A GIS TECHNICAL APPROACH TO THE SPATIAL PATTERN RECOGNITION OF ARCHAEOLOGICAL SITE DISTRIBUTIONS ON THE EASTERN SHORES OF LAKE URMIA, NORTHWESTERN IRAN

Kamal A. Niknami[a] and A. Chaychi Amirkhiz[b]

[a]Department of Archaeology, University of Tehran - kniknami@ut.ac.ir
[b]Iranian Cultural Heritage and Tourism Organization, Tehran - ahmadchaychi@yahoo.com

KEY WORDS: GIS, GPS, Aerial Photograph, Archaeological Sites, Point Pattern Analysis, Spatial Analysis, Settlement Pattern, Spatial Statistics, Lake Urmia, Iran.

ABSTRACT

A general model of settlement structures by means of spatial processes and a specification of a spatial model for an archaeological landscape are presented. The study was mainly concerned with the analyzing quadrates containing archaeological sites, their formulation according to the general spatial model applied. As an example the settlement pattern of ancient sites from a region of Eastern shores of Urmia Lake has been analyzed. Here, we detailed the results of an aerial photographic survey combined with an intensive ground survey of ancient archaeological sites designed to determine: 1) the spatial pattern of archaeological sites at a landscape scale; 2) whether a positive association exists between the density of archaeological sites and environmental variables and if so, at what scale this relationship is strongest. We then suggest that wider use of remotely sensed data and spatial statistical tests, which are designed for spatial inference, can be integrated into geographic information systems (GIS) and similar spatial analyses that are often graphically displayed.

1-INTRODUCTION

The use of archaeological site distribution patterns in order to account for archaeological landscape is a fairly striking experience in archaeology. Even though statistical theories and models in relation to site dispersion and distribution patterns have evolved since the middle of the 80s, there hasn't been much attention paid to the potential for utilizing it as an explanatory method for the analysis of archaeological landscape. (see, Hodder and Orton 1976, Orton 1982).

This article presents a model for 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 quadrat analysis.

2- STUDY AREA

The setting of this study spans an area of 18000 square kilometers and it includes parts of the cities of Charoymak, Hastroud, Maraghe, Malekan, Bonab, Ajabshir, Oskou, Azarshahr, Marand, tabriz, Bostanabad in Eastern Azerbaijan province, and parts of Miyandob 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 Gharangou, Aidogmoush, Zarrine Roud, Simine Roud, Talkhe Roud, Sofi Chai, Shabestar and Tasouj.

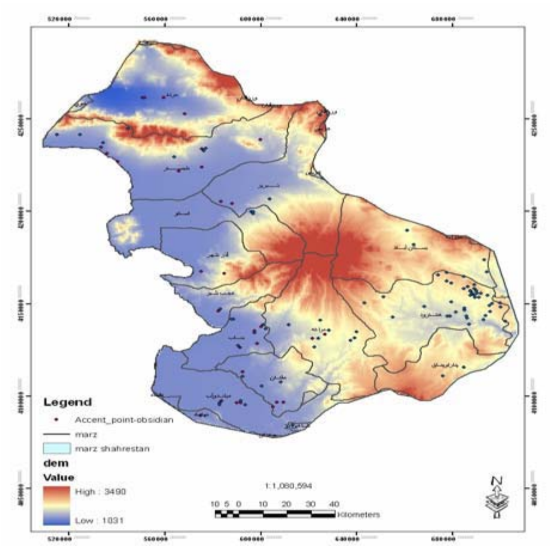

Figure 1. Topography and archaeological site distributions map of eastern Lake Urmia shores, Northwestern Iran

The main elevation in this area are 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 Gharedadh 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. 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 isn't covered with lots of plant. However, small wild almond trees in Shorkat area near Urmia could be seen (Figure 1).

3- MATERIALS AND METHODS

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. With spatial archaeology there are various methods for understanding the distribution of archaeological sites in landscape and thus it is possible to detect spatial pattern from the point distributions and changes in point patterns at different times. Quadrat Analysis, which is one of the most common methods used in archeology, was employed in this study. Quadrat Analysis is used when sites are measured in terms of point rather than their weights. This method evaluates and measures the changes of distributions of points (the sites of the study) in terms of density and the number of points in each quadrat. The density, which is measured in the quadrat analysis, is compared to a hypothetical random pattern in order to find out from which pattern it is derived. 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 quadrat analysis. For this reason, in 2005 and 2006 survey seasons, we first overlay the study area with a regular square grid (10m. × 10m.), and count 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 the whole desired archaeological sites. Another important point about the approach to analysis of this research was determining the number and size of the quadrats. The studies of (Grifith and Amrheim 1991: 131) indicate that the required size of the quadrats can be obtained by the following equation:

Size of the quadrat= 2A ⁄ r (1)

Where A represents the size of the area under investigation and r represents the points in the distribution.

By adopting the above equation, it became clear that given the right size, a quadrat has a width of 2A⁄ r when the quadrats in question are selected in the form of a square. Therefore, given the above correlation, it is possible to perform this calculation when the quadrats are selected with the required size. The number of quadrats can be obtained through the correlation n = r ⁄2. When the area under investigation was located within coverage of quadrats, some of the quadrats were lacking in any kind of archaeological sites whereas some quadrats which had one, two, three, or more sites were distributed within. Then, the frequency of the points within each quadrat was counted and their density was measured (table 1).

In table 1 the distribution of sites within the quadrats can be seen in such a way that 38 quadrats don't show to have any kind of archaeological sites and 8 quadrats exhibit only one site within it. On the other hand, one quadrat contains 32 sites. A glimpse at the frequency distribution of the sites within the quadrats may reinforce the idea that the sites within the quadrats tend to form in clusters. Even though this conclusion-up to a point- can be borne out by site distribution analysis, real corroboration occurs when the degree of difference and similarity of the observed frequencies is gauged in a measurement system in the form of statistics with a theoretical distribution basis. The type of site dispersion pattern has a huge impact on identifying the properties of the site. For instance, if we envisage that the observed distribution pattern tends toward clusters, then we will need to look into the factors of this phenomenon. But if we encounter this phenomenon where the sites are distributed without any specific pattern, this might show that the usual factors such as environment which affects the sites do not have any role here. In fact, other factors more than the above come into play in site distribution and dispersion (see the rest of the article)

Number of sites in each quadrat	Observed frequency
0	38
1	8
2	4
3	8
4	1
5	2
6	2
7	3
32	1
Total	67

Table 1. Frequency distribution of 118 sites observedfrom the eastern shores of of Urmia Lake

In order to see the difference between an observed pattern and a pattern whose basis is a random process, we can use a common method, namely Poisson Process (equation 2) which is a suitable backdrop against which random point pattern can take place in the form of numerical data or frequency data.

$$P(x) = \frac{e^{-\lambda}\lambda^{x}}{x_{!}} \quad (2)$$

Where e is the natural logarithm and $x_!$ is the factorial of x .

To illustrate the difference between the observed amounts and the amounts obtained from Poisson process, a statistical and analysis system and K-S (Kolmogrov Smirnov) were employed. K-S is a statistical method which measures the differences and similarities in statistics in frequency distribution. In running K-S measurement, our (H_0) hypothesis was that there is no significant difference between the two distributions or if a very slight difference is observed, this difference is seen either as an error of sampling or a chance happening (Table 2).

4- RESULTS

The study of distribution pattern of 118 archaeological sites in the eastern shores of Urmia Lake and which was conducted by the use of archaeological ground survey in 2006 indicated a clustered pattern for archaeological sites. It isn't the aim of the present article to identify the correlation of distribution pattern and existing factors in the area, because understanding the correlation of site dispersion pattern and environmental and cultural factors in the region plus the correlation of their interaction necessitates collecting and analyzing more pertinent data which they are at the preparatory stage. Nevertheless, the analysis which has been run so far reveals that up to a certain measure site distribution pattern follows a clustering pattern.

Number of sites in each quadrat	Observed frequency	Observed Proportions	Cumulative proportion	Expected (poisson) proportion	Cumulative expected (poisson) proportion	Proportion differences
0	38	0.567	0.567	0.1308	0.1308	0.4362
1	8	0.119	0. 686	0.2660	0.3968	0.2892
2	4	0.059	0.745	0.2705	0.6673	0.0777
3	8	0.119	0.867	0.1834	0.8507	0.0163
4	1	0.0149	0.878	0.0935	0.9442	0.0662
5	2	0.029	0.9079	0.0379	0.9821	0.0742
6	2	0.029	0.9369	0.0128	1.00	0.0631
7	3	0.044	0.9809	0.000	1.00	0.0191
>7	1	0.0149	1.00	0.000	1.00	0.00

Table2. K-Sstatistical inferences based on a comparison of the observed pattern with Poisson probability distribution

Table 1 shows site cluster distribution where it is only here we see the number of quadrats containing more amounts than the sites. This theory is borne out by site dispersion frequencies where quadrat alone has almost more sites than all the other quadrats combined. Other than this, site distribution isn't the same in all the quadrats and based on this we can draw the conclusion that site distribution across the area being studied hasn't been considered as the same. Analysis of table 2 in which K-S test was performed as well, establishes acceptable bases for rejecting random site distribution. In K-S measurement, the value of the test was equal:

$$D = Max\,|\,O_i - E_i\,| \qquad (3)$$

Dmax = 0. 4362
thus
Dmax = 0.5= 0.166<0.4362

Therefore, the similarity between site distribution pattern and Poisson random pattern is also rejected. Furthermore, considering the statistical process of table 3, the ratio of variance and a mean of 8/824 are big enough to confirm site cluster distribution (equation 4).

$$\sigma = \frac{\Sigma n_i (x - \lambda)^2}{n} \qquad (4)$$

Where x, is the number of archaeological sites in a quadrat, n_i, is the number of quadrat with x_i points, and n is the total number of quadrats.

On the other hand, the fact that statistical value of t is also 44/950 repudiates the possibility of a pattern other than clustering for site distributions (equation 5).

$$t_{(d_f = n-1)} = \frac{|(\frac{\sigma}{\lambda}) - 1|}{\sqrt{\frac{2}{(n-1)}}} \qquad (5)$$

Where df is the number of degree of freedom, and n is the number of quadrats.

Number of sites in each quadrat	Observed frequency	$\overline{(x_i - \lambda)^2}$	$n_i(x_i - \lambda)^2$
0	38	4.137	157.206
1	8	1.067	8.553
2	4	1.156	4.624
3	8	0.9331	7.465
4	1	3.865	3.865
5	2	8.797	17.594
6	2	15.729	31.458
7	3	24.661	73.983
32	1	897.961	897.961

Table 3 Variance mean ratio of the observed and expected patterns of archaeological sites in the eastern shores of Urmia Lake

5- DISCUSSION

Today, it has become frequently prevalent to use point pattern analysis in archaeology to show the location of artifacts, features, and archaeological sites. Therefore, point pattern analysis is seen as an important tool for describing, interpreting, and analyzing spatial distribution features of the above archaeological phenomena. (Conolly and Lake 2006:162)

Analysis of archaeological settlement pattern is a brilliant approach as far as site dispersion settlement 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 a 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 centres have often be highlighted (Ladefoged and Pearson 2000).

Random distribution have usually been treated as statistical null hypothesis, though some commentators provide good examples of how apparently random distributions can be conditioned by less-obvious environmental, biological and social variables (see Daniel 2001; Woodman 2000; Maschner and Stein 1995)

Today, a high degree of interconnections between environmental factors and archaeological site distribution patterns is the assumption of serious researches in archaeology (see Ebert and Kohler 1988, Veth et al. 2000, Niknami and Saeedi 2006 for some of the issues).

Findings of such researches show the importance of the effect of environmental variables on the kind of activities of archaeological community. However, other tendencies, which have been established, show that although environmental factors play an influential role in some processes, they can not explain every change of archaeological place (for an example see Gaffney and Leusen 1995).

It is true that environmental factor have easily found their way into today's systems (GIS) to play a practical part in the description of spatial models, but the role of non-environmental factors shouldn't be overlooked (Whitley 2000). It seems that if these kinds of factors were to be evaluated independently, the main differences in the models which have been provided so far would be possible.

The present research directly examined numerous site settlement patterns from different cultural periods in the eastern region of Urmia Lake. Also it independently evaluated a set of political, environmental, and economical systems which existed in the regional scale. Despite the special features of each system, they had some relationships in common. As a general rule, most of the data discovered in the field study can be used to predict their places in a yet to be identified areas. By accepting this theory and by studying surface spatial distribution which we employed in this research, it is possible to evaluate the behaviors which give rise to the regional organizational patterns in the landscape scale.

The geographical features of the area in the east of Urmia Lake have two parts that are entirely different from each other. These parts include a flat alluvial area which was irrigated from several permanent rivers and a network of seasonal rivers. By contrast, the other part includes high 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 high 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. This shows that even though still there are not valid sources of archaeological records in the area, it can be surmised that historical population movement within this area might have been related to socio-economical 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 dispersion structures (Gaffney and Van Leusen 1995: 375).

As Gaffney and Van Leusen have shown, it is very difficult to see any difference between environment-derived behaviors and man-made cultural behaviors which human exhibit in trying to adapt to the environment. As an example, settlement patterns in the region show that most sites by Urmia Lake and along a wide range of connecting roads were formed in pre-history. The close proximity of the sites and their assembling in areas where there might be fresh water show distribution patterns in which the possibility of having economic relations among them, is not ruled out.

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 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 still has not been able to attract inhabitation at any time. Another crucial and relevant point here is that the accumulation of clustering settlement in this area have occurred in places with potentiality for subsistence, technological development in terms of securing sources for a reasonable population. Alluvial landscape around the lake secure arable areas for agriculture. Suitable mineral soil-centers that are almost close to each other-have brought about 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 relationship which can be seen in the rest of the sites.

Water source system follows a linear pattern in 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. Besides securing access to water resources, linear distribution of water resources also made it possible for sites to connect. In addition, there is a strong tendency of archaeological sites here where the bigger places more than smaller ones tend to get distributed close to water resources. Distance estimation along with site distribution pattern is another important issue to be considered.

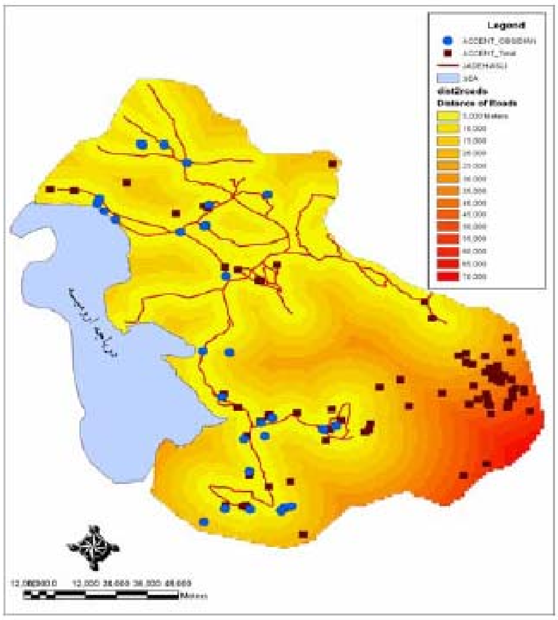

Figure 2. Proximity measurements of archaeological sites from the water resources and possible ancient road networks

It is worth mentioning that about one third of the observed sites contain Obsidian artifacts which for the most part have distributed on the surface of the sites. It is interesting that almost all the sites with Obsidian have been located in areas with low elevations in the coasts of Urmia Lake. Layers whose distance from passable ancient roads was calculated, show a linear pattern which has connected Obsidian-laden sites with each other. This assumption may account for the economic site distribution patterns however, pinpointing it needs further studies (Figure 2).

As a final word, archaeological challenges in the region-such as this research ran into- may be comprehended by considering the effect of socio-economic and political behaviors on the formation of archaeological sites. But it is very difficult to observe such behaviors by the conventional method (Pickering 1994).

In this article, 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.

ACKNOWLEDGEMENTS

The authors gratefully acknowledges the preceding work required to develop the ArcView Extensions by Wong, D.W.S. and Lee, J. These are available from : USGS Planetary GIS web server (PIGWAD).

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