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Comparison and Analysis of Statistical and Experimental Methods in Land Slide Hazard Zonation Using Geographical Information System (Study Region: Pishkooh District, Fereidonshahr City)

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ABSTRACT

Landslide is one of natural phenomena which happen due to the falling or massive and often rapid movement of the sediments along amplitudes. Today, this phenomenon has been focused as one of the natural disasters because it causes serious life and financial damage.
In this research, Pishkooh district of Fereidonshahr city with an area of 77646 was chosen to evaluate statistical and experimental methods in Isfahan province. then, landslide dispersion map was prepared by using air photographs, to graphical maps, geographical maps and field investigations then ,eight factors were selected from among effective factors on slid including: slope, slope direction, precipitation, land use, distance from fult, distance from canal, distance from road and litho logy. Descriptive and place information was inserted into geographical information system, software Arc map in order to enhance precision, speed, easy analysis and digitizing data.
After preparing required information layers, the maps of landslide hazard zonation were prepared using effective parameters on slide with two statistical methods of information Value and density area and Nilsens experimental method. then they were evaluated and finally, their strength and weaknesses were determined.
Results showed information value method with po.559QS, 2459 is the best method in terms of precision and the accuracy and after that, density area method with 0.167QS, po.480 are good methods respectively. Therefore, statistical methods have higher precision and accuracy compared with experimental methods and they are more suitable methods for zonation and information value method is more precise and accurate than density area method.

KEYWORDS: statistical method, experimental method, landslide. Geographical information system, Fereidoonshahr.

INTRODUCTION

Landslide is one of natured phenomena which happens due to the falling or massive and often rapid movement of the sediments along amplitudes. Today, this phenomenon has been focused as one of natural disasters because it causes serious life and financial damages. After studying and investigating, it is necessary to consider susceptible areas to slide with a scientific view and help authorities and executive manager by the preparation of landslide hazard zonation maps and prevent life and financial damages in this way.

Haghshenas zoned watershed in Taleghan with invariant and multivariate statistical methods in 1996. Hein traduced multivariantregress in method as the most suitable method.

Pejam zoned Almotrood basin with multi-variant statistical method in 1996 and Haeri(1996) zoned Mazandaran province with modifying Mora and Warsons method.

Saadodin zoned watershed in chashm in Semnan province using information statistical method and multi-variant regression method in 1197. Badaghi (1997) zoned watershed in Shahrood using multivariate statistical method. ShareatJaafari zoned Taleghan using three experimental methods of kanagava, Nilsen and modified Nilsen and he introduced the method of nilsen as the best method.

FattahiArdakani zoned watershed in Letian by using variables weight, information value and density area in 2000. He zoned the area of Karoon by using four methods including variables weight, information value, density area and Nilsens method in 2003.

Ashghalifarahani zoned Roodbar using multivariate and bi-variant statistical methods in 2001 and introduce multi-variant statistical method, logistic, regression method. Jalali(2002) evaluated eight methods from different methods and models of landslide hazard zonation in watershed of Taleghan in his research plans titled" the

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evaluation of the methods of massive movements hazard zonation” in order to find methods compatible with Iran climate using GIS.

Sefidgari zoned Damavand region using multivariant and bivariant statistical method in 2002 and introduced multivariate statistical method.

Shirani evaluated seven methods such as multivariate and Bavarian method and Nilsens method in the basin of Marbar river in Semirom and introduced bivariant statistical method of density area as the most suitable method.

Feiznia and colleagues zoned shirinrood watershed- Tejan dam by using information value method, density area, over lapping index and systems hierarchical analysis in 2005.

Gholami(2007) evaluated the reservoir of Beheshabad dam in the center of Chaharmaholobakhtiari.

The position and the area of the region under study.

This region is located at the longitudes of 49 36 to 50 19, eastern length and at the latitudes of 32 37 to 33 50 northern width. The area of this region is 77646.893 hectares.

Fereidoonshahr city with average height of 2500 meters from sea level is a mountainous region that appears as a tongue among the provinces of Lorestan, Khoozestan and Chaharmahalobakhtiari.

Figure1: the map of general position of Phishkooh region in Fereidoonshahr city relative to political border of the province.

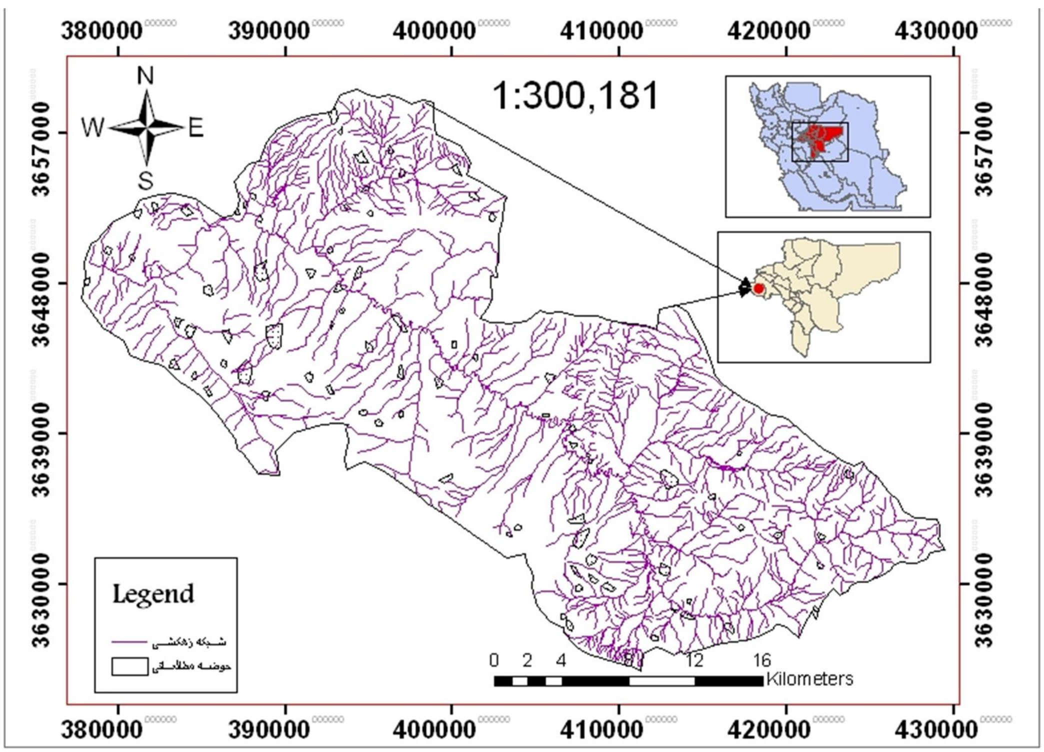


Figure1

MATERIAL AND METHODS

In order to determine different degrees of the landslide line in Pishkoohregion, statistics and information related to possible causes of the landslide have been prepared from different resources including:

Data from geology map

Geology situation of this region was investigated by studying maps 1:250000 related to oil company (Golpaiegan-shahrekord). In addition, fault, litho logy units and geology map was prepared by studying and interpreting air photographs 1:40000 and field investigations. After preparing the map of the faults and litho logy units and digitizing, output maps were prepared.

Data from topography map

In order to prepare digitized elevation model map, the map of slope, slope direction, distance from canal and classes related to them, topography maps with scale 1:50000 from military geographical organization was used. All elevation points and adjustment curves of 100 meters and canals in pishkooh region were digitized. Necessary operations were performed in order to use them in Software Arc Map.

Digitized elevation model was prepared using adjustment curves and digitized elevation points. Cell size (pixel size) is 30*30m2. After preparing digitized elevation model map, slope and slope direction map was prepared with the size of 30*30m2.

Vegetation and land use map

Vegetation and land use map was prepared using topography map 1:50000 and field survey. Land use form and the density and the form of the vegetation affect landslide occurrence. According to above explanations, 11 forms of Vegetation and land use were identified in region of this study and classification was performed based on density, Vegetation form and land use.(figure2)

Figure2: Vegetation and land use map

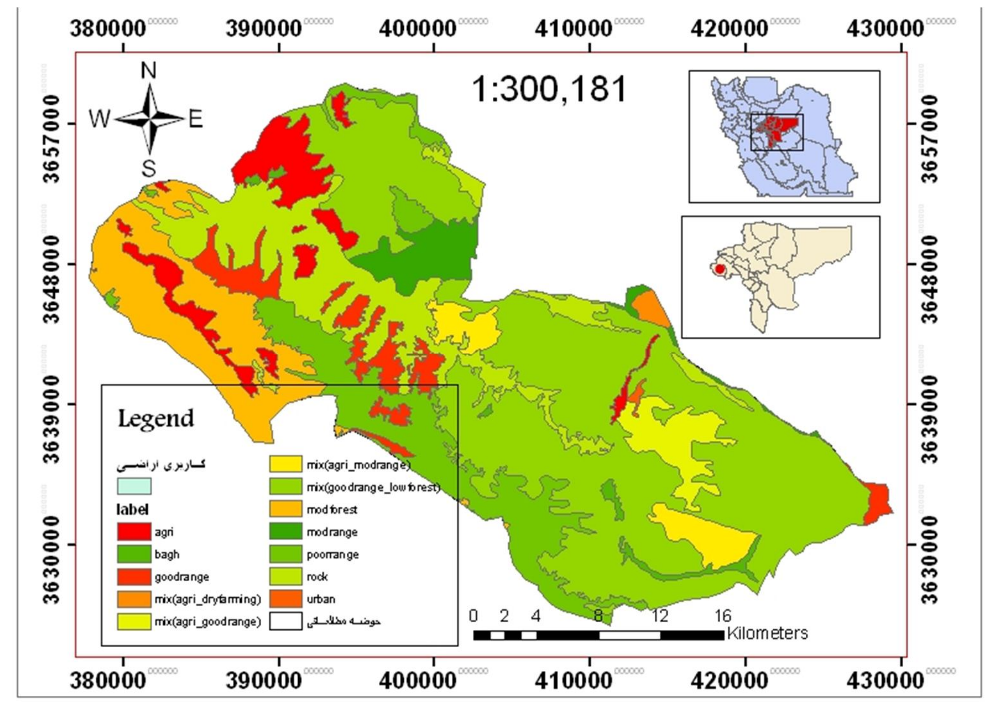


Figure2

Land slide dispersion

Isfahan province and Fereidoonshahr city have high potential of the landslide and they have experienced many landslides.

In order to map various occurred landslides in the region under study, air photographers related to 1997 with the scale of 1:40000, by Stereoscopic method, were interpreted and Slide regions were identified. Then, more detailed position of Slides wereMpped carefully using field investigations and GPS. (Figure3)

In general, ihis city consists of 5 rural districts including Barfanbar, Ashayer. Pishkoohmoogoaie, Pooshkoohmoogoaie, Cheshmehlangan. Each rural district has many village.

Figure3: Dispersion map of massive movements in Pishhoohregion .

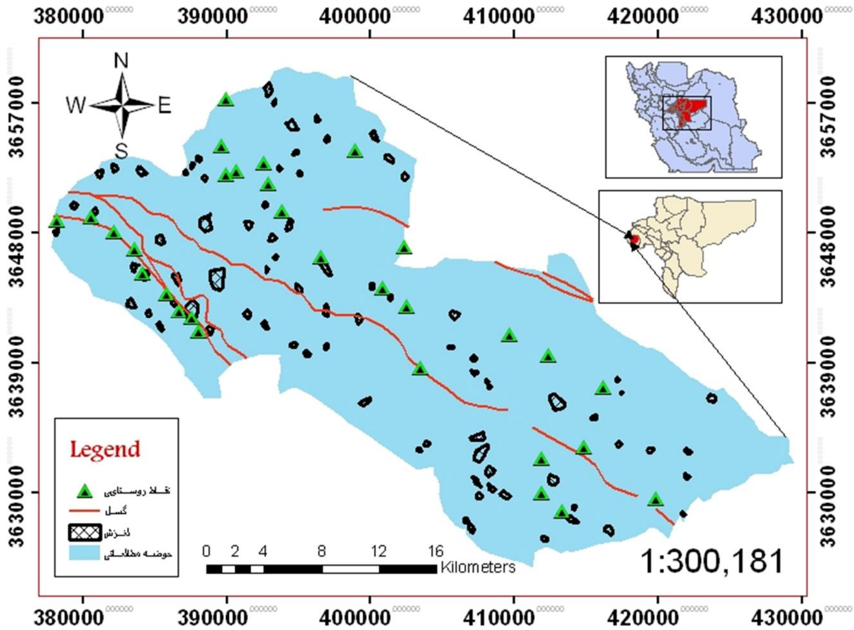


Figure 3

Zonation of Landslide line in the region under study

Zonation methods include experimental and statistical methods. Experimental methods are used for a special region and they may not be suitable for other region so, they cannot be used directly for other regions and they should be modified. In contrast to experimental methods, statistical methods can be used in different regions because in this methods. The effect of each parameter is investigated separately and parameters with more effect on slide occurrence, are more involved in zonation.in this research, three research methods were investigated and compared including bivariate statistical, information value and density area and Nilsen's experimental method.

Conditional analysis is the simplest kind of statistical analysis that shows probability relationship between landslide and effective parameter. According to conditional analysis, landslide frequency (LF) includes:

LF= slide area /total are relationship1

In above relationship, LF is defined as the probability of the occurrence of landslide condition in related unit as sample unit in the study of landslide hazard. In order to compare the difference of conditional probability of the unit in a region, conditional probability of total area should be identified.

P(total)= Total area of slide regions/ Total area of the region relationship2

After calculating the Values of above relationships, the region under study is ranhed into different degrees of the hazard with the help of the function of these two Values. In other word, instead of introducing a part of total region in formula as sample unit and generalizing it to total region, each factor is analysize desperately and then we suppose each factor has weak correlation with other effective factors on landslide and we gain final probability of landslide occurrence with adding up occurrence probability from all factors.

The most important limitation of this method is conditional independence of information layers. However, when low number of the factors related to landslide is available in a region and there is enough knowledge about the roles of effective factors on landslide, this method is a useful too for landslide hazard zonation. In order to calculate the weight of each factor and prepare the map of landslide hazard zonation, two methods of information Value and density area are used that they are available in GIS and they can be found easily and carefully.

Information Value method

In this method, pixel was selected as land unit and the relationship between effective parameters in landslide occurrence and landslide dispersion were considered and landslide hazard were evaluated. Then, based on this evaluation, the weight and the role of these classes and effective parameters were calculated with following relationship.

Wi= Ln (Densclass/Densmap)=Ln(Npix(Si)/Npix(Ni))/(Npix(Si)/∑npix(Ni))

Wi=weight related to a given class of a parameter

Dens class: landslide density in a given class of a parameter.
Dens map: landslide density in total region
Npix(Si): the cells number or the area of occurred landslides in each class of the parameter.
Npix(Ni): the cell number or total area of each class of the parameter.
In order to access to landslide zonation map, eight litho logy factors were used including slope amount, slope orientation, distance from fault, land use, distance from canal, precipitation, landslide layer. Zonation map was prepared in Arc Map with following steps:
1.Adoptation of between factor map and landslide map and the calculation of density area in each variable class.
2.The calculation of information Value for each variable class.
3.Theregisteration of calculated information for each class and the preparation of information Value map for each class.
4.Algebraic summation of information Value maps
5.The classification of prepared map from previous map and the prepation of landslide zonation map.
Figure (4):landslide hazard zonation map with information Value method.
Table (1):landslide distribution in hazard zonation units(Information Value method)

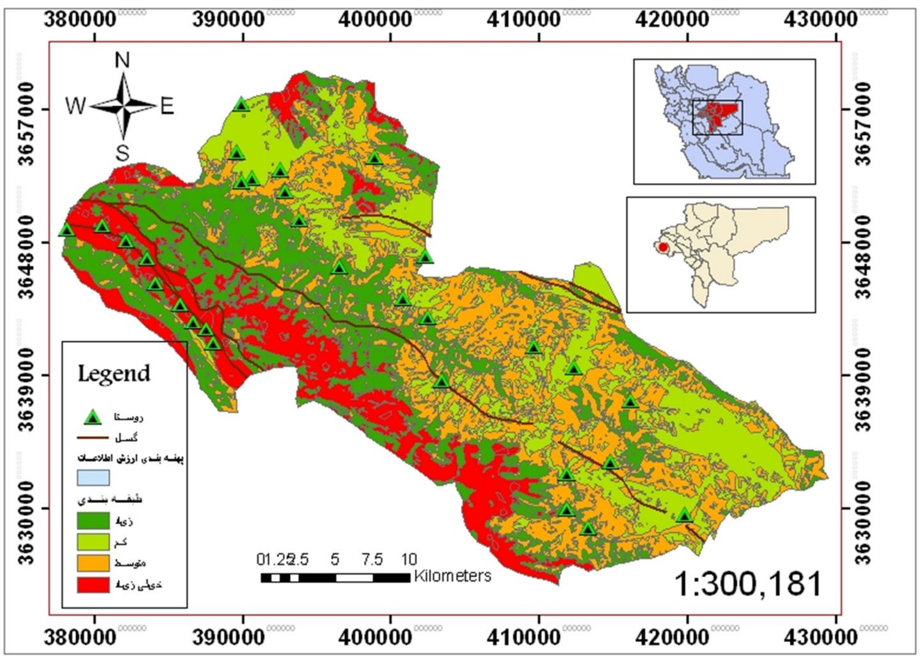


Figure (4)

Hazard classes	Slides area(hectare)	Area (hectare)	Area percentage	Dr	Total Qs	p
Low	69.160	18511.3731	.,2384046	.,19040805		
Middle	291.449	24502.7462	.,3155663	.,60619368	.,559	2.459
High	533.08	21163.5555	.,2725615	1.28371039		
Very high	629.874	13469.2189	.,1734676	2.38327802		

Table (1)

Density area method

As with information Value method, in this method, slide density parameteror factor is calculated using following relationships and then landslide zonation map is prepared like information Value methode.

D=Npix(Sxi)/Npix(Xi) relationship 4

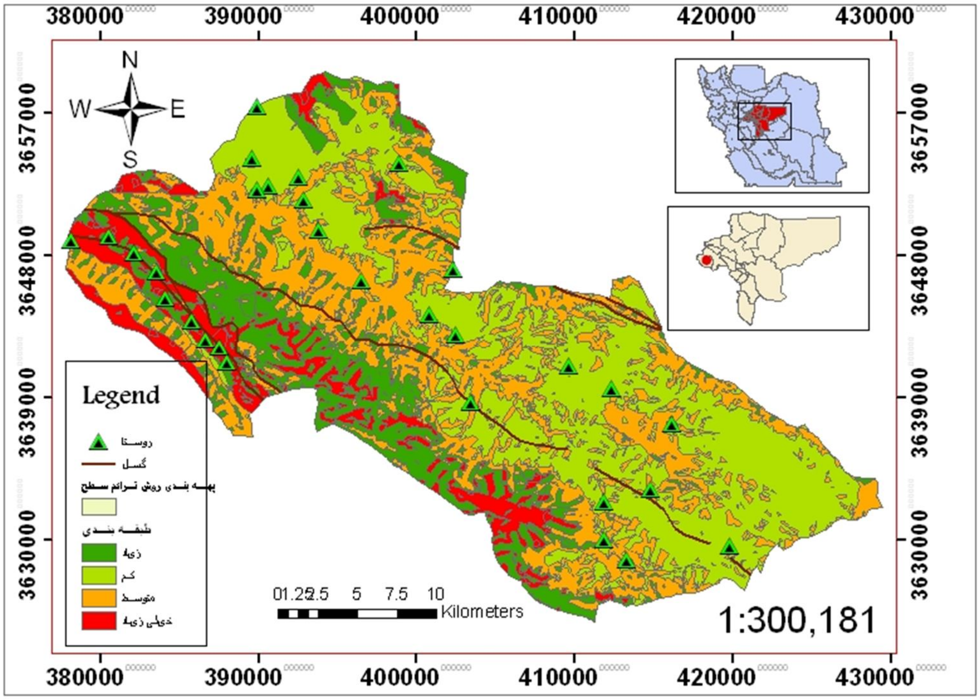
W= 1000*[D-(∑N Pix(Sxi)/∑Npix(Xi)] relationshipe 5

D: lanslide density in each class of a parameter or Variable
W: Variable Value in each class of a parameter
Npix(Sxi): The erea of occurred slide in each class or Variable Xi
Npix(Xi): The area of each class or Variable Xi

Then, Final weight map (W) and slide zonation map were prepared in Four hazard zones including low, middle, high and very high with algebraic summation of weight maps(W), for eight factors(slope, slope orientation,lithology,land use, distance from canal, distance from road and precipitation).

Figure(5):landslide hazard zonation map with statistical method of density area.

Table(2):land slides distribution in hazard zonation ynits(density area method).



Figure(5)

Hazar classes	Slided area(hectare)	Area (hectare)	Area perecentage	Dr	Total Qs	p
Low	442.3796	14800.4781	.2384	1.523855		
Middle	186.3884	29304.9315	.31557	.324267	.,555	2.552
High	479.1836	26132.0887	.27256	.934872		
Very high	415.6127	7409.3953	.173447	2.859764		

Table(2)

Zonation with Nilsens method

Work method of Nilsen includes:

1.The preparation of comprehensive in slope ranges(In this map, the region is divided in to three, slope less than 15%, slope between 5 and 15% and more than 15%).

2. The preparation of landslide deposits map using air photographs interpretation.

3. The preparation of the map of geologhy units sensitive to failure.

4. The adaptation of three above maps.

There fore, zonation is performed in Nilsen,s method using slope information layers and the sensitivity of stony units to failure.for this, the map of slope classes was prepared in three classes(table3).Then, prepared slope map is integrated into sensitivity map of stony units to failure and different hazard zones are determined using suggested table3.

In order to prepare sensitivity map of stonu units to failure, stony units were divided into three classes in terms of sensivitydegree(high sensitivity, middel sensitivity and low sensitivity)

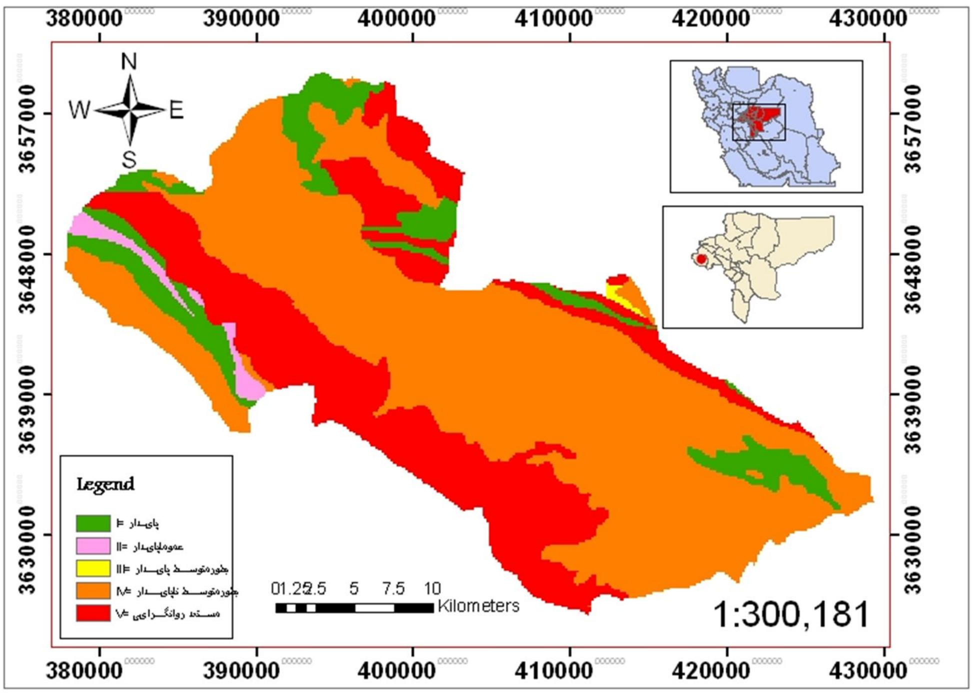
Table(3): The principle of landslide zonation based on Nilsen,s method.

slope units	**< 5%**	**5% - 15%**	**> 15%**
Units with low or without slide	Stable I	Usually stable II	Averagely stable III
Units with slopes	Averagely instable IV		
Sensitive units	Sensitive regions	to landslide V	

The adaptation of three maps and preparation of final map for slope relative instability .

As mentional in nilsen,s method, zonation is performed using slopeinformation layers and the sensitivity of stony units to failure. For this, slope classes map was prepared in three classes(based on table3). Then, prepared slope map was integrated into sensitivity map of stony units to failure. Finally, landslide hazard zonation map was prepared using Nilsen's method based in table(3) in five zone including stable, usually stable, averagely stable, averagely instable and sensitive regions to liquefaction. In table (4), slide amount has been identified. Different hazard zones are determined in ArcMap .

Figure(6):landslide hazard zonation map with Nilsen's method.



Figure(6)

Table(4):slide amount in each class

Stable zone in each class	Slide amount in each class	Sensitivity amount	Class
24239.335	686.5264	I	0
2105.6028	105.2175	II	1
21925.9662	311.9947	III	2
10545.7712	107.3624	IV	3
17306.654	312.4632	V	4

Evaluation methods of the precision in landslide hazard zonation

In order to analyze and investigate precision and accuracy for used methods in the determination of landslide hazard potential, the relationships of method precision(p) and method accuracy(QS) are used andthe best method is selected with the comparison of the precision and the accuracy of final weight map in the methods of information value, density area and Nilsen. Relationships include:

Method precision is defined as slide area in medium to high hazard zone to zones area. Following relationship shows above definition:

P=ks/s (relationship6)

P= method precision in medium high zones

KS=slided area in medium to high hazard zones

S= Area of related hazard zones

Method accuracy is obtained according to density ratio based on below formula.

DR= landslides percentage/area percetagerelationship(7)

QS= €<DR-1>2*Area<%>relationship(8)

Landslides percentage is defined as the ratio of landslides area in each hazard class to landslides area in the region. Finally, accuracy and precision amounts of zonation maps in the region of this study were determined using above relationships. If ascending trend, ascending density and area density are not observed from low to high hazard groups, related maps are not accepted and analyses should be controlled again and in other words, related method is not suitable for zonation in related region.

The valus of Pand QS are 2.459 and 0.55 in information, in information value method, they are 2.252 and 0.555 in density area method and they are 0.480 and 0.167 in Nilsens experimental method. Higher Values show higher precision and accuracy of the map. In fact, P shows map precision and GS shows map accuracy. Therefore, if P is higher in high classes, map precision is higher and if QS is higher, map accuracy is higher for total classes and subsequently, total model accuracy is higher.

As table(6) shows precision Value (P) IS higher in information Value method compared with density area method. In addition, accuracy value(QS) shows high accuracy of slide zonation map of the region. Statistical methods have higher precision and accuracy compared with Nilsens method. The investigation of the maps of these three methods show the most area of this region is devoted to medium hazard class in all three methods. The area are 22236.05 hectares in Nilsens method, 24502.7462 hectares in information Value method and 29304.9315 hectares in density area method. Therefore, there are slide accuracy conditions in many points of this region.

Table(5):precision and accuracy values in landslide zonation methods

Zonation method	QS	P
Information Value	0.559	2.459
Density area	0.555	2.252
Nilsen	0.16732	.480

Table(5)

The calculation of density ratio from relationship(7) and the comparison in two statistical methods and Nilsens method show ascending trend, ascending density and area density are observed from low hazard to high hazard group in information Value method(table6). In statistical method of density area, density ratio increases in low hazard class, then it decreases in medium and high hazard classes and finally, it increases in very high hazard class(table7). But in Nilsens method, density ratio does not benefit from necessary order. In other word, ascending trend, ascending density and area density are not observed from low hazard to high hazard classes. Density ratio increases in two stable and relatively stable classes and density ratio in relatively stable class is higher compared with in relatively instable class. This finding shows density ratio decreases from high hazard to low hazard classes and it is not accepted(table8). Therefore, zonation map from statistical method of information Value has more precision and accuracy and it is a good method for area zonation

Table(6): Density ratio comparison in statistical method of Value method

Hazard classes	Slided area(hectare)	Area(hectare)	Area percentage	Density ratio(DR)
low	69.1609	18511.3731	.2384046	.19040805
Medium	291.4492	24502.7462	.3155663	.60619368
High	533.08	21163.5555	.2725615	1.28371039
Very high	629.874	13469.2189	.1734676	2.38327802

Table(7): Density ratio comparison in statistical method of density area

Hazard classes	Slided area(hectare)	Area(hectare)	Area percentage	Density ratio(DR)
low	442.3796	14800.4781	.2384	1.523855
Medium	186.3884	29304.9315	.31557	.324267
High	479.1836	26132.0887	.2725615	.934872
Very high	415.6127	7409.3953	.1734676	2.859764

.

Table(8):Density ratio comparison in Nilsens experimental method

Hazard classes	Slided area(hectare)	Area(hectare)	Area percentage	Density ratio(DR)
I	686.4972	24928.74	.32105263	1.403466
II	104.9977	2211.275	.0284786	2.419917
III	311.7852	22236.05	.286373999	.714597
IV	107.7114	10652.63	.137193194	.51531
V	312.5727	17618.2	.226901577	.904176

Finally, information Value method is more precise and suitable compared with two statistical methods of information Value and density area and Nilsens experimental method and it has the highest amount of the precision of the accuracy.

CONCLUSIONS AND SUGGESTION

1. Eight factors including slope, slope orientation, land use, distance from canal, distance from road, distance from fault, litologhy and precipitation have been used in order to prepare landslide hazard zonation map.
2. The investigation of these three methods(information Value, density area Nilsen) shows the most area of this region is devoted to medium hazard region. Therefore, there are slide occurrence conditions in many points of the region.
3. slides dispersion map shows the most area of the region is devoted to low hazard class, medium class, high class and very high class respectively.
4. In terms of slides expansions in the units of the region lithology, the most slides are related to component, cretaceous limes, Eocene limes, Oligomucine marls, paleocen limes and shell interlayers in the region.
5. This research showed statistical methods are more suitable for landslide hazard zonation in pishkooh region. Statistical methods have more precision accuracy with regard to the complexity of geomorphic processes and the effect of environmental factor on landslide occurrence.
6. The comparison of the density ratio between statistical methods and experimental method showed Nilsens experimental method is not suitable for zonation in pishkoohregion .
7.The evaluation of zonation methods needs different methods in order to achieve satisfactory results.
8. Final conclusion is that statistical methods of information Value and density area are better compared with Nilsens method for landslide hazard zonation in pishkoohregion .
9. Before developmental activities and the chang of land use, prepared zonation map is considered and necessary activities are performed in to prevent the hazard of landslide accuracy.
10. prepared zonation maps are offered to governors offices, transportation office, electricity office, telecommunication.
11. Different methods of the zonation are performed and the most suitable method is selected and zonation map is prepared and this map is offered to related organization.
12. Just a single method is not enough for the evaluation of zonation methods.
13. Different methods should used in different regions because effective factors parameters are different in different regions.
14. It is recommended to use topography digitized maps 1:250000 prepared by mapping organization of the country in order to transfer information from air photographs to a base map because of good precision of these maps.

Transfer operation are performed more precise by using this map compared with other maps because necessary geometrical correction have been performed during the preparation of these maps and there are geographical coordinate, natural complications such as (contours and channels and…)
And artificial complication(such as, roads, artificial regions).

Acknowledgment

The authors declare that they have no conflicts of interest in the research.

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