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SPATIAL PATTERN OF ARCHAEOLOGICAL SITE DISTRIBUTIONS ON THE EASTERN SHORES OF LAKE URMIA, NORTHWESTERN IRAN

1. Introduction

The use of archaeological site distribution patterns in order to account for an archaeological landscape is a relatively new experiment in archaeology. Even though statistical theories and models in relation to site distribution patterns have evolved since the middle of the 80s, little attention has been paid to the potential for utilizing it as an explanatory method for the analysis of an archaeological landscape (Hodder, Orton 1976; Orton 1982).

This article presents a model for an archaeological landscape in relation to distribution patterns of archaeological sites through the use of spatial processes. Needless to say, a spatial process encompasses a wide range of various parameters and this article is confined to one of them, in other words, understanding distribution pattern through the use of nearest neighbor analysis.

Presented here are the results of a study to locate high-potential areas for archaeological sites in a largely surveyed area on the eastern shores of Lake Urmia northwestern Iran, including details of the analysis process. The project used environmental and archaeological data from over 118 known sites in the region and the results corresponded well with known sites in the study area. Generally, it is assumed that the selection of sites by the original inhabitants was at least partially based on a set of favorable environmental factors, such as distance to water or topographic setting. Another assumption is that modern day GIS layers consistently characterize changes from the prehistoric condition of the region sufficiently well for them to be used to help discover additional sites.

2. Study area

The setting of this study spans an area of 18000 square kilometers and it includes parts of the cities of Charoymak, Hashtroud, Maraghe, Malekan, Bonab, Ajabshir, Oskou, Azarshahr, Marand, Tabriz, Bostanabad in Eastern Azerbaijan province, and parts of Miyandoab city in western Azerbaijan. The area lies within E 47 16” to E 45 11” and N 36 53” to N 38 29”. The rivers which flow through this area are connected to two basins of Mazandaran Sea and Urmia Lake which include Garangou, Aidogmoush, Zarrine Roud, Simine Roud, Talkhe Roud, Sofi Chai, Shabestar and Tasouj.

Fig 1 – Map showing the study area of this research in the eastern parts of Urmia Lake, northwestern Iran.

Lake Urmia is a saline lake some 140 km long and 15-50 km wide located at an elevation of 1280 m above sea level in the northern part of the Zagros Chain. The lake constitutes an internal drainage basin fed by local rivers such as Zarrine Roud and Simine Roud. Most of the basin represents the areas left by the recession of the lake and is characterized by saline alluvial soils.

The area in which Lake Urmia is located is a remarkable zone according to its geological evolution complexity and geomorphologic variability (Darvishzadeh 2004). Lake Urmia is like a great flat depression. Ecosystem and human settlements of the marginal lake regions have always been affected by the patterns caused by the water level fluctuations of the Lake. Great variability in water level occurred in the Pleistocene as reflected in the wider alluvial terraces around the lake (Kelts, Shahrabi 1985).

The main elevation in this area is Sahand heights – above 2000 meters – in the eastern part of the Lake. In the northern part lie Mishadoagh mountain and a range of adjacent mountains such as Takhat Solyiman, Bozkosh, Sabalan, and Gharedagh to the north and northeast. Underneath these heights there are valleys, plains, plateaus and in-between roads. Similarly, major faults of Azerbaijan can be identified here which give rise to a lot of geological phenomena of the region (Alayi Taleghani 2003).

Despite the fact that there is enough rain due to snow and cold weather and despite the presence of the stony and steep slopes of Sahand, the area is not covered with lots of plant. However, small wild almond trees in Shorkat area near Urmia could be seen (Figs. 1 and 2).

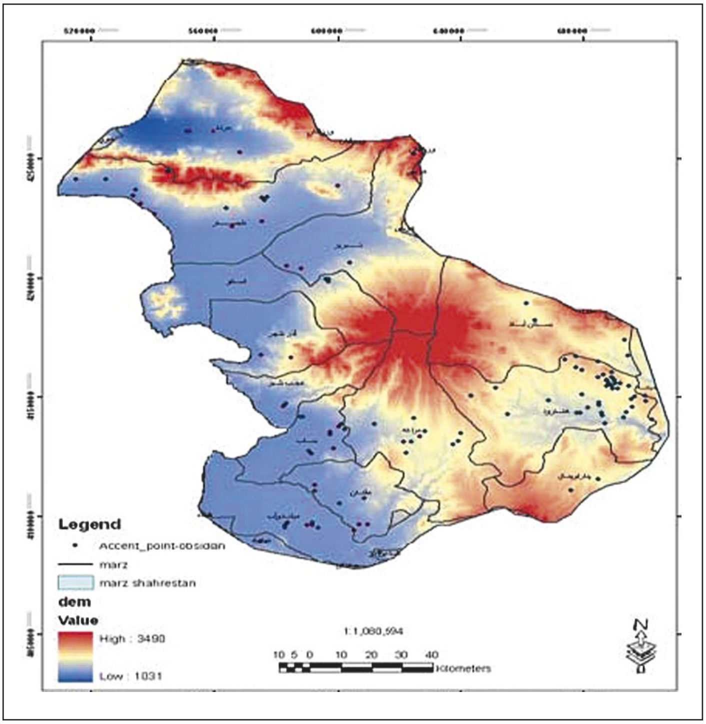

Fig. 2 – Topography and archaeological site distributions map of eastern Lake Urmia shores.

	Islamic	Historical	Iron	Bronze	Chalcolithic	Neolithic
Shabestar	8	2	5	6	8	2
Oskou	4	2	-	1	1	1
Azarshahr	1	-	-	2	2	-
Tabriz	2	-	-	-	-	-
Ajabshir	-	1	2	2	2	-
Bonab	5	3	2	4	8	1
Malekan	2	3	-	4	2	1
Miyandoab	2	6	6	4	3	1
Maraghe	7	6	1	4	4	2
Hashtroud	18	28	13	11	38	2
Charoymak	-	2	-	2	1	-
Bostanabad	-	1	-	3	3	1
Marand	2	2	-	2	3	2
Total	51	56	29	45	75	13

Tab. 1- Chronological distribution of sites observed during the survey project in the eastern shores of Lake Urmia.

The long-term Lake Urmia archaeological project is run by the University of Tehran in collaboration with Cultural Heritage and Tourism Organization (CHTO). The project has undergone a systematic field survey and by the end of the 2006 field season, about 1000 km^2 have been field-walked. The study area for this project composes some 670 km^2, from which a total of 67 survey quadrats in 13 separate fields were selected providing a number of observations with which a spatial analysis could be performed. The survey resulted in discovering traces of some 118 archaeological sites from the different cultural periods. Tab. 1 indicates the frequency of sites and their chronology discovered during the survey project (Tab. 1).

3. Material and methods

3.1 *The technique*

Every point distribution is the result of a certain spatial process at a given time and a given space. The distribution of points (archaeological sites) on the landscape may have various patterns. They may take the form of clusters or they may be dispersed in a consistent distribution or their distribution may be entirely random without any specific pattern.

There are three general categories of geographical patterns conventionally used as benchmark to describe how points structure spatially. The first category is cluster (aggregate) pattern when points of similar properties cluster together. Next, the disperse pattern is when points of similar properties are apart from each other. In the extreme case of disperse pattern, a uniform pattern is a pattern in which every point is surrounded by points of different property. Finally, the third category is the random pattern in which there does not seem to be any structural pattern.

With spatial archaeology using the three categories and together with nearest neighbor analysis calculated from a geographical pattern of points it is possible to construct a number of patterns that characterize different types of archaeological site distributions in landscape and thus it is possible to detect spatial pattern from the point distributions and changes in point patterns at different times (Fortin, Dale 2005, 32-35). This comparison is carried out within a framework of a spatial statistic system and its outcome is to arrive at a pattern that shows how the sites under investigation have formed. At the beginning of the analysis, it is crucial to determine the number and forms of the sites. For this reason, in the 2005 and 2006 survey seasons, we first overlaid the study area with a regular square grid (100×100 m), and counted the number of points falling in each square. Using precision military global positioning system (GPS) receivers with real time 5 m accuracy, aerial photography, a sighting compass and landmarks on the horizon, we were able to survey entire grids and mark all the desired archaeological sites.

3.2 *GIS database*

The GIS database covers the majority of the eastern Urmia Lake shores and its immediate environs. The current basic raster and vector layers of the GIS database include: elevation (derived from elevation data), aspect (derived from the elevation data), slope (derived from the digital elevation data), land use/land cover maps (derived from spot image data), geology (generated from 1:25.000 geology map of the upper part of the region), faults (from the same 1:50.000 geology map), hydrology (from the three 1:50.000 maps and 1:25.000 maps), modern roads (from 1:50.000 and 1:25.000 maps), ancient roads (from project information and old maps), archaeological sites and field survey transects (from project surveys and other sources). Additional derived data layers showing different distance categories, or buffer zones, from roads, streams, faults, archaeological sites, and ancient roads were then generated from the data above. Additional data have recently been added that were derived from the 1:25.000 maps, including reclassifications and distance measurements from sites, ancient roads, and hydrology. In all there are currently over 118 point, vector, and raster data layers in the database. Archaeological sites and basin characteristics were calculated using the data sets compiled as layers in GIS system.

To delineate boundaries of the sampling sites, a 50 m horizontal and vertical resolution Digital Elevation Model (DEM) and the river network were derived from 1:25.000 digital topographic map from the National Cartographic Centre of Iran; latitude and longitude coordinates of the 16 sampling sites were recorded in the field using a Global Positioning System unit, and then imported into GIS, where they were matched to the nearest point in the DEM. Each delineated feature was individually characterized in terms of topography (average altitude and slope), soils, river network and land use. Spatial features of these types of data sets included normalized difference vegetation index, land cover, elevation, slope, aspect, and total length of rivers.

Data on each of these variables were then extracted for "buffer zones" consisting of the area included in a circle of 3 km diameter centered on georeferenced points. Three kilometers is the minimum diameter in which at least one point was found in the study area. Land cover of the study area was obtained from the survey data. The study area land cover map had 8 classes (pixel values correspond to class numbers). The hectares of each class were calculated for each "buffer zone", overlaying the "buffer zone" grid to the land cover grid. Elevation, slope and aspect data on elevation, slope and aspect of the study area were obtained from the Digital Elevation Model (DEM). The elevation was divided into the following four classes: low (350 ft) to very high (10500 ft). Slope was divided into the following four classes:

flat (0°), low (0-15°), medium (15-30°) and high (30-54°). Utilizing the above data for each "buffer zone", the following variables were calculated: number of pixel of each elevation class, average and S.D. of elevation; number of pixel of each aspect class, average and S.D. of slope. Total length of rivers in the study area was obtained from digital map. Applying a new intersection of "buffer zones" with study area hydrographic network, the total length of the rivers in each "buffer zone" was calculated (for more details of the technique see Warren, Asch 2000).

More precise data regarding the presence of watercourses smaller than rivers (streams, springs and brooks) were recorded in the field, since they were not detectable from satellite images. All GIS databases were developed using ArcView 3.2. Five categories of obsidian material (in each quadrat) were determined as a function of the percentage of the land use patterns: lower (0-3 pieces), low (4-7 pieces), medium (8-12 pieces), high (13-16 pieces) and very high (> 17 pieces). Each find spot corresponded to a sampling point where obsidian distributions were determined by the project, as described in detail elsewhere (Niknami *et al.* in press). Knowledge of the environmental variables influencing activities of original inhabitants is used to produce GIS layers representing the spatial distribution of those variables. The GIS layers are then analyzed to identify locations where combinations of environmental variables match patterns observed at known sites.

3.3 *Statistical analyses*

We tested the null hypothesis that the spatial pattern of archaeological sites did not differ from complete spatial randomness to describe an array of points that are distributed independently (Lee, Wong 2003). Nearest neighbor analysis is commonplace in the analysis of point pattern. The nearest neighbor distance for an event in a point pattern, is the distance from that event to the nearest event, also in the point pattern. Nearest neighbor calculates the statistic R which is the ratio of the observed average distance between nearest neighbors of a point distribution (r_{obs}) and the expected average distance (r_{exp}) between nearest neighbors as determined by a theoretical pattern. For each pattern, the shortest distance among all neighbors becomes the nearest distance which is then averaged using all points. In its simplest form, the nearest neighbor statistic R compares the observed r_{obs}, with the expected, r_{exp} (random), nearest neighbor distances and identifies whether points are random (R≅), completely clustered (r= 0.0, in which all points lie on top of each other) or dispersed (R= 2, in which points distribute in a square lattice, or R= 2.149, which is the theoretical value for the most dispersed pattern, being that of a triangular lattice). The nearest neighbor general formula can be computed by the following process (Clark, Evans 1954):

$$r_{obs} = \frac{\sum d_i}{n}$$

$$r_{exp} = \frac{1}{2\sqrt{\frac{n}{A}}}$$

$$R = \frac{r_{obs}}{r_{exp}}$$

where
d_i is the nearest neighbor distance for point *i* and *n* is the number of points, *A*, is the area of the study region.

The key test statistic for evaluating the significance between an observed and random distribution is based upon the standardized Z score:

$$Z_R = \frac{r_{obs} - r_{exp}}{SE_r}$$

If $Z_R > 1.96$ or $Z_R < -1.96$, it can be concluded that the calculated difference between the observed pattern and the random pattern is statistically significant given that $\alpha = 0.05$. Alternatively, if $-1.96 < Z_R < 1.96$, we can conclude that the observed point pattern, although it may look somewhat clustered or somewhat dispersed visually, is not significantly different from a random pattern, and we will fail to reject the null hypothesis.

4. Results

Results from the nearest neighbor analysis suggested that all sites from the observed chronologies were aggregated (Tab. 2).

The mean nearest neighbor distance indicates a highest value for the Iron Age sites while the Chalcolithic sites experiencing the lowest values of mean distance. Values of nearest neighbor statistic for Islamic sites were nearly significant (p= 0.054), suggesting an aggregated pattern, but for the Neolithic sites indicating a less significant pattern of aggregations. Nearest neighbor

Variate	N	Robs	Rexp	R	Z	p
Islamic	51	69.12	76.45	0.90	-1.83	0.054
Historical	56	63.73	79.22	0.81	-1.40	**
Iron	29	78.29	88.36	0.88	-2.49	***
Bronze	45	70.10	95.40	0.73	-3.21	***
Chalcolithic	75	46.49	54.21	0.85	-5.34	***
Neolithic	13	73.34	84.50	0.86	-0.58	0.26

Tab. 2 – Nearest neighbor statistics for archaeological sites in eastern Urmia region. The parameter R represents the mean nearest neighbor distance (subscripts *obs*= observed, *exp*= expected). Values of R significantly different than unity ($p<0.05$) are either clustered (<1.00) or uniformly distributed (>1.00). R= observed x nearest neighbor distance/expected x nearest neighbor distance (r_{obs}/r_{exp}). *p <0.05 ***p* <0.01 ****p* <0.001.

distances for the Historical, the Iron Age, the Bronze Age and Chalcolithic sites were significantly different from 1.0, indicating a more aggregated pattern for those sites.

5. Discussion

Point pattern analysis is seen as an important tool for describing, interpreting, and analyzing spatial distribution features of the archaeological phenomena (Conolly, Lake 2006, 162).

Analysis of archaeological settlement pattern is a brilliant approach as far as site distribution and settlement pattern is concerned. This approach has carved a special niche for itself both on intellectual and practical levels in the development of analytic tools such as GIS within archaeology. For instance, in the case of settlement pattern analysis, regular spacing of sites has been taken to reflect either form of competition between settlements, the existence of site catchments, or a combination of both as a result of demographic growth from an initial random distribution. By contrast, clustering of sites may result from a number of factors, but localized distribution of resources and the emergence of polities or regional centers have often be highlighted (Ladefoged, Pearson 2000).

Interpretations of spatial pattern, especially in landscape scale, provide insight into the underlying mechanisms responsible for the pattern (Bradley 2000). We propose that spatial clustering of archaeological sites is expected for at least two fundamental reasons: land quality and cultural and socio-economic factors. Land quality can be associated with several important features of habitation area such as land environmental characteristics, i.e. elevation, slope, soil structure, availability and persistence of food and water sources as well as quality or quantity of connection networks. Cultural interactions predominantly relate to complex hierarchical social and economic factors practiced by local populations. The clustering of sites results in a clumping pattern of sites at a relatively smaller spatial scale (Schwarz, Mount 2006, 180-181). Spatial aggregation of sites may be evident because sites in each cultural period are distributed in a small range relative to the spatial scales that we examined. At our study region people traveled within a range from maximum 2 km in Neolithic to 3-5 km in the late Islamic period, assuming a perfectly home range movements of local site habitants. Home range dynamics would clearly result in aggregated spatial pattern of archaeological sites. The home range traveling of populations is best viewed as a circumscribed network of sites in any given period.

Land preference also helps to explain the aggregated pattern of sites, although the factors most responsible for distribution patterns remain generalized. Over their entire geographical range, sites are known to occur in a wide range of habitat types from coastal plains, alluvial plains and piedmonts. Our recent research results from an intensive survey and modeling effort, based on classification and predictive modeling of archaeological site distribution using GIS device in the Central Zagros region (Niknami, Saeedi 2006), indicated that densities of sites were related to the environmental variables of the region such as elevation, soil classes and distance to resources. We found that people mainly during prehistory preferentially selected their settlement areas at a moderately elevated part of the region (1500-2000 above sea level), and at a moderate cover of perennial vegetation as well as a short distance from the water supplies. Thus the selection of sites by ancient inhabitants may be driven, in part, by the physical characteristics of the land and water resources, which themselves may follow a clustered pattern.

Cultural, social and economic factors help to explain the aggregated pattern of archaeological sites and the strong association between site distributions and behaviorally derived factors (Kvamme 1993). A comprehensive model for social structure of the interest is not available, but in some extent the cultural pattern of some excavated site and economic connection of them are paramount. Over the years archaeologists have developed a number of theoretical models to explain the composition of archaeological sites based on both basic economic principles and analogies to ethnographic examples. In these models pastoral groups perform various activities in a patterned manner, leading to the remains of most structured and organizational evidence of different types. A basic distinction within many models concerns the acquisition of raw material and access to the necessary needs by mobile groups. These models suggest that mobile groups often acquire the goods they need (pottery and stone for tools) from contacting peoples by including raw material extraction within their other subsistence activities and transport such goods and materials to the places year round. Worn out and broken tools are discarded and replaced with new ones either as groups encounter sources of new material on the landscape or make contact with other groups (Daniel

2001). We also documented here traces of residentially stable populations which we assume were connected to their sedentary system of agriculture and their cultivated lands. Unlike mobile groups, stable populations often either directly make use of locally available materials or acquire their needs through trade.

However, access to high quality goods even for sedentary peoples may be tempered by their degree of mobility, whereas an intermediate distance covered during trips may allow them to directly access supplies and a greater range of non-local and or higher quality materials (Barton *et al.* 2002, 170). Although this perspective has not been thoroughly dealt with in our research, our analyses point out some interesting connections to these models that highlight important details on how the pastoral and residential populations in our study area integrated various aspects of social contacts within the organization of their cultural system. Here we would note that like the land quality model mentioned before, the social behavior of ancient eastern Urmia inhabitants may have been bounded by an aggregated pattern imposed on the connection networks to form a relatively short distance structure (see below).

As was explained earlier, the most important type of archaeological object occurring in the study area is obsidian artifacts (Niknami *et al.* in press). These obsidian sites are known to have played an important role in the maintenance of the economic characteristics and for the people in the region, and as such were likely to have played an important role in structuring behavior at the regional level. A visual examination of regression lines measuring relationships between obsidian site size and distance to obsidian source reveals that there is a tendency for the large sites, i.e. the largest sites containing class 4 and class 5 obsidians, to be located close to obsidian sources, suggesting that clustering around a source can be viewed as a behavioral trend of people making the least effort to obtain more valuable materials (Fig. 3). To explore this idea further, proximity to possible layers of ancient trade roads was calculated using a cost-distance function, the result was similar where high values indicate areas that are proximate to accessible routes. Thus if we were to think about access to a short distance water source in a similar way as we might model access to trade routes, then sites in this layer with high values might be preferentially chosen for clustering if being close to water sources was important. For this reason, the resulting layers demonstrate how the area along the drainage lines that are aggregated close to water sources produce values that are higher. Hence, in some cases at least, it would appear that following the drainage line could serve a dual purpose, providing access to water and several obsidian sites.

The geographical features of the area in the eastern parts of Urmia Lake have two distinctive geographical characteristics that are entirely different from each other. These parts include a flat alluvial area which was irrigated

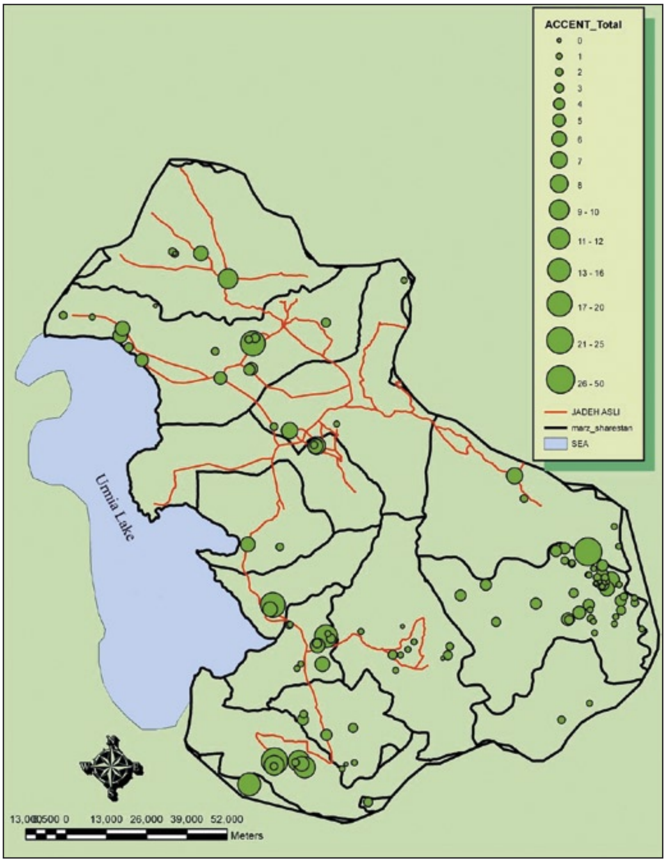

Fig. 3 – Clustered pattern of sites mentioned in the text based on the model on site size variables.

by several permanent rivers and a network of seasonal rivers while the other part includes mountainous areas which extend across from northeast, centre, and southeast of the area. The geography of the environment is such that we can infer that the low laying valleys in mountainous areas could have affected the free movement of the people in the past and therefore, the movement of the people naturally followed the natural course of the rivers. Plant features of the area coupled with abundance of water sources made for a relative density of population.

However, it is very difficult to see any difference between environment-derived behaviors and cultural behaviors which humans exhibit in trying to adapt to the environment (Fry *et al.* 2004, 98). For example, settlement patterns in the region show that most sites by Urmia Lake and along a wide range of connecting roads were formed in prehistory. The close proximity of the sites and their assembling in areas where there might be fresh water show distribution patterns in which we cannot exclude the possibility of their having economic relations with each other. While, for the later periods, even though there are still no valid sources of archaeological records on hand, it can be surmised that historical population movement within this area might have been related to socio-economic and political factors more than environmental. It is self-evident that inevitable environmental factors are inextricably intertwined with socio-political factors in terms of their effect on forming site distribution structures (Gaffney, Van Leusen 1995, 375).

Thus, it can be said that despite the potentialities and limitations of the environment, modes of living and economy might have had irrefutable role. At the same time, sites of later periods are dispersed mostly in areas away from the coasts of the lake and areas with average heights. It appears that in this period, the increase in water control management together with optimization of food production systems made it possible to benefit from sources away from the lake. In addition, a streak of Salina around Talkhe Roud river was never able to attract inhabitation at any time. Another crucial and relevant point here is that the accumulation of clustering settlements in this area occurred in places with potential for subsistence, and technological development in terms of securing sources for a reasonable population. The alluvial landscape around the lake guaranteed arable areas for agriculture. Suitable mineral soil centers that were close to each other gave rise to pottery production and processing. Besides sites such as Darvish Baghal, Yanik Tepe, Hasanlu, Sis and Kozeh Konan where this kind of economic relationship can be clearly seen, there are patterns with similar subsistence relationships which can be seen in other sites. The water source system follows a linear pattern to the east of Urmia Lake. For a better understanding of the relationship of settlement distribution patterns and water resources, we produced layers using GIS where the proximity of sites to water resources was taken into account (Niknami, Chaychi 2008). Besides securing access to water resources, linear distribution of water resources also made it possible for sites to connect. In addition, a significant tendency of archaeological sites here is the fact that the bigger places tend to be distributed close to water resources more than the smaller ones. Distance estimation along with site distribution pattern is another important issue to be considered.

It seems that the socio-economic trend in the clustering of archaeological sites in the eastern Urmia region is consistent with the distribution of obsidian sources and obsidian trades. In the eastern Urmia region, there are three obsidian sources from which the obsidian artifacts were obtained and utilized by the nearest populations. Interestingly, no long-distance trade of obsidian was

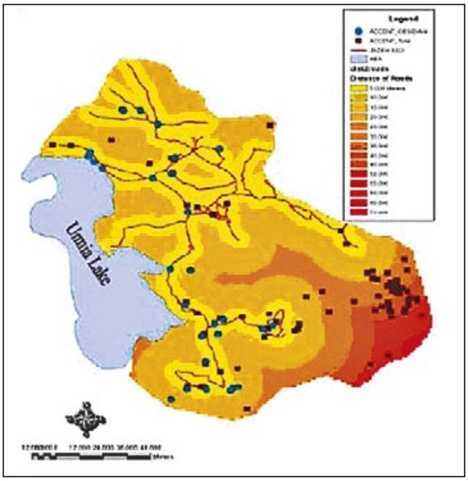

Fig. 4 – Proximity measurements of archaeological sites from possible ancient road networks.

practiced; in fact, as we have recently concluded (Niknami, Chaychi 2007), all of the obsidian sites that were exploited had an average distance of ca. 70 to 75 km from the sources. This short distance reinforces the hypothesis that the later inhabitants of these sites traveled a short distance to access the raw material. This finding also suggests that much of the trade in obsidian might have occurred here within an internal exchange system, however, so far there is no evidence regarding exploitation of obsidian from other sources. This is illustrated in Fig. 4. In this figure it can be seen that almost all obsidian sites were located very close to the trade route system implying a socio-economic structure for the region. This assumption may account for the behavioral pattern of site distributions however, demonstrating this point will require further study.

In summary, our findings related to land quality and socio-economic and cultural factors as the fundamental baselines for archaeological site clustering are consistent with the statements that are found in archaeological literature. For example, Hodder and Orton (1976, 85) maintained that «…clustering is due to the localization of resources...localized resources may include a preferred soil type, a linear resource such as river and a point resource such a well or geological outcrop». This is actually the same line of conclusions that in recent years the analytical approaches applied by Lock and Harris (2006, 44-52), Ridges (2006, 130-135) and Whitley (2006, 372-373) have proved to be the most applicable and acceptable.

Again, archaeological challenges in the region such as those that this project encountered may be comprehended by considering the effect of socio-economic and political behaviors on the formation of archaeological sites, although it is very difficult to observe such behaviors by the conventional method alone (Pickering 1994).

6. Conclusions

It has been shown that point pattern correlates with those sites that are most organized and regular in distribution. As a method for describing the spatial pattern with regional data set nearest neighbor analysis provides a useful means of identifying generalization about the distribution of archaeological sites. We hypothesized factors driving the aggregated pattern of sites, land characteristics, and social and economic interactions resulting in a home range contacting. The relationship between location, degree of clustering and morphology implies that the effects of positive spatial autocorrelation are present. For this reason, future studies should involve statistical measures of spatial autocorrelation to ensure that both the location of sites and their attributes are considered (Woodman 2000). This type of work could advance the understanding of spatial processes across both local and regional scales.

It has also been shown that spatial statistical analysis using ground survey data within a GIS offers quantitative methods from which an understanding of archaeological site distribution pattern can be surmised.

Analytical models of distribution patterns used in this research could show an adequate capability for the model to study the spatial characterizations of settlements from different time periods in the eastern parts of Urmia Lake. Nevertheless, effective use of the methods and their analytical approach will involve consideration of diverse perspectives (Church *et al.* 2000).

In this paper, site distribution analysis is proposed as an approach to discovering the spatial relationship of observed archaeological data. Therefore, this approach has the potential for explaining a wide range of theoretical and practical foundations of the behaviors which archaeology deals with.

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REFERENCES

Alayi Taleghani M. 2003, *Geomorphology of Iran*, 3rd ed., Tehran, Ghumes (in Persian).

Barton C.M., Bernabeu J., Aura J.E., Gracia O., La Roca N. 2002, *Dynamic landscapes, Artifact taphonomy, and landscape modeling in the western Mediterranean*, «Geoarchaeology: An International Journal», 17, 155-190.

Bradley R. 2000, *An Archaeology of Natural Place*, London, Routledge and Kegan Paul.

Church T., Brandon R.J., Burgett G.R. 2000, *GIS application in archaeology: method in search of theory*, in Wescott, Brandon 2000, 135-155.

Clark P.J., Evans F.S. 1954, *Distance to nearest neighbor as a measure of spatial relationships in populations*, «Ecology», 35, 445-453.

Conolly J., Lake M. 2006, *Geographical Information Systems in Archaeology*, Cambridge, Cambridge University Press.

Daniel I.R. 2001, *Stone raw material availability and early archaic settlement in the southeastern United Stated*, «American Antiquity», 66, 237-265.

Darvishzadeh A. 2004, *Volcanoes and Volcanic Outcrops*, Tehran, The University of Tehran Press (in Persian).

Fortin M.J., Dale M. 2005, *Spatial Analysis (A Guide for Ecologists)*, Cambridge, Cambridge University Press.

Fry G.L.A., Skar B., Jerpasen G., Bakkestuen V., Erikstad L. 2004, *Locating archaeological site in the landscape: a hierarchical approach based on landscape indicators*, «Landscape and Urban Planning», 67, 97-107.

Gaffney V., Van Leusen P.M. 1995, *GIS environmental determinism and archaeology, a parallel text*, in G. Lock, Z. Stančič (eds.), *Archaeology and Geographical Information Systems: An European Perspective*, London, Taylor and Francis, 367-362.

Hodder I., Orton C. 1976, *Spatial Analysis in Archaeology*, Cambridge, Cambridge University Press.

Kelts K., Shahrabi M. 1985, *Holocene sedimentology of hyper saline Lake Urmia, Northwestern Iran*, «Paleogeography, Paleoclimatology and Paleoecology», 54, 105-130.

Kvamme K.L. 1993, *Spatial statistics and GIS: an integrated approach*, in J. Andersen, T. Madsen, I. Scollar (eds.), *Computing the Past: Computer Application and Quantitative Methods in Archaeology. CAA 1992,* Aarhus, Aarhus University Press, 91-102.

Ladefoged T.N., Pearson R. 2000, *Fortified castle on Okinawa Island during the Gusuku period, AD 1200-1600*, «Antiquity», 74, 404-412.

Lee J., Wong D.W.S. 2003, *Statistical Analysis with ArchView GIS*, Willy, New York.

Lock G., Harris T. 2006, *Enhancing predictive archaeological modeling: integrating location, landscape, and culture*, in Mehrer, Wescott 2006, 41-62.

Maschner H.D.G., Stein J.W. 1995, *Multivariate approaches to site location on the Northwest Coast of North America*, «Antiquity», 69, 61-73.

Mehrer M.W., Wescott K.L. 2006 (eds.), *GIS and Archaeological Site Location Modeling*, London, Taylor and Francis.

Niknami K.A., Chaychi A.A. 2007, *Geochemical analysis of obsidian and the pattern recognition of sites spatial distribution in the Chalcolithic of the Eastern Lake Urmia, northwestern Iran*, «Geochimica et Cosmochimica ACTA», 71 (15), 718.

Niknami K.A., Chaychi A.A. 2008, *A GIS technical approach to the spatial pattern recognition of archaeological site distribution on the eastern shores of Lake Urmia, northwestern Iran*, in *Proceedings of the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVII, Part B4, Beijing, 167-172.

Niknami K.A., Chaychi A.A., Glascock M.D. in press, *Provenance studies of Chalcolithic obsidian artifacts from Lake Urmia, northwestern Iran using WDXRF analysis*, «Archaeometry».

Niknami K.A., Saeedi M.R. 2006, *A (GIS)-based predictive mapping to locate prehistoric site locations in the Gamasb River Basin, Central Zagros, Iran*, in S. Campana, M. Forte (eds.), *From Space to Place*, BAR International Series 1568, Oxford, Archaeopress, 249-255.

Orton C. 1982, *Stochastic process and archaeological mechanism in spatial analysis*, «Journal of Archaeological Sciences», 9, 1-7.

Pickering M. 1994, *The physical landscape as a social landscape, a Garawa example*, «Archaeology in Oceania», 29, 149-161.

Ridges M. 2006, *Regional dynamics of hunting and gathering: an Australian case study using archaeological predictive modeling*, in Mehrer, Wescott 2006, 123-143.

Schwarz K.R., Mount J. 2006, *Integrating spatial statistics into archaeological data modeling*, in Mehrer, Wescott 2006, 167-189.

Warren R.E., Asch D.L. 2000, *A predictive model of archaeological site location in the Eastern Prairie Peninsula*, in Westcott, Brandon 2000, 5-32.

Wescott K.L., Brandon R.J. (eds.) 2000, *Practical Application of GIS for Archaeology*, Philadelphia, Taylor and Francis.

Whitley T.G. 2006, *Predictive modeling in a homogeneous environment: an example from the Charleston Naval Weapons Station, South Carolina*, in Mehrer, Wescott 2006, 335-394.

Woodman P.E. 2000, *A predictive model for Mesolithic site location on Islay using logistic regression and GIS*, in *Hunter-Gatherer Landscape Archaeology: The Southern Hebrides Mesolithic Project 1988-1998*, Vol. 2, *Archaeological Fieldwork on Colonsay, Computer Modeling, Experimental Archaeology and Final Interpretations*, Cambridge, McDonald Institute for Archaeological Research, 445-464.

ABSTRACT

The Lake Urmia survey project carried out from 2004 to 2006 in northwestern Iran was aimed at obtaining a reliable overview of the occurrence of archaeological sites as well as to identify the spatial pattern of such sites across the area. This paper explores archaeological approaches to regional scale in dynamic landscape. Regional interpretation and the spatial statistical methods used to describe sites distribution, orientation, and pattern are often most reliant on point data. This paper also demonstrates how point pattern analysis offers quantitative information to the spatial process modeling of the natural and cultural landscape, which will aid at establishing a baseline from which other attributes of higher measurements for archaeological elements can be confidently mapped, described and modeled within a GIS. Point pattern analysis of archaeological sites has involved the advantages of visualization and iteration offered by a GIS. Therefore the significance of this study is three-fold. 1) it applies spatial analysis within a GIS to the understanding of archaeological site distributions. 2) it uses quantitative methods that are now available within a GIS to assess inferences concerning the survey data collected from the study area. Finally, this study offers insight into a methodology that is suitable to the spatial examination of more complicated surface data in landscape archaeology concept.