Using GIS & RS in Mass Movements Hazard Zonation -A Case Study in Germichay Watershed, Ardebil, Iran

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Abstract

Studying of landslides triggering factors and zonation of their hazards could help effectively in reducing their damages that this research is an effort in this connection and with studying of landslides triggering factors and mass movements hazard zonation methods, Germichay watershed has been zoned with Analytical Hierarchy Process (AHP) method, and in the end, the regional model has been presented. Methodologically, at first the landslides triggering factors of the area were studied and the important factors with their priority arrangement including lithology, slope, land use, lineament factors (road & river), precipitation, aspect and altitude were investigated. Then their maps with using GIS & RS were supplied and classified. Also the landslides distribution map was supplied with using GPS and GIS techniques. In Analytical Hierarchy Process (AHP) method, at first, the proposed factors for zonation (the seven factors that mentioned in the past) have compared couple and their weights have determined with using Analytical hierarchy process. Also, in this paper cumulative curve, has been used because of to classification the factors, and with due regard to per class landslides percentage, their values have been determined. In the end, with regard to earned weights for each factor and their class's values, the zonation model was presented. Also in analyzing the results and assessing the model, was used the GIS technique, so as the zoned map has been crossed with landslides distribution map and the model accuracy was confirmed with determining the landslides percentage in per zoned class.

Key words: Landslide, Mass movements, Analytical Hierarchy Process (AHP), Hazard, Zonation, GIS and RS.

Introduction

As a final goal, the investigation and studying of landslides is to find ways to reduce their damages. This objective is possible via different ways such as landslides hazard zonation for determining the hazardous areas and providing recipes and regulations for appropriate uses of these areas or for keep away from they. Also it can be earned by studying a one landslide and presenting ways to control it.

In the course of 1980 decade, using of GIS for supplying the slope instability map was accelerated as the result of developing commercial GIS systems such as Idrisi, Arc / Info, ArcView, Ilwis, Spans, Intergraph and increasing the abilities of PC-based platforms. In this decade, many of studies about GIS were to zonate the landslides hazard qualitatively. The application of GIS in mass movements hazard zonation is to providing the maps with high speed and accuracy. Some of the maps are DEM, slope, aspect, altitude, lineament factors, precipitation, lithology etc. Also the application of RS is very appropriate in providing the land use map. Therefore the using of GIS & RS must always be as a recipe of a natural resources expert and to use it as an instrument.

Nagarajan et al (1998) in part of western ghat in India used temporal remote sensing and GIS techniques to zonate the landslide hazard and said that their works were too successful in comparing with previous manual methods[3].

Hassanzadeh (2000) has been used the Multiple Regression method and GIS technique for landslides hazard zonation with using four factors lithology, slope angle, precipitation and land use, and has been assessed the results very successful [2].

Study area

Germichay watershed was selected for this study that runs from 48° 1´ to 48° 10´ eastern longitude and from 38° 54´ to 39° 12´ northern latitude. This watershed is a part of Ardebil province, Iran, and reaches from north and south to Azerbayjan republic, from east reaches to Arazchay watershed and from west reaches to Sarighamishchay watershed. This watershed contains Germi City that lies in it center. Its area is about 180 km2 that 55% of it is mountainous and 45% of it is the plain areas.

Methodology

1.Studying of landslides triggering factors

The common method to study the triggering factors is to use from questionnaire and morphometring the landslides inside the watershed as field works, which this method has been done for Germichay watershed. In field works, some instances such as, the location of landslides, lithological structure, vegetation coverall, type of land use around the landslides, slope angle, road construction, river & water ways, altitude, aspect etc. must to be determined that expert could recognize the important factors in triggering the landslides. Then the important factors must to be determined with their priority arrangement.

2. Providing the landslides distribution map

With interpreting the aerial photographs, the sustainable areas for landslides were recognized, so as the areas that their morphology show as a landslide must to be marked on the photos in order that in field checks to be controlled. But the most important part of providing the landslides distribution maps, has been done in field controls and field checks. In this stage all of the marked areas on the aerial photographs must be controlled with field observations and questionnaire complementing and the marked areas that probably are not the slides, be removed. For determining the minute location of landslides and to provide the landslides distribution map, was used from GPS1. In the end, the provided map was entered to Geographic Information System (GIS) with using GISs software, Arc/ Info, in order that to overlaying with the other maps to determine the landslides triggering factors, and the other objectives.

3. Providing the landslides triggering factors maps

GIS & RS techniques provided the maps of seven factors that had been recognized as important factors and had been arranged for their priority. Then for the reason of districting the maps, each map was classified in to several classes. These maps are:

1. Lithology agent map 2. Slope map 3. Land use map
4. Lineament factors map 5. Precipitation classes map
6. Altitude classes map 7. Aspect map

For providing the lithology agent, slope, lineament factors (river & road), precipitation classes, altitude classes and aspect maps, were used the GIS software's, Arc/Info, Idrisi and ArcView simultaneously, and for providing the land use map were used form satellite images and their digital data in Idrisi software circumference.

4. Zonation of Germichay watershed with using Analytical Hierarchy Process (AHP)

In this method, at first for the reason of determining different factor preference and conversion they into quantitative values are used from oral judgements. In this case, the preference of a factor as compared with the other factor take into as a table 1, then these judgements is changed into quantitative values from 1 to 9 [1&5].

Table 1: The preference of different factors and conversion they into quantitative values.

Preference of a factor as compared with the other	Numerical value
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intervals between preferences	2,4,6,8

After formation of the above table, in this time for the reason of zonation the area, under stages have been done orderly [5]:

1- Couple comparing of the factors and their priority based on their weights.

For the reason of couple comparing of the factors and determining their preference as compared with each other, was formed table 2.

Table2: Couple comparing of the factors in landslide triggering of Germichay watershed

	Lithology	Slope	Land use	Lineament factors	Precipitation	Aspect	Altitude
Lithology	1	3	5	5	7	8	9
Slope	1/3	1	3	3	4	5	6
Land use	1/5	1/3	1	1	3	4	5
Lineament factors	1/5	1/3	1	1	3	4	5
Precipitation	1/7	1/4	1/3	1/3	1	2	3
Aspect	1/8	1/5	1/4	1/4	1/2	1	2
Altitude	1/9	1/	1/5	1/5	1/3	1/2	1
Sum	**2.112**	**5.283**	**10.783**	**10.783**	**18.883**	**24.5**	**31**

At present for the reason of to calculate each alternative weight of couple comparing matrix, is used of arithmetic mean (approximate) method. In this method, at first, the values of each column are summed together (that this stage has been done in table2). Then the values of each alternative (element) of the matrix is divided by the sum value of the same factor column, and in the end stage, the factors mean values in derived in each rows (table 3). These mean values of each row are the weight values for each map.

Table 3: Arithmetic mean method for calculating the factors weights (maps weights)

	Lithology	Slope	Land use	Lineament factors	Precipitation	Aspect	Altitude	Mean
Lithology	0.4735	0.5679	0.4637	0.4637	0.3717	0.3265	0.2903	**0.423**
Slope	0.1578	0.1893	0.2782	0.2782	0.2124	0.2041	0.1935	**0.216**
Land use	0.0947	0.0631	0.0927	0.0927	0.1593	0.1633	0.1613	**0.118**
Lineament factors	0.0947	0.0631	0.0927	0.0927	0.1593	0.1633	0.1613	**0.118**
Precipitation	0.0676	0.0473	0.0309	0.0309	0.0531	0.0816	0.0968	**0.058**
Aspect	0.0592	0.0379	0.0232	0.0232	0.0265	0.0408	0.0645	**0.039**
Altitude	0.0526	0.0315	0.0185	0.0185	0.0177	0.0204	0.0323	**0.028**

Therefore, the priority of each factors based on earned weights in connection with landslides hazard in the study area is as the under arrangement:

1. Lithology, w1= 0.423 2. Slope, w2 = 0.216
3.Land use, w3=0.118 4. Lineament factors, w4 = 0.118
5. Precipitation, w5= 0.058 6. Aspect, w6= 0.039
7. Altitude, w7= 0.028

2- Classification of the factors with using cumulative curve

The method that has considered in this paper includes the classification of factors into several classes with regard to their changing in the nature. For example, if we want to classify the altitude map, it will be better that we take into the suddenly variations of the area topography in connection with the elevation. These suddenly variations could be recognized via drawing cumulative curves between the factors values (elevation amounts) versus their pixels frequency. This work contains the document file of DEM map that in Idrisi software, we can draw the histogram of it and determine the classes.

With using this method, the altitude map was classified into four classes: **a**) 290-600 m **b**) 600-1200m**c**) 1200- 1850 m **d**) 1850 – 2200 m

Also for the classification of the other factors, has been done the same method. Of course the classes of some maps such as, lithology agent, aspect and land use spontaneously are determined. Also for classifying the lineament factors map, has been used from its curve between distance from lineament factors and landslides percentage with distance from them.

3- Valuing to each classes of factors

With using of landslide area percentage in each classes of different factors, all classes were valued from 0 to 100. In this case, the class of each factor that had a maximum percent of landslides area, was contained the maximum value 100 and proportional with that, to each the other classes with regard to their landslides percentage, were given different values [5].

For example, the driven values for altitude factor are these:

1- two 290-600 & 1850 – 2220 m classes that had no landslides, m = 0

2- the class 600 – 1200m that had the maximum amount of landslides area percentage, m = 100

3- the class 1200 – 1850, m = 48.24

4- Presenting the model and zonation of watershed

After the valuing of area with regard to seven factors, at present, the values of seven factors classes (m) are multiplied by derived weights for each factor (w1…w7) and then are summed together. Finally the total value **M** for each pixel and the regional model will be derived:

$$\mathbf{M} = w1X1 + w2X2 + w3X3 + w4X4 + w5X5 + w6X6 + w7X7 \quad (1)$$

And with replacing the weights (w1…w7) that had been earned previously, the final model was derived:

$$\mathbf{M} = 0.423X1+0.216X2+0.118X3+0.118X4+0.059X5+0.039X6+0.028X7 \quad (2)$$

Where; **M** = susceptibility coefficient

X1…X7 = orderly are related to lithology, slope, land use, lineament factors, precipitation, aspect and altitude factors and,

W1…w7 = are the weights related to each x1…x7 factors

Because **M** variations are from 0 to 100, therefore, for the low values, the area relative to landslide danger will be lowing dangerous, and for the high values, the area relative to landslide danger will be very dangerous. For the reason of separation the **M** values into several (susceptibility classes, the cumulative curve between pixels frequency and **M** values, has been drawn (Figure 1).

With regard to this curve, Germichay watershed has been divided to five susceptibility classes:

1- 0 $\leq$ **M** $\leq$ 30 very low
2- 30 < **M** $\leq$ 45 low
3- 45 < **M** $\leq$ 62 Moderate
4- 62 < **M** $\leq$ 89 High
5- 89 < **M** $\leq$ 100 very high

Finally the zonation map of Germichay watershed with using Analytical Hierarchy Process (AHP) method was derived as figure 2.

Conclusions

For evaluating the AHP method in landslides hazard zonation of Germichay watershed, has been used from results of zoned map crossing with landslides distribution map. This work has been done by GIS software, Idrisi, crosstab menu. The results have been brought as a table, that shows the area and landslides area percentage in each zoned classes (Table 4).

Table 4: Specifications of the area and landslides area percentage in zoned classes.

Susceptibility class	Area (pixel)	Landslides area percent
1	98059	0
2	160779	0.11
3	149862	2.72
4	36126	9.51
5	580	59.83

Table 4 shows that AHP method is suitable in landslides hazard zonation of Germichay watershed from susceptibility to landslide point of view. Because it shows, that with increasing classes susceptibility, the landslide area percentage has been increased too, and their relations are logical.

One of the AHP method preferences, it is that in this method, the weighting of selected parameters is done very logical and the parameters could be arranged with their priorities. Also valuing of classes is very easy, that could repeat its stages several times until to give a better result. Therefore in this case, the derived model will be better for the reason of existence of more parameter [2]. The other preference of AHP method is the simple doing of it with GIS techniques, that in this method, the generalization of final model in homogeny units is done very easy.

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