Future Technology
Open Access Journal
ISSN 2832-0379

May 2024| Volume 03 | Issue 02 | Pages 11-21

Journal homepage: https://fupubco.com/futech

https://doi.org/10.55670/fpll.futech.3.2.2

Future Publishing LLC

Article

Earthquake, flood and resilience management through spatial planning, decision and information system

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ARTICLE INFO

Article history:
Received 16 July 2023
Received in revised form
18 August 2023
Accepted 26 August 2023

Keywords:
Flood zoning, Earthquake zoning, Resilience

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DOI: 10.55670/fpll.futech.3.2.2

ABSTRACT

Assessment and planning of crisis management with the natural disasters approach include many components. In this regard, floods and earthquakes are some of the fundamental pillars in this field. With this view, paying attention to the current and future planning and research priorities of the world shows that crisis management in flood-prone and earthquake-prone areas and increasing resilience are the most important priorities for sustainable development studies and planning in the world. The western region of Iran (Lorestan province) has a special place due to the prominent features of flood and seismicity. This study aims to investigate the current situation regarding floods and earthquakes and increase the resilience of settlements with emphasis on the study area. After studying the current structure of flood and earthquake zoning according to multi-factor criteria, zoning was performed based on the integration of GIS and AHP information systems, and at the output of the work, high-risk settlements were determined separately for rural and urban areas with geographical coordinates, and then areas with low, very low, medium, high, and very high resilience were presented separately for rural and urban settlements. Also, after analyzing the SWOT model, strategies to increase the resilience of settlements to floods and earthquakes were presented. The study method of this research and the results, strategies, and operational options presented while being used in the study area are also applicable in other areas.

1. Introduction

Evaluation and planning of crisis management with the approach of natural earthquake disasters include many components. In this regard, one of the fundamental pillars of construction management is based on resilience [1]. With this view, paying attention to the world's current and future planning and research priorities shows that construction management in earthquake-prone areas is one of the most critical priorities for sustainable development studies and planning in the world. According to the studies, Iran is one of the earthquake-prone areas, and according to the earthquakes that have occurred, a lot of casualties and infrastructure have been witnessed in Lorestan province [2]. The study of residential constructions in the study area shows that with the construction management approach, many buildings have been built and are being built in this area, which has many challenges from the crisis management approach [3]. In this regard, the main direction of earthquake zoning research in the Lorestan region is to develop strategies to increase resilience. Earthquake is one of the most devastating natural disasters due to its unpredictability. In the last thirty years (1990-2020), seven hundred and six earthquakes have occurred worldwide, killing 380,000 people and causing significant material damage [4]. Approximately, 77% of these casualties were in China, Iran, Pakistan, Russia, India, and Turkey [5]. Evaluation is one of the most effective solutions to reduce the effects of earthquakes. Assessing the vulnerability of existing buildings is a kind of prediction of their damage in the face of possible earthquakes. Seismic hazard assessment is related to four elements: seismic hazards, hazards, location, and vulnerability. A flood is a combination of short currents in a particular place with a steep slope that usually occurs in impermeable and low-strength rocks and formations and consists of three main parts: catchment area, waterway, and alluvial fan [6]. All rainfall in the catchment area is combined into small streams to provide considerable flow in a large stream that is narrow and somewhat long [7]. The basis of the formation of irregular discharges due to sudden and heavy rains is often in the form of showers that occur in feeble and intermittent currents [8]. Floods are characterized by solid detection currents that arise after each storm on bare and unstable ground and in waterways that have been previously dug by water currents and often on steep mountain slopes and are often highly destructive in terms of severity [9]. Therefore, most villages and towns located at the foot of the mountains are constantly at risk of this phenomenon [10]. There are two major natural disaster risk reduction types: Structural and non-structural risk reduction, often referred to as hard and soft risk reduction [11]. Structural risk reduction (hard); This type of risk reduction involves the strengthening of buildings and infrastructure at risk in various ways (building codes, design, advanced engineering, advanced construction technology, etc.). Non-structural risk mitigation (soft); This type of risk mitigation includes directing development away from known hazardous areas or high-risk sites, moving existing product that is likely to be frequently damaged to safer areas, and maintaining more protective environmental features normal. For example, dunes, forests, and vegetated areas can absorb and reduce the effects of hazards through land use plans and regulations. Non-structural risk reduction also includes addressing the specific needs of at-risk populations. This category includes housing needs as well as other quality-of-life issues. While it is often more difficult to implement non-structural risk mitigation, this type of hazard mitigation has tremendous value in reducing risk and costs [12].

The application of the concept of resilience to natural hazards was initially considered a legal argument in assessing natural hazards. While Eiser et al. suggested resilience to a community's ability to recover using its resources [13], Cox et al. [14] also focused on community resilience, describing it as a process of linking adaptive capacities (such as social capital and economic development) to responses and changes after adverse events. In this regard, resilience is a set of capacities that can be developed through interventions and policies, which help build and increase society's ability to respond and recover, and achieve improvement from risks. One very different concept is risk engineering resilience, emphasizing buildings and critical infrastructure resilience. Shakou et al. [15] proposed a resilience framework with an emphasis on structural modification, in particular, the concepts of engineering systems that include robustness, excessive frequency, resourcefulness, and speed of action. Recent research has focused on flexibility and resilience from a national security perspective, primarily on protecting critical infrastructure from terrorism and resilience on critical infrastructure. Assuming that resilience is the result of measuring an ultimate goal of limiting damage to infrastructure [16]. Disaster resilience is important to understand and reduce the damage caused by natural hazards [17]. Due to different types of hazards and different spatial characteristics, it isn't easy to get a general and uniform understanding of the resilience of other geographical areas. But disaster resilience must be constantly considered, and the resilience of vulnerable areas must be improved. Disaster resilience analysis requires physical, socio-economic information of many places, each of which has a unique geographical location. While there are currently three problems for researchers in the field of resilience studies:

- At the conceptual or perceptual level, resilience from a geographical point of view lacks a clear explanation.
- At the operational level, modeling the resilience of individual, group, and community behavior in a single framework is difficult.
- At the application level, resilience can hardly be transferred at different spatial scales.

The resilience models used so far are shown in Table 1. The components of resilience in infrastructure used by previous research are listed in Table 2.

In this research, Lorestan earthquake and flood zoning is done in the GIS system, and strategies to increase resilience are presented. Compared to other studies, the innovation in this study is the use of new approaches and the integration of quantitative and qualitative models in evaluating and presenting resilience strategies against floods and earthquakes.

2. Methodology

The type of research is applied in terms of purpose and descriptive-analytical, and exploratory in terms of method and nature. Descriptive-analytical research is divided into two categories in-depth and expansive research [38]. This type of research is also called survey research.

2.1 Seismic zonation of Lorestan

Different layers of information and sources were examined. According to the factors affecting the occurrence of the earthquake and based on the characteristics of Lorestan province, the following factors were selected as effective factors.

- Fault: This layer includes all faults in the area that are separated from active and inactive fault maps. According to the regulations approved by the Ministry of Housing and Urban Development, the boundaries of the main faults are 1000 meters, and sub-faults are 300 meters on each side. Therefore, in these borders, the creation of any building and any activity accompanied by crowds should be prevented.
- Earthquake centers: This layer is based on the epicenter of earthquakes that have occurred in the past. If we draw a vertical line from the epicenter of the earthquake that is inside the earth to the surface of the earth, the place where this line collides with the earth's surface is called the center of the earthquake.

2.2 Flood zonation of Lorestan

In general, the steps of the current zoning were done in the form of two main steps; Collecting the required data and preparing information layers. At this stage, by reviewing the previous data, the necessary data and information have been collected from various sources, and adequate information layers on flooding have been prepared.

Table 1. Disaster resilience models

Model	Property
Tobin model [18]	This model has been proposed to study and evaluate the resilience of communities located in high-risk areas, the framework of which is more ecological. To show how the society is stable and resilient, three models: risk reduction to study risk reduction plans, recovery model to recover physical capital structure, public and private attitudes, and strategies, and finally, structural-demographic model to study the factors of structural and material changes. Culturally and economically used. These are interrelated and affect sustainability goals; Finally, in this model, the characteristics of a stable and resilient society are introduced. The ultimate goal of this framework is to achieve the degree of sustainability and resilience of communities to technological and natural hazards. The focus of this model is on risk reduction in such a way that sustainable and resilient societies are societies that structurally reduce the consequences of disasters and rapid recovery by rebuilding vital socio-economic factors of society.
Linear-temporal Davis model [19]	According to the definition of resilient society, it shows that a country or a large urban area in the form of a timeline in specific circumstances following development can improve its vulnerability over time. This model has three stages: Absorption and tolerance of stress and impact before the accident Return to balance after a disaster means the ability and capacity to go back during and after disasters changes in societies to make them safe and resilient.
Spatial model (DROP) [20]	Designed to provide the relationship between resilience and vulnerability, a comparative assessment of disaster resilience at the local and community levels. This model defines resilience as a dynamic process dependent on previous conditions, the severity of disasters, time between risks, and extroverts' effects. The first step of this model is to provide a proposed set of infrastructural, social, economic, and institutional variables. The next step in this model is to operate and create a set of indicators and then examine it in the real world.
Baseline index model [21]	This model provides a methodology and a set of indicators for measuring the existing effective conditions for disaster recovery in communities. Its method is to use a hybrid index to determine and achieve specific variables to create a collective scale of resilience. To determine the indicators from the spatial model of resilience (DROP) in which the relationship between vulnerability and resilience is determined and also focuses on the previous conditions, and based on the dimensions of resilience, the desired indicators were formed from these dimensions and used for analysis; Finally, this model gives the results of a quick comparative overview of which methods and dimensions in resilience-based indices are needed more than others; It also determines what infrastructural, economic, institutional, and physical interventions contribute to the overall well-being of society.
Community Based Disaster Management (CBDM) [22]	This model is a bottom-up management approach that focuses on people's participation in solving disasters caused by natural disasters, which aims to reduce communities' vulnerability and strengthen people's capacity and participation to deal with the risks of natural disasters.

Geological maps of Lorestan province, digital elevation model of Lorestan province (DEM), land use map, hydrometric information and waterways of the region, and rainfall data have been collected. The collected information has been analyzed using the GIS system, and the decision tree diagram has been compiled as criteria and sub-criteria. The effective boundaries of each criterion are identified in flood potential and weighted and standardized by the analytic hierarchy process (AHP) method. The degree of importance of the criteria is estimated, and a flood zoning map is prepared by combining all criteria. Different layers of information and sources were examined. According to the factors affecting the occurrence of floods, based on the characteristics of Lorestan province, the following factors were selected as influential factors:

- Slope: This layer is the topographic slope of the area. Land use: This layer includes various natural and unnatural benefits.
- Rainfall: This layer includes the average annual rainfall in different areas of the province
- Waterway density: This layer includes the main and secondary waterways of Lorestan province.
- Soil erosion: This layer contains geological information and soil formations.

2.3 Resilience zonation of Lorestan

Different layers of information and sources were examined. According to the factors affecting resilience and based on the characteristics of Lorestan province, the following factors were examined as effective factors for zoning resilience in Lorestan province.

- Distance from flood areas: This factor was considered so that according to the results obtained in flood-prone zoning, the closer it is to the areas that had a very high and high potential for flooding, the less its resilience and the less to areas with less risk. In terms of flooding, the closer it gets, the more its resilience increases.
- Distance from seismic areas: This factor was considered so that according to the results obtained in the seismic zoning of the region, the closer it is to the areas that had very high and high seismic potential, the less resilience

and the closer to the areas where the risk is less seismically, the higher the resilience.

- Distance from main roads: Main roads play a significant role in resilience during natural disasters such as floods and earthquakes. Thus, when faced with a crisis, communication channels play a very key role in restoring the performance of infrastructure and residential areas to their pre-crisis state, and the closer the crisis area is to the main roads, the more possibility of providing assistance to those areas from other provinces and the other regions that are not in crisis are more easily done. In other words, the reconstruction of crisis areas and the return to the pre-crisis state in these areas take less time. As a result, the closer the surveyed areas are to the main roads, the more resilient those areas will be.
- Distance from open spaces and shelters: Distance from open spaces and shelters Outdoors plays an important role in the aftermath of a crisis, so much so that after a crisis, the possibility of transporting the injured and using this type of space as an emergency accommodation is one of the most important indicators in the study of resilience.

2.4 Criteria weighting using Analytic Hierarchy Process (AHP) technique

After selecting the effective criteria in zoning to combine them in the form of information layers, the weight of each criterion should be determined in proportion to their importance following one of the weighting methods [39]. Given that some of the selected criteria are quantitative and some qualitative, we must use a method that can compare and quantify quantitative criteria with qualitative, which is one of the weighting problems in multi-criteria decision-making. The given weight is included in the evaluation as a number, which indicates the relative importance of that criterion compared to other criteria.

In this research, a hierarchical analysis method has been used to weigh the criteria.

2.5 Combining effective layers

One of the essential stages of zoning after determining the criteria and weighting is that the information layers are combined using a suitable method [40]. This operation can be a spatial operation that combines several geographical layers, and then the information is Slow, defined. In order to produce a map of Lorestan's vulnerable zones, the system analyzer was entered into the GIS environment. The weights obtained in the adequate zoning layers were multiplied, and obtained each criterion's coefficient in the Arc map environment using the Raster command. The calculation of the coefficients for each standard in the scoring map is multiplied by the same criterion. Then all these multiplied maps in the coefficients get Over Lay and scalarly obtained, and a final map is obtained in which each pixel has a specific value. The combination of sub-criteria together is such that the weight obtained from the AHP method in expert choice software for each sub-criterion in the relevant layer was performed by the RASTER CALCULATE command in ARC GIS software, and the final Lorestan earthquake, flood, and resilience maps were obtained. According to the weighting done, it is observed that the standard weight of an earthquake has the highest weight in resilience, as shown in Figure 1, because it is related to human lives and also because the financial damage it causes is much more than other crises.

2.6 SWOT Matrix

By Comparison pair of internal strong points, a comparison pair of internal weak points, a comparison pair of external opportunity points, a comparison pair of external threat points, and a pairwise comparison of external threats, the SWOT matrix will be reached in Table 3.

Table 2. Components of resilience in infrastructure

Emergency service centers (fire, emergency)	bridges	buildings	IT infrastructure	Infrastructure (water electricity, gas)	Wastewater	Transport network	Dimensions of resilience
		*		*	*	*	Fleischhauer [23]
				*	*	*	Burby et al. [24]
				*	*		Mitchell et al. [25]
	*					*	Saunders et al. [26]
*		*	*				Sharifi et al. [27]
*		*					Rega et al. [28]
						*	Meshkini et al. [29]
		*			*	*	Nakanishiet al. [30]
*		*	*				Pokhrel et al. [31]
				*	*		Mehmood et al. [32]
				*	*		Brugmann [33]
*				*	*	*	Lunecke [34]
				*			Johnson [35]
				*	*	*	Villagra et al. [36]
*			*	*	*	*	Sharifi et al. [37]

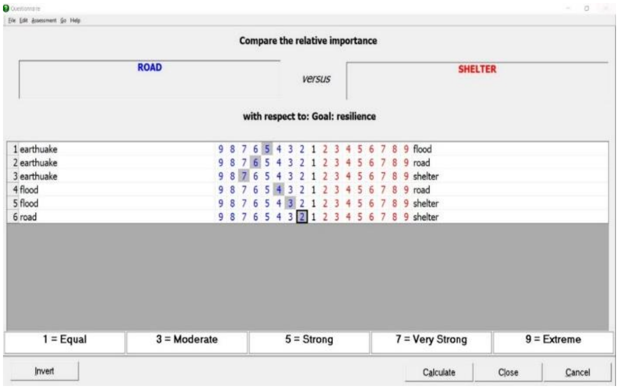

Figure 1. Weight of criteria obtained in expert choice software

Table 3. SWOT matrix strategies [41]

	Strong Points	Weak Points
Opportunities	SO Strategy	WO Strategy
Threats	ST Strategy	WT Strategy

SO strategy: By using internal strengths, external opportunities can be exploited, or in other words, the strategy is to make maximum use of environmental opportunities by using the strengths of the organization or system.
ST Strategy: Reduce the effects of external environmental threats by using strengths or, in other words, usage strategies maximum strengths to avoid threats.
WO strategy: Maximizing the opportunities in the external environment to improve internal weaknesses, or in other words, the strategy of compensating for the existing weaknesses by using the benefits that lie in the opportunities to compensate for the weaknesses, is the function of the WO strategy.
WT strategy: Reducing internal weaknesses by avoiding external environmental threats or in other words minimizing the damage caused by threats and weaknesses with the aim of reducing internal weaknesses and avoiding external environmental threats is the function of WT strategy.

3. Results and Discussion

3.1 Seismic maps of Lorestan

The earthquake center layer is based on historical earthquakes that occurred in Lorestan province. The occurrence of a large number of earthquakes in a place that has almost no faults indicates the possible presence of hidden faults in this part of the region. Therefore, increasing the thickness of the crust in these areas is an effective factor in hiding faults affecting the seismicity of the province. Figure 2 shows the map of Lorestan's active and inactive fault layers, standardization of the density layer of Lorestan faults, Lorestan earthquake centers, and standardization of the density layer of earthquake centers. Lorestan seismic zonation layer was obtained by combining the standard fault density and earthquake center density layers with the RASTER CALCULATE command in ARC-GIS software. Figure 3 shows the final Seismic zonation of Lorestan.

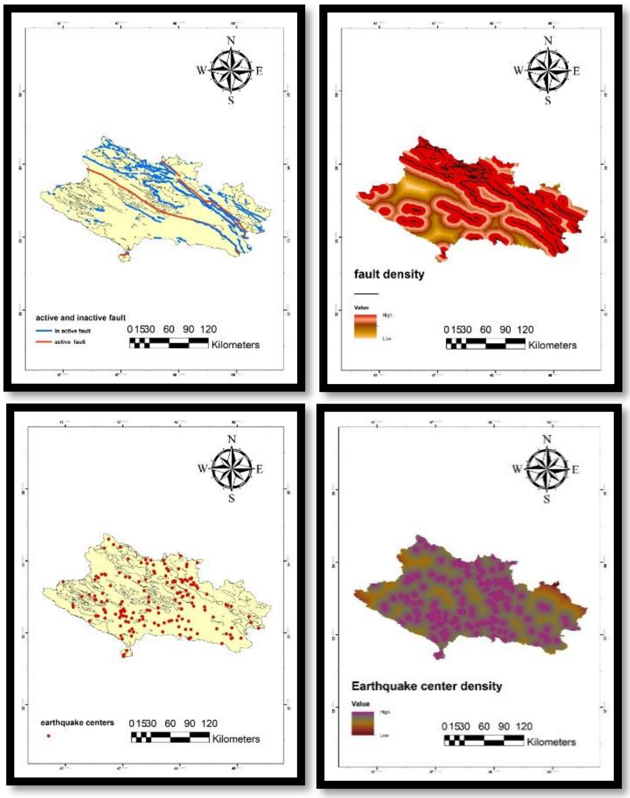

Figure 2. Map of Lorestan active and inactive fault layers, standardization of the density layer of Lorestan faults, Lorestan earthquake centers, and standardization of the density layer of earthquake centers

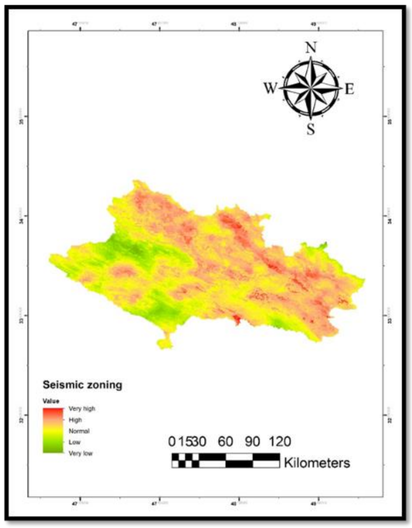

Figure 3. Finale seismic zonation map of Lorestan

According to the seismic hazard zoning map, it can be seen that the eastern and northeastern regions of Lorestan have the highest seismic hazard. The further we go to the province's west, the seismic hazard decreases. The cities with the highest seismic hazards are: Borujerd, Aligudarz, Durud, and Azena. Cities with moderate seismic hazards are: Khorramabad, Dore, and Selsele. The cities with the lowest seismic hazard are: Delfan, Kohdasht, and Poldokhtar. In areas with less seismic risk, it does not mean that these areas are completely safe against earthquakes, and this issue is expressed compared to other areas of Lorestan. As can be seen on the map, most earthquakes occurred in areas with active faults, but in addition, areas such as the north of Poldakhtar, Bakhtar Kuhdasht, and parts of Khorramabad are the focus of earthquakes. Probably, this phenomenon can be attributed to the existence of hidden and covered faults under sediments, which despite their activity, did not have a surface outcrop.

3.2 Flood maps of Lorestan

In addition to the verification performed with field evidence and the ongoing floods, the comparison and analysis of the prepared map with the previous research of the flow statistics of hydrometric stations is another proof of the accuracy of the zoning. Among the factors influencing the occurrence of floods, slope factors, rainfall intensity, and physiographic characteristics are the most critical factors in causing floods. According to the final output, these points are flood-prone and high-risk areas. Such issues are mainly in the eastern parts and parts of the northeast of Lorestan province. The map of different layers for flood zoning is shown in Figure 4. By combining the five flood criteria types, the final flood map of Lorestan is achieved, as shown in Figure 5.

3.3 Resilience maps of Lorestan

According to the standardized map of the main roads, as we move from the green areas to the red areas, due to moving away from the main roads, the reduction decreases considering this index. The status of the study area in terms of outdoor access is shown in Figure 6. The study of the geographical location of this index shows that the Lorestan region is in a favorable condition in terms of access to open spaces, and in general, there are two protected shelters in this province, one with an area of 90186.3 hectares in the east of the province and the other with an area of 71214.6 hectares in West of the province, according to the standardized map, the closer the affected areas are to the shelters, the sooner the relief operation will be carried out, and the more favorable the situation will be in terms of resilience. After weighing criteria in GIS with raster calculation, the final resilience map of Lorestan is achieved, as shown in Figure 7.

To prepare an external factors evaluation matrix, it is necessary to perform the above steps. The difference is that in this matrix, on the one hand, the factors that cause the opportunity and situation of development in the future. On the other hand, the external factors that threaten this development are listed in this matrix. In the next step, after coding each of the factors in the internal and external matrices with a systemic approach to these factors, as shown in Tables 4 to 7, the appropriate strategies are determined as a combination of the mentioned factors in the form of SWOT 4-cell table and based on the frequency of strategies in the relevant house, its position is determined in the 4-cell SWOT table in terms of determining the general policy in adopting an appropriate development strategy. In the inner and outer square matrix, the sum of the final scores from 1 to 2.5 indicates the internal weakness, and the score of 2.5 to 4 indicates the strength. Similarly, the sum of the final scores of the external factors evaluation matrix from 1 to 2.5 indicates the level of threat, and the scores of 2.5 to 4 indicate the amount of opportunity. Being located in each of the internal and external matrix cells has four specific strategic concepts.

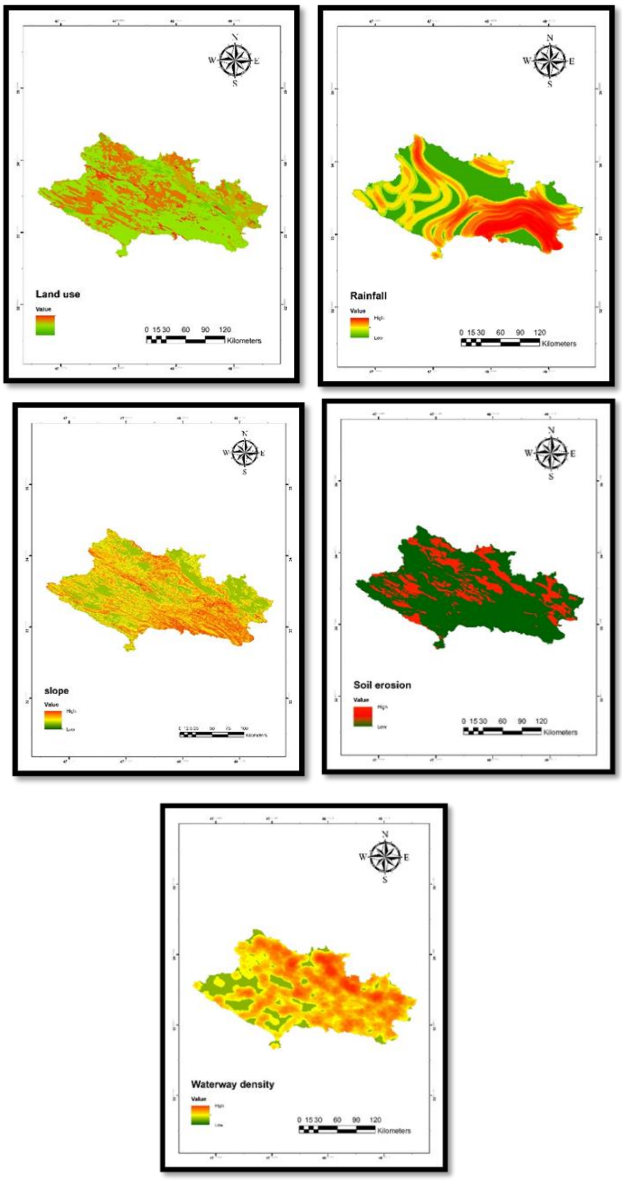

Figure 4. Map of Lorestan for land use, slope, rainfall, waterway density, and soil erosion flood criteria

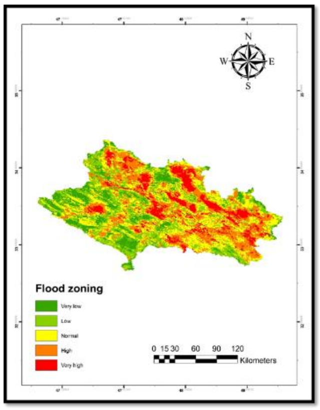

Figure 5. Finale flood zonation map of Lorestan

Table 4. Internal weakness SWOT matrix

Final score (coefficient * score)	Score	Weight (AHP)	Description	Internal weaknesses (w)
0.156	3	0.052	Low financial ability to strengthen housing by the people	w1
0.114	2	0.057	Low credits of local institutions for the purchase and protection of accident-prone lands	w2
0.1755	3	0.0585	Lack of solid supervision over construction control in flood and earthquake-prone areas by the responsible institutions	w3
0.128	2	0.064	Construction in the river area	w4
0.1095	3	0.0365	Lack of strong supervision over construction control in flood and seismic zones by the responsible institutions	w5
0.121	2	0.0605	Lack of dredging rivers	w6
0.153	2	0.0765	Increasing the level of soil erosion, especially fertile soil in the region by river runoff	w7
0.132	3	0.044	Degradation of pastures and forests, change of land use pattern, and incorrect land reclamation due to low knowledge	w8
0.153	3	0.051	The location of many villages in the area of faults	w9
1.242				**Total**

Table 5. Internal powers SWOT matrix

Final score (coefficient * score)	Score	Weight (AHP)	Description	Internal powers (S)
0.0555	1	0.0555	Existence of public desire to participate in the transfer of flood-prone and earthquake-prone lands to the government, subject to awareness and support	s1
0.073	2	0.0365	The activity of villagers as executive arms in villages to attract public participation for land management	s2
0.2745	3	0.0915	Existence of empty spaces in some of the studied areas	s3
0.096	2	0.048	Existence of primary ways to access	s4
0.273	3	0.091	Planning and prioritizing programs and crisis preparedness	s5
0.0525	1	0.0525	Efforts to establish and strengthen emergency operations centers	s6
0.065	2	0.0325	Provide the necessary validity, financial resources, and structural mechanisms to prepare for the crisis	s7
0.1275	3	0.0425	Apply sufficient standards for the construction of buildings and urban development plans	s8
0.05	1	0.05	Existence of open and empty spaces in the city for the construction of parks and public spaces	s9
1.067				**Total**

Table 6. SWOT matrix of external threats

Final score (coefficient * score)	Score	Weight (AHP)	Description	External threats (T)
0.159	3	0.053	Lack of planning based on the return period of floods and earthquakes and the threat posed by it in the province	t1
0.1095	3	0.0365	Weak monitoring of river area and the plan implemented in the flood watershed by the responsible institutions	t2
0.126	2	0.063	Weak construction monitoring in the fault area	t3
0.36	4	0.09	Weakness is having a comprehensive local, regional and national flood warning and information system	t4
0.12	2	0.06	Counting style of enforcing the laws related to the privacy of rivers and faults and dealing with its aggressors	t5
0.127	2	0.0635	Lack of attention to the participation of people and their indigenous knowledge in the management of local floods by the authorities	t6
0.1365	3	0.0455	Earthquake history in the region	t7
0.0385	1	0.0385	Rapid population growth and density	t8
0.2	4	0.05	History of floods in the area	t9
1.3765				**Total**

Table 7. External Opportunity SWOT Matrix

Final score (coefficient * score)	Score	Weight (AHP)	Description	External Opportunities (O)
0.09	2	0.045	Provide credit assistance for the reconstruction of flood and earthquake damage by the government	o1
0.201	2	0.1005	The willingness of the responsible institutions for education, awareness-raising, holding flood and earthquake maneuvers, and determining hazardous areas and public awareness	o2
0.107	2	0.0535	Efforts of responsible institutions to plant trees around rivers and watershed management, prevent livestock grazing, change land use in flood-prone areas for special uses	o3
0.058	2	0.029	Improving services and infrastructure facilities of the water supply network, telecommunications, the electricity company, and surface water disposal	o4
0.123	3	0.041	Emphasis on regeneration of worn tissues	o5
0.1815	3	0.0605	Existence of regulations 2800 tenet of construction standards	o6
0.0705	1	0.0705	Utilizing the educational potential of the Red Crescent for public education	o7
0.0565	1	0.0565	Strengthen the culture of crisis preparedness at the provincial level	o8
0.087	2	0.0435	Raising the attention of the authorities to the earthquake in the region, emphasizing the optimal management of information and communication in times of crisis	o9
0.9745				**Total**

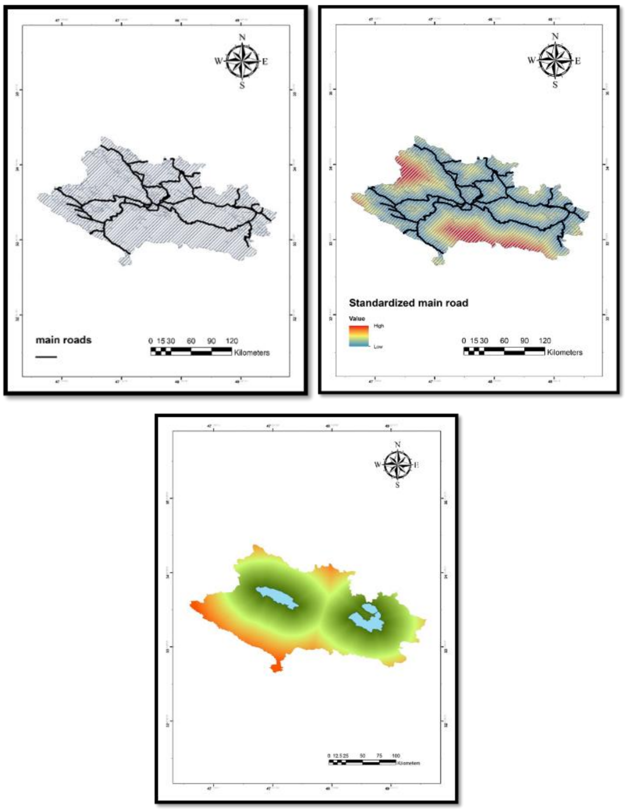

Figure 6. Map of the main communication network, standardized main road layer, and open spaces layer of Lorestan

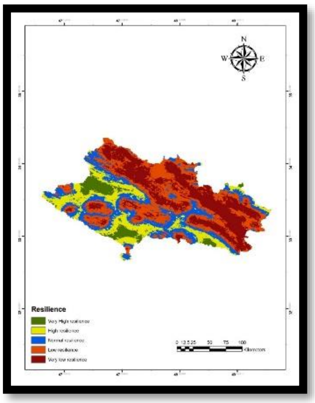

Figure 7. Finale resilience zonation map of Lorestan

As can be seen, the total score of internal factors is 2.309, which is less than 2.5, indicating an internal weakness according to our current plan. In the matrix of external factors, it can be seen that the total of external scores is equal to 2.351, which is less than 2.5, which indicates that the conditions of this sector are also unfavorable and more external threats threaten the plan. The combination of internal and external factors for the SWOT matrix is shown in Table 8. According to the results, the most significant number obtained is related to WT factors, project weaknesses, and threats. In this case, defensive strategies should be adopted, and the project position is risky.

Table 8. Combination of internal and external factors

internal factors		foreign causes	
S (strength)	W (weakness)	O (opportunity)	T(threat)
1.067	1.242	0.9745	1.3765
Total coefficients of composite factors			
SO	WT	ST	WO
2.0415	2.6185	2.4435	2.2165

4. Conclusion

The required data and information have been collected from various sources, and practical information layers in earthquakes and floods have been prepared by reviewing the previous data. The collected information was analyzed using the GIS system, and the decision tree diagram was compiled as criteria and sub-criteria. The effective boundaries of each criterion in earthquake and flood potential were identified, weighed, and standardized by the analytic hierarchy process (AHP) method. The degree of importance of the criteria was estimated and by combining all the requirements. According to the output map of cities with high potential in terms of zoning and low resilience are: Khorramabad, Borujerd, Pol-e Dokhtar, Azna, Oshtorinan, Noorabad, Aleshtar, Kakareza-ye Sofla, Sepiddasht, Qolian, and Chalanchulan. Based on the SWOT analysis, it is concluded that the eastern and northeastern regions of the province had the highest potential in terms of flooding, and the central and northern regions of the province had the average potential in terms of earthquake. The southern and western regions of the province had the lowest earthquake and flood potentials, therefore Lorestan should be in a defensive position, WT, which is the riskiest position. Therefore, the following operational strategies and options can be considered for urban and rural areas of Lorestan. Suggestions for increasing earthquake resilience are:

- Increase physical strength in residential buildings to reduce damage with proper management and preparation of construction criteria with special attention to the seismic characteristics of each area.
- Implementation of resilience, renovation, and reconstruction programs in dilapidated and semi-resilient areas to increase their resilience and obligation to carry out zoning plans and make them operational in areas with active faults in the region.
- Acquisition of fault lands by the public sector and prevention of construction strengthens the role and efficiency of open spaces.
- Plan to organize the communication network to connect with sensitive uses such as hospitals and fire brigades to prepare for crises.
- Identifying barren lands and their ownership and replacing them with the use of green and open space, as well as providing urban facilities and equipment and fair distribution of urban facilities and services in proportion to the population of neighborhoods and the level of vulnerability.

Suggestions for increasing flood resilience include:

- Flood reduction through basin-level construction methods such as the use of dry-stone dams and use of diversion channels.
- Flood reduction through construction methods specific to urban and rural lands, such as the use of water gates and use of flood block heritage flood guards.

- Flood reduction through ineffective development methods for runoff disposal like vegetable swale and porous Asphalt.
- Management strategies to mitigate and mitigate the effects of floods like observance of the privacy of canals and rivers and zoning of flood plains, continuous flood bed control, creating permeable surfaces in the city and not converting free lands into urban structures, converting the lowlands of large cities into parks and green spaces and reduce river slope.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

Datasets analyzed during the current study are available and can be given following a reasonable request from the corresponding author.

Conflict of interest

The authors declare no potential conflict of interest.

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