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An Assessment of Social Resilience against Natural Hazards through Multi-Criteria Decision Making in Geographical Setting: A Case Study of Sarpol-e Zahab, Iran

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Abstract: The aim of this study was to propose an approach for assessing the social resilience of citizens, using a locative multi-criteria decision-making (MCDM) model for an exemplary case study of Sarpol-e Zahab city, Iran. To do so, a set of 10 variables and 28 criteria affecting social resilience were used and their weights were measured using the Analytical Hierarchy Process, which was then inserted into the Weighted Linear Combination (WLC) model for mapping social resilience across our case study. Finally, the accuracy of the generated social resilience map, the correlation coefficient between the results of the WLC model and the accuracy level of the social resilience map were assessed, based on in-situ data collection after conducting a survey. The outcomes revealed that more than 60% of the study area falls into the low social resilience category, categorized as the most vulnerable areas. The correlation coefficient between the WLC model and the social resilience level was 79%, which proves the acceptability of our approach for mapping social resilience of citizens across cities vulnerable to diverse risks. The proposed methodological approach, which focuses on chosen data and presented discussions, borne from this study can be beneficial to a wide range of stakeholders and decision makers in prioritizing resources and efforts to benefit more vulnerable areas and inhabitants.

Keywords: social resilience; natural hazards; locative multi-criteria decision-making (MCDM) model; Sarpol-e Zahab

1. Introduction

According to United Nations estimates, more than 70 percent of the world's population will live in urban areas by 2050 [1]. Due to the population growth in cities, it is of great importance to consider the socio-economic and administrative processes related to the performance of cities, and to evaluate the resilience of residents to natural hazards [2,3]. Cities today have not only taken the path of development, but have also expanded their spatial areas into areas that need physical development against natural hazards to ensure they are ready to accommodate more people [4].

Natural hazards are "disasters that occur suddenly and cause harm to humans and the environment" [5,6]. These hazards can be highly devastating in terms of human lives, assets and infrastructure, and pose major challenges to sustainable urban development [7,8]. Therefore, preparing for these hazards can lead to increased adaptive capacity and sustainable livelihoods for urban communities [9,10]. One of the ways to prepare cities for these risks is to increase *social resilience* [7,11]. Adger [12] defines social resilience as the ability of individuals, groups, and communities/cities to cope with external stresses and environmental disturbances. The goal of this study wa/*s to assess social resilience with a view to finding ways to increase the resilience capacity of communities and strengthen the ability of citizens and urban managers to cope with the impacts of natural hazards [13].

Given the continuous growth of the urban population and its density, as well as the threat of natural hazards, it is of outmost importance to pay attention to, and strengthen, social resilience in cities as the backbone of disaster risk management [14,15]. Considering that natural disasters cause immense social disruption in cities, promoting social resilience as a capability not only helps to maintain the basic performance of cities, but also leads to the improvement and prosperity of cities after disasters [16]. Resilient cities are capable of positively responding to hazards or stresses [17,18]. These cities can also maintain their primary functions as a whole, despite existing tensions, and move towards sustainable development through a cohesive and integrated approach [3,19].

Iran is frequently affected by natural hazards due to its geographical and geological conditions [20,21], as 31.7 percent of the country's territory is exposed to natural hazards, and 70 percent of its population are residing in vulnerable areas [21,22]. Sarpol-e Zahab city has been one of the most affected cities by natural disasters in Iran in recent decades. Statistical and historical studies show that this city has experienced many natural disasters so far. Natural disasters such as earthquakes, floods, droughts, air pollution and dust storms are the main hazards that severely affect this city. Examples of natural disasters that have caused major challenges to the citizens of Sarpol-e Zahab and have, hence, indicated that the building of social resilience against natural hazards is an imperative, include the following: Floods in 1998 and 2007; Earthquakes in 2003, 2014 and 2017, and recent droughts and dust storms (Iran Crisis Management Organization, 2020).

Social resilience is influenced by various criteria with spatial reference, so the use of spatial systems and analysis can be useful in spatial measurement and analysis of social resilience. In addition, the use of spatial multifactor decision-making models can increase the accuracy of measurement. In this paper, GIS-MCDM spatial multi-criteria decision-making models were used to measure the social resilience of the Sarpol-Zahab urban areas. The general purpose of GIS-MCDM techniques is to help decision-making processes towards selecting the most suitable option among existing options. These techniques combine in-situ data and decision makers' priorities, based on decision-making principles [23,24]. Considering the fact that making a right and timely decision can have a substantial effect in choosing suitable options using various criteria, the need for a robust technique that can help various stakeholders is important. The MCDM techniques are effectively used in various studies, such as geothermal sources [25], usage of lands [26,27], migration [28,29], thermal comfort [30], solar energy [31,32] and natural hazards [33–35].

Many studies have been conducted in relation to analysis of resilience and its role in reducing the consequent effects of natural incidents, but previous studies to assess social resilience are descriptive and statistically-based, and the weight of effective metrics and user preferences are not considered. Therefore, to make data-informed decisions, it is necessary to consider various effective criteria in a comprehensive approach. As mentioned earlier, the GIS-MCDM approach can be very useful in this regard. Furthermore, previous studies have not combined GIS and MCDM. Therefore, the main objective of this study was to measure social resilience in Sarpol-e Zahab so as to raise awareness against natural hazards. The results of this study could be very useful and practical for managers and urban planners.

2. Literature Review

The term social resilience, in social systems, was first coined by Adger [12]. Social resilience provides a conceptual framework for measuring community capacity to cope with change and emergencies [36]. A resilient society is able to respond positively to changes or tensions and is able to maintain its core function as a society despite tensions. A particular change can have far-reaching and different consequences in different societies, and different societies will show different degrees of resilience to change. A resilient society not only minimizes the difficulty of overcoming vulnerability, but also implements it through education and adaptation to advance society [37]. According to Bogardi [38], social resilience is measured over time. In particular; how long does it take for a community to respond to an incident, organize itself, and integrate lessons learned before returning to a new practice? The amount of time it takes to escape a hazard not only affects a society's economic presence, but also its social context or the "intermediary" that holds it together. The longer this recovery lasts, the more likely society is to be destroyed as recession ensues and emotional and psychological pressures spread [39].

In recent years, several studies have been conducted on the analysis of social resilience and its role in reducing the effects of natural disasters. Some studies have identified *social harms*, *social capital* and *demographic characteristics* as features characterizing the resilience of societies to natural hazards [11,12,40–42]. Some studies [43,44] also consider *religious beliefs* and values to be effective in creating a sense of calm, hope, and a return to the pre-crisis state. Various studies [12,45–47] also *consider local community capabilities*, *diversity of resources/skills*, *level of awareness and human capital* as resilience requirements against hazards. Various studies [46,48–50] have also pointed out the negative effects of lack of *security* and *social inequality* on the resilience of society to disasters. Most previous attempts to assess social resilience are descriptive and statistically based, and the weight of effective metrics and user preferences are not considered. Moreover, this topic has not been studied visually and from a spatial perspective. Therefore, to make an accurate decision in this regard, it is necessary to consider various effective criteria in a comprehensive approach. As mentioned earlier, the GIS -MCDM approach can be very useful in this regard. Furthermore, previous research has not combined GIS and MCDM. Therefore, the main objective of this study was to measure the social resilience of urban areas in Sarpol-e Zahab with a view to reducing risk against natural hazards, based on multi-criteria decision models. The results of this study could be very useful and practical for managers and urban planners. Effective criteria in social resilience analysis and description of each of them are presented in Table 1.

Table 1. The variables used for assessing social resilience.

Variables	Sub-Variables	Description	References
Demographic Characteristics	Age Structure (population aged under 15 and over 65); Literacy Status; Gender (ratio); Population Density; Immigration; Female-headed households; Occupation Status	Population and its characteristics are among the most important criteria affecting the rate of resilience in a region. In order to achieve a resilient society, special attention should be given to the demographic structure and context of the regions and their changes. Accurate knowledge about the demographic structure of a region before, during and after the occurrence of hazards, is of particular importance.	[11,12,40–42,51–53]
Social harms	Poverty; Addiction; Suicide; Divorce	Social harms disturb relationships between members of the society, cause failures in social relations and lead to inability of society to integrate itself; this can be one of the important factors reducing the resilience of societies against crises.	[12,17,54–57]

Table 1. *Cont.*

Variables	Sub-Variables	Description	References
Social Capital	Social Trust; Social Participation; Social Integrity; Social Awareness; Social Support; Social Networks; Social Relations	Social capital, referring to the social relations of individuals with each other, can have a very positive effect on social resilience and developing security in cities. The greater the amount of social capital in a region, the more resilient that region will be in the course of a crisis.	[12,46,51,58–62]
Religious Beliefs and Values	-	Beliefs are considered as an essential factor in strengthening the social resilience of societies against hazards, having an influential role in creating a sense of calmness, hope and returning to a pre-crisis state.	[43,44,63,64]
The General Capability of Local Community	Sense of Belonging to a Place; Sympathy and Altruism; Cooperation	Membership in the local community is one of the necessities for resilience and an important resource for encouraging community members to be efficiently capable when faced with challenges. With a sense of local community, participation in social networks takes form and capabilities of individuals increase capabilities of the community to use internal resources when encountering crises.	[12,45–47,65,66]
Resources and Skills	-	Resources and skills in a society are positively correlated with social resilience of that society against crises, because they promote the qualities of time and effort spent on planning	[10,12,44,65,67–69]
Social Inequality	-	Inequalities lead a society to mistrustfulness, isolation and lawlessness; strengthening such unfairness leads to forming a kind of anger caused by disparities in individuals. This will affect social ties and break individual and group relationships.	[45,46,50,62,65]
Social Security	Theft; Murder; Individual Conflicts; Group Conflicts	In a society that has maximum security, it will be easily possible to implement knowledge of design and construction related to encountering hazards, through strengthening these features to achieve resilience.	[12,48,49,54]
Human Assets	Public Health; Having Trained and Skilled Workforce	Human assets bring flexibility power, which is one of the principals of resilience. Having a sufficient, skilled and trained workforce is a prerequisite for economic development and capacity building. This means that the more human assets available in society, equals more capacity to develop better resilience.	[11,40,46,62,70–72]
Awareness and ducation	-	The level of public awareness and knowledge about the incidents that might threaten them is very effective in building resilience of society and for proper reaction to the events; thus, greatly reducing the damage inflicted.	[11,47,62,65,66,72,73]

3. Materials and Methods

3.1. Study Area

The city of Sarpol-e Zahab is the center of a county with the same name in Kermanshah province, with an area of 1271 km^2, located between 45°52″ E longitude and 34°24″ latitude, in the western part of Iran, at the end of the slopes of the Zagros heights. According to the 2016 census, conducted by the Statistical Center of Iran (SCI), the city includes 35 urban areas (Figure 1). Regarding population, Sarpol-e Zahab is the third most populated county in Kermanshah province. According to the latest census (mentioned above), the population of the county was 85,342, 53% of which (45,481) lived in urban areas. According to the official statistics of the Statistical Center of Iran, the city of Sarpol-e Zahab did not fare well in terms of social resilience indicators before the earthquake. A comparison of the average sex ratio, percentage of households headed by women, employment percentage, and literacy rate in the country, and in Sarpol-e Zahab city, shows that Sarpol-e Zahab city was in an unfavorable situation in all these indicators, compared to the country as a whole. In terms of statistics on suicide, divorce rate and unemployment, Sarpol-e Zahab is also in a worse situation than the country average. Being the city with the most unemployment among the country's cities indicates problems, such as addiction, domestic violence, reduction of social capital, etc. The city also ranks first in the country in suicides. In addition, the divorce rate in this city is higher than the national average, which may reduce social skills in this city. In areas where these conditions are evident, disaster prevention issues can no longer be given much importance. Therefore, based on the particular conditions in Sarpol-e-Zahab city, it can be said that the poor responses to the consequences of natural disasters, such as floods and earthquakes, are due to lack of risk management, lack of education, lack of empowerment and, finally, lack of social resilience. Sarpol-e Zahab has been categorized as one of the most disaster-prone cities of Iran, experiencing various natural hazards. According to field observations and reports from urban dwellers and experts from the earthquake-exposed areas of Kermanshah province, the damaged buildings and infrastructure resulting from previous earthquakes are not yet restored and living conditions are still unsuitable. The earthquake in 2017, with a magnitude of 7.3 on the Richter scale, was devastating and caused deaths exceeding 621, along with 9388 people injured and almost 70,000 people becoming homeless. Subsequent events such as torrential rains, lack of adequate emergency and temporary accommodation, the inadequacy of tents against cold and heat, social damage and increasing poverty, and the price of construction materials and labor have aggravated the situation (Iran Crisis Management Organization, 2020).

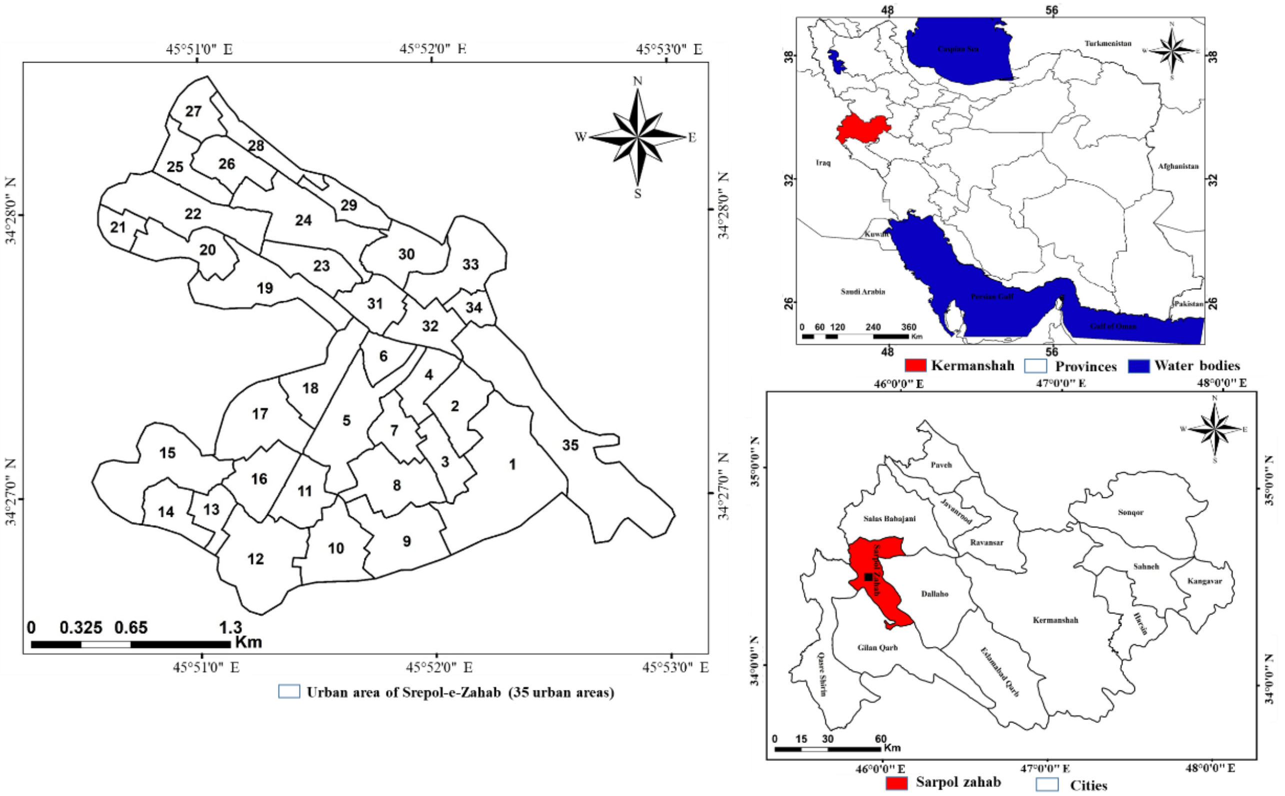

Figure 1. Study area.

3.2. Data Collection

The sources of the data used for each index is presented in Table 2. As is known, some data sources have been obtained using surveys and questionnaires with the support of the Iranian Sociological Association. In order to determine the sample size, we used the framework of the census by the Statistics Center of Iran in 2016. Cochran's Formula was applied to estimate an optimal sample size, which suggested 385 people to include in a random sampling setting.

Table 2. The characteristics of data used in this study.

Row	Data	Format	Source
1	Demographic Characteristics	Vector (polygon)	Civil Registration Organization and Statistics Center of Iran
2	Social harms	Vector (polygon)	National Plan for Family Conversations and Statistics Center of Iran
3	Social Capital	Vector (polygon)	Sarpol-e Zahab Health Center and Statistical Center of Iran
4	Religious Beliefs and Values	Vector (polygon)	Questionnaire
5	The General Capability of Local Community	Vector (polygon)	Questionnaire
6	Resources and Skills	Vector (polygon)	Questionnaire
7	Social Inequality	Vector (polygon)	Questionnaire
8	Social Security	Vector (polygon)	Sar-pol-e Zahab Police Force
9	Human Assets	Vector (polygon)	Questionnaire
10	Awareness and education	Vector (polygon)	Questionnaire

3.3. Overall Method

In Figure 2, the overall flowchart of the proposed methodology is illustrated. In the first step of this proposed approach, the effective social resilience variables were selected and standardized with reference to theoretical literature and previous studies. In the second step, the criteria were weighted based on experts' opinions and an Analytical Hierarchy Processes [28] method. In the third step, using the suggested GIS-MCDM approach and the map of criteria and the resulted weights, the final social resilience map of the target region was prepared. At the end, in the fourth step, the obtained results were assessed.

3.3.1. Variables Selection and Standardization

After reviewing experts' opinions and the literature related to the concept of resilience, a total of 28 sub-indicators embedded within 10 locative variables were selected for making social resilience maps. These selected variables included demographic characteristics, social harms, social capital, religious beliefs and values, general capability of the local community, resources and skills, social inequality, social security, human assets, and level of awareness and education (Table 1).

After the set of variables for assessing social resilience were selected, each index was stored on a locative database as a GIS map. GIS-MCDM requires standardized criterion maps, as evaluating all criteria together requires converting layers into comparable units [74]. In this study, it was, therefore, necessary to standardize the criteria, considering that the data of each index came from different sources, in order for the criteria to be comparable with each other.

As "maximum" values for some variables, and "minimum" values for other variables, have more significance regarding the definition of resilience, in the present study a "maximum–minimum" standardization method was employed. The variables were categorized into two main groups: benefit variables (the variables in which maximum value was of significance) and cost variables (the variables in which minimum value was of significance). The benefit variables, including demographic characteristics, social capital, religious beliefs and values, general capability of the local community, resources and skills, social security, human capital, and the level of awareness and education were standardized through Equation (1), and the cost variables, including social harms, and social inequality were standardized through Equation (2) (Table 3). For instance, to calculate social capital, the higher the social capital, the higher the level of social resilience. Therefore, the maximum values were more important and, as a result, Equation (2) was adapted, while for the social harms variable, the lower the value of this index, the higher the social resilience. As a result, Equation (1) was applied to create a normal marker.

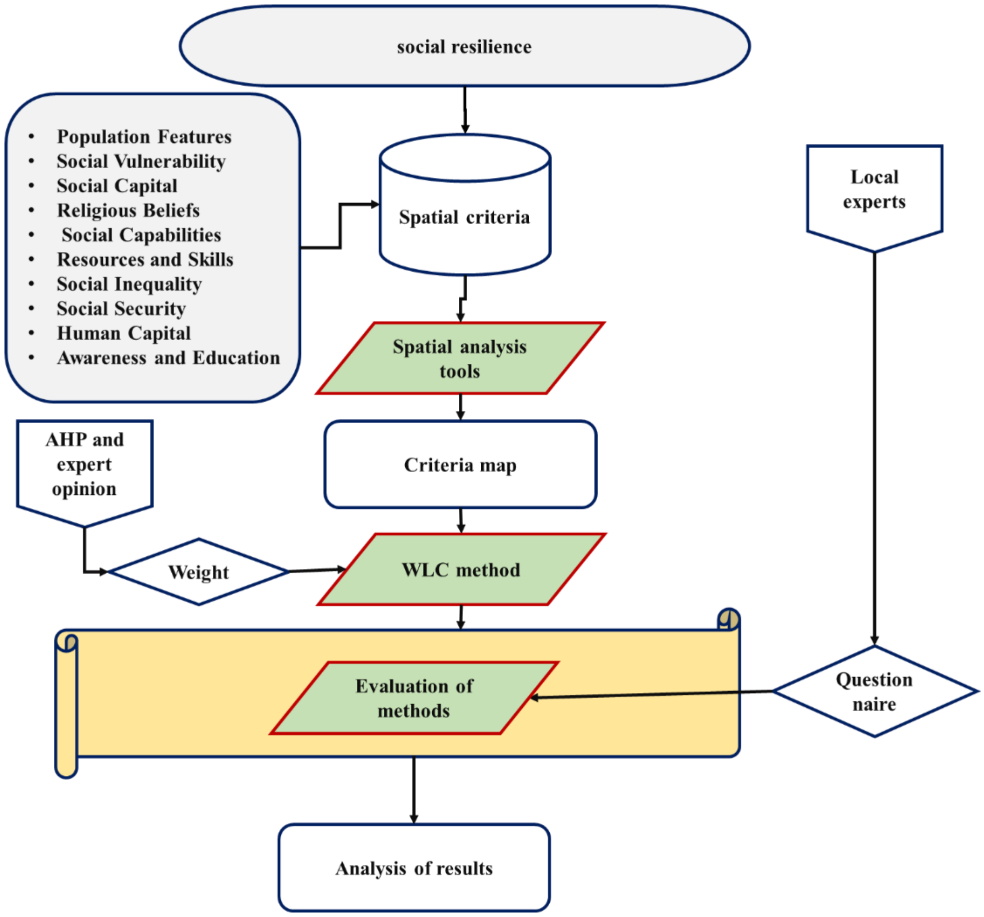

Figure 2. The flowchart of the main steps of the study.

Table 3. The equations used for standardization of social resilience variables.

	Equation	Applied Condition	Standardization Technique
(1)	$n_{ij} = \frac{r_{ij} - r_{min}}{r_{max} - r_{min}}$	Minimum variables	Linear: Maximum-Minimum
(2)	$n_{ij} = \frac{r_{max} - r_{ij}}{r_{max} - r_{min}}$	Maximum variables	

3.3.2. AHP Method

The AHP is one of the most efficient techniques of multi-criteria decision making, which was first suggested by Saaty [75]. A general overview of multi-criteria decision-making methods was conducted by Pohekar and Ramachandran [76] who concluded that, among all weighting techniques, the AHP method was the most popular one. This method is based on pairwise comparisons of criteria and gives managers and decision-makers the possibility of reviewing different strategies [75,77]. This technique is one of the most comprehensive systems designed for decision-making with multiple criteria; because it provides the possibility of formulation of complicated problems in a hierarchical manner, and also offers the possibility of considering different quantitative and qualitative criteria in the problem [77,78].

The first step in the AHP method, is to construct a hierarchical structure. This is the most crucial step of the hierarchical analysis process, because, in this step, with decomposition of difficult and complicated problems, it becomes possible to transform the problems into simple forms corresponding to human mind and nature [79,80]. At the top of this hierarchy would be the general goal of the problem and on the other layers, the criteria and options. The second step is forming a pairwise comparison matrix. At this stage, elements of each layer in the hierarchy are compared with their corresponding criteria in the higher layers to form pairs, and the pairwise comparison matrix is formed [74]. In order to determine importance and preference in pairwise comparisons, a 1 to 9 range is used (Table 4). The third step is calculating the inconsistency rate. The inconsistency rate clarifies whether the pairwise comparisons have stability and consistency or not. If the value of this rate is lower than 0.1, it is indicative of higher consistency of the matrix, while if the value is above 0.1, there needs to be reconsideration about the pairwise comparison results [81].

Table 4. Weighting variables according to priority in the form of pairwise comparison.

Value	Status of Comparing *i* to *j*	Description
1	Similar Priority	Index *i* ranks similar to index *j* in terms of significance, or there is no priority.
2	A Little Prioritized	Index *i* slightly outranks index *j* in terms of significance.
5	Moderately Prioritized	Index *i* moderately outranks index *j* in terms of significance.
7	Highly Prioritized	Index *i* significantly outranks index *j*.
9	Absolutely Prioritized	Index *i* has absolute priority over index *j*.
2-4-6-8	In-between	These figures indicate "in-between" values; e.g., a value of 8, is higher in priority than 7, but lower than 9 for a given index (*i*).

In this study, using the AHP method and the opinion of 30 experts in the fields of social sciences (sociology, demography, etc.), geography and urban planning, remote sensing and GIS, regional planning and development, and crisis management, the criteria were ranked at different levels relative to each other and according to the degree of their importance at each decision-making level.

3.3.3. Weighted Linear Combination (WLC) Method

There are several methods for analyzing multi-criteria assessments, and the WLC method is one of the most applied and most common ones for preparing suitability maps [82–84]. This technique is also called "the simple collectible weighting method", or "the scoring method", which operates according to mean weight; namely, the relative weight of each criterion measured by experts and the weighting method [28], is multiplied by the value of each pixel [85–87]. Once the final value of each option is determined, the options with the highest values are selected as the appropriate locations for the target [88]. In this study, the WLC model was used to combine different criteria to create the final social resilience index (standard map). In this model, the map of each criterion was multiplied by its own weight (which was determined by experts using the AHP method), and, finally, the sum of all the criteria together was the final result of the WLC model (WLC section, relationship 3), which resulted in the same map. The ultimate aim in this study was that of assessing social resilience. This method was calculated using Equation (3):

$$A_j = \sum_{j=1}^{n} W_j \times X_j \quad (3)$$

In the above equation, W_j is the relative weight of each criterion/index and X_j is the value of each pixel or location.

3.3.4. Evaluation of the Accuracy of the Proposed Model

The results of multi-criteria decision-making methods are not complete, until their accuracy is evaluated, and in order to ensure the actuality ratio of the prepared map, its accuracy had to be evaluated. In order to evaluate the final map of social resilience obtained from the multi-criteria spatial decision-making system, another questionnaire was designed to represent the current situation, the information of which was collected from the officials of the city administration system and the local government of Sarpol-e Zahab. Based on the combination of information collected from the questionnaires, an urban social resilience map of the city was prepared on the principles of public participation geographic information system (PPGIS). Finally, the correlation coefficient between the social resilience status model, based on the multi-criteria spatial decision-making system, and the social resilience status, based on the questionnaire, were evaluated. The accuracy of the produced map showed the level of confidence in the results of the multi-criteria decision models [89]. Vanolya, et al. [90] used PPGIS results to evaluate the validity of the results of the multi-criteria spatial decision system.

4. Results

In this study, using the AHP model, the final weights for the criteria at each level were calculated and the results are presented in Table 5. According to the experts, social capital (0.23) and social harm (0.19) variables had the greatest influence and religious beliefs and values (0.01) and awareness and education (0.03) variables had the least influence on social resilience.

In order to investigate the locative distribution of the effective criteria on social resilience, each criterion was standardized according to its highest and lowest values. For a more precise review of resilience conditions for the studied region under the locative aspect, the standardized values of the different sub-criteria were calculated for different urban areas. Below, the standardized sub-criteria maps for the study region are shown. Indicator values range from 0 to 1. Values of zero (brown color) represent very low resilience and values of one (blue color) represent very high resilience.

According to the results shown in Figure 3, the demographic parameters influencing social resilience in Sarpol-e Zahab tended to have a lot of locative variances. Regarding literacy status, social resilience of urban areas appeared to be on an optimal level and only three urban areas had unfavorable conditions. As is clear, regarding occupation status, southern areas of the city were not in good conditions, while, compared to other areas, the northwestern parts had better conditions regarding employment. Also, regarding population density, the status of central areas was not good.

The statuses regarding the criteria related to the social harms index are shown in Figure 4, and indicate that, from this regard, Sarpol-e Zahab was not in a good condition. As can be clearly seen, the suicide criterion had a high locative variance throughout the city compared to other criteria; specifically, the southern and southwestern areas were not in good condition, while the northwestern regions were in a better state than the others. Regarding addiction and poverty, in most parts conditions were not suitable.

Table 5. The variables and criteria used for assessing social resilience, and their corresponding weight values.

Variables	Variable–Weight	CR *	Sub-Variables	Criterion Weight	CR	Criterion Type
Demographic Characteristics	0.07	0.004	Age Structure (population aged under 15 and over 65)	0.23	0.002	Minimum
			Literacy Status	0.19		Maximum
			Gender (ratio)	0.11		Maximum
			Population Density	0.28		Minimum
			Immigration	0.04		Minimum
			Female-headed households	0.07		Minimum
			Occupation Status	0.08		Maximum
Social Harms	0.19		Poverty	0.31	0.008	Minimum
			Addiction	0.26		Minimum
			Suicide	0.24		Minimum
			Divorce	0.19		Minimum
Social Capital	0.23		Social Trust	0.18	0.005	Maximum
			Social Participation	0.22		Maximum
			Social Integrity	0.12		Maximum
			Social Awareness	0.09		Maximum
			Social Support	0.08		Maximum
			Social Networks	0.16		Maximum
			Social Relations	0.15		Maximum
Religious Beliefs and Values	0.01		-			Maximum
The General Capability of Local Community	0.05		Sense of Belonging to a Place	0.48	0.004	Maximum
			Sympathy and Altruism	0.13		Maximum
			Cooperation	0.39		Maximum
Resources and Skills	0.09		-		0.001	Maximum
Social Inequality	0.14		-		0.005	Minimum
Social Security	0.11		Theft	0.28	0.005	Minimum
			Murder	0.37		Minimum
			Individual Conflicts	0.14		Minimum
			Group Conflicts	0.21		Minimum
Social Capital	0.08		Public Health	0.68	0.008	Maximum
			Having Trained and Skilled Workforce	0.32		Maximum
Awareness and Education	0.03		-		0.006	Maximum

* Consistency Rate.

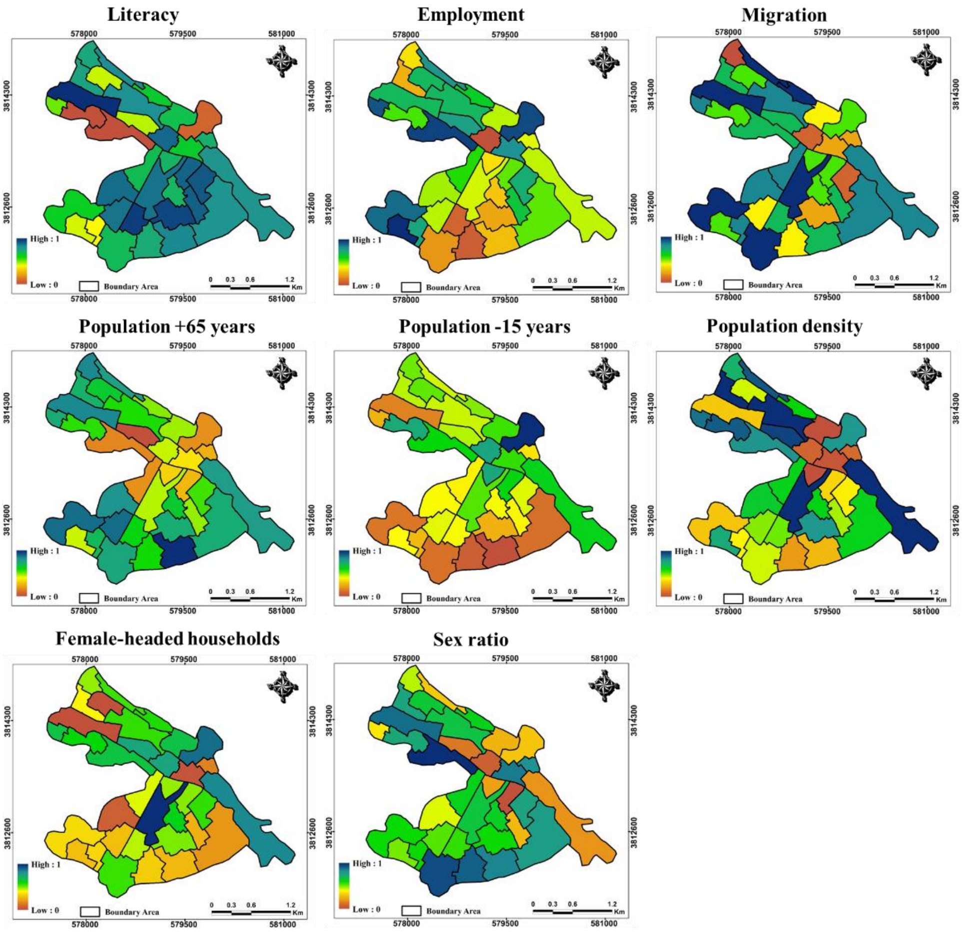

Figure 3. The standardized maps of different criteria related to the demographic index.

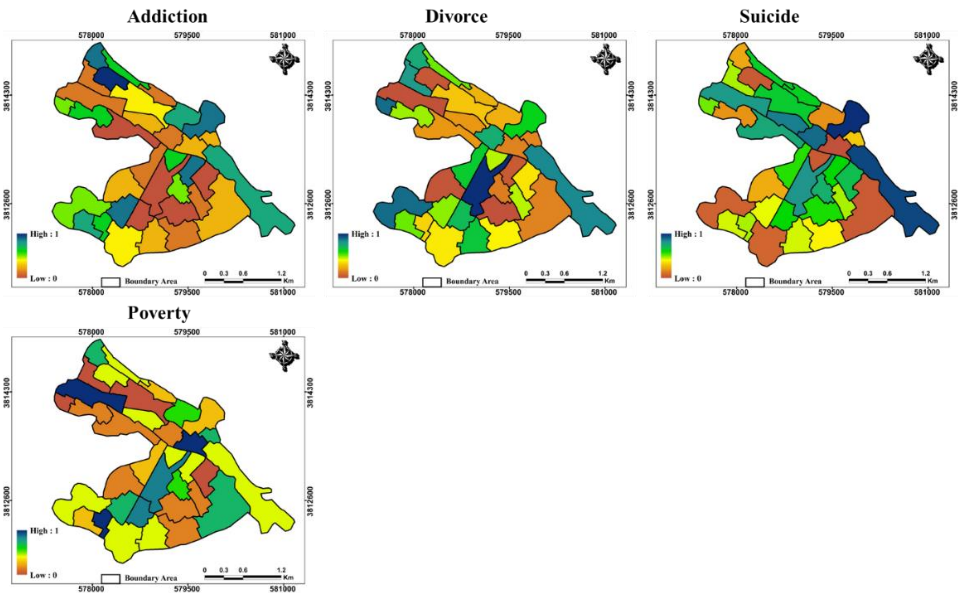

Figure 4. The standardized maps of different criteria related to social harms index.

Figure 5 shows the status of the criteria related to the social capital index. As is observable, regarding social participation, most urban areas were in a favorable status. Furthermore, considering the social integration criterion, most urban areas were in a moderate condition. Among the criteria related to the index of social capital, social trust was not at a good level in most of the urban areas; in other words, the majority of the urban areas were on a low level in terms of the social trust criterion. Considering social awareness, most of the urban areas were in a moderate status. Besides this, social relations were at moderate and low levels in most of the urban areas.

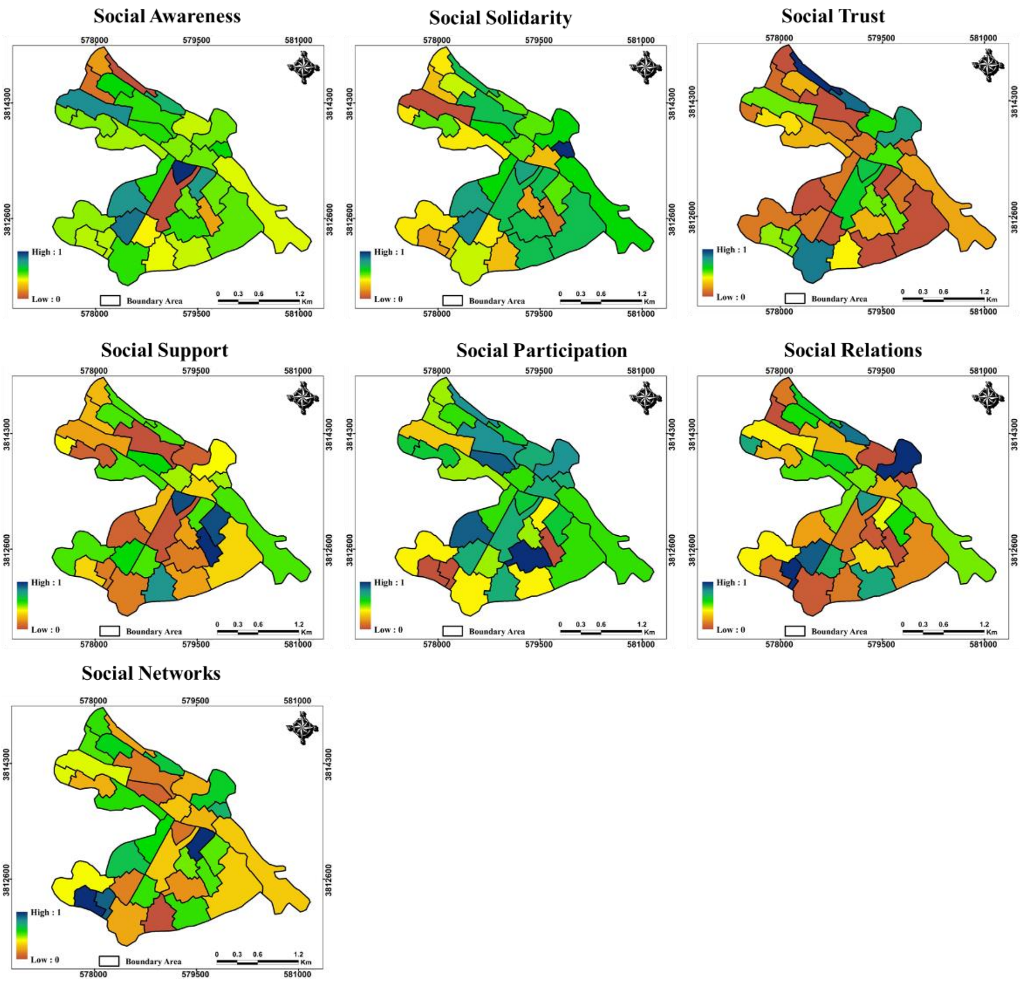

Figure 5. The standardized maps of different criteria related to social capital index.

Figure 6 depicts the status of the religious beliefs index as a significant factor affecting social resilience against various hazards. As is clear from the maps, in this regard, a specific locative pattern was observable throughout the urban areas; the northwestern parts, that are mainly populated by Sunnis, were in an unsuitable state. The central regions, the population of which mostly believe in the Yarsan religion, were in a relatively good state. Additionally, the southeastern parts were in a suitable status, while the southern areas were in unsuitable conditions.

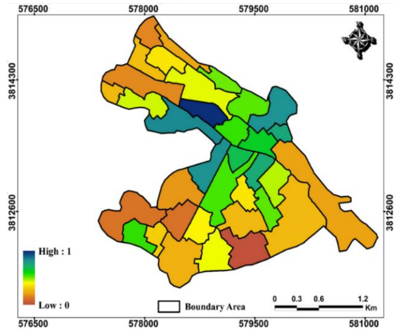

Figure 6. The standardized maps of the criteria related to religious beliefs and values index.

According to the findings depicted in Figure 7, showing the status of the local community capability index, it is observable that there was a certain locative diversity among urban areas in all the criteria. The sense of belonging to place was relatively low in the central areas, medium in the southern areas, high in the southeastern areas, and relatively high in the northwestern areas of the city. Besides this, the sense of empathy and altruism were low in the southern areas, moderate in the northwestern areas, and high in parts of the southeastern areas.

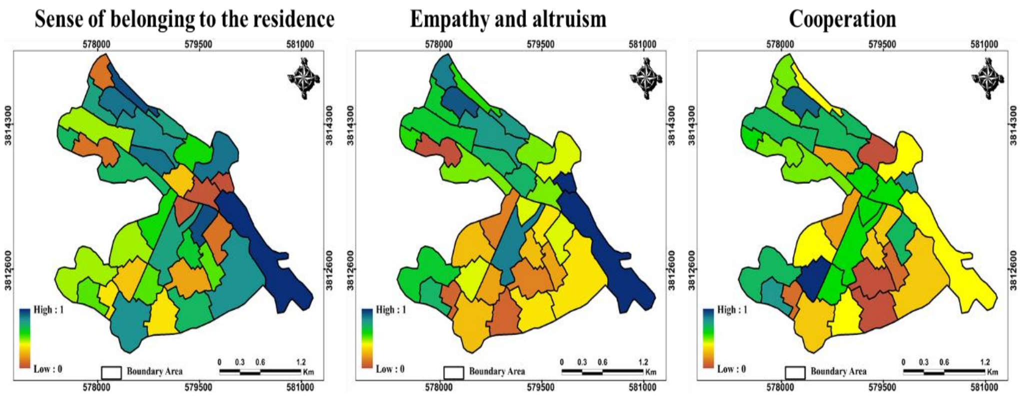

Figure 7. The standardized maps of the criteria related to general capability of local community index.

The results illustrated in Figure 8 show that in terms of the resources and skills index status, except for some areas in the center and northwest, most other urban areas were not in good conditions. As is observable, in this regard, the southern and suburban areas of the city were in unacceptable conditions, and centralization of resources in the central part of the city was higher than in other areas.

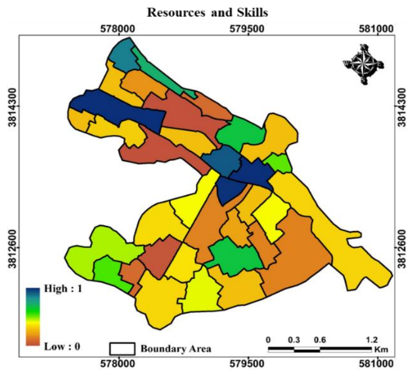

Figure 8. The standardized map of resources and skills index.

The status of the social inequality index presented in Figure 9 shows the imbalance of educational, cultural and social facilities in the private and public sectors of Sarpol-e Zahab. As is observable, the southeastern parts were in better conditions than other urban areas. Most of the governmental centers and organizations are located in this part of the city. The southern, southwestern and northwestern regions (except for one urban area) were not in favorable conditions in this regard.

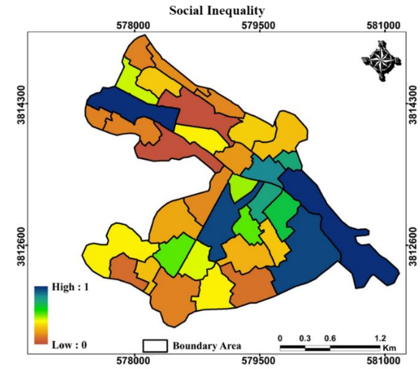

Figure 9. The standardized map of social inequality index.

The findings depicted in Figure 10 show that there is great locative diversity between urban areas in terms of the social security index criterion in Sarpol-e Zahab. As is clear, the murder rate was high in southern and central areas, low in southeastern areas and moderate in northwestern areas. Also, the rate of theft was very high in the southern and central areas of the city, and moderate in the southeastern areas.

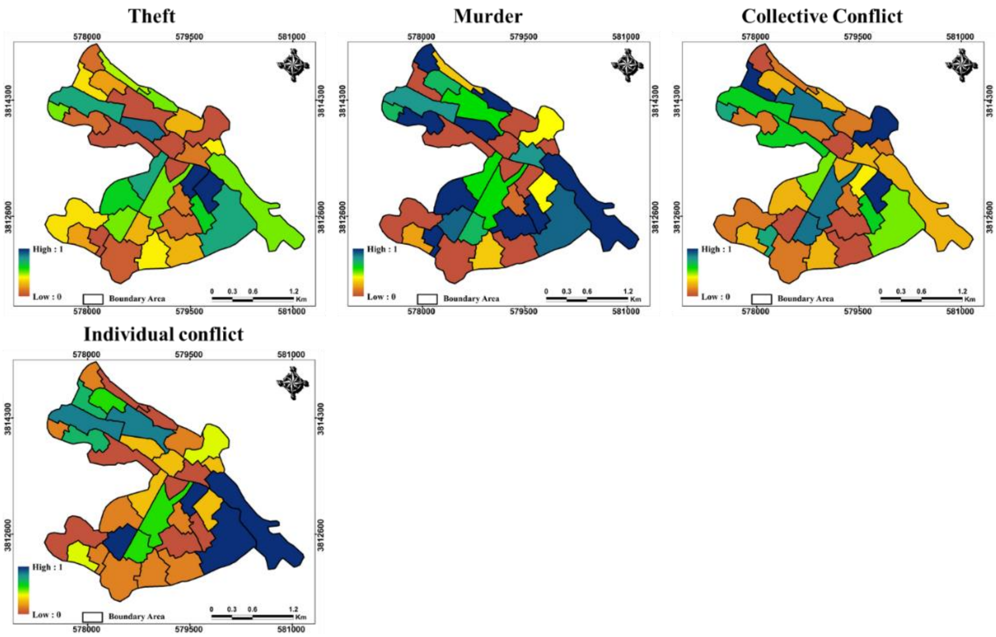

Figure 10. The standardized maps of the criteria related to social security index.

According to the results shown in Figure 11, that are indicative of the conditions of the human assets index criterion, it is clearly observable that, considering population health, there was locative diversity throughout the city. Southern parts were not in good conditions, central regions were in good conditions, southeastern areas were in moderate conditions and northwestern parts were in relatively good conditions. On the other hand, considering the criterion of a trained and skilled workforce, most of the urban areas were not in good conditions.

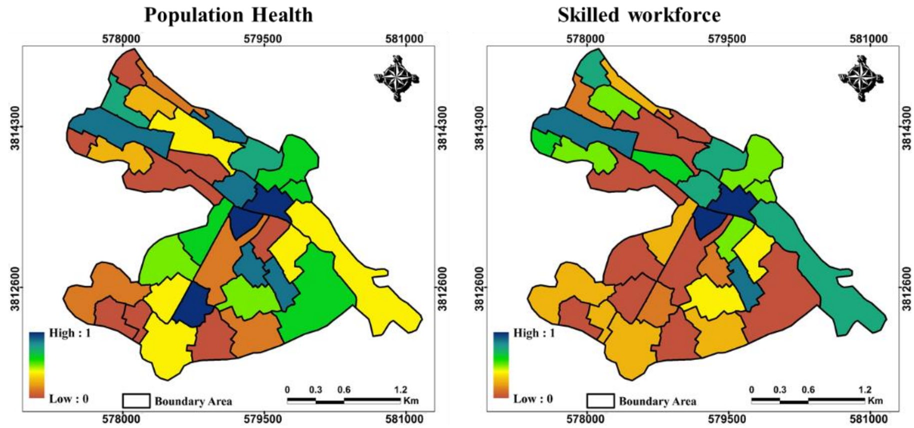

Figure 11. The standardized maps of the criteria related to human assets index.

The status of the urban areas in Sarpol-e Zahab, regarding the awareness and education index, as one of the key variables for social resilience against incidents and shocks, is illustrated in Figure 12; it shows that, in this regard, except for the central areas, most of the other parts were in unfavorable conditions.

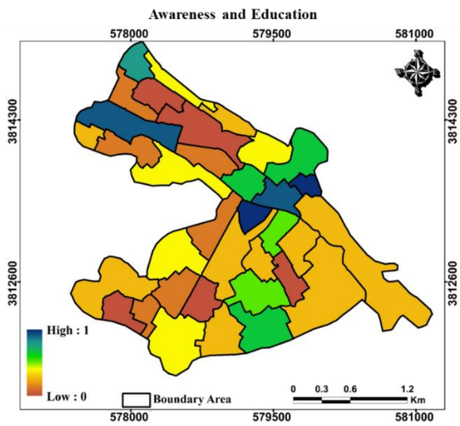

Figure 12. The standardized map of awareness and education index.

4.1. Locative Distribution of the Criteria Affecting Social Resilience

According to the values of the standardized criteria and criteria weights, the decision-making analysis method could be used to create a set of social resilience maps, based on the WLC method. Social resilience maps are prepared on the basis that the weights of the criteria are different for all variables. The values of variables range from 0 to 1. Values of 0 indicate very low resilience and values of 1 indicate very high resilience. The maps of variables were categorized into 5 categories, based on the degree of social resilience: very low (0–0.2), low (0.2–0.4), medium (0.4–0.6), high (0.6–0.8) and very high (0.8–1).

Figure 13 illustrates the extent of the variables, including demographic characteristics, social harms, social capital, religious beliefs and values, general capability of local communities, resources and skills, social inequality, social security, human assets, and awareness and education, on social resilience. Overall, the results indicated a variant locative distribution of the mentioned variables throughout the study region. The status of social capital, as the most significant factor that can promote social resilience of society, generally (country) and specifically (cities), shows that more than 48% of urban areas in the studied region were at a low level and had unfavorable conditions in terms of social resilience. Moreover, the results for social harms of individual urban areas were indicative of a generally low level of social resilience in the city; only 20 percent of the urban areas had high or very high social resilience levels. The status of resources and skills, as another affecting index for social resilience, showed that, except for the central areas and one area in the northwest, where the level of resilience was high, other areas were in unfavorable conditions regarding social resilience level. The southeastern areas and urban area 22 in the northwest were in a very high level of resilience, in terms of social security and social inequality variables. Generally, it can be claimed that, considering the results of most of the variables, urban areas 35 and 22 were at good levels of social resilience, while the southern areas were at poor levels for most of the variables.

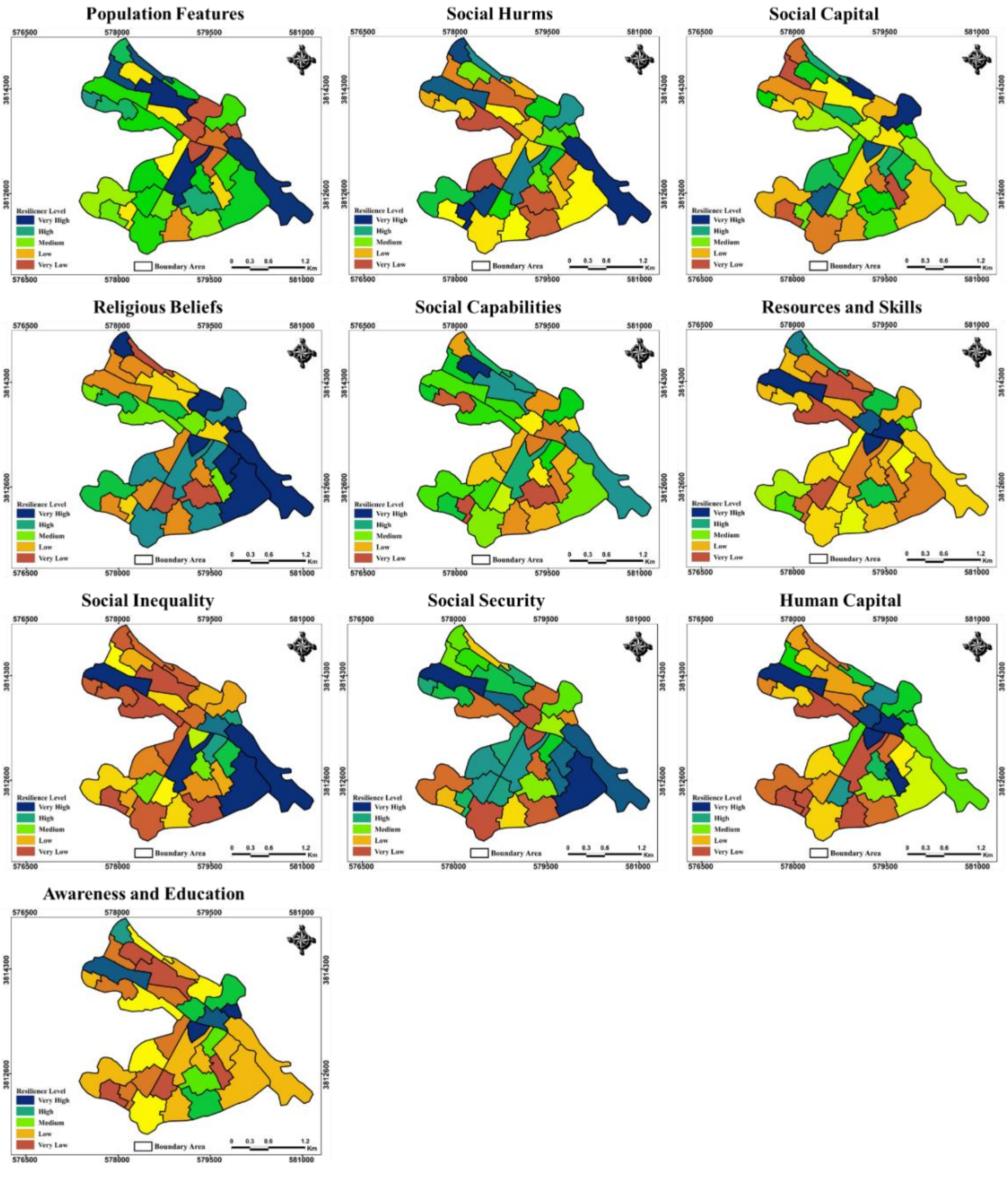

Figure 13. The standardized maps of the variables affecting social resilience.

In Figure 14, the final map of social resilience obtained from the WLC model, based on GIS-MCDM and the diagram of the percentage of social resilience in the urban areas in different classes, is presented. The results indicated that the levels and scope of social resilience were not evenly distributed throughout the city. Almost all areas in the south and southwest were in poor social resilience conditions. The central and eastern areas had better conditions, in terms of social resilience, compared to other districts and urban areas.

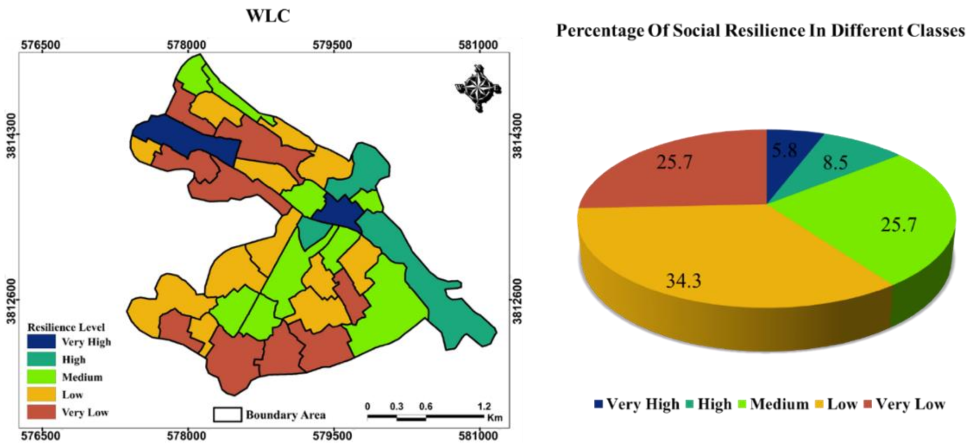

Figure 14. Final social resilience map prepared based on wlc model.

4.2. Accuracy Assessment

In order to assess the accuracy of the final social resilience map, the correlation coefficient between the results of the WLC model and the real-world resilience data from each urban area acquired through the questionnaires, was calculated. The results are presented in Figure 15. The results showed that the correlation coefficient between the WLC model and the level of social resilience was 0.79, which was indicative of the high capability of the proposed WLC model for preparing the locative map of social resilience.

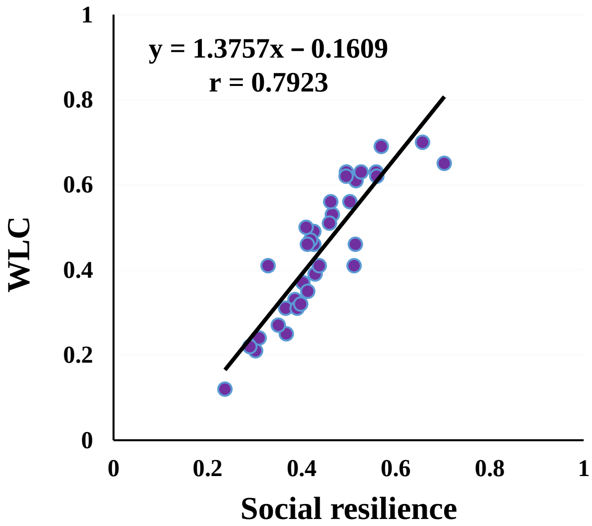

Figure 15. Correlation coefficient between the results of WLC model and real-world social resilience data.

5. Discussion

Facing natural hazards is one of the most important concerns of human communities [91]. Despite developments in encountering these hazards, there are limitations imposed on humans from nature, preventing effective mitigation actions [7]. Social resilience, as one of the effective metrics in the process of crisis management, is a community-based approach to improve the preparedness of urban communities against instabilities resulting from natural hazards [7,18]. In the meantime, identifying the resilient points of a city before, during, and after the occurrence of natural hazards has a great effect on the amount and time of recovery after the occurrence of shocks in every area [41,59–61].

This study was conducted with the aim of measuring the social resilience of Sarpol-e Zahab city against natural hazards. The results showed that most of the urban areas of Sarpol-e Zahab are in an unfavorable situation in terms of social resilience to natural hazards. In most urban areas, the situation is unfavorable in social capital and social damage variables compared to other variables. According to experts, these two variables have the greatest weight in reducing social resilience. In this regard, the research findings are consistent with the results of studies [11,59,60,92,93] shown in a study of Jabareen [92]. In a society where social capital is strong, a return from a damaged state is quick. Peregrine [93], in his study, concluded that social capital can strengthen and expand the area of cohesion and solidarity, sense of responsibility, social participation and awareness of citizens to develop and strengthen social justice in cities (Provide). The results of a study by Cutter, Barnes, Berry, Burton, Evans, Tate and Webb [59] also showed that reducing social vulnerability (poverty, addiction, etc.) and empowering people strengthens social resilience in urban communities. It also showed that, considering social resilience, more than 60% of the studied urban areas were at low to very low levels, 25% were at a moderate level, and nearly 14% at high to very high levels. This was indicative of the low defensive power of the city against shocks and incidents. Evidence on the retrieval rate in all urban areas of Sarpol-e Zahab shows that recovery from the earthquake in 2017 has remained really slow and unchanged in recent years. After almost four years since the incident, most of the urban areas have not dealt properly with the shock and have not returned to their initial states. The occurrence of that incident has affected all aspects of the survivors' lives and has had consequences, such as homelessness, displacement, social dispersions, social discrimination and inequality, poverty and unemployment, violence against women, social rejection, lack of social and psychological security, and various other social problems.

From the viewpoints of the researchers studying resilience of urban communities, the basis of resilience and sustainability of a whole society against natural hazards, lies in the extent of its social resilience [3,94,95]. In this approach, the concepts of public engagement and social development are given deeper and more serious attention; and because this approach includes community-oriented factors, it has a significant impact on reducing vulnerability, and, thus, enhancing the power of defense mechanisms and the resilience of cities against natural hazards [17,59]. Nevertheless, the approach of urban crisis management concerning the encountering of natural hazards in Iran, tends to be more physical and only reinforcement of buildings is taken into consideration, while other aspects of social resilience, such as economic and social aspects, are overlooked. Due to the non-participatory, highly centralized, vertical (top-to-down), and politicized characteristics of the urban management structure in Iran, there is a lack of horizontal convergence and mutual relations among different urban levels, and so, modern approaches of urban management are overlooked. This, along with other issues, is why retrieval after an incident is belated or delayed, thereby turning any natural hazard into a crisis.

Considering the applications and strengths of GIS-MCDM techniques in various decision-making processes relating to natural and human phenomena, this method was used in this study as a proposed method to identify the degree of social resilience of different urban areas and to determine the optimal areas for resilience in Sarpol-e Zahab city. In GIS-MCDM models, areas with high or low resilience can be determined according to the values and weights of the effective criteria. Obviously, the region with high resilience is one that has good conditions in terms of all variables.

The methods of GIS-MCDM consider the user's preferences, manipulate the data, and help decision-makers in complex multi-criteria decision scenarios by combining preferences and data [83]. The WLC method is one of the simplest and most common techniques in GIS-MCDA and was used in this study to identify urban resilient areas to natural hazards. The main advantage of this technique is that it can be implemented very easily in a GIS environment. Moreover, it is easy to understand and intuitively appealing to analysts [96].

6. Conclusions

Today, following the growth of urbanization and increasing natural hazards, investigating and measuring urban resilience to reduce the impact of natural hazards is considered one of the effective and most important factors of urban planning and management. Appropriate and accurate knowledge of the characteristics of each urban area, facilitates decision making and planning to monitor natural hazards, use of urban capacity, optimal location and finally management and decision making in urban affairs.

In this study, the level of social resilience in different urban areas of Sarpol-e Zahab city, Iran, was evaluated using local multi-criteria decision-making models with 10 variables and 28 criteria. The results showed that the southern, southwestern and northwestern parts of the city were unsuitable in all criteria (except for one urban area) and the central and southeastern areas had a significant area of medium and suitable rating in terms of flexibility. They were social. Considering that most of the urban areas, 60% of the study area, had very low levels in terms of social resilience, it is suggested that by strengthening communication between people and institutions, enhancing risk awareness, improving environmental quality, increasing the preparedness of people and NGOs, and developing and implementing disaster management plans to support the recovery process, social resilience could be achieved, resulting in improved urban areas.

Our findings indicate the relatively high performance of locative multi-criteria decision-making models for assessing the level of social resilience in highly vulnerable cities. The following limitations were encountered in the course of this study: (a) the strong dependency of the accuracy of the results on the experts' knowledge; (b) the input data were collected from different sources and at heterogenous coordinate systems, resolutions (i.e., spatial or temporal), and data formats (i.e., raster or vector); (c) data redundancy. As per future studies, we suggest considering models with the ability to consider the concept of risk in decision-making, based on Ordered Weight Averaging (OWA) logic for better mapping of optimal areas, in terms of social resilience. Furthermore, the incorporation of fuzzy logic-based models could be very useful, in order to consider uncertainty in measuring urban social resilience.

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