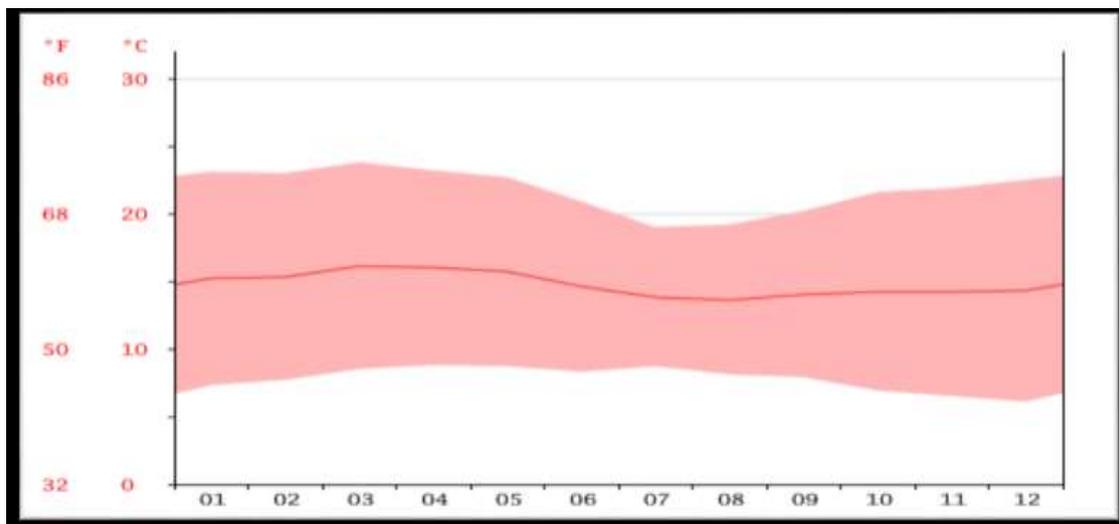


Figure-6: Monthly Temperature of Study area

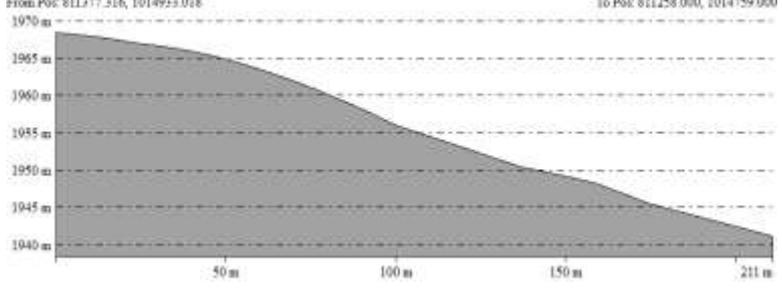
**Influence of Erosion Processes**

It is well known that landslide & associated gully erosion has been a major problem in Ethiopia. Based on engineering geology their two main types of gully erosion are common in the highlands of Ethiopia: (a) discontinuous gully, which generally develop on low slope gradients, and (2) stream gullies, which are formed by deep erosion, processes typically migrating up-slopes. The existence of deep gorges with active geomorphologic processes like stream/river incisions and gulling indicate that the landmass is still active in surface processes which could have influence on landslide evolutions. Similarly, Gimbi Town is characterized by deep erosion gully.

VI. RESULT AND DISCUSSION

Site Identification (K-03, LEGA- GABA) STUDY AREA

Table-3 Site identification with characteristic and types

| Site Identification | Local Name         | Date  | Problem   | Geographic coordinate (GPS) |         |      |
|---------------------|--------------------|---|---|-----------------------------|---------|------|
|                     |                    |   |   | X                           | Y       | Z    |
| K 03                | Lega- Gaba         | June, 2015  | Land degradation due landslide  | 811256                      | 1014759 | 1942 |
| No.                 | TYPE               | CHARACTERISTICS   |   |                             |         |      |
| 1                   | Drainage           | The catchment area= 0.03609 km <sup>2</sup><br>Annual rainfall=1225 mm<br>Catchment length=200 m<br>Max elevation=2025 m<br>Min. Elevation=1900 m   |   |                             |         |      |
| 2                   | Geomorphology      | Average slope from top of catchment to affected area is 24% and it is very steep slope<br>From Pos: 811377.316, 1014933.018 To Pos: 811258.000, 1014759.000<br> |   |                             |         |      |
| 3                   | Drainage culvert   | There is no proper drainage system and out fall structure<br>There is natural river channel downstream of the affected area   |   |                             |         |      |
| 4                   | Land use           | The land use is covered by vegetation and residential homes in the left bank and right bank there is residential houses   |   |                             |         |      |
| 5                   | Landslide property | Landslide type  | Landslide   |                             |         |      |
|                     |                    | Timing for landslide  | Rainy season  |                             |         |      |
|                     |                    | Cause of landslide  | Lack of proper drainage   |                             |         |      |
|                     |                    | Affected area   | Land degradation in the right bank of the river and destroy houses, retaining well and road |                             |         |      |

Triggering Factors of Study Area

A triggering factor is an external stimulus that triggers the movement and one of the renowned triggering factors is rainfall. Rainfall is an important factor in triggering landslides. Precipitation conditions determine infiltration and run-off. Prolonged rains with a lower intensity result in a higher and deeper infiltration and lower run-off in sloping areas. On the other hand, in these regions, torrential rains increase run-off and result in a lower amount of infiltration. Nevertheless, they promote the wetting of soil along fissures, which serve as natural rainwater collectors (UNESCO/UNEP, 1988). The amount of rainfall has a considerable influence on the moisture content and the pore pressure in the soils (Ayalew, 1999).

Landslide/ land degradation Trigger Mechanism

The major trigger factor as per field observation is lack of proper outfall structure and scouring protection as per field observation. The overburden soil is silt clay soil and it is easily erodible material.

Landslide/land degradation characteristics

The land degradation is mainly due to drainage problem and it score the foot of the overburden soil. The soil degradation is inclined moment and it is categorized as landslide type of land degradation (figure below).

Geotechnical recommendation

- Culver and Retaining well should be constructed at the bank of the river.
- The river channel bed should be protected from flood erosion with the use of appropriate structure, which extends at least 200 m from the culver to protect.
- Proper drainage channel should constructed upstream of culver site
- All the retaining well and structure foundation should be basement rock formation and its bearing capacity is about 3M Pa.

## Road and public utility impact

During field observation we observed the land slide is affect destroy homes, retaining well structure and road. Moreover, it is affect another area 100 m away from retain wall in downstream. The total estimated affected area is about 700 m<sup>2</sup>.

## Mitigation measure

- Construction of Drainage Box Culverts
- Construction & Maintenance of Road with Masonry retaining structures
- Construction of Dwarf Concrete retaining Wall
- Construction Short Concrete wall along the river bank
- River train by gabion

## V. CONCLUSION & RECOMMENDATION

### Conclusion

The site specific assessment showed that almost all the affected area are bottom slopes with deep gorges and areas where there is small soil layer over basement rock ; such areas could be traced easily and probable damages might be limited. And the environmental hazard and problem in the area could be categorized in to:

- I. Drainage Problem leading to deep erosion and degradation
- II. Drainage Problem leading triggering landslide &
- III. Bottom Slope Landslide

Therefore; all of the above problems require special attention and specific solutions; accordingly;

- ✓ Drainage problem associated with lack of proper drop and discharge structures have to be provided with proper drop and discharge structure and the adjacent area has to be reinstated. Moreover; the overall drainage problem in the town has to be carefully and Integrated Drainage Master Plan has to be prepared.
- ✓ Drainage triggering landslide is also part of the integrated solution; however, the immediate approaches of landslide areas will be provided with proper channeling and guiding structures and the bottom slope of the slide will be stabilized.
- ✓ The bottom slope landslide will be provided with a series of structures from the sliding plane toe to the upper overburden, accordingly; massive concrete retaining structures will be embedded to the toe rocks and upstream of these will be stabilized with moderated masonry and gabion structures.

### Recommendation

In this study, hazard mitigation is referred to as the sustainable action that reduces or eliminates long-term risk to people and property from natural hazards and their effects. The goal, therefore, is to reduce vulnerability and exposure to landslides. The suggested mitigations are both soft and hard. In this case, soft measures will mainly address issues of avoidance, zoning, and use of regulations. Hard measures will involve construction of structures to create more stable slopes. Although hard measures have been advocated and

implemented in slope stabilization, studies have shown that soft solutions can achieve effectively long term hazard reduction. Soft solutions have also been found to be more cost effective measures over long term than hard measures.

## VI. ACKNOWLEDGMENT

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## REFERENCES

- [1] **Assefa G.** Litho-stratigraphic and environment of deposition of the late Jurassic-early Cretaceous sequence of the central part of north-western Plateau. Ethiopia. N. Jb. Geol. Paleontology Abh. 1991; 183(3): 255-282.
- [2] **Assefa G.** Gohatsion Formation. A new Lias-Malm litho-stratigraphic unit from the Abay river basin Ethiopia. Geos. 1981;2: 63-88.
- [3] **Ayalew L.** The effect of seasonal rainfall on landslides in the highlands of Ethiopia. Bull. Eng. Geol. Environ. 1999;58:9-19.
- [4] **Ayele S.** Slope Stability and Hazard Zonation Mapping Using Remote Sensing and GIS Technique in Abay Gorge, Central Ethiopia. M.Sc Thesis. Addis Ababa University. 2009; 77p.
- [5] **Ayenew T, Beriberi G.** Inventory of landslides and susceptibility mapping in the Dessie area, Northern Ethiopia. Engineering Geology. 2005;77:1-15.
- [6] **Berakhi O, Brancaccio L.** Some reflections on the origin and land use of pediments on the Ethiopian highlands. Geographia Fisica e Dinamica Quaternaria. 1993;16: 101-106.
- [7] **Billi P, Dramis F.** Geomorphological investigations on gully erosion in the Rift valley and the northern highlands of Ethiopia. Catena. 2003;50: 353-368.
- [8] **Bull W.** Discontinuous ephemeral streams. Geomorphology. 1997;19:227-276.
- [9] **Chernet T.** Hydrogeology of Ethiopia. Ethiopian Institute of Geological Surveys. Professional Paper. Addis Ababa. 1993;175p.
- [10] **Hurni H, Perich I.** Towards a Tigray Environmental and Economic Strategy (TREES) Group for Development and Environment, Institute of Geography, University of Berne, Switzerland. 1992;32p.
- [11] **Kazmin V.** Geological map of Ethiopia. Ministry of Mines, Energy and Water Resources, Geological Survey of Ethiopia, First edition, Addis Ababa. 1972.
- [12] **Kitutu.** Influence of soil properties on landslide occurrences in Buddha district, Eastern Uganda, African Journal of Agricultural Research. 2009;4 (7):611-620.

- [13] **Lemmesa G. et al.** Mass Movement hazard assessment on Betto and Parts of Sawla sub sheet of Goffa district, North Omro Zone, Southern Nations, Nationalities and People's Regional State, Report, Geological Survey of Ethiopia, Addis Ababa, Ethiopia (unpublished) 2000.
- [14] **Mesfin WM.** An atlas of Ethiopia. II Poligrafico, Asmara. 1970.
- [15] **Mohr PA. et al.** The Ethiopian flood basalt province In: McDougall JD (Ed.), Continental flood basalts. Kluwer Acad. Publ. Dordrecht. 1988;63-110.
- [16] **Mohr PA.** Review of the geology of the Siemen Mountains. Bulletin of Geophysical Observatory, Addis Ababa University, Ethiopia. 1967;10:79-93.
- [17] **Mohr PA.** Ethiopian flood basalt province. Nature. 1983;303: 577-583.
- [18] **Mohr PA.** In: The Geology of Ethiopia. II Poligrafico, Asmara. 1962.
- [19] **National Metrological Agency.** Addis Ababa, Ethiopia. 2011.
- [20] **Nyssen J et al.** Human impact on the environment in the Ethiopian and Eritrean highlands a state of the art. Earth-Science Reviews. 2004;64: 273-320.
- [21] **Selby MJ.** Hill slope Materials and Processes, 2nd edition. Oxford University Press: New York. 1993;451p.
- [22] **Sidle RC, Pearce AJ, O'Loughlin CL.** Hill slope Stability and Land Use. Washington, D.C., American Geophysical Union, Water Resources Monograph Series. 1985;11:140p.
- [23] **UNESCO.** "Geology for Sustainable Development", UNESCO, Paris, France, Bulletin. 1993-1994; 10:75p.
- [24] **Woldearegay K.** Rainfall-triggered landslides in the northern highlands of Ethiopia: Characterization, GIS-based Prediction and Mitigation. PhD Thesis. Graz University of Technology, Austria. 2005.

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