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Statistical Analyses on Bioarchaeological Materials: Comparison between the Subsistence Economies in Tepe Sagzabad and Haftavan Tepe during the Iron Age

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Abstract: In this paper we compare the subsistence economies based on the study of the faunal remains of two Iron Age settlements, Haftavan Tepe and Sagzabad in two different environments in northwestern Iran. These two examples are used to illustrate the use of various statistical methods in archaeozoology to test the significance of the quantitative and qualitative data. This analysis includes various measures for bone count and also for testing the morphological variability in various animal populations. By using Chi-Squared test, we show that although the two assemblages are very different in size, they still can be compared. In both Haftavan Tepe and Sagzabad, cattle is an important component of the subsistence economy. We compared these two populations geographically distant. With a Student t test we demonstrate the existence of two morphologically different cattle population during the Iron Age in northern part of the Iranian Plateau. In this paper, we aimed at demonstrating the importance of statistical methods in anthropological discussions.

Keywords: Statistical Analysis, Archaeozoology, Subsistence Economy, Haftavan Tepe, Sagzabad, Iron Age.

Introduction

In this paper, we focus on the reconstruction of the subsistence economy in the past, using statistical approaches in archaeozoological analyses, as well as the application of statistics to qualitative and quantitative studies of bioarchaeological materials. Generally, the description of archaeological materials is realized in two different ways: qualitative and quantitative, depending on the nature of these materials. In archaeology, these materials are divided into two groups: 1- hand-made like ceramics and stone tools 2- natural like animal and plant remains. The main aim of this research is to understand the application of statistics, and especially statistical tests, in archaeozoology. By using this methodological approach, we should be able to answer many archaeological, historical and cultural questions. For this purpose, we will compare the subsistence economies of the two archaeological sites of Tepe Sagzabad and Haftavan Tepe, located in two different environmental regions. Generally, the aim of this project is to define the natural and cultural factors affecting the development of the subsistence economy in these two sites.

The faunal assemblages of the two mentioned sites were studied as part of the PhD thesis of the two authors. Currently, the assemblage of Tepe Sagzabad is stored in the

Institute of Archaeology of the University of Tehran and the assemblage of Haftavan Tepe is curated in the British Institute of Persian studies (BIPS) (Mashkour 2001; Mohaseb 2012).

Cultural framework of the archaeozoological assemblages of Tepe Sagzabad and Haftavan Tepe

Sagzabad is an archaeological site dating to the first and second millennia BC. located in the northernmost part of the Iranian plateau near Qazvin, 140 km away from Tehran (Fig. 1). This site was excavated in the 1970s under the

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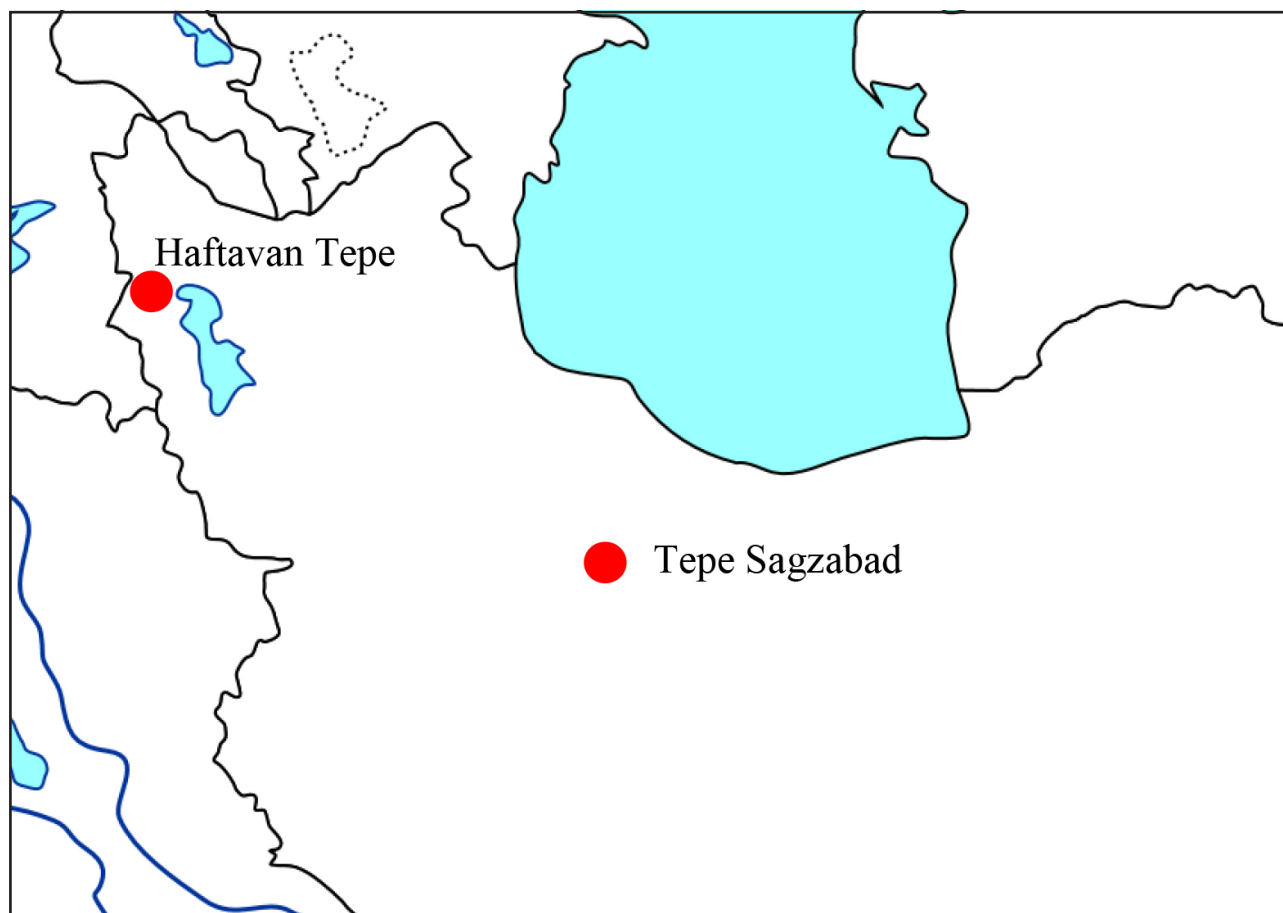


Fig. 1. Location of the two archaeological sites of Tepe Sagzabad and Haftavan Tepe

direction of Dr. Ezatollah Negahban (Negahban 1973). Sagzabad, locally known as Ghara Tepe (Black mound), is an oval mound extending over 14 hectares, in which remains from the Early Bronze Age to the Iron Age were recovered (Malek Shahmirzadi 1977). Sagzabad is a sedentary village settlement and hundreds of such archaeological settlements have been identified in this plain up until now (Fazeli and Aliyari 2006).

The Qazvin plain is located between the two large mountain chains of Alborz in the northeast, which separate it from the Caspian Sea and the Zagros mountains in the southwest. There is a wide diversity of important faunal species in this plain, such as the Persian onager, goitered gazelle, caracal, jungle cat, wildcat and migratory birds. Among these, the Persian onager and the goitered gazelle are now endangered species. Qazvin province is characterized by two types of forest and grassland vegetation and Qazvin plain is covered by the most extensive grasslands in the province. Despite economic developments, this region has preserved its agricultural and pastoralist characteristics, as can be seen by the presence of traditional sheep and goat husbandry alongside dry and irrigated farming.

Haftavan Tepe is located in the middle of the small plain of Salmas, in the north-western part of the Lake Urmia basin, and is one of the largest archaeological sites in the province of Western Azerbaijan in Iran (Burney 1972). The surface of the mound extends over 22 hectares and was excavated during the 1970s under the direction of Charles A. Burney (Burney 1973). The excavation at Haftavan Tepe took place over four seasons and eight levels of occupation were exposed, yielding architectural remains dating from the Early Bronze Age through to the very Early Islamic period. The archaeological evidence and traces of urbanism in Haftavan Tepe show that this was a sedentary society and that the most important settlement period was from the Middle Bronze Age to the end of the Iron Age.

The settlement was built on a small plain with specific characteristics, such as water supplies and soil fertility (Burney 1970). Dry and irrigated farming developed in this region due to the high degree of precipitation and the diversity of water supplies, such as rivers and lakes. The province of Western Azerbaijan is known as one of the most important habitats in Iran due to its location and

topographical structure. The main animal species in this region are wild caprines, red deer, wild boar, brown bear, grey wolf, rabbit, red fox, leopard, squirrel and diverse migratory birds that spend the winter in this area. The vegetation in this region is mostly composed of forests and grasslands due to the high degree of humidity and the altitude. The forests are mainly oak forests, which are very resistant to cold temperatures. The region is covered by abundant and wet grasslands and water buffalo husbandry is very common (Cultural Atlas of Iran, af.samta.ir).

Faunal spectra of Tepe Sagzabad and Haftavan Tepe during the Iron Age

The archaeozoological concept of an archaeological site is defined quantitatively by the faunal spectrum, which is the percentage of different animal species in a site. One of the main problems with these studies is the state of bone preservation, which directly affects the quality and the quantity of the materials. Different factors like butchering, cooking and also natural events occurring after throwing the bones away or after the death of an animal, called taphonomy, affect the number of bone remains. For instance, the number of bones in a sheep skeleton is more than 200, but this can vary between 5 and 500 bones during excavation by an archaeologist. Over the past seven decades, archaeozoological methods have progressed in parallel with the development of archaeozoology and the use of faunal remains in order to reconstruct the past subsistence economy. By taking account of human and taphonomic factors, archaeozoological methods have been trying to record the modes of exploitation of natural resources and the environment. In this regard, in order to quantify the faunal remains, different scales using simple or complex mathematical equations are used. The number of identified specimens (NISP) and the minimum number

of individuals (MNI) are among the most important scales, mentioned above. However, these scales alone cannot validate the analyses and statistical tests are required.

The parametric and nonparametric statistical tests most commonly applied in archaeozoology, considering the number of remains, are as follows: Percentage difference test, Confidence interval and Pearson's chi-squared test (χ^2). These tests are performed in order to evaluate the reality of the quantitative observations. In this paper, the statistical tests and chart drawing are applied using Past and Excel software. Past (Paleontological statistics) is specialized statistical software for analyzing scientific data using mathematical and statistical operations, charts, univariate or multivariate analyses and ecological, morphometric and stratigraphic analyses.

In this section, we will discuss the differences between the faunal spectra of Tepe Sagzabad and Haftavan Tepe during the Iron Age (Mashkour 2001; Mohaseb 2012, 2013; Mohaseb and Mashkour 2017). The number of animal bone remains in Sagzabad and Haftavan Tepe during the Iron Age is 9,816 and 177 respectively. The identified animals in both sites are mainly domestic and wild caprines (sheep and goat), cattle, equids (onager, horse, ass and hybrids), deer, gazelle, suids (pig and boar), camelids, carnivores (dog, fox and felids), birds and the tortoise (Table 1 and Fig. 2). The non-herbivore category consists of carnivores, birds and the tortoise.

The faunal spectra are represented on the basis of the contribution of the different groups of animals in each site, which show the relative importance of the animals. In Sagzabad, domestic caprines, followed by equids and cattle, are the most important species. The other species are relatively poorly represented in this site. Based on studies of equid morphology in Sagzabad, this group consists of a high proportion of onager and a lower contribution of horse, ass and hybrids. Meanwhile, it could be mentioned

Table 1. Faunal spectra of Tepe Sagzabad and Haftavan Tepe during the Iron Age.

Taxa	Sagzabad		Haftavan Tepe	
	NISP	NISP%	NISP	NISP%
Caprini domestic	5153	52.5	56	31.6
Caprini wild	345	3.5	0	0
<i>Gazella</i>	487	5	1	0.6
<i>Bos</i>	1410	14.4	80	45.2
<i>Equus</i>	1963	20	36	20.3
<i>Sus</i>	232	2.4	0	0
<i>Cervus</i>	11	0.1	4	2.3
<i>Camelus</i>	43	0.4	0	0
Non-herbivore	172	1.8	0	0
Totla	9816	100	177	100

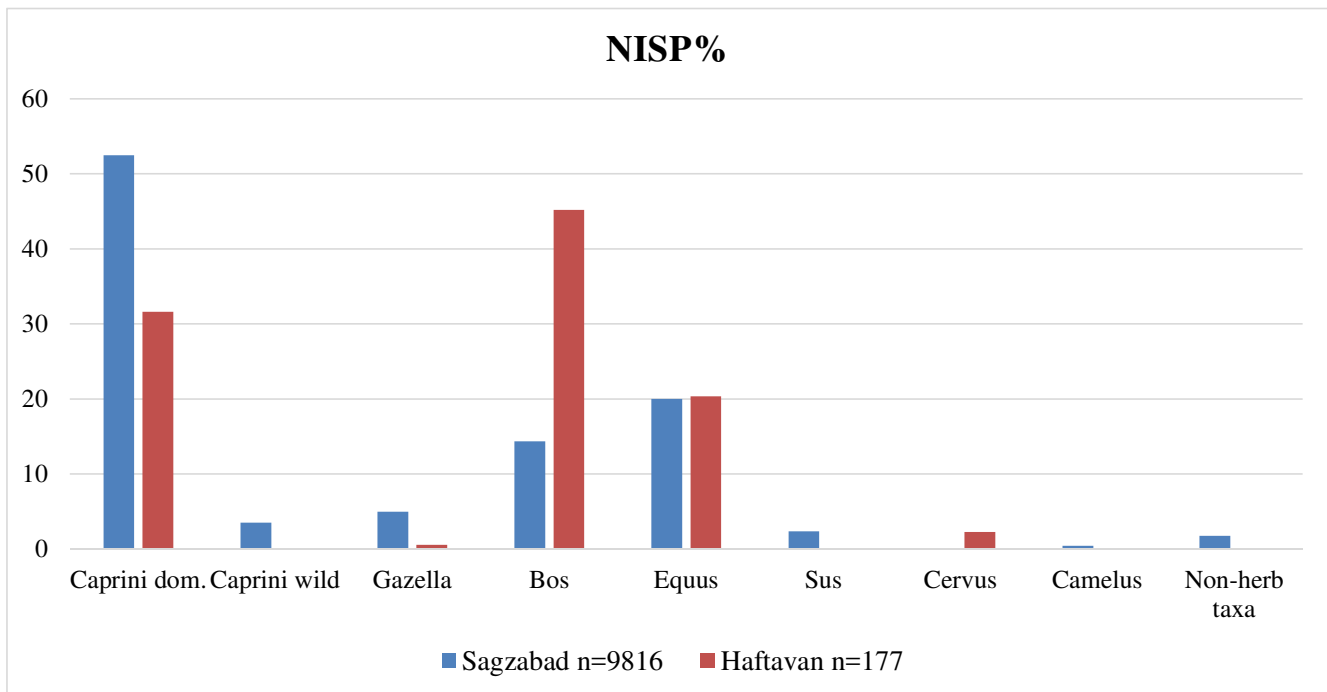


Fig. 2. Faunal spectra of Tepe Sagzabad and Haftavan Tepe during the Iron Age

that the main characteristic of Sagzabad is the importance of wild species, such as wild goat and wild sheep, onager, gazelle, wild boar and carnivores.

In Haftavan Tepe, cattle, followed by domestic caprines and equids (ass and hybrids) are the most important species. The other animals are very poorly represented, which could, of course be due to the lack of data. One of the statistical consequences of the lack of data is that the rare species are less likely to be represented.

Due to the quantitative differences between these two assemblages, and in order to validate them, it is necessary to use statistical methods. One of the ways of doing this is to estimate the confidence interval (Fig. 3). A confidence interval gives an estimated range of values likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data (Easton and McColl 1997). The equation used to obtain the confidence interval is as follows:

$$IC_{1-\alpha} = \left[p - u_{\alpha} \sqrt{\frac{p(1-p)}{n}}; p + u_{\alpha} \sqrt{\frac{p(1-p)}{n}} \right]$$

As some of the animal groups from Haftavan Tepe are not present in Sagzabad and are therefore not statistically significant, we decided to eliminate or regroup some of these animal groups. As shown in Fig. 3, wild caprines, suids, camelids and non-herbivores are eliminated and

only the four economically important groups, comprising domestic caprines, cattle, wild species (gazelle and deer) representing hunting activities and equids, including domestic and wild forms are considered.

There is no overlap between the intervals of domestic caprines and cattle in Sagzabad and Haftavan Tepe, whereas this difference does not exist for equids. Although our knowledge of the equids from both sites shows that wild forms predominate in Sagzabad and domestic forms are dominant in Haftavan Tepe, the general contribution of equids is almost the same. The difference between the wild groups including gazelle and deer is not significant either.

In order to validate the results from the confidence interval, we use the statistical chi-squared test (χ^2). The Pearson's chi-squared test (χ^2) is one of the nonparametric statistical tests applied when there are two categorical variables from a single population. It is used to determine whether there is a significant association between the two variables (www.stattek.com) (Fig. 4 and Table 2).

On the basis of the chi-squared test (χ^2), the two sites are significantly different and the difference is mainly between cattle, followed by caprines. The p value (probability) from this test is less than 0.001, which represents highly significant differences between Sagzabad and Haftavan Tepe. For now, we can conclude that the main difference between Sagzabad and Haftavan Tepe concerns cattle, and therefore we can continue examining cattle populations and husbandry in both regions. We will first focus on the morphological characteristics and then on the kill-off

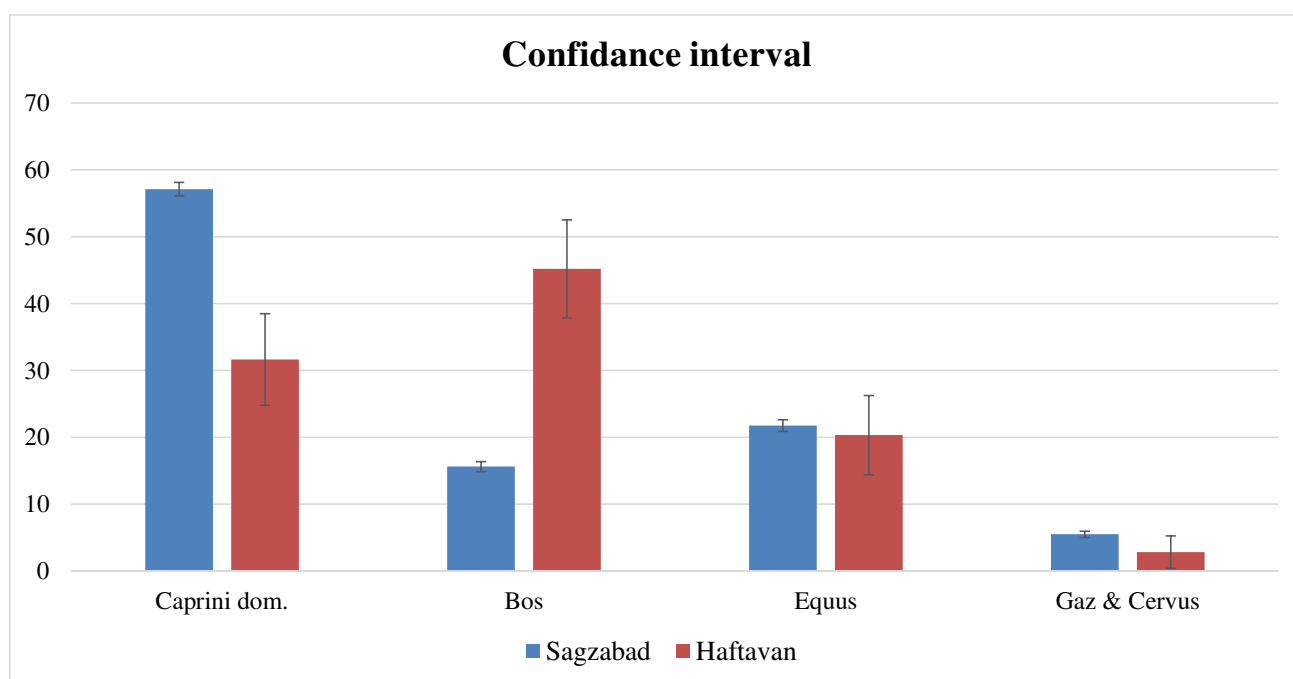
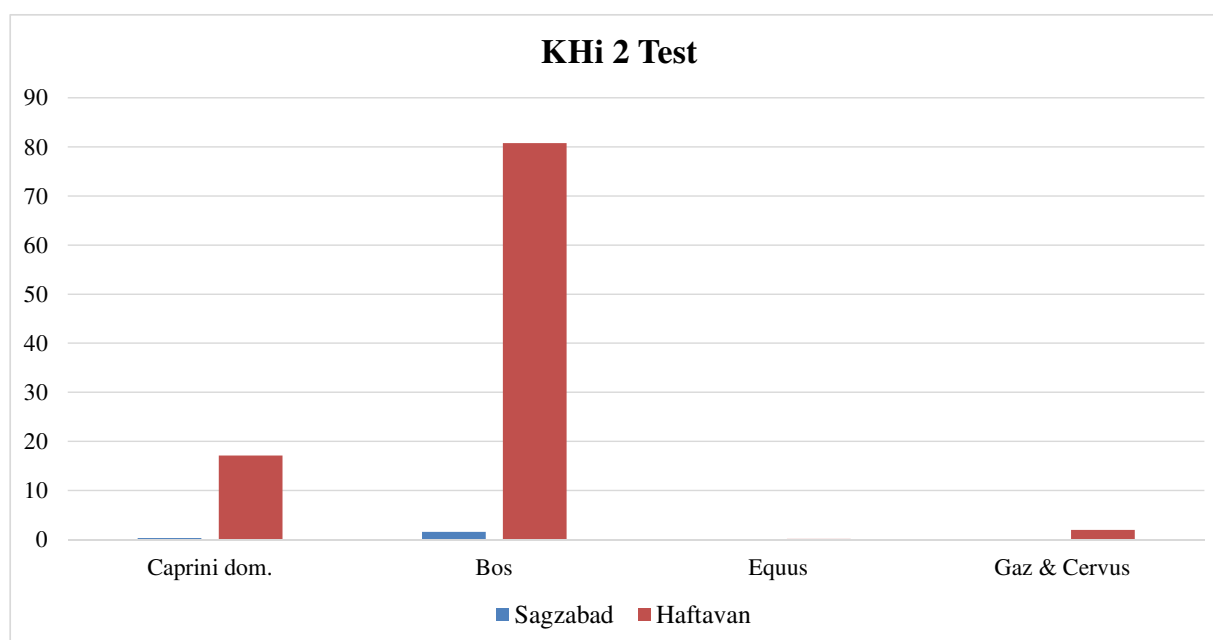


Fig. 3. Faunal spectra of Tepe Sagzabad and Haftavan Tepe during the Iron Age using the confidence interval

Fig 4. Pearson's chi-squared test (χ^2) in Tepe Sagzabad and Haftavan Tepe during the Iron Age.Table 2. Pearson's chi-squared test (χ^2) in Tepe Sagzabad and Haftavan Tepe during the Iron Age

Contribution	Caprini dom.	Bos	Equus	Gaz & Cervus
Sagzabad	0.383	1.803	0.003	0.044
Haftavan	19.503	91.902	0.158	2.247
KHi2	Probability	Degree of freedom		
113.753	1.70788E-24	3		

patterns, which reflect both the ecological characteristics and the modes of animal husbandry.

Morphological characteristics

One of the most important aspects of archaeozoology is to identify the morphological development of the animals in response to ecological changes, or human factors, including cultural factors, and also different types of animal husbandry. Animal evolution during domestication or breeding is a good example of these changes. Different biometric methods are used to substantiate morphological development. These methods enable us to compare different animal populations synchronically and diachronically. In biometry, the measurements of different animal bones are compared using different methods of analysis including univariate, bivariate or multivariate methods. In archaeozoology, one of the most common biometry methods is the Log Size Index (LSI). With this method,

it is possible to compare the biometric characteristics (including all measurements, such as length, width and depth of all bones) of the different animal populations belonging to a single species.

By using this method, rather than univariate and multivariate analyses, it is possible to compare all the bone measurements simultaneously. This technique was developed in order to graphically compare the relative rather than the absolute dimensions of a number of animals or groups of animals (Simpson *et al.* 1960). The first step in this method is to convert all the measurements into logarithms so that the measurement scales, which can be very different because of morphological differences between bones such as the femur and patella, become similar. With this method, one specimen or a group of specimens is chosen as reference data for comparisons. Then, the difference between the logarithmic value of the reference and each of the other specimens is calculated (Meadow 1999): $d = \log X - \log \text{reference data}$. The main

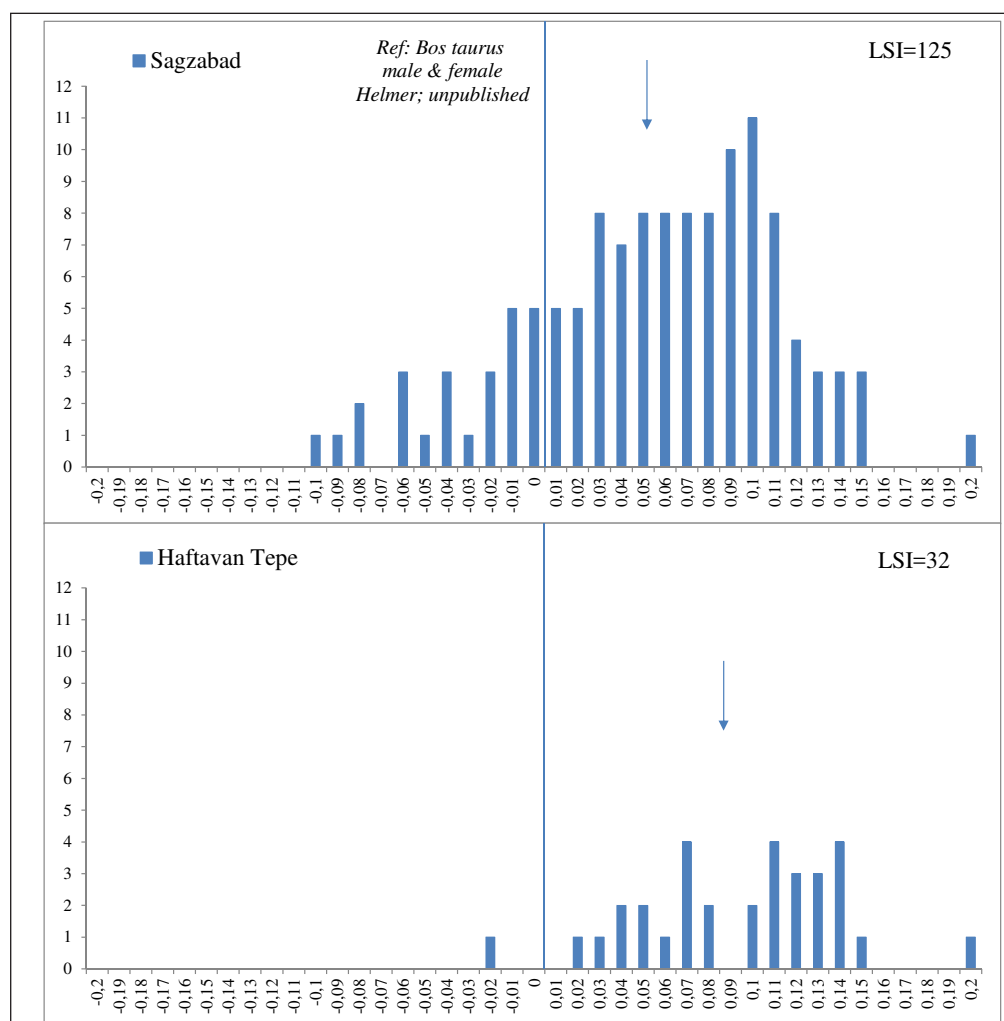


Fig. 5. Log size index (LSI) diagrams in Tepe Sagzabad and Haftavan Tepe during the Iron Age. The LSI is the number of measurements used for this analysis and the small arrow shows the average size. The zero line represents the reference data.

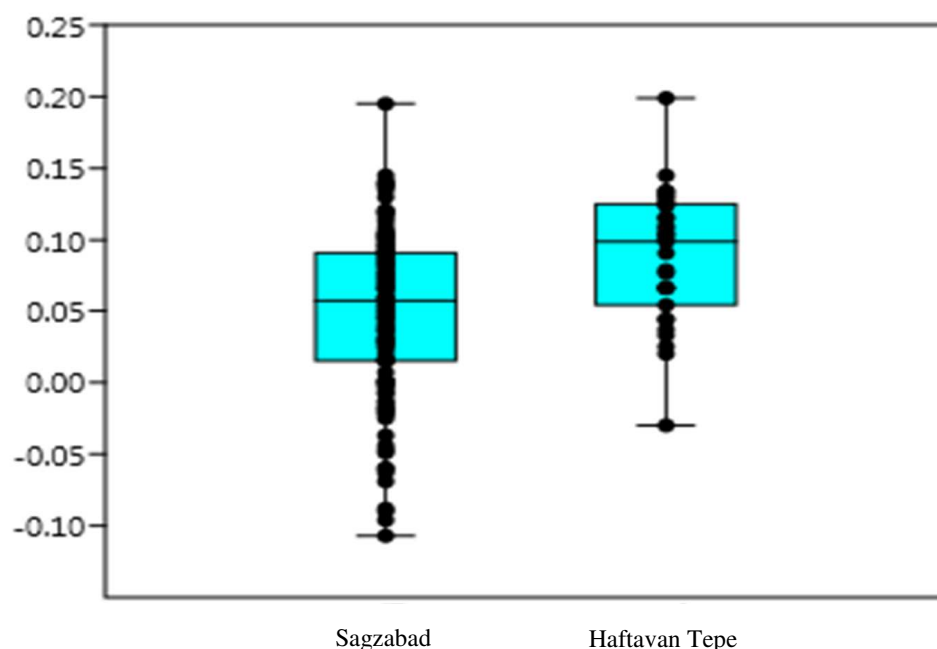


Fig. 6. Box plot of logarithmic data for cattle measurements in Tepe Sagzabad and Haftavan Tepe during the Iron Age

Table 3. Student t test and the significance of size difference in cattle from Tepe Sagzabad and Haftavan Tepe during the Iron Age

Tests for Equal means			
Tepe Sagzabad	Haftavan Tepe		
N:	125	N:	32
Mean:	0.048904	Mean:	0.088906
95% conf:	(0.059163 0.038645)	95% conf:	(0.10555 0.072264)
Variance:	0.0033584	Variance:	0.0021306
Difference between means:	0.040002		
95% conf interval (parametric):	(0.061837 0.018167)		
95% conf interval (bootstrap):	(0.05852 0.021259)		
t:	-3.619	p (same mean):	0.0003999
Uneq. var. t:	-4.1381	p (same mean):	0.00011336
Monte Carb permutation	p (same mean):	0.0003	

aim of this analysis is to obtain descriptive statistical data, such as the number of data, the minimum, maximum, average, median, standard deviation, etc.

The LSI diagrams for the sites of Sagzabad and Haftavan Tepe are represented in Fig. 5. The reference measurement for this analysis is the biometric data from two modern male and female cattle from France.¹ The first observation of these diagrams is that both the

1. Helmer, unpublished data

Sagzabad and Haftavan Tepe cattle populations could be allocated to domestic forms. As shown in the diagrams, the measurements used for this analysis from Sagzabad are much more abundant than those from Haftavan Tepe. For Sagzabad, a lower minimum value and a rather similar maximum value in comparison with Haftavan Tepe show that the interval between measurements and therefore the diversity of cattle size is higher for Sagzabad. The average of the measurements shows that cattle size is generally larger in Sagzabad than in Haftavan Tepe. In both sites,

one measurement, which is much higher than the others, could be representative of a castrated animal, although the probability of wild forms must also be considered.

The logarithmic data for the cattle of Sagzabad and Haftavan Tepe are shown as box plots in Fig. 6. A box plot is a convenient way of visually displaying groups of numerical data through their quartiles. The upper and lower lines in the box are known as the upper and lower quartiles respectively, and the middle line shows the median. The lines extending parallel from the boxes are known as the "whiskers", which are used to indicate variability outside the upper and lower quartiles. The upper and lower extremes show the maximum and minimum and the dots in-line with whiskers are known as outliers, which show data distribution. In box plots, just like in the LSI diagram, the size interval is higher in Sagzabad and the average is larger in Haftavan Tepe.

But these observations are not sufficient to decide about the significance of the differences or similarities between the two sites. Information concerning the descriptive statistics, and in particular the comparison of the averages test and the Student t test are capable of answering this question. Considering the p value (probability) results from both sites, which is less than 0.001, the difference in cattle size from Sagzabad and Haftavan Tepe is significant (Table 3).

Here, we examine the data from the mixture analysis (Fig. 7 and Table 4). In each diagram, the abundance of measurements is divided into two groups, shown by red curves. The small and large groups represent females and males respectively. In Sagzabad, about 66% of the animals could be attributed to females and 34% to males whereas this ratio is different in Haftavan Tepe: 71% females to 29% males. This result provides an image of demographic herd structure and considering data distribution and statistical tests, both sites represent a normal and logical herd structure in which females make up the majority. We will discuss this aspect further below.

Regarding the results obtained by the morphological and biometrical analysis of cattle in Sagzabad and Haftavan Tepe, we will focus on the kill-off patterns of this species in both sites during the Iron Age.

Kill-off patterns

Information concerning the age at which animals are slaughtered gives valuable indications about animal management. This depends on different factors: the characteristics of herded animals, environmental conditions as well as the needs for different products in society (Payne 1973). The methods used to determine the age of animals

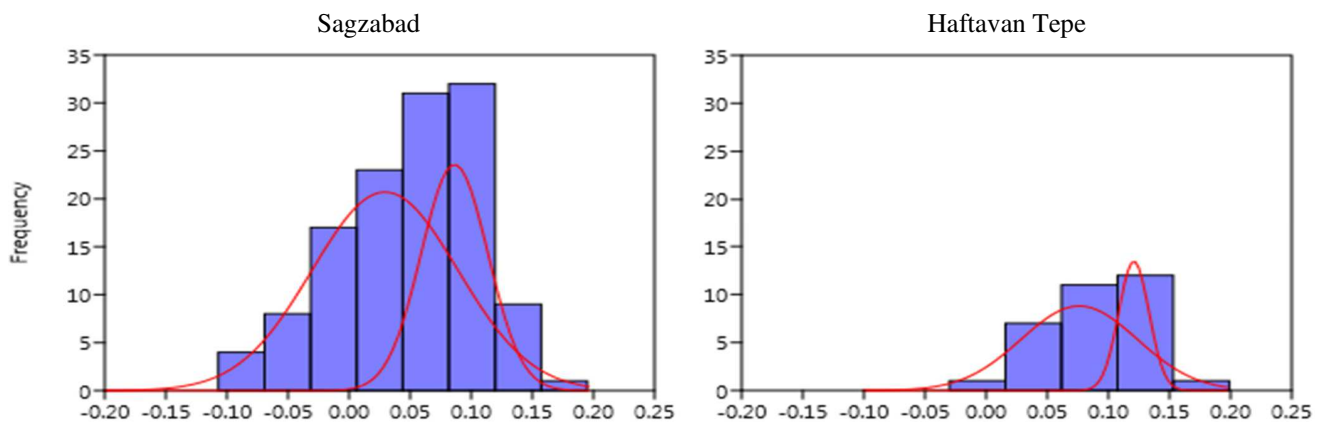


Fig. 7. Mixture analysis in Tepe Sagzabad and Haftavan Tepe during the Iron Age. Red curves represent female and male cattle groups in both sites

Table 4. Mixture analysis statistical data in Tepe Sagzabad and Haftavan Tepe during the Iron Age

Sagzabad			Haftavan Tepe		
Prob	Mean	Stdev	Prob	Mean	Stdev
0.065724	0.029403	0.059739	0.71477	0.076157	0.047503
0.34276	0.086297	0.027373	0.28523	0.12086	0.012391

at death provide information about the use of different products (meat, milk and dairy products, wool and skin).

The kill-off pattern for cattle is based on the growth stages and the sequence of deciduous and permanent teeth wear stages on lower cheek teeth, (Ducos 1968; Grant 1982; Silver 1969; Higham 1967; Grigson 1982).

The understanding of kill-off patterns in cattle is based on animal physiology (Balasse *et al.* 2000). Cows need a stimulus to produce milk, which can be the manipulation of the udder, or various visual, auditory or olfactory stimuli (Metge 1990). The high representation of young animals (from birth to 2 years old) points to milk processing (Tresset 1996; Balasse *et al.* 2000). The presence of these

young animals is generally associated with the presence of old females (6.5–9 years old). Meat is obtained from slaughtered animals between 2–4 and 4–6.5 years old, where the latter clearly yield less tender meat. The presence of very old animals points to the use of cattle for their strength (more than 9 years old).

On the basis of this source of information, the herding strategies in Sagzabad and Haftavan Tepe based on the reconstruction of the kill-off pattern of 107 and 37 teeth respectively, are more or less the same (Fig. 8). The most important difference is the absence of animals slaughtered at the age of 4–6.5 years old in Haftavan Tepe and at the age of 11.5–16 years old in Sagzabad, which in Haftavan

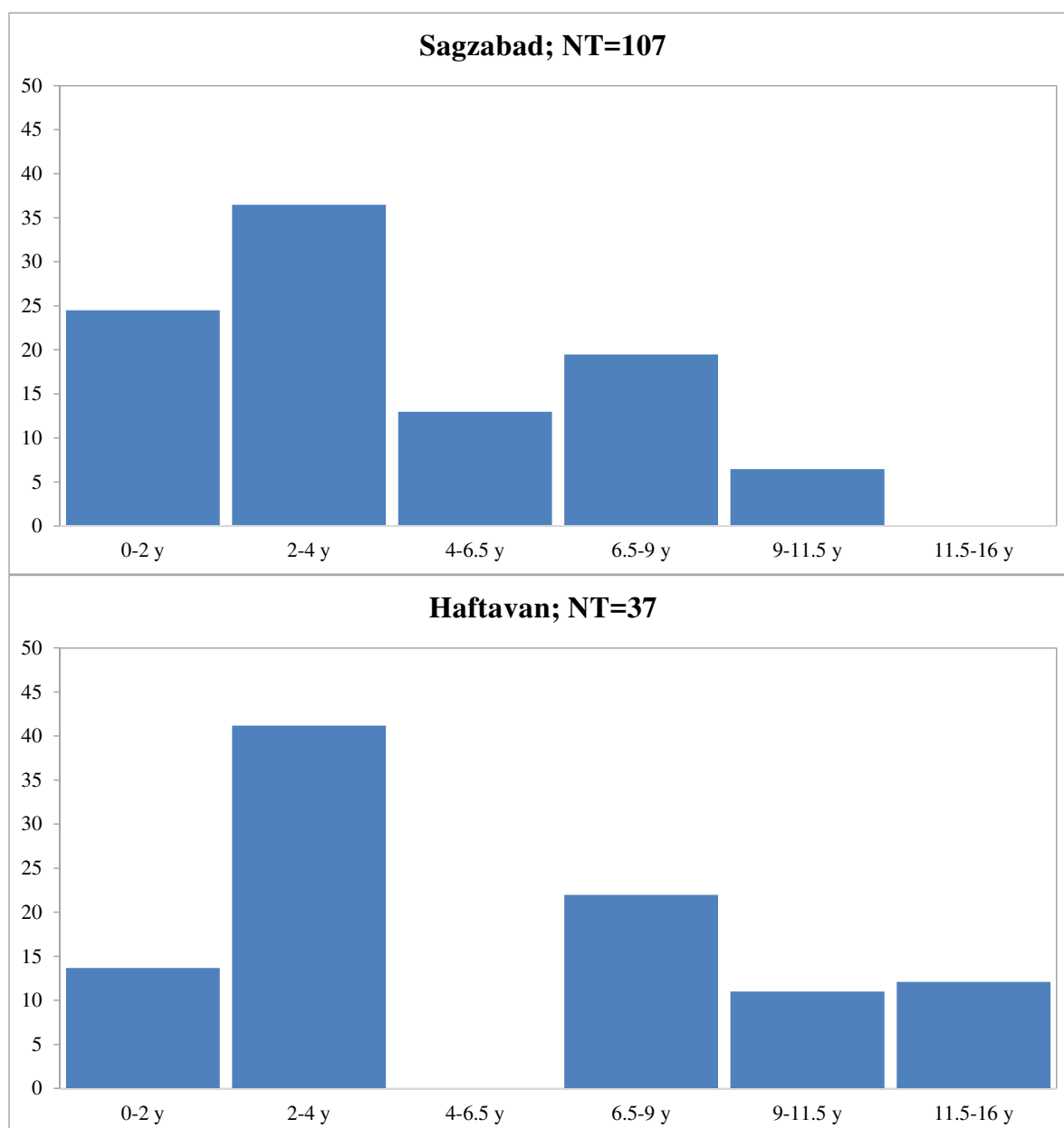


Fig. 8. Cattle kill-off patterns in Tepe Sagzabad and Haftavan Tepe during the Iron Age. NT is the number of teeth used for the analyses

Tepe could be due to the lack of data. The peak at the age of 2-4 years old at both sites (41% in Haftavan Tepe and 36.5% in Sagzabad), which are most probably males, demonstrates the consumption of high quality meat. In Sagzabad, after the age of 2-4 years old, the slaughter peak is at 0-2 years old and 6.5-9 years old in Haftavan Tepe. The cattle slaughtered at the age of 6.5-9 years old are old females with decreased milk quality. At the age of 0-2 years old, most of them are probably animals slaughtered between 6-9 months old. This group consists of the males kept alive to obtain milk from females and then slaughtered for economic reasons, such as herding costs. The contribution of slaughter at the age of 4-6.5 years old, which is representative of less tender meat, is low (about 13%) in Sagzabad. The use of cattle as draught animals clearly points to the development of agricultural practices such as ploughing (Sagona 2013). This aspect is more marked in Haftavan Tepe (23%) and can be confirmed by bone pathologies and pressure on lower organs (Fig. 9).

Discussion

This paper, which presents the archaeozoological analyses of the two Iron Age faunal assemblages of Tepe Sagzabad and Haftavan Tepe, contributes to highlighting differences and similarities in animal exploitation in two different regions of north-western Iran. We will discuss the possible reasons for these differences below.

This analysis is based on archaeozoological methods combining quantitative and qualitative approaches. In

order to confirm or refute observations, statistical tests seem necessary. Statistical tests used in archaeozoology are the same as those applied in biology and ecology.

In this paper, we also aimed to present a didactic assessment in order to use the statistical analyses to elaborate the hypothesis of our work.

We also characterized:

1- The faunal spectra from both sites by:

a- The quantification of anatomically and taxonomically identified skeletal remains.

b- The use of statistical tests to examine the hypothesis of differences or similarities of the two assemblages, in terms of the relative contribution of the different constitutive elements (confidence interval and chi-squared test χ^2).

2- The morphology of animal populations studied by:

a- The use of biometry, the measurements of some parts of the bone using a precise protocol.

b- Quantitative and qualitative analysis of these measurements by mathematical transformation for a general analysis of all measurements (Log Size Index method).

c- The use of statistical tests to examine the hypothesis of differences or similarities between the two animal populations, which are bovines.

d- The use of mixture analysis for the reconstitution of the demographic profile of the herd.

3- Quantitative and qualitative analysis of tooth remains.

On the basis of solid statistics, each analysis leads us to the next step.

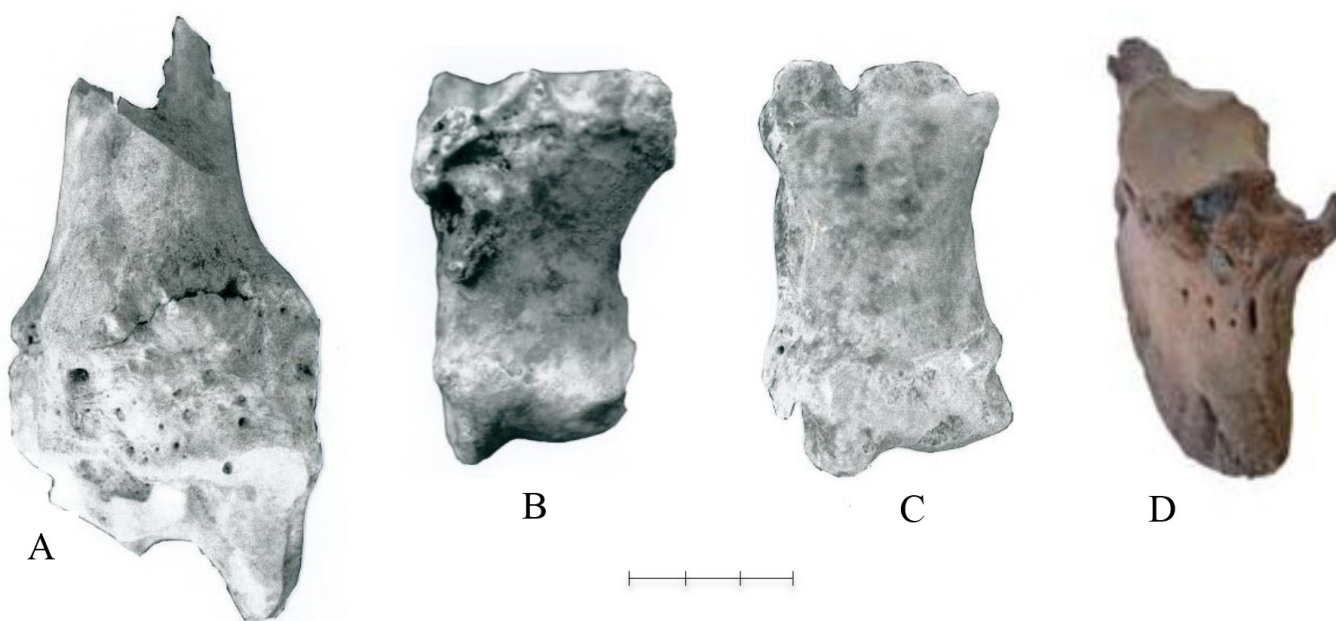


Fig. 9. Bone pathologies and pressure on lower organs in draught cattle in Tepe Sagzabad (A: radius, B and C: first phalanx) and Haftavan Tepe (D: third phalanx) during the Iron Age.

The assemblages from Tepe Sagzabad and Haftavan Tepe are contemporaneous. However, they are from sites situated in two different ecological regions, even during prehistoric times. The faunal spectrum of Sagzabad clearly shows that the site is in a steppe environment, as the presence of gazelle and hemione remains indicate an arid environment. However, the presence of cervids and suids shows the presence of woods or humid environments around the site. Despite the fact that the current environment of Qazvin Plain is completely degraded by excessive anthropization, which caused the destruction of natural fauna and flora, it is still possible to reconstruct the natural environment of Qazvin Plain in the past, by using historical archives and photography from the past two centuries. The position of this plain, surrounded by the Alborz Mountains, and the presence of seasonal rivers, allows for the development of several ecological niches and diversified habitats, leading to the simultaneous exploitation of animals from arid and humid environments.

In parallel, Haftavan Tepe is a site situated in Azerbaijan, near Urmia Lake, where the climate is less contrasted than in Qazvin Plain. The importance of cattle in this assemblage signifies a more suitable environment for herding.

Statistical analyses emphasized these differences, despite the quantitative disparity of bone remains in the assemblages. Haftavan Tepe is characterized by cattle herding and secondarily by caprine herding. Sagzabad is characterized by caprine herding and the important contribution of hunting.

However, it should be noted that statistical analyses have also their limits. The representation of equids in Sagzabad and Haftavan Tepe is a good example of this. Although the proportion of equids in both sites is nearly the same, the morphoscopic and morphometric analyses of the bones showed that the equids from Sagzabad are comprised of wild species whereas those from Haftavan Tepe represent domestic forms.

Conclusion

Finally, this comparative archaeozoological study allows us to highlight two types of subsistence economies in two regions of Iran during the Iron Age. These observations are fundamental in order to realize the diversity of cultures during the Iron Age. Although the agro-pastoral characteristics of both communities are evident, particularly with the presence of pathologies on cattle bones, we can see that Haftavan Tepe is more dependent on herding and Tepe Sagzabad on pastoralism, and that hunting is a more important activity in the latter site. In addition, environmental constraints are partially responsible for the economical orientation of past societies, even if they are not the only factors.

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