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CONTENTS

STUDIES

ANCIENT HISTORY

ARCHAEOLOGY

ARCHAEOLOGICAL MATERIAL

ARCHAEOLOGICAL TOPOGRAPHY

NUMISMATICS

REVIEWS

Design & layout:
Petru Ureche

Studies

ARCHAEOLOGY

APPLICATION OF MORAN'S I STATISTICS IN SPATIAL ANALYSIS OF ARCHAEOLOGICAL SITES OF THE SARFIROUZABAD PLAIN, CENTRAL ZAGROS, IRAN

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Abstract: The emergence of human settlements has always been based on natural factors; Factors such as altitude, water resources, communication routes, slope, temperature, and rainfall are the natural etiologies affecting the distribution of human settlements, which of course, some of them play a more effective role in this regard. This study investigates the correlation between the chalcolithic sites of Sarfirouzabad plain and environmental factors according to natural criteria. Sarfirouzabad plain is one of the environs of Firouzabad district, located 35 km southeast of Kermanshah province, along the natural plain of Mahidasht. This plain is extended to the southern and southeastern parts of Mahidasht in terms of natural geography. Six natural variables as affective factors in the establishment of settlements include altitude, distance from rivers and roads, the extent and continuity of periods of the sites, and position in the plains or mountainsides being selected and have been analyzed by using statistical methods and Moran I regional area index by GIS. Exploratory spatial data analysis is a method for studying random and non-random spatial distribution patterns of these variables, and spatial autocorrelation is one of the most practical and substantial analytical tools for research on spatial data. The results show that the archaeological sites are formed in connection with each other in addition to environmental factors. The spatial distribution of the archaeological sites in the area of research is cluster type. Based on hotspot analyses, past humans may have chosen to settle in two regions, namely the plain floor and the southern margin of the Sarfirouzabad plain, to adapt to their environment. These two types of settlements are indicative of two lifestyles and livelihoods.
Keywords: *Environmental factors, chalcolithic sites, Moran's I, Sarfirouzabad plain, Central Zagros, Iran.*

INTRODUCTION

The emergence of an ancient settlement mainly depends on its environmental conditions and geographical location. Ancient settlements or sites in each area indicate the close relationship between the ancient site with the environment[1] or the relation of humans with the natural environment;[2] therefore, it is essential to identify the influential environmental factors influencing on the formation of ancient settlements.

[1] RASHID 2020, 45.
[2] ZHANG *et alii* 2014, 2018.

Analysis of residential spaces as the foundation of human settlement is of prime importance because the capabilities of the natural environment are effective in economic benefits of the environment by humans and are an essential factor in population distribution in different areas.[3] Human does not choose a place to settle by chance but selects the settlements based on the type of resources and reserves available areas for habitation that has more primary resources and provides the possibility of long-term productivity. Therefore, the ancient people paid much attention to environmental factors in choosing their residence, including easy access to water and suitable land for agriculture, natural nutrient resources, and minerals. Thus, human settlements in an area have always been based on natural factors. As the first form of collective human life in a natural area, early villages were influenced by various natural, economic, and other characteristics. Altogether, the location and distribution of human settlements are often influenced by various factors, including natural, economic, social, and historical factors.[4]

Landscape archaeology, meanwhile, seeks to use the spatial distribution of static cultural materials and human interventions in nature and changes in the landscape of its time to understand the dynamics of culture and the environmental activities of human settlement systems.[5] As we know, cultural materials such as archeological sites, pottery, and stone tools represent the remnants of cultural materials that once lived in the context of their natural environment; these archaeological sites and other remains inside the sediments make this possible. For example, alluvial soils with suitable slopes have always been used for very long periods for the establishment and possibly for agricultural activities. The purpose of such analyzes at this stage is to find a model for explaining the distribution of archaeological sites concerning the environmental variables of the region; Unlike classical statistics, spatial statistics techniques use space and environment, distance, proximity, orientation, and spatial relationships directly in their calculations.[6] In fact, in spatial statistics, an attempt is made to establish a relationship between the different values of a variable in terms of distance and orientation relative to each other.

The Sarfirouzabad plain, which is the eastern part of the Mahidasht plain, consists of high mountains, steppe hills, forests, and rich sedimentary lands. The Mereg River originates from the Sarab Sarfirouzabad source, located southwest of Mahidasht, and flows through the plain. This river is considered Mahidasht drainage and dramatically impacts the livelihood of the inhabitants of this region of the province. This river significantly impacts daily life, so considering the reliance of the agricultural economy and livestock on river water, surface water in this area plays an essential role. This study intends to investigate the impact of environmental factors on the Calcolithic sites of Sarfirouzabad. Accordingly, there are questions that this study intends to answer; among other things, to what extent do the ancient sites of the Sarfirouzabad plain depend on environmental factors? What patterns can the result of this relationship show?

The research method is based on statistical analysis, including inferential statistical analysis using the autocorrelation method. To conduct the research, multi-criteria analysis techniques and Arc GIS software have been used. Today, multivariate analysis methods are well used in archaeological studies for various purposes.

THEORETICAL AND PRACTICAL DIMENSIONS OF THE RESEARCH

In a statistical analysis, the quantitative or spatial similarity is called spatial dependence, and when observations have a natural sequence in a sequence, this correlation is called autocorrelation. Autocorrelation can occur because neighboring or contiguous remnants may be similar in spatial and temporal dimensions or are closely related or adjacent points, or sampled observations from sample points are either closely related to each other or in adjacent areas because they may be affected by similar external conditions.[7]

Moran's spatial correlation model has been proposed according to the first law of geography, where each phenomenon is dependent on other phenomena. Therefore, the closer the phenomena are to each other, the stronger the correlation between them.[8] Therefore, to address the shortcomings of regression patterns, researchers have developed a new term called spatial autocorrelation or spatial dependence for spatial data.[9] One of the statistical methods and determining the relationship between environmental factors and archaeological sites is Global and Local Moran Indices.[10] The spatial autocorrelations have a significant effect on the efficiency of spatial patterns. Therefore, for a better understanding of the spatial autocorrelations between the units of the baseline map (as sample data in the analyzes), an index is required to measure the spatial correlation that shows the quantitative or spatial similarity more clearly. In this regard, the Moran index is one of the most valid measures of spatial autocorrelation.[11] Global and Local Moran Indices show the spatial autocorrelation of samples or points[12] and analyze the proximity of places and the similarity of their properties. The proximity of places is obtained by measuring the distance between them and the similarity of their characteristics. This indicator shows the existence of scattered, random, and clustered patterns between sites.[13] This tool simultaneously measures spatial autocorrelation based on the feature's location and the feature's value and evaluates the pattern of concentration, scatter, or randomness of the features.[14]

[3] MANDAL 1989, 169.
[4] REINMANN *et alii* 2016.
[5] TRIGGER1967.
[6] SCOTT/GETIS 2008.

[7] CHATTERJEE/HADI 2006, 206-208.
[8] PEETERS *et alii* 2015,142.
[9] ZHANG *et alii* 2005, 154-155.
[10] SAIZEN *et alii* 2010.
[11] MAN 2006, 63-71.
[12] ZHANG *et alii* 2009.
[13] ZHANG *et alii* 2008.
[14] ANDY 2005, 31- 42.

Spatial correlation, like other correlation analyzes, can be positive or negative.[15] If the Moran index is close to +1, the data have a spatial autocorrelation and cluster pattern. On the other hand, the data are scattered if the Moran index value is close to -1. In Moran Global, the null hypothesis is no spatial clustering between elemental values associated with the geographic features[16]. Positive spatial correlation occurs when high or low values of two or more similar variables tend to be grouped.

On the other hand, a negative correlation is when neighboring or border geographical areas include neighbors with different and dissimilar values and characteristics. Finally, when the correlation and value of the points also reach zero, the pattern is random.[17] The local Moran's I statistic is also one of the standard methods of Local Indicator of Spatial Association that is widely used in determining hotspots and coolspots.[18] This analysis calculates hotspots for all the data features; the results show which areas and to what extent the data are clustered. Statistically, the higher the correlation, the more clusters, and hotspots are formed in a significantly positive correlation; conversely, in a significantly negative correlation, the higher the negative correlation, the less clustering and consequently cool spots. In this study, the relationship between the ancient sites of the Sarfirouzabad plain and natural factors to the spatial autocorrelation of these sites using Global and Local Moran Indices will be discussed. Furthermore, a zoning map of hotspots and coolspots will be prepared, and the causes of this situation will be analyzed using the mentioned indicators.

GEOGRAPHY OF THE SARFIROUZABAD PLAIN

In general, the Zagros consists of two parts: high and parallel mountains and alluvial and sedimentary mountain plains.[19] From ancient times the alluvial zones, including plains and alluvial fans, especially in areas with arid and warm climates, due to favorable environmental conditions, are attractive areas of population in the location of settlements.[20] Sarfirouzabad plain is one of the environs of the Firoozabad district. It is one of these alluvial zones with high mountains, alluvial fields with large and small alluvial fans, scattered hills, forest cover at the edge of the plain, and agricultural lands, located 35 km southeast of Kermanshah province. (Fig. 1).

This plain is part of Firoozabad city and is located in the Central Zagros Mountains[21] along the natural plain of Mahidasht; in terms of natural geography is in the southern and southeastern part of Mahidasht.[22] As we

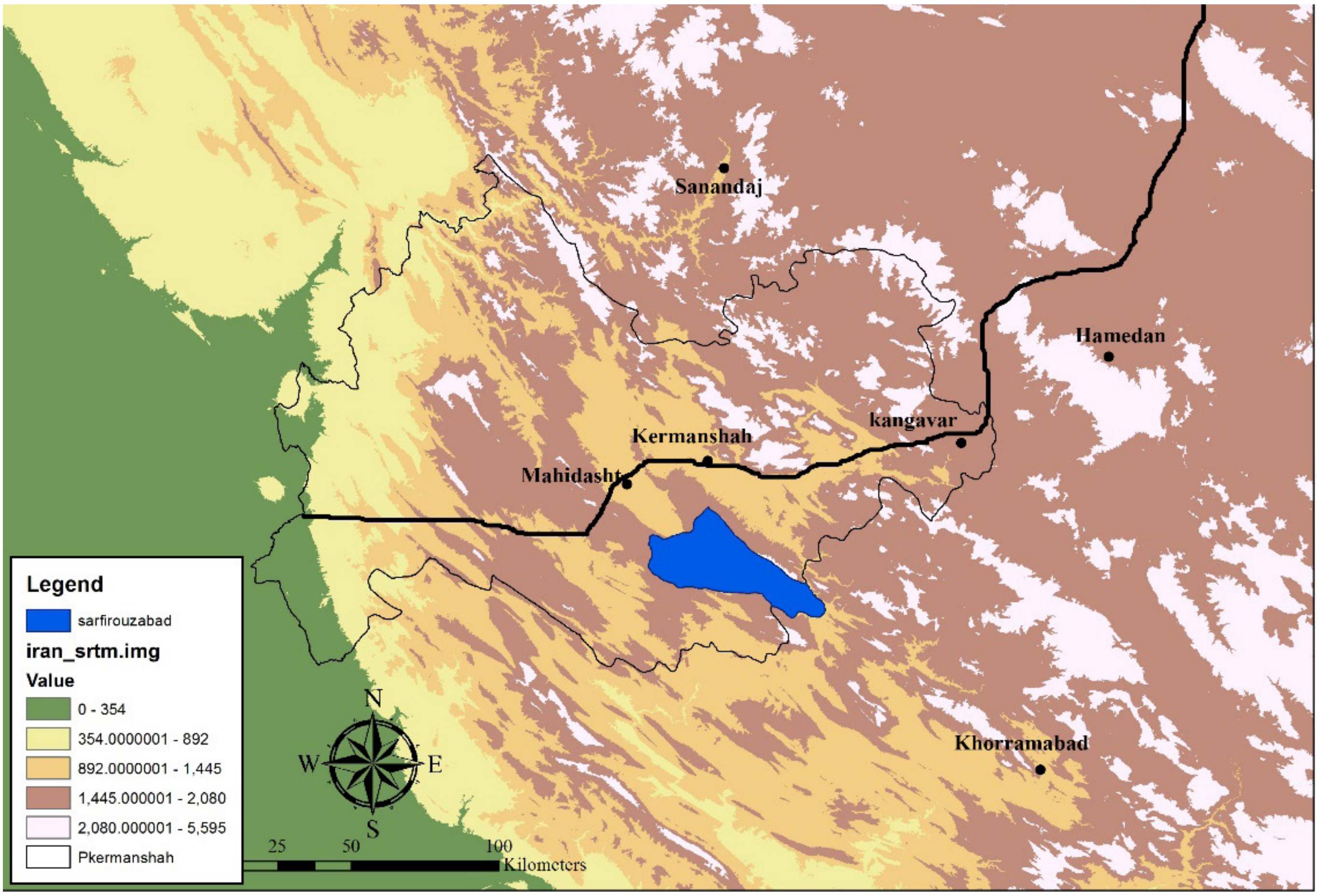

Fig. 1. Location of Sarfirouzabad plain and Greater Khorasan Road.

15 SCHWARZ/MOUNT 2006, 156.
16 VOJTKOVA *et alii* 2019, 5.
17 MAN, 63-71.
18 SAIZEN *et alii* 2010.
19 HEYDARI GURAN 2015, 42.
20 MAGHSOUDI 2009, 74.
21 BROOKES1989, 4.
22 NIKNAMI/ASKARPOUR 2015, 132.

know, Sarfirouzabad plain, along with Mahidasht, is located in the catchment area of the Mereg River, and this area includes mountainous areas with forest areas, plains, hills with pastures, and agricultural lands.[23] The Mereg River originates from the southwestern and southeastern heights of Mahidasht plain and Sarab Sarfirouzabad, Sarab Tiran, Mir Azizi, Khior Burbur, and Sarab Qaredaneh and also waters from melting snow of heights located in the south of Kermanshah, such as Sabz Amu, Nesar heights and Sefid kooh heights. This river is considered the canal of Mahidasht; its route in Sarcheshmeh from east to west and after passing through the middle of Mahidasht near a place called Doab is connected to Gharasou River. This region is located in one of the open plains of the country, which starts with a gentle slope from the mountains and ends at the point or points of the central post and ends in the main drain, which is enclosed as a composite syncline between the mountains and over thousands of years.

As a result of orogenic activity, the adjacent areas have expanded in a northwest-southeast direction. As mentioned, the central part of the synclinal plain has a lot of alluvial sediments, and most of the areas of Sarfirouzabad plain are located on alluvial fans and alluviums of the fourth geological period. In addition to the Mereg River and its seasonal tributaries, which have emerged as seasonal issues throughout the Sarfirouzabad Plain, there are several springs, most of which have dried up during archaeological excavations. In the Ontario project, many of these springs can be seen on the map of the Mahidasht and Sarfirouzabad plains.[24] Two mountain ranges southwest and northeast surround this plain. The northeast strip includes Kamajar (Kamehjar), Zangaliyan, Khoarah Tav and Kuh-e Sefi d. The southwest strip is at a lower altitude and includes Nesar, Kola Mal, La'al Abad (Laleh van), Sivelx, Shir Narmi, Barikeh and Qaleh Qazi (Qela Qazi).[25]

This plain, along with a part of Mahidasht plain, is also called the Mereg River watershed, which geologically includes mountains, foothills, and hills and has a cold semi-arid climate with relatively cold winters and mild summers. The average annual rainfall of this plain is 400 to 500 mm. The meteorological statistics and information review concluded that the annual temperature of 5/5 ° C varies in January to 26.7 ° C in July. April temperature is 12.1 ° C, and until October, the temperature is more than an annual average. Local folded rocks and faults create the topographic drainage and depression pattern. Marl, limestone, sandstone, and shales are important materials/sediments that form the region's geological formations.[26]

ARCHAEOLOGICAL BACKGROUND OF THE REGION

Despite being located in the Central Zagros, adjacent to Mahidasht, and being located on the road of Great Khorasan, the Sarfirouzabad plain has not been much considered by archaeologists. Although foreign archaeologists have noted the Central Zagros during the 1960s and 1970s, archaeologists have rarely set foot in the Sarfirouzabad plain. Only a few archaeological delegations' in the area have visited the plain briefly but have never explored it. Among the archaeologists who have visited Sarfirouzabad, the following delegations can be mentioned:

Schmidt's study of the 1930s in an area that recorded a small number of sites Schmidt flies over the Mahidasht plain by plane and sees many hills. He considers the southern half of it suitable for extensive excavation. Schmitt believes the pottery on the surface of some of this plain's hills is similar to Anatolian pottery and compares with the Hittite at Boğazkōy and the painted pottery to belong to Lorestan,[27] Stein's survey during the 1940s in western Iran recorded 26 sites in Mahidasht. He also visited Do-Chia and other sites such as Chia-Bahar, Se-Chia, Chia-Narges, and Tape Khaibar in the Mahidasht plain. On them, He found many red potteries and flint.[28]

Also, Braidwood's survey in 1959-1960 in this area (Mahidasht) and neighboring areas recorded 170 sites.[29] Braidwood survey the valleys of Kermanshah, Shahabad, and Mahidasht and identified some sites from 100 thousand years ago to 5000 years ago. The surface findings of these sites include stone tools, painted pottery, and other findings. Finally, he excavated Tape Sarab, Asiab, Siah Bid, and Maran.

Between 1963 and 1967, while Goff was conducting archaeological research in the Pishkouh area of Lorestan, she visited the Sarfirouzabad plain and identified and recorded some sites. Unfortunately, Goff did not specify the number of sites or the date of the artifacts identified in Sarfirouzabad. However, in the published maps, she referred to Bronze Age settlements in the area.[30]

In 1968, Ali Akbar Sarfaraz and her colleagues registered 43 significant sites in Mahidasht. This delegation has identified only two sites named Pa-Cohqa and Tape Sarab Sarfirozabad. They considered Pa-Cohqa related to the Iron Age and Sarab to the Chalcolithic period. The great hill of Pa-Chqa was one of the sites that this delegation managed to visit and record.[31]

The Ontario Museum's archeological project, led by Lewis Levine, has studied parts of Sarfirouzabad in a limited way during its research. Levine has considered the plains of Kermanshah, Mahidasht, and Shian as the territory of Mahidasht and has referred to these plains in general as Mahidasht. The Ontario delegation surveyed only 50 percent of Mahidasht's 4,000 square kilometers[32] and in this plain, he identified about 550 sites from the Neolithic period to the Islamic period. Although the group does not specifically mention the number of sites identified in Sarfirouzabad, McDonald mentions three Neolithic settlements and several copper and stone settlements with J ware in Sarfirouzabad.[33]

[23] HESHMATI *et alii* 2011, 1037.
[24] BROOKES 1989. PL: II.
[25] NIKNAMI/MIRGHADERI 2019, 164.
[26] HESHMATI *et alii* 2011, 1073.
[27] SCHMIDT 1940, 46.
[28] STEIN 1940, 415-417.
[29] BRAIDWOOD 1960a; 1960b; LEVINE 1974.
[30] GOFF 1971.
[31] SARFARAZ/SARRAF/YAGHMAEI 1968.
[32] LEVINE 1974.
[33] MC DONALD 1979, 552; LEVINE 1974.

Members of the "Royal Ontario Royal Museum Mahidasht Project" delegation discussed the geological status of the area, especially the Mahidasht area, and the impact of these processes on the formation, continuation, and burial of ancient settlements in the area.[34]

Considering this situation, in 2009, to study and identify the areas of the Sarfirouzabad district, a delegation from the University of Tehran headed by Kamal Adin Niknami set foot in Sarfirouzabad to get acquainted with the history of human communities and studied settlement patterns in prehistoric and historical periods in the region. As a result, the Sarfirouzabad plain in the summer of 2009 was studied intensively for 60 days. During the study in 2009, a total of 332 works from different periods from the Middle Paleolithic to the late Islamic period were identified and recorded. Discovered remains include caves, grounds, hills, shrines, castles, and landmarks.[35] There are 110 Chalcolithic sites (early, Middle and Late) (Fig. 2 and 3).

ENVIRONMENTAL FACTORS AND SETTLEMENT TEXTURE OF SARFIROUZABAD PLAIN

To draw the relationship between environmental factors and Chalcolithic settlements of Sarfirouzabad plain, the area of the sites, the number of periods, the distance of the sites from the river, and the communication route of the plain floor and altitude were considered. It is noteworthy that rank, numerical and descriptive variables have been used in this analysis. In this research, the nominal scale or variable is if sites are located at the bottom of the plain or not? In addition, ranking variables or ordinal scales were used in one section so that the area of the sites was classified into four groups. In this ranking, sites with an area of less than one hectare are ranked first (lowest rank), sites up to 1 to 2 hectares are ranked second, up to 2 to 3 hectares are ranked third, and up to more than 3 hectares are in the fourth rank (highest rank). In the numerical part or interval scale, the distance of each site to water sources, altitude, and the main communication route are considered.

Fig. 2. An example of Chalcolithic Sites (1. Banchia Aghamansour, 2. Chia Poshtineh, 3. Amrovena, 4. Tape Pachogha).

[34] BROOKS 1989; BROOKS *et alii* 1982.
[35] NIKNAMI/NIKZAD 2012; NIKNAMI/ASKARPOUR 2013; NIKNAMI/IRANDOUST/TAHMASEBI 2013; NIKNAMI/ASKARPOUR 2015; NIKNAMI/MIRGHADERI 2019.

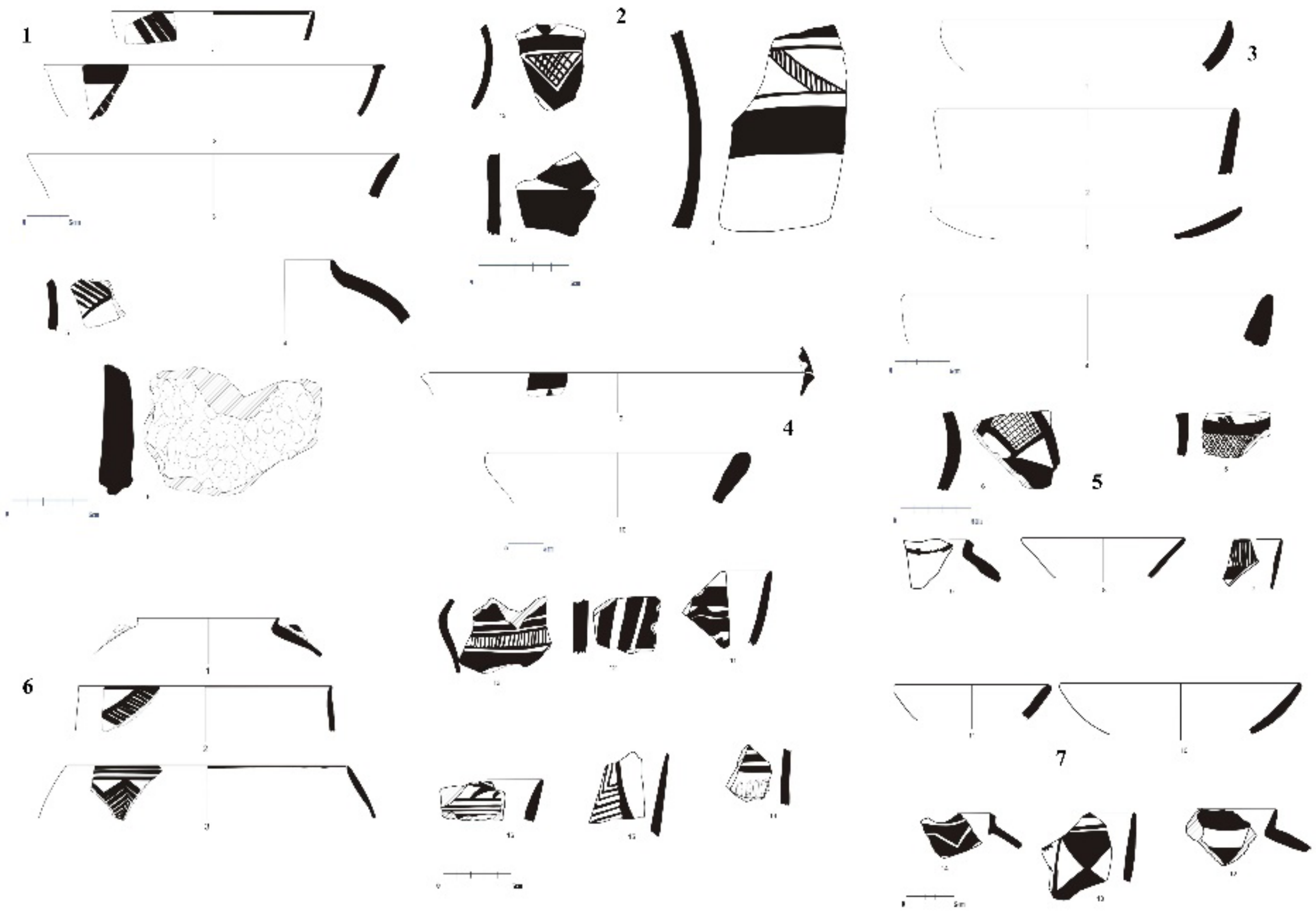

Fig. 3. An example of Middle Chalcolithic pottery (1. Nesar 6, 2. Tape Sarab, 3. Sarcham 3, 4. 5. Chia Poshtineh 6. Amrovena Ahmadabad, 7. Banchia Aghamansour).

THE AREA OF SARFIROUZABAD PLAIN SITES

One of the essential characteristics in the analysis of settlements is the evaluation of the area. This variable indicates the importance of the sites and the population[36] who lived at different times. The analysis of this variable can be evaluated as a factor for the analysis of internal and external settlements and how ancient sites interact with each other in different eras. Although determining the exact size of an area is a bit difficult and can only be conjectured, almost all archaeologists agree on the extent of the area with a significant dispersion of ancient pottery. [37]As mentioned above, ranking variables or ordinal scales were used to measure the area, and the results were classified into four groups. Accordingly, these areas are between 450 square meters to 22,500,000 square meters (2.2 hectares), and the average is 6581 square meters. Therefore, this grouping is as follows (Fig. 4):

1. 98 sites with an area of less than one hectare (85%);
2. 10 sites with an area between 1 to 2 hectares (9%);
3. 2 sites with an area between 2 to 3 hectares (4%);
4. 5 sites with an area of more than 3 hectares (2%).

[36] JOHNSON 1973, 14.
[37] PLOG *et alii* 1978, 389; HODDER/ORTON 1976.

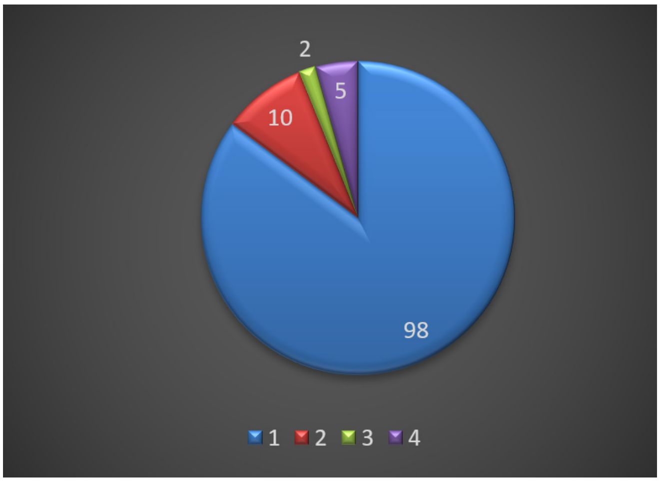

Fig. 4. Grouping of Sarfirouzabad plain sites based on area.

PLACEMENT OF THE SITES IN PLAINS OR MOUNTAINS

In this study, the nominal scale or variable is if areas are located at the bottom of the plain or not? Accordingly, all areas were divided into two groups based on their location in the area. The first group is the areas located at the bottom of the plain. The second group is located next to or between the hills on the edge of the plain, at the foothill of the mountains,

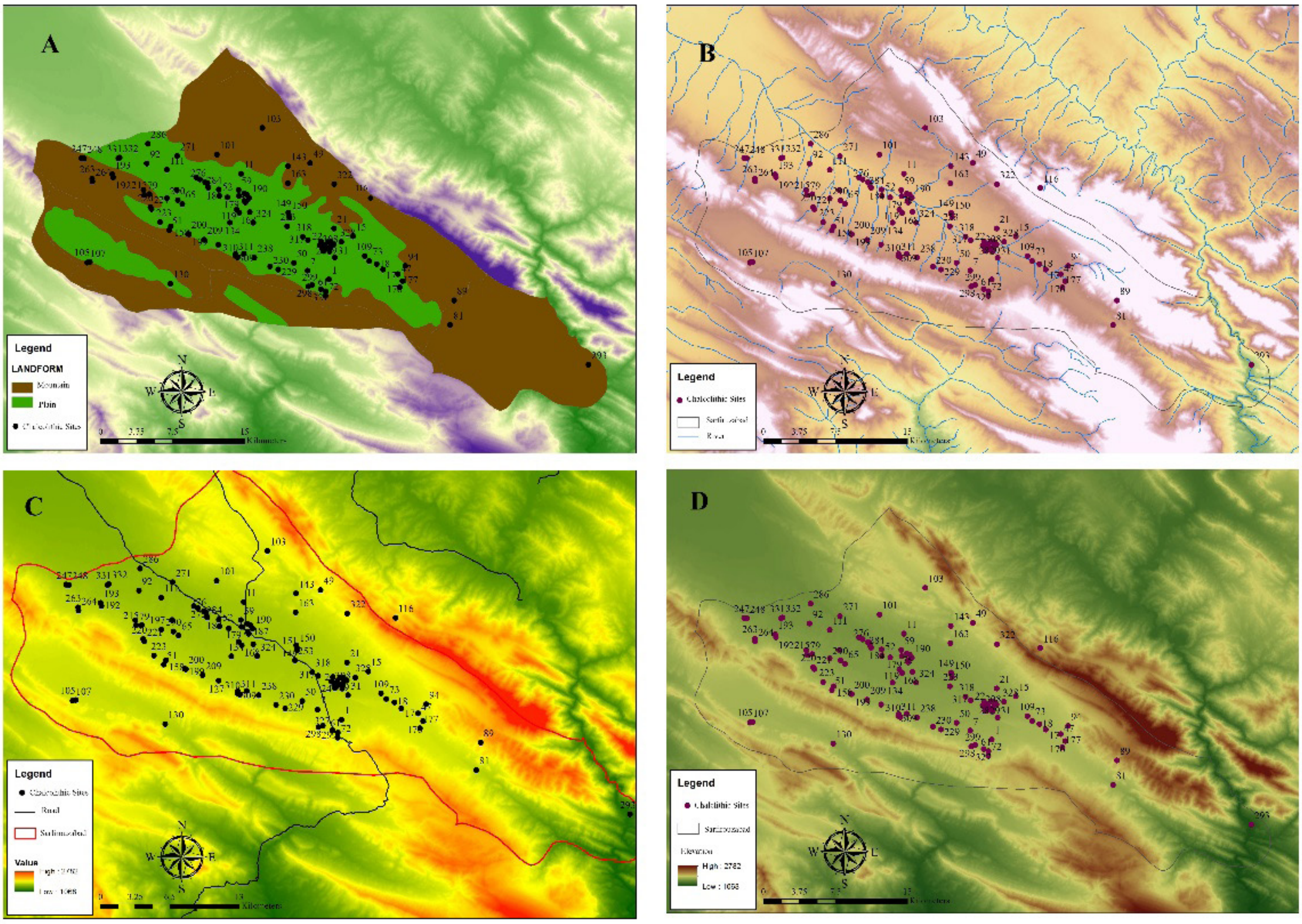

Fig. 5. Maps of the location of Chalcolithic sites concerning environmental factors (A. The placement of the sites in foothills and plains, b. distance of sites to communication River, c. distance of sites to communication roads, d. height above sea level).

hills, places higher than the plain, in the middle of the mountains, or in the forest (Fig. 5. A). Large areas of the plain near the permanent water resources are usually permanent settlements, and areas small in size in the foothills, rocky lands, hilly areas, and similar locations are seasonal.[38] Among the Chalclithic sites in Sarfirouzabad plain (Fig. 6):

- 76 sites are located in the plain (76/7%);
- 33 sites are located in the foothills or hills on the edge of the plain (33/3%).

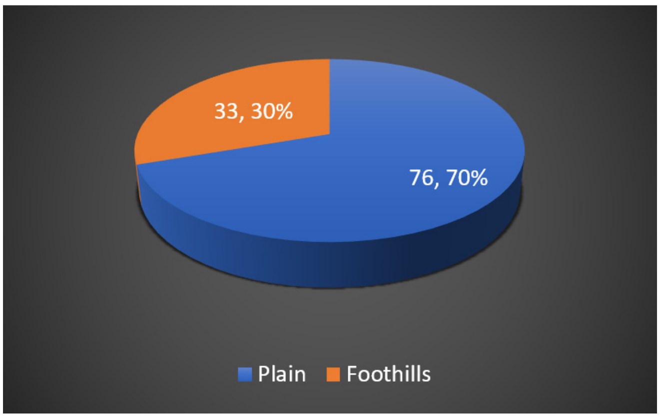

Fig. 6. Sarfirouzabad plain sites based on placements.

[38] MASHKOUR/ABDI 2002; ABDI 2003; NIKNAMI/ASKARPOUR 2013, 355; NIKNAMI/ASKARPOUR 2015, 140.

NUMBER OF PERIODS IN SARFIROUZABAD PLAIN

Usually, the higher the number of periods in each ancient site, the higher its height; this indicates the importance of the geographical location in which the ancient site is located because its inhabitants have considered this area in different periods. With this assumption, the number of periods of the Sarfirouzabad plain was examined. In terms of the number of periods in the Chalcolithic sites in Sarfirouzabad plain (Fig. 7):

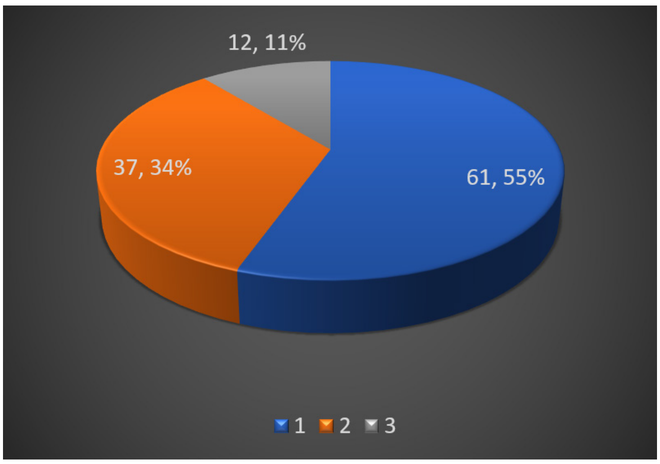

Fig. 7. Sarfirouzabad plain sites based on periods.

- 61sites have a single period (55/4%);
- 37 sites have two periods (33/6%);
- 12 sites have three periods (11%).

DISTANCE FROM WATER RESOURCES

One of the most critical factors in forming settlements and distributing them is access to water resources. The location of the sites relative to the primary water resources (permanent and seasonal rivers) has also been studied. In the roughness of Zagros, sources and springs have been influential factors in establishing settlements due to their particular characteristics (supplying drinking and agricultural water), which leads to settlements in Kermanshah city at different distances to be always close to karstic sources and springs. Therefore, karstic sources and springs played an essential role in establishing settlements. In the Zagros, such springs are abundantly seen.[39] A numerical factor or interval scale is considered in calculating these distances. The minimum distance of the sites is 1 meter (the distance of the site from water resources) and the maximum distance is 4332 meters. Accordingly, villages and settlements are set up in places with enough water. The average distance between these areas is 927 meters (Fig. 5. B). as shown on the map, the focus of the sites is along the Mereg River and its tributaries are as follows (Fig. 8):

1. 0-500 meters from water sources 49 sites (49/44%);
2. 501-1000 meters from water sources 74 sites (27/25%);
3. 1001-1500 meters from water sources 18 sites (18/16%);
4. 1501-2000 meters from water sources 2 sites (2%);
5. 2000 meters and above, 14 sites (14/13%).

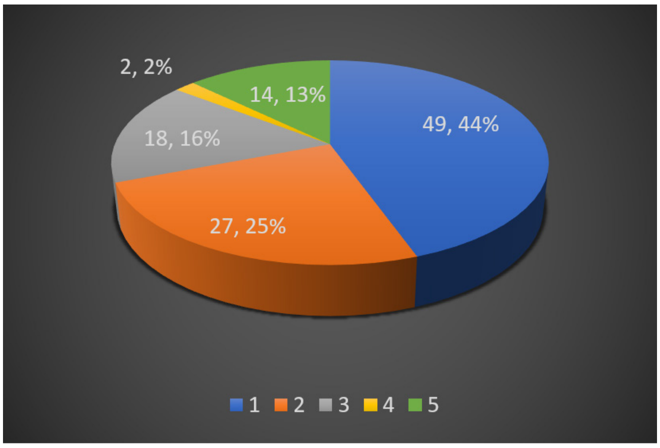

Fig. 8. Sarfirouzabad plain sites based on distance from the rivers.

DISTANCE FROM THE COMMUNICATION PATH

The study of roads and the exploitation of natural passages are of considerable importance in archaeological research; the importance of roads is such that the cultural level of each region and its level of development can be determined according to its distance or proximity to roads.[40]

[39] RAEISI/STEVANOVIC 2010, 505.
[40] HEYDARI DASTENAEI/NIKNAMI 2020, 87.

The main communication route passes through the valley along the Mereg River, extending towards Osmanvand. Also, the end of the area of study is near the Great Khorasan Road,[41] which connects the central plateau of Iran to Mesopotamia. Perhaps the most crucial evidence of the communication route in the Sarfirouzabad plain is the ancient sites along the Mereg River, which are located next to each other and have created a close connection between them. Henrickson states that in the Zagros Mountains, especially in this area, numerous caravan routes often cross the valleys, and modern-day trails.[42] Accordingly, the numerical factor or interval scale is calculated. The minimum distance of the sites is 1 meter (the placement of the sites next to the main communication route), and the maximum distance is 19045 meters. The average distance between these areas is 3804 meters (Fig. 5. C), and the distances are as below (Fig. 9):

1. 0-2000 meters, 43 sites (43/3%);
2. 2001-4000 meters, 24 sites (24/2%);
3. 4001-6000 meters, 23 sites (23/2%);
4. 6000 meters and above, 20 sites (20/18%).

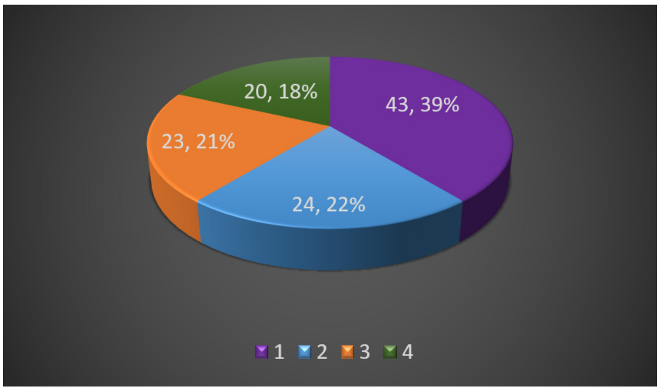

Fig. 9. Sarfirouzabad plain sites based on distance from the main road.

ALTITUDE FROM THE SEA LEVEL

One of the essential matters in studying ancient settlements is the distribution of sites at different altitudes, and this factor can affect the way and type of people's livelihood. The population of rural areas and the infrastructure load are also directly related to the altitude factor. The main reason for the decrease in the population living in rural settlements located in mountainous areas is the altitude factor. As altitude increases, the share of agricultural land decreases, the climate cools, and the space for agricultural-related activities is limited. Therefore, villages will be small in scale[43] Altitude in this region varies between 1047 to 2774 meters and mainly consists of two distinct units: mountainous areas and plateau plains. The highlands and mountains are divided into three parts:

- The first part: includes altitudes of more than 2000 meters, characterized by steep slopes, severe erosion, and narrow valleys.

[41] GOPNIK 2012, 1.
[42] HENRICKSON 1985.
[43] POTOSYAN 2017, 2.

- The second part: includes an altitude of 1500 to 2000 meters, between the steep folds of mountains and flat plains, and includes steppe areas of hilly hills and steppe and forest areas.
- The third part: includes an altitude of 1000 to 1500 meters, a flat and sedimentary area, and is considered an important center of population and agriculture in the region.

In total, 110 sites in this area can be seen in two regions (Fig. 5. D):

- 34 sites or 33/31% in the hills and steppes area;
- 76 areas or 76/69% on the plain floor.

Also, in terms of altitude, the number of areas is as follows (Fig. 10):

- 2 sites at an altitude of 900-1200 meters (1/8%);
- 42 sites at an altitude of 1200 to 1500 meters (38/3%);
- 65 sites at an altitude of 1500 to 1800 meters (59%);
- 1 sites at an altitude of 1800-2100 meters (/9%).

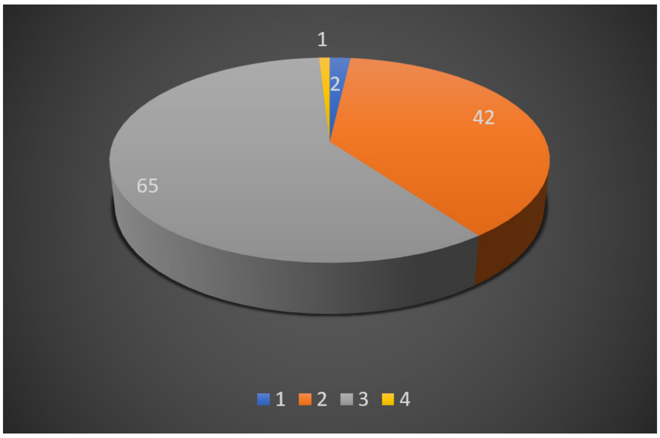

Fig. 10. Sarfirouzabad plain sites based on the altitude from the sea Level.

SPATIAL AUTOCORRELATION AND ENVIRONMENTAL FACTORS

Table 1 is the output of the values obtained from the analysis of Moran statistics. According to the table, it is determined whether the distribution of values of the environmental factors at the spatial level formed a cluster pattern or not? Strong autocorrelation occurs when the values of a variable that are geographically close to each other are related. If the effects or the values of the variables associated with them are randomly distributed in space, there should be no relationship between them. If the Moran value is positive, similar features surround the intended features; therefore, the intended feature is part of that cluster. If the value of Moran is negative, it means that dissimilar features surround the intended feature. This type of feature is called non-cluster or accidental. The null hypothesis can be rejected when the P-value is too small, and the calculated Z is too large.

The value of the Moran index was measured in terms of land area, plain or mountain slope, the number of periods, water resources, distance to communication route, altitude (see Tab. 1), and it was found that the Moran index for plain location And mountain foothill and altitude are 0.377541, The area is 0.367647, and the high value of the Z Moran statistic for altitude and placement in the plain or mountain slope is 3.605258, which refutes the null hypothesis and shows that altitude From the sea level and the location of the sites on the plain or mountain slope is consistent with their extent. The relationship between water resources and ancient sites is positive in the next step.

However, the amount of Moran statistic is 0.201638, and the value of the Moran Z statistic is 3.605258, but it is less than the previous group. Perhaps one of the reasons is the seasonal water sources next to some sites which currently do not exist. This statistic rejects the null hypothesis and states that the pattern of these areas is organized in clusters next to water sources. The frequency of periods with the value of the Moran statistic is 0.023802. The value of the Z Moran statistic is 0.259589. The correlation paths with the value of the statistic are 0.015573, and the value of the Z statistic is 0.208651. (Fig. 11) It shows that there is little relationship between these two factors, and this relationship is so low that it can be ignored. Finally, it can be said that the high and positive value of the P-value and also the value of Z show that there is no lack of spatial correlation between values (altitude, distance to water resources, plain or mountain location, and area). Thus, there is a correlation between environmental factors and ancient sites. Furthermore, since the value of the Moran index is positive, it is concluded that there is a high spatial correlation, and the spatial pattern between the ancient sites has been formed in clusters. In other words, the distribution of values related to environmental factors is such that it forms a cluster or areas with similar values that are significantly adjacent to each other. Therefore, the spatial distribution pattern of ancient sites to environmental factors is significant, with a high cluster pattern at a confidence level of 1%.

Tab. 1. The Moran's Local Statistics result's value.

Environmental Factors	Moran's Index	Z-score	P-value
Area	0.367647	3.500245	0.000305
Placement in plains or mountains	0.377541	3.605258	0.000312
Number of periods	0.023802	0.259589	0.795181
Water resources	0.201638	1.943412	0.051966
Connection routs	0.015573	0.208651	0.834720
Altitude from the sea level	0.377541	3.605258	0.000312

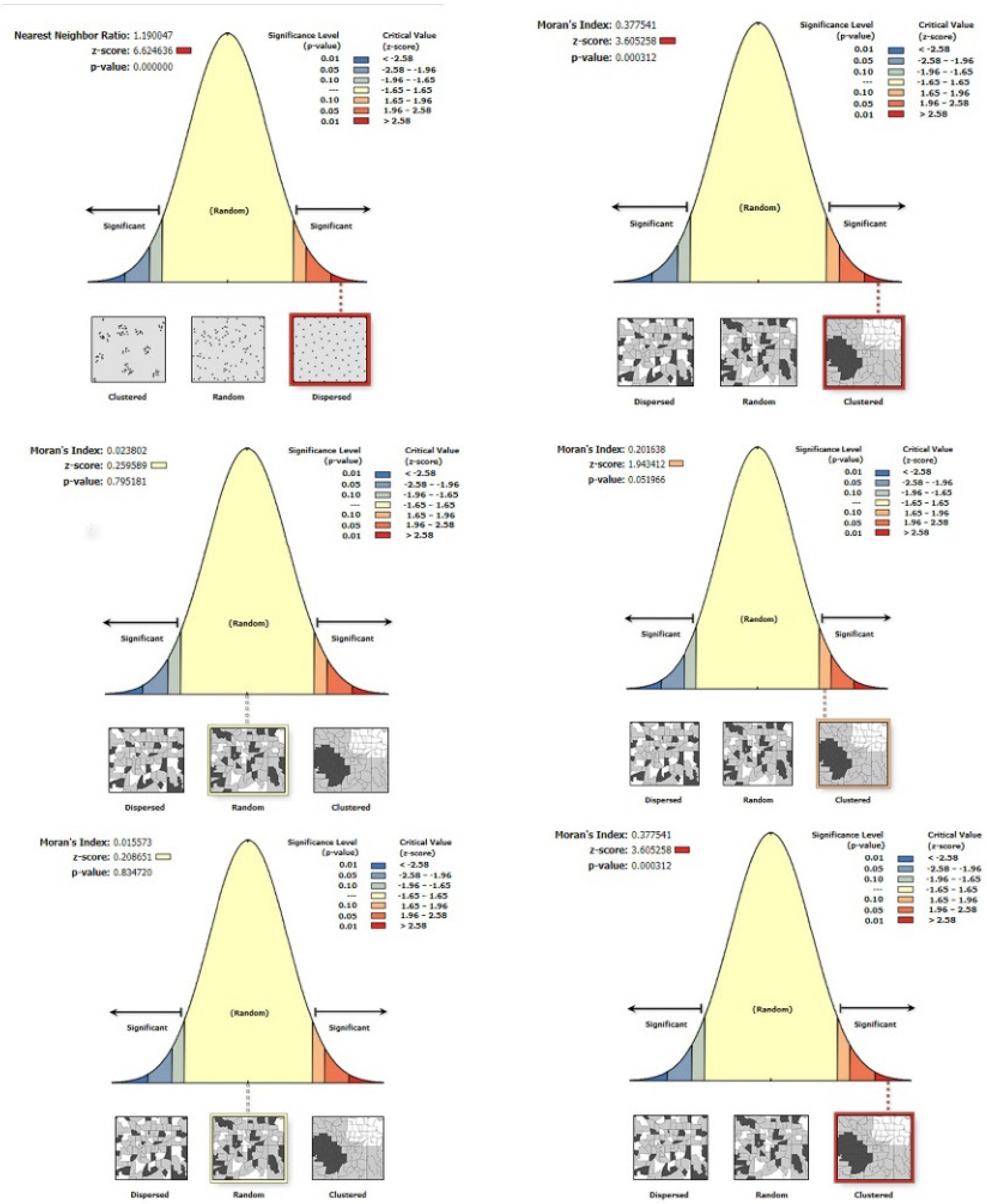

Fig. 11. Spatial pattern of distribution of Chalcolithic sites in Sarfirouzabad plain with Moran index.

Statistical analysis of hotspots is calculated for all features in the data. The calculated Z score indicates where the data are clustered in high or low values. This tool looks at each feature in the context of the features that are in its neighborhood. A feature with high value; it's exciting and essential, but a hotspot alone may not be statistically significant. To be considered a hotspot feature and be statistically significant, both itself and its neighboring features must have high values.[44]

The Z score obtained indicates which sections the data is clustered with more or fewer values. Statistically, the larger the Z score, the more clusters, and hotspots are formed for the positive and significant Z score. The smaller

[44] FU *et alii* 2014, 2403.

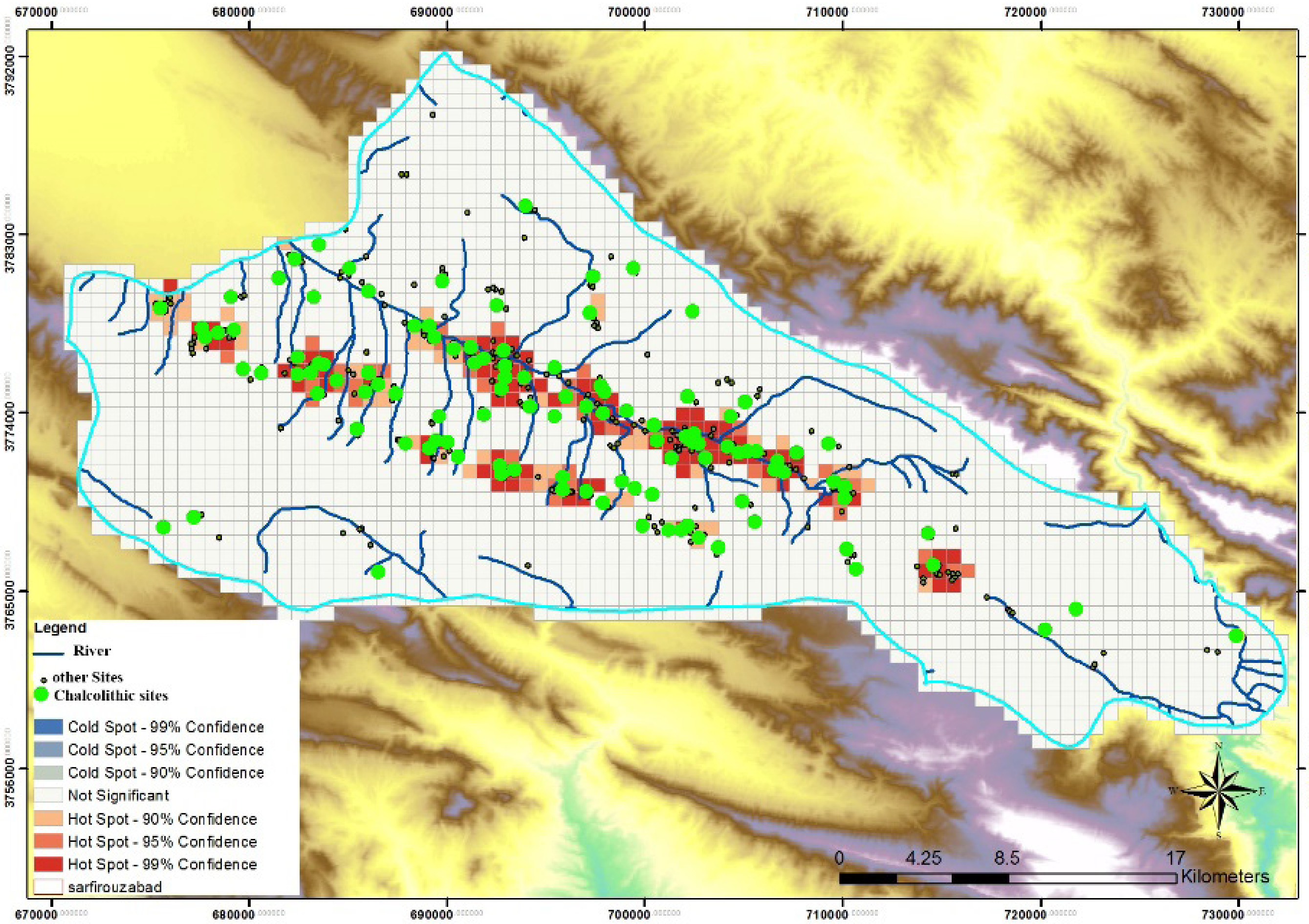

Fig. 12. Location of Chalcolithic and other sites and hot and cool spots.

the Z score for the negative and significant Z score, the lower the clustering will be; these indicate cool spots. The zoning map (Fig. 12) shows that in the central parts of the region and the southern margin of Sarfirouzabad plain, ancient sites with a value higher than the average have formed hotspots (red color). These are located at the bottom or on the edge of the plain, water sources are located near them, and their attitude is not high. In other words, these areas are most similar to their neighbors in terms of location in the environment, and the impact of environmental factors has been more significant on them. In the northern and northwestern parts of the region, marked in white, amounts with low value or, in other words, without value are formed; in this part, their relationship is minimal, and the impact of environmental factors has been less.

DISCUSSION AND CONCLUSION

As mentioned, the Sarfirouzabad plain is, in fact, a synclinal that is drained by the Mereg River, which there are large and small alluvial fans on it that have formed ancient sites in different places of this plain. In many parts of the world, sedimentary plains and alluvial fans have been important for the establishment of settlements and human settlements since prehistoric times.[45] In general, the analysis and the relationship between archaeological sites and environmental factors show a direct and positive relationship at high levels between environmental factors and Chalcolithic sites of Sarfirouzabad plain, which is confirmed by Moran statistics. Among these, altitude, placement in the plains or slopes, and extent show that this relationship is positive and strong. In general, the settlements formed in this plain are formed in two different beds; High and mountainous areas and fertile plain.

Statistical studies show that 33/3% of sites are located in the hills and steppes and 76/7% in the plains. It is noteworthy that the hotspot test also confirms that in two parts of the Sarfirouzabad plain, the settlements have formed a hotspot in the form of a belt, and this is a sign of their relationship and similarity with each other. In terms of the location of these sites in the region's landscape, the settlement pattern of the sites is divided into two groups. Several sites are located next to water resources and at the bottom of the plain along the Mereg River, and some are located on the edge of the plain in the steppe area, on the hills, slopes of the Nesar Mountains, and the hills of the Sefid-kooh.[46] These two groups of sites in different parts of the landscape indicate a different way of life and different social and cultural systems that include sedentary farmers in the sedimentary plain and along the Mereg River and

45 MAGHSOUDI *et alii* 2015,122.

46 NIKNAMI/ASKARPOUR 2013.

seasonal habitats of Livestock nomads on the slopes of hills and mountains[47] which in other regions of Zagros, especially Gamasiab and Harsin plain,[48] Nahavand and Kangavar[49] Islamabad[50] and Holeylan[51] have also been reported.

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[47] NIKNAMI/ASKARPOUR 2015, 145.
[48] SAEEDI HARSINI 2014.
[49] BALMAKI *et alii* 2013.
[50] ABDI 2003.
[51] MORTENSEN 1974 a; 1974 b.

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