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A STOCHASTIC MODEL TO SIMULATE AND PREDICT ARCHAEOLOGICAL LANDSCAPE TAPHONOMY: MONITORING CULTURAL LANDSCAPE VALUES BASED ON AN IRANIAN SURVEY PROJECT

1. Introduction

The geomorphology, ecology, and material culture of archeological landscapes are always changing and the vectors of such changes are occurring as long-term processes. In order to recognize the changes of landscapes, they should be studied in their own spatial-temporal context. This paper deals with the geodynamics of landscapes altered by humans which are at the heart of environmental archaeology; understanding of environmental effects on ancient landscapes and the reconstruction of the resource exploitation patterns and land use have priority in the research conducted on this subject (McGlade 1995).

A truly useful research policy is one that puts human use of the area into an environmental context. Not only will it define the environmental variables or combination of variables that would attract human use, it will also address the problem of landscape taphonomy that could obscure or destroy the landscapes. As Butzer (1980) has pointed out, the primary goal of environmental archaeology should be the characteristics and processes of the biophysical environment that provide a matrix for, and that interact with, past human behavior and socio-economic systems of ancient landscapes. Therefore, the term landscape taphonomy used here deals with the processes by which elements of the landscape become selectively removed or transformed by both natural and cultural processes (Wilkinson 2003).

The nature of the patterned data derived from ancient landscapes useful for the interpretation of past human activities has not been adequately studied. In recent years the notion that climatic change was the primary cause of landscape instability has been generally replaced with explanations stressing human land abuse (Bintliff 2005). In semi-arid regions like most of the Near East and Iran, land surfaces were actually relatively stable with rare and irregular episodes of disruption, erosion, and deposition. Thus, the message for surface material interpretation appears to be that what we see and collect from the modern surface is likely to be not the product of only natural processes, but a set of cultural processes as well. Future archaeological field surveys need to determine the taphonomic processes of the landscapes we walk over today and the artefacts contained within them, therefore it is more likely, from a geo-archaeological point of view, that the nature and taphonomic processes of the landscape themselves create the patterns of surface material configurations. If this is true,

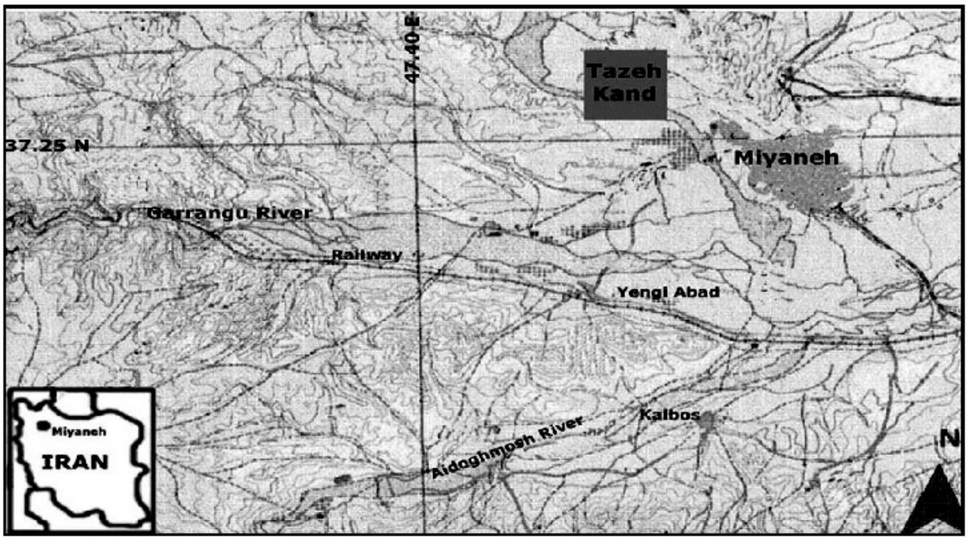

Fig. 1 – Map of study area in Northern Iran, location of survey project and sampled areas.

then it calls into question the standard interpretative methodology for exploring past human behavior on the basis of present day scatter patterns while such patterns are subjected to the diverse natural and cultural degradations.

This paper describes work carried out at Garrangu River Basin, some 5 km northwest of Miyaneh in Eastern Azerbaijan (Fig. 1) as part of a broader study to investigate the archaeology of the region (Niknami 2004a, 2004b). One goal of this project is to build a statistical model of landscape change, based purely on land use variables, in order to establish a screen on which to project taphonomic processes. It also aims to illustrate the effects of intense modern land use on the decomposition of the patterns of cultural materials (in this article, pottery sherds) on the cultural landscapes. We will also discuss the issue of landscape management to ensure the survival of patterned archaeological resources in the study area.

Many of the problems and concerns identified for the study area reflect broader issues for other cultural landscapes in Iran. However, it is important to note here that this article describes an exercise in methodology rather than the presentation of significant archaeological results. This seems a reasonable approach because the particular area of study, as of this writing, has never been the object of archaeological reserach; also, no chronological framework has been established in order to model the long-term dynamics of archaeological and environmental processes. This shortcoming and a general lack of a fine degree of temporal resolution for natural and cultural materials prevented the present research from considering materials and processes in their chronological contexts.

Before proceeding with a discussion of how modern land use activities can be employed as taphonomic indicators, some fundamental theoretical assumptions must be presented:

– a) The archaeological record consists of a virtually continuous spatial distribution of material over the landscape. A problem emerged when archaeologists began to reconstruct full human use of the landscape. They realized that there were very faint scatters that might not qualify as sites, but which represent significant human activity. This phenomenon can be seen in areas especially where mobile societies have left sparse archaeological remains. In order to define them archaeologists used the term "non-site" or "off-site", but these require special methodology to locate and to record the artifacts found there (Foley 1981; Dunnell, Dancey 1983; Binford 1992; Dunnell 1992). The landscape approach to archaeology seeks to explore the entire range of a region rather than a single site, since human behavior tends to be regionally circumscribed. Settlement and land use in one part of a region tends to be closely tied with settlement and land use in other parts of the same region. Such ties are not static but change through time, and the study of the changing interrelationship between different parts of a region is a crucial guide to understanding processes of culture. Thus, the data like that which artifact scatters are used to evaluate, determine and reconstruct the behavioral contexts of humans in the past on changeable landscapes (Tilley 1994).

Formation process and variability of archaeological sites as well as the effective factor on the replacements of artifacts, and taphonomic process of landscapes, are all indispensable for determining and analysing scatter distribution patterns (Wilkinson 2001). Archaeologists went to great lengths to evaluate the impact of human and natural factors in the transposition of artifact distribution patterns, which consist of the distributions of scatter patterns in agricultural fields, and the effects of plowing on the destruction and transposition of artifacts (Ebert 1992; Stafford, Hajic 1992; van Nest 1993), and their results appeared as articles and analytical criticism (e.g. Haselgrove *et al.* 1985; Gallant 1986; Schofield 1991; Alcock *et al.* 1994; Boismier 1997). In these kinds of analysis of archaeological surveys, data on the vast landscapes and regional units are utilized for the evaluation of archaeological contexts. The main goal of this type approach is based on a reconsideration of methodology and a thorough understanding of taphonomic processes of both landscape and artifacts. Despite this fact, Iranian archaeology pays little attention to the identification and measuring of such processes, and regional studies across the country still remain questionable.

– b) The natural components and the existing cultural phenomena of a landscape have been integrated to form a system in which the presence of all appropriate elements and the occurrence of all processes are at appropriate rates. This integration includes two important points. First, system integrity is reflected in both the natural and cultural elements, and the processes that generate and maintain those elements. Second, integrity is directly associated with the evolutionary context. For example, mechanized land cultivation increases production rates but it reduces integrity (KAMEI, NAKAGOSHI 2002). Therefore, the optimal state of a landscape depends on the integration of its system and it should be noted that any changes within the integrated system will lead to changes not only in the physical pattern but also in the biological and ecological conditions; thus, assessing the degree of change will depend upon both the modified and unmodified systems as well as the evaluation of existing elements and related processes (ANGERMEIER, KARR 1994; see also VOS, MEEKES 1999).

The spatial structure of landscape elements forms the spatial structure of archaeological records through time (STAFFORD 1995). In other words, these are the long term processes which produce aggregation of archaeological data. The places which were occupied in a landscape are assigned by a sampling of artifacts scattered on the field. Variation in the density scatter indicates the rate of cultural material accumulated in each ecological context. This measurement does not intend to present the activities conducted at one point or at an isolated site, but to demonstrate the structure of spatial distribution of artifacts scattered on the landscape as well as an assessment of the relationships between cultural materials and their ecological contexts in order to understand the interaction between humans and their environment (DUNNELL, DANCEY 1983; BUTZER 1997; FEINMAN 1999; WARREN, ASCH 2000).

– c) In the current theoretical study of landscapes, the holistic approach has found a special place. In this approach, mutual relations of cultural and natural elements are taken into consideration (NASSAUER 1995). In other words, the holistic approach deals with integration of natural and cultural components as major parts of the landscape system. It follows that landscape history must also take a holistic view of a landscape, integrating natural and human activity as part of a single evolving system (CRUMLEY 1994; PATTERSON 1994; MARCUCCI 2000).

One of the connotations of this view in the history of any landscape is that the cultural system of that landscape is demonstrated as infinite series of phenomena which indicate the cultural transformation of that region. This can be achieved by regarding the material culture of a landscape within its broader context (FLORES 1994). Generally speaking, the history of a landscape elaborates the genesis and long term process of its changes. The changes within a landscape occur when the flow of energy and consequent movement of material in a landscape over time create new structures and new functional characteristics (THORNE 1993). The transformation history of a landscape is always based on the realization of factors which change the landscape through time (NASSAUER 1995). Cultural process is one of the major factors of landscape formation, since any landscape is a thorough manifestation of cultural and natural systems, and any changes within these systems appear to affect not only the physical patterns of landscape but also the cultural system itself (DRAMSTAD *et al.* 2001; see also GRIMM *et al.* 2000). Creating such a system is useful in analyzing its relation to the landscape. It seems that the recognition of the transformation history of a landscape can assist environmental planning (Marcucci 2000) as all landscapes have a dynamic mode (McGlade 1997; Feinman 1999), and a comprehensive and precise description of landscape history can assign the ecological and cultural processes of changing landscapes. Moreover, understanding the changing history creates an appropriate basis for next step planning. At the same time, recognition of a past cultural system which was based on human beliefs provides adequate feed back to resolve probable conflicts.

2. The study area

The Garrangu River Basin is located to the west of the city of Miyaneh in Eastern Azerbaijan Province of Northern Iran. The area of focus, a relatively small part of the greater valley system consists of about 400 km^2 along the Garrangu River. Within this area a total of 0.094 km^2 have been surveyed throughout approximately 0.47 km^2 disturbed by modern land use practices.

The study area is situated in the alluvial subsection of the Azerbaijan Mountain Chain with the general topography consisting of mountain chains and shallow depressions holding water seasonally. The study area is in the low land physiographic zone and lies within a mountainous region between the Azerbaijan mountain system that constitutes the northern extent of the Bozgoush system of mountains that encircles the northern and northeastern margins of the study area, while it is bordered to the west by the Ghaflankuh mountain range, generally referred to as the Miyaneh valley zone. The physical landscape is typical of that formed by alluvial and pluvial processes; the two most prominent physical features in the area are the mountains lying approximately 20 km to the northeast and south, and the Garrangu River Basin which dominates the whole study area located directly to the west. The study area is highly dissected by intermittent and permanent torrents due to its close proximity to the Garrangu River. This river is the headwater for Sefid Roud, the major drainage of the country. The vegetation is typical of that found in the semi-arid temperate zone and contains mostly Artemisia with other species such as dwarf bushes, grasses and herbs, but the ground cover is made up of a complete steppe complex. In terms of modern land use, the study area is predominately cropland.

The Garrangu River Basin and surrounding area is thought to have been a destination of ancient peoples within the region because of the variety and abundance of resources available. Some of the resources that likely attracted people to this area include a variety of plants and animals, wood as a source of energy, fertile soil on the river banks for crops and water for consumption and processing activities. Throughout the great valley system, there are many villages located on the both sides of the river, one of which, namely Tazeh Kand, attracted our research interest.

The main attraction of this village for our research project was the amount of different kinds of information which seemed to be available here. First, perhaps the most notable characteristic of the village is the abundance of evidence including a large number of pottery sherd scatters visible on the ground[1]. During the 1992 field season utilizing a non-site methodology for surface recording (i.e. counting and mapping the density of surface artefacts, which consisted almost entirely of broken potsherds) continuously over many square metres of the land surface, revealed that in this area, at least in zones of present-day activities, the observed artefact densities are probably a function of the heavy investment in such activities. Second, the situation at Tazeh Kand, where we found that it was the only village throughout the valley system where almost all land use practices were represented in a single area (matching the project objectives), is very interesting for any relevant studies.

3. Materials and methods

For the initial 1992 survey several key issues concerning how to record off-site materials were taken into consideration, as off-site sampling for better estimation of target parameters requires the creation of a clear sampling strategy. For any off-site sampling model one characteristic is based on the understanding of the differences between element sampling and cluster sampling models. At the same time, determining sampling unit shape and size is also a very important issue in this strategy (Nance 1983; Shennan 1997).

In most parts of our study area there is a significant amount of off-site material and the materials on the surface have been widely spread on the landscape. In addition, the spatial distribution of scatters were affected by landforms, and the original patterns of scatters are very disturbed by land use practices (Haselgrove 1985; Wilkinson, Tucker 1995). Furthermore, active sedimentation during hundreds of years throughout the area would have considerably reduce the visibility of on-site as well as off-site scatters (Alcock *et al.* 1994).

Theoretically, adjusting sampling unit shapes to small squares may provide some advantages, but in fact, the archaeological records may be clustered within a few squares. In these positions the probability of discovery is directly related to the abundance of the material and inversely with the degree of clustering, as clustering increases, the sample size needs to be increased. Data clustered within squares using simple random sampling generally would lead to a statistical mistake by increasing the estimation standard error (Nance 1983). Instead, large sampling squares reveal more clustering than small

[1]All pottery sherds counted from the sampling units of the study area were tentatively classified as: Early Prehistoric 18.3%; Chalcolithic 17%; Bronze Age 6.1%; Iron Age 17.4%; Parthian and Sassanian 5.6%; Middle Islamic 1.2%; Late Islamic 8.1%; Unknown 26.1%.

ones, but even with this method, the effect of aggregation in the parameter estimation still remains problematic. On the other hand, assigning sampling units to transect not only would reduce such effects (Wilkinson 2001), but would also be more applicable in the extensive regional studies than squares for sampling archaeological and environmental variables, although, because of their greater size, some materials may potentially be overlooked (Hodder, Orton 1976; Cherry *et al.* 1991; Bintliff 1996; Lock *et al.* 1996; Wheatley 1996; Shennan 1997; Gillings, Sbonias 1999). In dealing with the issues described above, we have become convinced that making use of a combined method of grid squares and transects defined as extensive and intensive would overcome the shortcomings of a single method and would enhance sampling and parameter estimation precisions (Shennan 1985, 1997).

In the GRB project, to maintain a greater finding probability, the shapes and sizes of transects were adjusted to the formula proposed by Sundstrom (1993), through which the probability of discovering archaeological sites is a function of the size and shape of the transect and the spacing of the search pattern. In this method, the smaller the transect spaced, the greater the likelihood of finding more materials.

In 1992, in order to facilitate the study and to understand the impact of different land use practices and to increase the feasibility of comparing the sherd distributions, the whole study area was assigned to six land use types which have been common in the area. These types included residential lands, industrial activity lands, gardens, lands under heavy constructions, agricultural and uncultivated barren lands. Because there have been variations in the ecological and geographical settings for the types of land use, the environmental setting of each type is regarded as a stratum. In these cases, survey strategy requires systematic data collection from a series of landscape strata defined environmentally rather than on the basis of data characteristics. To do this, first, a detailed topographic map of the study area (1:50.000) overlaid with a 10×10 m grid of squares was used to define the size of land use types and survey units and locate study units on the ground during field work. Second, each stratum was divided into 100×100 m parcels and all parcels were assigned to grid squares on the basis of total size of each land use type (Fig. 2).

To assess off-site pottery sherd distribution on the surface of each context, a systematic survey was then carried out within all 47 pre-defined parcels by providing transects at 10 m intervals. Since there were variables such as land forms and land covers affecting considerably the sherds' visibility, the transect system employed here appeared to be unsatisfactory. To overcome this and to increase the level of accuracy, each parcel was sub-divided into 100 recording units of 100 m^2, from which 20 grids (20%) were randomly selected as recording and analyzing units. All pottery sherds were retained from each sampling unit. Further analysis indicated that each parcel provided a varying amount of

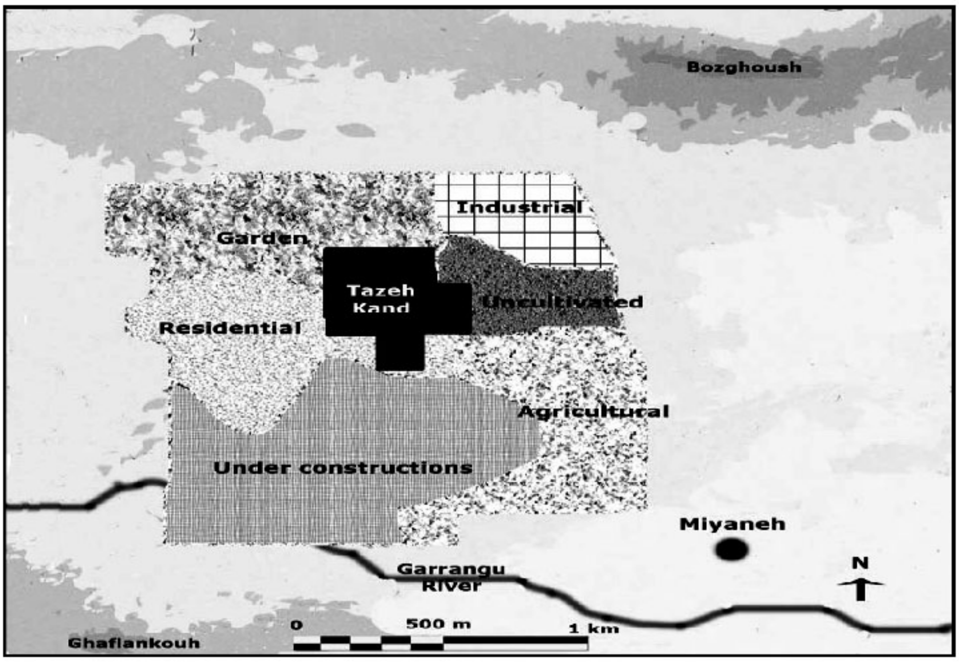

Fig. 2 – Graphical representation of sampled modern land use types in the study area.

sherds on the surface in which the mean density of sherds varied from 54.6 to 386.2 sherds in any 100 m^2 analysis unit. However, with the application of this more rigorous sampling method, it is now possible to estimate with greater accuracy the probability of intersecting and detecting any sherd distribution on the surface throughout the study area. For more details and uses of this strategy see Redman 1987; Gaffney *et al.* 1991; Shennan 1997.

In 2002, to quantify the processes of landscape transformation, the parcels inspected in 1992 were examined and surveyed again. The latter observation revealed for the study area a considerable change in terms of the size of the parcels and their associated activities, as in some parcels the type of land use was replaced by another type. Most importantly, a number of parcels that had been identified in the 1992 field work were fenced and occupied for use as a depot or warehouse for the needs of development projects. It made our access impossible for further recording.

Tab. 1 indicates types of land use, size and number of parcels allocating for each type the different amounts of sherds exposed on the surface in the GRB study area during the observations conducted in 1992 and 2002.

As can be seen from Tab. 1, looking at the overall pottery density for

		1992				2002		
States	Mean sherd density (20% sampled)	Amount of parcels producing sherds	Total unit size in km²	Dominant land use pattern	Geographical setting	Amount of parcels producing sherds	Total unit size in km²	Dominant land use pattern
State 1	54.6	7	0.07	Residential	Alluvial plain	10	0.10	Residential
State 2	99.7	4	0.04	Industrial	Alluvial plain	7	0.77	Industrial
State 3	162.6	11	0.11	Garden	River banks	8	0.08	Gardens
State 4	259.4	13	0.13	Under construction	Piedmonts, flood and alluvial plain	8	0.08	Under constructions
State 5	324.7	8	0.08	Agricultural	Piedmonts, alluvial plain, foothills	5	0.05	Agricultural
State 6	386.2	4	0.04	Uncultivated and barren lands	Moderately level steepy slopes	2	0.02	Uncultivated and barren lands
	Total	**47**	**0.47**			**40***	**0.40**	

* Note: Inaccessible parcels were not included in the analysis.

Tab. 1 – Sherd density measurements, parcels attributes and types of land use practices recorded for GRB study area in 1992 and 2002.

the study area, we see that in general terms there is a correspondence between high density off-site areas and the kind of land use practices. The rate of background scatter varies among the designed sampling units. Yet it seems that a distinct variability in terms of off-site density within the survey area, with a higher rate of pottery sherds being more valid for the barren lands. The same is true of the cultivated lands of the study area, where much more fragmented sherds can be observed.

The residential area provides the least sherds visible on the surface; this is due to the mechanized leveling and clearing of the land for construction. This activity masks the density signature of pottery sherds and makes their identification impossible over the whole residential area. The same is comparatively true with a slow rise in the number of pottery sherds for the industrial and construction areas. On the other hand, cultivation produced a moderate range of pottery sherds. This pattern of land use makes buried cultural materials visible at the surface and it reduces the resolution of spatial patterning (Barton *et al.* 2000). Artifacts do not seem to move far from their position before plowing, and the rates at which they disperse from their original locations depend on the duration of the practice used. In most parts of the study area they practice dry farming of cereals for which entire fields are plowed and harrowed, and artifacts are exposed at that time.

Our observations also indicated that for gardens the exposure of sherds never exceeds the cultivated areas, although in gardens the planting of trees can be very deep and expose deeply buried materials. Hence, in well cared for gardens, where there is less trampling by human and animals than the

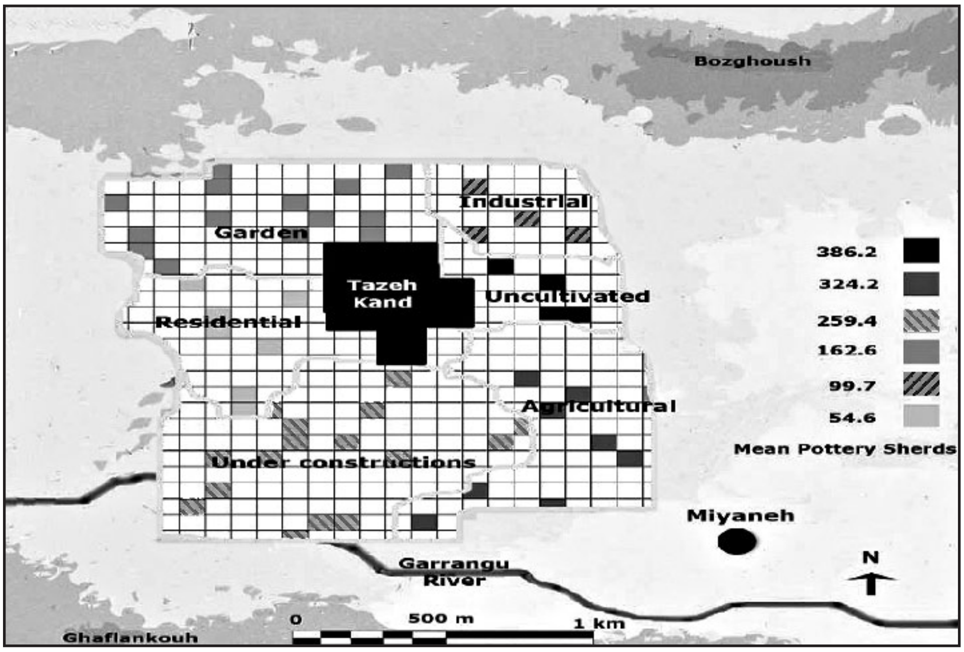

Fig. 3 – Frequency of mean pottery sherds sampled from each land use type.

cultivated lands, the rate of fragmentation on the surface is expected to be relatively lower than the cultivated lands. There is also a barren zone containing uncultivated fields which were abandoned many years ago. In this region, fields like this are covered sparsely by a thistle-like vegetation and are no longer suitable for herd grazing. In these fields the modern topography is generally affected by post-depositional processes (not presented here), and because there is no modern land utilization, the amount of sherds remains considerably higher than the other fields. Barren fields make ground visibility of sherds slightly lower in the wet seasons, but it is much higher in the same field when it is covered with vegetation during dry seasons.

Overall, as the above observation indicates, much of the study area seems broadly characterized by surfaces that have been comparatively unstable since the beginning of modern land use practice. Significant disturbance is brought to the landscape by housing and modernization projects which locally remove land surface sediments containing cultural materials. In such contexts, the patterns of pottery sherd accumulations are likely to be the result of a complex mix of materials differing in their density, location and morphology from their original contexts (Fig. 3).

4. Markov Chain statistical model analysis

A Markov Chain model consists of a system with a series of changes from one state to another over time, which can be measured in discrete intervals. An existing discrete state composition ($\mathbf{w}_t$) can be used to predict expected discrete state composition ($\mathbf{w}_{t+1}$) by multiplying a matrix of transition probabilities corresponding to the current time interval **t:** $\mathbf{w}_{t+1}=\mathbf{w}_t\mathbf{p}_t$, where $\mathbf{w}_t$ is a $1\times n$ state vector at time **t,** $\mathbf{p}_t$ is a $n\times n$ matrix of transition probabilities created $\mathbf{p}_{ij}$ values, n is the maximum number of discrete states in the chain, and $\mathbf{p}_{ij}$ gives the probability of transition from discrete state **i** to state **j** between **t** and **t+1**: $(ij \leq n)$

$$pt = \begin{cases} p_{11} & p_{12} \cdots\cdots p_{1n} \\ p_{21} & p_{22} \cdots\cdots p_{2n} \\ p_{n1} & p_{n2} \cdots\cdots p_{nn} \end{cases}$$

For the considered time phase t (t=1, 2, …k), the transition probability will be as follows:

$$\left\{P_{ij}(t) \geq o, \forall i, j \in 1,\ldots.N\right\} \qquad \sum_{j=1}^{N} Pij(t) = 1$$

If the transition probability does not change through time k, the process can be written as $\mathbf{w}_{(t+k)}=\mathbf{w}_{(t)}\mathbf{P}^k$. In other words, the probability of staying in one state concerns knowing current and succeeding state and does not depend on the time spent in that state. If the states of system to be $\{A_1, A_2, \ldots, A_K\}$, for example, the probability that the system from $\mathbf{A}_j$ at time **t** proceeds to $\mathbf{A}_i$ at time $\mathbf{t+1=P_jP_{ji}}$. Thus, the probability that the system will be at state $\mathbf{A}_i$ at time **t+1** can be calculated from following formula:

$$Pi = \sum_{j=1}^{k} pjpji$$

It can be seen that $\mathbf{P}_j$ is concluded by multiplying vector **P** in the $\mathbf{i}_{th}$ column of matrix P. Therefore, the transitional probability at time **t+1** can be written as following:

$$P(t+1) = \left(\sum_{j=1}^{k} PjPj_1, \sum_{j=1}^{k} PjPj_2, \ldots. \sum_{j=1}^{k} PjPjK \right)$$

	States 2002					
States 1992	State 1	State 2	State 3	State 4	State 5	State 6
State 1	0.7	0.00	0.00	0.00	0.3	0.00
State 2	0.00	0.57	0.142	0.28	0.00	0.00
State 3	0.00	0.09	0.72	0.00	0.00	0.00
State 4	0.00	0.00	0.15	0.61	0.00	0.00
State 5	0.387	0.00	0.00	0.00	0.62	0.00
State 6	0.00	0.00	0.00	0.00	0.00	0.5

Tab. 2 – Transitional matrix from states 1992 to states 2002.

To create a transitional probability model, the present project used first hand data yielded by fieldwork. This technique provides the $\mathbf{P}_{ij}$ values directly from the fieldwork data.

For each discrete time intervals Δt, transition probabilities are calculated from the transition frequencies $\mathbf{Z}_{ij}$ of replacement from discrete state **i** by state **j** during $\Delta t : Pij = \frac{zij}{\sum_j zij}$ (Papoulis, Pillai 2002).

This approach is used in studies of change detection in landscapes. In this method the only successional data (e.g. archaeological data) are attributed to the change of proportions between discrete states over time. These data allow the user to find approximate values of transition probabilities via optimization procedures with elements of linear programming (Balter 2000; Yemshanov, Perera 2002). The $\mathbf{p}_{ij}$ values are constrained to the interval (0;1) and attempt to produce input proportions data. This technique is based on the assumption that transition probabilities do not change through the time.

5. Results

The model ran a 10-year simulation of change in land use patterns for the study area. Tab. 2 illustrates changes in these patterns after one simulation. However, there is much variation in the extent of parcels (and consequently in sherd densities) experiencing various land use. This is seen in chi-square values for comparison among parcels of study units. To test the null hypothesis that the frequency of land use types are stable between 1992-2002, a chi-square test was run and the results were significant (X^2=383.19, df=5, p<0.001), indicating that the frequency of land use types changed during the study period (Fig. 4).

The transition matrix for 1992-2002 indicates that except state 1 and 3, which remain relatively stable with 70% and 72% probability respectively, other states dynamically faced a greater change. It means that these two states to a lesser degree than the others have been converted to other states, while conversely, about one third of state 5 has been converted to state 1 during the same time period. This exchange pattern with a lesser extent can be seen among other states as well. This would suggest that the primary effect of modern land use can be seen in the variation in the visibility of sherds on the surface by the different levels of land use practiced. For example, in some parts of state 5, the observed mean values of 324.7 sherds per sampling unit in 1992, encountered a sharp reduction to reach about 54.6 sherds in the same unit in 2002 observation, soon after they appeared to be used as part of the housing areas.

A 50 year simulation of Markov's model to predict the long term range of changes was also run for the study area (Fig. 5), and indicated that the size of state 1 showed an increase of 15/8% while at the same time state 2 and state 4 registered a reduction in their size of 39% and 38% respectively. This

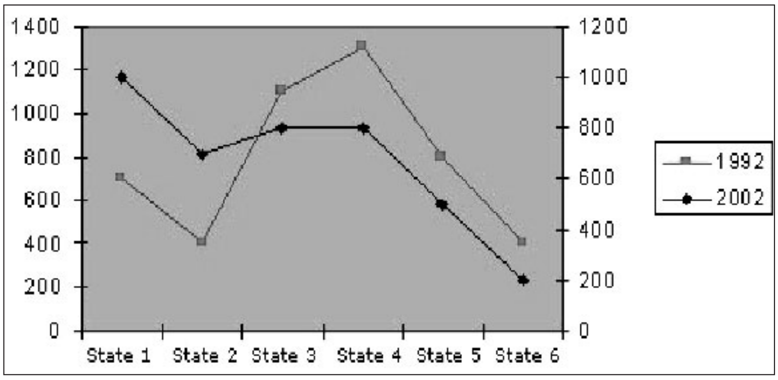

Fig. 4 – Frequency of land use types between 1992 and 2002.

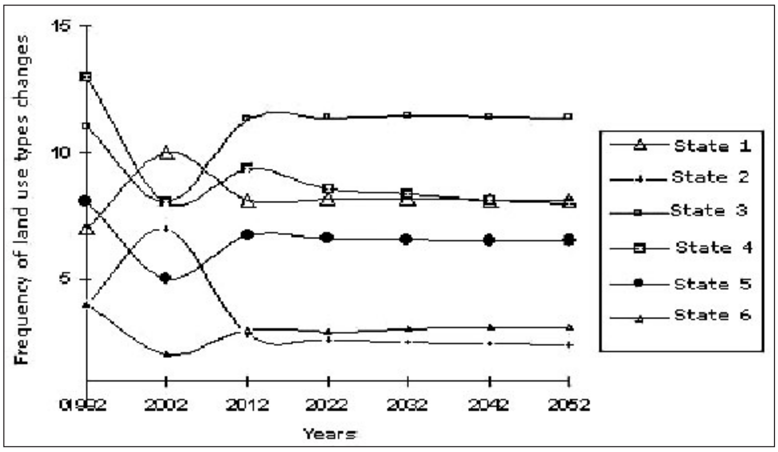

Fig. 5 – Expected values of land use changes during 50 years.

was also true for states 5 and 6 which registered a reduction of about 19% and 21% in their size respectively. In other words, the most striking result of Markov modeling for a 50 year time period is that the extent of parcels which are dominated by residential type would increase, while other types, especially cultivated lands, will be converted to other land use types. It is important to add that, over the study periods, only the garden type will not show a considerable change (Tab. 3).

This analysis also suggests a correlation between amounts of pottery sherds and parcel size. Using this rough indication of correlation, I have evaluated evidence for the landscape taphonomy in the Garrangu River Basin. These results are shown in Tab. 3. The increase in sherd amount during a 50

	Measured 1992		Predicted 2052	
States	parcels size surveyed (km^2)	amount of sherds sampled	parcels size predicted (km^2)	amount of sherds predicted
State 1	0.07	383	0.081	443.5
State 2	0.04	399	0.024	243.4
State 3	0.11	1789	No change	1789
State 4	0.13	3373	0.080	2091.3
State 5	0.80	2598	0.064	2104.4
State 6	0.04	1545	0.031	1220.6
Total		**10089**		**7892.2**

Tab. 3 – Frequency of change predicted for parcel size and sherd amounts during a 50 year time period.

year cycle is generally rare; it is seen only for state 1, indicating an increase of over 60 pieces of pottery whereas a reduction in their amounts is seen very frequently. Except for state 3, for which transitional probability indicated a constant pattern to this state, all others are predicted very likely to have experienced significant degradations. Overall, the study area is predicted to loose over 2000 pieces of important cultural materials reflecting the rapid transformation of landscape, however, it is worth saying here that the loose material mentioned above is related only to a small sampled study area, while for a whole landscape one expects that it should be this great. Furthermore, if we were able to include the inaccessible parcel's material in this analysis, the result would also indicate a higher rate of modification. However, even with these limitations, the result seems to better reflect the potential effects of the transforming processes on landscape, especially on the cultural materials.

6. Discussion

Successive studies of the Garrangu River Basin provided some preliminary data for further analysis. The data are mostly in form of pottery sherds scatterings in sampling units which can be attributed to different archaeological periods. There are some heterogeneous ecological units which the varied utilization of land as well as land formation processes and sedimentation have led to a conversion of material cultural scattering on the surface, while the remains of deeper cultural phases come up on the surface as a result of erosion or ploughing (Taylor 2000). Under the modern land use systems, most of these materials have been broken into pieces or crushed, and scattered from their original contexts to the adjacent areas. The appearance rate of deeper artifacts on the surface depends on various factors especially modern or traditional land use practices (Haselgrove 1985; Wilkinson, Tucker 1995). The distribution of material culture on the cultural landscapes and providing the appropriate distributional models are the major subjects of spatial analysis and inter- and intra-site analysis of archaeological sites. The site's structures, growth and developing mechanisms, chronology and cultural-economic relations of past cultures can be reconstructed through the systematic study of artifact scattering on the surface. Considering the spatial distribution of archaeological data, this would make the archaeologists able to estimate the distribution and structure of material through spatial analysis methods and extensive use of statistical models (Blankholm 1991; Orton 2000).

Understanding the taphonomy of the landscape is important. One must analyze the landscape as well as the material distributions before venturing into the world of hypotheses and interpretations, because the greater the modifications of landscape through time, the greater the likelihood of bias within that landscape (Allen 1991). Material culture on the surface is ultimately subject to the impact of human and environmental factors. Understanding an optimized material scattering pattern and an appropriate interpretation of material culture distribution would only be possible through a better evaluation of the impacting factors. In the regions where environmental factors such as weathering and erosion or human modifications are active, the spatial patterns of material culture are permanently changing. Thus, on the landscape new arrangements of scattering patterns appear which may be completely different from their original patterns. Since the material scatters are being used to interpret landscape activity, comprehensive background knowledge of the landscape processes is essential in order to allow the interpretation of material distributions.

As the case study showed, the model outputs indicated that the amounts of cultural material (pottery sherds) will change according to the kinds of land use types (Fig. 3). In this study, the most common types of land use affecting archaeological materials are residential and arable plowing. In both systems, mechanization is now used within the study area. It is still a common sight to see land clearance followed by the removal of coarse soil elements exposed by land preparation. Without doubt, the continuing process of clearance is causing a vast modification of the archaeological materials. Most archaeological literature points out the fact (references in Gaffney *et al.* 1991) that coarse materials tend to move to the surface of sites during land disturbance, and it is these objects which will tend to be removed during land clearance activities within the Garrangu River area. Most of the study area is now under extensive construction; huge dams such as Ostour and Aidogmoush are built here and not only do they cause great destruction and change to the surface materials, but they will also cause a great part of the area to be submerged in the near future. Some parts of the area were allocated to industrial activities, while the growth and expansion of the city of Miyaneh itself, in all directions, accelerates the rate of the landscape changes. The Markov model demonstrates the evaluation of these changes and the probabilities of a change of state. The model also shows that the parcels in which the cultural materials reveal themselves on the surface, under the impacting factors would soon become devoid of or, face a great reduction of, these materials. At the same time, villagers who previously worked on their own agricultural lands, now migrate as workmen to the industrial zones. This phenomenon leads to the extensive growth of such zones, as villages and cultivated lands are gradually abandoned.

7. Conclusions

In conclusion, the aims of this discussion have been threefold. Firstly, an attempt has been made to define the roles of archaeological surface survey along with quantitative analysis of landscape data using the Markov Chain model as part of the GRB project, by a critical analysis of the evaluation of landscape taphonomic processes. In doing so, the strategy was utilized in a number of ways, making it possible for the sampling methodologies and collection strategies to be evaluated and used for the interpretation process. Taking a landscape approach in a dynamic region requires that the scattered archaeological record be systematically evaluated. Since land use and changes are fundamental determinants of landscape taphonomy, the approaches used in landscape study, which emphasize landscape integrity, offer useful applications in a holistic analysis of cultural landscapes (Forman 1995). The complexity of landscape taphonomy may be better understood as such measures are incorporated into landscape analysis (Stafford 1995).

I have argued that since the spatial distribution of archaeological materials can be used to evaluate changes in the patterning of past human cultural and behavioral traditions and the quantifiable archaeological resources encode information in patterned ways, later modifications would potentially enhance the biases in decoding archaeological material and hence, inferences about past meaning of regularities and deviations. If this is the case, the management and protection of archaeological and cultural landscapes as a large geographical expanse with a common ecology and a common set of adaptations, which are sensitive to the human based modifications and alterations, represents a challenge which the archaeologist must take into consideration. This study has focused on understanding the processes responsible for the creation of the diverse artifact configurations that comprise the modern archaeological record, and has revealed that a taphonomic perspective on land surface degradations can be useful.

Secondly, as a result of the assessment of the landscape after a 50 year period, the evidence points to an overall degradation process in the study area that is seriously threatening the archaeological and environmental resources. This was found to be consistent not only throughout the project area, but with landscapes everywhere and especially in our country where cultural landscapes are degrading at a faster rate than others. Whether this process can be stopped or even reversed falls within the scope of future research, but what is clear is that it is not possible to detect this degradation process without a multi disciplinary research project. In such cases a broader management system is needed, but up to this time has been completely absent from the Iranian archaeological management policy. Research projects that include a geo-archaeological background of the landscape as the key component may be the only way to establish the extent of these processes. The exact form of such research projects remains to be established, but it is clear that if cultural landscapes like the projected area remain under current management policies, there may be little left to study in years to come.

Finally, the approach of this study is helpful in determining the appropriate context for further assessment. The Markov probabilistic transition model has been used in this project as a computationally efficient alternative method to predict the long term changes of land use types on a regional scale. This study indicates how the archaeological survey data can be formalized into the spatially explicit transition models. The model used here magnifies the transitions that are taking place by extrapolating over time. The model prediction also shows how land use patterns in the study area change to another state, and how they eventually affect the distributional patterns of archaeological material on the surface. Thus, it appears that current changes in land use would diminish the existing integrity of the study landscape and would accelerate landscape taphonomy.

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ABSTRACT

Archaeological scatters on the landscape present us with spatially patterned materials and features. Linking these spatial patterns to proximate aspects of scatter structure formation, and, ultimately, to understand the effect of land use systems in which landscape taphonomy occurred is one goal I see for landscape degradation analysis. While in the literature there has been a growing awareness of the pattern recognition problems posed by surface artifact distributions, due to the destruction or alteration of accompanying contextual information by landscape taphonomy processes, no substantive results have appeared in Iran. Analytical techniques for the description, classification and quantitative analysis of surface data remain poorly developed here and have often been incorrectly used and interpreted. These shortcomings demonstrate the need for some consideration to be given to the role of problem orientation in addressing the methodological and technical problems posed by surface scatter distributions. The main concern of this paper is to investigate and interpret the effects of land use patterns on the distribution of surface artifacts. My discussion focuses on providing a quantitative model which constitutes an analytical framework integrating methods and theory. This project uses an example provided by the archaeological survey project undertaken at Garrangu River Basin from 1992 onwards in Northwestern Iran. As a case study, land use dynamics of an archaeological landscape were measured through the study period, and Markov Chain models were used to project observed changes of artifact distributional structures over a 50 year period.