UNIVERSITY OF TWENTE.

Faculty of Geo-Information Science and Earth Observation

Report on the project of AES Geohazards Stream

Landslide hazard assessment in the Khelvachauri area, Georgia

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George Gaprindashvili
Jianping Guo
Panisara Daorueang

Institute of Geo-Information Science and Earth Observation (ITC) of the University of Twente

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1. Introduction

As in most developing countries, quantitative landslide assessment is still scarce in Georgia, due to the too limited resources available for research, on historic record of landslides, detailed socio-economic elements at risk. In particular, there are not enough data on the probability of landslides of different magnitudes to make a quantitative risk. Most conventional landslide studies in Georgia are descriptive, more data-driven assessment with in-depth knowledge of all the causal factors for landslide, therefore, are extremely urgent.

Landslide risk assessment methods are classified into three groups, as qualitative (probability and losses in qualitative terms), semi-quantitative (indicative probability, qualitative terms) and quantitative (probability and losses both numerical) (Lee and Jones, 2004).

The study area (shown in Fig. 1), Khelvachauri, is one of five regions in Adjara, an Authonomous Republic in the southwest Georgia. It is located 8 km south-east from one of the major city of Georgia - Batumi. Also, it covers an area of about 97.5 km^2 with population approximately 38,000 people, includes the city of Khelvachauri and Makhinjauri, as well as 30 villages. This area is bounded by the Black Sea to the west and Turkey to the south. The plane lowlands morphologically create beach. The most important and biggest river is the Chorokhi, which flows 26km along the Region. The region has specific geographic and climate conditions. Most of its parts are mountainous. It is practically unable to explore new areas.

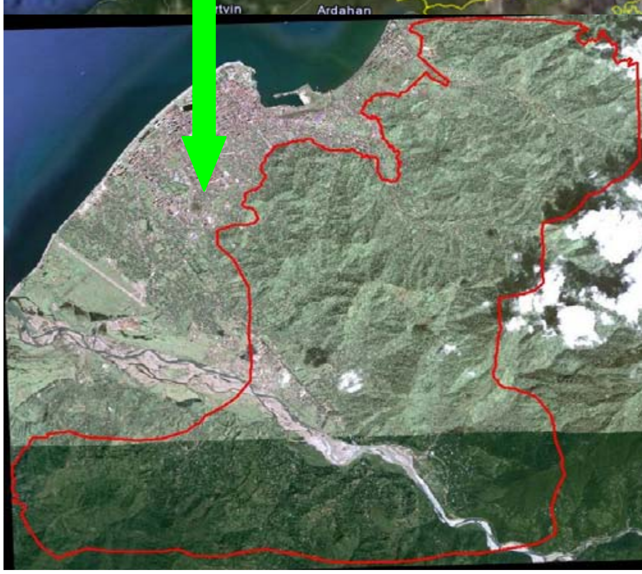

Figure 1: The Study area of Khelvachauri, Georgia shown within the red boundary (Source: Google Earth)

Agriculture dominates in the regional economy though industry is also developed there. There are three tea factories, stagnant materials plant, constructing blocks workshop. Agriculture takes the leading part. There is developed tea, citrus, cattle breeding, and other branches there. Also, tourism is developed in the region.

Many environmental factors, related to the fields of geology, geomorphology, topography and land use, have the potential to affect land sliding (Clerici et al., 2002). Moreover, most of the quantitative risk assessment methods that have been developed elsewhere are case-specific and require many types of data, on landslide occurrence and impact, most of which are not yet available in Georgia.

The purpose of this project was to evaluate landslide hazard using quantitative method. The study is based on the landslide inventory, generated by interpretation of aerial photos, satellite images and field data.

The objectives of this project are as follows:

- Define and justify a relevant set of spatial criteria for this case of landslide hazard assessment.
- Carry out a proto-type landslide susceptibility assessment to demonstrate the possibilities and limitations of a SMCE-based approach.
- Contrast ASTER-GDEM data and a contour-based DEM data sources for generating "spatial criteria" maps.
- Construct an exposure map by comparing the produced landslide susceptibility map with available cadastral data.

2. Data Description

In order to assess the landslide hazard in the Khelvachauri area, Georgia, the following dataset were utilized:

- Landslide inventory map directly visually interpreted from high resolution Google-Earth image
- Egineering geological map(scale at 1:10,000) produced from the study during 1976-1980 (Source: Ministry of geology of Georgia, 1980)
- Topographic map data at 1:50,000 scale
- Geomorphological map
- Soil dept data

- Landuse data deriving from parcel data
- Spatial distribution and the number of buildings extracted from cadastral data

3. Methodology

3.1. Work flow

According to Figure 2, this study is based on a vulnerability assessment at the Khelvachauri area, Georgia. The scope of this study comprises of integration of landslide susceptibility and physical vulnerability (number of building and landuse information). The integral result will identify the physical vulnerability. As for the input data, especially landslide inventory, it is a crucial mandatory data for assessing landslide vulnerability, predicting the future landslide occurrence, and its level of risk. Besides, it is very neccessary to understand the different casual factors as well. The selected data used are lithology, geomorphology, landuse, including DEM.

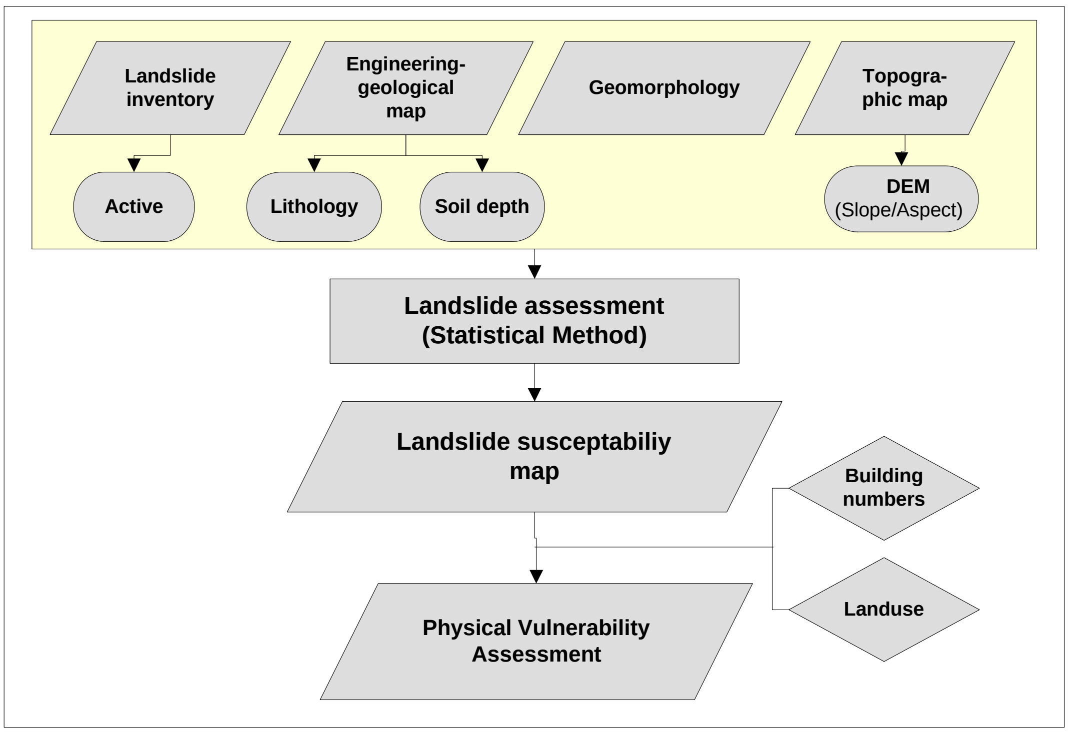

Figure 2: Flowchart of landslide vulnerability assessment in Khelvachauri, Georgia.

3.2. Methodology

Due to the complete lack of historical landslide information and geotechnical data precluding the development of quantitative deterministic or probabilistic models, we carried out a basic bivariate statistical landse and soil depth), and only the landslide type of “active”, which is seen as the result of the combination of six causal factors.

In this project we will generate a landslide susceptibility map, using a basic, but useful, statistical method, called hazard index method, which is based upon the following formula:

$$W_i = \ln\left[\frac{Densclas}{Densmap}\right] = \ln\left[\frac{Area(Si)}{Area(Ni)} \Big/ \frac{\sum Area(Si)}{\sum Area(Ni)}\right] \text{………………………………….. (1)}$$

Where Wi is the weight given to 6 parameters: slope, aspect, lithology, geomorphology, land use and soil depth. Densclas is the landslide density within the parameter class. Densmap is the landslide density within the entire map. Area (Si) is area, which contain landslides, in a certain parameter class. Area (Ni) indicates total area in a certain parameter class.

The method is based on map crossing of a landslide map with one of the 6 parameter map. The map crossing results are shown in a cross table, which can be used to calculate the density of landslides per parameter class. A standardization of these density values can be obtained by relating them to the overall density in the entire area. The relation can be done by division or by subtraction. In this project the landslide density per class is divided by the landslide density in the entire map. The natural logarithm is used to give negative weights when the landslide density is lower than normal and positive when it is higher than normal. By combining the six maps of weight-values a susceptibility hazard map can be created, as is obtained by simply adding the separate weight-values. After that, the values will be converted into 3 classes: low, moderate and high susceptibilities. The details of this method are shown in Fig. 3.

4. Results and discussion

We produced the DEM data from two different data sources of ASTER and topographic contour map.

4.1.1 Terrain parameters

Slope, aspect and other DEM-derived terrain parameters are good indicators of the spatial criteria maps needed in SMCE-based landslide susceptibility assessment. All the terrain parameters are from DEM. First of all, we produced the DEM over the study area using two different data sources, i.e. ASTER image and contour map, which have their pros and cons, and corresponding implications for the DEM-derived criteria map for the vulnerability assessment.

We compared contour lines from 1:50,000 scale topographic map with that from Aster GDEM and big errors were found, which was demonstrate in Fig 4.

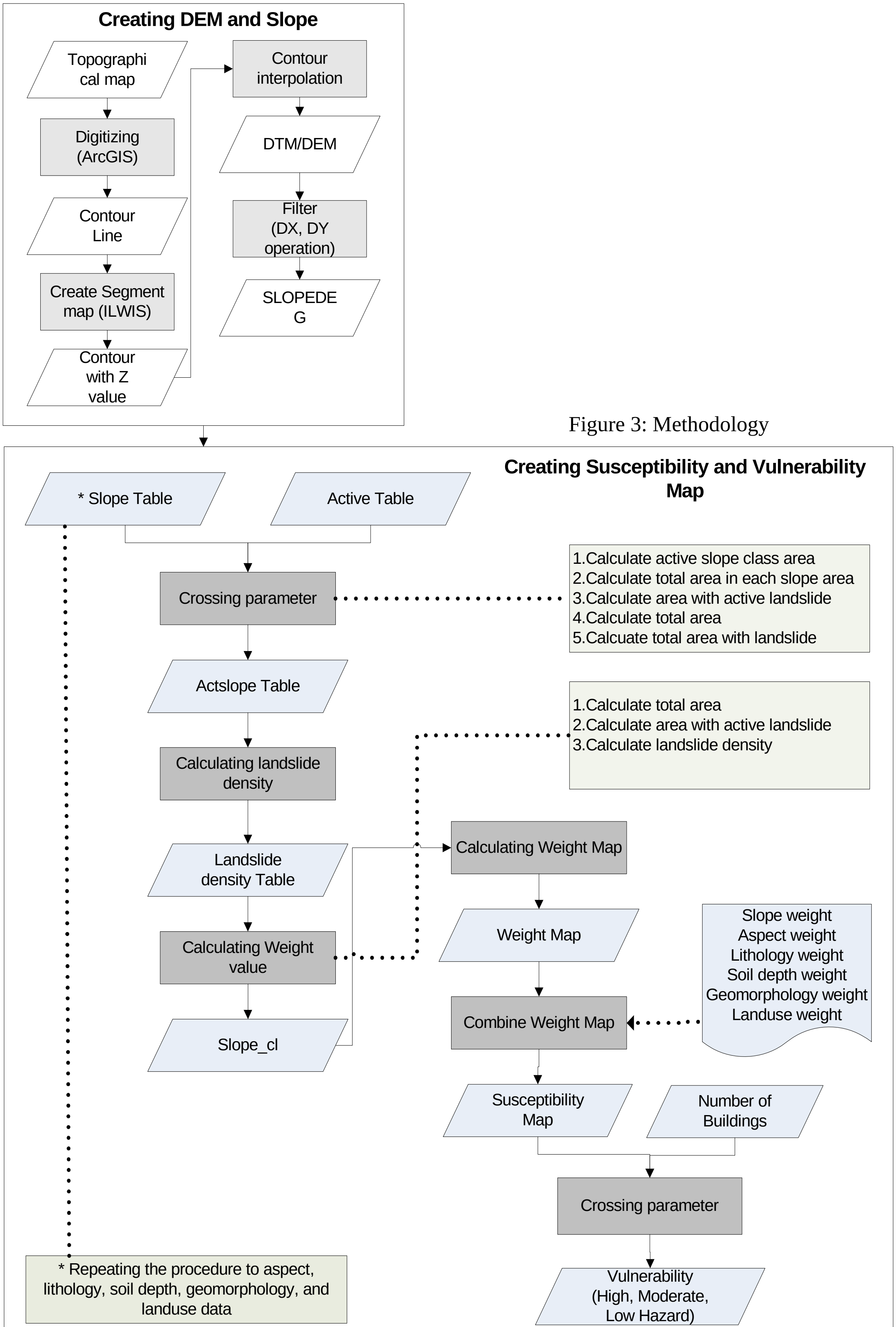

Figure 3: Methodology

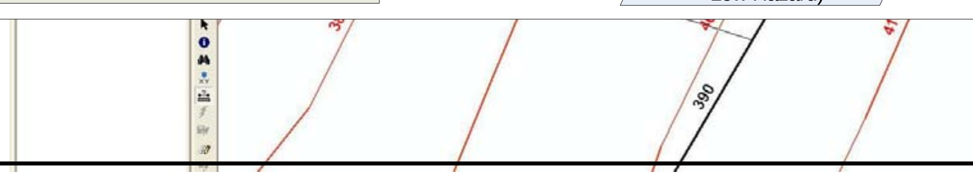

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Figure 4: Schematic map for the error between Aster GDEM and topographic map

4.1.2 Active landslide extraction

Due to the severe impact of active landslide on environment, we extracted 38 active type of landslide, and performed the assessment based only on this type. Landslides are spreading sporadically almost everywhere in the study area (Fig. 5), they maybe have different characteristics and causative factors.

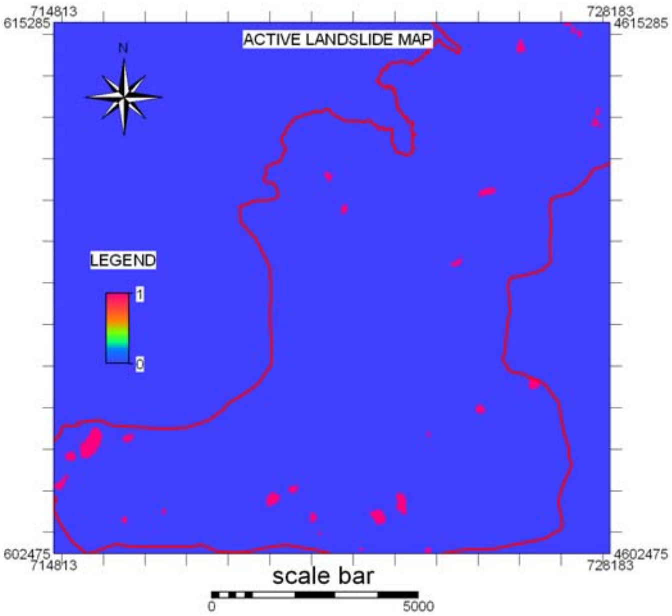
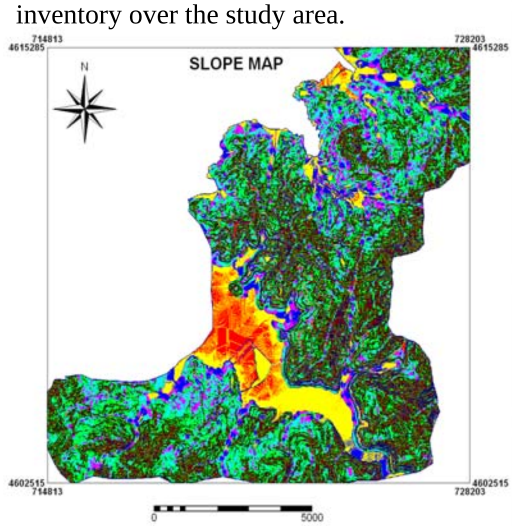
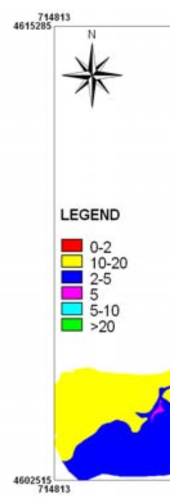
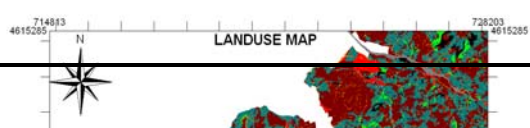


Figure 5: Active landslide map extracted from the landslide inventory over the study area.







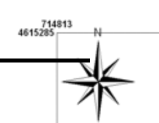
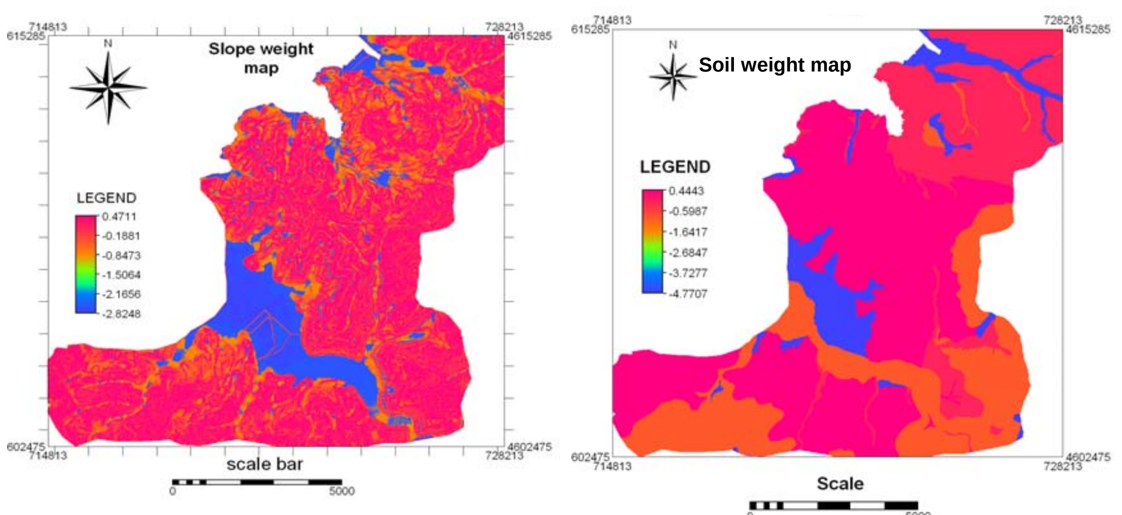


Figure 6: Causative factor maps (slope, soil depth, geomorphology, aspect, landuse and lithology)



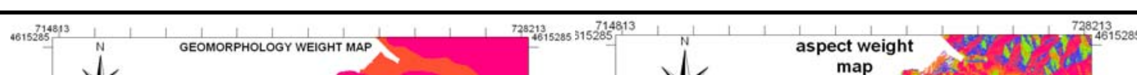


Figure 7: Weight maps for causative factor maps (slope, soil depth, geomorphology, aspect, land use and lithology)

4.1.3 Weight assignment

To identify the most influential causative parameters on active landslides in the study area and to quantify their relative contribution, we calculated the corresponding weight of the six parameters described in Section 3.2 using the equation (1). Different causative parameter has quite different influence on the landslide occurrence, which means it is favourable, or unfavourable (Castellanos and van Westen, 2008).

The weight results for the six causative parameters were shown in Fig. 7. By adding up the weight of such causative factor as slope, soil depth, geomorphology, aspect, land use and lithology, we got the overall weight map, which was shown in Fig. 8.

From the resulting weights in the table 1, the most important influential types of factor maps related with landslide were recognized. As for aspect factor, NW had the most important relation with landslides, mountain class for geomorphology, private use for landuse, and laterized loam and clay for lithology presented the highest hazard, 19-24 degree for slope and soil depth between 10-20 had the same influence on landslide.

Causative factor maps	ASPECT	Geomorphology	Landuse	Lithology	Slope(in degree)	Soil depth (in meter)
Most influential types	NW	mountain	private use	laterized loam and clay	19-24	10-20

Table 1: Most influential type or value range versus each causative parameter map

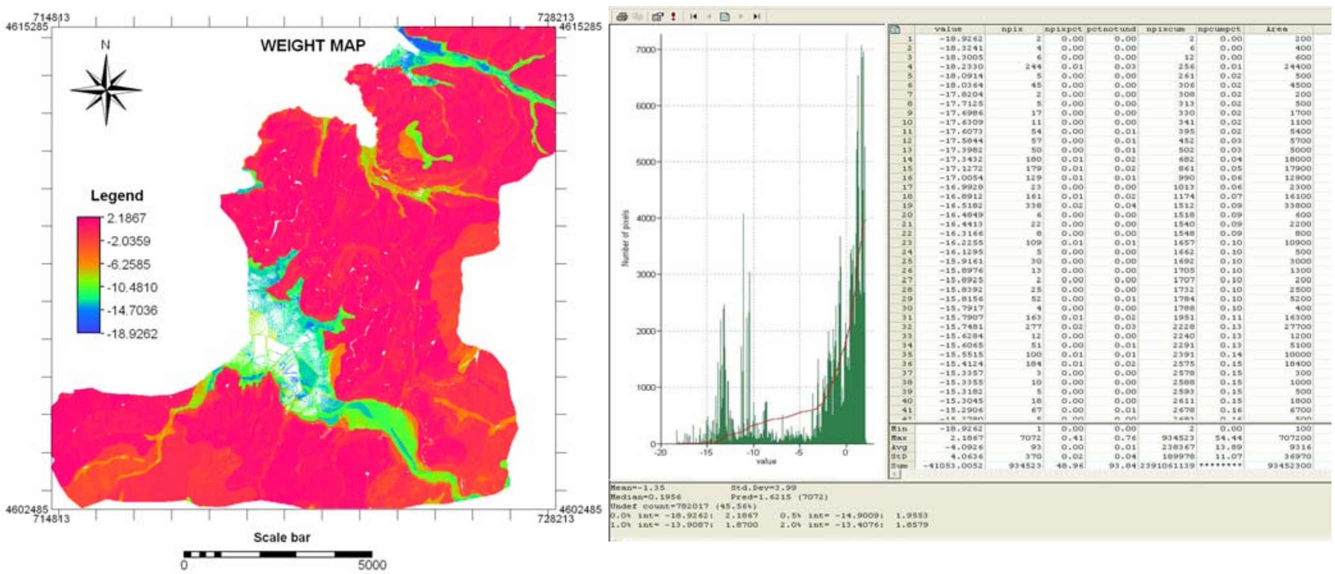
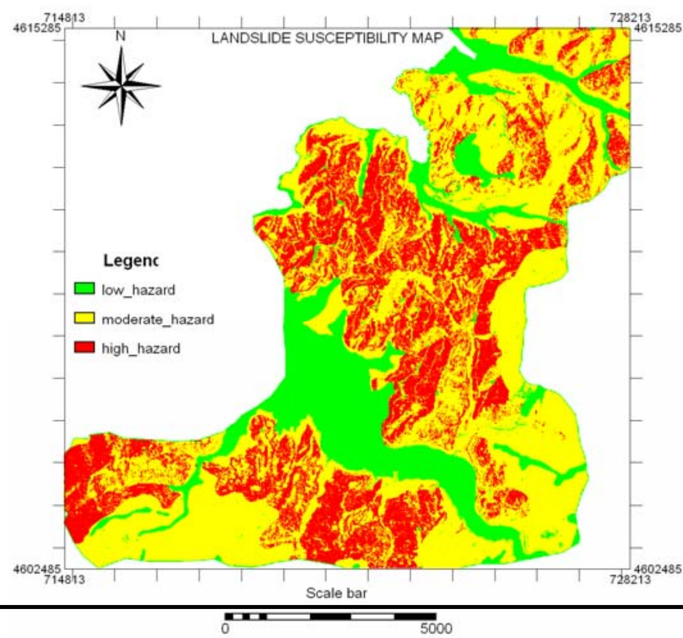


Figure 8: The overall weight (left panel) produced by averaging the six factor weight maps and the corresponding histogram (right panel) based on overall weight on the landslide occurrence.



4.1.4 Susceptibility assessment

Based on the weights assignment, we carried out the susceptibility assessment. The final weights of the resulting map ranged from -18.9 to 2.2. Although the map (Fig.7) gives a good indication of the quantitative landslide hazard in the study area, too wide range might make it difficult to use by decision makers for development planning. Therefore, the hazard map was grouped into three simplified categories based on the histogram of the final weight map shown in Fig. 6: high, moderate and low (Fig. 8). Low hazard corresponded to the range of (-18.9, -4), the moderate to (-4, 1.1) and the high one to (1.1, 2.2).

Figure 9: The susceptibility map based on the statistic methods described in section

4.1.5 Vulnerability assessment

Here we only performed the physical vulnerability assessment over the study area due to the limited availability of data types related to population and social properties. The assessment results were given in table 2. Within this study area, in total 9909 of building are included. Amongst them, 3382 buildings (34.13%) represented high susceptibility class, followed by 4584 buildings as moderate susceptible. According to table 3, within in study area main landuse types were private and government. In low susceptibility class, with 17.9 sq.km. of area, there were the governmental landuse about 26% and private about 23.3%. In moderate susceptibility class, with 51.9 sq.km. of area, there were the governmental landuse about 26.6% and private about 25.6%. In high susceptibility class, with 27.6 sq.km. of area, there were the governmental landuse about 39.9% and private about 40.9%.

	Number of buildings	Percentage of total
High susceptibility class	3,382	34.13
Moderate susceptibility class	4,584	46.26
Low susceptibility class	1,943	19.61
Total	**9,909**	**100**

Table 2: Physical vulnerability results (Number of buildings)

Hazard * Landuse	Area (sq.km.)	%
Low hazard * government	4.7	26.0
Low hazard * private	4.2	23.3
Total Low susceptibility class area	17.9	
Moderate hazard * government	13.9	26.6
Moderate hazard * private	13.3	25.6
Total Moderate susceptibility class area	51.9	
High hazard * government	11.0	39.9
High hazard * private	11.3	40.9
Total High susceptibility class area	27.7	
Total area of Khelvachauri	**97.5**	

Table 3: Physical vulnerability results (Landuse)

5. Conclusions and recommendations

Based on the work we did in this project, we found that there is limitation for spatial analysis due to data availability. The analysis can be done only in terms of physical vulnerability (by overlaying the number of buildings, including landuse data, in the different hazardous areas). Besides, there is big difference between a contour-based DEM data and ASTER-GDEM, which may be attributed by the data source errors.

By calculating the respective weight for six different causative factors, we recognized the most important influential types of factor maps related with landslide, i.e. NW for aspect, mountain class for geomorphology, private use for landuse, and laterized loam and clay for lithology, 19-24 degree for slope and soil depth between 10 and 20 resented the highest hazard of landslide.

The susceptibility map is reliable, however, due to the lack of social, economic, environmental and physical vulnerability data, only building and landuse vulnerability assessments were carried out in our study. We found that 34.13% of buildings were represented as high susceptibility class. Also we estimated that in high susceptibility class there was 39.9% from the governmental landuse and 40.9% from the private.

For further study which can improve the vulnerability assessment results, we suggested that other factors such as river distance, number of population per household, climate data, history of landslide event should be taken into account. The landslide data should be more reliable. This is because the quality of landslide information is important to generate the output of model results. Also, it is useful to make use of stereo image interpretation to investigate landslide inventory.

References

Castellanos Abella, E. A. and C. J. Van Western, 2007. Generation of a landslide risk index map for Cuba using spatial multi-criteria evaluation, in: *Landslides* 4 (2007) 4.

Clerici, A., Perego, S., Tellini, C., and Vescovi, P. 2002. A procedure for landslide susceptibility zonation by the conditional analysis method. [doi: DOI: 10.1016/S0169-555X(02)00079-X]. *Geomorphology*, 48(4), 349-364.

Lee, E.M., and D. K. C., Jones, 2004. Landslide Risk Assessment. Thomas Telford, London. 454 pp.

Castellanos Abella, E.A. and van Westen, C.J., 2008. Qualitative landslide susceptibility assessment by multicriteria analysis: a case study from San Antonio del Sur, Guantánamo, Cuba. *Geomorphology*, 94 (2008)3-4, pp. 453-466

Ministry of geology of Georgia, 1980. Expedition Geology and Hydro Geology, report of engineering-geological studies in Khelvachauri district in 1976-1980, volume 1-2. Tbilisi Georgia.