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DETERMINING THE OPTIMAL SETTLEMENT LOCATING OF ANCIENT SITES USING TOPSIS MULTI-CRITERIA DECISION MODEL: A CASE STUDY: ESTABLISHMENTS IN MOUNTAINOUS AREAS OF NORTH KHORASAN, NORTHEAST IRAN

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Abstract: Human settlements emerged based on natural factors such as adequate water resources and suitable and fertile soil. Other factors such as altitude, slope, and slope direction, the distance to permanent water sources, and communication paths are natural substrates that affect the distribution of human settlements, some of which have a more influential role in the formation and survival of life. This study aims to investigate the status of the Iron Age settlement in the Atrak River Basin. To achieve the objectives of the research and hierarchical analysis of Iron Age sites, seven natural variables, including altitude, slope, slope direction, landing, soil type, distance to rivers, and communication routes that have been effective in establishing settlements, have been selected and by using the statistical methods in the GIS, the TOPSIS hierarchical analysis process, and Excel, and they have finally been studied. In terms of statistical analysis, the distance from river, Landuse and the distance to communication routes have been assigned the most ideal values. The slope degree, above sea level and Slope Direction have the lowest ideal value, respectively. Based on this, the IAMA60 site ranked first, the IAMA49 site ranked second, and the IAMA18 site ranked third in terms of natural indicators. In the lowest rank, IAMA25, IAMA35, and IAMA56 sites are located. In addition to these, the rest of the sites are considered relatively privileged areas.
Keywords: *Optimal settlement locating, ancient sites, TOPSIS multi-criteria decision-making, mountainous areas, northeast Iran.*

INTRODUCTION

Ancient settlements, as an interconnected system, are composed of interconnected components and elements and formed by interacting environmental forces and factors.[1] Archeological sites provide a

[1] ZHANG *et alii* 2014.

unique source for understanding human-environment interactions and ecosystems strongly influenced by human interactions over a wide range of temporal and spatial scales; thus, both reconstruct past environmental conditions and reveal human behavior.[2] Each region's conditions and environmental factors have a significant role in the creation and development of human settlements and the formation of units located in them.[3] Also, these human settlements in the region's ecosystem have specific structures and functions. The environmental structure of the region has a significant role in establishing settlements in that area. The key to developing this structure is the harmonious and sustainable development of the geographical environment and human activities.[4] Of course, it should be noted that the spatial and local patterns of human settlements are influenced by heterogeneous landscapes and access to natural resources;[5] which itself indicates the type of system of living with latent information about the spatial structure and their change during the time.[6] In other words, environmental capabilities (natural and human) provide the ground for patterns of human settlements in geographical and environmental spaces, and the spatial structure of each settlement is the result of interaction between human society and the surrounding physical environment.[7] Ancient societies, therefore, lived in places that provided favorable conditions for life and development, along with environmental factors such as rivers, communication routes, and the bed of deltas and river terraces, next to foothills or mineral resources, raw materials, and the possibility of protection against enemies.[8] Finally, natural factors' effects on spatial structures are particularly important in understanding how geographical spaces are formed and organized. Explaining and evaluating the form and manner of establishment and, in general, the reason for the existence of ancient centers requires a comprehensive study.

One of Iran's watersheds is the Atrak basin, the middle part of which is mainly mountainous with small intermountain plains. This mountainous region borders Eastern Alborz and the inner regions of Khorasan. For this reason, its climate is something between the dry and cold climate of Khorasan and the humid and moderate climate of the Gorgan Plain. Here, based on the detailed study of the Iron Age sites in the middle Atrak basin, which is located in North Khorasan province today, a more detailed analysis of the settlement of the Iron Age people in the region is done. Based on this, we will answer these questions relying on geographic and environmental factors and variables: Which of the Iron Age sites of the Middle Atrak Basin has been most affected by their environment? What is their hierarchy in terms of being influenced by their surrounding environment? Which one of the geographical and environmental factors had a more significant impact on locating this settlement?

[2] HAMBRECHT *et alii* 2020.
[3] YARAHMADI/SHARAFI 2016.
[4] WANG *et alii* 2020.
[5] ZHANG *et alii* 2014.
[6] VOGEL1986.
[7] COATES/JOHN STON/KNOX 1977.
[8] MAGAS/GAJSKI/DZIEGIELEWSKA-GAJSKI 2021.

This research has been conducted with a descriptive-analytical method. For the analysis of the distribution of the sites, the geographic information system (Arc GIS) along with the hierarchical analysis process of TOPSIS and Excel was used. By organizing the data based on their local distribution, it is possible to observe the structure of the data, understand the complex relationships of the data in extensive study units and transfer the data. The Arc GIS makes it possible to digitally prepare the physical aspects of the landscape and its physical surroundings and compute such processes as understanding spatial behaviors, choosing a location, how to use the landscape, and the like.[9] Also, seven indicators have been used to identify the affectability of ancient sites from environmental variables; including the distance of ancient sites to communication routes, altitude above sea level, the distance of ancient sites to water sources, soil type, Landuse, slope direction, and slope degree.

THEORETICAL FOUNDATIONS

The TOPSIS method is one of the most widely used multivariate decision-making methods for prioritization and comparison and was first proposed by Hwang & Yoon in 1981.[10] The TOPSIS algorithm is a compensatory multiple attribute decision making with high power for prioritizing factors and variables by simulating the ideal answer, which has minor sensitivity to weighting techniques. The answers obtained from this method do not change much. In the data analysis by this method, the selected options should have the shortest distance from the ideal answer and the farthest or the most distance from the most inefficient answer.[11] In other words, it calculates the distance of options and variables from the positive and negative ideal solution, then ranks the options based on the least distance from the positive ideal and the most distance from the negative ideal.[12] TOPSIS is one of the compensatory methods in MADM; compensatory is that the exchange between indicators is allowed in this model; that is, the weakness of one index may be compensated by the strength of another index.[13] In this method, an index called "relative proximity of the *i-th* option to the ideal solution or or " is introduced and the option with the most + is selected.[14] TOPSIS is a tool that can help prioritize options to achieve the desired result. This tool relies on three basic steps:

1. Identifying alternatives for selection and decision criteria.
2. Determining how criteria affect selection.
3. Evaluating and processing the performance of alternatives against these criteria to provide a single rate for each alternative so they can be ranked.[15]

This method has six steps:[16]

[9] ALDENDERFER 1998.
[10] HWANG/YOON 1981.
[11] CHEN 2000.
[12] DENG/ YEH/ WILLIS 2000.
[13] KARAM/SAFA KISH/KIANI 2014.
[14] ATES *et alii* 2006.
[15] YAU 2009.
[16] BEHZAD/ASADIAN 2017, 5-7.

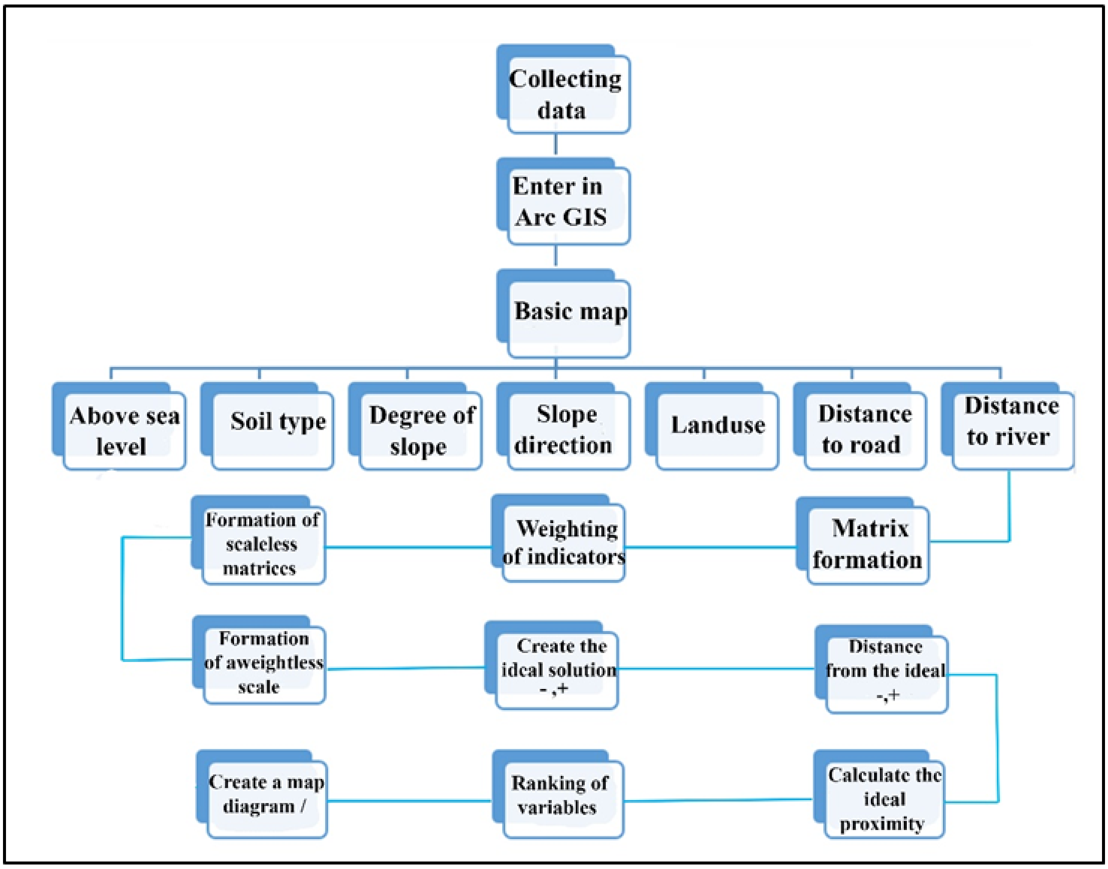

Fig. 1. Analysis steps using the TOPSIS process.

Step zero: obtaining the decision matrix; in this method, the decision matrix is evaluated, including the m options and the n indicators.

Step one: normalizing the decision matrix; in this step, the scales in the decision matrix become unscaled. In this way, each value is divided by the size of the vector corresponding to the same index. As a result, each directory rij is obtained from the following relationship:

$$rij = \frac{xrij}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Step two: weighting the normalized matrix; the decision matrix is actually parametric and needs to be quantified; for this purpose, the decision-maker determines the weight for each index. The weights (w) set is multiplied by the normalized matrix (R):

$$W = w_1\, w_2 \;\; \dots, w_j, \dots, w_n$$

$$\sum_{j=1}^{n} w_j = 1$$

Step three: determining the ideal solution and the negative ideal solution; two virtual options and are defined as follows:

$$Positive\ ideal\ option\ A^* = \left\{ \left(\underset{i}{maxv}_{ij} \backslash j \in J \right), \left(\underset{i}{minv}_{ij} \backslash j \in J^1 \right) | i = 1, 2, \dots . m \right\}$$

$$= \{ v_1^*, v_2^*, \dots, v_j^*, \dots, v_n^* \}$$

$$Negative\ ideal\ option\ A^- = \left\{ \left(\underset{i}{minv}_{ij} \backslash j \in J \right), \left(\underset{i}{maxv}_{ij} \backslash j \in J^1 \right) | i = 1, 2, \dots . m \right\}$$

$$= \{ v_1^-, v_2^-, \dots, v_j^-, \dots, v_n^- \}$$

Step four: obtaining the size of the distances; the distance between each n of the next option is measured by the Euclidean method; That is, the distance of the option i from positive and negative ideal options are found:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j\ max})^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j\ min})^2}$$

Step five: Determining the relative closeness of CL of an option to the ideal solution:

$$cl_i = \frac{d_i^-}{d_i^- + d_i^+}$$

Step six: ranking the options; finally, any option with a larger CL has a higher rank than the others (**Fig. 1**). In this research, the Iron Age sites of the Atrak river basin were selected as criteria and influential environmental factors as indicators.

MATERIALS AND METHODS

The descriptive-analytical method has formed this research considering the importance and position of hierarchical analysis for settlement selection. Accordingly, after collecting the required information and also reviewing the status of the Iron Age settlements in the Middle Atrak Basin, Databases were created using ARC GIS10 software, including entering variables and criteria, preparing information layers and new maps, classification, and evaluation of variables, information layers and the combination of these layers, suitable locations for settlements have been identified. Also, seven indicators including distance from ancient sites to communication routes, distance from ancient sites to water

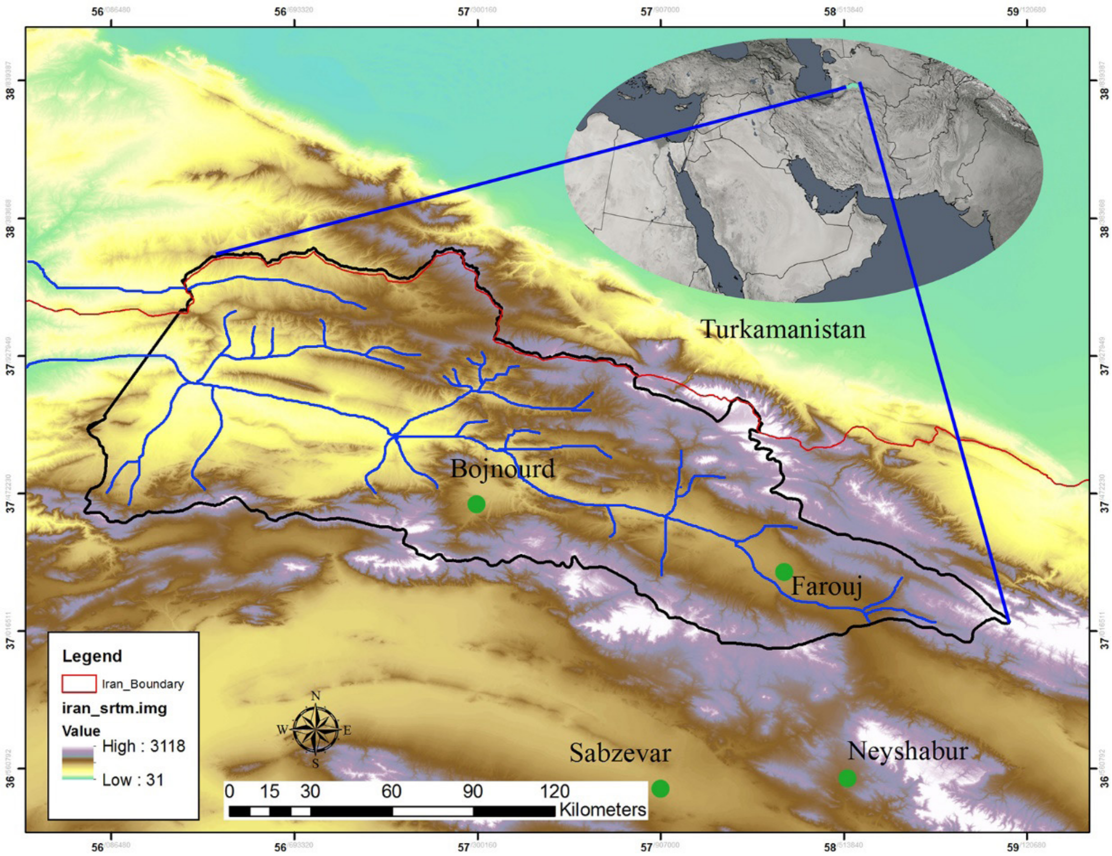

Fig. 2. Upper and middle Atrak river basin.

sources, Landuse, altitude, soil type, slope direction, and slope degree have been used to identify suitable lands for selection. Finally, to analyze the information obtained from the above layers, the ancient sites were ranked according to priority by the hierarchical analysis process of TOPSIS and Excel.

GEOGRAPHY AND ECOLOGY OF THE ATRAK RIVER BASIN

The Atrak basin, one of the largest water basins in northeastern Iran with an area of 33890 square kilometers, originates from the mountains of Hezar Masjed in the north of Quchan. About 26,500 square kilometers of this basin's area is located in the political area of Iran, and the rest in Turkmenistan (**Fig. 2**). The Atrak basin is bounded by Turkmenistan in the north, Gorgan and Kălshor basin in the south, the Qaraqum basin in the east, and the Caspian Sea in the west.[17] This basin consists of two parts; plains and mountains. Its climate is barren or continental. Rainfall is less than 200 mm in the plains and up to 500 mm in the highlands. The maximum altitude of this basin at the site of Tabărak River is about 2903 meters, and a minimum of -22 meters above sea level is estimated.[18] The main waterway of the basin can be divided into three parts: upper, middle, and lower (border) Atrak. After crossing the plains of Quchan, Shirvan, and Bojnourd (Upper Atrak), This River continued its route in Măneh, Ghori Meidan, and Marăveh Tappeh, then to the border of Iran and Turkmenistan (Middle Atrak). After connecting to the Sumbar branch at the Chat site and forming the Border Atrak (Lower Atrak), it finally flows into the Caspian Sea. The study area includes the middle part of the Atrak River with a length of approximately 150 km (the boundary between Rezaabad Gharbi and Sisab villages on the border of Shirvan and Bojnourd cities to Ghazan Ghayeh village on the border of Mane and Solmaghan cities with Maraveh Tappeh).[19]

The Middle Atrak Basin is geographically located between the Hyrkani Plain in the west and the land of Khorasan in the east. The high mountains of Alborz in the west separate it from Hyrkani, and the mountains of Kopeh Dagh in the north separate it from the Qarehqom desert. With the Aladagh-Binalood Mountains in the south, the Middle Atrak Basin is safe from the central desert of Iran. The not-so-high altitude set separates this basin from the upper Atrak valley, and such a situation has made the central Atrak basin a relatively independent and closed basin. This feature has a significant impact on the climate of this region, so its climate is something between the humid climate of Hyrkani and the cold and dryness of Khorasan. The western parts of this basin, especially in the Solmaghan's plain, sometimes find a climate similar to the Gorgan plain, such as in summer. Especially since the Aladagh Mountains, overlooking the Solmaghan Plain, have a relatively dense forest cover. However, in higher latitudes (northwest of the central Atrak Basin), due to the Turkmen Sahra lowlands impact in the west on the one hand and the soil of the region on the other, this part is warmer and very poor in terms of vegetation and water resources.

[17] NOORI *et alii* 2011.
[18] SHEIKHVAHED/BAHREMAND/MUSHEKHIAN 2011.
[19] YAMANI/DOLATI/ZAREI 2010.

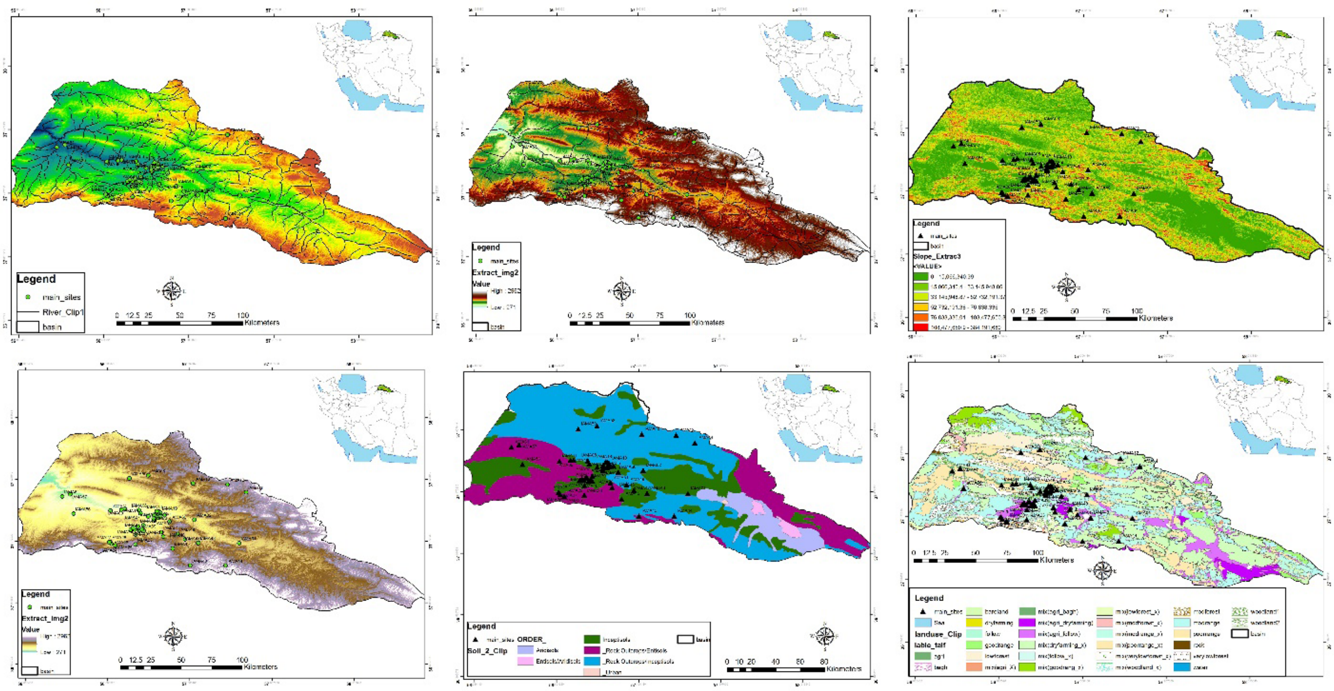

Fig. 3. Maps of the location of Iron Age sites concerning environmental factors (1. distance of sites to water sources, 2. distance of sites to communication routes, 3. degree of slope, 4. height above sea level, 5. location of the site on soil type, 6. Landuse).

RESEARCH BACKGROUND OF ARCHAEOLOGICAL RESEARCHES IN THE MIDDLE ATRAK BASIN

The first archeological activity in the area of the Middle Atrak was the studies and activities of Faegh Tohidi, which led to the arena determination of some sites. However, the first scientific excavation in this basin was carried out on the Tape Qaleh Khan, which showed an extended sequence from the Neolithic to the contemporary period.[20] Exploration reports on the Tape Ashkhaneh Bimarestan,[21] Tape Ashkhaneh Rivi,[22] Tape Eshgh Bojnourd,[23] speculation to determine the area and boundaries of the Tape Kalateh Mostofi Bojnourd,[24] Tape Bruski Ashkhaneh[25] and Kohnekand Bojnourd[26] have also been published on this basin. The studies of Shirvan,[27] Bojnourd, Raz and Jirgalan,[28] Mane and Solmaghan[29] cities in this area have not been published yet.

IRON AGE SITES OF THE MIDDLE ATRAK BASIN

In the study and identification carried out in the Middle Atrak basin, over 360 archaeological sites from all periods have been identified. In Shirin Darreh springs (a tiny part of Shirvan city) which are located in the middle Atrak area, 17 sites;[30] in Bojnourd city, which is completely located in the middle Atrak basin, 143 sites, in Raz and Jarglan city, which is about half of It is located in Atrak basin, 43 sites[31] and in Mane and Solmaghan city, which is completely located in the middle Atrak basin, 160 sites have been identified and introduced[32] (see, Tab. 1). Of these, 61 sites were inhabited during the Iron Age.

Tab. 1. Location of Iron Age Sites in Middle Atrak Basin base on Counties.

Middle Atrak Basin based on city	Percentage of Iron Age sites	Percentage of identified sites	Number of identified sites
Shirvan	2	5	17
Bojnourd	23	39	143
Raz and Jarglan	3	12	43
Mane and Solmaghan	72	44	160
Total	100	100	363

EXAMINING VARIABLES AND ENVIRONMENTAL FACTORS

Seven variables have been used to estimate the affectability of ancient sites from the surrounding environment and landscape, including the distance of ancient sites to communication routes, altitude above sea level, the distance of ancient sites to rivers, soil type in the area, Landuse, direction of slope and slope degree in the location of the sites (**Fig. 3**). Each of them is mentioned below.

20 GARAZHIAN/JAFARI/HOZHABRI 2011; GARAZHIAN/PAPOLI YAZDI/FAKHR-E GHASEMI 2014; GARAZHAN/ASKARPOUR 2018.
21 DANA/HEJEBRI /RAHMATI 2018; DANA/HEJEBRI NOBARI 2018.
22 JAFARI/THOMALSKY 2016.
23 VAHDATI 2014.
24 YAZDANI 2015.
25 ADINEH 2012.
26 DANA/HEJEBRI NOBARI/MOUSAVI KOUHPAR 2020.
27 MIRZAEI 2008
28 RAJABI 2013.
29 GARAZHIAN 2007; ATAEI 2009; ZARE 2011.
30 MIRZAEI 2008.
31 RAJABI 2013.
32 GARAZHIAN 2007; ATAEI 2009; ZARE 2011.

WATER RESOURCES FACTOR

Usually, human settlements are located where access to surface water is possible; in other words, water is an essential factor in the emergence of human habitats and the most crucial factor in their growth and development. [33]The land type and topographic status of each place significantly impact water storage and flow. Accordingly, villages are established where there is enough water to be established.[34] Atrak and its tributaries (**Fig. 3. 1**) as a permanent and reliable water source is one of the best options for choosing a location. Suitable soil and reliable altitude are also crucial for avoiding periodic or seasonal river floods in locating settlements. As shown in **Fig. 4**, 80% of the Iron Age sites are located up to 1000 meters from the running waters, indicating the connection between the ancient sites and water resources.

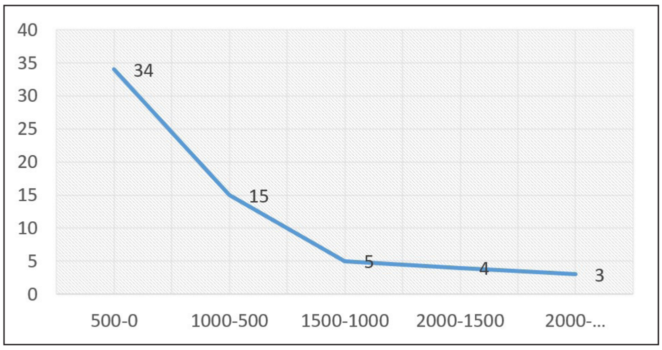

Fig. 4. Location of Iron Age sites in the Middle Atrak Basin in terms of distance from water sources.

COMMUNICATION ROUTES FACTOR

Communication routes are another essential variable in the formation of ancient sites, especially in the Bronze Age and beyond when we see the formation of cities with long-distance and trans-regional trade relations in the Greater Khorasan region. In the past, ancient roads were usually built based on natural paths and systems of valleys and plains,[35] and this region follows this due to its mountainous nature. Usually, communication routes in mountainous areas pass from the bottom of the valleys. What we have in mind today as a communication route is very different from the past; before the creation of modern roads, people used gorges and cuts caused by geological activity to travel. Due to the mountainous location and the forested nature of the area, the only passable routes were inevitably the same cuts and the length of other valleys located between relatively high and steep mountains and are used as paths.[36] This also applies in historical times, even in adjacent areas such as Dargaz, and historic sites have sometimes been formed adjacent to the main communication roads. This communication role is one of the essential factors in securing the economy of the inhabitants of these cities and rural areas.[37]

In the range of 0 to 1000 meters from the roads in this area, there are 42 sites (69 %), in the distance of 1000 to 2000 meters 7 sites (11%), in the distance of 2000 to 3000 meters 8 sites (13%), and in the distance of 3000 meters and above, four sites (7 %), located from the communication routes (**Fig. 5**). Among these, only one site, Tape Dăshăd (IAMA60), is located 9000 meters far from the communication routes. More than 70% of the sites are located at the bottom of the valleys, in the middle of the mid-mountain plains, next to the communication routes (**Fig. 3. 2**).

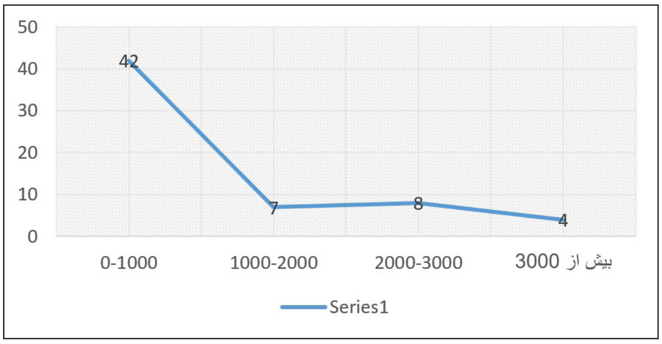

Fig. 5. Distance of sites from communication routes.

SLOPE DEGREE FACTOR

One of the influential environmental factors in the human settlement distribution system is the height and slope criterion. The slope is one of the essential factors in the transformation of land surface roughness,[38] and thus, it affects human life and activities such as agriculture, livestock, and even some human settlements on the slopes either directly or indirectly.[39]

According to the forthcoming objectives, the degree of slopes in the region was classified into nine separate groups. The lowest slopes (0-5 degrees) were determined as the first group, and the highest slopes were classified as group 9. Considering that the best slope for establishing human habitation is a slope of 0-10 degrees,[40] we examine the location of the sites on the slopes. The slope degree of the location of ancient sites is an essential factor that affects their area due to its economic nature. Among the sites of this period (**Fig. 3.3**), 18 sites (28%) were on the slope of 0-5

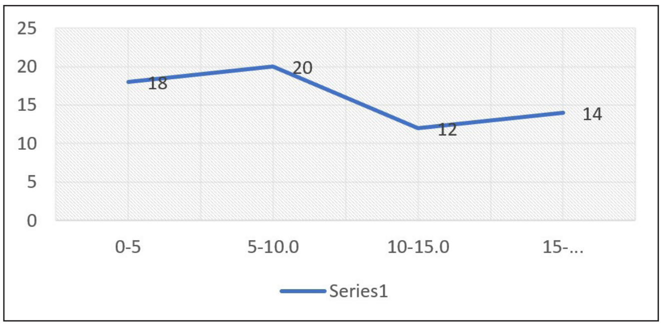

Fig. 6. Percentage of ancient sites based on their slope.

[33] HEYDARI DASTENAEI/NIKNAMI 2020.
[34] MOTARJEM SIASAR 2017.
[35] HEJEBRI NOBARI *et alii* 2021.
[36] VOSOGH BABAEI/MEHRAFARIN 2018.
[37] NAMI/MOUSAVINI 2019.
[38] AKBAR AGHALLI/VELAYATI 2007.
[39] ZOMORRODIAN1995.
[40] ANABESTANI 2011.

degrees, 20 sites (32%) on the slope of 5-10 degrees, 12 sites (18%) on the slope of 10 -15 degrees and 14 sites (22%) were located on slopes more than 15 degrees (**Fig. 6**).

ALTITUDE FROM THE SEA LEVEL FACTOR

Altitude from sea level can cause climate changes and, consequently, changes in lifestyle and some climatic features.[41] In addition, it directly affects ecosystems, vegetation, animals, and livelihood choices.[42] The central Atrak region's sea-level altitude varies between 226 and 2962 meters. The location of the sites in terms of altitude (**Fig. 3. 4**) shows that about 60% of the sites are located at an altitude between 226 to 819 meters above sea level (**Fig. 7**). In this region, the average annual rainfall in meteorological stations is about 250 mm, which is suitable for rainfed cultivation. However, it should be noted that despite the appropriate rainfall and altitude, the soil type is also crucial for cultivation. Sufficient rainfall and humidity at altitudes of about 600 m above sea level and above allow optimal rainfed cultivation[43]. However, the annual rainfall is a more critical factor for rainfed cultivation. The minimum rainfall suitable for rainfed cultivation is about 200 mm,[44] indicating that this area is suitable for rainfed agriculture due to more rainfall.

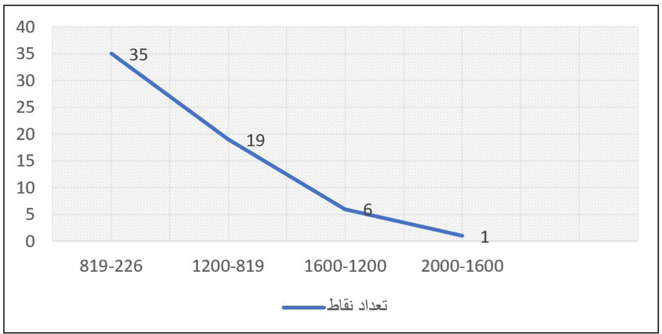

Fig. 7. Location of Iron Age sites in the middle Atrak Basin in terms of altitude.

SOIL TYPE FACTOR

Today, Geoarchaeological studies have found a special place as a helpful tool in archaeological studies and explaining the ancient Quaternary environments.[45] Soil is a non-dense organic matter that has been created over many years under the influence of various factors such as climate, vegetation, and elevation;[46] thus, soil type affects the livelihood structure of the area.[47] As can be seen on the map, large areas of the western parts of the Middle Atrak Basin are geologically calcareous and unsuitable soils that are also very poor in vegetation. The Iron Age sites of the region are in the category of Inceptisol/Entisol rocky outcrop soils with a small amount of Inceptisol (**Fig. 3. 5**).

In this area, 42 sites (68%) of Iron Age sites are located in Inceptisols, seven sites (12%) are located in Inseptisol rocky outcrop soil, and 12 sites (20%) are located in areas with Entisol rocky outcrop soil (**Fig. 8**). The presence of fine-grained and fertile sediments usually provides suitable materials for agriculture, pottery, and other economic activities and acceptable conditions for developing establishments. [48]As we all know, Inceptisols are spread all over the world. Interpretation of Inceptisols is necessarily suitable for agricultural and non-agricultural uses and can be widely used for crop cultivation, provided that artificial drainage is possible in them.[49]

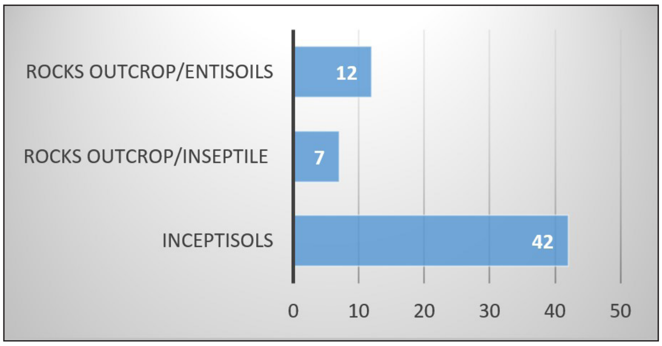

Fig. 8. Sites placement on different types of soils.

LANDUSE FACTOR

Landuse results from a combination of human activity and the capabilities of a place. Although Landuse is the result of population activities, it is somehow a reason for the existence of capabilities and the possibility of using the capabilities of the natural environment.[50] The Cultivability of land is one of the factors that is influenced by many effective criteria such as altitude, presence or absence of surface water, soil type, human manipulation in the environment, and climate. This manipulation, on the other hand, can have a decisive role in the erosion rate. Most importantly, the land cultivability and the type of vegetation in it can also be a very determining factor in the type of livelihood of the residents of the settlements; So that the settlement or leaving of many shelters, especially with livestock livelihood, depends on this category.[51] In fact, the purpose of land surveying is to determine the land value from the location point of view.[52]

The map of the area based on Landuse (**Fig. 3. 6**) shows that about half of the sites are located in areas that are currently used for agriculture, whether irrigated or rainfed, and the other half are in areas that are located in a pasture or forest areas (**Fig. 9**). This local difference in the sites should be considered related to the livelihood of the residents of them. This means that in pasture areas, the sites indicate that nomads used them for temporary settlement or cemeteries and that the sites on suitable agricultural land belonged to sedentary farmers.

[41] QAZANFARPOUR/KAMANDARI/MOHAMMAD SOLEYMANI 2013.
[42] DUCKSTEIN/FOGEL/THAMES 1973.
[43] KIRKBY 1979, Table 83-84.
[44] ADAMS 1981.
[45] MAGHSOUDI *et alii* 2020.
[46] SALMANPOUR/SENMAR/BAKHTIARVAND BAKHTIARI 2013.
[47] ESTELAJI/GADIRI MASOUM 1995.
[48] MAGHSOUDI *et alii* 2020, 7.
[49] SOHRABI *et alii* 2013.
[50] SADR MOUSAVI/TALEBIFAR/NIAZY 2018.
[51] AFIFI 2018.
[52] RAHIMI/HASANPOUR 2011.

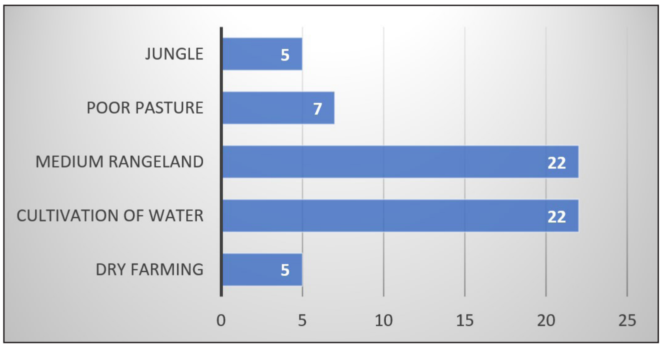

Fig. 9. Location of Iron Age sites in the Middle Atrak Basin in terms of Landuse.

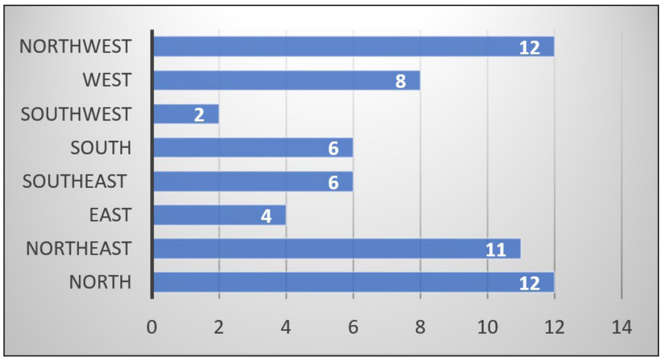

Fig. 10. Percentage of Iron Age sites in Atrak Basin in relation to slope direction.

SLOPE DIRECTION FACTOR

In the general concept, the direction is a well-defined feature for the linear effects of a phenomenon in geometry. It includes other concepts such as slope, slope, and geological slope.[53] Slope direction determines the amount of solar energy that the soil receives this energy determines the temperature of air and soil and the amount of available water in the soil, which are the factors that cause differences in the vegetation of different slopes. In mountainous areas, slopes facing the sun, and in tropical areas, slopes that do not face the sun seem to be more suitable for living. In this region, in different seasons, the southern slopes are the most important, and the northern slopes are the least important, because the southern direction receives the lowest heat in summer and the most heat in winter. The eastern and western slopes are less important than the southern slopes and are used in spring and autumn.[54] Surveying the location of Iron Age sites indicates that the northern slopes contain more establishments, and the southern slopes are less used (**Fig. 10**). Accordingly, 12 sites are located on the northern direction slope, 11 sites on the northeast, two sites on the east, six sites on the southeast, six sites on the south, two sites on the southwest, eight sites on the west, and 12 sites on the west areas.

RESEARCH FINDINGS USING THE TOPSIS MODEL

This research was carried out using the aforementioned statistical methods to analyze and rank the environmental factors affecting the Iron Age ancient sites of Atrak Basin. This research ranks seven criteria and 61 options based on the TOPSIS method. Table 2 shows the specifications of the criteria.

Step zero: The first step in this method is forming the decision matrix. The decision matrix of this method includes a series of criteria and options. A matrix where the criteria are placed in the columns, and the options are in the rows. Each cell of the matrix evaluates each option concerning each criterion. This table contains specifications of ancient sites that are measured numerically with environmental factors. If several elites have been used in the evaluation, the said matrix is the average of all elites.

[53] HEYDARI DASTENAEI/NIKNAMI 2020.
[54] HEYDARI DASTENAEI 2018.

Tab. 2. Specifications of the types of criteria used in the analysis.

	Factor (criterion)	Factor type	Factor weight
1	Altitude from the Sea Level	-	0.2
2	Communication routes	+	0.5
3	Water resources	+	0.6
4	Slope degree	-	0.1
5	Soil type	+	0.3
6	Land use	+	0.4
7	Slope Direction	+	0.2

Step one: Normalizing the decision matrix (de-scaling the decision matrix): De-scaling in the TOPSIS method is done using the soft method. It is done in such a way that each component is divided by the square root of the sum of the square of the components of that criterion column. In this step, the decision matrix becomes dimensionless (Table 3). The following equation is used for normalization.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \dots, m \quad ; j = 1, \dots \quad , n$$

Step two: Calculating the normalized weighted matrix (Table 4) (determining the weighted scaleless matrix): in this step, the weight of the criteria obtained by other methods must be multiplied by the normal matrix to obtain the weighted matrix (the TOPSIS method alone is not able to calculate the weight of the criteria, so The weights of criteria should be calculated by other methods such as AHP, entropy, and so forth, and used as input.).

According to the following equation, the normalized matrix is multiplied by the weight of the criteria.

$$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \qquad i = 1, \dots, m \quad ; j = 1, \dots \quad , n$$

Step three: Determining positive and negative ideal points: here, the type of criteria must be specified; Criteria are either positive or negative. Positive criteria are criteria whose increase leads to improvement in the system. This

Tab. 3. Normalized Matrix.

Site code	Slope Direction	Landuse	Soil type	Slope degree	Water resources	Communication routes	Altitude from the Sea Level
1	0.135	0.046	0.062	0.004	0.032	0.046	0.139
2	0.135	0.053	0.227	0.006	0.009	0.028	0.131
3	0.09	0.02	0.062	0.004	0.045	0.058	0.092
4	0.09	0.08	0.062	0.004	0.069	0.186	0.092
5	0.09	0.066	0.062	0.004	0.045	0.046	0.089
6	0.09	0.01	0.062	0.004	0.073	0.209	0.089
7	0.135	0.083	0.207	0.004	0.149	0.209	0.093
8	0.09	0.007	0.062	0.004	0.006	0.186	0.08
9	0.135	0.007	0.227	0.004	0.009	0.139	0.08
10	0.09	0.166	0.062	0.004	0.013	0.023	0.079
11	0.135	0.002	0.227	0.005	0.149	0.139	0.075
12	0.225	0.02	0.186	0.006	0.011	0.07	0.223
13	0.135	0.033	0.062	0.006	0.134	0.046	0.163
14	0.225	0.013	0.186	0.006	0.149	0.046	0.21
15	0.18	0.01	0.062	0.004	0.048	0.325	0.094
16	0.09	0.133	0.227	0.004	0.015	0.232	0.097
17	0.135	0.023	0.227	0.004	0.021	0.197	0.094
18	0.09	0.099	0.207	0.004	0.084	0.464	0.099
19	0.045	0.003	0.062	0.004	0.078	0.058	0.093
20	0.045	0.109	0.062	0.004	0.009	0.162	0.092
21	0.09	0.036	0.227	0.004	0.075	0.139	0.091
22	0.045	0.007	0.207	0.004	0.034	0.081	0.088
23	0.271	0.043	0.103	0.005	0.063	0.046	0.216
24	0.225	0.099	0.186	0.005	0.134	0.046	0.154
25	0.225	0.001	0.021	0.005	0.036	0.023	0.153
26	0.045	0.017	0.062	0.005	0.036	0.093	0.139
27	0.225	0.023	0.145	0.005	0.039	0.015	0.125
28	0.135	0.056	0.145	0.005	0.038	0.012	0.127
29	0.18	0.027	0.186	0.004	0.048	0.278	0.122
30	0.045	0.007	0.062	0.004	0.224	0.104	0.104
31	0.045	0.017	0.062	0.004	0.231	0.046	0.105
32	0.045	0.01	0.062	0.004	0.052	0	0.104
33	0.045	0.06	0.062	0.004	0.149	0.035	0.103
34	0.045	0.331	0.062	0.004	0.05	0.093	0.104
35	0.18	0.027	0.062	0.004	0.039	0	0.106
36	0.09	0.278	0.062	0.005	0.041	0.046	0.102
37	0.09	0.08	0.207	0.004	0.056	0.046	0.115
38	0.09	0.08	0.062	0.004	0.205	0.046	0.11
39	0.18	0.007	0.062	0.004	0.298	0	0.126
40	0.09	0.249	0.062	0.004	0.164	0.015	0.111

Site code	Slope Direction	Landuse	Soil type	Slope degree	Water resources	Communication routes	Altitude from the Sea Level
41	0.09	0.043	0.062	0.004	0.16	0.008	0.111
42	0.09	0.043	0.062	0.005	0.058	0.035	0.099
43	0.135	0.169	0.124	0.005	0.037	0	0.213
44	0.18	0.086	0.062	0.006	0.019	0.012	0.23
45	0.045	0.03	0.124	0.004	0.172	0.139	0.206
46	0.045	0.053	0.227	0.004	0.022	0.116	0.154
47	0.09	0.007	0.062	0.004	0.075	0.093	0.15
48	0.09	0.083	0.062	0.004	0.062	0.07	0.15
49	0.18	0.746	0.124	0.004	0.045	0.046	0.189
50	0.135	0.02	0.124	0.005	0.075	0.139	0.145
51	0.09	0.027	0.062	0.004	0.058	0.046	0.129
52	0.09	0.066	0.062	0.004	0.021	0.093	0.088
53	0.135	0.036	0.062	0.004	0.052	0.186	0.096
54	0.045	0.007	0.062	0.004	0.021	0.139	0.083
55	0.045	0.066	0.062	0.004	0.06	0.209	0.08
56	0.045	0.013	0.062	0.004	0.056	0	0.091
57	0.135	0.01	0.227	0.004	0.061	0.046	0.059
58	0.09	0.053	0.124	0.006	0.045	0.07	0.152
59	0.18	0.013	0.021	0.999	0.062	0.046	0.136
60	0.18	0.053	0.124	0.004	0.671	0	0.161
61	0.045	0.003	0.062	0.005	0.002	0.104	0.062

Tab. 4. Normal weighted matrix.

Site code	Slope Direction	Landuse	Soil type	Slope degree	Water resources	Communication routes	Altitude from the Sea Level
1	0.027	0.019	0.019	0	0.019	0.023	0.028
2	0.027	0.021	0.068	0.001	0.005	0.014	0.026
3	0.018	0.008	0.019	0	0.027	0.029	0.018
4	0.018	0.032	0.019	0	0.041	0.093	0.018
5	0.018	0.027	0.019	0	0.027	0.023	0.018
6	0.018	0.004	0.019	0	0.044	0.104	0.018
7	0.027	0.033	0.062	0	0.09	0.104	0.019
8	0.018	0.003	0.019	0	0.004	0.093	0.016
9	0.027	0.003	0.068	0	0.005	0.07	0.016
10	0.018	0.066	0.019	0	0.008	0.012	0.016
11	0.027	0.001	0.068	0	0.09	0.07	0.015
12	0.045	0.008	0.056	0.001	0.007	0.035	0.045
13	0.027	0.013	0.019	0.001	0.081	0.023	0.033
14	0.045	0.005	0.056	0.001	0.09	0.023	0.042
15	0.036	0.004	0.019	0	0.029	0.162	0.019
16	0.018	0.053	0.068	0	0.009	0.116	0.019
17	0.027	0.009	0.068	0	0.013	0.099	0.019

Site code	Slope Direction	Landuse	Soil type	Slope degree	Water resources	Communication routes	Altitude from the Sea Level
18	0.018	0.04	0.062	0	0.05	0.232	0.02
19	0.009	0.001	0.019	0	0.047	0.029	0.019
20	0.009	0.044	0.019	0	0.005	0.081	0.018
21	0.018	0.015	0.068	0	0.045	0.07	0.018
22	0.009	0.003	0.062	0	0.02	0.041	0.018
23	0.054	0.017	0.031	0	0.038	0.023	0.043
24	0.045	0.04	0.056	0	0.081	0.023	0.031
25	0.045	0.001	0.006	0	0.021	0.012	0.031
26	0.009	0.007	0.019	0	0.022	0.046	0.028
27	0.045	0.009	0.043	0	0.023	0.008	0.025
28	0.027	0.023	0.043	0	0.023	0.006	0.025
29	0.036	0.011	0.056	0	0.029	0.139	0.024
30	0.009	0.003	0.019	0	0.134	0.052	0.021
31	0.009	0.007	0.019	0	0.139	0.023	0.021
32	0.009	0.004	0.019	0	0.031	0	0.021
33	0.009	0.024	0.019	0	0.09	0.017	0.021
34	0.009	0.133	0.019	0	0.03	0.046	0.021
35	0.036	0.011	0.019	0	0.023	0	0.021
36	0.018	0.111	0.019	0	0.025	0.023	0.02
37	0.018	0.032	0.062	0	0.034	0.023	0.023
38	0.018	0.032	0.019	0	0.123	0.023	0.022
39	0.036	0.003	0.019	0	0.179	0	0.025
40	0.018	0.099	0.019	0	0.098	0.008	0.022
41	0.018	0.017	0.019	0	0.096	0.004	0.022
42	0.018	0.017	0.019	0	0.035	0.017	0.02
43	0.027	0.068	0.037	0	0.022	0	0.043
44	0.036	0.034	0.019	0.001	0.011	0.006	0.046
45	0.009	0.012	0.037	0	0.103	0.07	0.041
46	0.009	0.021	0.068	0	0.013	0.058	0.031
47	0.018	0.003	0.019	0	0.045	0.046	0.03
48	0.018	0.033	0.019	0	0.037	0.035	0.03
49	0.036	0.298	0.037	0	0.027	0.023	0.038
50	0.027	0.008	0.037	0	0.045	0.07	0.029
51	0.018	0.011	0.019	0	0.035	0.023	0.026
52	0.018	0.027	0.019	0	0.013	0.046	0.018
53	0.027	0.015	0.019	0	0.031	0.093	0.019
54	0.009	0.003	0.019	0	0.013	0.07	0.017
55	0.009	0.027	0.019	0	0.036	0.104	0.016
56	0.009	0.005	0.019	0	0.034	0	0.018
57	0.027	0.004	0.068	0	0.037	0.023	0.012
58	0.018	0.021	0.037	0.001	0.027	0.035	0.03
59	0.036	0.005	0.006	0.1	0.037	0.023	0.027
60	0.036	0.021	0.037	0	0.403	0	0.032
61	0.009	0.001	0.019	0	0.001	0.052	0.012

criterion is of a positive type, and its ideal solution is equal to the largest component of the criterion column. The anti-ideal is equal to the smallest component of the cell. The basis of the TOPSIS method is to calculate the distance of the options from the positive and negative ideal (Table 5). Therefore, at this stage, the positive and negative ideal solutions are determined according to the following equations.

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+)$$
$$A^- = (v_1^-, v_2^-, \dots, v_n^-)$$

So that:

$$v_j^+ = \{(max\ v_{ij}(x) |\ j\epsilon j_1), (min\ v_{ij}(x) |\ j\epsilon j_2)\}\ \ i = 1, \dots, m$$
$$v_j^- = \{(min\ v_{ij}(x) |\ j\epsilon j_1), (max\ v_{ij}(x) |\ j\epsilon j_2)\}\ \ i = 1, \dots, m$$

j_1 و j_2 are related to positive and negative criteria respectively.

Tab. 5. Positive and negative ideal values.

Factor (criterion)	Negative ideal	Positive ideal
Altitude from the Sea	0.046	0.012
Communication routes	0	0.232
Water resources	0.001	0.403
Slope degree	0.1	0
Soil type	0.006	0.068
Landuse	0.001	0.298
Slope Direction	0.009	0.054

Step four: Calculating the distance between positive and negative ideal points: In this step, the relative proximity of each option to the ideal solution is calculated. The Euclidean distance of each option from the positive and negative ideal will be calculated with the following formula. The final step is to calculate the ideal solution. In this step, the relative closeness of each option to the ideal solution is calculated (Table 6). The TOPSIS method ranks the options based on how close they are to the positive ideal and how far they are from the negative ideal. Therefore, at this step, the distance of each option to the positive and negative ideal is calculated based on the following equation.

$$d_i^+ = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^+(x)]^2}\ \ ,\ \ i = 1, \dots, m$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^-(x)]^2}\ \ ,\ \ i = 1, \dots, m$$

Step five: Calculating the proximity of the options to the ideal: in this step, the proximity of each option to the ideal solution is measured and obtained by the following equation. The closer this amount is to 1, the more the considered option has a smaller distance from the positive ideal and a greater distance from the negative one.

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)}\ \ ,\ \ i = 1, \dots, m$$

Tab. 6. The distance between the options and the positive and negative ideal.

Site code	Positive ideal distance	Negative ideal distance	Site code	Positive ideal distance	Negative ideal distance
1	0.522	0.109	32	0.532	0.108
2	0.532	0.123	33	0.473	0.139
3	0.52	0.112	34	0.453	0.176
4	0.474	0.149	35	0.532	0.11
5	0.512	0.113	36	0.475	0.155
6	0.485	0.154	37	0.502	0.127
7	0.431	0.184	38	0.443	0.164
8	0.519	0.14	39	0.441	0.207
9	0.522	0.141	40	0.432	0.173
10	0.512	0.125	41	0.478	0.141
11	0.462	0.166	42	0.514	0.112
12	0.53	0.122	43	0.505	0.127
13	0.482	0.132	44	0.527	0.11
14	0.478	0.148	45	0.45	0.162
15	0.484	0.197	46	0.511	0.134
16	0.48	0.176	47	0.504	0.12
17	0.504	0.157	48	0.497	0.118
18	0.439	0.267	49	0.432	0.319
19	0.51	0.117	50	0.491	0.135
20	0.5	0.139	51	0.515	0.111
21	0.486	0.147	52	0.514	0.118
22	0.522	0.126	53	0.491	0.144
23	0.508	0.121	54	0.52	0.126
24	0.463	0.149	55	0.479	0.154
25	0.536	0.109	56	0.53	0.109
26	0.519	0.114	57	0.515	0.131
27	0.528	0.117	58	0.509	0.116
28	0.523	0.114	59	0.527	0.054
29	0.481	0.184	60	0.364	0.416
30	0.443	0.176	61	0.535	0.118
31	0.45	0.174	32	-	-

Step six: Ranking the options (similarity index (CL)): the value of the similarity index is between zero and one. The closer this value is to one, the solution is closer to the ideal solution, and therefore, it is a better one. Finally, this ranking can be presented as a map or graph (**Fig. 11**).

Tab. 7. Ci amount and ranking.

Site code	value	Ci	Site code	ranking	Ci
1	43	0.173	32	47	0.168
2	37	0.187	33	24	0.227
3	42	0.177	34	9	0.28
4	19	0.239	35	45	0.171
5	39	0.181	36	16	0.247
6	18	0.241	37	30	0.202
7	5	0.299	38	12	0.271
8	28	0.213	39	4	0.319
9	28	0.213	40	7	0.286
10	32	0.196	41	23	0.228
11	15	0.264	42	41	0.179
12	37	0.187	43	31	0.201
13	27	0.215	44	44	0.172
14	21	0.237	45	14	0.265
15	6	0.289	46	29	0.208
16	13	0.268	47	35	0.193
17	20	0.238	48	36	0.192
18	3	0.379	49	2	0.424
19	37	0.187	50	26	0.216
20	25	0.217	51	42	0.177
21	22	0.232	52	37	0.187
22	34	0.194	53	24	0.227
23	35	0.193	54	33	0.195
24	17	0.243	55	17	0.243
25	46	0.17	56	45	0.171
26	40	0.18	57	30	0.202
27	39	0.181	58	38	0.185
28	41	0.179	59	48	0.093
29	11	0.276	60	1	0.534
30	8	0.285	61	39	0.181
31	10	0.278	32	-	-

CONCLUSION

The formation of human settlements has always been based on natural and environmental factors, and the effect of these factors on ancient sites will be different in different geographical areas, so the selection of these environmental factors and their investigation depends on the geographical conditions of each place. The archaeological landscape of ancient sites results from the interaction of environmental forces and factors. The natural location of a settlement is directly related to natural factors such as elevation and altitude, climate, water sources, and vegetation. This research has investigated the status of Iron Age settlements in the Atrak Basin according to natural variables and criteria. To achieve the research goals, seven natural variables, including: altitude above sea level, slope degree, soil type, distance to the river, distance to road, slope direction, and Landuse, were selected as influential factors in establishing settlements. These data were analyzed using statistical methods in the GIS and TOPSIS multi-criteria decision-making model. According to the statistical analysis of environmental resources, the distance to the river with 0.403, Landuse with 0.298, and the distance to the communication routes with 0.232, respectively, have the most ideal values. The slope degree with zero, height above sea level 0.012, and 0.054 have the lowest ideal values, respectively. The IAMA60 site was ranked first in the evaluated natural indicators with a CI coefficient of 0.534. The IAMA49 site with a CI coefficient of 0.424 was ranked second. The IAMA18 site was ranked third with a coefficient of 0.379.

The IAMA59 site is ranked the lowest in evaluated natural indicators, with a CI coefficient of 0.093. In terms of natural indicators, IAMA25 is in the next stage with a CI coefficient of 0.170, and IAMA35 and IAMA56 are the weakest groups in terms of natural indicators evaluated with a CI coefficient of 0.171 in the third stage. In addition, the rest of the sites are considered relatively privileged. According to the statistical analysis, it is clear that the sites that have higher ranks and have higher priority have been most affected by the surrounding geographical environment. The factor of distance from water sources, Landuse, and the distance from communication routes have a more significant effect than other variables on ancient sites. In addition, it is clear that although some ancient sites have lower ranks, it is still observed that environmental factors also had an impact on their establishment and survival.

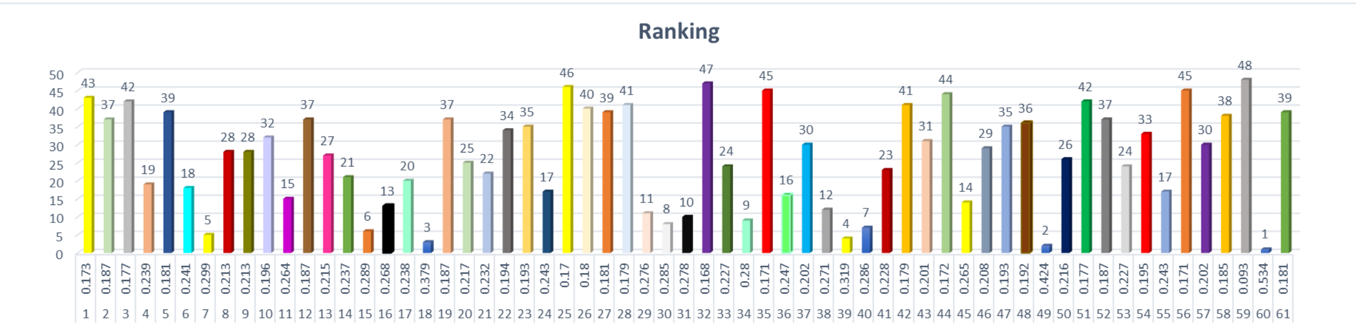

Fig. 11. Ranking of the ancient sites of the Atrak basin in terms of environmental effects in their creation.

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