

Research Article

Using Frequency Ratio Method for Spatial Landslide Prediction

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Abstract: Numerous landslides have occurred in the study area and they damage to agriculture and pasturelands. Since the study area do not have any landslide inventory and landslide predicted maps, landslide inventory produced based on field research (GPS) and satellite image (Geoeye and Ikonos). Frequency ratio technique is a statistical approach to simulation environmental conditions. It also uses to take the factors related to dependent variable. Frequency technique considered for generating landslide susceptibility map. Pixel landsliding and non-landsliding calculated in eight factors related-landslide. Landslide susceptibility map produce in five insensitive to very high sensitive classes based on natural breaks method. Receiver Operating Characteristics (ROC) graph implement to evaluate of the frequency ratio method. In particular, the model will be able to predict landslide area occurrence in future completely (sensitivity = 1). Although, model identify insensitive area with 17% errors (specificity = 0.83).

Keywords: Frequency ratio, landslide, ROC curve, validation

INTRODUCTION

Landslide is the world's third largest natural disaster that causes many damages (Zillman, 2000). Human casualties and settlement damages as well as the infrastructure problems caused by landslide are increasing worldwide. In the world scale, landslides cause billions of dollars in loss and thousands of deaths and injuries each year. Most part of Iran has mass movement, which includes landslide, rock fall, earth flow and creep because of relief and mountainous terrain. The Study area in this research is west of Iran-an area of 250 km² in the Kermanshah province in Iran. This area is quite susceptible to landslide due to its climatic conditions, geology, geomorphologic characteristics and human activities. Many villages and farms are located on unstable ground and then if landslide susceptibility map is prepared, it can help to displace some buildings in hazardous area. Landslide hazard evaluation is based on the analysis of the ground conditions in those regions where a previous landslide occurred (Carrara *et al.*, 1999). The purpose of the present study was to produce landslide inventory and then landslide susceptibility map of the selected area by frequency ratio approach. Statistical methods are more applicable for prediction and classification of environmental problems in various regions (Paliwal and Kumar, 2009). Landslide zonation mapping methods can be divided into the following categories:

quantitative or statistical (Guzzetti *et al.*, 1999; Rautela and Lakhera, 2000; Lineback *et al.*, 2001; Cevik and Topal, 2003; Gorsevski *et al.*, 2003; Lee, 2004; Tangestani, 2004; Sakellariou and Ferentinou, 2005; Ayalew and Yamagishi, 2005), deterministic methods (Gökceoglu and Aksoy, 1996) and qualitative or knowledge-based (Ives and Messerli, 1981; Rupke and Veilleux, 2011; Regmi *et al.*, 2010).

For the landslide-hazard analysis, the main steps were data collection and construction of a spatial database from which the relevant factors were extracted, followed by assessment of the landslide hazard using the relation between the landslide and landslide-related factors and validation of the results. A key assumption of this approach is that the past and present is the key to the future. In other words, the potential (occurrence possibility) of landslides can be comparable to the actual frequency of landslides (Pradhan and Lee, 2010).

The aim of present article is to use and to identify the implications frequency ratio method for generating sensitive land in the study area for landsliding. It also to evaluate the accuracy of the model in ROC graph and to present advantage and disadvantage of the frequency ratio method.

Study area: The study area lies in the east south of Kermanshah province in west of Iran. It is mountainous area between 34°:05':6"N to 34°:13':06"N latitude and

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Fig. 1: Map of the study area and distribution of shallow landslide (inventory) in the area that show on Ikonos (above) and Geoeeye (low) images (courtesy from Geoeeye company)



Fig. 2: Effect of land-use on shallow landslide



Fig. 3: Landslide occurred above the village settlement (Cheshme Kabud)

47°:22':03" E to 47°:35':26"E longitude, with a total area of 250 km² (Fig. 1). It is characterized by rugged hills and mountain terrains covered by scattered trees and forest fragmentation. The study area is frequently subjected to landslides following land use change, especially alongside the agriculture land since they were changed (Fig. 1 to 3).

MATERIALS AND METHODS

Landslide inventory: Landslide inventory maps show locations and characteristics of landslides that have displaced in the past but generally do not indicate the mechanism (s) that triggered them. Landslide inventory map necessary to evaluate the validation in any study for assessing or zoning of landslide. After implementation of our method, we need to evaluate the model, so only landslides previously occurred could help to assess of the result. Therefore, inventory maps provide useful information about the landslide potential area. In addition, recognizing the type and recency of land-sliding can also facilitate the scope and design of site-specific geotechnical investigations and guide for slope remediation strategies. In previous studies, the inventory maps will be prepared from four methods that including: geo-morphological, event, seasonal and multi- temporal inventories (Guzzetti *et al.*, 2012). For the study area we determined some situation landslides (about 35% of total exist landslides in area (29 landslide)) with GPS (global position system). The study area is varying in relative topography and lithology (Fig. 4), therefore distribution of landslide occurrence is very different. Aerial photography can aid to identify landslide especially with suitable scale (i.e., 1:20000 or larger). Interpretation of aerial photography and satellite images with view of stereoscopic determined boundary of landslide which we cannot see in the field work especially where topography is hummocky or vegetation is dense (We determined 85 landslides in the entire area). Most of the landslides in the area are more than 3000 m², so we easily identify them because aerial photograph stereoscopic with 1:20000 scale can accelerate for landslide finding in the study area. These include old and new landslides which most of old landslide need to control from ground for accuracy in the landslide inventory preparing (Fig. 1).

Factors related-landslide: According to the research background, 8 parameters collected such as slope, slope aspect, lithology, land use, erosion, distance to fault, distance to river and distance to road. Geological paper maps at 1:100, 000-scale covering the study area were digitized and the geologic formations were identified. The two largest datasets were topographical parameters that were collected from the 1:25000-scale paper topographic maps. A Digital Elevation Model (DEM) was generated from a Triangulated Irregular Network

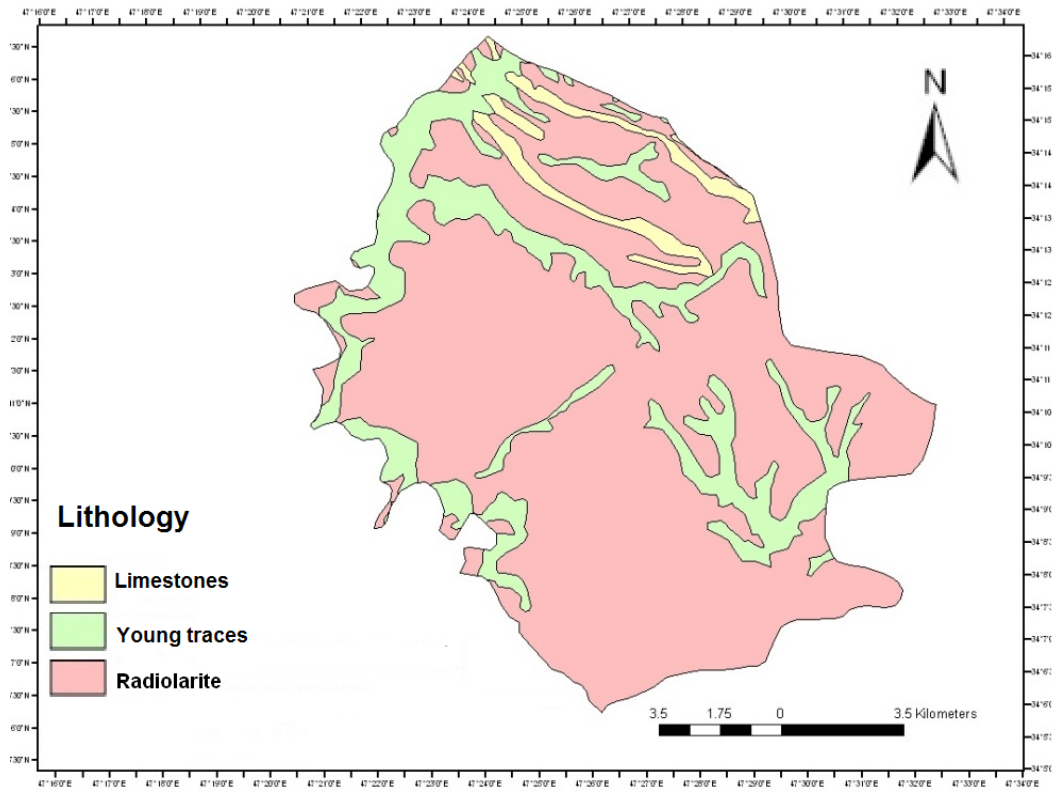


Fig. 4: Lithology map of Cheshme Kabud

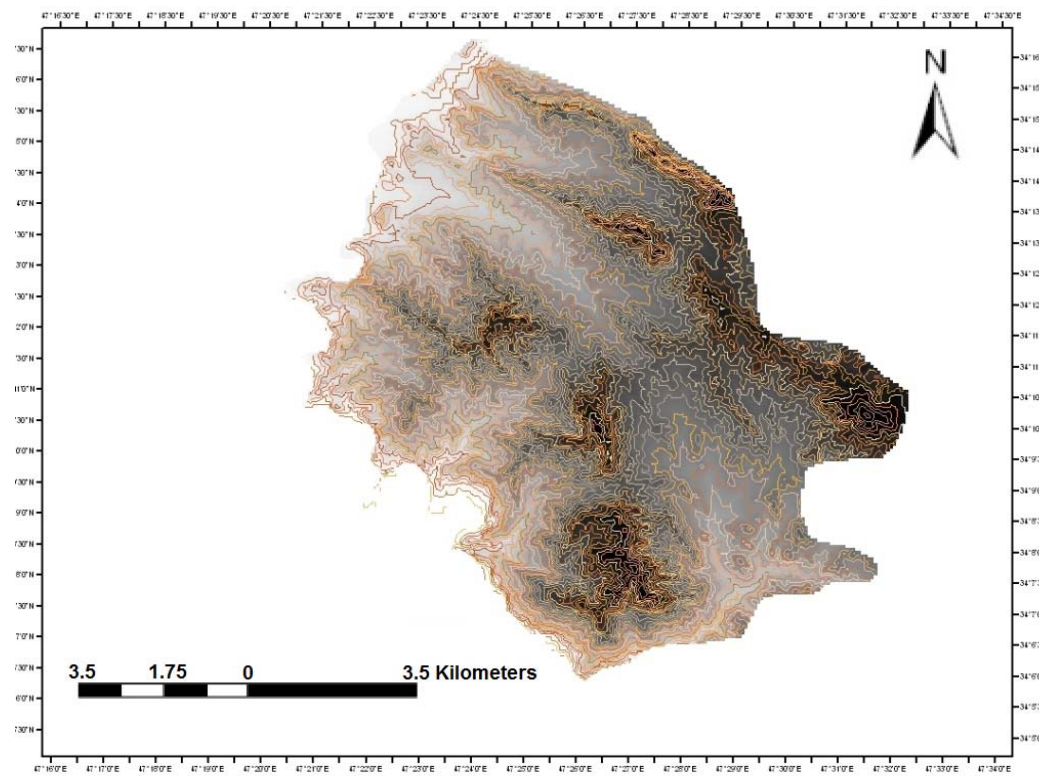


Fig. 5: DEM and counter line of Cheshme Kabud map

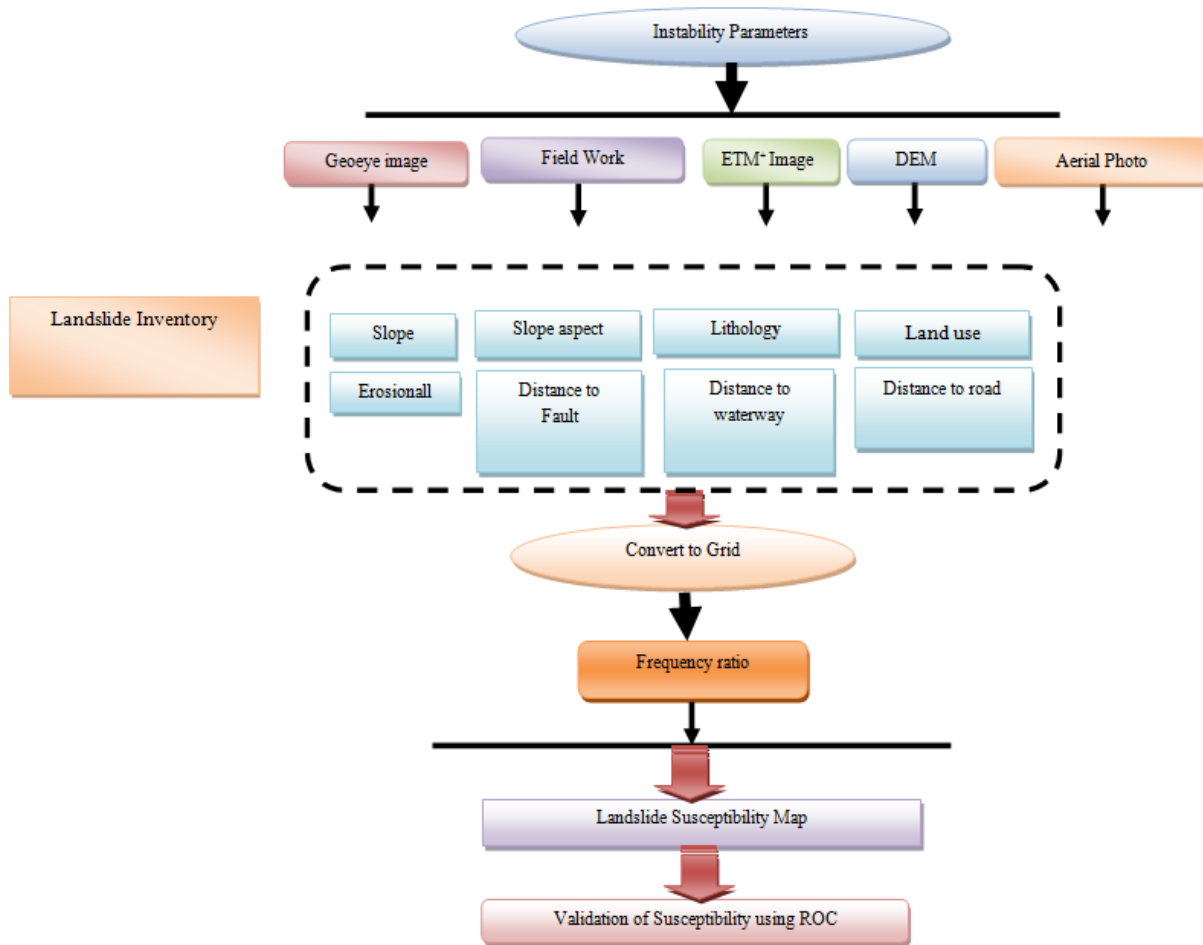


Fig. 6: Briefly of the producing landslide susceptibility map in the study area

(TIN) model that was derived from digitized topography contours with a contour interval of 25 m (Fig. 5). The elevation, slope angle, aspect and shape of the slope parameters were obtained from the DEM.

Another dataset was land use, which was interpreted from ETM+ images on the 21 April 2009. It was calibrated from using field observations. Because of significant cloud coverage, results of the classification were edited and simplified by manual digitization. The images modify the boundaries by supervision classification with ERDAS (Earth Resource Data Analysis System) software. The accuracy of the land use interpretation was checked in the field. Seven main lands considered and classified. Based on validation from field observations, the land use map has the accuracy of the Landsat image spatial resolution (~30 m). After geo-referencing the image, a combination of bands 1, 4 and 7 was used to make complex color images and operational information layer created by the method of Categorization of Utmost Probability (Dymond *et al.*, 2006). Finally, zoning and susceptibility of landslide were done through frequency ratio method. Figure 6 shows the flowchart stages of study.

RESULTS AND DISCUSSION

Instability is a phenomenon sometimes it is observable and sometimes it is imperceptible. If the latter occurs, only evidence of it can be searched. This needs to be analysis of data and information. That is, to analyze this phenomenon, it is necessary to fit the data and information.

In principle, the only way to demonstrate the real accuracy of the landslide evaluation maps when new landslides occur after the generation of landslide susceptibility. Spatial relationship between the factors and the landslide susceptibility map was done using a frequency ratio method. Weights and values the various factors have been calculated for the classes is shown in Table 1. Based on ratio it can be suggested that the slope, lithology and landuse are the main role in the occurrence of landslides in the area.

The relation between landslide distribution and model was analyzed using Frequency Ratio (FR) model. In the FR model, percentage of landslide occurrence in a factor class divided by the total percentage of that factor in the area Fig. 7.

Table 1: Frequency ratio calculation of landslide influencing factors

Factor	Class	Landslide point	Landslide (%)	Number of pixel in the class	Class area (%)	Ratio
Slope	0-5%	3	3.50	453412	35.70	0.10
	6-10%	27	31.80	345673	27.50	1.16
	11-30%	38	44.70	287654	22.60	1.98
	31-60%	15	17.70	102876	8.10	2.19
	>60%	2	2.30	78345	6.10	0.38
Aspect	N	16	18.80	181216	14.30	1.31
	NE	25	29.40	126026	9.90	1.10
	E	10	11.80	235057	18.50	0.64
	SE	10	11.80	135794	10.70	1.10
	SE	5	5.90	127425	10.10	0.58
	SW	3	3.50	103236	8.20	0.43
	W	7	8.20	283795	22.40	0.37
	NW	9	10.60	75411	5.90	1.80
Lithology	Limestone	24	28.20	281487	22.20	1.27
	Young traces gravel fan	34	40.00	754437	59.50	0.67
	Radiolarian	27	31.80	232036	18.30	1.73
Landuse	As.spp-A.sc-Da.mu	6	7.10	195266	15.40	0.46
	As.spp-Fes.ov-Ho.bu	7	8.20	110312	8.70	0.94
	As.spp-po.bu	1	1.20	40575	3.20	0.62
	As.spp-po.bu-st.ba	15	17.60	460270	36.30	0.48
	CL	17	20.00	51986	4.10	4.87
	F	29	34.10	282755	22.30	1.52
	As.spp-Po.bu-An.gr	10	11.80	126796	10.00	1.18
Erosion	Low	15	17.60	402133	31.70	0.55
	Moderate	37	43.60	574405	45.30	0.96
	High	33	38.80	291422	23.00	1.68
Road	0-50	42	49.50	568923	44.90	1.10
	50-100	24	28.20	352678	27.80	1.01
	100-150	15	17.60	100852	7.90	2.23
	>150	4	4.70	245507	19.40	0.24
Fault	0-1000 M	37	43.52	392133	30.93	1.40
	1000-2000 M	20	23.52	344340	27.16	0.86
	2000-4000 M	18	21.18	231480	18.26	1.16
	>5000	10	11.78	300007	23.65	0.50
River	0-50	47	55.30	492133	38.81	1.42
	50-100	22	25.88	444343	35.04	0.74
	>100	16	18.82	331484	26.15	0.72

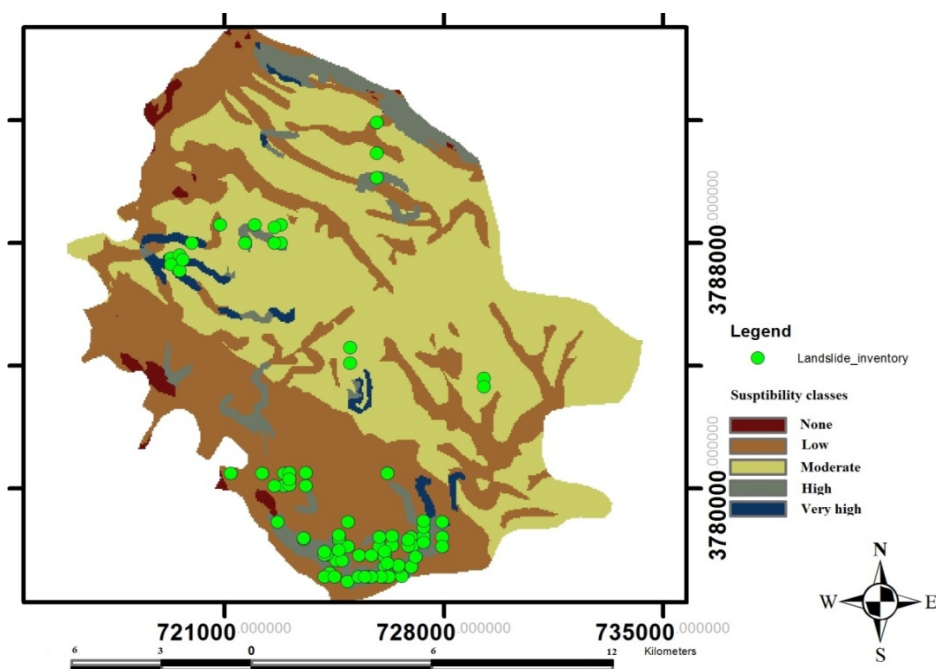


Fig. 7: Landslide susceptibility map generated from frequency ratio method

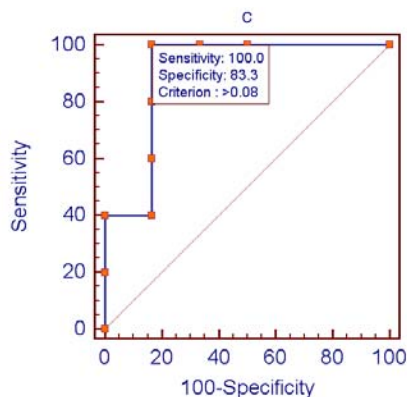


Fig. 8: ROC graph for landslide susceptibility map validation

The FR value greater 1 represent probability of landslide occurrence in this class is higher than average of landslide occurrence in the area. Slope greater than 60° due to the lack of soil has small number of landslides. Slope aspect is in degree (between 0 and 360°) from the north. It also defines the azimuth of the flow. It was found that landslides in the study area in the North West and North facing hillside (Table 1), which are more abundant due to unexposed to the sun.

Fault and lineament map extracted directly of geology map and it was controlled by Geoeye image and band 7 of Landsat satellite image. There are not large seismic faults in the study area, but it can be divided into four regions based on the area density of seismicity from high to low lineament density. The map represent landslide points are more frequency at the location where area is high seismicity. Also, by using FR method, buffer zones between seismicity and landslide occurrence assigning by buffer zones based on various distance from lineaments. Up to the distance of 2,000 m, the FR ratio indicated strong correlation with landslide occurrence. It can be stated that near to 70% of landslide occurrence were around this area and below the distance of 2,000 m, the ratio shows less correlation, which is again an expected result.

The area under the ROC curve for each model is a global statistical accuracy for each model. It is independent of single prediction threshold which value is varies between 0.5 and 1. If the curve has a more distance from the reference line is better (Begueria, 2006). And, however, the closer the ROC curve is to the upper left corner of the area is more accurate. If the ROC is 1, it shows a perfect model and that the ROC is equal to 0.5 indicates a random fit.

"Sensitivity" is probability of prediction of the positive case which indicates, it is properly classified and it is plotted on the y-axis in a ROC curve (Erener et al., 2010). Based on their distance from the reference line, the models show good results. From detection of

positive area (Sensitivity), FR model is more performance. Area under curve for FR model was 0.93 (Fig. 8).

CONCLUSION

In this study, results of the susceptibility map have been validated with the Receiver Operating Characteristics (ROC) curve. Result of validation represent more than 80% of prediction of the landslide occurrence is suitable compare to past landslide occurrence. The distribution of the landslide density among different susceptibility classes is acceptability. Landslides occurrence in the None-susceptible class is the least while their density increases in the high-and very high-susceptibility level.

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