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Flood zoning and developing strategies to increase resilience against floods with a crisis management approach

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Abstract

Assessment and planning of crisis management with the approach to natural flood disasters include many factors. In this regard, one of the basic principles of crisis management is based on the resilience of urban infrastructure against floods. This study developed strategies to increase resilience by flood zoning and crisis management. The investigation of the current situation shows that despite the efforts being made, the climatic and environmental conditions of the rivers, the settlements of the infiltration basin, the constructions, and the location inaccuracy of the following structures indicate many challenges in managing the current situation in various components of crisis management. In this regard, the main direction of this article is to evaluate the urban resilience of the Khuzestan region against floods based on a crisis management approach and technique for order preference by similarity to ideal solution (TOPSIS) and Fuzzy weighting methods using geographic information system (GIS).

Keywords: Crisis management, Flood disasters, Flood zoning, GIS, Urban resilience, TOPSIS.

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Contents

Contribution of this paper to the literature
In this research, considering the slope of the land, land use, density of faults and fractures, geology, the density of waterways, amount of precipitation, and intensity of rainfall, the zoning of Khuzestan region against floods using TOPSIS and Fuzzy weighting methods was done using GIS.

1. Introduction

After flood occurrence, the performance of communication networks decreases significantly due to the possible closure of communication routes [1]. This contrasts with the fact that after natural disasters and emergencies, communication networks and access to relief centers play a vital role in saving human lives [2]. For this reason, the optimal distribution of utilities and relief centers is a problem that urban planners often deal with; because of the rapid population growth, there have been problems such as lack and lack of proper distribution of the necessary space for relief centers [3]. Today, a geographic information system serves as a tool to create a unified and efficient database [4]. One of the fundamental goals of policymakers in the health sector of any country is to facilitate people's access to healthcare services so that all sections of society can benefit from these services [5]. Therefore, the level of performance and coverage of relief centers is crucial to reducing human casualties during floods [6]. Crisis management should not be considered only as a tactical response when a disaster occurs but as preventive activities within processes related to crisis prevention [7]. Therefore, the location of public facilities is an example of the policies of plan-oriented governments, understanding the benefits of saving resources, increasing the efficiency and synergy of services, especially during a flood crisis, and increasing the sense of collectivism. Such benefits are especially critical for governments experiencing rapid population growth [8].

1.1. Flood

A flood is any flow, regardless of its generation source, that causes a significant increase in the amount of water at a certain point and has a limited duration. In this case, the water overflows from its natural bed and covers the surrounding lands, which may lead to financial and human losses [9]. According to the definition of the UNESCO hydrological culture, a flood is a short-term increase in the river's water level to a peak from which the water level recedes with a slower rhythm [10]. In another definition, a flood may occur due to heavy, continuous rainfall, sudden snow melting in a watershed, or a dam breakage. However, the occurrence of flood causes destruction and damage to human centers and structures along the flood path [11].

In general, from a physical point of view, any surface flow, regardless of its creation factor, exceeding the natural or artificial bank of the river and covering the lowlands and river banks, is defined as a river flood [12]. As long as this phenomenon does not threaten life and assets of humans, it is not considered a dangerous event. A flood is a combination of short flows in a particular place with a steep slope, usually created in impermeable and low-resistant rocks and structures, that consists of three main parts: catchment basin, waterway, and alluvial cone. All the rains in the catchment basin meet in the form of small waterways to provide a significant flow rate in a large, elongated, narrow, and relatively long waterway. The basis for the formation of irregular discharges caused by sudden and heavy rains is mainly in the form of showers that occur in feeble and intermittent currents. Floods are characterized by solid detection currents generated after each rain shower on bare and unstable lands and in waterways already cut by water flow and often on steep mountain slopes. In terms of intensity, they are often highly destructive. Therefore, most of the villages and cities located at the foot of the mountains are constantly exposed to the danger of this phenomenon. Considering the different views of the concept of a flood, it seems necessary to provide a comprehensive and complete definition of a flood. In general, it can be concluded that any surface flow is called a flood if:

1. According to custom and general opinion, it should be accompanied by an increase in the volume of water at a certain point.
2. to have a limited duration.
3. It usually overflows from the natural bed and covers the marginal lands.
4. Bring Financial and life losses.

1.2. Urban Resilience

Resilience means the ability to deal with difficult situations and respond flexibly to incidents that occur in the city. Historically, the term "resilience" was first used in the early 17th century, meaning leap and return to one's self. After Holling, the term resilience evolved in material science, ecology, and environmental studies and became a concept for the use of professionals, planners, and academics. Based on that, resilience was described as returning to a stable state after any disruption in the system's performance or as the ability to absorb force or change with minor disruption to the efficiency of that system [13].

Resilience has become critical as one of the main goals of empowerment in post-crisis rehabilitation and reconstruction. Resilience in the context of social systems and when faced with an accident is defined as the ability of a social unit to absorb the risk of accidents, reduce the physical effects, postpone the time of social disruption when it occurs, and reduce the impact of future crises.

1.3. Crisis

Disaster studies emphasize the impact of natural hazards on the artificial environment. This form of natural disaster consequence occurs when human activities and natural phenomena collide and turn disasters into crises [14]. Therefore, the crisis can be considered the result of the interference of a series of factors of natural hazards among human communities [15].

Recently, the role of planning in reducing accidents has been recognized. For example, risk reduction or integrated programs are one potential strategy to encourage safer development and gain public support [16]. It is necessary to make plans before the incidents. These plans will be effective when accompanied by the powerful presence of the community [17]. Quality programs of local interest groups greatly impact environmental problems, especially natural hazards, and can increase the commitment level of elected officials [18]. Based on these findings, selective areas to solve environmental problems should be created to use the existing communities in the planning process and facilitate reconstruction operations. Politically oriented and influential social networks can improve civil servants' commitment and society's capacity. Crisis in human societies happen periodically; Therefore, people and societies have adopted different approaches in facing crises.

The crisis cycle from the point of view of Militia [19] is a four-stage cycle with the following stages in time.

- Preparedness: the ability of society to react and deal with disasters.
- Reconstruction: the set of measures taken after a disaster to save lives and minimize future losses.
- Short-term rehabilitation: short-term restoration and repair of vital arteries and infrastructure and livelihoods.
- Long-term rehabilitation: long-term restoration of the community to return to the past normal state [20]

2. Literature Review

In 2018 Wang, et al. [21] used a hybrid multi-criteria decision-making method for flood susceptibility mapping based on GIS comparative assessment. This study proposed an approach to recognize flood-prone areas of the Topla river. Machine learning, statistical index, bivariate regression, multi-criteria decision-making approach, and GIS were used as the main approaches for the abovementioned purpose. In another study carried out by Ogato, et al. [22] a GIS-Based multi-criteria analysis of flooding risk and hazard in Ambo Town and its watershed was done. The investigation used the flooding hazard layer and two factors: land use and human population. The weighted linear combination method was used in the criteria map aggregation process for both flooding risk and flooding hazard. Results demonstrated that more proportion of the watershed and the town are high and very high flooding hazard areas. Flooding risk analysis revealed that more of the watershed, like half of the city, is a high and very high flooding risk area. In another study by Ajjur and Mogheir [23] using multi-criteria decision analysis and GIS, urban flood hazard zoning was carried out in Argentina.

The methodology concentrated on analyzing the variables that control the water routing when high peak flows pass the drainage-system capacity [24]. The model consisted of four parameters: topography, groundwater table depths, distance to drainage channels, and urban land use. A final hazard map for each category was obtained Using an algorithm derived from factors in a weighted linear combination. Da Silva, et al. [25] proposed a GIS-based multidimensional decision model for improving flood risk prioritization in urban areas. The modeling is a Multi-Attribute Utility Theory (MAUT). To validate the model, a case study in a Brazilian municipality is simulated with real data. Visualizations of risk mapping developed from GIS were used to discuss the results. Being flexible and replicable in any region of the world brings advantages to this method. In 2022 a combination of Machine Learning, Remote Sensing, and GIS was used by Ullah, et al. [26].

To investigate the effects of changing climates and land uses on flood probability [27]. For this purpose, land use changes were predicted for the next 20 years by monitoring the past 20 years' land use changes. This was done using the land change modeler (LCM) method. Future climate change was evaluated as well using Lars-WG software. The results manifested that elevation, land use, slope, distance from the river, and rainfall are the critical elements affecting flooding in this basin. Jahangir, et al. [28] provided a spatial prediction of flood zonation mapping using an artificial neural network algorithm in the Kan river basin. Using this, discharge values and spatial modeling of floods in the Kan river basin were predicted. Seven inputs were considered in the optimized AI network, including slope curvature, slope, NDVI, geological units, flow accumulation, soil type, and rainfall. The output of the neural network was discharge values in stations. Results demonstrated that utilizing GIS spatial analysis with AI algorithms is one of the most efficient methods for forecasting the potential of natural disasters. Batarseh, et al. [29] assessed groundwater quality for irrigation in arid regions using GIS-zoning maps and Irrigation Water Quality Index (IWQI). Due to USSL and Wilcox diagrams which were in line with IWQI results, the groundwater was primarily classified as unsuitable for irrigation purposes without prior treatment.

Cai, et al. [30] utilized a hydrodynamic model and fuzzy comprehensive evaluation with the GIS technique for flood risk assessment. The MFCE model consists of three input indicators: the exposure factor, the hazard factor, and the vulnerability factor. The results indicated that compared with the risk assessment of the MFCE model, the risk distribution map of the hazard factor changed significantly when the studied area was under a storm. Chau, et al. [31] used GIS to map the impacts on agriculture from severe floods in Vietnam. Eighty-six flood depth marks were interpolated using the inverse distance weighting algorithm to generate the water surface, and a DEM was employed to form the flood inundation map. The generated maps indicated that the 1:10, 1:20, and 1:100-year floods led to the land being inundated by 27%, 31%, and 33%, respectively. In 2019 land-use zoning for protecting the built heritage in the Bagan Archeological Zone in Myanmar was evaluated by Edwards, et al. [32]. Publicly available satellite information was analyzed as one of the vital factors of the local conservation regime. Doing so, it was concluded that a restrictive zoning regime has controlled urban sprawl and helped conserve the monuments. Lai, et al. [33] used a rule mining for flood risk zoning based on an ant colony. The results showed that Ant-Miner expresses higher accuracy and more simple rules that can be utilized to generate flood risk zoning maps faster and easier than the decision tree method. Compared to the fuzzy comprehensive evaluation and random forest, Ant-Miner has significant superiorities both in computing time-saving and implementation step-reducing.

Qi and Altinakar [34] provided a GIS-based decision support system for integrated flood management under uncertainty using two-dimensional numerical simulations. This system can use classified Remote Sensing and interact with image layers and GIS feature layers like survey database, zoning layer, and census block boundaries. Test results indicated that this new system introduces a very reliable and versatile environment for predicting various flood damage. Sadeghi-Pouya, et al. [35] proposed an indexing approach to assess flood vulnerability in the western coastal cities of Mazandaran. Results demonstrated that the indexing method results in a relative sense and an overall picture of the exposure of urban toward floods, the urban zones surrounded by two rivers are in danger of a high level of vulnerability. Zhang and Song [36] introduced a case study in which the optimization of wetland restoration siting and zoning in flood retention areas of river basins was done. A site-specific methodology was developed to identify potential functional zones and sites for wetland restoration, optimizing the available zones and spatial distribution to maximize flood control and human and regional development.

3. Methodology

3.1. Khuzestan's Flood Zoning

Generally zoning in the current study consists of two main stages:

1. Gathering the needed information and obtaining data layers: in this stage, essential information layers such as Khuzestan's geological map, DEM, hydrometric information, region's streams, and precipitation regime data regarding flood potential in the area were gathered by gathering the previous data from various data sources. At this stage, the information was evaluated using GIS, and a decision tree diagram as criteria and sub-criteria was compiled. Adequate privacy for each potential flooding criterion was determined and standardized using fuzzy membership functions and the TOPSIS Process. Afterward, using TOPSIS and Fuzzy procedures, which are multi-criteria decision-making methods, the criteria's degree of importance was calculated. Finally, by Compiling all the information using the index overlap method, flood zoning was prepared. Figure 1 shows the flowchart of the research

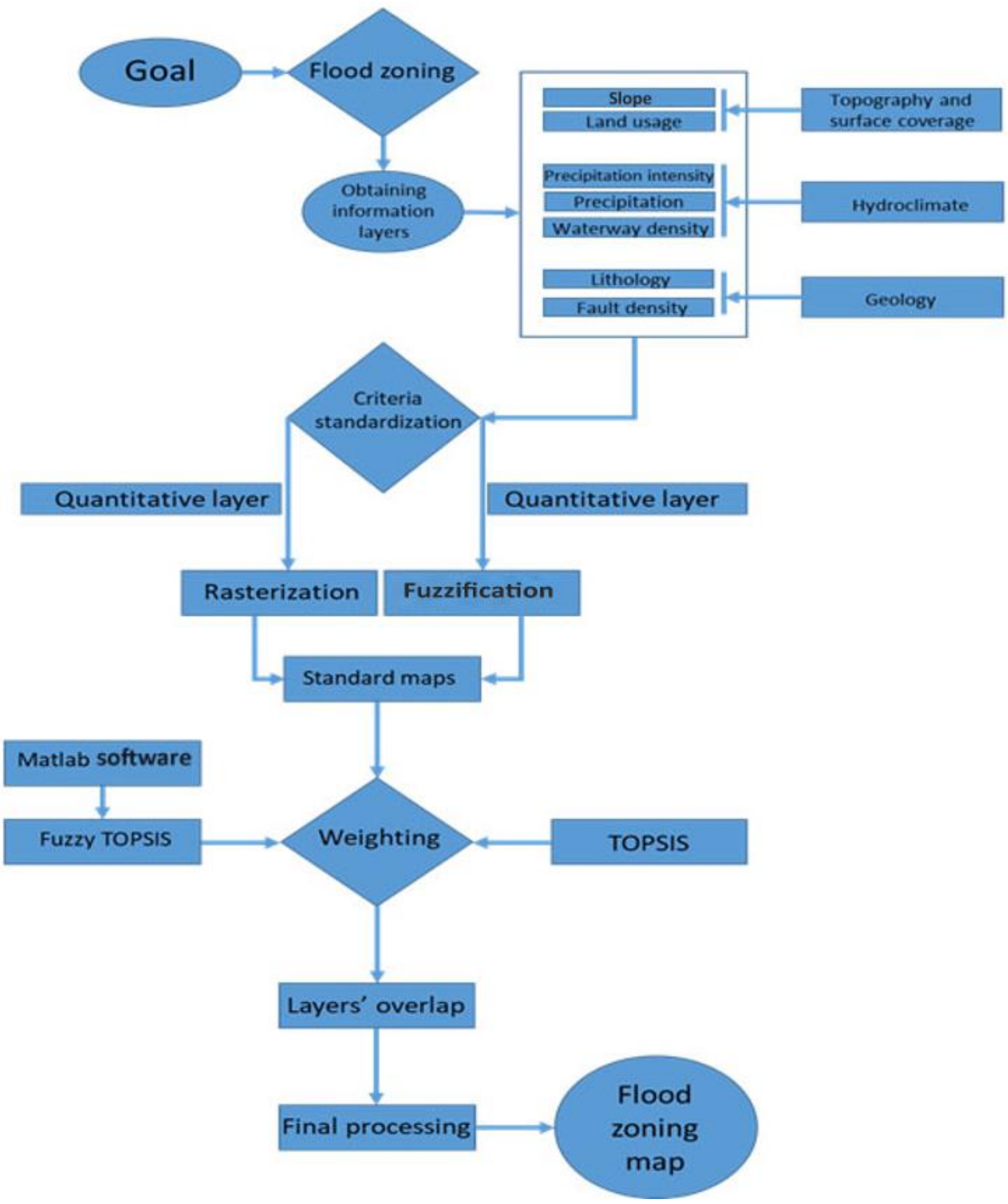

Figure 1. Research's flowchart.

2. Obtaining the effective factors: At this stage, information layers and various data sources were evaluated, and due to the factors practical to the flood occurrence and Khuzestan's geological specifications, upcoming elements were introduced as the effective ones:

- Ground inclination: including the region's topographic slope information layers.
- Land use: consists of natural or unnatural land usage.
- Density of faults and fractures: consists of all the regional faults.
- Geology: this layer contains the lithology of the formations in the region.
- Density of the stream: has the main and sub-streams of the Khuzestan city.
- Precipitation amount: contains the average annual rain in different regional zones.
- Precipitation intensity: includes the moderate maximum daily rain.

3.2. Data Processing

After influential factors determination in the flood occurrence, related information layers should be prepared. The following section will discuss how the data was organized and entered into the function.

3.2.1. Processing the Steep Layer

The basins' slope is one of the main factors that control the river's surface flow time and water concentration. It affects the amount of infiltration, surface flow, soil moisture, and groundwater in the basin. Basins with a steep slope usually have a compensation profile. As a result of the steep slope, the speed of the water flow increases, which in turn decreases the infiltration and evaporation amount. After a short period, the rain turns into a stream, and a flood occurs. Such basins have a shorter hydrograph range and higher peaks. For this reason, if the permeability is low in mountainous areas, flood damages and inundation will sour. In this research, after preparing DEM using the slope software, Khuzestan city's slope map was obtained. The slope layer stands among the linear quantitative layers, standardized using fuzzy functions. According to the characteristics of the studied area and experts' opinion, the minimum slope that causes run-off and flood is -1% (equal to 5 degrees), and the maximum slope up to which the amount of flooding increases linearly is 100% (equivalent to 45degrees). Slopes over 45 degrees are completely flooded regardless of the experimental flooding factors. The slope map, DEM and standardized slope are shown in Figure 2.

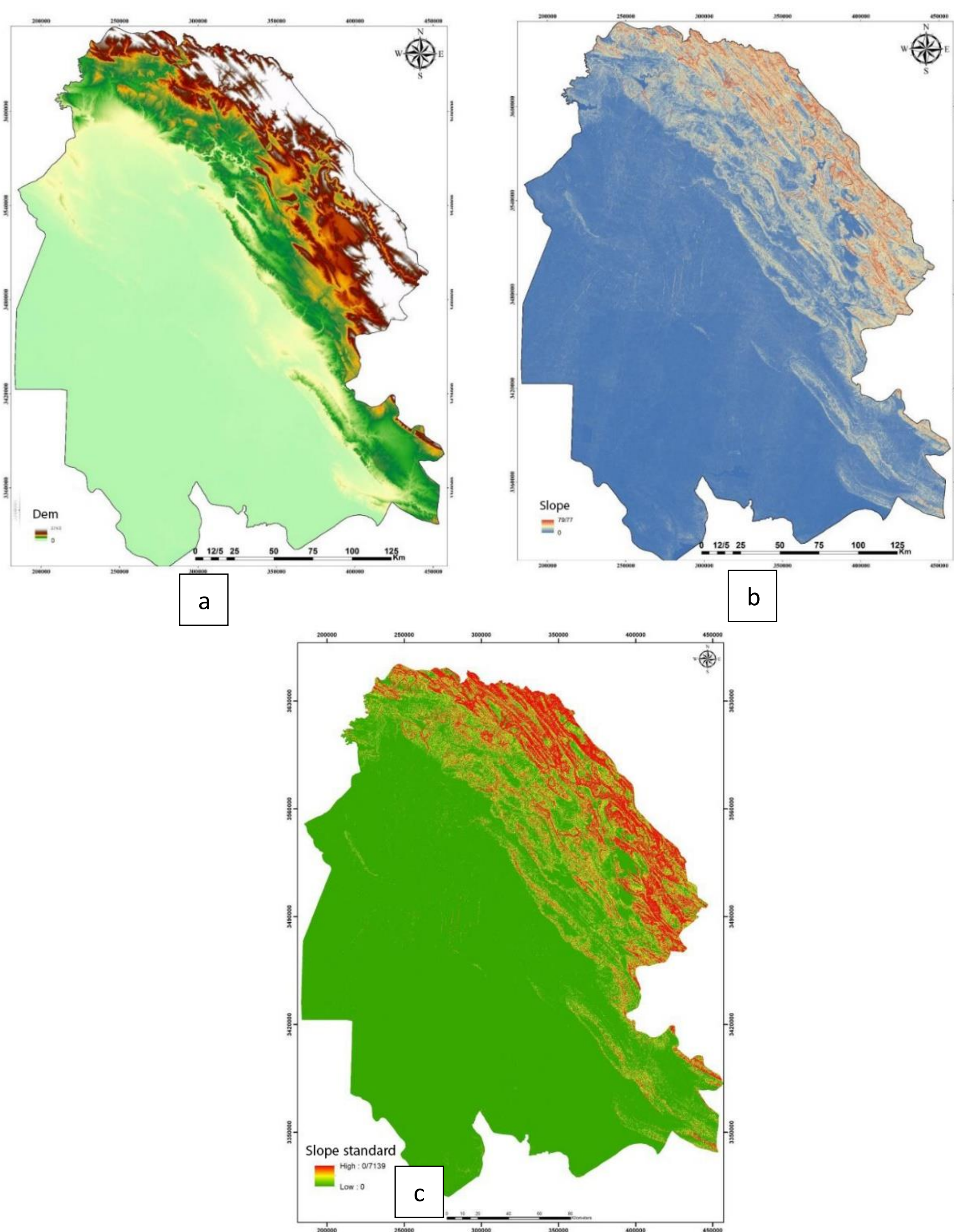

Figure 2. a) Slope map, b) DEM, c) Standardized slope.

3.2.2. Land Usage Layer

This layer demonstrates land use (like agricultural lands, jungles, and residential). The land-usage map Figure 3 illustrates essential information about the type of surface cover of the land, changes and developments made by humans, and the density of the vegetation. This information changes regarding the type of land use, surface permeability, and flood potential. The land use map prepared by the Natural Resources and Environmental Protection Organization of Khuzestan has been used to create this layer. The land use layer is one of the land cover types that shows the surface characteristics of the basin, such as the vegetation of agricultural lands in urban areas, etc. The changes and transformations of the surface cover of the land can create a neutralizing or destructive effect when floods occur. With increasing vegetation, the runoff rate and flood risk decrease and increase as the urban levels increase. For this purpose, the prepared land use layer has been standardized by assigning importance values between zero and one according to expert opinion and field vision. The critical values of different uses and the standardized map of the land use layer can be seen in Table 1.

Table 1. Values of importance of different uses in Khuzestan province.

Application	Weight
Salty and salty lands (Canopy less than 5%)	0
Marsh (Wet areas)	0
Thickets and shrubs (Canopy cover more than 10%)	0.35
Sand dunes (Less than 5% canopy cover)	0.33
Dense forest (Canopy cover more than 50%)	0.1
Thin forest (Canopy cover 5-25%)	0.2
semi-dense forest (Canopy cover 25-50%)	0.15
Dense pastures (Over 50% canopy cover)	0.3
Semi-dense pastures (Canopy cover 25-50%)	0.5
Low-density pastures (Canopy cover 5-25%)	0.6
Sandy areas (Less than 5% canopy cover)	0.33
Uncovered lands and rocky outcrops	0.9
River bed	0.7
Hand-planted forests	0.2
Aquaculture and gardens	0.15
Dry farming	0.3
Water levels	0
Residential areas	1
Reeds	0.15

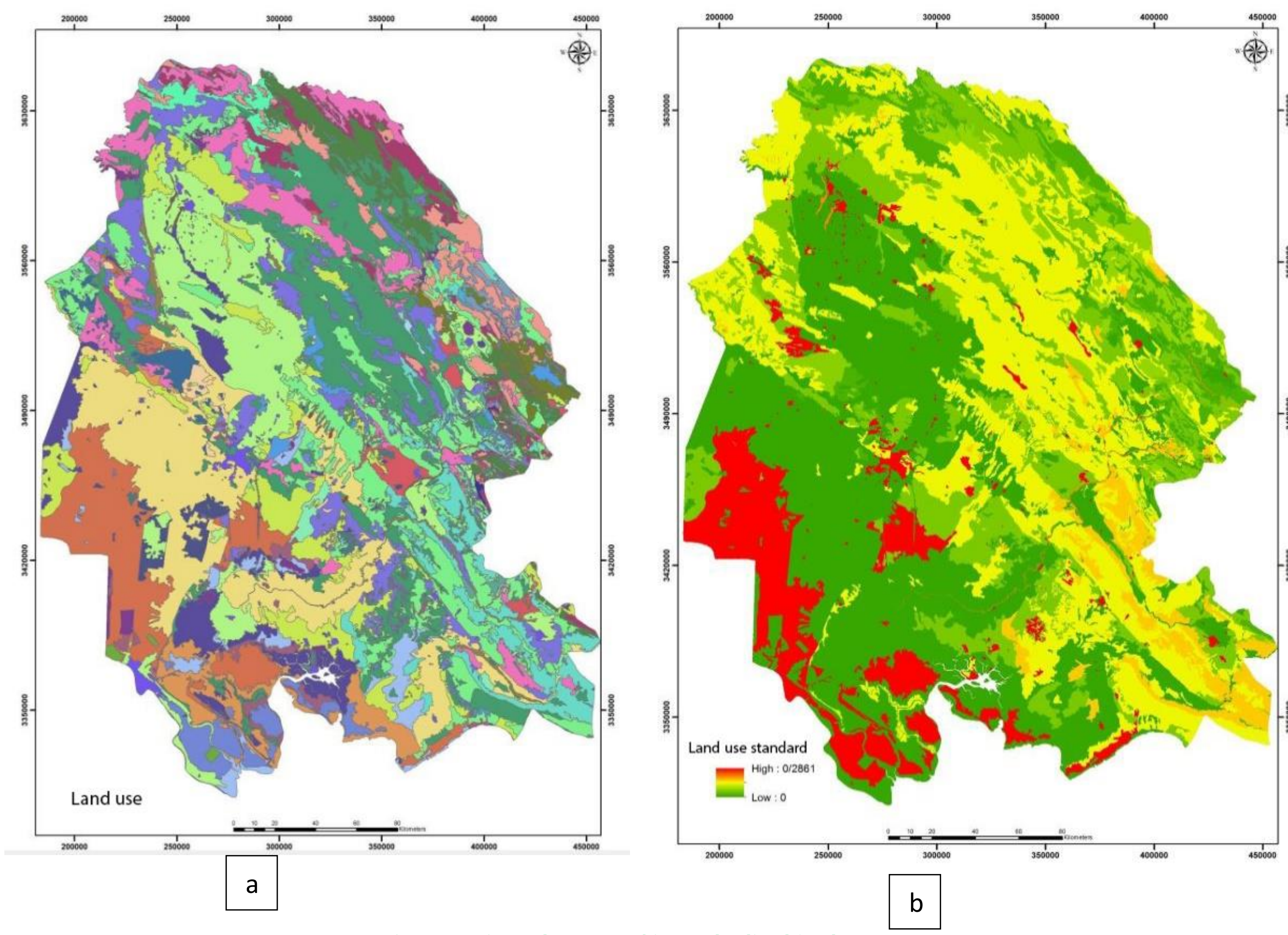

Figure 3. a) Land use map, b) Standardized land use map.

3.2.3. Rain Intensity Layer Processing

Among the precipitation characteristics, precipitation intensity stands among the most critical factors that cause runoff and flooding. If the rainfall's intensity exceeds the infiltration capacity of the watershed, it causes the runoff to flow and causes floods. The more the intensity of rainfall increases, the more the runoff volume is created throughout the basin, and more severe floods occur. This layer is obtained using the average maximum intensity of daily rainfall. The average of the 25 years was prepared in the synoptic stations of Khuzestan province. The rainfall intensity layer is of importance in the flood potential. As the intensity increases, the volume of runoff and flooding will rise. Therefore, a linear and increasing relationship between the intensity of precipitation in the field and the flood potential is observed. Considering that any point with higher rainfall intensity will have more intense floods, the maximum phase membership for this layer is equivalent to the highest daily rainfall intensity (99.1 mm/day), and the minimum phase membership is equal to the lowest daily rainfall intensity (31 mm/day). standardized rainfall map is shown in Figure 4. Average annual rainfall intensity map and its standardized.

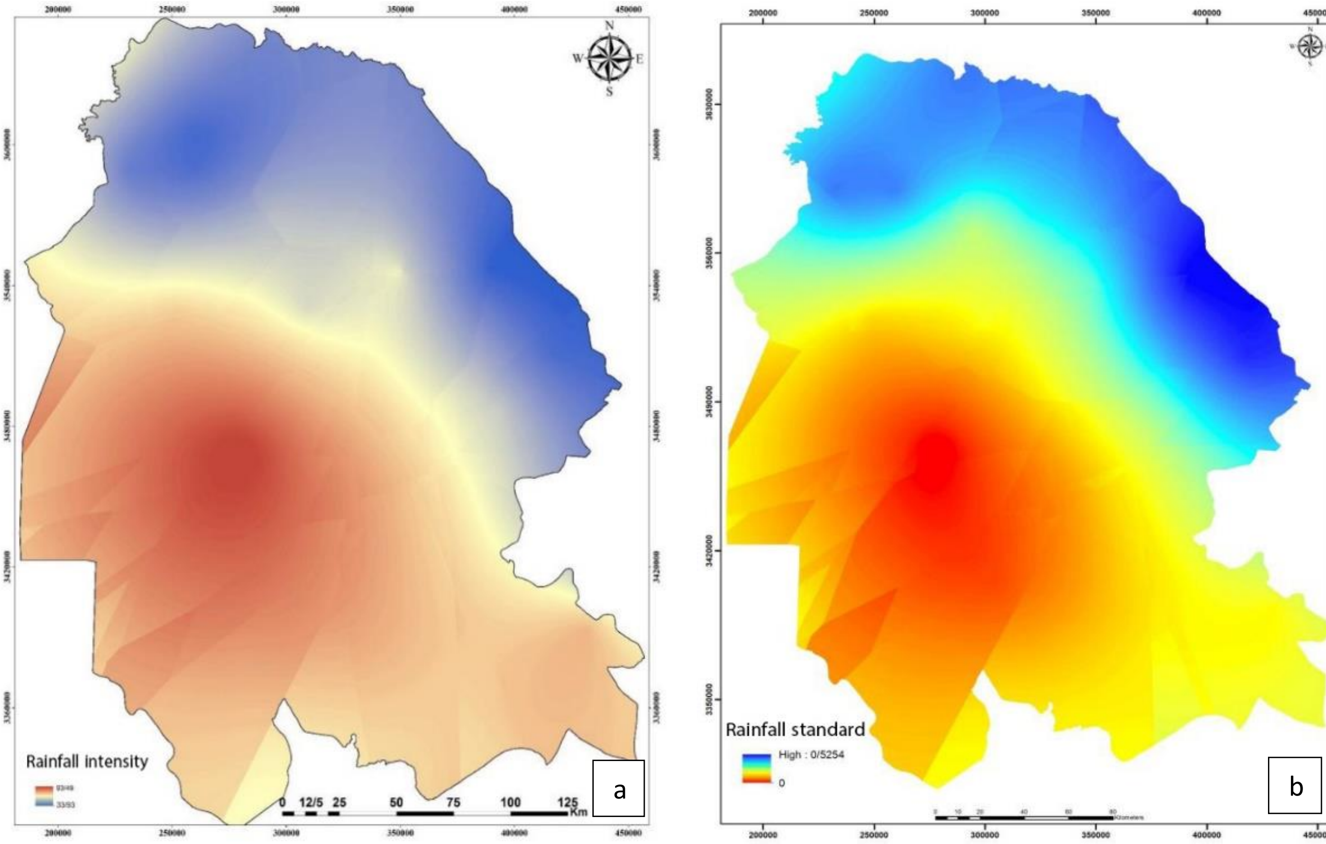

Figure 4. a) Average annual rainfall intensity map, b) Standardized annual rainfall intensity map.

3.2.4. Precipitation Layer Processing

Besides the precipitation intensity, the amount of precipitation is also considered one of the critical meteorological characteristics of the flood potential in an area. Flooding and the amount of precipitation have a direct relationship. Generally, more flooding will occur as the rainfall in one region is more remarkable than in others. The average annual rainfall of meteorological devices of Khuzestan province was used to investigate the effect of precipitation amount on flood zoning. The equation of the precipitation height of Khuzestan province was obtained using the average annual precipitation of the stations regarding the direct relationship between the land surface's height and the amount of precipitation and insufficient regional stations. Afterward, using the obtained equation and the digital elevation model (DEM), the average annual rainfall map of the province was prepared. As mentioned, precipitation is the most critical cause of flooding and is directly related to the increase in altitude and the risk of flooding. In other words, precipitation is the raw material for floods. Therefore, according to the expert opinion and characteristics of the studied area, the linear and ascending membership function was used to standardize this layer. Since there are floods in the areas with the lowest rainfall, this layer's minimum (zero) value was considered lower than the minimum rainfall amount of (175 mm). The minimum value of (zero) for this layer, equivalent to the lowest average precipitation among the stations of the Abadan station, was set to (150 mm) in the function. The maximum value was considered equal to the maximum amount of precipitation in this layer of (14.3 mm) Figure 5 shows a) the average annual rainfall map and b) the standard deviation of annual rainfall map.

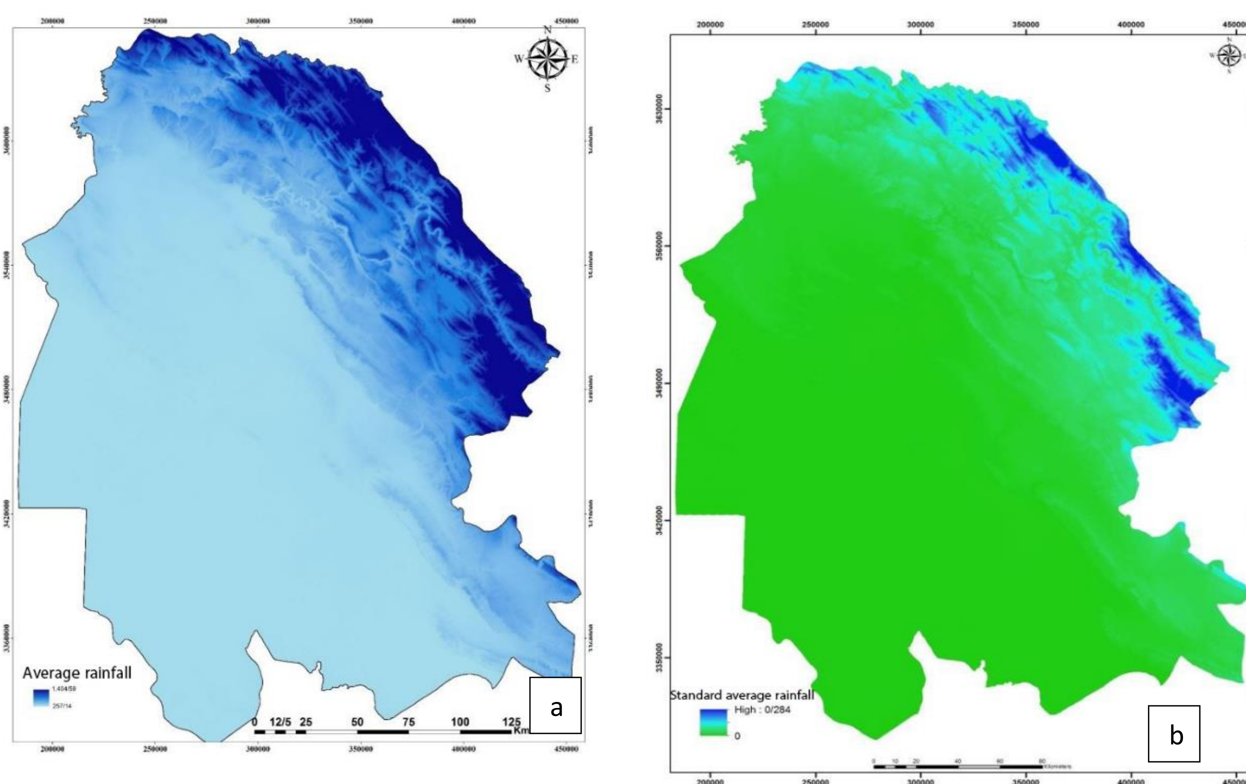

Figure 5. a) Average annual rainfall map, b) Standard deviation of annual rainfall map.

3.2.5. Waterway Compaction Layer Processing

The network of waterways in the basin shows how the runoff is discharged from the basin's surface. The lower the permeability of the basin surface, the more developed the network of waterways in the basin will be. Simply put, the waterways network results from the volume of runoff and floods in an area. Therefore, the more developed the basin channels are, the more flood-prone that bay is. First, the province's waterways shape file, prepared by the Khuzestan Water and Electricity Organization, was combined with the canals obtained from the DEM layers in the ArcGIS environment to prepare this layer. Then the output layer in Google Earth software was verified with actual waterways, adding new channels and excluding the others. After measuring the length of the finalized lines, the density layer of waterways was calculated using the Density function in the ArcGIS environment. This parameter is directly related to flooding. The higher the density of waterways, the higher the runoff performance and faster drainage in the basin. Therefore, the incremental linear relationship has been used to determine the membership of this layer. According to the study area's waterways network, the minimum density of waterways with the potential of creating a flood should be considered zero. This indicates that the area with high permeability or sedimentation basins that could not form a waterway network practically is not flood-prone. Waterway density map is shown in Figure 6.

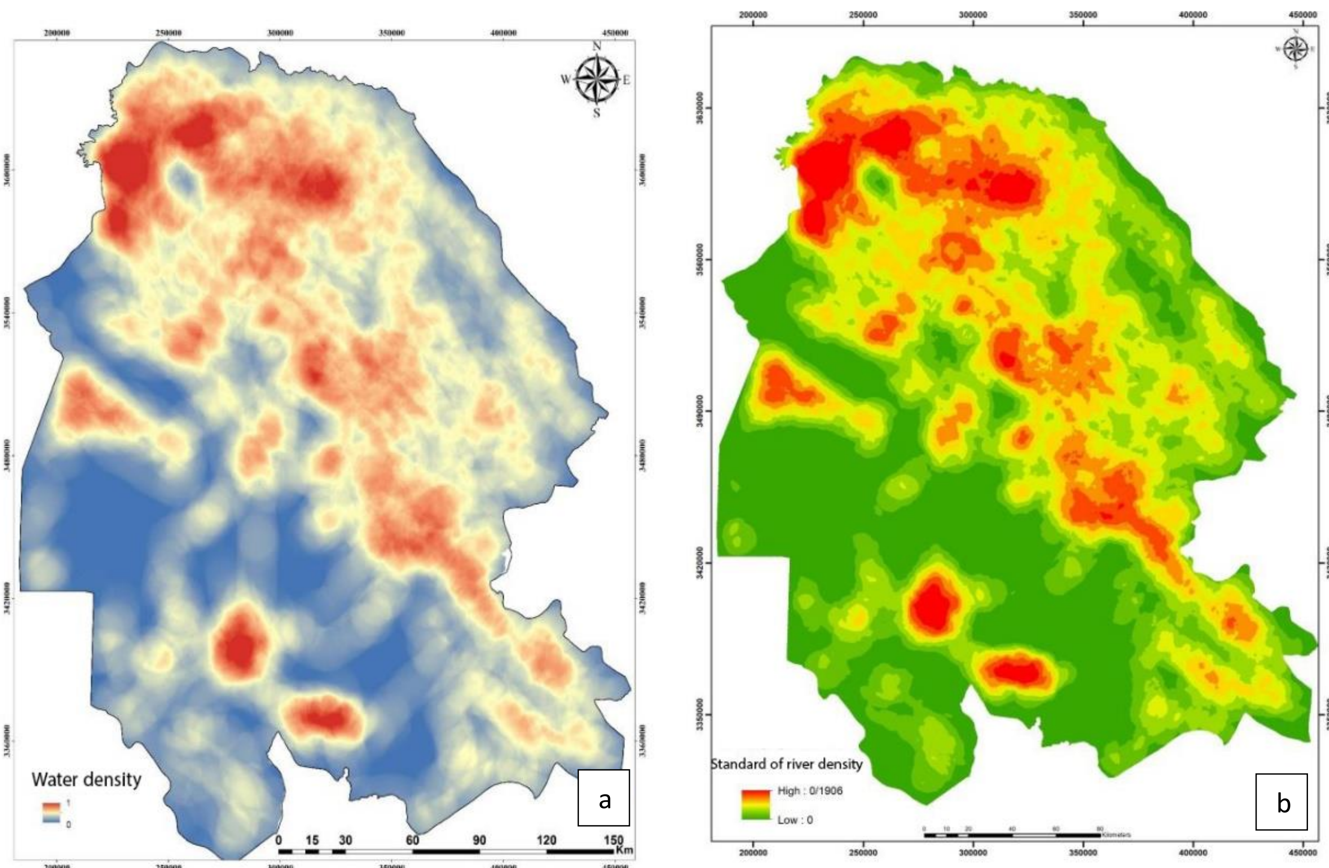

Figure 6. a) Waterway density map, b) Standardized waterway density map.

3.2.6. Geological Layer Processing

One of the influential factors in creating floods is the resistance of the formations that make up the basin's surface against erosion and water permeability, each formation showing a different resistance. The resistance of the formations depends on the constituent minerals composition type, sintering way, porosity of the layering, the outcrop and erosion between the layers, etc. The geological map of Khuzestan province was used to prepare this layer Figure 7 and divide the different lithologies of the basin in terms of flood potential. An essential phenomenon in creating runoff and flooding is permeability. Any factor that reduces this phenomenon will increase runoff and flood. The permeability is more affected by lithological characteristics such as porosity, grain size, layering, and degree of crystallization. Tectonics and structural geology are other factors that cause changes in the permeability of rock units to the extent that it sometimes plays an influential role concerning lithology.

The tectonic factor, applying stress to different rock units, causes faults and fractures. These fractures create secondary porosity in the rock, which causes permeability and eventually reduces flooding. The higher the density of these fractures, the higher the permeability. It is practically impossible to determine the location and measure the fractures, considering the studied area's size. But since the existence of a fracture depends on its fault, on a large scale, it is possible to achieve the highest density of fractures logically by locating the faults and calculating their density. Merging the faults illustrated by satellite images and those drawn in the geological maps of the province, this layer was prepared. Afterward, the distribution map of the faults of the province was obtained. Fault density is a critical geological factor that plays a vital role in surface water infiltration alterations. The higher the density of faults and fractures, the greater the permeability and the lower the flood risk. Therefore, there is a linear and decreasing relationship between these two phenomena. Considering the characteristics of the area and the fact that runoff is formed in areas with a high density of faults and fractures (permeability is not 100%), the minimum value of this layer was considered to be a little higher than the maximum density of faults. Its maximum value was equivalent to the lowest fault density (lowest permeability), zero. In this way, as the density increases from zero, the risk of flooding decreases. The lithology layer is one of the most important for knowing the permeability strength and runoff creation potential from the geological perspective. The lithology layer is prepared using the characteristics of the area's geological formations. It has been standardized by assigning importance values between zero and one for each lithology in terms of flood risk. The assigned values are based on field observations and expert judgment. Matters of lithology importance of Various formations are shown in Table 2.

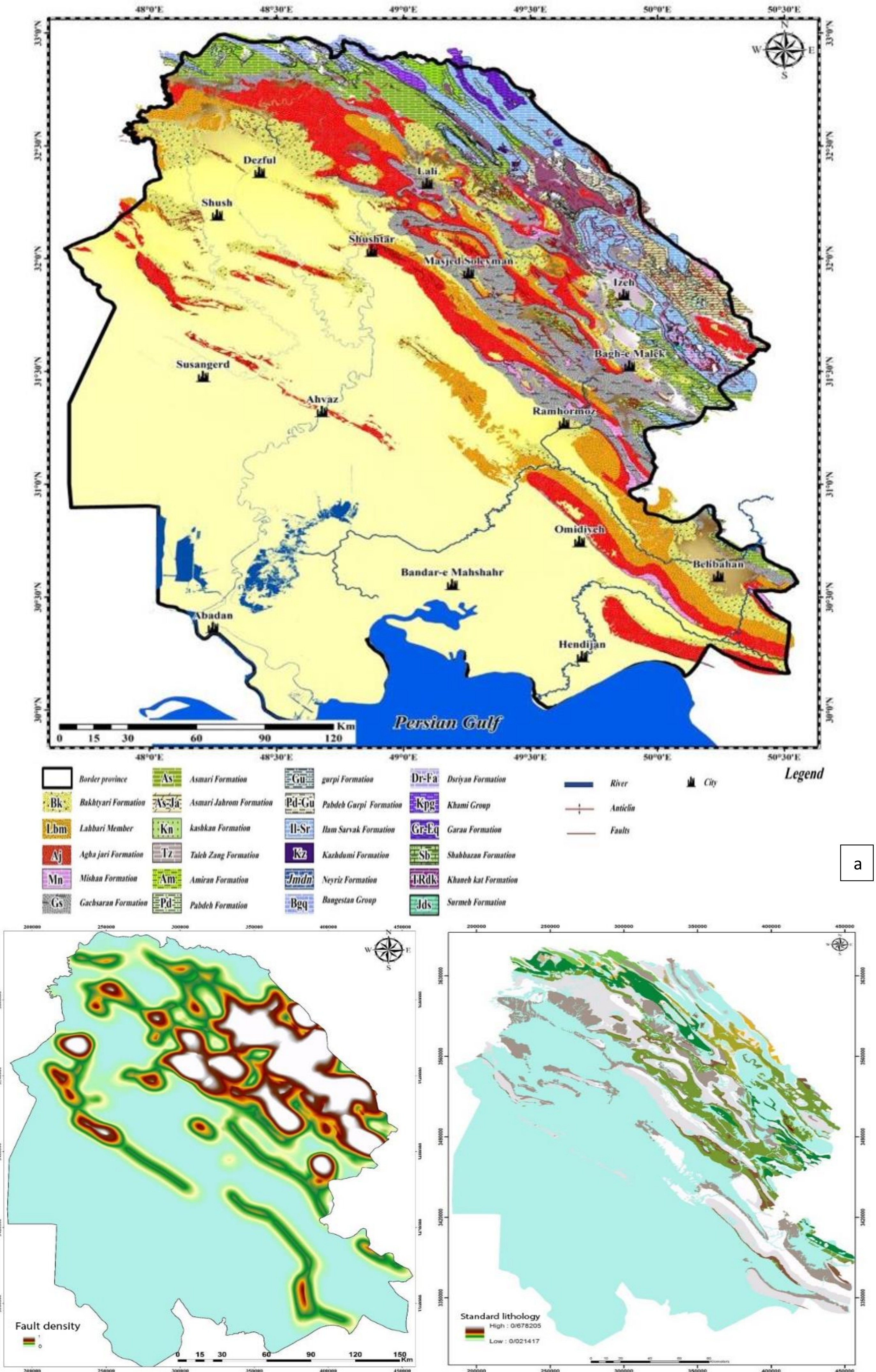

Figure 7. a) Geological layers processing, b) Active faults of the region.

Table 2. Importance values of geological formations in flood potential.

Formation	Weight	Formation	Weight
Quaternary	0.2	Tale Zang	0.5
Quaternary (Sandy sediments)	0.05	Asmari Shahbazan	0.47
Lahbary	0.92	Kashkan	0.83
Nishan	0.75	Shahbazan	0.53
Aghajari	0.89	Darian	0.42
Bakhtiari	0.8	Geru	0.85
Gachsaran	0.45	Emam Hassan	0.8
Gurpi	0.95	Amiran	0.89
Pabde	0.87	Bangestan	0.35
Asmari	0.4	Darian Fahlian	0.44
Ilam Seruk	0.3	Asmari Jahrom	0.45
Kajdomi	0.75	Sorme	0.6
Pabde Gurpi	0.9	Conglomerate	0.15
Landslide	0.32	Razak	0.85

4. Results and Discussion

4.1. Weighting the Criteria

The weight of each factor indicates its importance and value compared to other elements in flood potential zoning operations. Therefore, the conscious and correct selection of weights is a great help in proper zoning. After applying the membership functions to the layers, considering their distinct effect on the flood potential, weighting to Layers becomes crucial. This operation is done using expert knowledge.

4.2. CRITIC Weighting

In this method, expert opinion is not very involved. In the critic method, for each evaluation criterion, there is a range of changes in measured values among pixels (options), which is expressed as a membership function. The changes in the measured values of each criterion are reflected on a vector. The vector carries the measured criteria changes in each pixel (options), expressed in the standardized model. Each vector for the criteria used has statistical parameters, including standard deviation. These parameters represent the degree of difference in the corresponding criterion values. After calculating the standard deviation of the investigated factors and parameters, a different matrix of m * m dimensions is created, which includes the correlation coefficients between the formed vectors. The coefficients are determined by summation of the divided columns, which were the product of contrast and the standard deviation. In connection with the CRITIC weighting method, it can be said that the most critical capability of this method is that the expert is not involved in the calculations, and the data is analyzed based on the amount of interference and conflict and correlation between the criteria. This process of data processing causes the role of each factor to be correctly applied in the final calculation result. In Table 3, the final weight of the criterion proposed in flood risk zoning is stated.

Table 3. The level of conflict, standard deviation and final weight of the criteria proposed in flood risk zoning.

Hazard's name	Information layer	Criterion name	Set of contradictions	Standard deviation	Final weight
Flood	Cover and surface topography	Slope	0.898	94.421	0.209
		Land use	4.698	104.214	0.095
	Hydroclimate	Precipitation intensity	6.889	171.681	0.238
		Precipitation	4.641	268.171	0.135
		Waterway density	0.684	43.559	0.118
	Geology	Lithology	4.668	101.703	0.103
		Fault density	0.719	92.329	0.098

4.3. Overlap

As effective criteria and sub-criteria have different weights and all of them should participate in overlapping, the index overlapping method has been used for this task. In this method, the standardized layer obtained from each criterion (Xi) is multiplied by the weight of that criterion (WJ). This is done for all criteria and sub-criteria, and new layers are created which are overlapped using different functions such as product, SUM OR, AND and GAMA.

$\Sigma wj = 1$

$Ai = \Sigma WjXij$

Following the field and statistical evidence for the zoning of potential floods, and at this stage, the output of the TOPSIS method is considered as the final output.

Among the factors influencing flood occurrence, slope factors, precipitation intensity, and physiographic characteristics stand among the most important ones in causing floods. According to the final output of TOPSIS, these points are flood-prone and high-risk areas. Such places are mainly in the northern to eastern regions and parts of the southeast of Khuzestan province, which corresponds to the steepest and rainiest places. Figure 8 shows the flood zoning of Khuzestan province. Khuzestan province is divided into four areas with high flood potential, which is shown in red, medium flood potential in green, low flood potential in yellow, and places without possibility in blue. As shown, the northern and northeastern regions have the highest flood potential, and as we move through the northeast to the south and southeast of this province, the flood potential decreases. In this research, after identifying the flood-prone areas with high potential, using a strengths, weaknesses, opportunities and threats analysis (SWOT) matrix with the analytic hierarchy process (AHP) weighting method in Expert choice software, strategies were presented to increase the resilience of the residential regions against floods. Table 4 and Table 5 show the SWOT analysis.

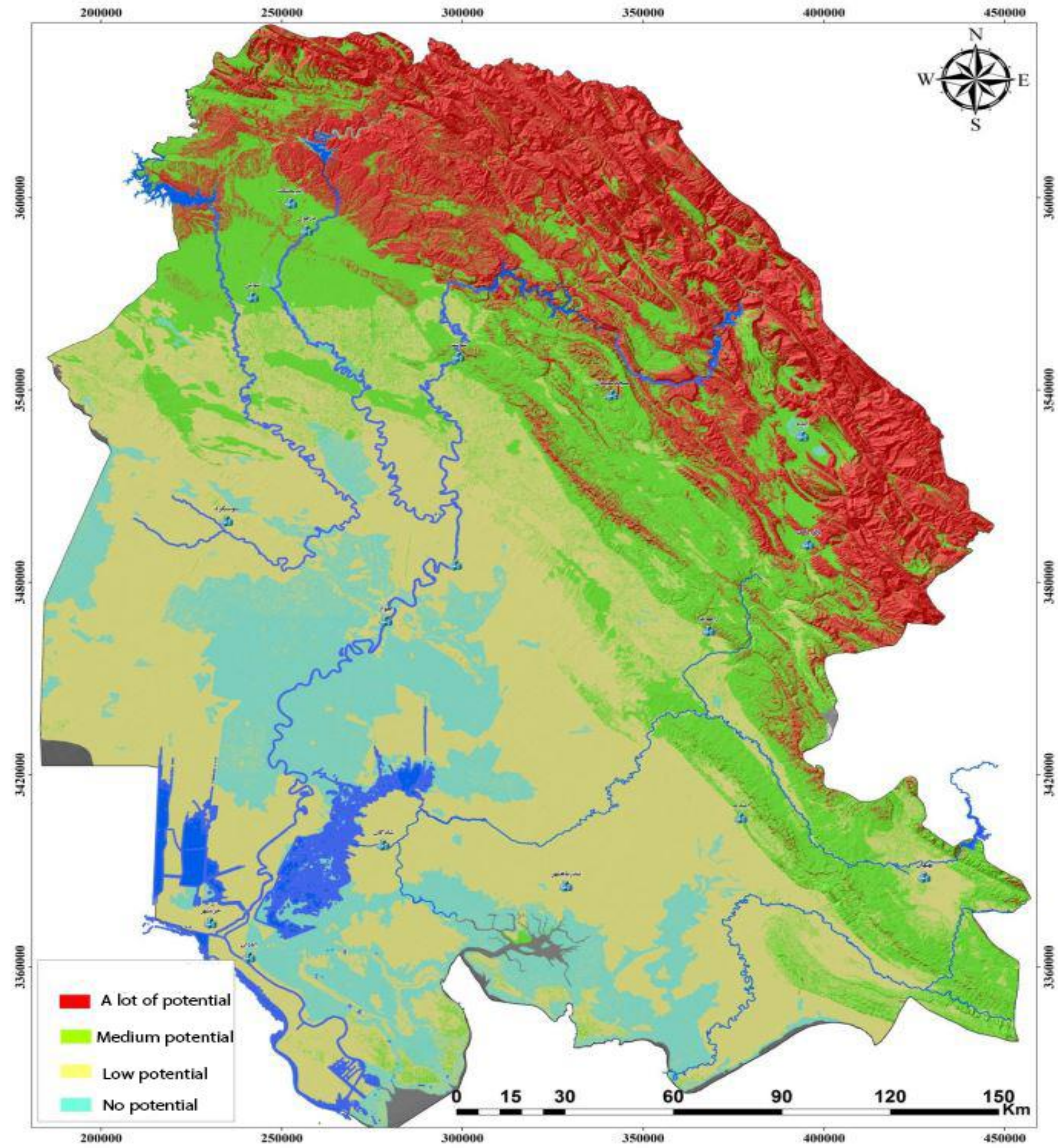

Figure 8. Flood zoning in Khuzestan province.

Table 4. Evaluation matrix of internal strengths and weaknesses.

Row	**Internal weaknesses (W)**	**Score**	**Coefficient (AHP)**	**Final score (Score*coefficient)**
1	Construction in the area of Dez, Karun, Karkheh rivers	2	0.1	0.2
2	Roads inadequate slope to dispose surface water	1	0.085	0.085
3	Insufficient number of surface water disposal channels	2	0.015	0.03
4	Passage of critical infrastructures in the borders	2	0.075	0.15
5	Heterogeneous land use	1	0.025	0.025
6	High potential of flooding in the plains and northern areas of Khuzestan province	2	0.1	0.2
7	High potential of flooding in the eastern basins of the province	1	0.035	0.035
8	High potential of flooding in the southeastern basins of the province	1	0.065	0.065
9	Danger existence in the field of Dez	2	0.055	0.11
10	Danger existence in the field of Karun	2	0.045	0.09
11	Danger Existence in the field of Karkhe	1	0.025	0.025
12	Lack of management coordination between organizations	2	0.035	0.07
13	Lack of preparation for rescue in accidents	2	0.04	0.08
14	No rivers' dredging	2	0.067	0.134
15	Settlements construction in the dams' area	2	0.033	0.066
Row	Internal powers (S)	Score	Coefficient (AHP)	Final score (Score*coefficient)
16	Waterways' density	3	0.055	0.165
17	Faults' density	4	0.045	0.18
18	Low flood potential in central basins	4	0.036	0.144
19	Vegetation in the area	4	0.064	0.256
	Sum	40	1	2.11

It can be seen that the total score of internal factors is equal to 2.11, which is less than 2.5, which indicates that there is an internal weakness based on our existing plan.

Table 5. Evaluation matrix of points of external threats and opportunities.

Row	External threats (T)	Score	Coefficient (AHP)	Final score (Score*coefficient)
1	Heavy rainfall with long return periods	1	0.134	0.134
2	High gradient upstream	2	0.1	0.2
3	Low flood potential in central basins	2	0.066	0.132
4	Lack of dams in the upstream of the province (Lorestan province)	2	0.06	0.12
5	High flood potential in upstream areas	1	0.041	0
6	The period of abundant returns of rainfall in the upper reaches of the province	2	0.058	0.041
7	The impact of global warming and climate change in the last 2 years	1	0.17	0.116
8	Soil erosion in the upstream	2	0.121	0.17
9	No dredging of rivers in the upstream	2	0.05	0.242
Row	External opportunities (O)	Score	Coefficient (AHP)	Final score (Score*coefficient)
10	Construction of dams	4	0.079	0.316
11	Presence of specialist for flood planning	4	0.121	0.484
Sum		23	1	2.05

In the matrix of external factors, it can be seen that the sum of external points is equal to 2.055, less than 2.5, which indicates unfavorable conditions of this sector. This means that external threats are mostly threatening the plan. Results show a 0.055 difference in the obtained value meaning that the internal factors are in a better condition than the external factors. Table 6 shows the Summation of internal and external factors

Table 6. Summation of internal and external factors.

Internal factors		External factors	
Strength (S)	Weakness (W)	Opportunity (O)	Threat (T)
0.745	1.365	0.8	1.155
Coefficient summation of composite factors			
SO	WT	ST	WO
1.545	2.52	1.9	2.165

4.4. Implementation Suggestions and Solutions

As it can be seen, the largest number obtained is related to the WT factors of the project's weaknesses and threats. Considering that, defensive strategies should be adopted and the project's position is in a risky state. Therefore, we suggest the following strategies:

1. Using prefabricated dams for use in critical times and increasing resilience.
2. Continuous dredging of rivers (once a year).
3. Conducting studies to reduce losses through crisis management.
4. Preparing to bear losses (increasing resilience).
5. Strengthening the position of risk management instead of crisis management in future floods.
6. Certificating geotechnical and engineering characteristics of important structures (dams, bridges, main roads, industrial towns, power plants, etc.)
7. Identifying and revising technical sanctuaries of rivers based on sedimentological and morphological components as a support for hydrometric device data.
8. Comprehensive studies of the erodibility of rock units by basin and climate.
9. Obligation to carry out watershed plans.

Suggestions for increasing flood resilience include flood mitigation through watershed-level construction methods such as:

a. Use of water containment method with water
b. Use of dry dams
c. Use of wipp walls
d. Use of diversion dam
e. Use of dams
f. Pi Ting
g. Use of reservoir dams
h. Farrowing
i. Banquet
j. Use of protective walls
k. Use of diversion channels

2) Flood reduction through construction methods specific to urban and rural areas such as:

a. Use of water gate device
b. Use of Quick Dam
c. Use Flood Block
d. Heritage Flood guard

3) Flood reduction through low-impact development methods to dispose of runoff:

a. Vegetative swale
b. Porous asphalt
c. Permeable pavement (Porous pavement)
d. Filter strip

4) Management strategies for mitigating the effects of floods:
a. Careful and sufficient attention in complying with the rules and standards of urban development
b. Observing the privacy of waterways and rivers and flood plain zoning
c. Continuous control of the floodplain
d. Non-interference in canals and manipulation of water passages
e. Creating permeable surfaces in the city and not converting open lands into urban structures
f. Converting low lands and pits of big cities into parks and green spaces
g. Modifying the course and section of the river
h. Reducing the slope of the river
i. Grading of canals and rivers
j. Flood spreading
k. Watershed management
5) People's participation strategy in flood crisis management cycle:
a. Public information and education
b. Specialized training
c. Building trust between people and officials in flood management
d. Handing over some local land management affairs to the people

5. Conclusion

Khuzestan region has a special place due to its prominent features of flooding. The investigation of the current situation shows that despite the efforts being made, the climatic and environmental conditions of the rivers, the settlements of the infiltration basin, the existing spaces, and the constructions carried out in the sanctuaries of the rivers as well as the incorrect location of the infrastructures, has created challenges in the management of the current situation in the various components of construction management. Therefore, this research was conducted according to the existing challenges and the country's planning approach regarding the flood issue. In this article, considering the slope of the land, land use, density of faults and fractures, geology, the density of waterways, amount of precipitation, and intensity of rainfall, the zoning of Khuzestan region against floods using TOPSIS and Fuzzy weighting methods was done using GIS. The research results showed that the northern, northeastern, and southeastern parts have high potential compared to other areas in terms of floods. Then, using the SWOT model, strategies and practical suggestions were introduced to increase the resilience of this region against floods. The model of this research and the results of this research, while being used in the studied area, are also applicable in other areas.

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