Landslide Susceptibility Mapping Using Image Satellite and GIS Technology

H. Shahabi[1], B.B. Ahmad*[1], and S. Khezri[2]

[1]*Department of Remote sensing, Faculty of Geo Information and Real Estate, universiti Teknologi Malaysia, UTM, 81310 Johor Bahru, Johor, Malaysia*
[2]*Department of Physical Geography, Faculty of Natural resources, University of Kurdistan, Iran*
A

Abstract

Landslides are among the great destructive factors which cause lots of fatalities and financial losses all over the world every year. The aim of the research was landslide susceptibility mapping by remote sensing data processing and GIS spatial analysis. The area study in research is central Zab basin in west Azerbaijan province, Iran. In this research, through geological maps and field studies, we primarily prepared a map for landslide distributions in Zab basin. Then, applying other information sources such as the existing thematic maps, we studied and defined the 8 factors such as, lithology, slope, slope aspect, annual rainfall, land use, distance to waterway, distance to the fault , and distance to road. That affect occurrence of the landslides. To get more precision, speed and facility in our analysis all descriptive and spatial information was entered into GIS system. After preparation of the needed information layers by influential parameters on landslides, we drew the zoning maps of landslide hazard via information coming from satellite image classification (Quickbird, Ikonos), and then evaluated and compared them. According to the obtained index, and the comparison of landslide distribution map and zoning map of landslide hazard prepared by each of the methods in GIS environment, This model gives also indications about the relevant factors influencing slope instability.

Keywords- *Landslide; Susceptibility Mapping; Satellite images; central Zab basin*

1. Introduction

Mass movements are important geo-ecosystemic phenomena in nature, scattered in different places ranging from mild hills to steep mountains [9, 12]. Destructive results of landslides in human life and economy of many nations all over the world have been verified [11]. Landslides included about 9 percent of natural hazard that happened in 1990s. Therefore, in recent years, many international research institutes have allocated considerable funds for evaluation of landslide hazards, and preparation of proposals for description of their spatial distribution [13, 16]. Central Zab basin is one of the most susceptible regions for occurrence of landslides and their damages. Many GIS-based analysis models and quantitative prediction models of landslide hazard have been proposed in the literature [5,6,7]. The advantages in the use of GIS for assessing landslide hazards are the following:

- a much larger variety of hazard analysis techniques becomes attainable;
- It is possible to improve models by evaluating their results adjusting the input variables. Users can achieve maximum results by an iterative process of trial and error, whereas it is difficult to use these models even once in the conventional manner. Therefore, more accurate results can be expected.

2. Case study

Zab basin occupies southwestern section of West Azerbaijan and northwestern part of Kurdistan. The area under present study covers parts of mountains and slopes in southwestern West Azerbaijan in the central portion of Zab basin between the latitudes of (36° 8' 25") N and (36° 26' 27") N and the longitudes of (45° 21' 21") E and (45° 40' 44") E.

Central Zab basin has a north-south orientation and stretches almost 30km in east-west direction. The study area covers some 520km2 of its total area (Fig. 1). It is one of the settled geographical basins including a city,

ISSN: 2278-0181
Vol. 1 Issue 6, August - 2012

three towns or small cities, and over 80 villages [8]. Here, a north-west extension branches off from the east-west oriented ridges of Zab valley, creating a different landscape from that of the internal sections of Azerbaijan and Kurdistan.

The major part of the study area is located in the Sanandaj- Sirjan zone and its east and eastern north parts locate in the Mahabad- Khoy zone.

In aspect of tectonic since the region is located in major Zagros thrust direction and faults are the main causes of pit formation. The region morphology strongly affected by tectonic forces [7].

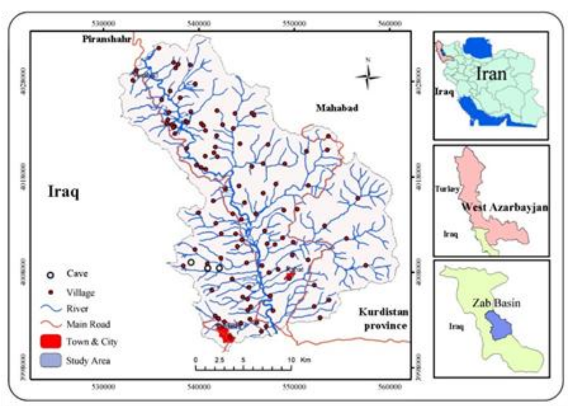

Fig.1. Geographical posation of study area

3. Methodology

Geological, topographical and plant cover maps, satellite images and the information about rainfalls were used for information processing in GIS environment. According to the research background, position of the region and the criterion and method applied for zoning, collectively 8 parameters of lithology, slope, slope aspect, annual rainfall, land use, distance to waterway, distance to the fault, and distance to road were studied.

In the first step, through compilation and investigation of 1:250000 geological map of sardasht, Rabat and Alan from National Geology Institute, geological status of the region was carefully studied (Geological map of the case study). After preparation of the map for litho logical units, they were digitalized. We used 1:50000 scale topographic maps supplied by Army Geography Organization, to prepare the Digital Elevation Model (DEM), slope map, slope aspect, distance to fault and their related layers. All elevation points and 100 meter counter curves and waterways of zab basin were digitalized and all the needed operations for using this information in Arc GIS environment were carried out. Through digitalized counter curves and elevation points and Interpolation technique, Digital Elevation Model prepared. We used digital data received from Quickbird, Ikonos satellites, to draw the operating map of this basin.

After geo-referencing the picture, a combination of bands 1, 4 and 7 was used to make complex color pictures, and operational information layer created by the method of Categorization of Utmost Probability [2]. Since the function type of the land and density and form of its plant life affect occurrence of landslides, we prepared the map of plant cover and function of the lands in zab basin. According to the abovementioned issues, four various form for plant cover and function of the lands in the basin were recognized. Based on density, plant form and the function type of the lands, they were classified. Finally, zoning and evaluation of landslide were done through all of the above mentioned methods. The GIS has been developed by means of Arc GIS ver. 9.3. The landslide occurrences and the instability factors have been recorded as vector data, re-classed, saved as separate layers in the database and then rasterised for the next analysis (Spatial Analyst Tool).Identification of the physical factors, which are directly or indirectly correlated with slope instability (instability factors), and construction of thematic maps related to landslide affecting factors [10];

- Evaluation of contribution of each factor to landslide susceptibility by means of a bivariate statistical method;

- Production of the final landslide susceptibility map based on GIS techniques coming from the land surface classification according to different susceptibility degrees.

4. Discussion and Results

4.1. Landslide Susceptibility

Many efforts in the hazard zonation research have been made in the past 30 years, as a consequence of the urgent demand for slope instability hazard mapping [19]. Different methods can be applied in order to rank slope-instability factors. They assign different hazard levels to the mapping units of the region to be investigated [3, 15]. We can distinguish direct or indirect methods. Direct methods essentially consist of the Geomorphological mapping. Among the indirect methods, the heuristic (index) and the statistical approaches have been more frequently applied in mapping hazard over wide regions with the aid of GIS related techniques. In the heuristic approach, instability factors are ranked and weighted according to their assumed or expected importance in causing mass-movement. The statistical approach is based on the observed relationships between each factor and the past and present landslide distribution. Among the commonly used GIS analysis models for landslide hazard, Certainty Factors (CF) have been experimentally investigated [1],[4]. The CF, defined as a function of probability, was originally proposed by Shortliffe and Buchanan [14] and later modified by Heckerman (Equation 1):

$$CF = \begin{cases} \dfrac{ppa - pps}{ppa(1-pps)} \, if ppa \geq pps \\ \dfrac{ppa(1-pps)}{pps(1-ppa)} \, if ppa < pps \end{cases} \tag{1}$$

Where ppa is the conditional probability of a number of landslide events occurring in class a and pps is the prior probability of the total number of landslide events occurring in the study area. The *CF* value varies between -1 and 1, a positive value means an increasing certainty in landslide occurrence, while a negative value corresponds to a decreasing certainty.

The favorability values (*ppa*, *pps*) have been derived by overlaying each data layer with the land slide inventory layer in Arc GIS and calculating the landslide occurrence frequency. Morphology is shown to be the major controlling factor for land sliding.

Calculating CF values for different typologies of landslide we obtained different values. In particular we observed that: for slope angles lower than 20%, the *CF* value remains always negative; for slope angles higher than 40%, the *CF* value is positive only for falls, topples and for widespread landslides. For rapid flow, the 40-50 slope class has the higher *CF* factor (Fig. 2).

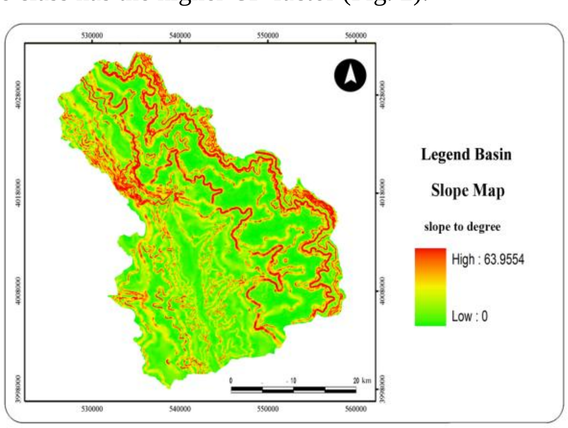

Fig.2. Slope map of study area

Aspect factor: Approximately 30% of the slopes are localised in surfaces with aspect N, NW, NE In fact. The influence of aspect on the occurrence of landslides can be direct or indirect: direct, because the aspect influences the amount of water absorbed by soil or evaporated; indirect, because a correlation could be found between other landslide factors and the aspect factor [18],[17]. Thus, the high correlation of landslides with the aspect factor can depend on the particular geological structure that could be investigated (Fig. 3).

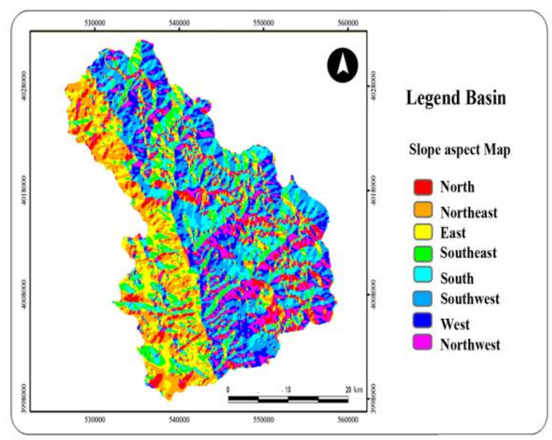

Fig.3. Aspect map of study area

Litho logy factor: Most of slide events in the study area occurred in loose formations including fine-grained sediments in particular in alluvial terraces. The highest value of *CF* corresponds to Stones, homogenous phylite formations; marble, lime, green Andesite, dolomite and sandstone have the widest distribution in the region.

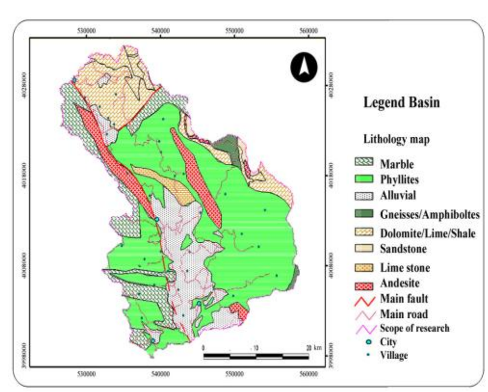

Fig.4.Litho logy map of study area

Land Use factor: The only class that gives a meaningful contribution to the landslide contains dry farm land has the most landslides among landuse classes but the extent area is big than other classes particularly mane made forest class. Second class pasture is the most of insensitive area in among landuse classes because it has a cover of plants (Fig. 5).

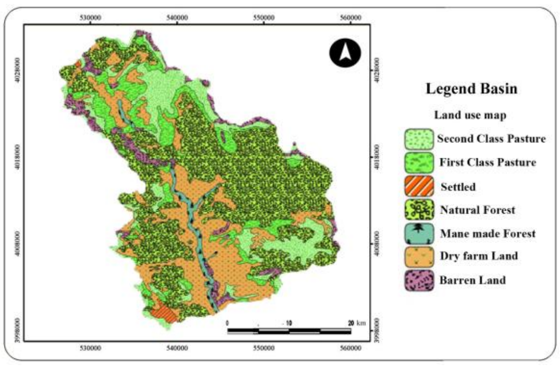

Fig.5.Land use map of study area

Finally, the database obtained by overlaying each data layer with the landslide inventory layer, contains the information relative to the landslide type. We have analyzed CF values relative to each landslide type, with two types of results: Correlation similar to this obtained by the total landslide area; no correlation depending of the reduction of samples. So we chose to use only one model for the susceptibility assessment.

4.2. Susceptibility Map

The overall estimation of the landslide susceptibility for an area results from the combination of the susceptibility levels of the individual factors. In particular, the maps have been first re-classed according to the *CF* value; then the data layers have been combined using the *CF* integration rule in Arc GIS (Raster Calculator Tool – Spatial Analyst).

The integrated *CF* values have been classified into five hazard classes on the base of the threshold criterion in accordance with the methodology. According to this criterion, we produced the final map reclassifying the areas by means of these five different landslide susceptibility levels (Fig. 6). Finally, the active landslide map was posed on the layer of re-classed *CF* value (Susceptibility Class). We can observe that most landslides happen in the low susceptibility class.

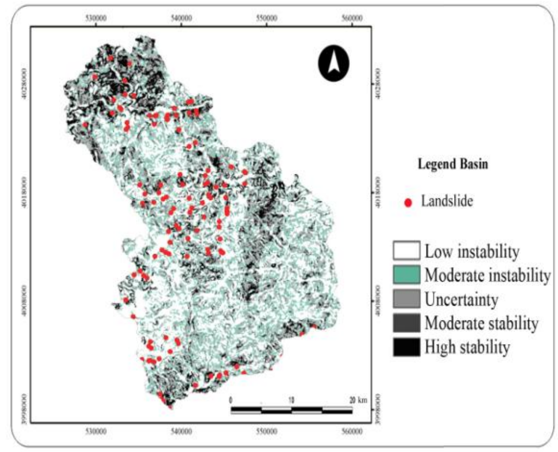

Fig.6.Landslide susceptibility map segmented by threshold criteria

The second classification seems to perform better, with 33% of the area in a medium level of instability (Fig. 7) and 42% of landslides in the medium susceptibility class.

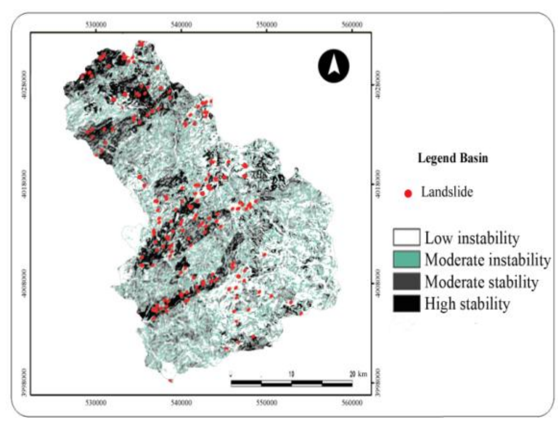

Fig.7.Landslide susceptibility map segmented by statistical analysis of the distribution of values

In the instability map, the largest part of the territory is characterised by a moderate level of instability. The most critical area is an ecosystem characterised by steep slopes, bare soils on weathered substrata. In the land use map, the highest level of criticity is concentrated in the areas near the Zab River, frequently involved in erosion processes strictly connected with human activities. The relatively high frequency of landslides in class 1 (low instability) underlines the necessity of much more information to assess the landslide susceptibility and a major control during the data collection and processing. The analysis has provided information on the susceptibility of the terrain to slope failures and can be used for the soil loss estimation, the localization of new building sites and for the disaster management planning.

Acknowledgment

We are thankful to the Department of Remote sensing in Universiti Teknologi Malaysia and Department of Physical Geography in University of Kurdistan and UTM International Doctorial Fellowship (IDF) for providing the facilities for this investigation.

References

[1] E. Binaghi, L. Luzi and P. Madella, "Slope instability zonation:a comparison between certainty factor and fuzzy Dempster-Shafer approaches", *Natural Hazards*, vol. 17, 1988, pp. 77-97.

[2] A. Carrara and F. Guzzetti, "Use of GIS technology in the prediction and monitoring of landslide hazard", *Natural Hazards*, vol.20, 1999, pp. 117-135.

[3] A. Hansen, "Landslide hazard analysis. In: Slope Instability", edited by D Brunsden & D B Prior, New York: Wiley, 1984, pp.523-602.

[4] D. Heckerman, "Probabilistic interpretation of MYCIN's certainty factors. In: Uncertainty in Artificial Intelligence", edited by L N Kanal & J F Lemmer, New York: Elsevier, 1986, pp. 298–311.

[5] A. G. Journel and C. J. Huijbregts, "Mining Geostatistics, New York, Academic Press, 1978, pp. 600.

[6] S. Kamyabi, M. Salari, H. Shahabi, "Determining the Best method of Stability Landslide by Using of DSS (Case Study: landslide in Hasan Salaran, Kurdistan province in Iran," International Conference on Geographic Information Systems, Paris, France, 2009.

[7] S. Khezri, "Discovery of the "Tuzhal" Cave from Geomorphological Aspect," The 2nd International Geography Symposium GEOMED 2010, Turkey: Kemer, 2010.

[8] S. Khezri, S. Roostaei, A.H, "Rajaie Evaluation and mass movement hazard zonation in central section of Zab basin by using Anabalagan method," *Humanities science Journal (issue geography)*, vol.38, 2006, pp. 32-42.

[9] H. X. Lan, C. H. Zhou, L. J. Wang, H. Y. Zhang and R. H. Li, "Landslide hazard spatial analysis and prediction using GIS in the Xiaojiang watershed, Yunnan, China," Engineering Geology, vol.76, 2004, pp. 109-128.

[10] D. L. Phillips, J. Dolph and D. Marks, "A comparison of geostatistical procedures for spatial analysis of precipitations in mountainous terrain," Agricultural and Forest Meteorology, vol.58, 1992, pp: 119-141.

[11] A. K. Saha, R. P. Gupta, I. Sarkar, M .K. Arora and E. Csaplovics, "An approach for GIS-based statistical landslide susceptibility zonation with a case study in the Himalayas," Landslides, vol.2, 2005, pp: 61-6.

[12] H. Shahabi, "Landslide Hazard Investigation in Saqqez-Marivan main road in Kurdistan province," The 1th International Applied Geological Congress, Department of Geology, Islamic Azad University - Mashad Branch, Iran, April 2010, pp.26-28.

[13] H. Shahabi, B. Bin Ahmad, "Application of MODIS Image satellite and GIS technique in Assessment of Avalanche fall in Roads," International Conference on Environmental Science and Engineering (ICESE 2011), Singapore, 2011.

[14] A. A. Shamsipour, H. Shahabi, M. Salary, M. Abbasi, "Classification of Landslide Using AHP in Saghez Catchment," *Journal of Geographical Environment (Scientific-Research)*, vol. 1, No. 1, 2010, pp. 99-111.

[15] E. H. Shortliffe and G. G. Buchanan, "A model of inexact reasoning in medicine," *Mathematical Biosciences*, vol.23, 1975, pp. 351-379.

[16] M. L. Suzen and V. Doyuran, "Data driven bivariate landslide susceptibility assessment using geographical information systems: a method and application to Asarsuyu catchment, Turkey," *Engineering Geology*, vol.71, 2004, pp. 303-321.

[17] Kh. Valizadeh Kamran, H. Shahabi, A. Piroti, "Natural disasters evaluation of landslide hazard by using fuzzy logic," The 2nd International Geography Symposium, Kemer-Antalya-Turkey, 2010.

[18] C. J. Van Westen, "GIS in landslide hazard zonation: a review with examples from the Colombian Andes. In: Mountain Environment and GIS," edited by M F Price & D I Keywood, London: Taylor and Francis, 1994, pp.35-65.

[19] J. L. Zezere, "Landslide susceptibility assessment considering landslide typology. A case study in the area north of Lisbon (Portugal)", *Natural Hazards and Earth System Sciences*, 2(1-2), European Geophysical Society, 2002, pp. 73-82.