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Fuzzy-based multiple decision method for landslide susceptibility and hazard assessment: A case study of Tabriz, Iran

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Abstract. Due to the complexity of the causes of the sliding mass instabilities, landslide susceptibility and hazard evaluation are difficult, but they can be more carefully considered and regionally evaluated by using new programming technologies to minimize the hazard. This study aims to evaluate the landslide hazard zonation in the Tabriz region, Iran. A fuzzy logic-based multi-criteria decision-making method was proposed for susceptibility analysis and preparing the hazard zonation maps implemented in MATLAB programming language and Geographic Information System (GIS) environment. In this study, five main factors have been identified as triggering including climate (i.e., precipitation, temperature), geomorphology (i.e., slope gradient, slope aspect, land cover), tectonic and seismic parameters (i.e., tectonic lineament congestion, distribution of earthquakes, the unsafe radius of main faults, seismicity), geological and hydrological conditions (i.e., drainage patterns, hydraulic gradient, groundwater table depth, weathered geo-materials), and human activities (i.e., distance to roads, distance to the municipal areas) in the study area. The results of analyses are presented as a landslide hazard map which is classified into 5 different sensitive categories (i.e., insignificant to very high potential). Then, landslide susceptibility maps were prepared for the Tabriz region, which is categorized in a high-sensitive area located in the northern parts of the area. Based on these maps, the Bozgoosh-Sahand mountainous belt, Misho-Miro Mountains and western highlands of Jolfa have been delineated as risk-able zones.

Keywords: landslide susceptibility; geohazard; multiple-decision method; geographic information system (GIS); fuzzy logic

1. Introduction

Landslide, one of the most destructive geohazard, is a complicated geological phenomenon that occurs on non-condensing sedimentary layers, soil, mud, and weathered rocks on the prone slipping surfaces in slopes. Various factors, such as geological conditions, topography, hydrological conditions, seismic activity, human activities, may lead to landslides (Ercanoglu and Gokceoglu 2004, Kanungo *et al.* 2006, Highland and Bobrowsky 2008, Yin 2011, Rhim 2011, Choi *et al.* 2012, Zheng *et al.* 2012, Liu and Chen 2015, Chen *et al.* 2016, Zhu *et al.* 2016, Kim and Jeong 2017, Chen *et al.* 2019, Du *et al.* 2020). In general, apart from the structural nature and in-situ stress field, most of the landslides that annually lead to many losses of life and property every year in the world are caused by heavy rainfall and earthquake in mountainous areas. Based on the preliminary annual estimates, about billions of US dollar financial losses are caused by landslides. Besides, accurate estimates of life and property losses are not available because of the limited information in several countries as well. The main factors that trigger the occurrence of landslides exhibit different aspects and characteristics in each region, which can be divided into regions according to high and low sliding potential and can be used as a hazard map in crisis management studies (Neuhäuser *et al.* 2012). Although several approaches such as deterministic, probabilistic, geostatistical, heuristical, inventory-based, and knowledge-based methods are used for evaluating landslide susceptibility, which is mainly divided into the quantitative and qualitative groups, a comprehensive standard has not been presented in the literature so far (Abella and Westen 2008). This has led researchers to apply approaches that employ more quantitative methods for optimal and accurate evaluation, especially computational intelligence techniques to cover more elements and reduce the number of analysis uncertainties (Azarafza and Ghazifard 2016, Azarafza *et al.* 2017a,b, 2018). In the meantime, knowledge-based approaches are also respected by scholars that use to retrieve, recognize, and improve traditional methods (Chen *et al.* 2017, Bagheri Shendi and

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Azarafza 2018). With the emerging technologies today, application knowledge-based methods such as fuzzy logic, logistic regression, neural network, neural fuzzy network, naïve Bayes, decision trees are gained more attention due to the extensive incoming data coverage and the possibility of integration with decision approaches. In particular, the analytic hierarchy process (AHP), multiple-criteria decision-making (MCDM) along with the global Geographic Information System (GIS) are successfully used for mapping and implementing spatial analysis and field data. These models have good integration with the GIS environment because of their capability (Yilmaz 2010).

The application of AHP/MCDM in landslide sustainability assessment has made significant achievements around the world. In Japan, Yoshimatsu and Abe (2006) presented the review of landslide hazards to describe the topographical related distribution of landslides by using the AHP-based MCDM method. Komac (2006), by preparing the landslide susceptibility model for Central Slovenia states that successful landslide susceptibility has the ability to identify and categorize factors affected by landslide events in relation to undesirable consequences. AHP is illustrated as a suitable path to evaluate and weighting the triggering factors. This method was also used by Yalcin (2008) for bivariate statistical indexes and weighting factor methods to landslide susceptibility and hazard mapping for Ardesen in Turkey. In their study, Yalcin (2008) presented the triggering factors, which can be classified and statistically expanded, help to reduce errors in the analysis. Lithology, weathering effect, topographical conditions, land cover, hydrology, and human activities have been considered as landslide triggering factors. Ercanoglu *et al.* (2008) utilized a combinatorial method with AHP as an expert opinion system and an artificial neural network to evaluate landslide susceptibility in the west of the Black Sea region of Turkey. Khezri (2011) used AHP, MCDM, and GIS to suitable modeling of landslide occurrence hazards in the Zab Basin, northwest of Iran. The researcher states that the topographical aspects, land use, geological aspects, and human activities were the main triggering factors in landslide susceptibility assessment. Hasekioğulları and Ercanoglu (2012) applied a new approach based on AHP and inventory-based methods to evaluate the risk-ability of landslide events for Yenice, Karabuk, Turkey. To this end, 13 parameters were considered as triggering factors that were categorized in topographical, geological and hydrological aspects. Pourghasemi *et al.* (2012) used the fuzzy logic, AHP, and MCDM to produce landslide susceptibility maps of a landslide-prone area in the Haraz watershed of Iran. Kayastha *et al.* (2013) mentioned AHP and MCDM, an appropriate method to evaluate landslide susceptibility in Tinau watershed, west Nepal, and identified the triggering factors which are used to classify the topography, geology, land-use, and hydrology. Roodposhti *et al.* (2013) employed the MCDM based preference ranking organization method for enrichment (PROMETHEE II) in combination with fuzzy-based AHP methods to assess the landslide susceptibility mapping in Minoo Dasht, Gorgan, Iran. Chen *et al.* (2016) used AHP and certainty factor (CF) models to prepare GIS-based landslide susceptibility mapping in the Baozhong region of Baoji city in China. Lorentz *et al.* (2016) applied MCDM based analytical GIS toolkits for landslide susceptibility mapping of the mountainous region in Rio de Janeiro state, Brazil. The researchers have tried to establish a relationship between disorganized urbanization and the preparation of landslide triggering conditions. Vakhshoori and Zare (2016) mentioned the application of fuzzy logic, frequency ratio, and comparing weight evidence with AHP present more suitable results for landslide susceptibility assessment. Zhao *et al.* (2017) presented a comparative study for GIS-based fuzzy-AHP models for landslide susceptibility mapping which stated the considerable success in this regard. Azarafza *et al.* (2018) utilized a combinatorial method which containing multi-criteria decision-making, likelihood ratio, and fuzzy logic for preparing landslide susceptibility mapping in the South Pars Special Zone, and stated that the fuzzy-based models are more capable of assessing risk-ability regions. Mokarram and Zarei (2018) utilized Fuzzy-AHP satisfactorily in the hazard analyses to evaluate the landslide susceptibility in the north of Khorramabad, Iran. Abay *et al.* (2019) applied a fuzzy-based AHP model to analyze landslide sensitivity in the Tarmaber District of Ethiopia and stated that fuzzy logic is an appropriate method to combine application and increased accuracy in evaluations.

In this study, a fuzzy logic-based AHP-MCDM coupled method is used for landslide susceptibility assessment. As it is known, in the regular decision-making process based on AHP / MCDM, crisp values and sets are used to reordering the values in the decision matrices. However, instead of crisp sets, the fuzzy clusters used in the application help to include uncertainties and intuitive changes in decision matrices that increase the accuracy of the evaluation. On the other hand, the MCDM system can take into account various ambiguity components for the definition of triggering conditional criteria for sliding. Thus, the application of coupled methodology can provide more accurate results than standard assessment. The identified triggering factors controlled by heuristic and inventory-based approaches are used as the main factors in sustainability assessment as an input data set in a GIS environment.

2. Materials and methods

2.1 Geological setting

Tabriz is one of the most important commercial and industrial centers in the northwest of Iran. This area is geomorphologically limited from northward to the Miro-Misho Mountain, southward to the Sahand Mountain and westward to the Urmia Lake Basin which is located in the center of the drainage system of Urmia Lake. The location maps of the study area are presented in Figs. 1 and 2 show the digital elevation model (DEM) based on topographical and geological maps of the Tabriz region, respectively. Based on the structural geology point of view, the area is based on the two structural sections of the Tabriz region.

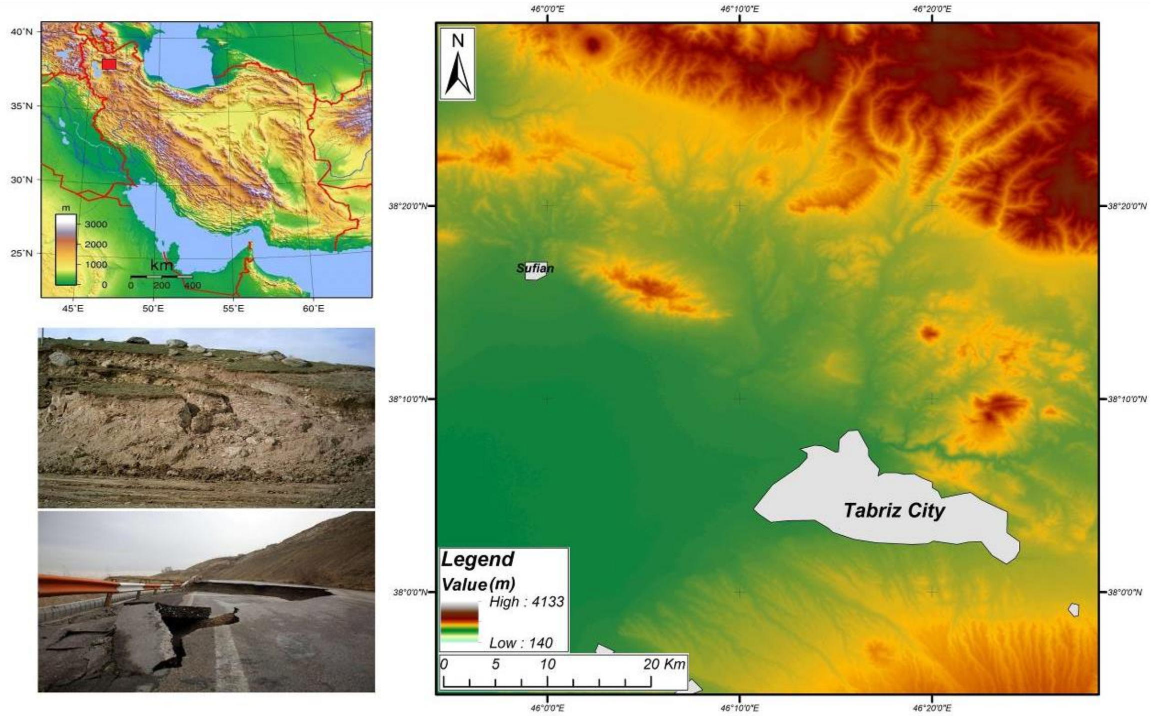

Fig. 1 Location map along with DEM model of the study area

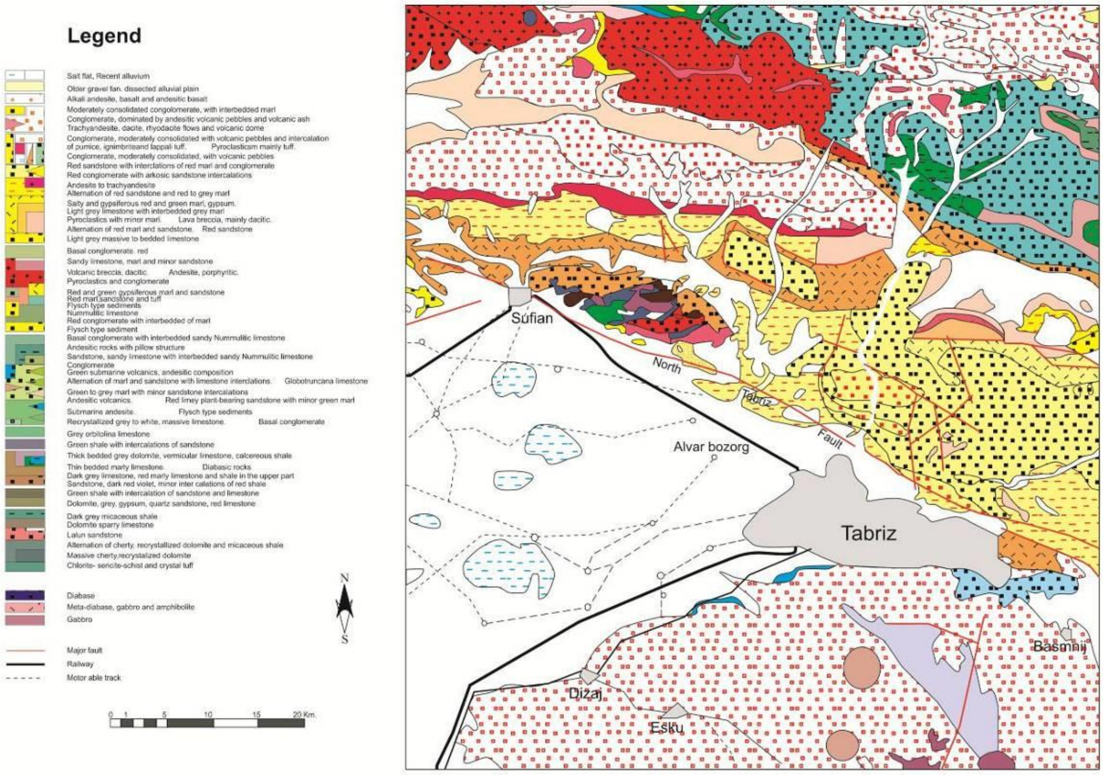

Fig. 2 Geological map of the Tabriz region (adapted from the Geological Survey of Iran 2009)

These are the west and south-west of the Palaeozoic platforms of central Iran and west Alborz. These sections include Bozgoosh Mountain, Sahand Mountain, the northern highlands of Tabriz (Misho-Miro Mountain) and the western highlands of Jolfa. In the north-eastern part, the Paleozoic platform facies, similar to other parts of Iran, does not appear to exist. The Mesozoic flimsy facies is widely distributed in that area and the tartar sediment facies is a distinct feature here. Median and Upper Carboniferous deposits are not visible in the main part. Instead, the crustal and granodiorite bodies of Miro-Misho and the red cemetery deposits of the early Permian were probably

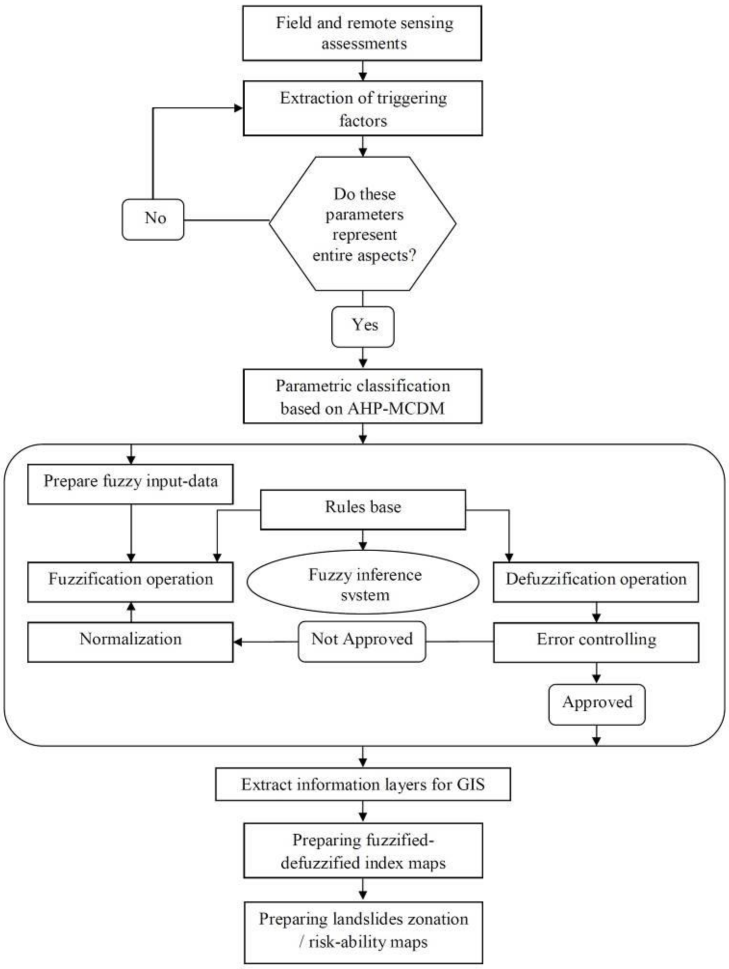

Fig. 3 Flowchart of the fuzzy-based process of landslide assessment

formed due to the function of the Hiericilene orogenic phase. Submarine volcanic activity has been noted to increase westward during the Eocene in the Azerbaijan region, such as Central Alborz. According to the orogeny of the Pyrenees, the Azerbaijan region behaves like central Alborz, showing intense magmatism, especially in the Miyaneh and Sahand regions, which are mostly granitic, crustal, and injected into green tuffs. During the Mesozoic period, this area was covered by continental sedimentary basins or shallow marine waters, but intense volcanic activity occurred in the Eocene and Quaternary. The main foldings in the studied region are related to the Cretaceous, Palaeogene, Oligocene, and Pleistocene (associated with plutonium and metamorphic activities), which indicate the performance of the young Alpine phase. The Sahand volcanic mass is a stratovolcano containing a pyroclastic ion-membrane and lava that have been emitted in a large area of more than 3000 square kilometers covering the Miocene and older sediments (Aghanabati 2007).

2.2 Fuzzy-based method

This study is divided into two main steps. The first stage describes the characteristics of the study area, triggering factors, remotely assessing determinations, defining the landslide-prone regions. The second stage refers to the definition of fuzzy membership functions, the weighted parameters, the prioritization and classification with fuzzy MCDM methodology, and the development and training of fuzzy-based multi-criteria decision-making algorithms. Both stages are utilized for landslide susceptibility and preparation of hazard zonation maps for the region. In this regard, during the first step of this research, the database as the geological characteristics, geomorphic characteristics, and environmental conditions of the study area has been prepared and used in regional or spatial scales obtained for hazard analyses framework (Castellanos Abella and Van Westen 2008) having 1: 250,000 and 1: 100,000 scale of Tabriz maps. In order to evaluate the landslide susceptibility, the scale level specified here was taken into account. In order to achieve the accuracy required for analysis at such a level, satellite images and digital elevation models (DEM) of the Tabriz region have also been used with an accuracy of ±30 meters. The results of these evaluations were introduced as an input parameter in the fuzzy-based model. In the second stage, the fuzzy-based multi-criteria decision-making algorithm has been implemented by using the MATLAB programming language and GIS environment. The fuzzy inference section consists of three decision-making units which are namely the rules-base, database-related membership functions, and an inference mechanism (analyses core). The core section of

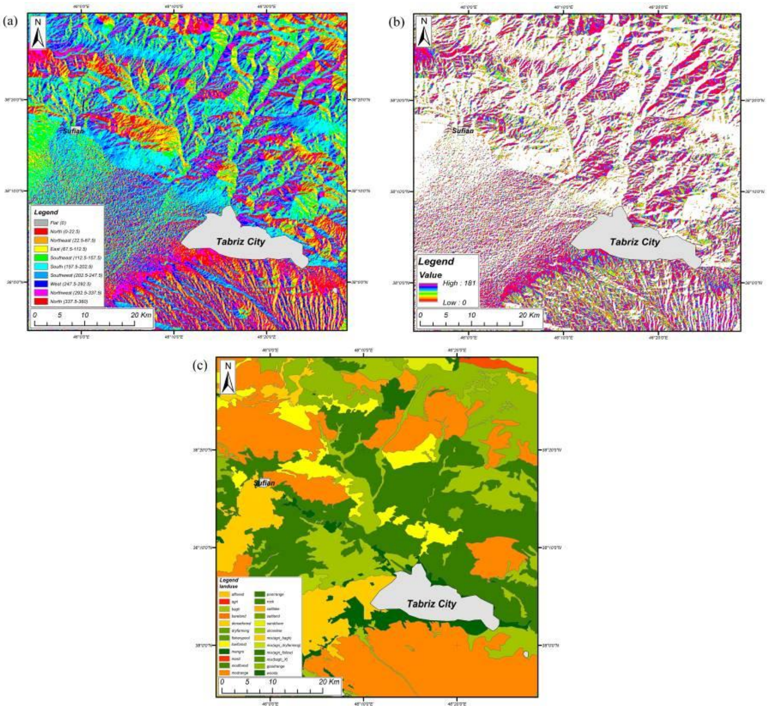

Fig. 4 Utilized geomorphological parameters in the landslide susceptibility evaluations: (a) slope gradient, (b) slope aspect and (c) land cover

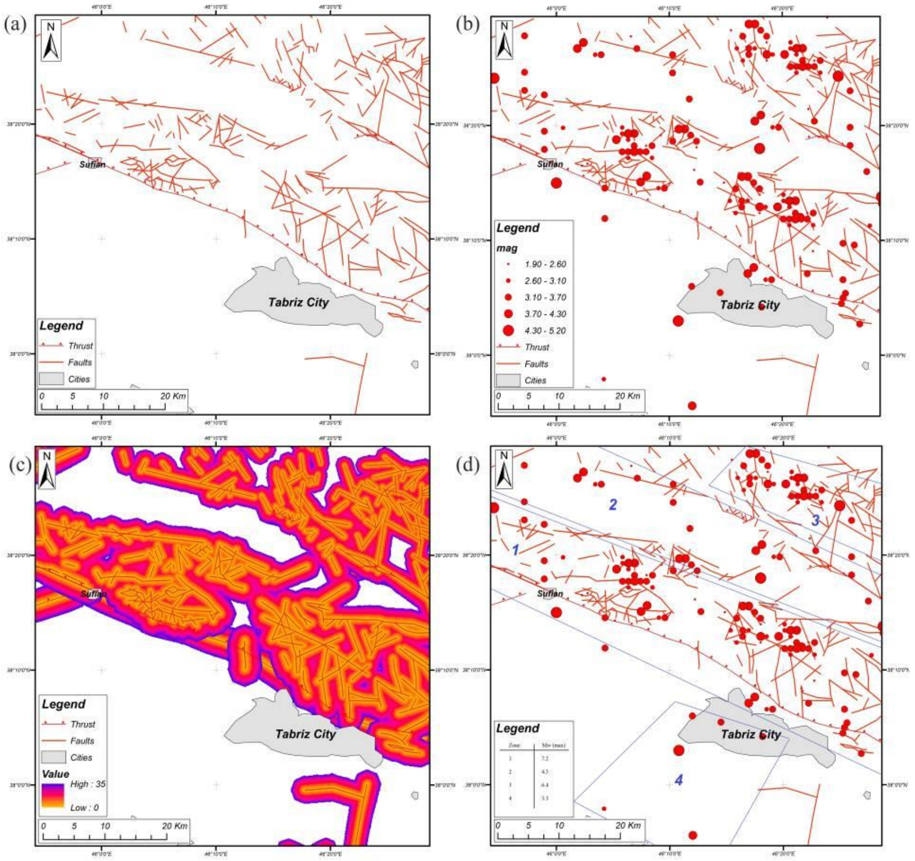

Fig. 5 Utilized tectonical and seismotectonic parameters in the landslide susceptibility evaluations: (a) tectonic lineament congestion, (b) distribution of earthquakes, (c) the unsafe radius of main faults and (d) seismicity

the analysis is to assess the linear/nonlinear components of the information by applying the definition of IF-THEN rules based on assumptions and expert supervised decisions. After fuzzification, the input parameters are processed by the analyses core and the post-defuzzification results are used as multi-layered information with high hybrid capability in the GIS environment. These layers were used for accurate susceptibility assessment for the landslide riskability of the Tabriz region. Fig. 3 shows the flowchart of the three-step fuzzy-based process, including fuzzification, main process and defuzzification stages.

2.3 Landslide conditioning factors

Five main components have been identified as triggering factors in the region using remote sensing assessments and field surveys in the study area. These factors are namely climate (i.e., precipitation, temperature), geomorphology (i.e., slope gradient, slope aspect, land cover), tectonic activity and seismicity (i.e., tectonical lineament congestion, distribution of earthquakes, the unsafe radius of main faults, seismicity), geological and hydrological parameters (i.e., drainage patterns, hydraulic gradient, groundwater table depth, weathered geo-materials), and human-activity (i.e., distance to roads, distance to the municipal areas). Regarding the climatic conditions, the study area is generally cold as it is a mountainous area. According to Iran Meteorological Organization (2019), precipitation variation in the Tabriz region varies between 0 and 28.6 mm, with the lowest rainfall in July and the highest in December. Also, considering the temperature, the lowest one was recorded at -4°C in February, and the highest one at 28.7°C in August. According to the information provided by Iran Meteorological Organization (2019), annual temperature variations in Tabriz are generally cool and uniform (from north to south) as they are limited to mountainous regions. However, the fact that the precipitation changes in the region over the consecutive years exceeded 180 mm annually caused the two main variables to have higher priority and sensitivity than the temperature in the decision of the precipitation region. Table 1 shows the results of AHP-MCDM analysis for climate parameters. As it is known, climate change is a factor affected by the physical and mechanical characteristics of geological formations; therefore, the presence of water increases continuously as pore pressure and causes massive weathering changes in geo-materials. These results not only reduce the strength of the host rock but also increase the geo-materials sensitivities on the slope movement (Calcaterra and Parise 2010).

The study area has undergone various geomorphological changes that caused a significant variation in the altitude of the region. This has led to the tectonic movement of Arabic plates under Central Iran and Eurasian plates, which face two triangular boundaries in the Azerbaijan region. Thus the Ararat region and the Caucasus (between Turkey, Iran, and Central Eurasian plates activities) caused by tectonic stresses, have led to the formation of tectonic complexity (Aghanabat 2007). These changes are in the form of topography variations and tectonic deformations (i.e., faults, folds) which are noticeably observed in the northern andsouthern parts of the study area. The presence of active faults such as the North Tabriz fault, Miro-Misho faults, and Sahand fault indicates the high seismic activity of the region (Azarafza and Ghazifard 2016). Regarding seismotectonic character, the region was classified as active and high risk by Nogol-Sadat and Almasian (1993). Considering the fact that Tabriz is active in terms of seismotectonic conditions, seismicity is one of the primary factors triggering landslide occurrence in the region (Highland and Bobrowsky 2008). However, geomorphological changes and altitude contour density which shows an increase in slope, are also accepted as effective factors in the landslide occurrence. Decision results of AHP-MCDM analysis for geomorphological parameters are presented in Table 2. Additionally, Table 3 presents the parametric decision results for tectonic and seismic characteristics. Due to the tectonic activity that depends on the susceptibility of the geostructures, the seismic factor will be given as a full weighted value (i.e., Table 1) in the analysis.

Figs. 4 and 5 illustrate geomorphological parameters, and tectonic and seismological parameters, respectively. The geological setting of the Tabriz region has a complex position due to its history of tectonic and orogenic processes. On the Tabriz geological map shown in Fig. 2, the outcrop of the younger formations show evidence that these formations were deformed after the last Sahand volcanic activity. On the other hand, the traces of younger discontinuities, namely fractures and joints, recorded in Quaternary formations indicate that the North Tabriz fault is highly active based on seismicity. In terms of geomechanical features, discontinuous rocks are more affected by sliding movements, since their shear strength is lower than durable rocks. In geological units, the sedimentary rocks are more suitable for landslide occurrence than igneous and metamorphic rocks. Therefore, weak formations can play an important role in sliding

Table 1 Descriptions of AHP-MCDM analysis for climatic parameters

Factors	Level of importance	AHP-MCDM results	
		Weighted value	Class
Precipitation	A-class	0.624	High
Temperature	B-class	0.376	Low

Table 2 Descriptions of AHP-MCDM analysis for geomorphological parameters

Factors	Level of importance	AHP-MCDM results	
		Weighted value	Class
Slope gradient	A-class	0.413	High
Slope aspect	B-class	0.276	Moderate
Land cover	C-class	0.311	Low

Table 3 Descriptions of AHP-MCDM analysis for tectonical and seismotectonic parameters

Factors	Level of importance	AHP-MCDM results	
		Weighted value	Class
Tectonical lineaments	D-class	0.113	High
Earthquake distributions	B-class	0.311	High
Main faults	C-class	0.234	High
Seismicity	A-class	0.342	High

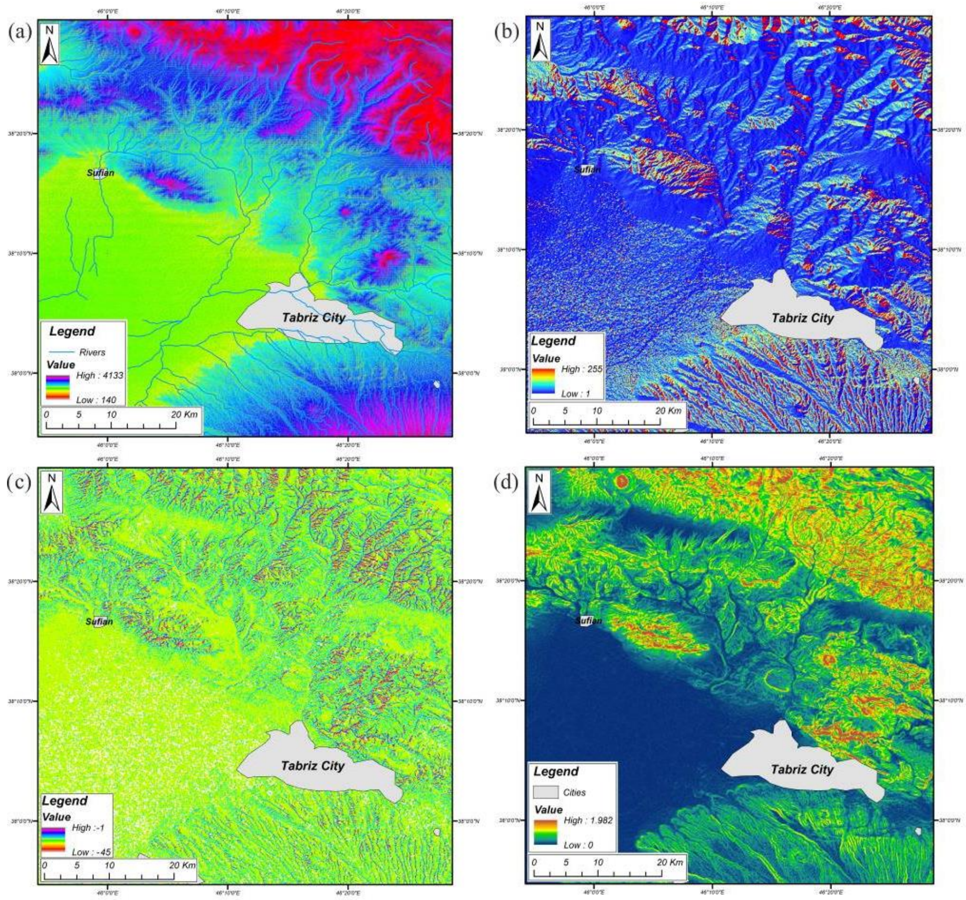

Fig. 6 Utilized geological and hydrological parameters in the landslide susceptibility evaluations: (a) drainage patterns, (b) hydraulic gradient, (c) groundwater table depth and (d) weathered geo-materials

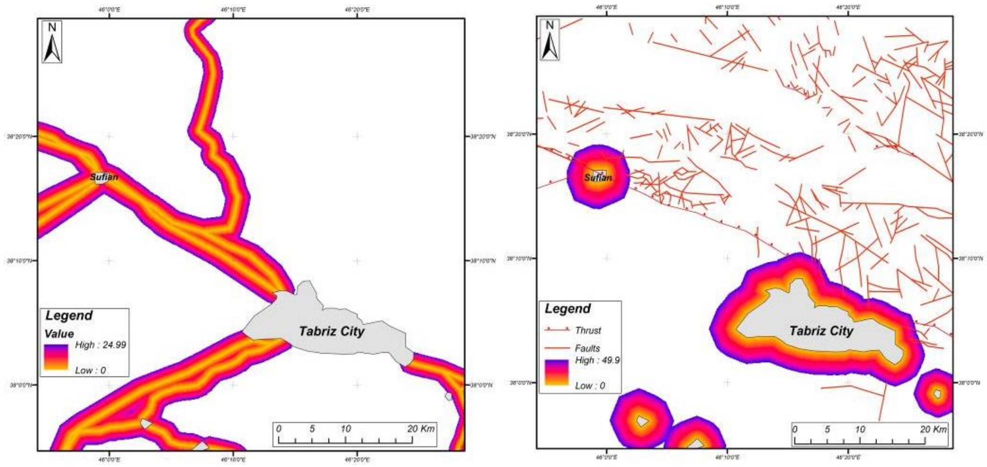

Fig. 7 Utilized man-made activity parameters in the landslide susceptibility evaluations: (a) distance to roads and (b) distance to the municipal areas

Table 4 Descriptions of AHP-MCDM analysis for geological and hydrological parameters

Factors	Level of importance	AHP-MCDM results	
		Weighted value	Class
Drainage patterns	B-class	0.253	High
Hydraulic gradient	A-class	0.280	High
Groundwater table	D-class	0.223	Low
Weathered geo-materials	C-class	0.244	Moderate

Table 5 Descriptions of AHP-MCDM analysis for human-activity parameters

Factors	Level of importance	AHP-MCDM results	
		Weighted value	Class
Distance to roads	B-class	0.418	High
Distance to the municipal areas	A-class	0.582	Moderate

Table 6 AHP rating values of the triggering factors for the Tabriz region

Aim	Criteria	Weighted	Normalized	Sub-criteria	Weighted	Normalized
Landslide susceptibility	Climatological parameters	0.163	0.565	Precipitation	0.624	1.000
				Temperature	0.376	0.602
	Geomorphologic parameters	0.239	0.829	Slope gradient	0.413	1.000
				Slope aspect	0.276	0.668
				Land cover	0.311	0.753
	Tectonic and seismotectonic parameters	0.288	1.000	Tectonic lineaments	0.113	0.330
				Earthquake distribution	0.311	0.909
				Main faults	0.234	0.684
				Seismicity	0.342	1.000
	Geologic and hydrological parameters	0.207	0.718	Drainage patterns	0.253	0.903
				Hydraulic gradient	0.280	1.000
				Ground water table	0.223	0.796
				Weathered geo-materials	0.244	0.871
	Human-activity parameters	0.103	0.357	Distance to roads	0.418	0.718
				Distance to the municipal areas	0.582	1.000

occurrences and slope instabilities (Bell 2007). Fig. 6 displays the geological and hydrological parameters considered in the landslide susceptibility assessment and Table 4 illustrates the decision-making results for geological and hydrological conditions. The parameters of the human activity that are effective in the landslide occurrence are presented in Fig. 7. Because of the constant expansion of the urban spaces, the sensitivity of human activities can be another important parameter for decision-making after the seismicity of the study area. Table 5 shows the parametric decision-making results regarding the characteristics of human activities.

3. Results and discussion

Although the specific procedures of landslide susceptibility have not been specifically presented, the qualitative, semi-quantitative, and quantitative methods are used by various researchers worldwide to assess risk-ability mapping of sliding. Meanwhile, intelligent quantitative methods that involve different variables and are associated with powerful computations are at the top of the applications that are always used. Using artificial intelligence techniques to obtain more reliable results while evaluating landslide susceptibility analysis is more successful than other methods. However, fuzzy logic and artificial neural network methods give also accurate results in computational susceptibility assessments. Fuzzy logic was first introduced in 1965 by Zadeh to describe the identification of a series of components using multi-agent decision-making intelligent systems (Yager and Zadeh 1992). This advantage helps to cover more uncertainties involved with MCDM and AHP analyses. For the study, firstly, the input parameters are fuzzified after pre-processing (i.e., filtering, controlling and removing unnecessary items). In the fuzzification step, classical data are basically transformed into fuzzy data using the expert system. The fuzzified parameters are analyzed by a fuzzy inference system operator (FIS) which applied by a rules database (IF-THEN rules were prepared by the expert system). In this study, the Mamdani fuzzy logic controller has been used as FIS which was presented by Mamdani and his colleagues (Mamdani and Assilian 1975; Mamdani 1977). After the main processing, the evaluated information is defuzzified and the processed fuzzy data is converted into classic data and classified as output data. To provide the expressed parameters for modeling, MATLAB software's fuzzy toolbox was used (Sivanandam *et al.* 2014, MathWorks 2014). The export results were then converted into information layers and into GIS environment (ESRI 2017) used in the preparation of risk-ability maps (landslide hazard potential maps). Using AHP and MCDM, the main triggering factors are ranked according to high impact directions for landslides occurrence potential assessment. Table 6 presents the AHP rating values of the triggering factors in the study area. These parameters were weighed as impacts on landslides susceptibility and used for preparing

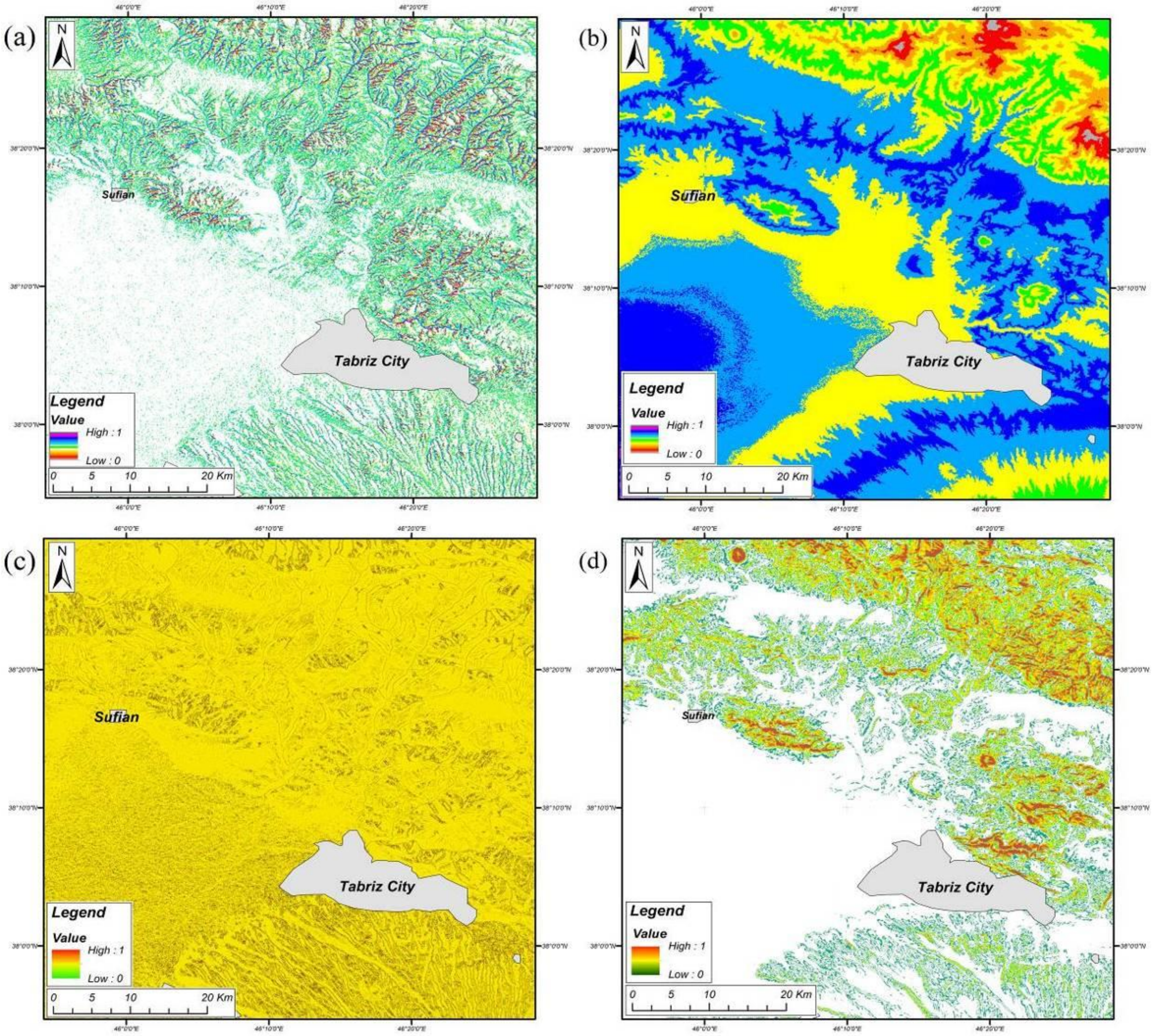

Fig. 8 Fuzzified index maps for the Tabriz region: (a) slope curvature, (b) land use, (c) hydrological conditions and (d) weathering

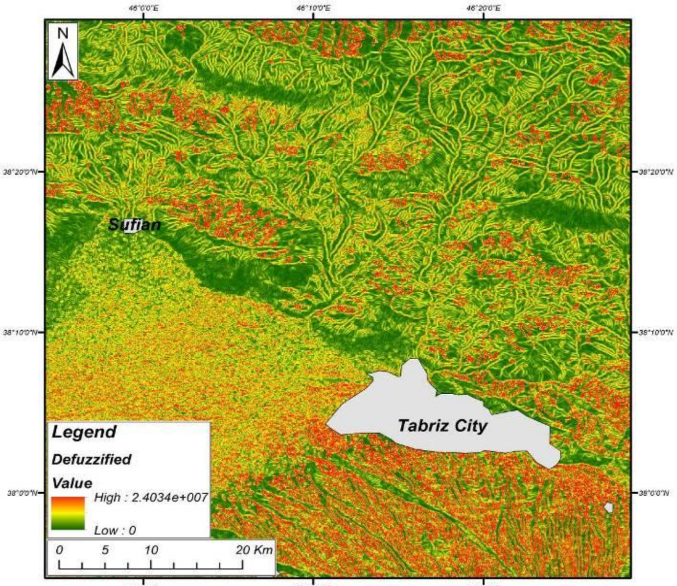

Fig. 9 Defuzzified index map for the Tabriz region

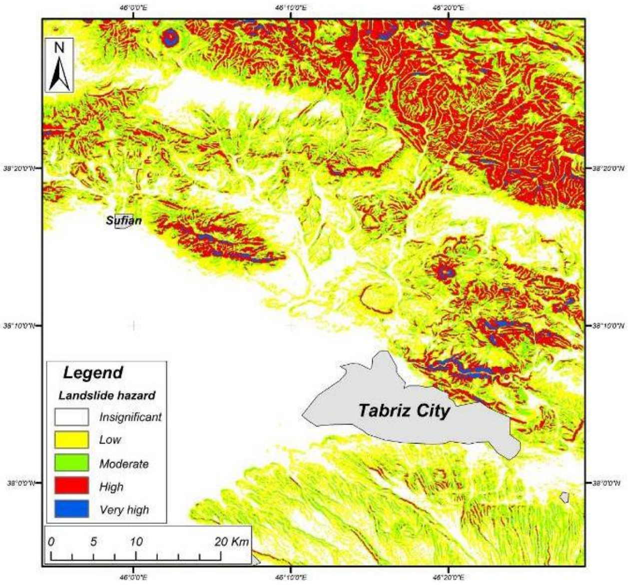

Fig. 10 Landslide susceptibility and hazard map of the Tabriz region

the fuzzy-based index maps (Fig. 8). Index maps describe by fuzzy values in which "1" is considered as a highly hazardous risk and "0" is considered as safer areas. After the fuzzification process, the results of susceptibility are defuzzified and presented in Fig. 9.

After defuzzification analysis of the susceptibility map for the study area, the result representing the landslide hazard potential of the Tabriz region was classified into five groups including the areas of 'very high, high, moderate, low, and insignificant'. As seen in Fig. 10, the northern parts of the Bozgoosh-Sahand mountain belt, the northern elevations of Tabriz called the Misho-Miro Mountains and the western highlands of Jolfa were considered to be the highest risk-able zones of the sliding mass. In addition, the old landslide concentrations in several parts in the studied area near the linear structures (which is related to tectonic/ seismotectonic activities) indicated the tectonic activity has affected the movements of the land in the northern part of Tabriz city (i.e., Tabriz fault, Bozgoosh fault). Therefore, it can be inferred that the main triggering or activation mechanism of landslide occurrence is related to tectonic and seismotectonic elements. In other words, geomorphological changes and geological complexity (i.e., expansion of weathered and weak geo-materials) together create favourable conditions for the sliding mass, which can be easily degraded by changing climatic conditions (i.e., precipitation) and human activities. The effect of these parameters independently or dependently on each other leads to complex situations that cause slopes instabilities. The arrangement along with tectonic structures and seismic activity matching witnessed the direct impact of these parameters, which is also confirmed by Table 6. The northeast part of Tabriz city is located on a very high sensitive area for landslide occurrence which directly impacts urban and residential locations and that issue should be taken into consideration immediately.

4. Conclusions

This study is presented for the preparation of more accurate and reliable hazard analysis and landslide hazard zonation maps by using fuzzy logic, AHP, and MCDM analyses approach for landslide susceptibility assessment in the Tabriz region. According to the results of a two-step survey conducted in remote sensing and field assessments, the five most effective triggering mechanisms identified in the occurrence of a sliding mass are climate, geomorphology, tectonic and seismicity, geological and hydrological, and man-made parameters. These factors were used as the input parameters to the fuzzy logic-based multi-criteria decision-making method simulated with MATLAB software. The fuzzification, main process, and defuzzification stages have been used in the three-stage fuzzy-based processing method applied in this study. In the fuzzification stage, the input parameters (triggering factors/sub-factors) were fuzzified. Then, the fuzzified parameters in the main stage have been evaluated with Mamdani analysis core as main FIS and defuzzified. Providing accurate results at these stages, the information layers in the GIS environment have been used to produce the hazard maps. According to the landslide susceptibility map developed for the study area in the Tabriz region, the northern parts of the Bozgoosh-Sahand mountain belt, the northern altitudes of Tabriz called the Misho-Miro Mountains, and the western highlands of Jolfa were determined to be the highest risk-able zones for the sliding mass. In addition, the main triggering factors of landslides should be classified according to seismotectonic and geomorphological components prepared with the high-risk potential of the sliding masses, which can affect the urban and residential areas in the northern part of the city of Tabriz.

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