Research Paper: Analysis of the Spatial Structure of Rural Settlements Surrounding Urmia Lake's Western Region

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ABSTRACT

Purpose: Rural settlements are a part of Land use and regional planning discussed at the national and regional levels. The subject of the research is to analyze the patterns of the spatial distribution structure of the rural settlements in the western region of Lake Urmia. The study aims to explore the spatial distribution and the relationship and effectiveness of natural foundations on how the spatial structure is formed and to know the factors affecting the spatial distribution of rural settlements in the western region of Urmia Lake.

Methods: The primary data were used in the form of several layers of information, such as the layer of centers of rural settlements in the western region of Urmia Lake, the surface density layer of settlements, the layer of height, slope, hydrographic network, geomorphology, geology, tectonics (faults), Google Earth satellite images and field survey observations. Geostatistics and spatial analysis methods were used in the ArcGIS environment, including various data extraction and transformation techniques, kernel function techniques, geographic distribution measurement techniques, and visual analysis.

Results: The research results show that the spatial structure of rural settlements of the western region of Urmia Lake does not have a normal distribution and natural balance, and irregularities are observed in the form of clusters and scattered cases of settlements. The findings show that this irregularity is caused by the morphostructure of the spatial distribution of natural factors and foundations, especially the height and geomorphological factors in the region. Fault systems are the most critical factors of morphogenesis, which, in the form of horst (hills and mountains) and graben (pediments) landforms with a north-south trend, play a more influential role in the spatial structure of rural settlements. The results show that the highest concentration is in the grabens of the Urmia and intermountain pediment (74% of settlements) and the scattered pattern in the landforms of the horst with hilly (26%) and mountainous (0.01%).

Conclusion: The spatial distribution structure of rural settlements of the western region of Urmia Lake has a direct inverse relationship with the height factor, and contrary to the increasing trend of the region's height from east to west, the spatial distribution density of rural settlements decreases sharply. The overlaying of the geomorphology layer (landforms) with the centers and the surface density layers of settlements shows that the compound conical cluster pattern is the dominant spatial pattern and the center of gravity (with a density most value of 44.5-62.4). Among the natural foundations, combination factors of fault, height, and geomorphology have the most significant effect on abnormal spatial distribution and the formation of scattered and cone-shaped cluster spatial structures in the rural settlements of the region.

Keywords:
Spatial Structure, Rural settlements, Analysis, Urmia

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1. Introduction

Settlements are the process of human settlement and living places, and they are one of the most beautiful cultural landscapes. Investigating the spatial structure of settlement and how various environmental factors influence the forms and processes of human habitation through locating and occupying land and building housing is the primary subject of studying the geography of habitation and sustainable development. Settlements appear and develop under the influence of various factors. Today, human settlements' stability, instability, and resilience are challenging issues of regional planning management and forward-looking development. The formation and development of settlements have broadened and complicated the relations between the natural environment and humans in a way that has changed the rules of the spatial system. How are rural settlements established and distributed? Does their distribution and stability follow the laws of the natural system? What are the patterns of spatial phenomenology of settlements? Does the spatial structure of the village settlements in the study area have spatial balance? Where are the clusters? How effective are natural factors in the spatial structure of settlements? Does the spatial distribution of rural settlements in the research area follow the spatial structure of natural factors? What are the relationships between the spatial structure of settlements and the spatial structure of the natural environment? How can the spatial system of settlements be effective in the stability of their spatial structure? The characteristics of the phenomena, including the spatial center of the phenomena, the degree of clustering or dispersion of the phenomena around the center, and any directional trends, were analyzed and explained using spatial statistics analysis. Analyzing the distribution of phenomena helps study their changes over time. For example, it is valuable to see the central location of cases of a particular subject during a specific period, such as several months or decades, or to compare two or more sets of phenomena. Spatial statistics can be used to measure whether settlements' spatial distribution creates a pattern. If the phenomena form a cluster pattern, there are probably local sources (places with high environmental capacity and fertility that accommodate more settlements). We can also identify patterns in the distribution of feature values related to phenomena. For example, we can calculate the clustering of settlements in an area. If the regions of interest coincide with different and similar clusters, it may mean that the resources are not evenly distributed.

The selection of human settlement positions, especially rural settlements, has been made and systematized over time according to several locational factors such as topography, geomorphology (landform units), fertile soil, climate and water resources, communication, religion, and security positions. In the evolutionary process of low and high quality of the establishment system and its continued life and continuity throughout history due to the set of factors mentioned and other social, economic, and cultural factors, environmental hazards (explosive changes in the environment, numerous ecological crises, global warming, climate changes, drought), the spread of various epidemics and social unrest, wars and revolutions, population growth, industrial growth and development, the increasing growth of inappropriate urbanization, lack of mental peace of citizens, environmental disturbance, lifestyle changes, changes like businesses and current Population, capital and materials, the unprecedented growth of vehicles including cars, the development of communication and information technology, the process of globalization, the transformation of the relationship between urban centers and villages have undergone fundamental changes and transformations. Today, the spatial distribution system of rural settlements has changed. In the new system (which is usually associated with the transformation of functions), excessive clutter and dispersion of rural settlements, especially secondary settlements (villas), can be observed, which has caused many disturbances in the functioning of the spatial system of rural settlements. Spatial statistics analyses identify the trends, patterns, and relations of spatial distribution of phenomena, events, spatial relations, or spatial characteristics. Understanding the characteristics of the phenomena distribution helps us reach the correct conclusions from our analysis. Also, knowing how the phenomena are distributed even before starting the analysis is helpful. For example, it is essential to detect extraordinarily high or low values that may change the results of our analysis. Statistical methods are usually used to study the distribution of phenomena. Since there are many discrete and continuous statistical distributions and some of them can be converted to each other by changing some parameters, only the widely used distributions are mentioned, which include discrete distributions, including Bernoulli distribution, Binomial, geometric distribution, Poisson distribution and also continuous distributions: such as uniform distribution, normal distribution, and exponential distribution. Of course, it is necessary to remember that although statistical distributions are widely used in geographical spatial analysis, geographical spatial distribution has many differences from statistical distributions. Statistical distributions are created based on random data and probability theory to express the random (mental) pattern mathematically. Geographical distribution is a multidimensional topic based on accurate spatial data. These data are measured and collected based on spatial variables such as nature, location, and spatial relationships between phenomena. Spatial data includes features of the surface, height, geology, soil type, slope and geographical direction water sources, security, and location, which have been investigated and analyzed.

Rural settlements' spatial, physical distribution is the spatial arrangement of settlements in a place, region, or a specific part of the land surface. The perspective of such an arrangement is an essential tool in the fundamental analysis of how and the origin of spatial distribution in territorial geography to plan sustainable regional development. Spatial distribution is a multi-dimensional issue that is analyzed using different approaches. Spatial distribution can be studied as a spatial network based on performance criteria, in which case the spatial distribution pattern can be balanced. However, from a physical point of view, spatial distribution can have standard or other patterns. Analyzing the structure of the spatial distribution of rural settlements is very important in planning and spatial organization and future-oriented development. Knowing the influential factors in rural settlements' spatial distribution structure and identifying distribution patterns and spatial inequalities provides valuable information. The spatial system of rural settlements is proposed using two approaches. First, each settlement's internal and external spatial systems of the entire set of rural settlements in the region are discussed and investigated (Figure 1). The spatial system patterns of rural settlements, such as cluster, linear, conical, concentrated (compressed), scattered (or wide), crescent, star, etc., are formed under the influence of multiple spatial and institutional or regional and external factors. The spatial system of each settlement can be studied in the form of one of these patterns or a combination of them. Also, the spatial structure of rural settlements in a geographical area can be developed in the form of one of these patterns or a combination of them. The pattern of the internal spatial system of each settlement can be influenced by the general pattern of the regional spatial system and external factors. Analyzing how the spatial systems of rural settlements are formed based on different criteria and perspectives, such as distribution patterns, structures, functions, and special situations, can have different formulations. In this article, the spatial distribution system of rural settlements in the Urmia region has been analyzed and investigated.

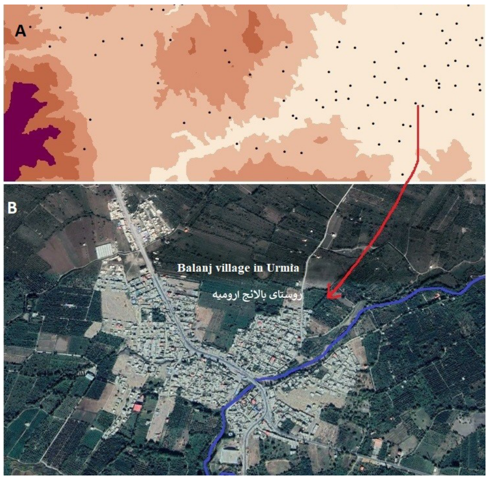

Figure 1. A- the above image of its regional spatial system (external) and B The spatial system (internal) of the settlements of Balanj village in Urmia

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2. Literature Review

In recent years, due to numerous urban environmental crises, the decrease in the quality of the urban living environment has led to the essential importance of villages as a healthy, quality, and peaceful atmosphere and the backyard of life. On the other hand, the limitation of resources and habitable land has caused the essential role of villages in sustainable national development to be given serious attention. Examining various sources related to the research topic in recent decades indicates that scientific studies and reviews have been conducted under different titles regarding the spatial system of rural settlements. These limited studies have been done by researchers from various points of view here we can refer to the researches of Faraji Sobqbar (2013), Ahmadian and Makrani (1375), Sejasi Khedari et al. (2016), Askari Rabri et al. (2014), Goli et al. (1383), Fazlinia et al. (2014), Astelaghi and Qadiri (1384) and Sidaei and Avergani (1389). Sidaei and Avergani (2009) analyzed the spatial patterns of rural settlements in Chahar Mahal Bakhtiari province. They concluded that the spatial pattern of rural settlements in the province is mainly influenced by natural factors (roughness, climate, and rivers) as well as human factors (structure and organization of the society of tribes and nomads and their property) and in some cases, the combined effect of several organized factors. They reported that the spatial distribution pattern of the settlements is mainly linear. Kazemi Chamsourek et al. (2009) reported that the physical, economic, and spatial dimensions as external and internal factors have had the most significant impact on the transformations of the transitioning villages of Ivan City. The dominant pattern of spatial distribution of rural settlements in Iran is spatially and point-wise (Talshi & Fakhrian, 2011).

Finding the root of the spatial distribution of rural settlements in Iran has been caused by the spatial distribution of primary resources in the form of points and zones. Various spatial structures of rural settlements have been reported in different sources as scattered and homogeneous, centralized and polarized, unbalanced and balanced random, centralized, decentralized, hierarchical, point, and regional. This formulation of the spatial distribution of rural settlements is controversial in terms of the nature of the issue. Sadr Mousavi et al. (2016) showed that the dominant distribution pattern of rural settlements in Sahne City is linear, and out of the total of 189 villages in this city, most of them are located at an altitude of 1250-1500 meters, at watery lands and plains. Finally, based on the regression fitting model, they showed that water resources, soil resources, climate, topography, altitude, slope, vegetation, and land use, respectively, have the most significant effect on the geographical distribution of settlements. Therefore, the survival and sustainable development of rural areas should be provided by protecting environmental resources and choosing suitable places for sustainable production and employment for the residents of the settlements. The results of the 2018 Aliai research show that 70% of the villages in Zanjan city are located at an altitude of more than 1600 meters, which indicates that most of the areas of this city are mountainous. Also, according to the tendency of villages to be located in areas with suitable slopes, 76.2% of the villages of this city are located in the slope class of 0-15%. As a result, due to the lack of significant correlation of natural factors in the location selection of rural areas, using Moran's index, which is one of the spatial autocorrelation functions, the spatial distribution of the rural points in the studied area is of a cluster type. In this regard, Moran's coefficient is positive and equal to 0.45, which is significant at the confidence level of 1%. Nemat Elahi and Ramsht (1400) used environmental and physical factors such as height, slope, slope direction, earth curvature, and climatic elements such as temperature, precipitation, and relative humidity to analyze the spatial distribution of rural settlements in Iran. They concluded that the spatial distribution pattern of rural settlements in Iran was formed in interaction with morphogenic systems and morphological-climatic components. Of course, this research is based on and under the title of geomorphological factors about the distribution of rural settlements, which contains many controversial ambiguities.

3. Methodology

In this research, primary data such as height data, geomorphology, slope, geology, rural settlement centers hydrographic network, and Google Earth images were collected as information layers and used to produce new information layers. Layers of data and basic information were collected through relevant colleagues and centers. The current research method is applied and descriptive-analytical. Visual analysis methods, geostatistics, and spatial analyses were used in the geographic information system environment in data processing and preparation; various transformation functions and geostatistical methods were used in geographic distribution analysis.

The political area of Urmia township is the study area of this research (Figure 2). Urmia City is one of the twelve cities of West Azerbaijan province, which is located in the center of the province and has five cities, five districts, 20 villages, and 668 villages. The city of Urmia is situated at 45 degrees and 4 minutes of east longitude and 37 degrees and 33 minutes of north latitude, located in the plain of Urmia, which is 70 kilometers long and 30 kilometers wide (Figure 2). According to the studies of the National Physical Plan of Iran, Urmia city is located in the land unit of river plains with relatively flat alluvial plains with river sediments and deep soil suitable for growing plants and gardens. The area where Urmia township is located includes the west of Lake Urmia, a mountainous region with a height of 1270 meters in the coastal line and 3600 meters above the sea level near the international border. In this mountainous area, their height decreases parallel to the movement from the west to the east. Alluvial fans of rivers in the region, such as Nazlochai, Rouzah Chai, Shahr Chai, and Barandoz Chai, form the Urmia plain, which is enclosed by these heights and Qoshchi heights in the north and Haj Abdallah and Klodagh in the south. The lands located at the extreme east of it, near the lake, are marshy and salt marshes. Urmia is located in a landslide on the path of the Shahrchai River after the outlet of the Urmia Band, surrounded by alluvial fans and Shahrchai sediments.

In terms of climate, the township of Urmia is located in the mountainous temperate climate zone, which is hot and dry with a maximum average temperature of 35 degrees Celsius in July and cold and humid (minimum average temperature of -15 degrees in the coldest month) in the cold seasons of the year. The mentioned area is mainly affected by different air masses. This area is affected by the influence of tropical air masses from the southeast, the humid western and Mediterranean air masses from the west and southwest, and the polar air masses from the north and northwest of the Black Sea. Its average annual precipitation is 357 mm.

Table 1. of villages and villages of the west region of Lake Urmia

Row	name of village	number of vil-lages	center	row	name of village	number of vil-lages	center
1	Barandoz	33	Barandoz	11	North Nazlochai	47	Noushin Shahr
2	Bakshlochai	65	Kashtiban	12	Rouzeh Chai	57	Baluv
3	Dol	13	Dizj Dol	13	Turkmen	40	Turkmen
4	South Anzal	32	Qulanji	14	Bash Qala	36	Yurgun Abad
5	North Anzal	8	Ghoshchi	15	Broadcast	56	Ravande sofa
6	Tala Tepe	14	Tala Tepe	16	Northern Somay	25	Mamakan
7	Nazlochai	23	Nazlu	17	Southern Somay	23	Horvarsin
8	South Barandozchai	36	Balanoj	18	Targavar	35	Movana
9	North Barandozchai	36	Kara Aghaj	19	Dasht	32	Rajan
10	South Nazlu	44	Nazlu	20	Margavar	54	Zivah

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4. Findings

The results of investigations, processing, and analysis of the mentioned data, as well as research findings, have been discussed and concluded, as described in the following headings.

Spatial distribution analysis of rural settlements in Urmia Township

Spatial distribution analysis of rural settlements in the west region of Lake Urmia, measuring the spatial structure of rural settlements in Urmia, allows us to identify and calculate indicators or criteria that show their geographical space structure characteristics. Criteria such as the spatial centrality of settlements, compactness, distribution, and the direction of the distribution process explain the spatial system of rural settlements. These criteria can be used to track changes in spatial distribution over time or to compare different spatial distribution characteristics.

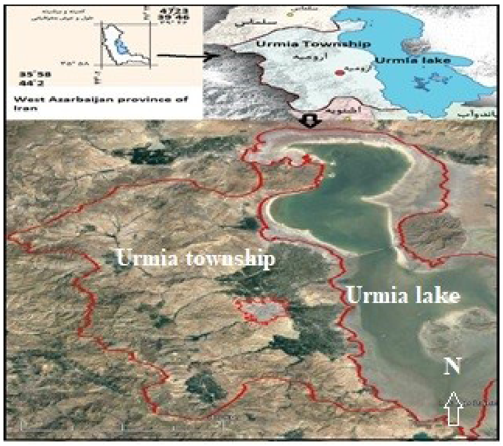

Figure 2. Location of the west region of the Lake Urmia (Urmia Township)

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The techniques for measuring geographic distributions answer the following questions: Where is the center of geographic distribution of settlements? Does the spatial structure of rural settlements have a specific pattern or not? Does the spatial structure of the settlements have a particular direction and trend? How scattered are the settlements? What are the natural foundations of the spatial structure of the settlements in the region? The distribution of the position associated with the smallest cumulative distance to other settlements defines the most central settlement. The structure of the spatial distribution of settlements in the region is shown in Figure 3.

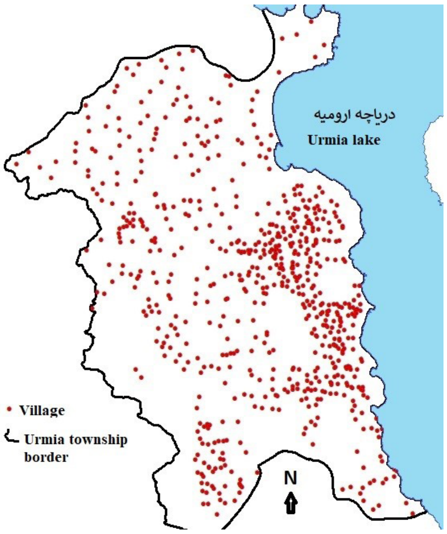

Figure 3. Spatial distribution structure of rural settlements in the west region of Lake Urmia

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Centrality analysis of the spatial distribution of rural settlements

Measuring a set of characteristics of the spatial distribution of rural settlements allows us to determine values or indices that indicate the structure of settlements, such as centrality, extent, density, compactness, and direction of distribution. To measure the spatial distribution structure, we need a criterion and a basis to measure, monitor, and analyze the spatial distribution structure of rural settlements. For this purpose, the centrality index of the spatial distribution structure can be considered one of the most critical criteria in measuring and analyzing such a structure. The position of the centrality index of each phenomenon or event at the regional level is different. It depends on the spatial distribution structure of the influencing factors and the sources of each of them. The measure of distribution compactness provides a quantitative distance value that indicates the dispersion of settlements around the center. Therefore, the compactness of a set of settlements can be determined by drawing a circle with a radius equal to the value of the standard distance on the map. The standard deviation is obtained through the following equation.

$$\mathrm{Cp}SD = \sqrt{\frac{\sum_{i=\text{١}}^{n}\left(x_{i}-\bar{X}\right)^{\text{٢}}}{n}+\frac{\sum_{i=\text{١}}^{n}\left(y_{i}-\bar{Y}\right)^{\text{٢}}}{n}} \qquad (1)$$

In this relationship, sub i. y sub i. cap X bar cap Y bar, x sub i. and y sub i. are the coordinates of settlement I. Cap X bar and cap Y bar indicate the center of the average settlements in the region, and n is the total number of settlements.

The centrality of the spatial distribution of rural settlements in Urmia township was calculated and determined according to the spatial distances of the center of all rural settlements relative to each other, with the shortest cumulative distance from the center using the Manhattan distance method. This technique measures the distance between two settlements along the coordinate axes at a right angle in the clockwise direction. It is calculated by adding the (absolute) difference between the x and y coordinates.

Three methods have been proposed to determine the centrality of geographic distribution. The determination of the spatial center was carried out using the median, mean, and central methods in the environment of the geographic information system, which shows a minimal difference (Figure 4). In this way, the center of gravity of the region's spatial distribution structure of rural settlements was identified and determined using the central method. In this method, the most central position is identified and defined about all the settlements with the shortest distance at the region's level. As shown in Figure 3, the spatial distribution of rural settlements does not have a regular pattern and a normal distribution at the regional level, and it is different for several reasons, which are discussed in this research. This form of the various distribution structures of the settlements in the region shows the different distribution of factors and fundamental natural resources influencing it. Likewise, it can be seen that as the settlements get closer and more compact, the spatial position of the distribution center tends towards the center of compaction (Figure 4). The highest concentration of settlements is observed with a compound conical pattern in the form of a belt with a north-south trend corresponding to the conical plain of Urmia, located in the eastern part of the distribution center. In the western part of the mentioned pattern, compression is more evident in a single concentrated cluster along the north-south along the intermountain graben plains of Mansour Abad-Margavar - Gangachin. Between the two mentioned belts, including the hilly and mountainous lands with an altitude of less than 2550 meters, the settlements show a scattered spatial distribution and sometimes a linear pattern at the heads of the branches of the hydrographic network. In the western areas, i.e., the border heights and the southern part of the region above the mentioned height (i.e., 2550 meters) up to 3600 meters, there is a space for any rural settlements. This residential vacuum was clearly visible in the altitude layer (2550-3600 meters) in the form of a belt with a north-south trend in the western part of the region and in the southwest and south (Figure 4). This fact shows the strong influence of high slope and height factors in how the spatial distribution structure of settlements is formed in the region.

The process of spatial distribution of rural settlements

Measuring the trend of the spatial distribution of rural settlements allows us to determine the characteristics of the trend, the causes of the trend, its significance, and its relationship with the trends of other factors or the absence of a trend in the spatial distribution structure. Using the trend value of the spatial distribution, we can trace the distribution changes over time or compare the characteristics of different distributions. The standard method to determine the trend of the spatial distribution structure for a set of rural settlements of each region is to calculate the standard deviation separately in the direction of the x and y axes. The two axes above define the oval axes, including the spatial distribution of rural settlements. This ellipse is referred to as the standard deviation ellipse because, in this method, the standard deviation of the x-coordinate and y-coordinate is calculated from the center of the average to determine the axes of the ellipse. Determining the mentioned ellipse allows us to examine the spatial distribution of rural settlements in the study area and see if it has a specific trend and direction. The ellipse size can be set from 1 to 3 standard deviations; the default is 1. The standard deviation ellipse is calculated from the following formula to determine the trend of the spatial distribution of settlements:

Subscript $EDS_{y_i} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{Y})^{2}}{n}}$ (۲) $EDS_{x_i} = \sqrt{\frac{\sum_{i=1}^{n}(xi - \bar{X})^{2}}{n}}$ (۱)

where y sub i. and x sub i. are the coordinates of rural settlements, i.e., Y bar and cap X bar are the central average of settlements, and n is the number of rural settlements in the region.

As shown in Figure 3, the spatial distribution structure of rural settlements in the research area is not balanced and is without trends. The analysis of spatial relationships of the layer data shows that the general trend of spatial distribution and development of rural settlements in the study area is northwest-southeast. The trend's type and direction differ from the direction of the trend of different natural factors. The direction of the trend with the trend of pediment landforms (alluvial plains) of geomorphology is a positive and upward correlation, but the trend is downward with the height. This trend strictly follows the geomorphological trend of the morphostructure of the region's landforms, especially the landforms of the pediments (of the graben alluvial - faults plains) (Figures 5 and 7). This trend is characterized by two axes: the dominant eastern axis with a northwest-southeast trend (corresponding to the pediments landform axis) and the other western axis with the same trend (intermountain graben pediments landform axis).

Analysis of the spatial distribution structure of settlements based on natural factors

The spatial establishment of human settlements and their changes and transformations is a multi-dimensional issue, which in any region is influenced by a set of spatial-temporal factors such as natural, security, cultural, economic, political, religious, military, war, and various epidemics, environmental crises, dam construction, and power plant projects, proximity to urban centers, urbanization development, industrial growth, technology and communication development, globalization and environmental inequalities. The amount of contribution of each of these factors (or a combination of them) and their effectiveness and role-playing over time is different and variable in each region. The mentioned factors influence the location and site, spatial changes and physical-spatial formation, and rural settlements' future growth and development (or stagnation and evacuation). Today, the legality of the establishment and development of rural settlements does not follow the principles of sustainable development and its natural process. As mentioned earlier, in locating how to form and develop the spatial distribution structure of rural settlements, there are many natural factors such as height, slope, geographical direction, environmental hazards (flood, earthquake, drought, etc.), soil, climate, climate changes, geographical location, natural and mineral resources, water resources and susceptible lands and their combination are effective. Identifying the influential factors and determining their role in the spatial distribution structure of rural settlements is essential for understanding and planning the study area, which we examine here.

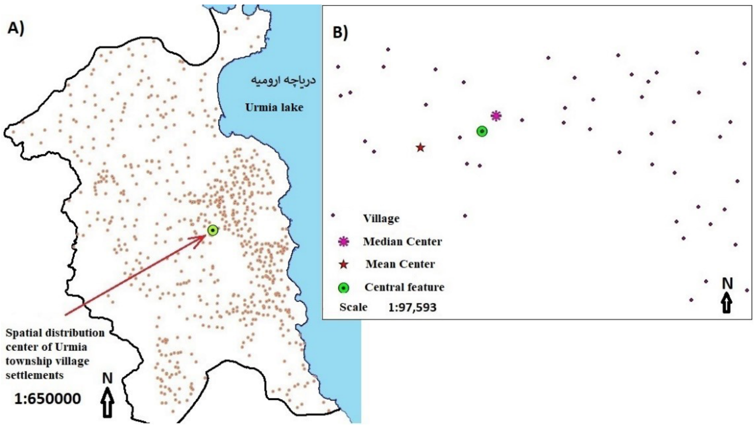

Figure 4. The centrality of the spatial distribution of rural settlements in Urmia city is shown in part A, and the middle, average, and central centers are in part B

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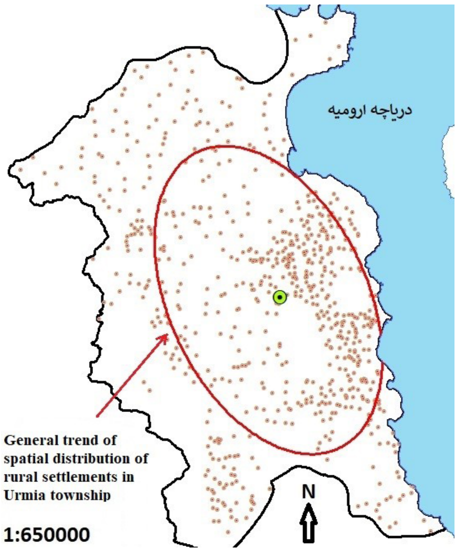

Figure 5. The general trend of the spatial distribution of rural settlements of the west region of Lake Urmia JSRD

The effect of altitude on the spatial structure of rural settlements in the study area

Height above sea level is one of the most critical factors affecting natural systems, which causes changes in the chain of other natural factors. Altitude is one of the most essential factors determining the local characteristics, which directly and indirectly affects several factors such as climatic elements, temperature and humidity, soil, water resources, geology, and slope. With the increase in altitude above the sea level, the air temperature decreases, and according to other local climate factors, diverse climatic areas are created. As a result, different plant and animal communities are created. The noteworthy point is that its effective contribution to the spatial distribution structure of rural settlements and the level of relationships between environmental factors and human life will differ in each region. Diagnosing and determining the impact of height on the spatial structure of rural settlements in the research area is very important. The research site is a mountainous area with high altitude changes (minimum 1237 and maximum 3612 meters) with a height difference of 2375 meters in a short distance of 40 kilometers. It is also a geologically young land where tectonic activities are very active. The spatial landscape of this area is visible from the east side as a mountain wall with stepped elevation levels among the obvious fault grabens (intermountain plains) in the west of Urmia's large structural hole. Based on the altitude changes of the region, five altitude zones were identified and zoned (Figure 6).

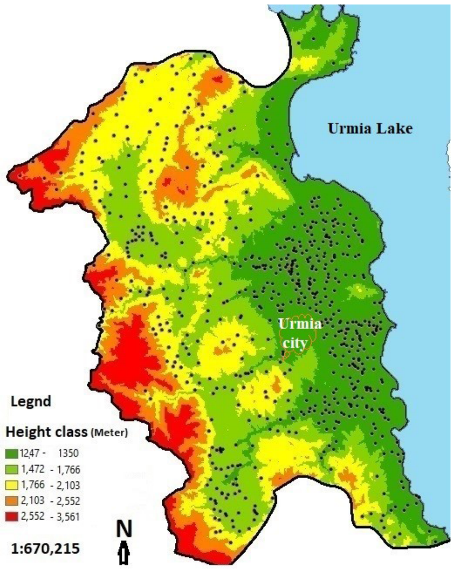

Figure 6. Correlation of spatial distribution of rural settlements with altitude classes JSRD

The region's spatial density of rural settlements is also different at different altitude levels. As shown in Figure 10, the highest spatial density of rural settlements is at an altitude of 1320 meters according to the landscape of alluvial plains. With the increase in height, the spatial density of rural settlements also decreases with a significant slope (Figure 7). The next spatial height density of rural settlements can be seen up to a height of 1790 meters in the mountainous plains (fault grabens with a north trend). Examining the relationship between the height data and the faults in the region shows that the faults cause severe spatial changes in the area's height. Thus, the faults (by creating the landform of the Grabani plains) are an influential factor in the changes in the spatial structure of rural settlements in the form of individual cluster spatial patterns with a size proportional to the scale of the plains (Figure 7).

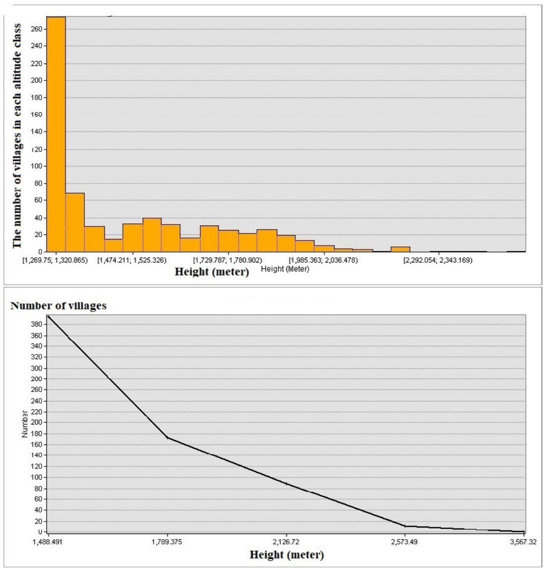

Figure 7. Abnormal spatial height distribution of rural settlements in the study area

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Slope effects on the spatial distribution structure of settlements in the region

The slope is one of the most critical factors affecting the characteristics of the environment and human activities. This index determines the ratio of changes in the structure of the spatial distribution of settlements in the area. It is evident that due to the mountainous nature of the region, the amount of spatial changes in the slope significantly affects the spatial distribution structure of the settlements. The local effect of the slope on the spatial structure of rural settlements is very different in classes with different degrees so with the increase of the spatial changes of the slope, the spatial density of rural settlements has decreased (Figure 8 and Table 1). The entire region of Urmia city is divided into five zones based on the intensity of the spatial changes of the slope. The region's spatial density of rural settlements shows a strong spatial correlation with topographic slope changes, so 74.85 percent of rural settlements are located in zone 1 with a slope range of 0 to 10.38 percent (Figure 8 and Table 1). More than 90% of settlements are located in zones 1 and 2, with up to 26% slope. The analysis of the relationship between the spatial changes of the slope and the spatial changes of the settlements shows that due to the slope factor, the structure of the settlements has changed, and their balanced environmental distribution has been disturbed. For this reason, in a slope of less than 10%, it has become a compact state or a colony pattern. This fact shows the profound influence of the slope in the current formation of the spatial distribution structure of the settlements in the Urmia region.

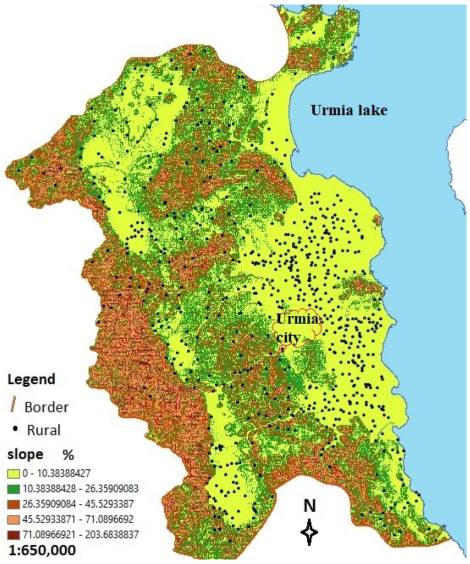

Figure 8. The relationship between the spatial structure of rural settlements and the spatial changes of the slope

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One of the influential factors in the spatial structure of the slope of Urmia township is the tectonic activities, such as the uplift of the land (increasing the hill) as a result of the convergence movements of the Arabian tectonic plates from the southwest and the Eurasian tectonic plates from the northeast. These tectonic movements have caused the formation of impulses of fault systems (slope reduction) in the region. In this way, the landform has formed the plains of Grabani Pediplain. These plains have caused changes in the spatial structure of the slope of the region, and as a result, the balance of the spatial distribution structure of rural settlements has been disturbed. The highest spatial density of settlements has been formed in these plains. The rate of changes in the spatial density of settlements shows a strong spatial correlation with the rate of slope changes inversely (Figure 9 and Table 2). Of course, the hydrological networks are affected by the type of clay and marl soil in the region, which has caused more density of the network and high discharge, as well as with a flow bed Perpendicular to the axis of mountains, as a result of more sediment have caused the formation of relatively vast alluvial plains in the region. In this way, the processes of morphogenesis affecting the number of changes (positive-negative) of the slope have been more effective in forming the spatial distribution structure of the settlements in the region.

The effects of geomorphology on the spatial distribution structure of settlements in the region

The science of geomorphology studies and analyzes the system and type of landforms (land units) by monitoring the morphogenesis processes of the earth's surface changes. In other words, this science identifies the types of land, explains their spatial characteristics, and analyzes their relationships with the spatial distribution structure of rural settlements in the region. 9 types of landforms have been identified, separated, and classified in all lands of Urmia Township (Figure 9).

At first look at Figure 9, it is clear that the change in the landforms' spatial nature has affected the settlements' distribution structure and caused differences in their environmental distribution system. The spatial distribution structure of landforms shows a good adaptation and coordination with the spatial distribution structure of settlements. In each landform type, a specific pattern of the spatial distribution structure of the settlements is observed; in other words, the boundaries of the distribution patterns of the spatial structure of the settlements match the boundaries of the landforms. Examining the spatial relationships between the spatial structure of settlements and landforms clarifies that the patterns of the spatial distribution structure of landforms clearly define and show the structure of rural settlement patterns. In general, three spatial distribution patterns of settlements can be distinguished based on geomorphological units in Urmia city. We have a compact conical and spatially dense pattern of settlements in the Piedmont landform or foothill plains, both in the alluvial cone and between the mountains. A sparse pattern with a linear outline is observed in the hilly landform. The over-dispersed pattern can be seen in clusters in the mountainous landforms (Figure 9).

Table 2. Slope classes and spatial density of rural settlements in Urmia Township

Slope zone code	Slop (percent)	Area (km2)	Number of settlements	Cumulative percentage of the number of settlements
1	0- 10.38	2366	500	74.85
2	10.38 -26.35	1323	104	15.56
3	26.35 -45.52	895	49	7.33
4	45.52 – 71.08	477	13	1.94
5	71.8 – 203.68	129	2	0.299

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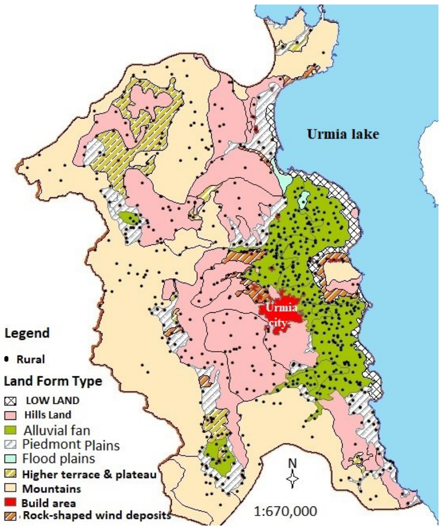

Figure 9. Relationships between patterns of spatial distribution structure of rural settlements with spatial patterns of regional landforms

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Spatial relationships of the hydrological network with the spatial distribution structure of rural settlements in the region

Today, water is one of the deep and fundamental challenges faced by Middle Eastern governments, especially Iran. Considering the vital role of water in human life and the dry climate of our country, rivers and surface runoff are the most important sources of water that play a significant role in the creation and location of rural settlements. The main streams of the region with their characteristics from the north of the region to the south are Kehriz, Nazlochai, Roze Chai, Shahrchai, and Barandoz rivers, which are dense and relatively developed in the entire hydrological network, and so rank five streams have also been observed in it. Also, the frequency of network branches is significant compared to the region's area. Contrary to the geomorphological and geological trends, these networks flow west to east, and their alluvial cones have created the Urmia Plain. Influenced by factors such as high mountainous areas, geologically young lands, and impermeable clay and marl soils, rivers have played an essential role in the current formation of the spatial distribution structure of rural settlements. Reasons such as high altitude, greater slope, the opposite flow direction of geomorphic-geological trends (of the type of antecedent river, i.e., rivers older than the tectonics and orogeny of the region), and low permeable clay and marl soils lead to the formation of a dense and extended hydrological network. The runoff mentioned above network with many thick branches, with more erosion and accumulation of abundant sediments on the western shore of the Urmia Lake over time, has created the alluvial plain of Urmia with very fertile soil and ample water. In this way, this hydrological system has disturbed the uniformity of the environmental balance of the spatial distribution structure of rural settlements. The mentioned plain is the center of gravity of the spatial distribution structure of rural settlements in the region, which has a conical pattern influenced by the rivers' conical landforms. The active processes of the hydrological network with the interaction of tectonic activities (including the spatial structure of faults) have changed the spatial structure of rural settlements in different ways according to their different intensities. In other words, the condensation processes of the hydrological network have caused more compression of the spatial structure of the settlements, and the exploration processes have caused their more significant spatial expansion at the regional level (Figure 10). In this way, in the low slopes of the intermountain lands, the course of the rivers was affected by the faults; in this way, they formed the intermountain plains, which have various longitudinal and transverse linear patterns of the settlements, including the longitudinal pattern along the waterways with ranks 2 and 3 and the cross pattern in the waterways especially the waterways of rank one are observed (Figure 10). Spatial correlation between the structures of settlements and the size of different ranks of hydrological networks is also observed. As the ranking of waterways increases, the spatial density of settlements also increases, and with its decrease, the spatial density of settlements also decreases. In this way, we see the highest spatial density of settlements in the region's fourth and fifth ranks of the runoff hydrological network.

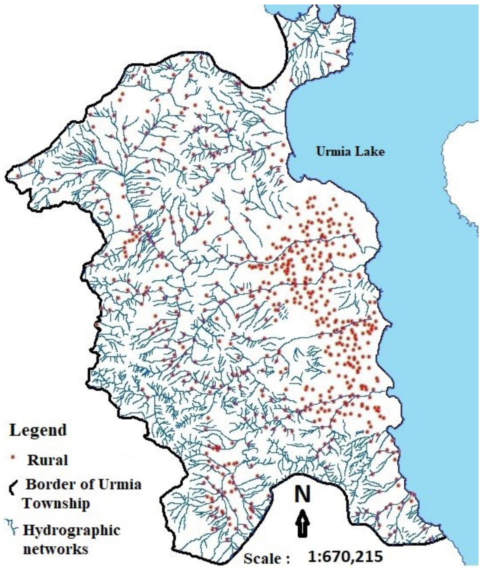

Figure 10. Spatial relations of hydrographic network with rural settlements of the west region of Lake Urmia

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Spatial density of rural settlements

One of the indicators of the spatial distribution structure of rural settlements is the flat and height density coefficient. The spatial density coefficients of rural settlements in the study area are not the same and are subject to multiple environmental factors such as geomorphology, altitude, and variable slope. In this research, the kernel function technique was used in the geographical information system environment to determine the spatial distribution density of rural settlements. This function calculates the number of settlements per unit area (from point features) and produces a conical value surface at each point. This technique can determine the density of both point and line effects. Also, possible applications of the mentioned technique include finding the density of settlements or houses, crime reports, roads, or utility lines that affect a regional space, urban space, or wildlife habitat. To obtain accurate results, the number of settlements or populations can be used to weigh based on some characteristics more than others, depending on their value and importance, frequency and size, or the possibility of multiple displays for a point. For example, a dwelling unit may represent a multi-unit housing complex or some offenses may be weighted more heavily than others when determining the overall offense level. Of course, in this research, it is essential to analyze the frequency and structure of the spatial distribution of rural settlements in the region. As shown in Figure 10, the spatial density values of the settlements are different in the area. The highest spatial density in geomorphology is observed in the landforms of alluvial plains and then in the intermountain-graben plains. Based on the surface density values, the rural settlements of Urmia township are divided into five zones of the distinct spatial density pattern, including the zone with a density value of the 44 -62.4 units of the highest density, so to a non-density or very scattered zone is with a density value of the 0 -7.5 units (Figure 11). The comparison of the mentioned different environmental spatial patterns shows that the five macro patterns of the spatial density of rural settlements are very similar to the patterns of the spatial structure of the regional landforms. The conical spatial pattern of zones with high-density values shows a strong spatial correlation with the conical pattern of alluvial cone landforms of Urmia plain and intermountain plains. The conical spatial pattern of zones with high-density values shows a strong spatial correlation with the conical pattern of alluvial cone landforms of Urmia plain and intermountain plains. In this way, zones with medium density values (7.5 - 16.8) include hilly landforms. In this way, the overall perspective of the spatial density of rural settlements is affected by geomorphological factors. It depends on the diversity of the spatial structure of landforms, especially sedimentary landforms such as the pediment plains of the region. The high mountains landform zone with geomorphological erosion processes shows the lowest spatial density values of rural settlements, most of which are empty of settlements. The analytical comparison of the characteristics of the spatial changes of the density of rural settlements with the spatial changes of the geomorphological structures of the region's landforms indicates its great effectiveness from the geomorphological spatial patterns. The visual analysis of the spatial density layer of rural settlements shows good compliance with the mentioned patterns and the objective facts of the spatial distribution structure of rural settlements in the region. As shown in Figure 11, the kernel function technique has successfully extracted five spatial density zones of rural settlements. These zones have a well-demarcated spatial distribution structure of the settlements in 5 classes: very dense, dense, medium, low density, and non-dense.

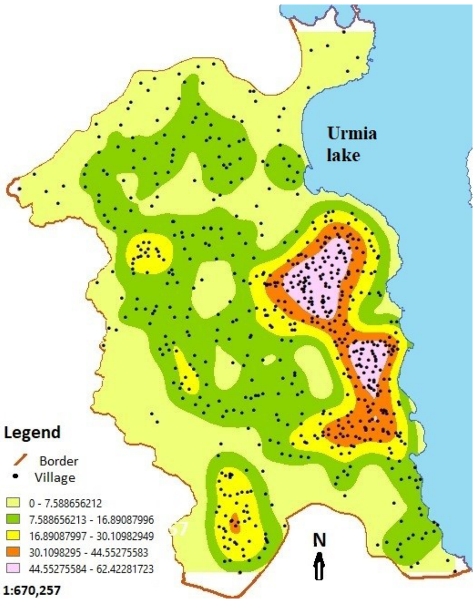

Figure 11. Density zones of spatial distribution structure of rural settlements of the west region of Lake Urmia

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5. Discussion

Knowing the effective factors and natural resources and how they influence the spatial distribution of rural settlements at the level of our research area will be a pathbreaker in rural spatial planning to achieve sustainable development. No information has been reported on the structure of the spatial distribution of rural settlements in Urmia and the analysis of factors and natural resources affecting that issue. This issue has many questions, such as: Does the spatial structure of rural settlements in the study area have spatial balance? Where are the clusters? Does their distribution and stability follow the laws of the natural system? What are the patterns of spatial phenomenology of settlements? How effective are natural factors in the spatial phenomenology of settlements? In other words, does the spatial distribution of rural settlements in the research area follow the spatial structure of natural factors? Data analysis and results show that the spatial structure of rural settlements does not have a natural environmental balance, and irregularities in the form of clusters and abnormal dispersion of settlements are observed. This irregularity is caused by the morphostructure of the spatial distribution of factors and natural resources, especially geomorphological factors in the region. The superimposition of the geomorphology layer (landforms) with the center layer and the surface density layer of settlements shows that the compound conical cluster pattern is the region's dominant spatial pattern of settlements. The mentioned pattern is affected by the spatial pattern of the Urmia Alluvial Cone Piedmont landform in the east of the region, which has caused the emergence of the center of gravity and the abnormal compression of settlements in it compared to the entire surface of the region (Figure 8). Also, individual cluster patterns on a smaller scale are observed in the intermountain graben pediments of the region. These cluster patterns are formed due to the presence of fertile soil and abundant water resources resulting from geomorphological processes in the mentioned landforms. This issue shows the strong influence of geomorphological infrastructure in forming the spatial distribution structure of rural settlements and the natural and biological landscape of the region (Figure 8). The influence of the structure of the spatial distribution patterns of the settlements on the landform foundations is due to the influence of the young land of the region and the tectonic activities (caused by the converging movements of the Eurasian-Arabian tectonic plates), especially the fault activities (uplift-subsidence). These movements continue strongly in the region and stimulate and strengthen the processes of morphogenesis. As previously observed, the second most effective natural factor in the spatial distribution structure of settlements in the region is the height factor (Figures 5 and 6). The spatial distribution structure of the settlements has an inverse relationship with the height, and the highest density is located in the 1st height zone (up to 1350 meters). This fact is related to the spatial structure of geomorphological facts and sedimentary processes and is affected by the hydrological network factor and its extent; this is also affected by the type of clay and marl soil in the region. The linear pattern of the spatial distribution of settlements is often seen in the headwaters in a limited way, with a transverse linear pattern along the 1st rank waterways and a longitudinal linear pattern along the 2nd and 3rd rank waterways (Figure 9). Based on the criterion of surface density of settlements, the research area was zoned into five zones using the kernel function (Figure 10). Examining the facts shows that based on the extent and characteristics of changes in the surface trend of the earth, the surface density zones of the spatial distribution structure of the settlements in the region are well-defined. The mentioned areas are the most consistent with the landform patterns and elevation classes, showing that the area with the highest density completely agrees with the pediment's landform. The following results are deduced by analyzing the relationships between the information layers of natural factors such as height, slope, hydrographic network, landform systems, spatial distribution, and density of rural settlements: 1- The spatial distribution of rural settlements is not normal. It does not have an environmental balance proportional to the region's area; it has irregularities in clusters and scattered cases (Figure 6). 2- The environmental imbalance of the spatial distribution of rural settlements in the study area strongly depends on the spatial structure of natural foundations such as height and landforms. 3- The center of gravity and spatial density of rural settlements with a compound conical cluster pattern in the region's eastern part corresponds to the Urmia pediment landform. 4- Different spatial distribution patterns of rural settlements can be observed in different landforms and altitude zones. For example, in the Urmia pediment, a conical cluster pattern, single and small intermountain pediments, a single small cluster pattern; in the hilly landform system, a scattered pattern, sometimes a transverse and longitudinal linear pattern in connection with the hydrological network, and finally, in the high mountain landform, a very scattered pattern of rural settlements can be seen. 5- The fault system is the most important factor in the region's morphogenesis in the form of horst (upland) and graben (the ground is down). Landforms with a north-south trend play an effective role in the region's spatial distribution of rural settlements. The settlements' spatial density is higher in the graben pediments such as Urmia and the intermountain plain. Still, the scattered pattern is evident in the horsts with hilly and mountainous landforms (Figure 12). 6- Contrary to the trend of the height system of the region, from east to west, the spatial density of the distribution of rural settlements is greatly reduced (Figure 6). 7- Factors such as faults, height, and geomorphology have the greatest contribution among natural fundamental factors in how the spatial distribution structure and density of rural settlements in the region are formed.

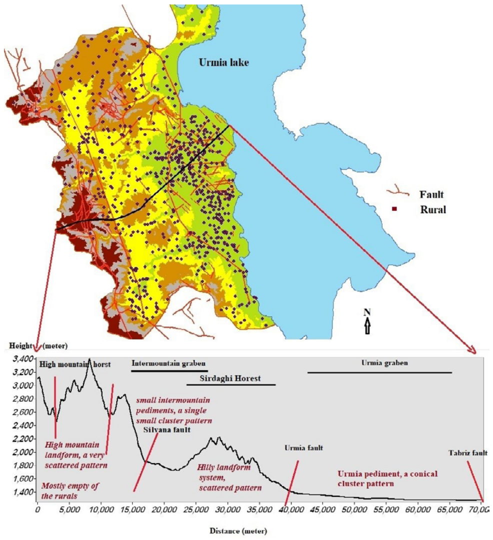

Figure 12. Spatial relationships of elevation zones, fault systems, and spatial distribution patterns of rural settlements of the west region of Lake Urmia

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Conflict of Interest

The authors declared no conflicts of interest.

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