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The combination of spectral and spatial data in zoning of landslide susceptibility (Case study: Sangorchay reservoir)

Mohmmad Hoessin Fathi*, Kazem Khohdel[1], Amir Shoreh Kandi[1], Zahra Ashrafifeini[1], Mohammad Ali Khaliji[2]

Geomorphology, Department of Geography, Mohaghegh Ardabili University, Ardabil, Iran

[1]Geomorphology, Department of Geography, Tabriz University, Tabriz, Iran

[2]Department of Urbanism, Young Researchers and Elite club, Bonab Branch, Islamic Azad University, Bonab, Iran

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Abstract

Maps of landslide susceptibility is one of the most important necessary tools for the environmental programmers and people who make decisions especially in mountainous areas. The main goal of this research is to evaluate and use the data and methods of far-distance evaluation such as satellite images and also to use Multiple Criteria Decision Making models in Zoning of landslide susceptibility. (ANP) Analytic Network process is among the models of preparing map of landslide susceptibility this model has kept the capabilities and advantages of AHP model and has fulfilled the related problems and therefore in recent years it has been used more than AHP and has actually replaced it. In this research, we have zoned the landslide susceptibility in Sangor Chay. For this research, we have used 17 natural and human parameters (rainfall, distance to fault, distance to river, drainage density, slope degree and direction, land usage, vegetation coverage and etc.) Choice, decision and ENVI are among the tools that are used for pair comparisons, providing data and performing the model. Evaluation results show that 76 percent of landslides that have been occurred in the region, belong to “dangerous” and “extremely dangerous” classes. According to this, Data and parameters resulted from far-distance models and also multiple criteria Decision making models, are likely to be suitable for forecasting the landslide susceptibility.

***Corresponding Author:** Mohmmad Hoessin Fathi ✉ Geo.fathi@gmail.com

Introduction

"Land slide" is one of the most serious dangers for the environment in the world and leads to lots of financial and physical injures to people of societies. These negative effects not only affect human but also affect the natural environment around us. Landslide is one of the geomorphological processes that are effective on developing the landscape of mountainous areas and is a special kind of landside process that results from local geomorphological hydrologic and geological conditions. According to the reports of the globalorganization of natural dangers in 2012, landslide was among the seven most dangerous natural disasters. In Iran also although it is very likely to have this natural disaster according to the climate and topographic conditions, most populated and agricultural areas are exposed to this danger. According to the primary estimations, in Iran there is about 500 billionRial financial damage every year because of the landslide. These landslides are really complicated and there are various factors effective in their occurrence. Therefore, it is also too difficult to forecast them. Having danger and land susceptibility maps is really necessary to determine the potential of areas in terms of land slide damages and increasing their social and economic damages. The maps of land susceptibility are based on the area of earth, they form the slope speed, type of the soil and stone, the structure of hydrological conditions and other effective parameters.

Sangor chay catchment (northwest Iran) is, for geological, geomorphological, climatic and seismic reasons, one of the most landslide prone areas of the Khazar sea basin regions, which is characterized by landslides of different types, in which mechanisms of evolution and processes of erosion are intensity selective. In some areas of Sangor chay catchment, the landslides are so intense and widespread that they sometimes genera In this area, Some of the responsible factors for loss of life, infrastructures breakdowns and associated financial losses were stone falls, landslides and mudslides. The urgent priority after a landslide catastrophe is to perform relief and rescue procedures that are usually affected by lack of appropriate details about the location, size and the quantity of landslides in mountainous regions which are highly inaccessible. The serious damage to people and properties. Hence, rapid detection of landslides is indispensable for quick damage estimation and emergency reactions for the management activities of a catastrophe. Hence, current research aims to perform landslides detection for the part of the Sangor chay by using multi criteria decision making (MCDM) & fuzzy logic method.

The truth of these maps depends on the number and quality of data, and choosing a suitable research method for analyzing modeling. The first stage of management and decrease of danger is evaluating the danger. Evaluating the danger of landslide can estimate the possibility of landslide occurrence in a location. (Wen western and *et al.*, 168: 2006). The investigations reveal that in the early 1378, there were about 2590 landslides in the country that led to 162 deaths, 176 houses were destroyed and the country faced 1866 billion Rials loss, 6763 hectare of jungles and 170 kilometer of ways were destroyed. In recent years, there have been lots of studies done on landslides. 1990s was called "Decade of Confronting Natural Disasters". Because of this decade, different research centers and universities, did some activities related to "knowing landslides as one of the natural disasters. There are some factors that have increased the condition for landslides to happen in Iran including Iran mountainous topography, geological actives, climate variety, geology, population increase, pressure on natural resources and changes in use. There are different approaches developed for studying landslides. We can divide them to four groups: analyzing the landslides, discovery method or index, statistical approach and geotechnical method. A lot of geologists and geomorphologies and engineers have worked in this field: Biza and kromin (2001), Li and Mine (2001), Ai Alo and Yamagtishi (2005), Nafisoghlu and *et al.* (2008), Das & *et al.* (2010), Soozan and Kia (2012), Pradan (2013), have used different methods like Logistic regression,

hierarchical analysis process (AHP), Network analysis process (ANP) Artificial neural network (ANN), different models of bi-variant Statistics, LNRF model, fuzzy logic model, to zone and analyze landslide susceptibility in places exposed to natural phenomenon. For instance, Meto and *et al.* (2007) used Biz theory to zone landslide susceptibility in some parts of India. In this research, we have used 15 natural and human factors for zoning. Evaluating the final map reveals that the accuracy of the prepared map is %6184 and acceptable. Piasentinia and *et al.* (2012) used Biz theory model to zone landslide susceptibility for the south of Tirol in Italy. The results of the research indicated that the map of landslide susceptibility is reliable for forecasting landslides with high percentage (75%).

In Iran also different activities have been done by geologists in this field. For example, Hosseinzadeh and *et al.* (2008) used Logistic regression to zone the path of Sanandaj – Dehaghan based on the potential of landslide occurrence and classified them in 5 final classes. The results of the research indicated that this model is proper in evaluating landslide potentials. Ebadinejad and *et al.* (2005) evaluated Shirood watershed by fuzzy logic model and its Gama operator in order to zone the potential landslide. The results of the research indicated that the Gama operator 810 has the best result in zoning landslides. Feiznia and *et al.* (2004) used four models, for landslide zoning of Shirinrood watershed. The results of the research revealed that Data Value Mode showed better results than three models of AHP, Surface Density and overlapping index. Niazi and *et al.* Zoned Ilam dam basin by bi – variant statistical model. The results revealed that surface density, variant weights, and data value were the most accurate in dividing the classes of landslide danger. Gharahi and *et al.* (2011) did the landslide of Alborzreservoir by means of bi – variant statistical model and AHP. The results indicated that the method of Statistical Index has a more real image from the landslide Susceptibility compared to the method of weighting factors. Abedini (2012) zoned the landslide danger in kivichay basin by hierarchical analysis of AHP and finally after weight combination of 9 effective factors, all basins were classified to four parts of “extremely dangerous”, “dangerous”, “quite dangerous” and “not very dangerous” in which the factors of “slope” and “Litology” were the most effective in landslide occurrence. Moghimi and *et al.* (2013) used Network Analysis Processes and Subcriteria that were classified into two clusters to model and zone landslide susceptibility for Roodbar. The result of the research was a map of landslide susceptibility that was classified to five danger classes. Nazm far and *et al.* (2013) used a combination model of Network Analysis Process and fuzzy logic (ANP-Fuzzy) in Ghoorichay catchment, to zone the regions in danger of landslides.

In order to provide maps of landslide susceptibility danger that shows a real and current situation of a region, we need accurate data and numerous parameters like investigating and evaluating landslides that have occurred in a region and register them in a base as the present landslides. Geological and geomorphological parameters (including height line maps, slope, direction, plan and profile curve, Sunshine, lithology and vegetation coverage, land usage and etc.) Although it’s not always possible to collect the data according to the time and cost restrictions, this problem has been solved since we used far-distance evaluation and satellite data and we can use up to date data in vast scale and even in places that don’t have local access. Among the data we can use in this field are Landsat and Tera satellite data whose images are in 7 bands related to ETM Landsat satellite and 14 bands related to star of Tera satellite. Since there are different bands in the length of different waves in these satellites, they are really useful and effective in finding landslide efficient parameters in phenomenon. Finding numerous indexes from satellite images such as SAVI, NDWI, NDVS, Quarts and kani indexes and also finding DEM from star satellite images with locative power of 15 meter, show the efficiency of far-distance evaluation is landslide studies. This research tries to combine

spatial data of Geographical Information System and spectral data resulted from spectral evaluation of different bands of Landsat and Terasatellite (ETM & different bands of Landsat and Terasatellites (ETM & Aster), and also find independent data from these and use AHP and ANP fuzzy logic model to provide maps of landslide susceptibility in Sangor Chay watershed in khalkhal town. some of the effective parameters for providing these kinds of maps are: a layer of digital earth height model and the quality of lithological classes. Digital elevation model (DEM) has a better and more useful efficiency among these environmental parameters and like geological data and land coverage; it can make and offer other effective data and parameters in zoning landslides. Also data that are related to the type of lithology are one of the most important sensitive elements in providing a map of landslide susceptibility that are separately in geological maps. In this research, it is tried that besides lithological and geologic maps, they provide some sensitive lithological layers such as clay and calcium oxide by satellite images. Sangor Chay river is one of the branches of Ghezel azan river that from the khalkal it reaches Baghrodogh mountain sides and starts from khoreshrostam part in the east of majdarullbge and joins Arpachay river in the south of Firoozabad geographically. Sangor Chay catchment is located in 48 degree and 3 minutes to 48 degree and 37 minutes of eastern length and 37 degrees and 28 minutes to 38 degrees and 56 minutes of northern width, the average height of the region is 1633 meter above the sea level. This region was chosen to be researched because of its villages and the population centers in watershed of this river such as khalfaloo, ganjgah and Firoozabad and also some villages of this part in the riverside and also the numerous Landslides in this region (Fig. 1). The purpose of this study is combination of spectral and spatial data in zoning of landslide susceptibility (Case study: Sangorchay reservoir) and resulted from far-distance models and also multiple criteria Decision making models, are likely to be suitable for forecasting the landslide susceptibility.

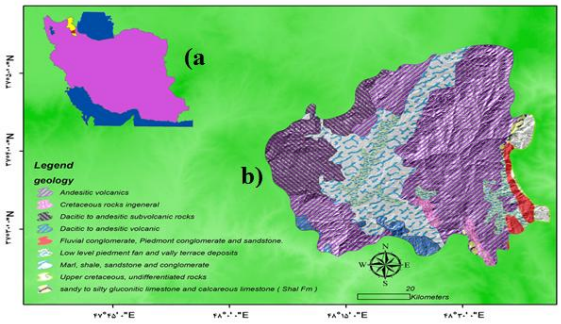

Fig. 1. a) Location of the study area, b) geology map of study area.

Materials and methods

In this research, we have used 17 natural and human parameters (petrology, rainfall, and distance to fault, distance to river, drainage density, slope degree and direction, land usage, vegetation density (SAVI, NDVI) in order to perform the model and zone the landslide susceptibility. In order to provide the data from geological maps 1:100000, we have used the statistics of weather stations of the region for providing rain fall layer, The image of ETM sensor of Landsat satellite for providing vegetation index (NDVI) and land usage. For finding DEM Layer we have used the images of star satellite. The layer of DEM was also used to provide slope layer, side direction, channel network and drainage network density and etc. Also band of star data was used to find lithological data and mineral indexes like clay, Calcium oxide and other minerals as shown in table 1. Preparing and providing data was done in two software's of Arc Map and ENVI.

Table 1. Mineral indexes were identified according to their spectral range of ASTER images.

Source	Formula	Unspecified
Thomas and Rabynstyn, 2007	B4/B5	Alunite
Vandrmr *et al.* ., 2012	B7/B5	Kaolinite
Rounou March 2003	(B7+B9)/B8	Lime
Ninomiya, 2002	(B11)2/(B12*B10)	Quartz

Mineral indexes were identified according to their spectral range of ASTER images. For creating Caolinic, Alonit and oxide indexes, we used short

waves of 8 bites and thermal bands of 12 bits were also used to find Quartz index in the research. The first step of using these indexes in for primary evaluation and identification of the minerals present in the studied region. It's obvious that in order to use and find the data and layers we should interpreted and analyze the results that have been received from star images. Then bands made by attracting considered minerals in terms of pixel transmittal according to their brightness, darkness and grayness should be selected and the considered data should be identified. Besides finding lithological data, normalized vegetation indexes and recognizing the vegetation surface by (NDVI, SAVI) indexes are some of the other spectral characteristics of satellite images for identifying vegetation situation of the studied region. The number of this index is between +1 and -1 and shows the vegetation situation from dense to very thin.

Results and discussions

Effective parameters in landslide occurrence

Geology

One of the most important effective parameters in landslide occurrence is "petrology" factor. Different petrologic units have different susceptibility degree in causing landslide. Having sensitive and weak formation like marl and deep materials, increases the possibility of landslide occurrence in a special region. Petrologic layer of the studied region has been provided by geological maps 1: 100000 of Ardebil, Sarab, Meshkinshahr and Givi. Most Northern, western and southwestern part of basin are covered with various ligneous stones. However central and southern part of the basin are mostly made of sedimentary materials of rivers and sedimentary stones like sandstone, kanglomeras, marl, calcium oxide and clay. The layer of the fault is used like a distance to faults. Faults damage the stones in their place and their movement increases the landslide of the region and when the distance increases, its effect decreases.

Topography

Topography is one of the important factors that is effective in creating and increasing landslides. In topography, earth has three layers of height, direction and slope. The earth height can control the phenomenon of landslide by controlling the type of erosion, focusing the human activities in low and mid heights, focusing sedimentary in lower parts and hard formations in high areas. The height of the studied region is between 1350 to 4760 meters. According to the "slope", we can say that those ranges that have more slopes in the same condition, are more ready for landslides. Since having more slope causes an increase in the relative volume and weight of the slide mass on the level of slide surface. Of-course, we should pay attention that having more slope to some extent fads to land slide and then because of a decrease in the volume of materials in extreme slopes and a change in the type of movements, landslides will decrease. The slope of the studied region is between 0 to 72 degrees. Most of the region has slopes from 0 to 5 degrees (45% OR the region). The slope direction is another effective parameter in landslides since it can affect them by controlling factors like rainfall, humidity, vegetation density and sunshine.

Hydrology

In this part, two layers of drainage network, density and distance to the main river have been used. Drainage density is actually ratio of the length of channel to the area of basin that when the density of a region increases, its permeability will decrease and the speed of surface flows will increase.

Channels also have affected the Consistency of sides by erosion and saturating lower parts of the sides. According to this issue, the landslide potential will decrease when the distance to channel increases.

Land Cover and usage

Land Cover and usage controls the surface and water flows, and stimulates the ranges and etc to increase or decrease landslides in a particular region. Civil activities that are done in roads by stimulating the ranges and empting the lower part of the ranges, will increase the landslides in a particular location. This layer has been used with a distance to road. The more

the distance is, the less the landslide susceptibility will be. Land use and vegetation density (NDVI index) are other used layers in this part. NDVI index is received by 3 and 4 bands of Landsat satellite images. Land use layer was also provided by means of Landsat satellite images and observed classified method in ENVI software.

SPI- the index of channel power

Murr and *et al.* (1986) offered (3) equation in order to calculate the river power index (SPI). In this equation, measuring the power of water flow erosion was assumed to perform emptying based on the basin area. In general, This model predicts the pure erosion in regions whose profile is convex-tangential and in this region the flow speed is really high and has convex status on the other hand, pure sedimentation is mostly done in places that have concave profile and in this region the flow speed decreases.

STI - sedimentation Transfer Index

One of the hydrological indexes used in this study is sedimentation Transfer Index. This index reveals the power of erosion of flows on the earth. Experimental formula (relation 1) that exists for getting this index, is like the global equation of soil erosion so it can be used to show the situation of regions in danger of erosion.

This parameter controls the capability of sediments transport based on the area of the basin (As) and grodionsinos. Therefore, it may disturbed the drainage system and ranges with low slope gradient may be attracted to cause landslides (Nafis Oghlu 100 and *et. al* 2008). Image12, shows the map related to this layer.

(TWI): Topographic wet Index

Topographic wet index (Combination Topographic Index (CTI) or soil humidity) that are used to describe the spatial pattern of soil humidity (Wilson and Glant, 2000) is defined as follows: This index is used to study the Landslide susceptibility (Grom and *et al.* 2008) we can use the topographic wetness index to evaluate the spatial pattern of soil wetness and the changes happened in the texture of soil because of erosion (Eshmit and proson, 2003: Grab and *et al.,* 2007) This index is generally used for determining topographic control on hydrologic processes (sorenz and *et al.,* 2006) and high amounts of TWI is usually found in landslide body.

(NDVI) normalized difference vegetation index

This is really suitable for showing vital mass (biomass), vegetation coverage, leaf area index, and vegetation production and vegetation coverage separation. Also we use this index for issues related to vegetation coverage. During time, the observed changes in NDVI shows the type of vegetation, phonology and environmental status. This index is mostly related to the live volume of plants among the vegetation characteristics. This index derives from the following relation:

As the vegetation coverage increases, the value of this ratio will increase. Among the capabilities of this index, we can point to a decrease in atmosphere effects, topography and also correcting sunshine changes. However, it does not remove the interference of plant and soil in infrared ray. On the other hand, as the difference of the reflection of vegetation coverage in these two bands is more than the difference of the reflection of soil in them, soil is less affected by this process than the vegetation coverage.

SAVI (soil adjusted vegetation index)

In dry and semi dry regions, thin vegetation coverage causes that the effects of the reflection of soil affect the effects of the reflection of vegetation. SAVI is the corrected index of NDVI. This index decreases the effects of soil and its wetness in NDVI index. L is correctness factor and equals 0 for high coverage, equals 1 for very low coverage and 0.5 for average coverage.

The method

In the science of making decision in which we have to choose a single strategy among the present ones or prioritize them and offer the best strategies, there are a few years that decios making methods have opened

their ways by different indexes. (Fathi, 19, 1389). Among these methods, we can mention the Hierarchical Analytic process and Network Analysis and fuzzy Logic and also combining this model with other effective methods for reaching optimal and effective results. In this research, we have used the Hierarchical Analytic process and Network Analysis and fuzzy Logic to perform the map of landslide susceptibility for Sangor Chay river basin.

AHP (Hierarchical Analytic Process)

This model starts its work by identifying the elements and making decision and prioritizing them. Changing the studied issue to a hierarchical structure is considered the most important part of the Hierarchical Analytic Process. Because in this part by analyzing complicated and difficult issues, it changes them into a very simple one adapted with the mind and nature of human. In the process of locating, evaluation starts after identifying the general goals and specifying different alternatives for reaching a proper location so that we can choose the best alternative based on their deserves. In order to evaluate the deserves of each alternative, we usually use the criteria in a way that we evaluate the validity of each place based on the criteria. In this research, also firstly, we identified the effective factors in finding martial centers and then we found the places by prioritizing and weighting.

Scoring the factors

The general score of each factor is calculated by multiplication of answers to each rate from the evaluation table (table no.1) and their addition. And to get the final score, the general score should be divided by the number of all expert ideas.

Table 2. Comparison of quantitative binary for Thomas L. Saaty, 1980.

Definition	Highly important
Equal importance	1
Equal importance to moderate importance	2
Moderate importance	3
The importance of moderate to Importance strong	4
Importance strong	5
Importance strong to Importance very strong	6
Importance very strong	7
Importance very strong to Extremely Importance Very Strong	8
Extremely Importance Very Strong	9

ANP (Analytic Network Process)

This process was introduced by Saati in 1980. The main hypothesis is the method of having independent sub-criteria. Saati introduces this method when this principle is violated and the structure of the problem is network. Analytic Network Process is the public form of AHP. Therefore, it has all its positive features like simplicity, flexibility, using qualitative and quantitative criteria simultaneously and can investigate the adaptability in judgments and also it can consider complicated relations (mutual dependence and feedback) between decision elements by using network structure instead of hierarchical one. Network Analysis Process considers every issue in the form of a network of criteria, sub-criteria and alternatives that are all collected in some clusters. All of the elements of a network can be related to each other in any form. In other words, it is possible in a feedback network and a mutual relation between the clusters. Therefore, ANP consists of two parts: a controlling hierarchy and network relation. The controlling hierarchy involves the relationship between aims, criteria and sub-criteria and affects the internal relation of the system. While network relation involves the dependence between the elements and clusters. Image 2 indicates the difference between a network and hierarchy structure.

Structural difference between ANP and AHP

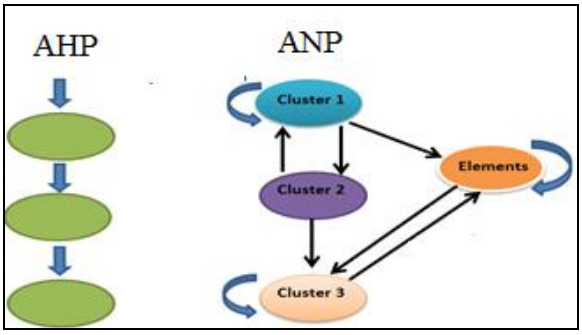

Fig. 2. The structural differences between a) ANP & b) AHP (Reference: Nazmfar *et al.*, 2013).

The process of network analysis can be written in the following steps briefly:

Constructing the model and creating a network structure

In the first step of the model, according to the goal of the research, the considered problem changes into a network. In this network, we can determine the relationship between the elements of the clusters (external dependence), the relationship between the elements (internal dependence). In the image1, we can see the relationship between the clusters and elements related to landslides in a simple model.

Pair comparisons and determining prioritizing vectors

Like what is done in AHP in comparing criteria, we have the same thing in ANP. In ANP, decision elements of each cluster are compared in pairs based on their importance in relation with controlling criteria. And clusters are also compared in pairs based on the role and effect they have on getting their aim.

Forming the primary and uneven super matrix

ANP elements are correlated with each other. These elements can be the unit that makes decision, criteria, sub-criteria, results, alternatives and any other thing. The received weights enter the primary super matrix by the paired comparisons and show a mutual relationship between the elements of the system.

Forming an even super matrix

This matrix is calculated by the multiplication of the elements of uneven super matrix in a cluster matrix. Then by normalizing the even super matrix, super matrix can change to accidental status in terms of column.

Forming limit super matrix

In this stage of the model, all elements of the even super matrix are exponentiated until they are converged and have equal amounts. We can get the vector of public weight by forming the limit super matrix.

Phasing the data

In classic theory of the collections, one element is a member of a collection or not (zero or one). The theory of phase collections (offered by professor Lotfizade: 1965) develops this concept and states the graded membership. In a way that an element can be a member of a collection to some extent not completely. In other words, phase collection, is a collection of elements with similar characteristics in which the collection has a degree from zero to one. Zero means not being a member and one means a complete membership. In each collection of Phase Logic like “A” dependence of a member (X) from a reference collection is defined by membership function as relation 3.

According to the above mentioned issues in this study, in order to be able to identify the effects of different classes of criteria on zoning landslide susceptibility, we should phase the layers based on the type of their function in landslide occurrence by means of phase membership functions in the range of 1 to 0 and in some cases by formulating ARC GIS. For doing this, we have used the functions in software (10 Th version). Vikor layers (Land Use and Structure) that are used in this model have also been phased in analyzer without Raster Calculator by giving 0 to 1 codes and changing them to layer. In the rest of the paper, we can prepare the map of landslide susceptibility in the studied region according to the

excavated parameters from satellite images and the layer of numerical height layer by using quantitative models of ANP and AHP and phase methods. Used parameters can be observed in image (3).

According to the phase calculations and membership functions, we have zoned the landslide susceptibility in the studied region by each parameter in ARCGIS software based on Gama operator and also by performing weights of paired comparisons in Network and Hierarchical Analysis in Super Decision and Expert Choice software based on the experts' ideas about prioritizing the factors. The results have shown adaptability between the capabilities of the used models in evaluating the issue (Image 4).

Table 3. The final weight metrics is calculated by Expert Choice and Super Decision software.

R	Q	P	O	N	M	L	K	I	H	G	F	E	D	C	B	A	Criteria / Weight
.470	0.880	0.223	0.492	0.734	0.486	0.255	0.260	0.313	0.253	0.648	0.600	0.428	0.428	0.610	0640	0.640	AHP
0.59	0.91	0.18	0.40	0.86	0.67	0.32	0.33	0.38	0.32	0.43	0.95	0.56	0.56	0.63	0.43	0.69	ANP

Layer DEM (A), the sun angle (B), the slope (C), layers Plan curvature (D), Layer Profile curvature (E), layer slope (F), the layer STI (G), layer SPI (H), layer TWI (I), the image sensor ester (J), index, SAVI (K), index NDVI (L), quartz cover index (M), and kaolinite clay cover index (N), the layer spacing of fault lines (O), distance from drainage layer (P), precipitation layer (Q), land use layer (R).

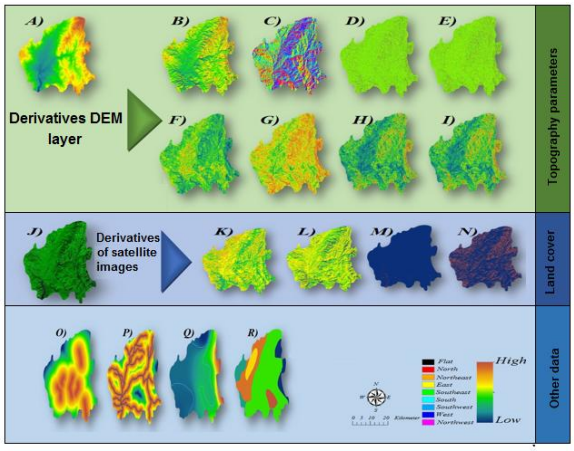

Fig. 3. Input data and parameters derived from them: Layer DEM (A), the sun angle (B), the slope (C), layers Plan curvature (D), Layer Profile curvature (E), Layer Dip (F), the layer STI (G), layer SPI (H), layer TWI (I), the image sensor ester (J), index, SAVI (K), index NDVI (L), quartz cover index (M), covering index and kaolinite clay (N), the layer spacing of fault lines (O), distance from drainage layer (P), precipitation layer (Q), land use layer (R).

The final calculated weight of criteria by Expert Choice and Super Decision: the map of Landslide susceptibility in Sangor Chay reservoir.

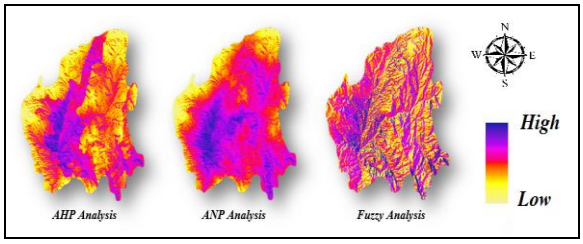

Fig. 4. Map of landslide susceptibility in the Sanghorchay catchment.

In order to evaluate the models among 65 cases of landslide occurrence in the region, we prepared the map of the model of statistical investigation. Its results have been shown in table no.4. According to this table, 76% of the landslides of this region have occurred in "very sensitive" and "extremely sensitive "classes. According to this, the above mentioned models have had a good capability in forecasting the landslides.

Table 4. Area zoning classes of landslide susceptibility and landslide occurred.

Sensitivity class	Method (AHP)	Method (ANP)	Method (FUZZY)	Area in%
Low sensitivity	13	9	11	
Moderate sensitivity	26.2	24	23	
High sensitivity	27.7	34.5	32.4	
Very high sensitivity	18.3	14.8	19.6	

Conclusion

There are different methods and models for evaluating and preparing the map of landslide susceptibility. In this research, spectral and spatial data from star and 8 Landsat satellite images have been a base for preparing and excavating the effective data and parameters in evaluating landslide occurrence in Sangor Chay reservoir. Excavating the layer of numeral height model from spectral images and providing spatial layers that are effective in zoning landslide susceptibility is one of the positive factors in using satellite images especially star images in zoning landslide occurrence. In the rest, by using quantitative models ANP, AHP and fuzzy methods we have combined the layers and provided the landslide map that according to evaluating the results of landslide occurred in the region with the final map and according to the data received among 17 considered parameters for zoning landslide susceptibility, sensitive structures of layer of lithology, slopes of 15 to 30 degrees, rainy regions and western and south western directions of slopes had the most effect in occurring the landslides and in regions in which the classes of these 4 parameters change, we can observe less landslide's and in the final map, the regions are mostly shown with “low sensitivity” and “very low sensitivity”. According to the mutual and network relations of parameters in landslide occurrence, we can say that Network Analysis Process has a high capability for doing this. Because this model can keep the present capabilities in the model of Hierarchical Analysis Process and also remove the present restrictions in the model like considering the mutual dependence between the elements and a one- way relation between them. Of course, we should consider that the expert’s knowledge and using experienced specialists in pair comparison of criteria and sub-criteria and also determining the relationship between them can increase the accuracy of this model in solving and for casting the considered problem. Also, using the combination of satellite images and multiple criteria decision making models by geologists and geographists can be an efficient tool in providing up to date maps and decrease occurring environmental disasters like landslides and their harmful effects.

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