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Evaluation and Slope Instability Hazard Zonation in Part of Tajan Basin, Sari, Iran, by Anbalagan Method

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Abstract: The aim of this study is an experimental investigation on landslide hazards in Tajan Basin and its increasing due to land use changing, deforesting, road and other construction. The main strategy for restricting the damage caused by the activity of landslides is to avoid these regions. To accomplish this, landslide zonation hazard map of the area is required. There are different methods for zoning of different regions in term of susceptibility to landslide. Because of geological conditions of the study area, Anbalagan method purposed to gain the results. For landslide hazards zonation map the required maps of slope, aspect, land use, lithology, structural lithology, ground water, landform and facet map prepared using GIS software of Arc view and Arc map related to Anbalagan method. For the accuracy evaluation of the used method landslide distribution map provided for the study area which has compared with the landslide zonation map. The results showed that the most of landslides are occurred in VHH zone (28%) and HH zone (55.5%) and the rest of them are occurred in MH zone, which have predicted by the mentioned method. The results of fieldwork performed in summer 2008 with the method of Anbalagan were used to assess slope failure.

Key words: Mass movement, slope instability, lithology, erosion, natural hazard

INTRODUCTION

Landslides are occurring frequently in northern part of Alborz in Mazandaran Province, Iran that results suffering to human and substantial economic and environmental losses. For that reason the hazard regions should be properly identified. The mass movements such as landslides cause annual costs in excess of 38×10^{7} Euro in Iran (Feyznia *et al*., 2005). Therefore it has become increasingly important, to plan land use so that hazards are avoided and so that construction projects can be designed to limit slope failures. Anbalagan (1992) has produced landslide hazards map using weighting lithology, relation between construction and slope, slope, land use, vegetation cover and ground water conditions. This method has termed Landslide Hazard Evaluation Factor (LHEF). Anbalagan (1992) was used this LHEF method, to zonation of landslide hazards in Katcom-Ninita of India. This method is a numerical system which is related to the geology, roughness, land use, vegetation cover and ground water conditions. Landslides, as one of the major natural hazards, account each year for enormous property damage in terms of both direct and indirect costs. Landslides, defined as the movement of a mass of rock, debris or earth down a slope (Cruden, 1991). Landslides have caused large numbers of casualties and huge economic losses in mountainous areas of the world. The most disastrous landslides have claimed as many as 100,000 lives (Li and Wang, 1992). Li and Wang (1992) conservatively estimated that in China the number of deaths caused by landslides totaled more than 5000 during the 1951-1989 periods, resulting in an average of more than 125 deaths annually and annual economic losses of about US$ 500 million. More sophisticated assessments are involved AHP, bivariate,

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multivariate, logistics regression, fuzzy logic, artificial neural network etc., analysis (Carrara, 1983; Van Westen, 1997; Dai *et al*., 2001; Lee and Min, 2001; Ercanoglu and Gokceoglu, 2004; Lee *et al*., 2004; Komac, 2006). Remondo *et al*. (2008) and Zolfaghari and Heath (2008) have investigated on landslide hazard zonation using GIS-based method. Slope morphology, land use and bedrock lithology are also used in modeling of landslide susceptibility (Schmidt and Beyer, 2001; Baeza and Corominas, 2001; Gorsevski *et al*., 2006). These parameters can also give an idea of the mass movement runout, a parameter closely related to potential damage on properties and infrastructure (Chen and Lee, 2003). Also in Iran, Oroumiei and Aminizadeh (1998), Oroumiei and Safaei (1998), Keshavarz and Mehmoodi (2000), Emami and Elhami (2005), Rezaeimoghadam and Eghbal (2005), Khezri *et al*. (2006) and Haghshenas *et al*. (2007) by Anbalagan method was applied to landslide hazard zonation which seems be suitable for Iran watershed such as this study area.

Mass movement and landslide zonation dividing the area into specific and severed regions which are potentially measured hazards. This process based on natural characteristics and quantitative modeling (Karam and Mahmoodi, 2002). Empirical methods are generally simple and relatively easy to use and dat required in such method is usually general and readily available. Where a local historic landslide database is available, the empirical relationships can be readily developed. However, empirical methods can only provide a preliminary estimate of the profile of the travel path (Dai *et al*., 2001).

The aim of this research is recognizing and classifying the principal factor which causes landslide to find an appropriate solution for prediction and control the landslide occurrence in susceptible regions and assessment the susceptibility measure based on instability factor.

MATERIALS AND METHODS

Study Area

The study region covering 62.07 km^2 is located on the South-Western part of Sari the capital of Mazandaran Province, Iran. Geographically is located in Tajan basin in the Northern Alborz range where is limited between 53° 0' 12" N to 53° 06' 34" N and 36° 20' 48" E to 36° 27' 50" E (Fig. 1). This study conducted in April 2008.

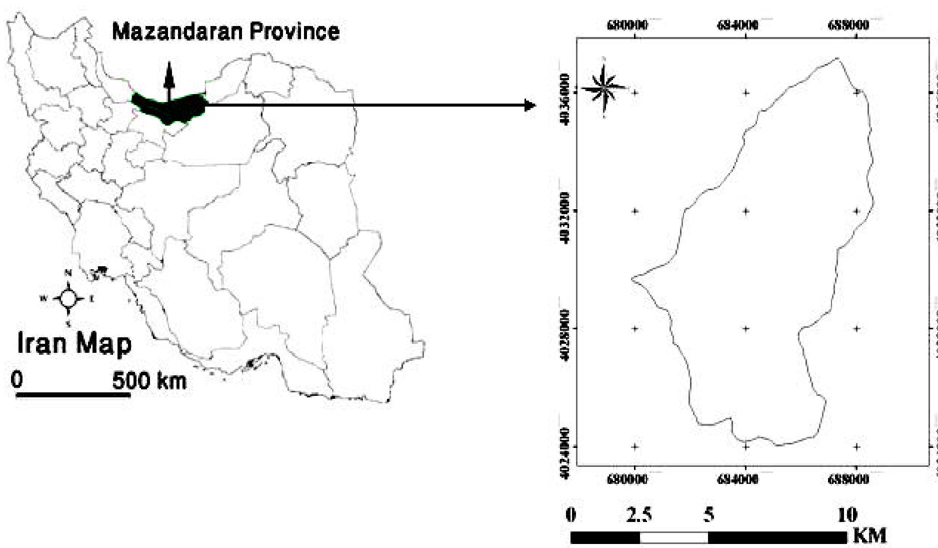

Fig. 1: Study area related to Mazandaran Province and Iran

Table 1: Limitation of each hazard class

Region	Weight	Hazard class
1	3.5>	Very Low Hazard (VLH)
2	3.5-5	Low Hazard (LH)
3	5.1-6	Medium Hazard (MH)
4	6.1-7.5	High Hazard (HH)
5	7.5<	Very High Hazard (VHH)

Methodology

The choice of hazard assessment method is basically dependent on the scale of investigation. For regional scale analysis, where the land-use planning is of main concern, hazard assessment is in the form of determining landslide-prone areas. For assessing landslide hazard, different methodologies are proposed. They are mainly grouped as: qualitative and quantitative methods. Qualitative approaches based on the site-specific experience of experts with the susceptibility/hazard determined directly in the field or by combining different index maps. Quantitative methods are based on numerical expressions of the relationship between controlling factors and landslides. The product of qualitative methods is usually susceptibility maps that do not provide information about the probability of sliding (Anbalagan, 1992). Numerous methods are presented by the related studies in the field of landslide zonation which of them used for specific purpose and area. In our study area with Mediterranean climatic conditions and effective factors on landslide occurrence, Anbalagan method was selected to run the related factors in GIS environment. This is method based on result of combining the basic map that related to natural characteristic of land. In this method after overlaying of the basic map, the weights of class were determined. Then the landslide hazard zonation map was preparing. This method is based on a quantitative data which is weighting the required factor to preparing the landslide hazard zonation map or LHEF (Table 1). Based on final factor of hazard evaluation, hazard classes were determined. Following to the maps overlying it is possible to identify several types of very low, low, medium, high and very high landslide hazard classes (Solaimani, 2007).

Work Unit Map

The study area divided into 10 work unit using 1:25000 topography map and aerial photos. In this division, the work units were determined by topographic border, sub border, gullies and channels which have similar characteristics of slope (Solaimani *et al*., 2007). The work unit map is basic map that should be overlay on other maps, then entered its weights, finally, by summing the resulted weights, landslide hazard rate is determined in each of work unit.

Landslide Inventory Map

For the landslide mapping, at the first stage, geographical coordinates provided for IRS and ETM data, then, field verification of landside data using GPS and finally, landslide inventory map and digitization of data was completed in ArcGIS environment.

Factors Map

Using of different data such as 1:20000 aerial photographs, 1:25000 topography map, 1:100000 geology map, IRS and ETM images together produced factors map.

Slope

Slope is one of the major factors in model, which is main parameter of the slope stability analysis (Lee and Min, 2001). Because the slope angle is directly related to the landslides, it is frequently used in preparing landslide susceptibility maps (Ercanoglu *et al*., 2004; Lee *et al*., 2004; Lee, 2005; Yalcin, 2005, 2008). The slope map of the study area is divided to different slope categories based on Table 2.

Table 2: The weight of factors

Considerations	Weight	Classification of factors	Descriptions	Factors
(I) Intense weathering:		**Type I**	Rock	Lithology
Eroded rock, broad split,	0.2	Quartzite and lime		
metamorphosed texture	0.3	Granite and gabbro		
by weathered material				
(correction coefficient C1)	0.4	Gneiss		
(II) Middle weathering:		**Type II**		
Rock relatively eroded,	1.0	Sedimentary rock by stable		
with not eroded fragments,		cement, often sandstone with		
weathering observed near		thin layer of claystone		
the splits and cracks	1.3	Sedimentary rock by weak		
(correction coefficient C2)		cement, often sandstone with		
		thin layers of shale, clay		
(III) Low weathering:		**Type III**		
Rock eroded little and	1.2	Slate and pilate		
weathering is observed	1.3	Schist		
near the splits and cracks	1.8	Shale with layer of clay and		
(correction coefficient C3)		non clay stone		
For rock of type I:	2.0	Intense weathered shale, filate		
C1+3C2+2C3 = 4		and schist		
For rock of type II:	0.8	Primitive and compressed	Soil type	
C1+1.5C2+1.25C3 = 1		properly fluvial		
	1.0	Clay soil by natural		
		surface of Eluvial		
	1.4	Sandy soil by natural surface,		
		debris often consists of rock		
		with clay soil or sand soil		
	1.2	Collovial:		
		Primitive and proper compressed		
	2.0	Weak and young material		
Meaning of cut	0.2	>30I	Relationship between	Structure
construction is platy cut or	0.25	21-30II	cut constructions with	
intersection between two	0.3	11-20III	slope (degree)	
platy cut, that are important	0.4	6-10IV	(I) Equal relation	
from stability		between cut		
Classification:	0.5	<5V	construction and	
Class I: Very susceptible			slope (degree)	
Class II: Susceptible			Sheet	
Class III: Relatively susceptible			Wedge	
Class IV: Insusceptible				
Class V: Very in susceptible	0.3	>10I	(II) Relation between	
	0.5	0-10II	cut slope and angle	
	0.7	0III	of slope (degree)	
	0.8	0-(-10)IV	Sheet	
	1.0	>(-10)V	Wedge	
	0.2	<15I	(III) Slope of cut (degree)	
	0.25	16-25II		
	0.3	26-35III		
	0.4	36-45IV		
	0.5	>45V		
	0.65	<5	Depth of soil	
	0.85	6-10		
	1.3	11-15		
	2.0	16-20		
	1.2	>20		
Slope angle 1:5000	2.0	>45	Cliff	Morphology of
>45 >25	1.7	36-45	Steepness slope	slope (degree)
36-45 19-25	1.2	26-35	Relatively steepness	
26-35 12-18			slope	
16-25 8-12	0.8	16-25	Smoothed slope	
<15 <7			very	
	0.5	>16	Smoothed slope	

Table 2: Continued

Considerations	Weight	Classification of factors	Descriptions	Factors
	0.3	<100	Low	Difference of
	0.6	101-300	Middle	elevation (m)
	1.0	>300	High	(roughness)
	0.6		Cropland/ inhabitative region	Land use and land cover
	0.8		Dense forest	
	1.2		Region by middle vegetation cover	
	1.5		Region by sparse vegetation cover	
	2.0		Uncultivated land	
	1.0		Flowing	Ground water
	0.8		Saturation	condition
	0.5		Moist	
	0.2		Humid	
	0.0		Dry	

Aspect

Such as slope, aspect is one of the important factors in preparing landslide susceptibility maps (Ercanoglu *et al*., 2004; Lee *et al*., 2004; Lee, 2005; Yalcin, 2008). The related parameters of aspect such as exposure to sunlight, drying winds, rainfall (degree of saturation) and discontinuities may control the occurrence of landslides (Suzen and Doyuran, 2004; Komac, 2006). Aspect degree are classified according to the aspect class as flat (-1°), North (315-360°, 0-45°), East (45-135°), South (135-225°) and West (225-315°).

Relative Relief

Based on the used model relative relief is an effective factor, due to its role in the rate and type of erosion (Ayalew *et al*., 2005; Dai *et al*., 2001) and also on land use changes (Gritzner *et al*., 2001). Relative relief of the study area is mapped using aerial photographs and topographic map.

Lithology

The main source of data related to the geomorphology of an area is its investigation by lithology properties (Dai *et al*., 2001). The study area contents $M_{2.3}$ m.s.l, $Plq_{c.s}$ and Q_2 formations. These types of lithology are very susceptible against landslide occurrence.

Fault

This factor is prepared from geology map which is used in numerous researches (Lee, 2005).

Land Use and Land Cover

Land use and land cover are play important role in instability of slope (Jakob, 2000; Anbalagan, 1992; Koukis and Ziourkas, 1991). With using IRS and ETM images, the land use map of the study area was produced and then their boundaries were determined in conformity with land use state. As a result of the evaluation, three different land cover are described including mixed of forest and garden, forests and croplands.

Ground Water

In the study area, this factor is determined using land use map, field verification and spring survey which is weighted based on Table 2.

Soil

This factor is important for zoning the landslide (Lee, 2005) which is obtained from 1:25000 soil maps for the study area with three different type of soil. According to the depth and drainage condition, this factor was weighted. After preparing of these maps using Table 2 each of them were weighted. Finally, using collecting the weights, the class weight of units was determined (Fig. 2).

RESULTS AND DISCUSSION

Using Table 2, each of factors were weighted, then by combining the layers of factors and comparing with work unit map, the weight of each work unit is determined (Table 3). Regarding to the Table 1, the study area divided into three class of landslide susceptibility; involve, very high hazard class, high hazard class and medium hazard class. Finally, the landslide zonation map was prepared (Fig. 2a-j).

For evaluation the accuracy of landslide zonation, this map is comparing with landslide inventory map; and the percent of landslide area in each class is calculated (Fig. 3). Then regarding to the ratio of landslide area percent to the hazard class area percent, determined that this model is suitable for the study area where the most of landslide are occurred in very high and high hazard classes.

Finally, to determine the importance of the used factors, the percent weight of each factor was calculated in each work unit from total weight of factors (Table 4). The gained result showed that lithology and soil are more importance in landslide occurrence. Then, roughness, land use, slope, ground water condition and structure are effective, respectively.

As mentioned lithology is more importance factor; which is the same with Komac (2006), Van Den Eeckhaut *et al*. (2006) and Kamp *et al*. (2008) and also, Yalcin (2008) achievements.

The study area is naturally susceptible to landslide occurrence; also Anbalagan method based on natural characteristics, therefore is suitable for zoning this area, that showed in Solaimani *et al*. (2007),

Table 3: The weights of work unit

Work unit	Slope	Lithology	Land use	Soil	Roughness	Ground water	Structure	Total weight
1	0.8	1.3	1.20	1.7	0.50	0.20	0.60	6.30
2	0.8	1.3	0.80	1.6	0.40	0.20	0.60	5.70
3	0.8	1.7	0.80	1.7	0.60	0.30	0.60	6.50
4	0.5	1.7	1.10	1.9	0.60	0.40	0.65	6.85
5	0.5	1.6	0.90	1.6	0.60	0.20	0.60	6.00
6	0.5	1.7	1.00	1.8	0.55	0.40	0.65	6.60
7	1.2	1.7	0.80	1.5	0.60	0.40	0.62	6.82
8	1.2	1.7	0.90	1.0	0.50	0.20	0.50	6.00
9	0.5	1.7	1.50	1.5	0.60	0.30	0.60	6.00
10	1.2	1.7	1.80	1.8	0.80	0.40	0.63	7.60
11	1.7	1.7	0.85	1.4	0.80	0.45	0.65	7.55

Table 4: Weight of class to total weight of factor (%)

Work unit	Slope	Lithology	Land use	Soil	Roughness	Ground water	Structure
1	40	65	60	85	50	20	30.0
2	40	65	40	80	40	20	30.0
3	40	85	40	85	60	30	30.0
4	25	85	55	95	60	40	32.5
5	25	80	45	80	60	20	30.0
6	25	85	50	90	55	40	32.5
7	60	85	40	75	60	40	31.0
8	60	85	45	50	50	20	25.0
9	25	85	75	75	60	30	30.0
10	60	85	90	90	80	40	31.5
11	85	85	42	70	80	45	32.5
Total	485	890	582	875	655	345	335.0

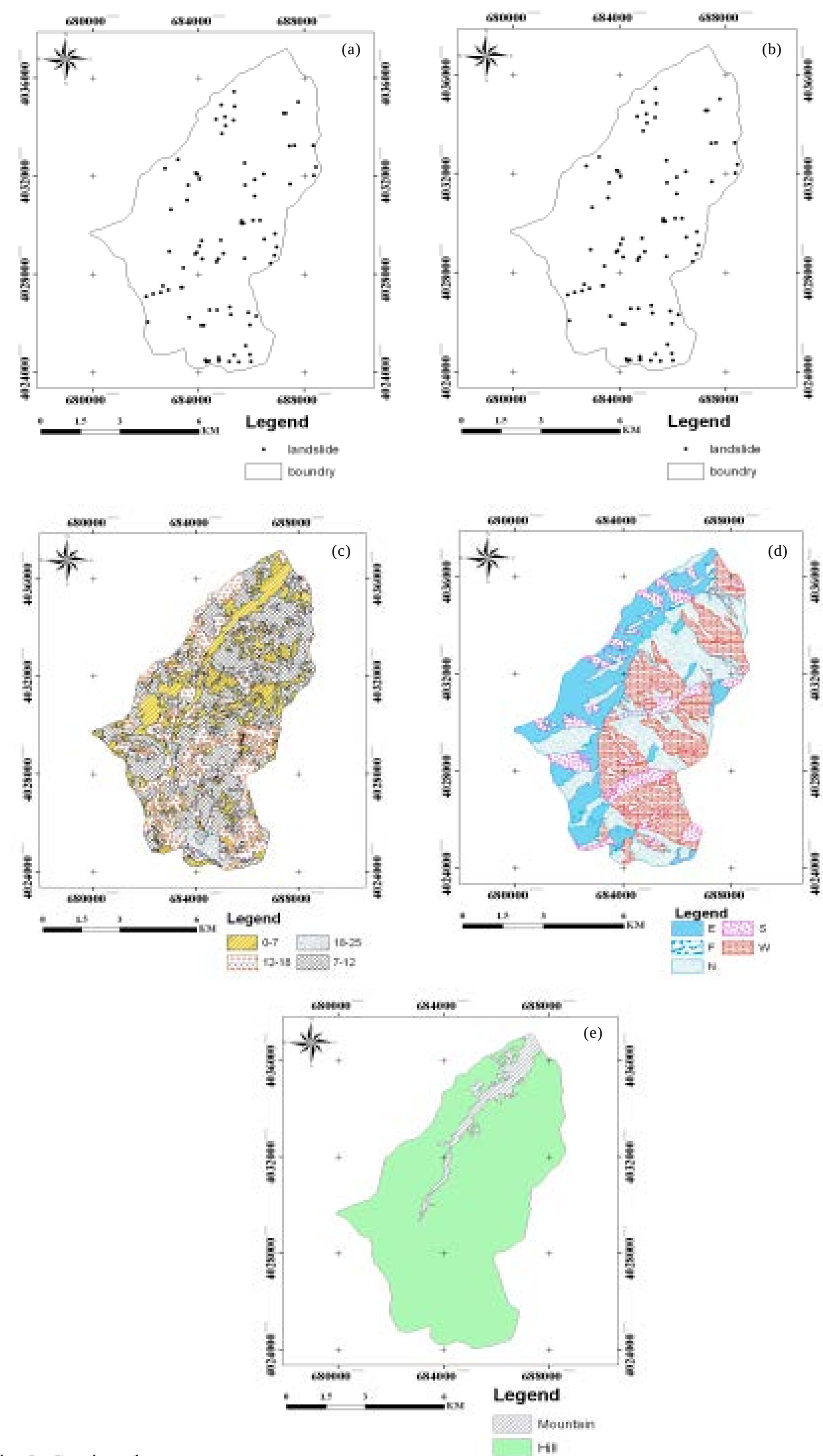

Fig. 2: Continued

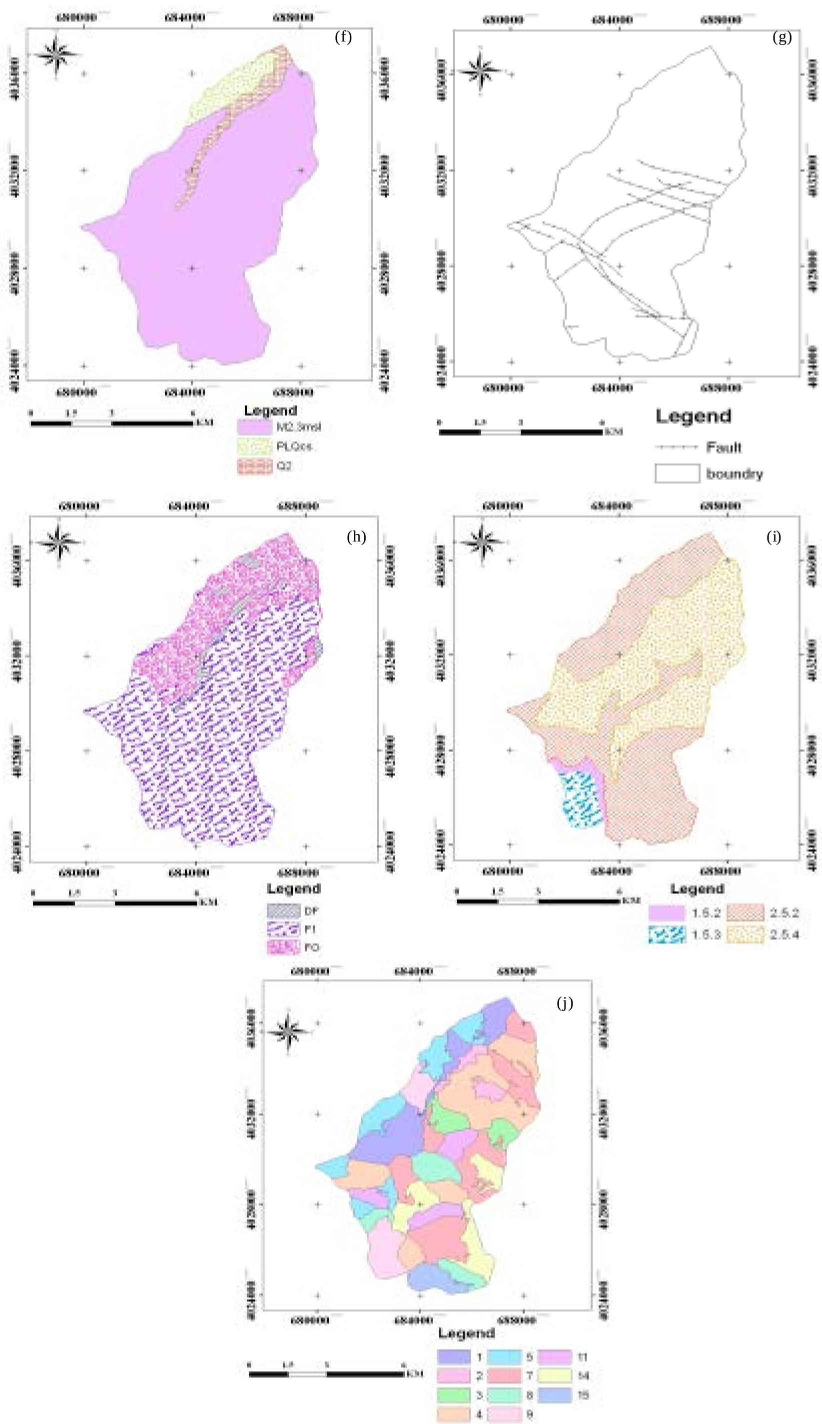

Fig. 2: Factors, work unit and zonation map

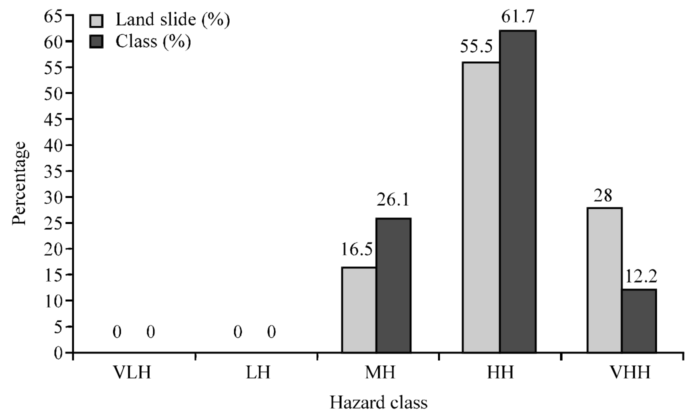

Fig. 3: Comparing area of landslide (%) with area of hazard class (%)

Oroumiei and Safaei (1998), Oroumiei and Aminizadeh (1998) and Emami and Elhami (2005), also it can be recommended that this method is best model for landslide zonation of this area. This method should be performed by assistance of different experts in tectonic, climatology and hydrology, because this method requires to different factors measurements. Refer to former researches that performed in similar condition and other regions of country, this method is appropriate and in compare to other method, gave better results. Furthermore, the study area is very susceptible; therefore, the zone of low hazard and very low hazard not existed. Certainly in this method, road were not contributed, whereas observed in this field. Therefore, road in this area constructed carefully and not constructed in high hazard zone and very high hazard zone, so that with lowest long having most of usage. Furthermore, observed that construction the animal husbandry and site of inhumation garbage, caused landslide occurrence due to high susceptibility to landslide. Finally this zonation map is recommended to use for construction design and road in forest area such as Pahnehkola basin.

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