Research Paper: Spatial Analysis of the Settlement System of Rural Settlements Using Fuzzy Logic in Southeast Iran (Case Study: Khash Rural Area)

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ABSTRACT

Purpose: Locating rural settlements in order to prevent the erosion and destruction of the village due to environmental hazards or to prevent indiscriminate migration from the village to the city. The role of effective natural factors in the dispersion of rural settlements, such as slope, height, fault, geological and tectonic structure, water resources, soil, communication routes, vegetation cover, and land capability, have been taken into consideration.

Methods: This research is of a descriptive-analytical type, in which the fuzzy model was used to evaluate the location of villages in Khash city. Also, according to the output maps, most of the villages in the region are located in unfavorable conditions and inappropriate locations. The reason for this is the high slope of the area, the lack of proper access to the road, and the fact that another part of the area does not have access to surface and underground water because it is a desert.

Results: The results of this research showed that in fuzzy logic, suitable areas are shown at 0.78%, good areas at 14.23%, average areas at 26.66%, and unsuitable areas at 58.31%.

Conclusion: Natural factors in the establishment of settlements in Khash city are among the most important factors in the establishment of villages, which were discussed and analyzed using the fuzzy logic model and spatial analysis in the GIS environment.

1. Introduction

From the point of view of rural geographers, environmental factors are one of the main aspects of establishing rural settlements. This involves analyzing and recognizing the rural community based on the role of various forces and trends in the ecological and socio-economic environment resulting from rural activities, as well as the various structures and functions in that area. However, despite efforts made in the country, especially after the revolution, to deprive villages of instability

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and lack of development, there is still evidence of these problems in rural areas of Iran. One contributing factor is the lack of a system for establishing suitable settlements and choosing the location of villages. As a result, villages suffer from high levels of destruction when natural disasters and floods occur (Arghan et al., 2014: 56). ran faces many problems in rural planning due to the diversity of villages in terms of topography, climate, livelihood, social and economic conditions, culture, etc. One of the most important natural factors in the establishment of rural settlements is the natural elements, including the height, slope, direction of the slope, as well as the availability of water resources and fertile soil conditions in the area. Generally, the geographical foundations that influence the settlement system and development process of villages include factors such as climate, topography, water resources, soil resources, livelihood, dependence on other mining and industry sectors, tourist attractions, roads, location, communication, distance from service centers, demographic factors, employment and income status, resources, economic opportunities, migrations, etc. In addition to all these factors, investigating the role of environmental factors in the location and distribution of villages is very important (Fazelnia et al., 2014: 62). It is undeniable that various natural factors have different impacts on the creation, acceptance, physical and spatial development, and communication of settlements. In different places, these factors can have both positive and negative effects, as well as reasons for limitations. In any case, in different places, the natural factors, density, differentiation of settlements, population, and the existence of some settlements justify favorable conditions, while others may lead to unfavorable conditions from a biological standpoint. This understanding is based on the fact that natural phenomena, as determinants of the deployment system, are visible and observable. On the other hand, the cultural environment, which is constantly evolving, is not easily identifiable. Over time, certain natural factors may lose their importance, while others may become more significant. Additionally, new requirements may emerge due to changes and reorganization of these factors. Nevertheless, the main focus of this research is to determine which environmental and human factors effectively influence the location of rural settlements in Khash City.?

2. Literature Review

In the evolutionary process of life, based on local experiences and knowledge, humans have sought to establish comfortable settlements. The emergence of these settlements, particularly villages, has been primarily influenced by natural factors such as water and suitable soil. This is because natural complications and phenomena have a significant impact on location, dispersion, sphere of influence, physical development, morphology, and other factors. Sometimes they act as positive factors, while at other times they act as negative and inhibiting factors. In general, location analysis is an activity that evaluates and analyzes the spatial and non-spatial characteristics of land in order to select the most appropriate place for a specific purpose. This occurs through a quick and accurate assessment of the attractiveness of different locations for a specific application (Alimardani & Vaezi, 2019: 29). Various models have been used for location analysis thus far. One model that has gained attention from many researchers in recent years is the fuzzy logic model, also known as fuzzy set theory. Fuzzy logic (or fuzzy and uncertain logic) is capable of mathematically formulating imprecise and ambiguous concepts, variables, and systems. It provides a basis for reasoning, control, and decision-making in uncertain conditions. Therefore, fuzzy logic appears to be a suitable tool for location analysis due to its ability to handle ambiguous situations and its use of natural language and linguistic values. When combined with geographic information systems, this theory has made the process of locating urban services and facilities much easier. In this research, the fuzzy logic model (fuzzy set theory) has been employed to examine the positioning of crisis management bases in the region. Another model used in this research is the analytic hierarchy process (AHP) model. The AHP is a mathematical method used to determine the importance and priority of criteria in the evaluation and decision-making process. It is one of the most well-known multiple-criteria decision-making (MCDM) techniques for complex situations involving multiple and conflicting criteria. Since its development, many books and articles have been written on this topic. This method, due to its ability to simultaneously consider quantitative and qualitative criteria, as well as its ability to assess consistency in judgments, can be useful in analyzing location-related issues to promote industrial development and its economic and social consequences. The aim is to maximize the benefits of industrial activities while minimizing negative effects and economic losses. The center of gravity of location theory can be traced back to Germany. The oldest location model was proposed by Shaffle in 1929, who based his theory on the gravity model. Launhardt introduced his industrial location theory in 1885-1882, but the scientific framework for this theory was established by the German economist Weber in 1909. Then, Lösch and Christaller expanded and developed the central place theory, and finally, Hoover

refined and perfected this theory (Pourtaheri et al., 2012). In general, location theories can be divided into three categories based on attitude and problem analysis, which are briefly presented in Table 1.

In general, the pattern of spatial settlement and rural settlement is more influenced by natural factors than urban settlement due to the dependence of most of its production activities on natural factors and conditions. One of the determining factors for the establishment of settlements is the roughness and shape of the land. There is a close relationship between unevenness factors and rural activities. Natural factors such as the sea, mountains, hills, or other uneven phenomena play an important role in restricting or expanding villages and act as a deterrent and limiting factor for rural settlements. In this regard, the research conducted is as follows; In research, Ghanbari, Rahmani Fazli, and Azizpour (2020) investigated the spatial analysis of the development of rural settlements using the sustainable development approach in a case study: the villages of Khorram Abad City. The purpose of this study was to identify and spatially analyze the components and criteria of eligibility in the framework of the concept of sustainable development by analytical-descriptive method. They concluded that in these villages, components such as access to services, economic participation, and economic well-being are in good condition, while some other components (agricultural production, education, and population growth) are not in good condition (Ghanbari et al., 2020).

Mahmoodi et al. (2022) conducted a spatial analysis of the tourism development potential of tourist destination villages in the Mashhad tourism area. The purpose of this research was to evaluate the ecological potential of the study area using SPSS and IS software analysis and analysis using a multi-criteria decision-making model. According to the findings of the research, the most influential index was the distance to tourism water sources, and the least influential was the distance to the fault. Therefore, the greatest ecological potential belongs to the foothill villages of the study area. Also, in terms of tourism capacity, the natural attractions of the village and suburbs and the quality of the village road have had the greatest impact (Mahmoodi et al., 2022).

Table 1. Location theories from the perspective of philosophers

Location theories	Theoretician	Year	Theory
Based on the least cost method (before the 60s)	Johann Heinrich von Thunen	1826	Emphasis on agricultural activities and transportation should be based on minimizing distance.
	Launhardt	1882	Presenting a simple triangular model for optimizing the location of industries, taking into account transportation costs.
	Webber	1909	Based on cost minimization, taking into account transportation, labor, and industry aggregation factors.
	Galpin	1915	Settlements that have the same number and level of services are distributed at uniform distances on the land surface, and the complementary areas of each center take on a circular shape.
	Dickinson	1930	We studied the relationship between population size and the number of different goods and services in the small towns of the East Anglia region, which were very rich in terms of agriculture.
	Hoover	1948	Industrial locations assume complete competition between producers and sellers and complete mobility of production factors.
Central place theory	Walter Christaller	1933	It is the description and explanation of the spatial organization of the settlements and their sphere of influence.
Based on the access analysis method (maximum revenue) (the 60s and 70s)	Lash	1940	Attention to demand in the general theory of positioning
based on the maximum profit method (late 70s)	Green hat	-	The optimal place for setting up industries is where the two cost and revenue curves are the most distant from each other.
	Walter Izzard	-	Determining the optimal location of the industry based on the application of the principle of substitution among production factors

Tabibian et al. (2022) researched to evaluate the ecological potential of the watershed for the development of ecotourism using AHP and fuzzy logic in GIS. The purpose of this current research is to evaluate the ecological potential of the watershed for the development of ecotourism using the Analytical Hierarchy Process (AHP) and Geographical Information Systems (GIS). Then, fuzzy logic and weighted linear combination (WLC) methods were used in GIS for intensive and extensive ecotourism development zoning. The results showed that 1.3 percent (273 hectares) and 11.3 percent (2327 hectares) of the watershed are very suitable for the development of intensive and extensive ecology. Also, 2.3 percent (475 hectares) and 14.1 percent (2903 hectares) of the region are in the appropriate category for intensive and extensive ecotourism development. The most suitable areas for intensive ecotourism are located in the southeastern part of Soleqhan district, Lower Keshar, and Upper Keshar villages. Extensive ecotourism potential areas are located throughout the watershed along coastal areas and in valley bottoms (Tabibian et al., 2022). Yunus, Kotb, Ghazaleh, and Elkadeem (2022) studied the spatial suitability analysis for choosing the location of refugee camps in Kenya using a combination of GIS and fuzzy AHP approaches. In this study, four main factors and 19 evaluation criteria related to geographical, environmental, infrastructural, and social aspects have been fully investigated. The results showed that the territory of Kenya is classified into four levels: 6.5% of the total surface area is less suitable, 10.6% is moderately suitable, 10.3% is suitable, and 7.5% is highly suitable. Additionally, the analysis showed that the existing camps are located in inappropriate areas, either in the north or east of the region (Younes et al., 2022).

Kargar et al. (2020), in an article titled "Urban spatial measurement for the purpose of locating law enforcement centers with emphasis on the fuzzy method (the example of the second and fourth regions of Qom city)," locating means finding areas with capacity and appropriate for supporting the city's needs. This research was carried out with a practical approach and a descriptive-analytical method. In the first step, after receiving different layers of urban uses effective in locating law enforcement centers from different organizations and centers, and after calculating the weights of the criteria and sub-criteria using the chain analysis model, distance maps were created in GIS software. Next, suitable areas were determined for developing police use. By examining the distribution of law enforcement centers in districts two and four of Qom City, it was determined that the distribution of law enforcement centers in these areas is faced with an unbalanced spatial distribution. Only a few police stations and law enforcement centers are facing numerous problems in ensuring the security of the city (Kargar et al., 2020). Javan et al. (2019), in an article titled "How to select the location of nominal-strategic centers based on natural geographical indicators (West Azarbaijan province)," emphasized the importance of selecting a suitable location for the establishment of military-strategic centers for defense purposes. Choosing a suitable location can increase the efficiency and effectiveness of these centers during times of crisis and military threats. When locating military centers, it is crucial to consider natural geographical factors. Natural geography has long played a decisive role in the selection, expansion, and development of human settlements (Javan et al., 2019). Rahimi and Madidizadeh (2018), in an article titled "Locating Neighborhood Parks with a Sustainable Development Approach (Kerman City Region 3)," aim to locate neighborhood parks with a sustainable development approach in the three cities of Kerman. The current research is applied in terms of purpose and descriptive-analytical in terms of method. To carry out the research, the layers related to the location were prepared using the distance-finding method in the environment of the geographic information system. Then, weights were given to the layers using hierarchical analysis. Each layer was classified into several classes and weighted according to its importance, and the related map was prepared using the classification command in the geographic information system environment. Then, weights were applied according to the importance and influence of each layer to obtain the final map that shows the suitable place for creating neighborhood parks. Finally, by overlapping the weighted layers using the fuzzy overlay command, the final map was created (Rahimi & Madadi Zadeh, 2018). Nasiri et al. (2017), in an article titled "Locating the Landfill in Mako City Using Fuzzy and Bolin Method" today, the management of waste and waste materials in cities is considered essential for the comfort of citizens and to preserve their health and well-being and to preserve the environment. The current research aims to find a suitable place for burying waste materials and urban waste in Mako City using fuzzy methods and Boolean logic using geographic information systems (GIS). For this purpose, several layers were used, including a topographic map, slope map, underground water map, road map, urban and rural areas map, land use map, etc. Then, each of these layers is made in a soft environment to determine the areas prone to waste burial (Nasiri et al., 2017). Ghanbari and Mohammadi (2017), in an article titled "Investigation of the level of satisfaction of rural communities with the location of uses in the rural guide plan (example: villages of Lordegan city)," argue

that the location of uses in rural guide plans should be done in such a way that their desirability decreases with time. Alternatively, changes should occur partially to ensure the sustainability of the rural development process. Based on this, planners have noticed all the coherent and regular activities that have been done in order to organize and improve the physical environment of rural settlements. The research aims to evaluate the level of satisfaction of rural communities with the location of proposed uses of the Rural Conductor Plan in sample villages of Khan Mirza. The current research is applied based on its purpose and descriptive-analytical based on its nature (Ghanbari & Mohammadi, 2017).

Also, in 2010, Fernandez and Lutz conducted research using the combined method of GIS and multi-criteria decision analysis for flood risk zoning in urban areas of Tucumán province, Argentina (Fernandez & Lutz, 2010). Müller-Jensen (1998) analyzed the location of education in Copenhagen, Denmark. In this research, he presented a model for the location of educational spaces, which is based on the registration of spaces according to the selected routes. Farhadi and Hemmati (2017). "Locating Social Housing (Case Study: Mehrshahr Housing in Kazeroon)." Today, choosing the right place to build a residential, industrial, etc., place is one of the most important issues in urban planning. Considering the importance of the topic, in this research, the location and establishment of the Mehr housing project in Kazeroon City have been examined and analyzed from the point of view of urban planning. The type of research is applied, and its method is descriptive-analytical. The technique used is the process of hierarchical analysis of analyses in the Arc software environment, GIS. Accordingly, the hypothesis of the research states that the location and establishment of this project in Kazeron City are in accordance with urban planning criteria. To conduct the research, first, the 16 proposed sites and options for the implementation of the project in this city were identified on the map. Then, the criteria and sub-criteria of residential location were determined and weighted using experts' opinions. After comparing each of the different sites based on the given weight criteria, the weight of each of the sites was calculated. Then, the combined priority weight of each site was obtained, and finally, the final score of each of them was calculated. In this way, the sites that got the most points in terms of urban planning were identified. The obtained results show that sites number ten (Dashtak lands) and twelve (land next to the college) have the most points for the construction of Mehr Kazeroon housing (Farhadi & Hemmati Goshtasb, 2017).

Sener et al. (2010) conducted a study on the localization of land surface changes in Turkey's Beyshahir Lake basin using the hierarchical hybrid method and GIS (Sener et al., 2010), all of which are in line with the present study. Li et al. (2012) in a research entitled "Shelter location and transportation planning under hurricane conditions," a programming model to optimize the selection of shelter locations considering a wide range of storms and emergency evacuation conditions during the event of a realistic study for the state of North Carolina have placed. In 2012, in a research entitled natural disasters and emergency management systems in urban areas, for example, the area and suburbs of Orlando in the state of Florida, Kapucu (2012) focused on the factors of formation and formation of management in urban emergency, multifaceted intra-organizational relationships and common goals at the local level and in particular, have been investigated at the city level. In a 2014 study, Anhorn and Khazai analyzed the suitability of open space for an emergency shelter after an earthquake in Kathmandu city, which used a geographic information system to classify the selected shelter sites. According to the results, out of 410 surveyed open spaces, 12.2% are not suitable (category D and E), while 10.7% are category A and 17.6% are category B.

3. Methodology

The methods of information gathering in this research have been library and field research. First, the required layers are collected, and then the final map is obtained by standardizing and weighting the layers. One important stage in location selection is the standardization and classification of each layer into specific classes. However, before the classification, the layers must be converted into raster layers. This is done by performing the layer overlapping operation in the final stage. To accomplish this, the buffer tool was utilized in the ArcMap environment. This function expresses the relationships of each cell in a complication in terms of distance, direction, and position. The distances around the complications are determined as equal distances, meaning that the smallest real distance of each cell to the desired complication is calculated (Ghahroudi, 2011).

In the fuzzy method, the layers used are weighted based on a weighting method, which is the most commonly used location method. The fuzzy method evaluates the membership of each layer according to its value. In this research, the layers were standardized first, as mentioned above. Then, the layers were made accessible, and through reclassification in terms of pixels, the size and

scale were entered. Finally, the final weights were assigned in this section, and the output map was prepared.

Khash city, with an area of 19,376 square kilometers, is located in the center of the Sistan and Baluchistan province. The distance between the city center and the provincial center is 180 km. This city consists of three urban centers, three districts, 11 villages, and 1,001 inhabited villages. In this research, the villages are shown on the maps and analyzed according to the environmental factors, in accordance with the research topic.

4. Findings

Analysis of environmental factors in location selection: The importance of effective criteria in choosing village locations was analyzed below. The natural factors studied include slope, height, and water resources, and the combination of these parameters is referred to as natural resources or ecological resources. When explaining the settlement system of settlements and activities at the geographical level, topographical factors are considered the primary factor. Unsuitable topography is a limiting factor in the creation and development of settlements, and unevenness is particularly important in locating rural areas. The slope and density of the village: Neglecting the issue of suitable slopes has resulted in landslides occurring after rainfall and earthquakes, leading to financial and human losses (Ghazban, 1996). Analyzing the topographical factor and its role in the stability of rural settlements without considering the slope does not seem logical. Given the importance of slope in various agricultural, civil, and residential uses, considering the slope factor, along with other parameters, can be essential in assessing the land's capabilities. Recent studies in village development have focused on village locations. According to the slope conditions of the studied area (Khash city), slopes less than 10% are deemed suitable for establishing villages. The map and table below indicate the locations and densities of villages on different slopes. There are 334 villages (39.89%) in the slope class of 0-2%, and 260 villages (32.43%) in the slope class of 2-5%. There are no villages on slopes with a gradient of more than 30 degrees.

The slope plays a crucial role in the establishment of rural settlements, determining the location of villages and creating favorable conditions for livelihoods, particularly in agriculture. This factor is pivotal in selecting optimal locations for settlement networks and mitigating natural disasters. Settlements on steep slopes pose challenges for village services and related activities such as animal husbandry and agriculture, with a decrease in settlements as slope steepness increases. Additionally, construction and equipment costs rise with steeper slopes. According to the International Geographical Union, smooth, low-sloping surfaces are ideal for settlements, with a recommended maximum slope of 11 degrees, varying based on environmental conditions. The distribution of villages reflects this, with fewer settlements on steeper slopes. Geomorphologically, slopes of 0-7% are most suitable for rural settlements. Altitude also influences village location, with human activities above 2000 meters generally considered less appropriate. In the mountainous studied area, the altitude standard for settlement is set at 2000 meters. The map illustrates the correlation between village density, altitude, and distribution across different altitude points.

Table 2. Population of the study area by division and district

Divide	Divide center	City	Villages	Villages center	Population in People (2016)
Central	Khash	Khash	Posht-e-koh	Afzal-Abad	58713
			Sangan	Sangan Olya	4116
			karvadar	Caravandar	1537
			Kohe-Sefied	Bit Abad	77313
			Esmaeelabad	Abbas Abad	57717
Nok-Abad	Nok-Abad	Nok-Abad	Oskolalabad	Dehpabid	156
			South Taftan	Tamendan	72511
			Gohar Kuh	Gohar kuh Shahrak	7810
			Nazil	Nasil	9711
Ayradagan	Ayradagan	Ayradagan	Kahnak	Ayradagan	2619
			Ayradagan	Ghaleh Paein	564

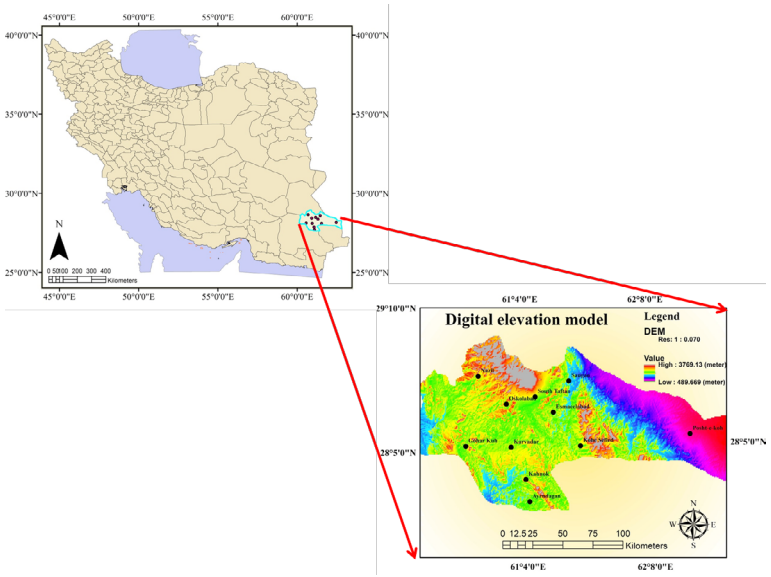

Figure 1. The location of Khash City in Iran and the provinces of Sistan and Baluchestan and the distribution of villages

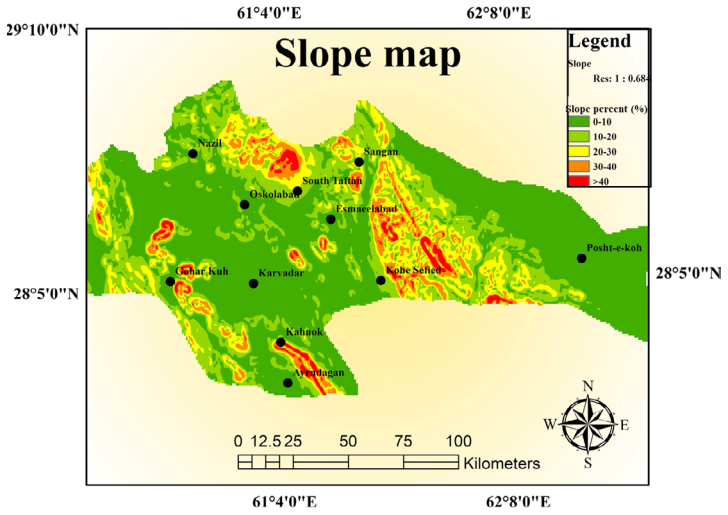

Figure 2. Slope map and village location

Table 3. Location and slope of villages

Row	Slope classes	Number of villages
1	0-2	334
2	2-5	260
3	5-8	90
4	8-10	74
5	10-12	80
6	12-15	81
7	15-20	10
8	20-25	1
9	25-30	3

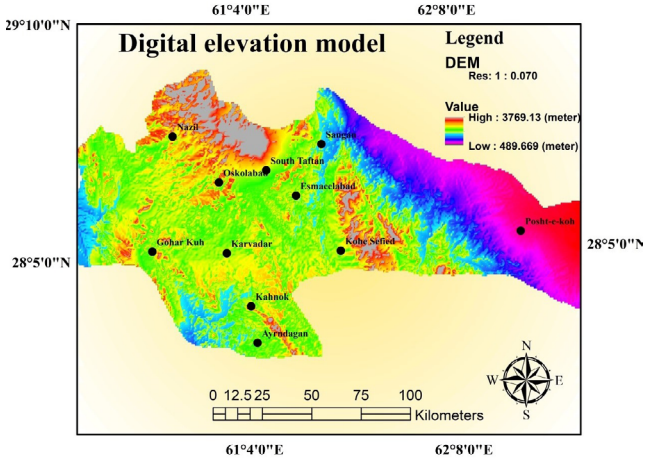

Figure 3. Distribution of villages at different altitude points of the region

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Additionally, the table below presents the percentage of villages located within each altitude class, revealing that 445 villages (94.51%) are situated within the altitude range of 1400-1200 meters, with no settlements recorded at altitudes exceeding 2400 meters (Table 4).

The highest concentration of villages is situated within the elevation range of 1200 to 1400 meters. As the elevation increases, the number of settlements decreases, particularly beyond 1800 meters, due to challenging mountain conditions, prolonged cold periods, adverse weather, and limited access to communication networks in these elevated areas, resulting in reduced rural development. Another influencing factor on slope location is its orientation; north-facing slopes often offer fertile conditions for agriculture, making them favorable settlement locations. The Figure 4 depicts the area's slope map.

As evident, the geographic orientation significantly influences sunlight exposure. Predominantly, villages are situated on southern slopes, which receive more sunlight and consequently are warmer and more evaporative compared to shaded slopes. This leads to reduced water storage and lesser vegetation growth on sunny slopes, making them more prone to soil humus breakdown and erosion. Despite some limitations, southern-facing fields receive the highest amount of sunlight throughout the day, creating favorable conditions for settlements. The high concentration of villages in the southern and northern directions is attributed to increased sunlight and moisture respectively, while the lowest dispersion is observed in the western and northwestern directions. Access to surface water and rural dispersion: Water, a vital resource, plays a pivotal role in human settlements, as reflected in the distribution of gathering centers around water sources (Tabibian, 2022: 19). In the study area, water is sourced from 918 wells, 393 canals, and 369 springs, providing a total water supply of 294 million cubic meters. Groundwater is the primary water source, as most rivers are seasonal. The city's watersheds encompass the clay plains and areas behind the mountain, the mountain gem plain, and the Ayrndagan and Karvadar range. The study considered a distance of less than two kilometers as the optimal criterion for surface water proximity in settlement location.

Table 4. The percentage of villages in each altitude class

Row	Elevation Class	Number of villages	Percentage
1	500-700	0	0
2	700-1000	0	0
3	1000-1200	34	6.97
4	1200-1400	445	51.93
5	1400-1600	249	34.30
6	1400-1600	68	7.94
7	1600-1800	12	1.40
8	1800-2000	3	0.35
9	2000-2200	1	0.11

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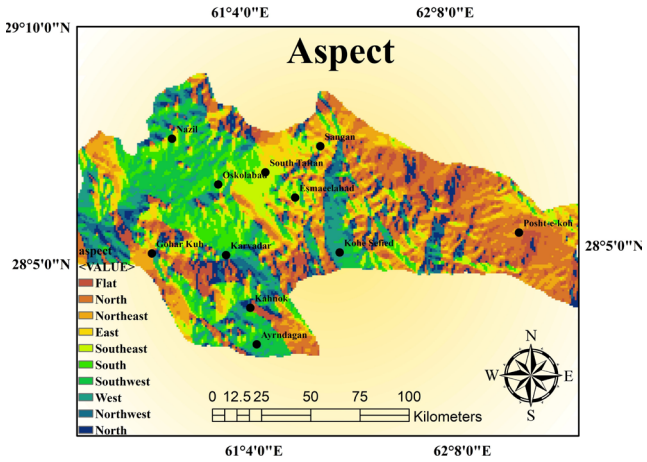

Figure 4. Direction of the slope of the area and the density of the village

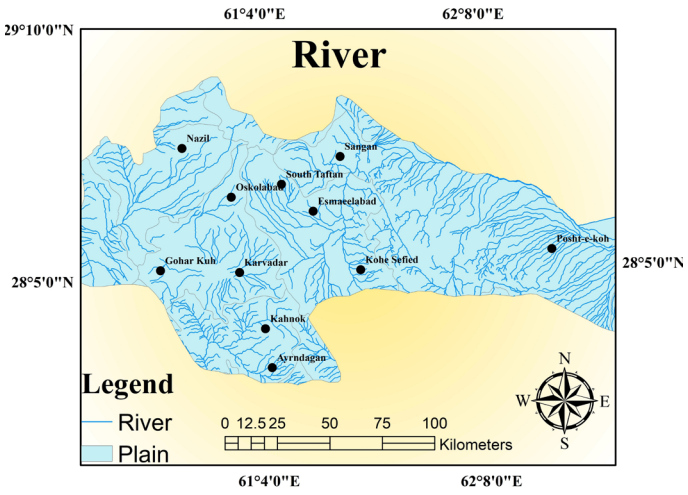

Figure 5. Surface water and village dispersion

Fault and villages: Considering that faults can limit settlement development, the fault base was assessed to determine the suitability of the area in relation to its proximity to faults. As per this assessment, villages are located less than 5 kilometers from unsuitable-range faults and more than 5 kilometers from suitable-range faults (Yarahmadi & Sharafi, 2016: 133). Based on the findings, the majority of villages in the city of Khash are situated at distances exceeding two thousand meters. Furthermore, a minor number of villages within the 1000-2000 meter range from the D fault exhibit low confidence coefficients. The distribution of villages and their distances from the faults in the area is shown in the map (Figure 6) and Table 5.

Population: The uneven distribution of population can be attributed to both natural and human factors, resulting in the migration of villagers to urban areas and the abandonment of rural villages in recent decades. It is possible that villages where infrastructure was initially established have since been deserted, or human actions, such as inappropriate placement of facilities, have worsened inequality. The map below illustrates the population distribution in the region (Zoleh & Jamshidi, 2011) (Figure 7).

Communication Routes (Roads): Among the factors influencing village location, easy and rapid access to urban centers, educational facilities, and healthcare centers play a significant role. In the study area, access to communication routes is limited, with the central and eastern parts being more accessible compared to other areas. The map below (Figure 8) illustrates the distance between each village and the road network within a 300-meter buffer zone.

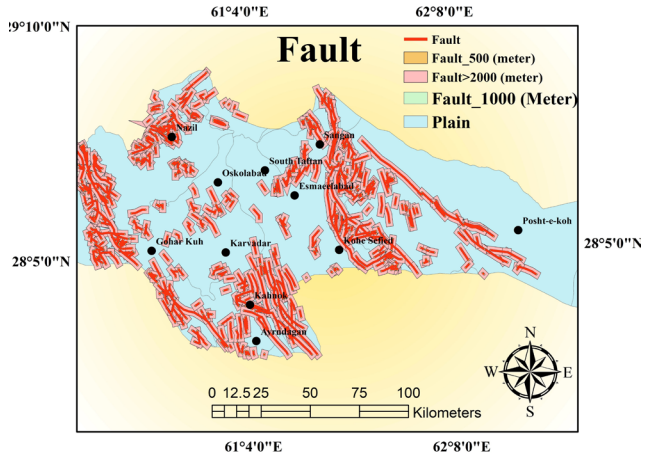

Figure 6. Map of faults and villages

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Table 5. Distance of faults from villages

Row	Buffer	Number of villages	Percentage
1	Buffer 500 meters	65	7.5
2	Buffer 1000m	120	20.3
3	Buffer 2000<m	875	72.6

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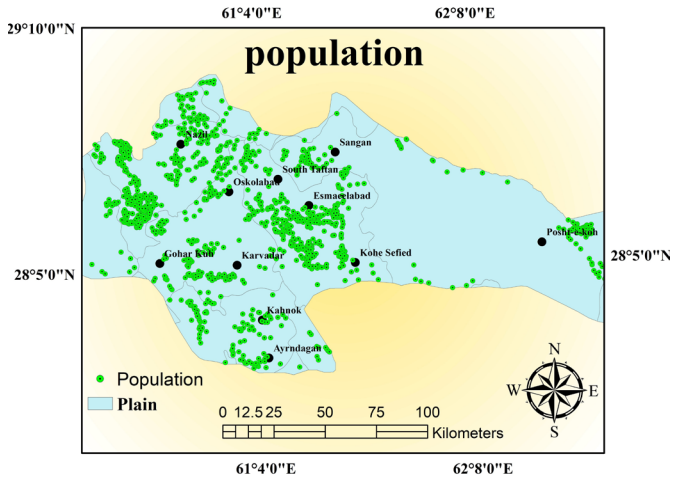

Figure 7. Map of villages and population

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Land Use: Land use is recognized as a crucial factor for maintaining the village population as it offers essential amenities such as educational, healthcare, and administrative facilities. The map below depicts the land use in the relevant area. It is evident that the majority of the study area is desert, and the utilization of gardens and green spaces is minimal due to the area's mountainous terrain (Figure 9).

Soil Resources: The dominant soil type in the study area is Aridisols, typical of dry and desert regions, along with rocky terrain, reflecting the area's arid climate. The map below illustrates the distribution of these soil types in the territory (Figure 10).

We will now examine the results and maps generated by the fuzzy model, which indicate the degree of suitability of village locations. The map below illustrates that the majority of the study area is unsuitable for village location, with only a small portion showing a high degree of suitability, attributed to the mountainous terrain, steep slopes, and dry climate (Figure 11).

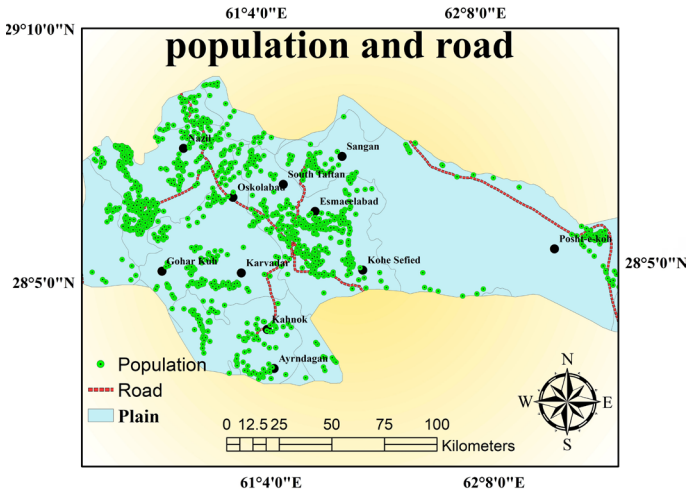

Figure 8. Map of villages and communication routes

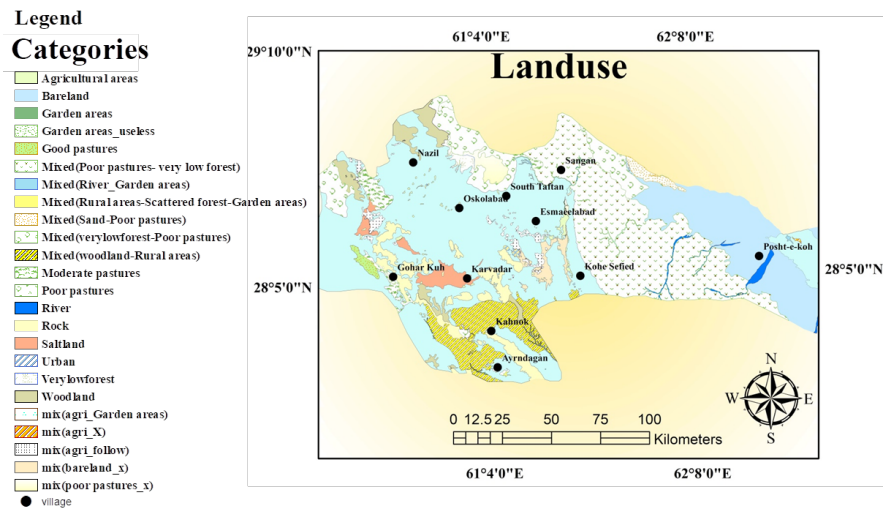

Figure 9. Land use map of the area

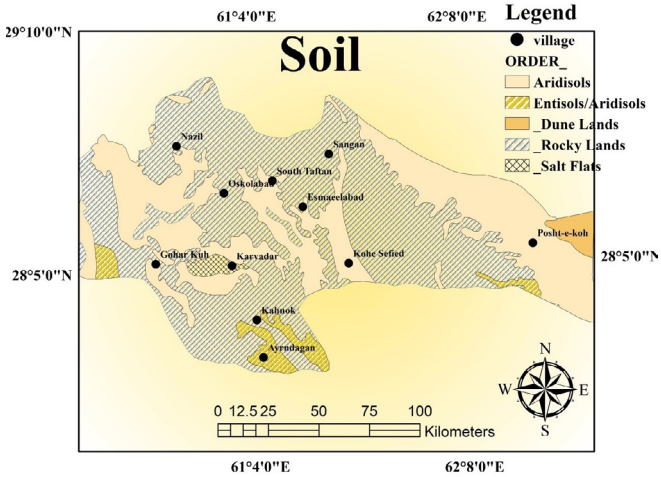

Figure 10. Classification map of the soil type of the area

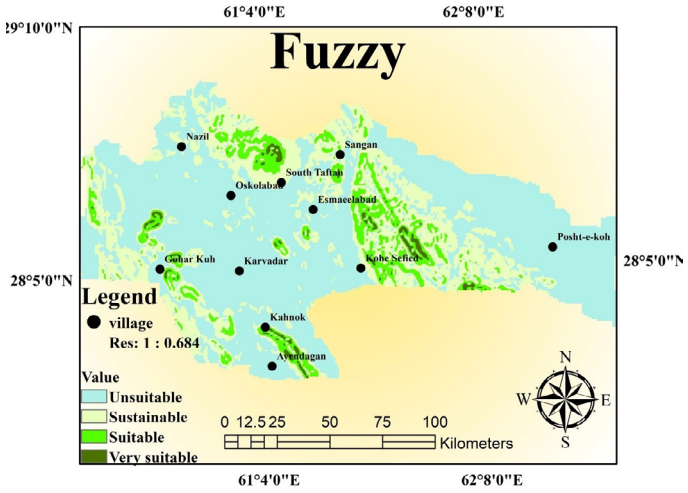

Figure 11. Location map based on the Fuzzy Model

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5. Discussion

The research findings indicate that, within the framework of fuzzy logic, suitable areas account for 0.78%, good areas for 14.23%, average areas for 26.66%, and unsuitable areas for 58.31%. It was concluded that the Fuzzy model demonstrates greater accuracy in selecting suitable locations due to its hierarchical nature. The hierarchical and highly accurate nature of the Fuzzy model was emphasized. Additionally, based on the output maps, it was observed that the majority of villages in the region are situated in unfavorable conditions and suboptimal locations. The study underscores the significance of spatial analysis in examining village locations, aligning with the research conducted by Ghanbari & Mohammadi (2017) on the spatial analysis of rural settlement development in Khurram-Abad, as well as the work of Mahmoodi (2022) and colleagues who analyzed the spatial potential of tourist destination villages in Mashhad within the field of tourism. The results also corroborate the findings of researchers who assessed the ecological potential of the Ken Basin for ecotourism development using the AHP and fuzzy logic in GIS. Moreover, the study highlights the importance of considering natural factors in location studies, consistent with the research by Javan et al. (2019) on locating nominal-strategic centers based on natural geographical indicators in the West Azerbaijan province. Given the environmental influence of geological phenomena such as faults, drought, poor climate, and seasonal rivers in the study area, the effective management of rural areas for sustainable development becomes crucial. The results indicate that most villages are situated in adverse conditions. The selection of optimal areas for sustainable development through the Phase model is of paramount importance. Considering the multifaceted factors involved in village deployment, the utilization of these two models can serve as valuable tools for development managers and planners. Furthermore, the models represent the most influential tools for identifying optimal areas for rural settlements.

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Conflict of Interest

The authors declared no conflicts of interest.

References

Alimardani, M., & Vaezi, M. (2019). Surveying the Level of Quality and Identity of Islaamshar Urban Sight from the Citizens' Viewpoint. Journal of Environmental Science and Technology, 21(1), 183-200. doi: 10.22034/jest.2018.13782

Anhorn, J., & Khazai, B. (2014). Open space suitability analysis for emergency shelter after an earthquake. Natural Hazards and Earth System Sciences Discussions. 2. 4263-4297. 10.5194/nhessd-2-4263-2014.

Arghan, A., Davari, A., & Farjzadeh, T. (2014). Location of optimal development centers of rural settlements in Samet City (case study: Kohsaran village), Regional Planning, 4(14), 133-146. URL: B2n.ir/q34058

Farhadi, R., & Hemmati Goshtasb, S. (2017). The Site Selection for Social Housing (Case Study: Mehr Housing Project of Kazerun City). Journal of Urban Social Geography, 4(2), 87-101. doi: 10.22103/JUSG.2018.1954

Fazelnia, Gh., Hakim Dost, S.Y., Poour Jafarabadi, M., & the rest of the world. (2014). Analysis of natural factors influencing the distribution and settlement of rural settlements in the city of Sirjan. Scientific quarterly research on regional planning, 4 (16), 109-124. Url: B2n.ir/j21884

Fernández, D.S., Lutz, M.A. (2010). Urban flood hazard zoning in Tucumán Province, Argentina, using GIS and multicriteria decision analysis. , 111(1-4), 90–98. doi:10.1016/j.enggeo.2009.12.006

Ghahroudi Tali, M. (2011). Application of the Fuzzy-Logic model in the identification of Karst Groundwater Resources case study: sirvan Basin, Eleventh National Seminar on irrigation and evaporation reduction, Kerman. https://civilica.com/doc/157897

Ghanbari, A., Rahmani Fazli, A., & Azizpour, F. (2020). Spatial Analysis of Rural Settlements Development Using Sustainable Development Approach (Case Study: Villages of Khorramabad County). Journal of Research and Rural Planning, 9(1), 53-71. doi: 10.22067/jrrp.v9i1.79914

Ghanbari, S., & Mohammadi, H. (2017). Study the Satisfaction rate of Rural Communities about Land use Locating in Rural Guide Plans (Case Study: Khanmirza Village Lordegan township). Geography and Development, 15(47), 37-50. doi: 10.22111/gdij.2017.3182

Ghazban, F. (1996). Environmental Geology, published by the University of Tehran.

Javan, K., Valizad, L., & Mahdavi, S. (2019). Site Selection of Military-Strategic Centers Based on Physical Geographic Factors (Case Study: West Azerbaijan Province). Strategy, 28(1), 185-207.

Kapucu, N. (2012). Disaster and emergency management systems in urban areas. Cities, 29, S41-S49. DOI:10.1016/j.cities.2011.11.009

Kargar, B., Osanlu, A., & Tavakoli Naghmeh, M. (2020). Spatial-spatial measurement of the city in order to locate law enforcement centers with emphasis on the Fuzzy method. Geography (Regional Planning), 10(40), 467-482. URL: B2n.ir/w34476

Møller-Jensen, L .(1998). Assessing Spatial Aspects of School Location-Allocation in Copenhagen, Geografisk Tidsskrift-Danish Journal of Geography, 98(1), 71-80, DOI: 10.1080/00167223.1998.10649412

Li, A., Nozick, L., Xu, N., & Davidson, R. (2012). Shelter location and transportation planning under hurricane conditions. Transportation Research Part E: Logistics and Transportation Review. 48. 715–729. 10.1016/j.tre.2011.12.004.

Mahmoodi, H., Shayan, H., Sojasi Qeidari, H., Sadeghloo, T., & Minaei, M. (2022). Spatial Analysis of Tourism Development Potential of Tourism Destination Villages (Case Study: Mashhad Tourism Sphere of Influence). Journal of Research and Rural Planning, 11(2), 1-22. doi: 10.22067/jrrp.v11i2.87483.

Nasiri, B., Ayas Nezhad, J., Yarmoradi, Z., & Abbas Nadadsarafroze, F. (2017). Site selection of waste disposal in Maku city By Fuzzy and BooleanLocation of a landfill in Macau by fuzzy and bulletin method. Journal of geographical space planning, 7(24), 87–98. Url: B2n.ir/p28514

Pourtaheri, M., Papli, M. H., & Fallahi, A. (2012). Evaluation of the performance of agricultural cooperatives in rural areas of Khurramabad, chronology of geography and development, Geography and Development, 10(26), 49-60. doi: 10.22111/gdij.2012.423

Rahimi, D., & Madadi Zadeh, F. (2018). Locating Neighborhood Parks with Sustainable Development Approach (Case Study: District 3 Of Kerman). Geography and Territorial Spatial Arrangement, 8(28), 199-216. doi: 10.22111/gaij.2018.4219

Sener, S., Sener, E., Nas, B., Karagüzel, R. (2010). Combining AHP with GIS for landfill site selection: a case study in the Lake Beyşehir catchment area (Konya, Turkey). Waste Manag. 2010 Nov;30(11):2037-46. doi: 10.1016/j.wasman.2010.05.024. Epub 2010 Jul 1. PMID: 20594819.

Tabibian, S., Hosseini, K., Rezvani, M., & Homayoon Nezhad, I. (2022). Ecological potential evaluation of the Kan watershed for ecotourism development using AHP and Fuzzy logic in GIS. Environmental Resources Research, 10(1), 9-22.

Yarahmadi, D., & Sharafi, S. (2016). Environmental factors affecting the formation and occurrence of natural hazards in rural settlements Silakhor Plains in Lorestan Province. Journal of Natural Environmental Hazards, 5(8), 123-134. doi: 10.22111/jneh.2016.2865

Younes, A., Kotb, K. M., Ghazala, M. O. A., & Elkadeem, M. R. (2022). Spatial suitability analysis for site selection of refugee camps using hybrid GIS and fuzzy AHP approach: The case of Kenya. International Journal of Disaster Risk Reduction, 77, 103062.

Zoleh, M., & Jamshidi, A. R. (2011). The importance of the cultivation model for sustainable agricultural development and providing a suitable solution to reform it, the first National Conference of strategies for achieving sustainable agriculture, Ahvaz, University of Payam Noor in Khuzestan province.