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Zoning Landslide by Use of Frequency Ratio Method (Case Study: Deylaman Region)

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Abstract: Landslide Study is one of the important issues in development of projects including construction of dams, setting up highways, development towns and villages, construction of industrial facilities and water channels. In this study, zoning landslides of Deylaman region, Siah-kal, in the East of Guilan province has been investigated. At first, by field views, the ground truth map of landslide was prepared and crossed by each of lithology, distance from faults, distance from roads, slope, aspect, land cover and precipitation layers in GIS. For zoning landslide, the Frequency Ratio Method (FRM) was used. Results showed that slope aspect and land use were the most important factors in the occurrence of landslides in Deylaman region. Finally, the zoning map of landslide risk were classified in five categories including very high, high, moderate, low and very low risk classes.

Key words: Deylaman · Frequency ratio · GIS · Landslide

INTRODUCTION

Landslide is major erosion which sometimes has life loss, such as huge sliding soil mass during an earthquake and buried adjacent residential areas. Any factor that causes to low soil resistance against shear forces, lead to increase landslide [1]. Bouma and Imeson [2] concluded of rainfall simulation experiments in the area of Petrer southeast in Spain that runoff, infiltration and soil chemical and mineralogically characteristics are affected mass movements. Also they concluded that high soil infiltration capacity, causing soil instability and increased risk of massive erosion. Landslide increase, massive erosion too much. Among the factors creating landslides, the erosion of the underground is that which increase soil mass instability [3]. Sassa [4] studied landslide movement and groundwater level in Zentokoy Japan and suggested that landslide has been created by groundwater erosion.

In different world countries, to achieve solutions, suitable methods to inhibit, control, mitigation of mass movements, the damage caused by natural disasters and the principles planning in using natural environment appear as seriously issue. Identification and classification of areas prone to landslide and its hazard zonation is an important step in the evaluation of environmental risks and play indisputable role in watershed management [5]. Busoni *et al*. [6] while study in the Eurasian basin in Italy, according to the relationship between land form, slope, hydrographic network model, river bed, erosion features, vegetation and the land use, culture management systems, was diagnosed, 17 land units and 46 types of land. Multivariate analysis of above parameters showed that the five variables of slope, hydrographic network patterns, erosion features, mass movement and land use are sufficient to determine erosion risk and mass movement efficient. In the western Gat in, India, GIS and RS techniques were used for finding the landslide prone areas and the mapping [7], this technique was more successful than previous methods.

In order to location landslide risk, Hassanzadeh [8] was used from multiple regression method and GIS techniques using four data layers of lithology, slope angle, rainfall and the usage and achieved successful results. Esmali and Ahmadi [9] used from GIS to prepare landslide. They determined landslide prone areas on aerial photographs and in the next step this areas were controlled by field views and areas that were not likely to slip, were removed. Landslide map was overlapped by each of the layers of lithology, slope, usage, linear factor (rivers and roads), precipitation classes, elevation classes and overlapping erosion features and calculate them in each unit of landslide number. Each unit was valued in accordance with landslide from 0 to 100.The weight of each factor associated with the risk of erosion in the region was calculated and finally they prepared the landslide hazard map in five class of very low to very high according to the AHP (Analytical Hierarchy process) method.

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Guilan province, Iran, is one of the regions susceptible to slides because of its climate, geology and topography [10]. Lack of attention to this issue can be tending to irreparable the next damages [11]. For instance, the Fatalak village was disappeared due to landslide incident followed by the Guilan earthquake in 1990, 22[th] June and partially of Germi town of Ardebil province in was destroyed in 1995 [10]. The aim of this study is landslide zonation by the help of Frequency Ratio model in Deylamn basin of Guilan province, Iran.

MATERIALS AND METHODS

The study was carried out in Deylaman region with an area of 11248 hectares is located longitudes 49°48'19" E and latitudes 49° 57'51"N in south of Caspian sea. This region is related to Rasht-Gorgan zone that geologically andesite-dacite tuffs are the largest unit with 93.29 km^2. The altitude ranges between 1300 to 2100 meter and the climate is semi-wet fallowed by Demarton method. Figure 1 shows the position of studying basin.

In this study, for determining the scope and identify the natural features topographic maps of 1:50000 scale and geology and land use maps of 1:100000-scale and climate information of six climatologically stations inside and outside area was used. Seven important factors to affect on landslide including slope, aspect, lithology, distance from fault, distance from roads, rainfall and land use were selected and the layers of these factors were prepared in GIS. With field operations and using aerial photographs, topography and geology maps, landslide map was prepared and digitized in GIS. The ground truth map of landslide was prepared by field views of 47 ground control points. This map is observed in Figure 1. Slope and aspect of slope layers were prepared by using a DEM layer.

Frequency ratio method presented by Lee & Talib [12] is the new method in landslide studies (equation 1). For every class of data layers, frequency ratio is calculated by the combination of landslide map with criterion map (e.g. land use).

$$Fr_i = \frac{N_{pix(S_i)} / N_{pix(N_i)}}{\sum N_{pix(S_i)} / \sum N_{pix(N_i)}} \quad (1)$$

$N_{pix(S_i)}$: The number of pixels containing slide in class (i),

$N_{pix(N_i)}$: Total number of pixels having class (i) in the whole area of basin,

$\sum N_{pix(S_i)}$: Total number of pixels containing landslide,

$\sum N_{pix(N_i)}$: Total number of pixels in the whole area of basin.

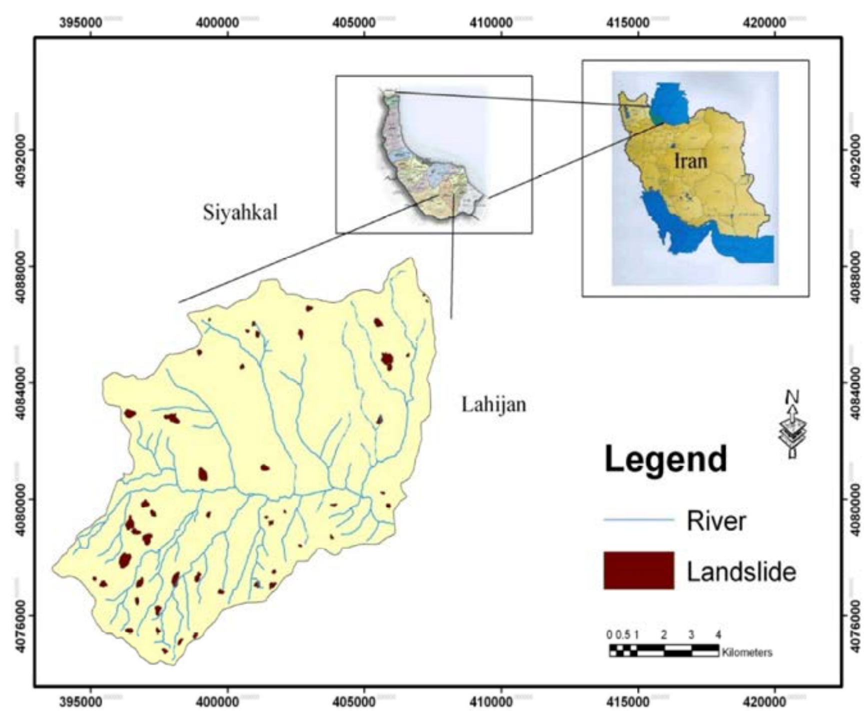

Fig. 1: The position of studying basin and the ground truth map of landslides

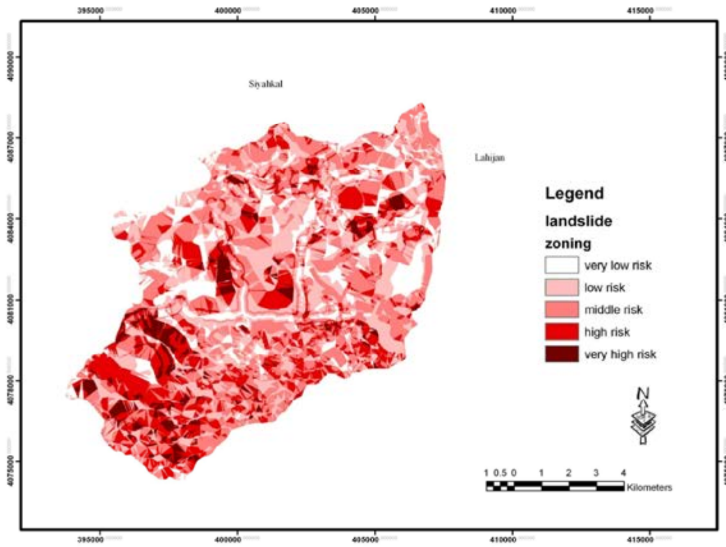

Fig. 2: The landslide zoning map of studying basin

Pixel dimensions were 10 × 10 m in the studying basin. When the quantity of Fri is larger than one, relationship is positive between landslide occurrence and the class of a data layer and if this ratio be smaller than one, this relationship is negative. The units' weight of every data layer will be calculated of the equation (2) and the weighted layers are combined together in GIS.

$$W = 1000 \times N_{pix(S_i)} / N_{pix(N_i)} - 1000 \sum N_{pix(S_i)} / \sum N_{pix(N_i)} \quad (2)$$

W : The weight of every unit in a data layer,

$N_{pix(S_i)} / N_{pix(N_i)}$: Density of landslides in every unit of a data layer,

$\sum N_{pix(S_i)} / \sum N_{pix(N_i)}$: Sum of landslide pixels per sum of total pixels of studying basin.

To verify the zoning map of landslide risk, equation 3 was used that has been offered by Gavynav *et al*. [13] and Ayalew *et al.* [14]. Map of landslide was crossed by map of zoning landslide risk and in every risk class, pixels number of landslide was calculated and then the accuracy of provided map was computed by equation 3.

$$AF(\%) = \frac{AF_i / A_{sci}}{\sum AF_i / A_{sci}} \quad (3)$$

AF (%) : The area of every landslide risk class (%),

A_{sci} : Pixels number of landslide in every risk class of landslide,

Af_i : Pixels Number in every risk class of landslide.

RESULTS AND DISCUSSION

Table 1 shows the frequency ratio and the weight of units in land use map. This table was inserted as an instance for indicating calculation of Fri and weight. In other layers, Fri and weight is calculated by same method. In tables 2 and 3, results of frequency ratio calculations and weighing to each of classes have been identified. Based on these tables the highest frequency ratio belongs to slopes 5 to 10 degrees. Slope aspect class had the highest frequency ratio and the north and northeast slopes also are the most effective aspects. QT1 lithology class and orchard land use showed a large frequency ratio and the most ratios are related to distance from fault and rainfall that respectively were 1000-1250 m and 600-650 mm.

Table 4 shows that 73% of basin has placed in very low, low and moderate risk classes of landslide, about 20% in high risk class and 6% in very high risk class. AF confirms the accuracy of landslide risk map in Deylaman region. According to the data table 4, AF is 45.7, 30.17, 17.84 and 4.2% respectively in landslide risk classes of very high, high, moderate, low and very low.

The frequency ratio method is a new way in zoning landslide. Arayesh Ahmad Saraye [15] used this model in zoning landslide of Lahijan region, Iran and concluded that changing land cover from forest to tea orchard caused to occur landslide. Pourghasemi [16] divided Safarood region into 4 zones from low to high in zoning landslide by the use of this method. Lee and pardhan [17]

Table 1: Frequency ratio and weighted unit of different land uses in Deylaman region

Land use	$N_{pix(N_i)}$	$N_{pix(S_i)}$	% $N_{pix(N_i)}$	% $N_{pix(S_i)}$	Fri	W
Forest	14988	57	1.32	0.25	0.19	-16.04
Orchards and Forest	219522	6436	19.37	28.62	1.47	9.47
Rangelands	57876	650	5.10	2.89	0.56	-8.61
Rangelands & Dry farming	127536	2381	11.25	10.59	0.94	- 1.17
Orchards and Cultivated lands	30209	149	2.66	0.66	0.24	-14.91
Tree & Garden	135507	6626	11.96	29.47	2.46	29.05
Cultivation & Garden	222975	834	19.68	3.7	0.18	- 16.1
Cultivated & Dry farming	156387	1815	13.8	8.07	0.58	- 8.23
Dense Forest	161411	3468	14.24	15.42	1.08	1.64
Urban	6479	0	0.57	0	0	- 19.84

$N_{pix(S_i)}$: The number of pixels containing slide in class (i),

$N_{pix(N_i)}$: Total number of pixels having class (i) in the whole area of basin

Table 2: The frequency Ratio of landslides in different classes of data layers

Slope (degrees)	Fri*	lithology	Fri	Aspect	Fri	Distance from road (m)	Fri	Distance from Fault (m)	Fri	land use	Fri	precipitation (mm)	Fri
0-5	0.1	QT1	1.3	Flat	0.23	40-0	0.13	500-0	1.07	Forest	0.19	550-500	0.66
5-10	2.83	MC	0.84	North	2.32	80-40	0.67	750-500	1.36	orchards and Forest	1.47	600-550	0.37
15-10	0.84	Eat	1.2	North-East	2.4	120-80	0.72	1000 – 750	1.07	Rangelands	0.56	650-600	1.8
20-15	0.86	Eva	0	East	0.4	160-120	1.8	1250 – 1000	1.67	Rangelands and dry planting	0.94	700-650	0
25-20	0.4	Kl1	0.8	South East	0.79	200-160	2.39	1500 – 1250	1.28	Orchards and Cultivated lands	0.24		
30-25	0.9	Kv2	0	South	1.7			1750 – 1500	0.5	Tree & Garden	2.46		
30>	1	JK1	0.1	South West	0.87			2000 – 1750	0.25	cultivation & Garden	0.18		
		dc	0.86	West	0.32					cultivation &Dry planting	0.58		
		an	0.36	North-West	1.31					Dense forest	1.08		
										Urban	0		

* Fri: Frequency Ratio

Table 3: The weight of different classes of data layers in the occurrence of landslides

Slope (degrees)	W*	lithology	W	Aspect	W	Distance from road (m)	W	Distance from Fault (m)	W	land use	W	precipitation (mm)	W
0-5	-17.5	QT1	7.19	Flat	-15.21	40-0	-17.11	500-0	6.15	Forest	-16.04	550-500	-6.59
5-10	34.13	MC	-3.38	North	24.47	80-40	-6.89	750-500	6.21	orchards and Forest	9.47	600-550	-12.3
15-10	-3.59	Eat	3.91	North-East	25.89	120-80	-5.91	1000 – 750	6.63	Rangelands	-8.61	650-600	-16.3
20-15	-3.37	Eva	-19.74	East	-11.99	160-120	14.49	1250 – 1000	12.09	Rangelands and dry planting	-1.17	700-650	-19.7
25-20	-11.97	Kl1	-4.46	South East	-4.7	200-160	25.8	1500 – 1250	4.68	Orchards and Cultivated lands	-14.9		
30-25	-1.22	Kv2	-19.74	South	12.78			1750 – 1500	-10.08	Tree & Garden	29.05		
30>	0.66	JK1	-17.71	South West	-5.4			2000 – 1750	-14.88	cultivation & Garden	-17		
		dc	-3.28	West	-13.5					cultivation &Dry planting	-8.23		
		an	-14.77	North-West	5.31					Dense forest	1.64		
										Urban	-19.84		

*Weight

Table 4: Risk categories of zoning landslide map in the Deylaman region

Risk classes	W	Number of pixels containing landslides risk in each of classes	Total Pixels of every risk class	Frequency ratio	AF (%)
Very low	-25 >	200	177686	0.056	0.91
Low	-25-0	1511	285124	0.26	4.2
Middle	0-30	7906	358483	1.11	17.84
High	30-64	8642	231690	1.88	30.17
Very high	64 <	3950	68311	2.91	46.78

compared the frequency ratio method and logic regression that the results of their study showed frequency ratio by 93.04 percent had a better accuracy than logic regression method with 90.34 percent.

Jada *et al.* [18] was achieved to satisfactory results in providing landslide map. Avinash *et al.* [19] calculated an 89.0% accuracy of landslide map.

The most important factor in the occurrence of landslides was slope aspect especially in north and north east directions, because of the accumulation of ice and snow in cold season that resulting in warm season caused to flow water on these slopes. This flow can be effective factor in occurrence of landslide especially in changed land uses. The land use parameter was the second important factor in occurrence of landslides because of high change in land uses. The change in forest land use to orchards and cultivated lands could be important factor on the hill slope movement particularly landslides in recent years.

Slope and distance from fault are important factors in the landslides. In this study, 5-10 and 20-25 degree slopes have the most frequent and the most stable, respectively. Deylaman region has located in high height, therefore, because of winter coldness, snow can be accumulated. Melting snow cause to instability of hillslope in changed land use and this increases the occurrence of landslide. Of course, faults can increase this danger (distance of fault in 1250-1000 m range have the most dangerous). Geological factor can be another factor in occurrence of landslide. In alluvial terraces (QT1), unstable sediments having clay can be reason on landslide that this factor with continuing precipitation has intensified the occurrence of landslide.

The results showed that the Frequency Ratio Method is one of the suitable methods in zoning landslide. This method is recommended for other areas having similar conditions such as regions with 5-10 slope degree, changed land uses with relatively high precipitation (650 mm) and the region with loose geologically formations.

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