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# Zoning The Risk of Landslide Using Entropy method Regions Under Study: Eastern Basin of Manjil Reservoir

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**Abstract**

Zoning the landslide risk as one of the natural dangers causing many damages annually is important. The region under study was evaluated by actors such as height, slope, its direction, precipitation, and distance to fault, distance from river and distance from the road using ENTROPY method. Results of this study indicated that 35%, 41% and 24% of the region under study are in the low risk, medium risk, and high-risk zones respectively and among 174 landslides occurred in the region of study, 36, 65 and 73 landslides occurred in the low risk, medium risk and high-risk zones respectively. . Also studying the factors influencing on a landslide in the region of the study indicates the higher relative importance of factors such as distance from road, slope and direction of slope comparing to factors such as height and distance from fault that has the lowest importance in a landslide.

**Keywords: Landslide , Entropy, LSM, Natural Hazzard**

## 1. INTRODUCTION

Iran is accounted as a high-risk country such that 38 risks out of 43 natural risks and to some extent by interference of man, have been detected and recorded and due to its abundance, repetition and intensive occurrence of natural disasters and environmental turbulences, it has been considered among 10 natural disaster- prone countries in the world [1].

The term ‘landslide’ includes a wide variety of slope movements, such as soil slips, deep-seated slides, mud flows, debris flows, rock falls, etc [2], [3], [4], [5]. Studying the landslide as a mass movement resulting in the displacement of surface materials of hillsides followed by many life and property damages is particularly important in landslide-prone areas [6]. Detecting and classifying the regions susceptible to landslide and its risk zoning is counted as main step for evaluating the environmental risks [7]. Landslide zoning includes dividing the earth into separate regions and ranking these regions based on the actual risk potential form emergence of a landslide on the slopes [8]. In addition, preparing the landslide map is considered as a fundamental tool for crisis management activities in the mountains [9].

In terms of zoning modelling, a fuzzy comprehensive method, and an analytic hierarchy process (AHP) have been used [10]. One more research has laid on three statistical models and a machine learning model for landslide susceptibility mapping in Wanzhou County, China [11]. In this research, the Entropy method employed for zoning the risk of landslide. Entropy is a measurement of the disorder, instability, imbalance, and uncertainty of a system. The quantity of entropy of a system has a one-to-one relationship with the degree of disorder; this relationship, called the Boltzmann principle, has been used to describe the thermodynamic status of a system [12]. Due to the proven efficiency of GIS in analysis and management of natural hazards, the coherence of GIS and entropy method seems beneficial. Six GIS-based methods such as frequency ratio, index of entropy and support vector machine with four different kernel functions were used to produce landslide susceptibility maps [13].

Conducting research relating to the field of landslides and its zoning management, it can be summarized on two general fronts: Model-based as explained earlier and area-based as will be depicted later. Both have been applied in one of the most significant vulnerable areas of Iran. There are some studies that have been done so far in Iran in the field of landslide zoning. One of them is the statistical model used in the follow-up of the Earth's thrust risk which quantified based on the quantified weight values in two sub-districts around Haraz [14]. The combination of GIS and Fuzzy Rule Base Inference System (FRBIS) was used to predict landslides in a part of Mazandaran province of Iran [15]. This research has been studied in one of the most important vulnerable regions of Iran.

## 2. DATA AND METHODOLOGY

### 2.1. Region

The study region is the northern boundary of Alborz and Qazvin provinces as well as extreme south of Mazandaran and Gilan provinces in Iran. The zone as the eastern basin of Manjil reservoir is in the height of 1896m upper than sea level. Minimum height of the that is 702m and its maximum height is 4289m. The total slope of the region is in ES- WN direction, for this reason by distancing from ES of the region towards WN, the heights will be reduced. The number of landslides is also increased by the movement towards WN. Figure (1) indicates the topographical and hydrographical properties of the basin together with landslides emerged.

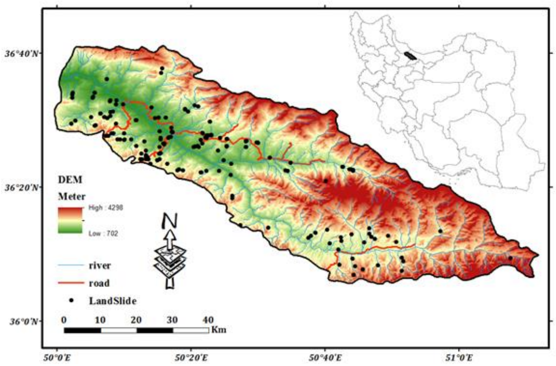


**Figure 1. Studied region**

### 2.2. Methodology

The methodology of this study was of the type of library, descriptive, analytic, field visits and modelling. Initially, by using aerial photographs and visual interpretation of satellite images, the landslides in the region of the study were detected (figure 1). Field visits were conducted in two parts to control the informational layers with surface data. More, by studying the landslides emerged in the region, seven factors including precipitation, distance from the river, distance from the road, distance from the fault, height, slope, and its direction were determined as factors influencing on the occurrence of the landslide.

Informational layers, slope, the direction of slope and height were extracted from regional DEM; informational layer for distance from fault was extracted from geographical map of the region. Informational layer for distance from the road was also digitalized by using the topographical map of the region. Precipitation data were collected from Forests Organization. After digitization, related layers entered in ArcGIS10.0 software. Then, by turning the vector layers to raster layers, the process of quantification of layers was conducted. Finally, according to the properties taken from landslides occurred in the region, the influence of layers on landslide occurrence was being investigated.

The main tools of this study included topographical maps, 1:50000, aerial photographs 1:55000, geographical map 1:100000; topographical maps 1:250000 and the latest IRS Landsat images. ArcGIS 10.0 was used for data analysis, visual interpretation and preparing the maps and images.

### 2.3. ENTROPY Model

On information theory, entropy is accounted as a qualitative degree of a chaotic system and is able to predict the development of the system entropy is the main concept in physical, social and information theory sciences such that it indicates the existing uncertainty from the expected informational content from a message; on the other hand, entropy in information theory is a measure for uncertainty values expressed by a discrete probability distribution (Pi) such that such uncertainty, in broad distribution, is more than when distribution frequency is sharper (Shannon) [10], [16] . Such uncertainty is described as below:

$$E_j = -(\ln m)^{-1} \sum_{i=1}^{m} P_{i,j} \ln P_{i,j} \, , \; P_{i,j} = r_{i,j} \Big/ \sum_{i=1}^{m} r_{i,j} \tag{1}$$

Here the parameter $r_{ij}$ is entropy matrix. After formation of decision matrix and obtaining the value of $E_j$, the amount of $V_j$ is obtained by:

$$V_j = 1 - E_j \tag{2}$$

And, for weights, $W_j$, from existing indices are:

$$W_j = V_j \Big/ \sum_{i=1}^{m} V_j \tag{3}$$

The decision maker should have a subjective judgment ($\lambda$) as a relative importance for each factor, then final weight ($W\lambda$) is given by:

$$W\lambda = \lambda W_j \Big/ \sum_{i=1}^{m} \lambda W_j \tag{4}$$

## 3. IMPLEMENTATION AND DISCUSSION

According to previous studies, effective factors and estimating the interference of each factor in the emergence of the landslide was detected. In this case, quantitative data (direction of landslide) were initially turned into quantitative data (table (1)) and then the effect of each layer on landslide was determined. Then, informational layers effective in the landslide were used as main data for the formation of ENTROPY matrix.

**Table 1- Value of each direction of slope in landslide emergence**

| Slope Direction | value for emergence |
|---|---|
| North | 8 |
| East | 6 |
| South | 4 |
| West | 5 |

### 3.1. Data Standardization

Because data used have different scales (mm, m, degree); for comparing and studying them, it is necessary to standardize the data. For this reason, based on positive or negative effect of data, following method was used. Positive effect means that by increased value of data they have maximum effect on landslide emergence (precipitation, height, slope, and quantitative value of slope direction) and negative effect indicates increased effect for landslide emergence by reducing the numerical value of related layer (distance from fault, distance from road and distance from river, by approaching to the road, rive and fault, landslide emergence will be increased).

### 3.2. Implementing the ENTROPY Model

In information theory, entropy is the quantitative measure of system disorder, instability, imbalance, and uncertainty and can forecast development trend of the specified system so in this study and after standardization of data based on the equations mentioned earlier, informational layers effective in landslides were turned to raster.

After preparing the informational layers, ENTROPY matrix obtained based on the spatial position of each landslide based on effective layers for its emergence.

## 4. NUMERICAL RESULTS

By formation of entropy matrix ($r_{ij}$) and turning the qualitative to quantitative values- in this study, the bipolar scale was used for turning the qualitative to quantitative values- informational content present in the matrix initially obtained by ($P_{ij}$) and for each factor, height, the direction of slope, distance from the fault, distance from the road, distance from river and precipitation, the value of informational content for each model factor is illustrated in table (2).

**Table 2- Informational content for each model factor**

| Item | DEM | Aspect | Slope | fault | road | river | Rain |
|---|---|---|---|---|---|---|---|
| **Ej** | 0.962 | 0.972 | 0.976 | 0.987 | 0.972 | 0.983 | 0.979 |
| **dj** | 0.038 | 0.028 | 0.024 | 0.013 | 0.028 | 0.017 | 0.021 |
| **$W_j$** | 0.226 | 0.164 | 0.143 | 0.079 | 0.164 | 0.100 | 0.123 |
| **λ** | 3 | 6 | 9 | 6 | 8 | 8 | 7 |
| **Wλ** | 0.105 | 0.154 | 0.200 | 0.074 | 0.205 | 0.124 | 0.134 |

All in all, final regional model for risk of landslide in the region is given as below:

$$H = 0.105D + 0.154A + 0.200S + 0.074Df + 0.205Dro + 0.124Dri + 0.134R \quad (5)$$

Where; *D* is the digitalized model for height; *A* is the direction of slope; *S* is slope; *Df* is distance from fault; *Dri* is distance from road and *R* is precipitation or raining.

Results from entropy model in the region under study is given in figure (2) and table (3).

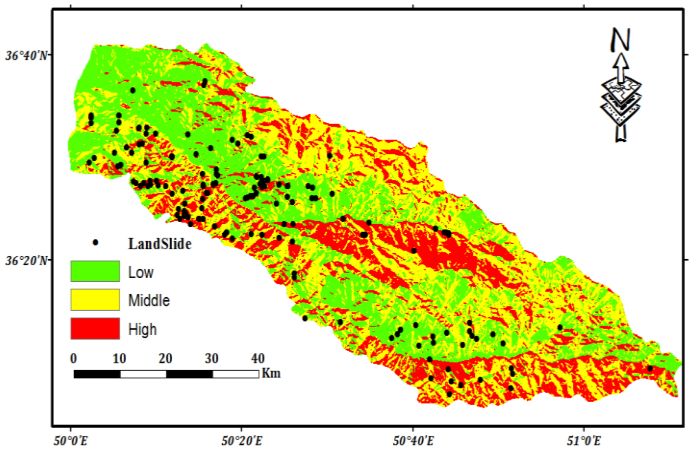


**Figure 2. Zoning the landslide risk using entropy model**

**Table 3- Evaluation of Zoning the landslide risk by entropy model.**

| | Area (Ha) | Area % | No. of landslide | Landslide % | Density $Km^2$ |
|---|---|---|---|---|---|
| Low | 110593 | 35 | 36 | 21 | 0.032 |
| Middle | 126158 | 41 | 65 | 37 | 0.051 |
| High | 75761 | 24 | 73 | 42 | 0.096 |
| sum | 312512 | 100 | 174 | 100 | |

Table (3) indicates the results of zoning of landslide risk in the eastern basin of Manjil reservoir. Studied region divided into three zones, low risk, medium risk and high risk including 35%,41% and 24% total area of the region respectively. And among 174 landslides occurred in the region of study, 36, 65 and 73 landslides occurred in the low risk, medium risk and high-risk zones respectively including 21%, 37% and 42% total landslides emerged in the region respectively.

The density of landslides indicating the number of landslides emerged in the area unit, can indicate the accuracy of this method, i.e. high-risk zone must have a higher density than low-risk zone and vice versa. The density of landslides as shown in table (4) indicates the maximum density of the high-risk zone than the low-risk zone.

**Table 4- Density of landslides in the area (number/km$^2$)**

| | Area (Ha) | No. of landslides | Density Km$^2$ |
|---|---|---|---|
| Low | 110593 | 36 | 0.032 |
| Middle | 126158 | 65 | 0.051 |
| High | 75761 | 73 | 0.096 |
| sum | 312512 | 174 | |

## 5. CONCLUSION

Zoning the landslide in the eastern basin of Manjil reservoir was conducted by using the entropy model. In this case, factors such as digitization model of height, slope, the direction of slope, distance from the fault, distance from the road, distance from river and precipitation were used as effective factors in landslide emergence. Results of this study indicate the higher effect of factor such as distance from the road on landslide emergence as well as the distance from fault that has the lowest effect on landslide emergence.

As a result, the factors including distance from the road, the direction of slope, precipitation, distance from the river, digitized height and distance from fault have these relative values respectively: 0.205, 0.201, 0.154, 0.135, 0.125, 0.106 and 0.074. Distance from the road has the most significant role among other factors in landslide emergence in our study area. This is probably due to making the foothills unstable by excavations that by increased distance from roads, the number of landslides will be reduced.

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