GIS Based Frequency Ratio for Landslide Susceptibility Mapping in Debre Sina Area, Central Ethiopia.

Matebie Meten Endalew*, N.P. Bhandary & Ryuichi Yatabe

Ehime University, Graduate School of Science & Engineering, Geo-Disaster Laboratory

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1. Introduction

Landslide in Ethiopia is posing a series problem particularly in the highland areas due to heavy rainfall that occurs from June to end of September. Debre Sina area is located between 39˚ 43’ 30” E - 39˚ 51’ E longitude and 9˚ 50’42” N - 10˚ N latitude, covering an area of 183.4Km^2. Its altitude varies from 1250m to 3200 m and it has an average annual rainfall of 1857mm.

This area is affected by series landslide problems in the last three decades owing to the different contributing and triggering factors. A large scale landslide incidence in Debre Sina area (yizaba & Shotel Amba locality) occurred in September 13, 2005 after a heavy rainfall reactivated the existing landslide. In this incident More than 3000 people have been displaced and 1250 dwelling houses have been demolished as a result of the landslide. In addition, 1 church, 4 Mills, and one satellite elementary school has been completely destroyed (K. Woldearegay, 2008). The landslide has also devastated about 1500 hectare of agricultural land and caused damage to the natural environment. The slope instability problem still remains an active problem in this area. In addition to the abovementioned case, Debre Sina area also suffers from rock falls, rock slides and earth flows.

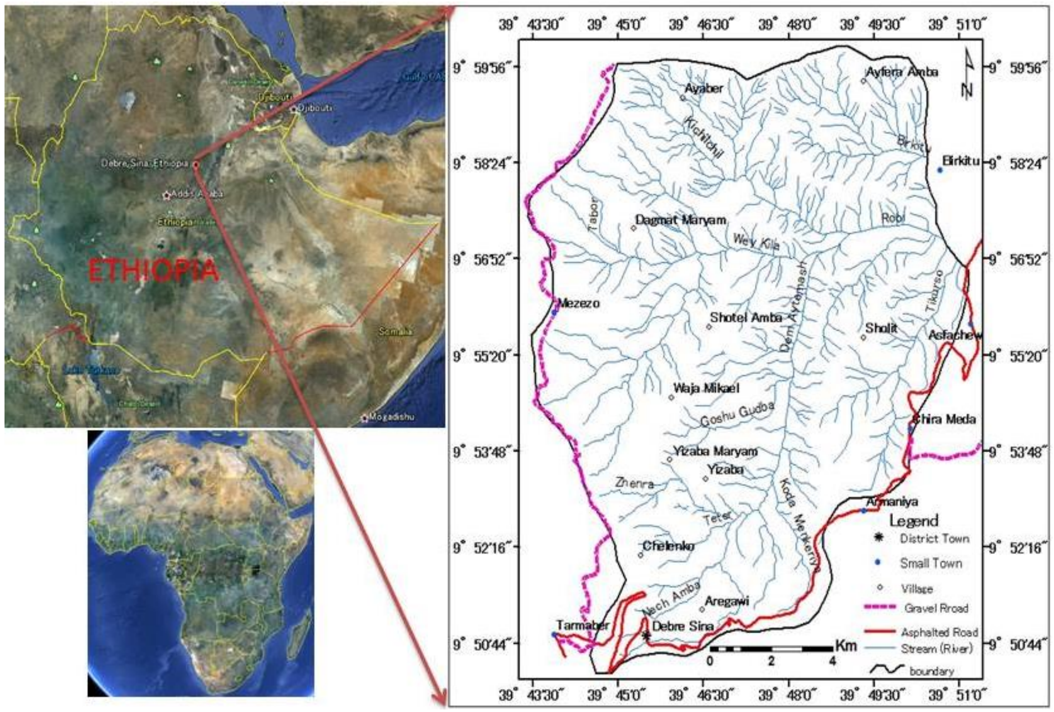

Figure 1 Location Map of the study area

2. Methodology

In this study an attempt has been made in order to produce the landslide susceptibility map of the Debre Sina area based on the relation of past & present landslides and the different contributory factors using GIS based Frequency ratio method. The frequency ratio can be obtained by dividing the landslide percentage by area percentage in each factor’s class. If the ratio is greater than 1, the higher the relationship between landslide and certain factor and if the ratio is less than 1, the lower is the relationship (Saro Lee & Ueechan Choi, 2003). Summing the frequency ratios of each factor’s frequency ratio will give the landslide susceptibility index, which will be further reclassified into different susceptibility classes based on a natural break method in Arc GIS. The spatial resolution in all analysis process was 30 m.

For the Frequency Ratio model nine landslide contributing factors were utilized in order to come up with the final landslide susceptibility map of the area. These factors include lithology, land use (land cover), distance to fault, distance to river, slope, aspect, curvature, elevation and annual rainfall. A total of 463 landslides were used by dividing in to training dataset (325 landslides =70%) and validating dataset (138 landslides=30%).

3. Results and Discussion

Using this model, the spatial relations between landslide and landslide contributing factors were derived (Saro Lee & Ueechan Choi, 2003). The result from the Frequency Ratio Analysis showed that 6% of the area falls in the very high landslide susceptibility class while 20%, 26%, 31% & 16% of the area fall in the high, medium, low and very low landslide susceptibility classes.

After the susceptibility map has been prepared, the prediction capability and the success in validating the model should be checked. By extracting the landslide points with the final landslide susceptibility map, the areas with landslide probability of 1 and their respective frequency ratio values will be obtained. Similarly the non-landslide dataset, with a landslide probability of 0, will also be used to extract the frequency ratio values of the final landslide susceptibility. By merging these extracted values in SPSS statistical software, the prediction capability and success rate of the model can be found using training and validating landslide datasets respectively.

The accuracy the models can be found from AUC (Area under the curve) of ROC (Relational operation Curve) in SPSS. Based on this the prediction and validation models have AUC values of 0.748 and 0.737 respectively. This showed that the prediction model can predict up to 74.8% while the validation model can predict up to 73.7% correctly. Based on this result, we can say that the model can predict the future probability of landslide occurrence in a good way.

The possible contributing factors to the frequent landslide in this area are lithology (basalt, pyroclastic rock, volcanic agglomerate & soils); structures (normal faults), steep topography (slope), elevation (1250 – 3200 m); land use, drainage network, slope aspect and the triggering heavy rainfall. Besides heavy rainfall, seismicity has also some influence in triggering landslide as the area is near the Afar Rift where a continental spreading is still active.

The field observation in this area showed that landslide has affected to a greater extent in case of highly fractured and weathered ignimbrites and basalts that forms moderate to steep morphologies. The presence of regional normal faults that run in N, NE-SW and NW-SE has also played a great role in facilitating the landslide incidences. The land use type with barren land, agricultural land and scarce bushes is highly susceptible to landslide. Perennial rivers like Robi and Dem Ayemash have incised the terrain and caused many landslides in their vicinity.

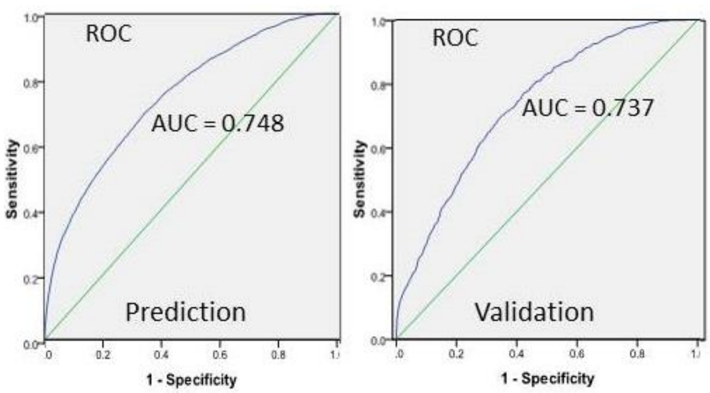

Figure 2 Landslide susceptibility Map of the study area.

4. Conclusion

The frequency ratio values of the factor's classes which are greater than 1 & showing a good correlation with landslide are listed in an increasing order with in their respective classes as follows.

Slope(15-20˚, 20-30˚, 30-40˚ & 40-64˚); elevation(1800-2100m & 2100-2400m); aspect(SW,S,SE &E), curvature(-2.97- -1.26, -15.31 - - 2.97& 2.73 – 13.93), distance to fault(2000-2400m, 1200- 1600m & 0 – 400m), distance to river(0 -120m), land use (bushes & shrubs, sparse forest & barren land), lithology(middle basalt and lower pyroclastic Rocks) and annual rainfall(1310 - 1420mm, 1500 – 1630 mm & 1630–1740mm).

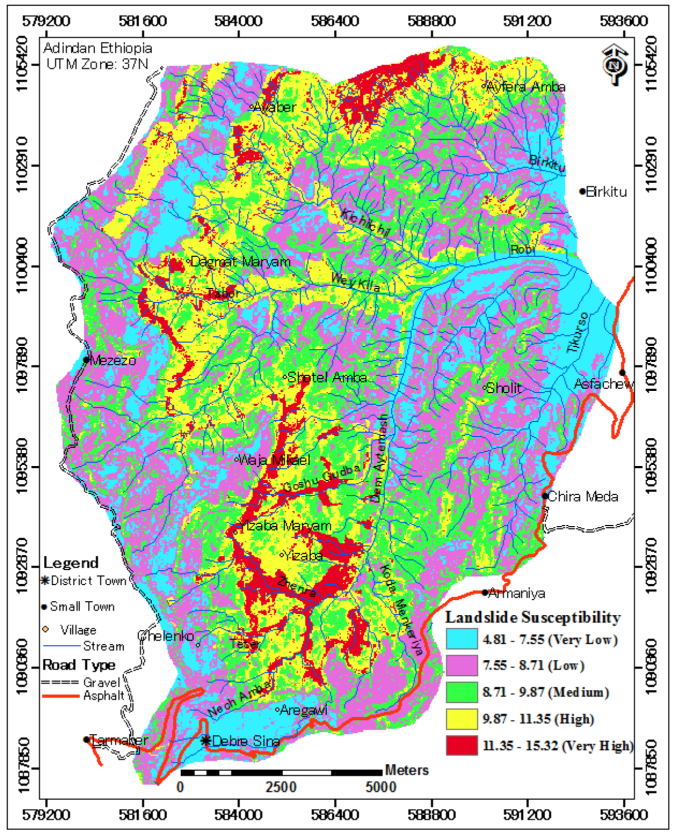

Figure 3 ROC Curves for Training and Validation

The main triggering factors of landslide in the study area are heavy rainfall and earthquake seismicity in the Afar Rift and escarpment zone, which initiates normal faulting in the region.

5. References

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2) Woldearegay, K.: Characteristics of large-scale landslide triggered by heavy rainfall in Tarmaber area, Central Highlands of Ethiopia, Geophysical Research Abstracts, Vol. 10, EGU2008-A-04506,2008, SRef – ID:1607-7962/gra/EGU2008-A-04506 EGU General Assembly 2008