Zoning analysis of Iron Age sites using Analytic Hierarchical Process (AHP) methods in the Middle Atrak River Basin, Northeast of Iran

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ABSTRACT – Iron Age settlements in the Middle Atrak Basin in Iran have a particular distribution pattern due to environmental, social, and economic variables, among which geographical factors play an essential role in creating and dispersing settlements. Some of these factors play a more effective and stable role than others. The present study examines and evaluates the role of geographical factors in the distribution of Iron Age sites to determine factors that have a more significant role than others. Moreover, the zoning map of the Middle Atrak Basin should be presented using four different types of location, grouped in terms of those with a perfectly suitable, relatively suitable, suitable, and unsuitable location. To achieve this goal, seven natural factors, including the distance of sites from the river, altitude, slope, slope direction, distance from communication routes, soil type, and land use, were selected as influential factors in choosing the location of the Iron Age sites. In this study operating maps were prepared digitally using ArcGIS, and then the weight of each index was determined using the AHP model. The results of this study show that 46.7% of the Iron Age settlements (or 28 sites) were located in a perfectly suitable environment and geography, 24 sites (29.3%) in a relatively suitable location, seven sites (11.4%) in a suitable place, and one site (1.6%) in a completely unsuitable environment. This last type of location in the region’s landscape indicates the choice of different livelihoods, including agriculture and animal husbandry with both seasonal and permanent methods.

KEY WORDS – Iron Age sites zoning; Analytic Hierarchical Process (AHP); Middle Atrak Basin; Northeast of Iran
Introduction

Archaeological findings show that the development and evolution of past human settlements are closely related to the substrate of the natural and social environment. Environmental and natural substrates create the necessary conditions for establishing settlements, and some create more stable conditions than others. These natural substrates are each region's slope, altitude, geological structure, water resources, and climate. Each of these factors, both individually and in relation to each other, shows differences. The existence of such differences causes the characteristics of different regions (Gholami Rad, Wali Shariatpanah 2013.56). Humans have long tried to settle in the natural environment in such a way that makes the best use of it. In other words, human settlements act as the most basic link between man and the Earth, and reflect human interactions with the environment (Zhang et al. 2014). Therefore, ancient societies lived in places that had favourable conditions for life and development – with environmental factors such as rivers, communication routes, and beds of deltas and river terraces along with foothills or mineral resources – which provided them with raw materials and the possibility of protection against enemies (Magaﬁ et al. 2021.21). In addition to these cases, various other factors and forces are involved in the location and formation of rural settlements, which should be considered in any location of settlements. Although the effects of these factors and forces depend greatly on the underlying characteristics of the environmental substrate and ecological structures (Zhang et al. 2014.2818), the primary stimulus in this process is the set of motivations that arise to meet basic needs, and the forms of various fundamental demands among different human groups. As such, different forms and varieties of locations, and the locating of human settlements in certain places because of the demands and motivations they are able to satisfy, are realized in different ways. As a result, settlements are structurally and functionally different from one area to another (Rahimi, Hassaneinpour 2013.14). For example, settlements formed in hilly areas are more affected by natural factors such as altitude, slope, and slope direction. In contrast, settlements formed in lowland areas are more affected by human factors such as communication routes and transportation, surface water networks (hydrography), and agricultural and cultivated lands (Ma et al. 2017.12). Therefore, these factors affect the texture and body of the settlements and the ways of life of their people.

In this study we use several environmental variables and natural criteria, along with the Analytic Hierarchical Process (AHP) integrated with the Geographic Information System (GIS), for zoning and evaluating the Iron Age sites of the Atrak River Basin to determine: (1) What are the zones in the Middle Atrak? (2) Which of these basins were considered by Iron Age people? (3) What do the Iron Age sites in the different zones reveal?

Theoretical foundations

AHP is one of the most efficient multi-criteria decision-making techniques, and was developed by the mathematician Thomas L. Saaty (1980) in the late 1970s. One of the advantages of the hierarchical analysis method in the context of this study is that it can deal with the various factors that influence the location of human settlements. It prioritizes residential areas by weighting factors with pairwise comparisons (Abdelouhed 2022.11) and the impact rates of each of them (Liao, Kao 2010.571). AHP is an effective and helpful method for solving multi-criteria problems that use a hierarchical structure to show the problem, and a better way to solve such issues and prioritize different options based on user judgment. In other words, this method is used both in reality and theory in decision-making (Toledo-Aceves et al. 2011.975). To be more specific, the ultimate goal of the AHP method is to determine the relative weight of each factor in a system (Yao, Zhao 2022.17). By solving decision problems, AHP allows researchers to focus on several criteria simultaneously and also allows decision-makers to compare quantitative and qualitative criteria (Rodhiah et al. 2021.197). AHP is a multi-objective, multi-criteria decision-making approach that enables the user to reach priorities based on a set of options derived from three principles: parsing, comparative judgment, and prioritization (Abdul Rahaman, Aruchamy 2017.3).

The AHP method has three basic steps: (1) creating a hierarchy, which is the essential part of the hierarchical analysis process (Cimren 2007.369); (2) determining the importance coefficients of variables and criteria using pairwise comparison methods; (3) assessing the consistency of judgments according to the percentage of consistency (Saaty 1980.287).

As discussed above, AHP can be used for relative measurements by pairwise comparison of criteria and data, or measurement of data according to criteria and variables. Ranking mode and preferences
include a pairwise comparison of criteria according to purpose. Ranking levels and preferences – such as excellent, very good, good, average, poor, and very poor – are then determined for each criterion. In the next step, pairwise comparisons are made between the ranking levels of each criterion to obtain a set of priorities (weights) for these levels. For each criterion, scaled weights are considered, and each option is assigned a ranking level and will be scaled (Bahurmoz 2004).

**Materials and methods**

This research was carried out using a descriptive-analytical method to consider the issue of land suitability and its analysis with regard to settlement selection. Accordingly, after collecting the required information and also reviewing the status of the Iron Age settlements in the Middle Atrak Basin, using AHP and going through the steps in ArcGIS – including entering variables and criteria, preparing informa-

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**Fig. 1.** Maps of the locations of Iron Age sites with regard to 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 land use.
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tion layers and new maps, classification and evaluation of variables, information layers and the combination of these layers – suitable locations for settlements were identified. Moreover, seven indicators – including distance from ancient sites to communication routes, distance from ancient sites to water sources, land use, altitude, soil type, slope direction, and slope degree – were used to identify suitable areas for settlement (Fig. 1). ArcGIS10 and AHP were used to prepare a database of the layers described above (Fig. 2).

Geography and ecology of the Atrak River Basin

Although there is no long-standing accurate climate record of the northeastern region of Iran for the Iron Age, studies by researchers have shown that, contrary to popular belief, there were stages of sudden climate change during the Holocene. There is a consensus that such phenomena are pervasive, and their results can be generalized to different parts of the world (Hejebri Nobari et al. 2021.298). Towards the end of this period, especially from the beginning of the first millennium BC, the tendency of temperature changes tended to be colder (Shaikh Baikloo Islam 2020.40). The same cold and humid climate phenomenon are seen in all parts of the Tibetan Plateau (Callegaro et al. 2018) and West Central Asia (Fouache et al. 2020.92). The most recent long-term climate studies have been carried out near the study area of Jazmourian Playa (Vaezi et al. 2019) and Hamoon Lake in Sistan (Hamzeh et al. 2016), and the coast of Gorgan (Kakroodi et al. 2015). The decrease in temperature caused the inhabitants of arid/semi-arid regions, such as north-central Iran (Shaikh Baikloo Islam, Chaychi Amirkhiz 2020.40), to adapt to the cold climate, in addition to agriculture. They also chose a nomadic-herding livelihood system, and a number of the areas covered in this article confirm this.

The Atrak basin, one of the largest water basins in northeastern Iran with an area of 33 890km², originates from the mountains of Hezar Masjed in the north of Quchan. About 26 500km² of this basin’s area is located in the political area of Iran, and the rest in Turkmenistan (Fig. 3). The Atrak basin is bounded by Turkmenistan in the north, Gorgan and Kâlshor basin in the south, the Qaraqum basin in the east, and the Caspian Sea in the west (Noori et al. 2011.160). This basin consists of two parts, plains and mountains. Its climate is barren or continental. Rainfall is less than 200mm in the plains and up to 500mm in the highlands. The maximum altitude of this basin at the site of Tabârak River is about 2903m, and a minimum of 22m above sea level is estimated (Sheikhvahed et al. 2011.5). 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), the river continues its route in Mâneh, Ghori Meidan, and Marâveh Tappeh, then runs 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 150km (the boundary between Rezabad Gharbi and Sisab villages on the border of Shirvan and Bojnourd cities to Ghazan Ghayeh village.

Fig. 2. The structure of the hierarchical analysis process used in the research.
on the border of Mane and Solmaghan cities with Maraveh Tappeh) (Yamani et al. 2010.4).

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, which 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 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) this part is warmer and very poor in terms of vegetation and water resources, due to the impact of the Turkmen Sahra lowlands in the west on the one hand and the soil of the region on the other.

Background of archaeological research

The first archaeological activities in the area of the Middle Atrak were the studies and work 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 (Garazhian 2011; Garazhian et al. 2014; Garazhian, Askarpour 2018). Exploration reports on the Tape Ashkhaneh Bimarestan (Dana et al. 2017; Dana, Hejebri Nobari 2018), Tape Ashkhaneh Rivi (Jafari, Thomalsky 2016), and Tape Eshgh Bojnourd (Valdati 2014), along with efforts to determine the area and boundaries of the tape Kalateh Mostofi Bojnourd (Yazdani 2015), Tape Bruski Ashkhaneh (Adine 2012) and Kohnekand Bojnourd (Dana et al. 2019), have also been published with regard to this basin. However, studies of the cities of Shirvan (Mirzaei 2008), Bojnourd, Raz and Jirgalan (Rajabi 2013), Mane and Solmaghan (Garazhian 2007; Atei 2009; Zare 2011) in this area have not been published yet.

Iron Age sites of the Middle Atrak Basin

In the study and identification work carried out in the Middle Atrak Basin, over 360 archaeological sites

![Fig. 3. Upper and middle Atrak River Basin.](image-url)
from all periods have been identified. Seventeen sites have been identified in Shirin Darreh springs (a tiny part of Shirvan city), which are located in the middle Atrak area (Mirzaei 2008); 143 sites have been identified in Bojnourd city, which is completely located in the Middle Atrak Basin; 43 sites have been found in Raz and Jarglan city, about half of which is located in the Middle Atrak Basin (Rajabi 2013); and 160 sites have been identified and introduced in Mane and Solmaghan city, which are completely located in the Middle Atrak Basin (Garazhian 2007; Ataei 2009; Zare 2011) (see Table 1). Of these, 61 sites were inhabited during the Iron Age.

**Environmental factors survey**

**Water resources factor**

Human settlements are usually located where access to surface water is possible, and thus water is an essential factor in the emergence of human habitats and the most crucial factor in their growth and development (Heydari Dastenaei, Niknami 2020. 316). The land type and topographic status of each location significantly impacts water storage and flow. Accordingly, villages are established where there is enough water to meet the needs of the inhabitants (Molarjem, Siasar 2017.58). Atrak and its tributaries (Fig. 1.1), as a permanent and reliable water source, would be present many attractive locations in this regard. Suitable soil and altitude are also crucial for avoiding periodic or seasonal river floods when locating settlements. As shown in Figure 4, 80% of the Iron Age sites are located within 1000m from running water, indicating the connection between the ancient sites and water resources.

**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 (Hejebri No-bari et al. 2021.301), and this region follows this due to its mountainous nature. Communication routes in mountainous areas usually pass from the bottom of the valleys. What we have in mind today as a communication route is very different from what existed in the past. Before the creation of modern roads, people used gorges and the cuts caused by geological activity to travel. Due to the mountainous location and the forested nature of the focal area, the only passable routes were inevitably the same cuts and the lengths of other valleys located between relatively high and steep mountains that were used as paths (Vosogh Babae, Mehrafarin 2018.197). This also applies in historical times, even in adjacent areas such as Dar-gaz, and historic sites have sometimes been formed adjacent to the main communication routes. This communication role is one of the essential factors in securing the economy of the inhabitants of these cities and rural areas (Nami, Mousavinia 2019.239).

There are 42 sites (69%) in the range of 0 to 1000m from the communication routes in this area, seven sites (11%) at a distance of 1000 to 2000m, eight sites (13%) at a distance of 2000m to 3000m, and four sites (7%) located 3000m or more from the communication routes (Fig. 5). Among these, only one site – Tape Da˘sha˘d (IAMA60) – is located c. 9000m away 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, and next to the communication routes (Fig. 1.2).

**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 (Akbar Aghalli, Velayati 2007.48), and thus it affects human life and activities such as agriculture, keeping livestock, and even some human settlements.
The degrees of the slopes in the region were 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. Since the best slope for establishing human habitation is a slope of 0–10 degrees (Anabestani 2011), we examined the location of the sites on the slopes. The slope degree of the location of ancient sites is an essential factor that affects the area due to its economic impact. Among the sites of this period (Fig. 1.3) 18 (28%) were on slopes of 0–5 degrees, 20 sites (32%) on slopes of 5–10 degrees, 12 sites (18%) on slopes of 10–15 degrees, and 14 sites (22%) on slopes of more than 15 degrees (Fig. 6).

Soil type factor

Today, geoarchaeological studies have found a special place as a helpful tool in archaeological research and explaining ancient Quaternary environments (Maghsoudi et al. 2020.2). 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 (Duckstein et al. 1973.22), and soil type affects the livelihood structure of an area (Estelaji, Ghadiri Masoum 1995.126). 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 Incepti soil/Entisoli rocky outcrop soils with a small amount of Incepti soil (Fig. 1.5).

In this area, 42 (68%) of the Iron Age sites are located on Incepti soil, seven sites (12%) are located on Incepti soil with rocky outcrop soil, and 12 sites (20%) are located in areas with entisoli with 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 settlements (Maghsoudi et al. 2020.7). Incepti soils are spread all over the world, and research shows that they are suitable for agricultural and non-agricultural uses, and can be widely used for crop culti-
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Land use factor
Land use results from a combination of human activity and the capabilities of a place. Although Land use is the result of population activities, it is also in some ways a reason for the existence of certain capabilities and the possibility of using the capabilities of the natural environment (Sadr Mousavi et al. 2018.734). The cultivability of land is one of the factors that is influenced by many important criteria, such as altitude, presence or absence of surface water, soil type, human manipulation of the environment, and climate. However, this human manipulation can also have a decisive role on the erosion rate. Most importantly, the land cultivability and type of vegetation can also be a very determining factor in the type of livelihood of those living in the related settlements. As such the settlement or use of many shelters in an area, especially in association with raising livestock, depends on land cultivability and type of vegetation (Afifi 2018.636). To this end, the purpose of land surveying is to determine the land value from the location point of view (Rahimi, Hasanpour 2011.21).

The map of the area based on land use (Fig. 1.6) 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 as related to the livelihood of the residents. 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.

Slope direction factor
As a general concept, direction is a well-defined feature for the linear effects of a phenomenon in geometry. In the context of this study it also includes other concepts, such as slope and geological slope (Heydari Dastenaei, Niknami 2020.320). 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 seem to be more suitable for settlement, while in tropical areas this is the case for slopes that do not face the sun. In the Middle Atrak Basin the southern slopes are the most important and the northern slopes the least, because the former receive 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 (Heydari Dastenaei 2018.7). Surveying the location of Iron Age sites indicates that the northern slopes contain more settlements and the southern slopes are less used (Fig. 10). Accordingly, 12 sites are located on northern slopes, 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.

Zoning of Atrak River Basin
Potential zones for the placement of Iron Age settlements have been determined by weighting and classification of the abovementioned criteria and environmental factors, including communication routes, distance from water resources, land use, slope, slope direction, altitude, and soil type. The layers’ weights, which are the same factors as determined in the model, were evaluated according to the available options, and finally the total weight of the layers was obtained using the calculation formulas. The weight of each layer according to the preference options is shown in Table 2.
In AHP, in addition to considering the factors and combining their different levels, the rate of the number of achieved priorities and the accuracy of weighting results can be trusted due to the method of calculating the comparisons’ compatibility with regard to the studied layers, and determining the overall compatibility rate. In this research, the value of the compatibility rate is calculated as 0.4, which indicates the appropriate compatibility of the studied layers. According to Table 3, it can be seen that altitude, distance to a water source, distance to a communication route, slope, and soil type have the highest weights, and land use and slope direction have the lowest weights.

In Table 4, according to the results obtained from the final weight of the factors affecting the creation of ancient sites, it can be seen that altitude is in the first place with a weight of 0.26, distance to rivers is in the second place with a weight of 0.19, distance to communication routes is third with a weight of 0.15, slope direction is fourth with a weight of 0.14, soil type is fifth with a weight of 0.08, land use is sixth with a weight of 0.08, and in seventh place is slope, with a weight of 0.07.

In the next step, GIS is used to prepare layers to select areas with a higher priority. The final map is obtained by stacking the existing layers in terms of weight, as extracted from Table 4. According to the results obtained in this section, those areas with a higher potential for locating settlements have lighter colours, while those with a lower potential for this settlements have darker colours.

Moreover, the areas marked in orange with an area of 12 550km², equivalent to 47% of the total area, also have relatively good values. These areas are geographically hilly, suitable for growing rainfed plants, and also a good place for livestock grazing. This section includes slopes up to 13 degrees, rainfed agricultural uses with an almost suitable soil type, and a short distance to water sources and communication routes. Twenty-four sites (39.3%) are located in this area.

The dark brown areas with an area of 7900km², equivalent to 22% of the total, have a relatively low value for settlement. These areas are hillsides with steep vegetation and steep slopes, and the land is used only for pasture. In addition, the type of soil and even the soil depth in these areas is low, and they are far from permanent water sources such as rivers, as well as communication routes. It is noteworthy that seasonal water springs are usually seen in these areas, and this type of area is used only for livestock.

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More specifically, those valuable areas that have the most potential for establishing settlements are the relatively limited areas shown in green. These have an area of 2235km², equivalent to 10% of the total area, with a low slope of about five degrees and a suitable slope direction, land use, suitable vegetation, and rich soil, and are generally suitable for the development of settlements (Fig. 11). This area has 28 Iron Age sites, accounting for 46.7% of the sites.

Moreover, the areas marked in orange with an area of 12 550km², equivalent to 47% of the total area, also have relatively good values. These areas are geographically hilly, suitable for growing rainfed plants, and also a good place for livestock grazing. This section includes slopes up to 13 degrees, rainfed agricultural uses with an almost suitable soil type, and a short distance to water sources and communication routes. Twenty-four sites (39.3%) are located in this area.

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grazing. Seven ancient sites in this area can be seen, accounting 11.4% of the sites.

Finally, the dark red areas, with an area of 393 km² and equivalent to 15% of the total area, do not have any settlement value. These areas have steep slopes and rocky, non-agricultural lands, with poor rangeland vegetation. Thus, due to their high altitude and steep slopes, unsuitable terrain for agriculture, and distance from communication routes, these areas are often unsuitable for settlement. However, an Iron Age site (IAMA 44) (1.6%) is located in this area, which seems to have been a short-term seasonal establishment.

Discussion and conclusion

The use of GIS and geostatistical techniques can be a useful, practical tool in archaeology. These tools make it possible to apply complex mathematical equations to maps. On the other hand, using the existing interpolation methods in the field of statistics, statistical and spatial analysis can be carried out in different places based on the locational and geographical situation of the phenomena. In the present study, we tried to evaluate the effects of environmental factors on the formation of Iron Age settlements. The results showed that environmental conditions in the form of slope characteristics, slope direction, altitude, distance from communication routes, access to water resources, soil type, and land use all positively affect the distribution and density of site in the area being studied.

In the first step, in order to determine the importance of each layer using the AHP method, indicators were compared pairwise with each other, and each indicator was weighted. According to the results of the AHP model, the highest weight is related to the altitude index with a weighted score of 0.26, and the lowest weight is related to the slope direction, with a score of 0.07. In the next step, the layers were standardized into four levels and a zoning

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<th>Layers</th>
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<th>Normalized weight</th>
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<td>0.071450106</td>
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<td>Landuse</td>
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<td>Degree of slope</td>
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</tr>
<tr>
<td>Distance to roads</td>
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<td>0.154775398</td>
</tr>
<tr>
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<td>0.266270269</td>
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<tr>
<td>Type of soil</td>
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<td>Total</td>
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Tab. 4. Calculation of final weights based on preferences with regard to the environmental factors.

Fig. 11. Iron Age zoning map.
map of the Iron Age areas of the Middle Atrak Basin was prepared. The results show that one site is in a zone with no settlement value, size sites are in a low importance zone, 24 sites are in a relatively appropriate zone and 28 sites are in a very important zone.

The results of analyses show that the locations of the sites in different zones indicates different kinds of livelihoods were pursued there. Based on zoning analysis, it is determined that the areas that are located in Zone 4 (shown in dark colours) are villages that engaged in irrigated and rainfed agriculture. The areas located in Zone 3 are areas that used both highland resources and plain agricultural resources. Such sites had a combined economy of livestock and agriculture, and also engaged in trade. Sites in Zone 3 are at the foot of the mountains and seasonal sites with livestock. Finally, Zone 1 is not suitable for settlement at all, and for this reason only one site is located in this area, and this site, like those in Zone 3, is a seasonal site.

References


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Ma L., Guo X., Tian Y., Wang Y., and Chen M. 2017. Micro-Study of the Evolution of Rural Settlement Patterns and Their Spatial Association with Water and Land Re-
Distribution of Rural Settlements (Case Study: Sahneh
Sadr Mousavi M., Talebifard R., and Niazy C. 2018. Inve-
nal of Archaeology of Egypt/Egyptology 18(2): 195–205
from creative industry in South Tangerang.
T. 2021. Application of the analytic Hierarchy process me-
Rodhiah D. M. M., Hidayah N., Adiputra G., and Mukmin
iments in Chamchamal Plain, Central Zagros. "Pazhu-hesh-
ha-ye Bastanshenasi Iran 6(11): 75–90.
https://doi.org/10.22084/nbsh.2016.1740
Noori R., Jafari F., Asgharzadeh F., and Akbarzadeh A.
Nami H., Mousavinia S. M. 2019. Archaeological Survey of
Parthian Sites in Dargaz Plain, North-East of Iran. "Pazhu-
hesh-ha-ye Bastanshenasi Iran 11:
Qazanfarpour H., Kamandari M., and Mohammadi Soleym-
ani M. 2013. The effect of geographical factors on the
pattern of rural housing in Kerman province. "Zagros Land-
scape Geography and Urban Planning Quarterly 5(18):
vays in Bojnord and Raz & Jargalan County, Northern
Rahimi M., Hasnapour Kh. 2011. Location finding of a
new village in Bastak province considering passive de-
fense in GIS environment using AHP model. "Journal of
Rodhiah D. M. M., Hidayah N., Adiputra G., and Mukmin
T. 2021. Application of the analytic Hierarchy process me-
method in determining a creative Industry strategy: evidence from creative industry in South Tangerang. "PalArch’s Jour-
Sadr Mousavi M., Talebifard R., and Niazy C. 2018. Inve-
vestigating the Role of Natural Factors in the Geographical
Distribution of Rural Settlements (Case Study: Sahineh
County). "Journal of Studies of Human Settlement Plan-
Salmanpour A., Senmar M., and Bakhtiari A. 2013. The
role of soil on archaeological analysis and studies. "The
First Symposium of Archaeology of Iran." Birjand.
Shaikh Baikloo Islam B. 2020. Holocene climatic events in
https://doi.org/10.30488/ccr.2020.244327.1017
Shaikh Baikloo Islam B., Chaychi Amirkhiz A. 2020. Adap-
tations of the Bronze and Iron Ages Societies of North
Central Iran to the Holocene Climatic Events. "Journal of
https://doi.org/10.30488/ccr.2020.111121
Sheikhvahed B., Bahremand A., and Mushhekhian Y. 2011. A
Comparison of Trends in Hydrologic Variables in the At-
rak River Basin Using Non-Parametric Trend Analysis Tests.
Sharifi A., Pourmand A., Canuel E. A., +7 authors, and
Lahijani H. A. 2015. Abrupt climate variability since the
last deglaciation based on a high-resolution, multi-proxy
peat record from NW Iran: The hand that rocked the Cra-
dle of Civilization? "Quaternary Science Reviews 123:
Timing of atmospheric precipitation in the Zagros Moun-
tains inferred from a multi-proxy record from Lake Mira-
https://doi.org/10.1016/j.qres.2006.06.008
system selection using fuzzy replacement analysis and
analytic hierarchy process. "Journal Production econo-
https://doi.org/10.1016/j.jpe.2004.07.001
Toledo-Aceves T., Meave J. A., González-Espinos M. and Ra-
mírez-Marcial N. 2011. Tropical montane cloud forests:
Current threats and opportunities for their conservation
and sustainable management in Mexico. "Journal of Envi-
https://doi.org/10.1016/j.jenvman.2010.11.007
Vaezi A., Ghazban F., Tavakoli V., +4 authors, and Kylin
H. 2019. A Late Pleistocene-Holocene multi-proxy record
of climate variability in the Jazmurian playa, southeast-
eran Iran. "Palaeogeography, Palaeoclimatology, Palaeo-
eology 514: 754–767.
https://doi.org/10.1016/j.palaeo.2018.09.026
Vahdati A. A. 2014. A BMAC Grave from Bojnord, North-
https://doi.org/10.1080/05786967.2014.11834735

sources: A Case Study of Shandan County, China. "Sustain-
nability 9(12): 1–18. https://doi.org/10.3390/su9122277
Maghsoudi M., Fazeli Nashli H., Azizi Gh., Gillmore G., and
Study from Jazrud and Hajiaraab Alluvial Fans in Iran.
https://doi.org/10.22059/jphgr.2012.30239
Mirzaei A. 2008. "Report on Surface Surveys in Faraj and
Shirvan County, Northern Khorasan." Iranian Center for
Motarjem A., Siasar N. 2017. Studying the Changes of Di-
tribution Patterns of the Bronze and Iron Ages Settle-
ments in Chamchamal Plain, Central Zagros. "Pazhu-hesh-
ha-ye Bastanshenasi Iran 6(11): 75–90.
https://doi.org/10.22084/nbsh.2016.1740
Vahdati A. A. 2014. A BMAC Grave from Bojnord, North-
https://doi.org/10.1080/05786967.2014.11834735


