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Maximum entropy and GIS: An approach to assessing the settlement pattern of the Ninevite 5 culture (3000–2500 BCE) in the Upper Great Zab region (Erbil Province, Kurdistan region of Iraq)

Biel Soriano-Elias [a,*], Francesc Xavier Garcia-Ramis [b], Miquel Molist [c]

[a] FI Joan Oró 2023. SAPPO-GRAMPO research group, Department of Prehistory, Universitat Autònoma de Barcelona, Mòdul de Recerca A, Parc de Recerca de la UAB, 08193 Bellaterra, Barcelona, Spain

[b] Prehistoric Archaeology. Assistant Researcher in the SAPPO-GRAMPO research group, Department of Prehistory, Universitat Autònoma de Barcelona. Mòdul de Recerca A, Parc de Recerca de la UAB, 08193 Bellaterra, Barcelona, Spain

[c] PI of the SAPPO-GRAMPO research group, Department of Prehistory, Universitat Autònoma de Barcelona. Mòdul de Recerca A, Parc de Recerca de la UAB, 08193 Bellaterra, Barcelona, Spain

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ABSTRACT

The Ninevite 5 culture extended across a large area throughout the Northern Mesopotamian plains, from the first ranges of the Zagros Mountains to the east, and the course of the Khabur River, in the plains of the Syrian Jazeera (Hassakah Province), to the west. This wide extension, combined with modern political divisions, the heterogeneous character of surveys undertaken in past decades, and uneven investigation efforts, has provided an incomplete general image of the settlement pattern of the Ninevite 5 period. This study addresses an attempt to describe the settlement pattern of a group of sites belonging to the Ninevite 5 period in a region in the Kurdistan of Iraq, an area known as UGZAR (Upper Great Zab Archaeological Survey). In order to fulfil our objective, the area has been studied using a combination of machine learning and GIS software to establish the settlement pattern through the modelling of several geographical and political variables. To do so, we applied the Maximum Entropy modelling to the UGZAR region during this period. Ultimately, this approach aims to overcome the fragmentary vision that currently rules the research on this period and offers an initial study of the Ninevite 5 settlement patterns and communities.

1. Introduction

The Ninevite 5 period in northern Mesopotamia has often been defined by a painted or incised/excised style of pottery that appeared in this region during the first half of the third millennium B.C. (ca. 3000–2500BCE). Since it was first described by Max Mallowan in his prehistoric pit in Nineveh in the early´30 s (Thomson & Mallowan, 1933), our knowledge of almost all aspects of this culture has improved greatly thanks to the development of many archaeological projects throughout northeastern Syria and northern Iraq. The excavation of key sites such as Tell Leilan (Mayo & Weiss, 2003; Ristvet, 2005; Weiss, 2013) in Syria or Telul eth-Thalathat V (Fukai et al., 1974) and the salvage excavations in the Eski-Mosul dam area (north of Mosul city), at sites such as Mohammad Arab (Roaf, 1984) or Tell Karrana 3 (Wilhelm & Zaccagnini, 1993; Rova, 2003) in northern Iraq, have allowed us to reconstruct complete sequences of pottery and obtain comprehensive radiocarbon dating for the Ninevite 5 period, a matter that has received very recent contribution in the ARCANE project (Lebeau, 2014; Arrivabeni, 2019). Nevertheless, even with this recent progress, our understanding of this culture remains relatively poor, with focused studies only emerging from the last decades of the 20th century (Schwartz, 1987; Roaf & Killick, 1987), but with important contributions in the first decades of the 21th century (Killick and Roaf, 2003; Weiss, 2003; Weiss & Rova, 2003; Lebeau, 2012; Laweka, 2016; Rova, 2019). Additionally, we need to take into account the disparity of the data available for each region.

For their part, the new technologies applied to the study of the Ancient Near East have undergone a great development. More precisely, the detection of archaeological sites and remote studies through the use of remote sensing technology have grown greatly. In Mesopotamia, the

* Corresponding author at: FI Joan Oró 2023. SAPPO-GRAMPO research group, Department of Prehistory, Universitat Autònoma de Barcelona, Mòdul de Recerca A, Parc de Recerca de la UAB, 08193 Bellaterra, Barcelona, Spain.

E-mail addresses: biel.soriano@uab.cat (B. Soriano-Elias), xiscogarciaramis@gmail.com (F.X. Garcia-Ramis), miquel.molist@uab.cat (M. Molist).

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tendency of sites to create artificial mounds made of accumulated sequences of mudbrick structures has favoured these remote sensing methods, as the artificially elevated surface of the mounds greatly contrasts with the surrounding flat terrain that dominates most of the land (Hammer & Ur, 2019; Starková, 2020).

With respect to spatial analysis, recent studies focusing on particular regions have emerged (Wilkinson and Tucker 1995; Ur 2002; 2010; Kolinski, 2017). The studies on the settlement patterns or spatial distribution of sites conducted focusing on all the extensions of the Ninevite 5 culture, despite the existence of some important contributions (Rova, 1988; Laweka, 2019), are scant. This is due to two main reasons: first, the emergence of specific archaeological studies focusing on this culture has been relatively recent; second, its great extent necessitates the collection and management of an enormous amount of information. Furthermore, the utilisation of statistical regression and machine learning methodologies in this spatial analysis, which has undergone substantial advancement in recent years (Alwi Muttaqin et al., 2019; Castiello & Tonini, 2021; Jones, 2017; Noviello et al., 2018; Yaworsky et al., 2020), is limited in the present region of study.

The aim of this paper is to address this question by studying the settlement pattern of this period from a regional perspective, as well as to establish the basis for future analyses involving and comparing other regions within the Ninevite 5 culture's extent. The Maximum Entropy modelling will be used to assess the distribution of the archaeological assemblages from the UGZAR region. This approach aims to provide an initial understanding of the features that influenced the distribution of sites during this time.

2. Historical background and problematics

The Ninevite 5 culture was developed throughout an extensive region roughly encompassing the area between the Zagros Mountains in Iraq and the region known as the upper course of the Khabur River, in the Syrian Jazeera, a region located in the northeastern corner of this modern country (Fig. 1). The Syrian Jazeera plains and the northern Iraqi Jazeera (just east of the border) display a flat land continuum with no major geographical features between them and the Tigris River flow. Only isolated mountainous massifs are dispersed from the Syrian border to the Tigris (the most important peak is the Sinjar mountain, 920 m above sea level). In Syrian territory, only the Jebel Abd al-Aziz, a mountain that is 1500 m high, stands out over the mostly flat terrain. Elena Rova (1988) was one of the first scholars to attempt to define the boundaries of the culture, but her conclusions need to be updated with the progress made by recent research projects, such as the aforementioned projects in the Kurdistan Region of Iraq.

Currently, the boundaries to the east are clearly delimited by the very first ranges of the Zagros Mountains, but the western limits are vaguer. The Syrian area is determined by the Khabur River and its tributaries, which extend across a large flat area suitable for agriculture and husbandry. However, the Early Bronze Age sites identified in the Upper Khabur and Middle Khabur River courses presented a discrete presence of Ninevite 5 pottery (Fig. 1). For instance, sites in the Middle Khabur excavated during a salvage project prompted by a dam construction (Monchambert, 1984) yielded in some cases scant percentages of less than 1 % of Ninevite 5 pottery (Lebeau, 1993: 259-60). However, it is also true that the percentages of material are certainly influenced by the limited excavated surface belonging to this period in some salvage excavations. In the upper course of the Tigris, within the Turkish territory, additional salvage excavations were conducted due to the construction of the Ilisu Dam (Valentini, 2012; Akçay, 2017; Ökse, 2019; Sağlamtimur, Batıhan and Aydoğan, 2020). Like in the Middle Khabur, Ninevite 5 pottery was recovered in varying quantities at some sites.

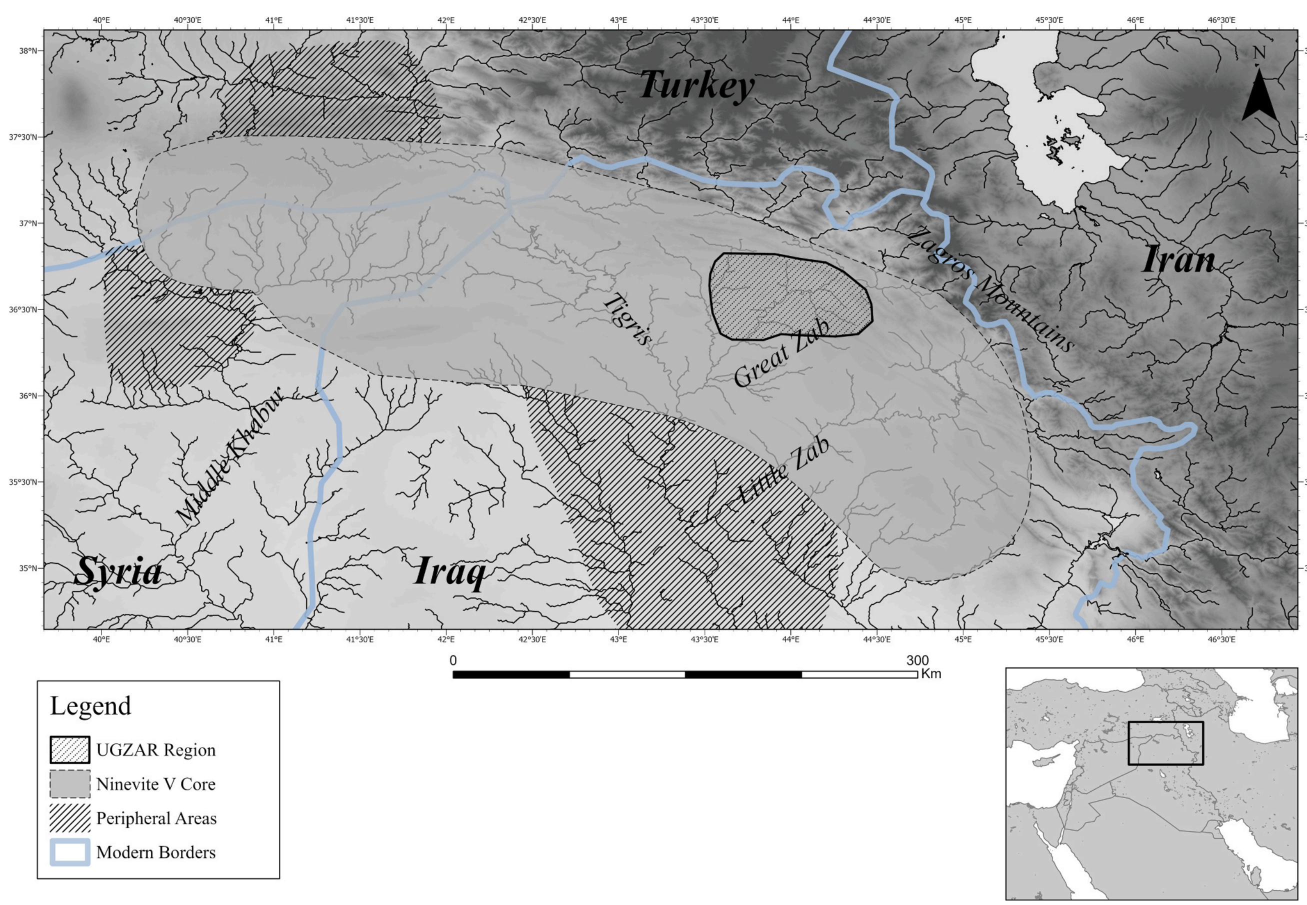

Fig. 1. Geographical Distribution of the Ninevite 5 Culture in Northern Mesopotamia.

However, some sites yielded no Ninevite 5 material, while in other locations, it was prominent, particularly in funerary contexts, alongside other pottery styles from different regions (Behm-Blancke, 2003). For these reasons, the presence of Ninevite 5 pottery in this area should be considered as an exogenous trading element, probably for prestige purposes. These two peripheral areas are marked with dashed lines on the map (Fig. 1).

Nevertheless, these areas cannot be excluded because, alongside with the material divergences, affinities were also found during excavations. For example, many excavations in the Middle Khabur documented the presence of 'grilled' plan buildings, interpreted as granaries, that have many parallels in the Eski-Mosul Dam area (Fortin, 1998; Roaf 2003: 320–321).

The core regions of the Ninevite 5 culture are located in regions adjacent to the course of the Tigris River in the Nineveh and Erbil provinces of northern Iraq, and also in the tributary rivers of the Khabur in Syria, which flow from the Taurus ranges to meet the main flow of the Khabur near the city of Hassakah. The sites in these regions yield complete assemblages of Ninevite 5 pottery, both decorated and undecorated, leaving no doubt of its affiliation within this cultural horizon.

Yet another problematic element in the study of the settlement patterns of the Ninevite 5 is the internal division of the period. The archaeological record seems to suggest that the settlement patterns of both the Early and Late Ninevite 5 periods could be substantially different. Unfortunately, the evidence to date is insufficient to evaluate them separately. In the study of the region around the site of Tell Leilan, in the Syrian Jazeera, a thorough survey conducted by a team from Yale University focused on the distinctions between the internal divisions of the Ninevite 5 period. As a result, they theorized that the patterns in the region differed; however, this study had few counterparts elsewhere (Ristvet, 2005; Arrivabeni, 2010).

Consequently, given the impossibility of testing internal divisions, we have decided to focus on the earliest part of the Ninevite 5 period, as forced by the selection of the UGZAR region as a case of study. According to the survey's results, most of the pottery found in the region belonged to the painted and early excised types, what suggests an early chronology in the pattern studied in the UGZAR region. This fact conditions this study, given the fact that most of what is known about the settlement pattern of the Ninevite 5 period directly derives from the later phase of the culture rather than the earliest. This is because all the urban-sized sites of the Ninevite 5 period only reached such dimensions toward the end of the period, thus representing the better documented and understood moment in the internal development of the Ninevite 5. For that reason, this study can be of great utility because it provides inferences about the settlement pattern of this lesser-known episode in the internal history of the Ninevite 5 period, and it could serve as a basis for future studies focusing on the same topic.

3. Archaeological surveys as a source of information

The vast extension of the Ninevite 5 culture has historically posed one of the greatest challenges scholars have had to face. Just to acquire a general vision on the magnitude of the data available, the thesis of one of this article's author compiled a comprehensive catalogue of sites, comprising more than 600 entries retrieved (Garcia-Ramis 2024). These entries contain all the available information about each site, including size, geographical coordinates, historical periods attested, and bibliography. However only one secluded region has been selected for this study for different reasons.

The first reason is that, given the massive size of the dataset available, the quality of the information for each individual site varies greatly depending on the available sources. Due to the nature of the study, we must rely on the information provided in the catalogues of surveys conducted by other scholars. Therefore, survey teams not always have published reports including list of sites, a feature that is absolutely necessary for statistical studies. In Northern Mesopotamia, regional surveys have been conducted from the early 20th century to the present (Mallowan, 1936; 1937; Lloyd, 1938; Meijer, 1986; Wilkinson & Tucker, 1995; Lyonnet, 2000; Ur, 2002; Ristvet, 2005; Ur & Wilkinson, 2008; Ur, 2010). However, the information provided is not always as complete as desirable.

Historically, the regions of Syria and Turkey have received far more attention than the northern Iraq plains due to political instability in that country. Throughout the 20th century, many archaeological surveys have been carried out in Syria, and additional surveys have been carried out in eastern Turkey in the last decade of the century and the 21th century (Algaze, 2012). However, with the eruption of the Syrian civil war, instability has forced scholars to move to new destinations, and the Kurdistan Region of Iraq, which is now stable and safe, has been one of the most important strongholds for foreign archaeologists in recent decades. This new and mostly unexplored destination prompted scholars to undertake survey expeditions, including the UGZAR among them (Gavagnin, 2016; Kolinski, 2017; Conati Barbaro et al., 2019; Ur et al., 2021). Nevertheless, many details, as well as complete reports and lists of sites, are still missing for most of these projects: therefore, a complete analysis of the data obtained by these teams is currently impossible.

Also, we are aware of the limits of surface collection: the estimated sizes of sites are often based on surface scatters, but surface material does not always necessarily represent all the periods to be found at each site. Also, the analysis of surface surveys is way less accurate than other techniques since many data can be obscured from surface collections due to several reasons. For instance, the article published by Guillermo Algaze on Entropic Cities was criticized by Piotr Steinkeller, who argued that Algaze had based large parts of his argument on the estimated size of the city of Uruk, obtained through surface surveys. However, Steinkeller states that the total area settled during the first quarter of the third millennium at Uruk is highly speculative, and ceramic scatters may not be sufficient to consider size data as conclusive. In this context, he argues that scatters may not only identify settled areas but also areas dedicated to other purposes, or even areas devoid of structures beneath the surface (comment by Steinkeller on Algaze 2018).

The size of each site per period typically used to be a mere estimation based on the scatter of artefacts, sometimes resulting in a rough approximation. This problem is more evident with larger, multiperiod mounded sites, where later occupations tend to obscure the earliest ones, burying all surface evidence of them. In such cases, only archaeological excavations can clarify the actual dimensions of each site for each period of occupation. However, the smallest sites presented a less problematic case because, even without excavations, if their size never exceeded that of a small village or hamlet, it can be concluded that these sites likely played this specific role throughout their history. Of course, other reasons may help to obscure or even completely cover entire sites, such as the alluvial deposits from rivers (Postgate, 1994: 48-50).

Other sources of information are feebler. One of these complementary sources is the Atlas of Archaeological Sites of Iraq edited by the Broad State of Antiquities of that country (Salman 1976). This Atlas is mostly a simple list of sites with chronological labels for each site listed, that are often too simple and give not much information. Some studies have been made on the information provided by this Atlas, like the studies of surface material made by Abu al-Soof (1968; 1970). However, it is also true that the pottery identifications made by this author are not always fully reliable, and many of his material classifications are, in fact, wrong. More recently, surveys in the Kurdistan region of Iraq have tried to utilize the Atlas, but the information obtained through this source is usually scant (Kolinski 2017).

The study of the distribution of settlements during this period has been recently tested, and several interesting results, though preliminary, have been obtained (Garcia-Ramis, 2024). For this analysis, the sites were classified into four groups based on their size. The boundaries of each group were defined by averaging the sizes of sites with known physical limits during the Ninevite 5 period. This classification is particularly relevant considering the taphonomic processes affecting most sites and the tendency for multi-period mounded sites to obscure the total extent of Ninevite 5 settlements, making them difficult to determine through surface surveys. Despite these challenges, the distribution of sites was considered to define possible hierarchical relationships between them. The sites were categorised as follows: the smallest sites (type one) ranged from zero to two hectares; the largest sites typically ranged between 10 and 15 ha during the early stages of the Ninevite 5 culture, but some grew to 90 (Tell Leilan) or more than a hundred (Hamoukar, Tell Mozan) (type four). Between these two ranges, our spatial analysis identified two additional categories: sites ranging from two to five (small-medium, type 2) hectares and from five to 10 ha (medium-large, type 3).

Even when these ranges could seem arbitrary, this system has been tested in other cases such as Tell Leilan (Ristvet, 2005) or Tell al-Hawa (Wilkinson & Tucker, 1995) with interesting results. When compared to the previous period, the Late Chalcolithic, it seems obvious that some villages multiplied their sizes, while a more or less evident network of secondary and tertiary sites appear to be scattered throughout the land. At some of the largest sites of the Ninevite 5 culture, such as Tell Brak, Tell Leilan, Tell Hawa and Hamoukar, the smaller sites gather together around the site, but at certain distances, in a possible hierarchical relationship in which the smaller ones never invade the area of the larger ones.

Nevertheless, sites larger than two hectares but smaller than 15 cannot be lumped together due to the different patterns of secondary sites and the difficulty of separating sites that fall directly on the divisor line between one group and the next. For this reason, considering that the smaller sites in group two could actually be classified as either group one or two and that the largest ones in group three could be classified as either group three or four, we decided to separate them into two groups rather than retain all of them in a single catch-all group.

As a result, a general pattern was observed in which type one settlements tended to cluster together around single sites belonging to type four, but type four sites were never located in a range less than 10 km one from another (perhaps both for subsistence and political reasons). Type two and three sites were also located close to type four sites, but in lesser numbers, thus suggesting a hierarchical organization in which type four sites conditioned the spatial distribution. However, it is also true that all the examples stated are located in the western part of the Ninevite 5 region, basically because there are much less data on regions in the eastern part, and only some regions in the Kurdistan of Iraq have sufficient published data to allow comparisons. For that reason, for this initial study, we have decided to select a particularly well-documented region in the Kurdistan of Iraq, the area surveyed by the Upper Greater Zab Archaeological Reconnaissance Project (UGZAR) (Kolinski 2017; 2018; 2020), as a case study that could allow us to compare it to the better documented western regions and study whether the same settlement pattern is followed or not.

However, in order to make this comparison useful, it is necessary to establish the particular conditions of the data in northern Iraq and in the Kurdistan region of Iraq. As compared to areas in the better studied northeastern Syria, many areas in the Kurdistan region of Iraq are still lacking of proper regional studies, and a similar frame is difficult to stablish. For instance, only a couple of excavated sites such as the site of Bassetki (Pfälzner & Qasim 2018) could be regarded as 'urban'. Focusing on the UGZAR region, the general situation seems to be conditioned by the lack of an apparent hierarchical arrangement, at least as apparent on the landscape. The only type 4 site is located in a valley that is not so densely populated and also the information involving the exact extension of the Ninevite 5 remains of the site remains unclear as no detailed report on the neighbouring sites have been released to the date (Kolinska, Kolinski & Lawecka 2024).

4. Materials and methods

The variable rasters' creation, graphics and Maximum entropy models presented in the following pages were recorded using GIS software, specifically ArcMap 10.8, in combination with the R language (version 4.4.3), RStudio software, and the terra (Hijmans, 2020), dismo (Hijmans et al., 2024), rJava (Urbanek, 2024), corrplot (Wei & Simko, 2024), viewscape (Yang et al., 2024) and sf (Pebesma, 2018; Pebesma & Brivand, 2023) packages.

4.1. The Upper great Zab region

This region was intensively surveyed in the frame of the Upper Greater Zab Archaeological Reconnaissance Project (UGZAR), a project led by Rafal Kolinski that carried out several field campaigns since 2012 (Kolinski 2017; 2018). The investigated region is located north of Erbil, the capital city of the Kurdistan Region of Iraq. The area is characterized by fertile plains delimited by short mountainous ranges and irrigated by the Greater Zab and other minor tributaries that vertebrate the landscape. This region was selected as a case of study for several reasons: First, the project released complete reports and catalogues for every campaign (Kolinski 2020), as well as books summarizing the results per periods (Kolinska, Kolinski & Laweka 2024). Second, the team registered many sites in the region, that turned out to be largely inhabited during this period, thus configuring a dataset with sufficient entries to generate reliable statistical studies.

We consider that the study of the UGZAR region can be interesting, and the results have a great potential for the advance in the understanding of the organization of the landscape during the Ninevite 5 period. However, no past political or geographical borders can be related to this specific region, so in order to establish a finite framework for the present study, we decided to use the limits of the buffer areas of all of the archaeological sites in the area. With this approach, the present region of study comprehends all the Ninevite 5 sites documented in the area and, as expected by the authors, a significant part of their surroundings, as it sufficiently represents the environment of the communities of this period.

However, the UGZAR region also has several problematic features in order to consider it as representative of a general picture of the settlement pattern during the Ninevite 5 period. First of all, the area must be considered rather marginal compared to the distribution of this culture as an area secluded near the piedmont of the Zagros mountains. Also, compared to other regions in Syria and Iraq, the UGZAR region does not display a clear hierarchical pattern and no large sites are evident. Additionally, the lack of any excavated site leaves this area without any archaeological data to test the survey results. On the other hand, this region presents a good opportunity to obtain settlement arrangement and landscape information from a region mostly populated during the Early Ninevite 5. Even when the region's results may not be directly extrapolated to explain the behavior of the settlement pattern throughout the entire culture, the potential information obtained via MaxEnt modeling may be useful for further work in the future and for understanding the behavior of the settlement pattern during the Early Ninevite 5 period in a rather marginal area. Also, it presents a good opportunity to compare the situation of marginal areas with that of central regions.

4.2. Landscape and variables reconstruction

The landscape in which the present analysis was conducted was reconstructed using a digital elevation model of the Near East provided by NASA in their ASTER Global Digital Elevation Model V003 and a map of the modern rivers from the same region, also provided by NASA, in their ASTER Global Water Bodies Database V001. This latter map was extended by adding a new set of rivers identified through the Corona Atlas & Referencing System. These "new" rivers are dry beds of formerly flowing streams, that today do not have water, but at the time the archaeological sites were occupied, some of them most likely did. This fact surely influenced the site placement during the Ninevite 5 period, as the dry landscape of the northern Mesopotamian Plain was difficult to settle without a constant source of water. As a comparison, southern Mesopotamia had a network of artificial channels that could have supported the subsistence of settlements (Weiss, 1986: 82). This channel system is mostly non-existent in the north, and settlements there had to mostly rely on natural river courses.

To reflect all these realities, a total of 12 variables (Table 1) were constructed in the present study, each represented as an individual raster map of the same resolution as the original. These variables were derived from the two previously mentioned maps. A first set of variables was created to encapsulate information about terrain characteristics and morphology, as this is one of the primary topics in settlement strategy research within archaeology (Gillings et al., 2020). In this set, variables such as height, slope, and solar exposition were calculated for each cell of the raster, along with their mean values within a 10 km circular buffer. This step was taken to include both the exact values at the specific locations of the points and representative values of their immediate surroundings. The 10 km buffer distance was chosen to ensure a reliable representation of the catchment areas of settlements from this period (Garcia-Ramis, 2024).

Additionally, the Topographic Prominence Index (TPI) (Weiss, 2001) was included in the same set as three distinct values: the TPI value calculated with a 300-meter radius, the TPI value calculated with a 3000-meter radius, and a derived classification of landforms into 10 classes. This variable was included alongside the others to ensure that the specific morphology of the terrain was adequately considered in the study. All three TPI values were necessary, as the index is highly influenced by the radius used in its calculation. Both a small radius and a large radius are required to construct the 10-class classification (Weiss, 2001).

A second set of variables was also constructed, combining the study's focus on terrain morphology with the relationships between sites. This set included variables related to the visual characteristics of the landscape and the sites, as these often reflect relationships between places in terms of mutual visual control. For each cell, several values were calculated. On one hand, the percentage of visible cells was used as a measure of the visual basin size. On the other hand, the number of visible sites was considered a proxy for the number of close social relationships. Both measures were constrained to a 3-kilometer buffer, adhering to the conservative approach outlined by (Murrieta-Flores, 2014) for defining visual basin limits.

In addition, the number of visible sites was further analysed based on site size classification described earlier. This involved breaking down the number of visible sites into four categories, each corresponding to a specific site size. As a result, four additional variables—one for each site size category—were included in this set. These variables were incorporated to examine both the settlement patterns in relation to the visual control of the landscape and the visual relationships between sites. This analysis also aimed to identify any potential hierarchical patterns within the network of settlements.

Lastly, a third set of variables was developed, focusing on the economic potential of the landscape, specifically its agricultural suitability. Two variables were created to capture this: the time required to travel from the hydrological network to each cell, measured in seconds (Tobler, 1993), and the classification of the terrain based on flatness and proximity to rivers. For the latter, the terrain was categorized into four groups, depending on whether it was flat (flatness defined as slopes below 12 %), near a river (within a 500-meter buffer), or both. This step was taken to account for the agricultural suitability of the terrain, especially as no detailed information on soil types or regional geology was available.

The 12 attributes and their associated values (Fig. 2) were recorded for the 60 Ninevite 5 sites documented in the study region and for 5,632 evenly spaced sample points, distributed at 1-kilometer intervals across the same area. This latter dataset, constrained to the UGZAR region, was used as background points for the Maximum Entropy models, which will be explained in detail later (See Fig. 3).

As previously mentioned, the study region was defined as the combined extent of all 20-kilometer buffers around each site, given the absence of political or geographical boundaries marking the region's limits. However, the sample points were placed no closer than 3 km from the region's border to minimize edge effects during value calculations. Additionally, they were set at least 1 km away from archaeological sites to avoid spatial correlation between sample points and archaeological locations.

Table 1
Attributes used in the present work, their objective and how they were measured.

Attributes	Objective	Measurement
Height at site	Settlement placement strategies	From ASTER 30 m DEM
Mean height within catchment[*]	Settlement placement strategies	Zonal Statistics n ArcGIS Pro on ASTER 30 m DEM
Slope at site	Settlement placement strategies	Used slope tool (measured in %) in ArcGIS Pro on ASTER 30 m DEM
Mean slope within catchment[*]	Settlement placement strategies	Used slope tool (measured in %) and Zonal Statistics in ArcGIS Pro on ASTER 30 m DEM
Insolation at site	Settlement placement strategies	Used slope from ASTER 30 m DEM and solar radiation tool in ArcGIS Pro (parameters set for annual radiation of 2024)
Mean insolation within catchment[*]	Settlement placement strategies	Used slope from ASTER 30 m DEM, solar radiation tool and Zonal Statistics in ArcGIS Pro (parameters set for annual radiation of 2024)
Topographic Prominence Index (radii of 300 m and 3000 m)	Settlement placement strategies	Derived from ASTER 30 m DEM (Weiss, 2001)
Landform classification (10 categories)	Settlement placement strategies	Based on TPI 300 and 3000 (Weiss, 2001)
Number of sites within visual basin[**]	Social relations	Used compute_viewscape function in viewscape R package
Visual basin size (Percentage of seen cells from point in buffer)[**]	Settlement placement strategies and social relations	Used compute_viewscape function in viewscape R package
Distance to river	Agricultural potentiality	Used distance accumulation tool (with Tobler, 1993) in ArcGIS Pro on ASTER rivers layer and ASTER 30 m DEM
Agriculture suitability	Agricultural potentiality	Used function extract in terra R package and st_buffer in sf R package on ASTER 30 m DEM and ASTER rivers layer

[*] Catchment area of 10 km (as identified in Garcia-Ramis, 2024).
[**] Visual basin with a maxim range of 3 km (as proposed in Murrieta-Flores, 2014).

4.3. Maximum entropy modelling

The Maximum Entropy modelling (from now on referred to as MaxEnt) method is a machine learning approach currently seeing widespread application in archaeology and cultural resource management (Yaworsky et al., 2020). MaxEnt is a tool designed to evaluate the importance and behaviour of multiple variables for a given set of points, based on the Maximum Entropy principle (Jaynes, 1957). This principle assumes that all locations of points are equally likely (a state of maximum entropy) and then iteratively processes the data to identify the combination of variables that best explains the observed distribution of points while minimizing complexity and the number of variables involved (Harte, 2011).

Like other similar methods, MaxEnt operates with two types of data: explanatory or predictor variables—represented here as raster layers

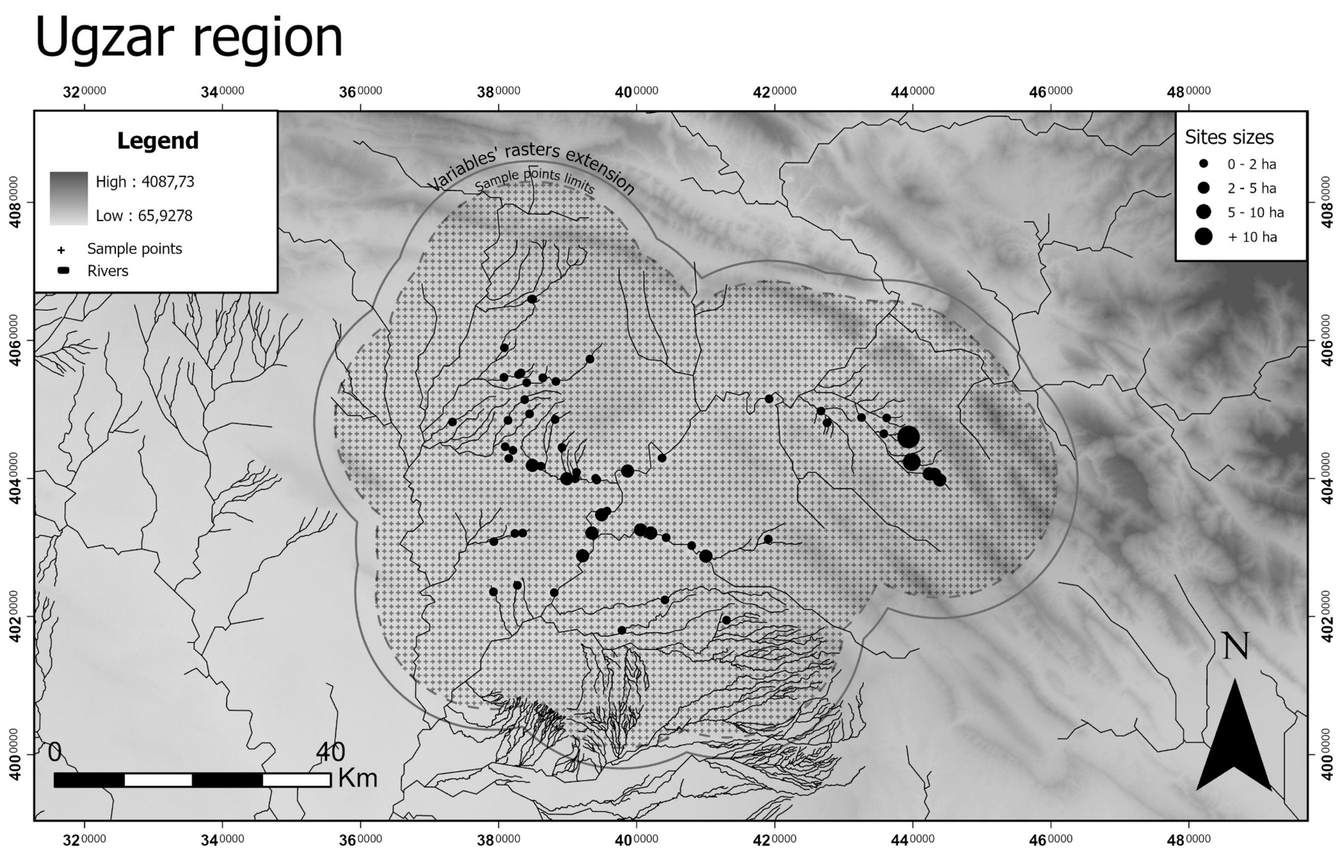

Fig. 2. Map of the UGZAR region.

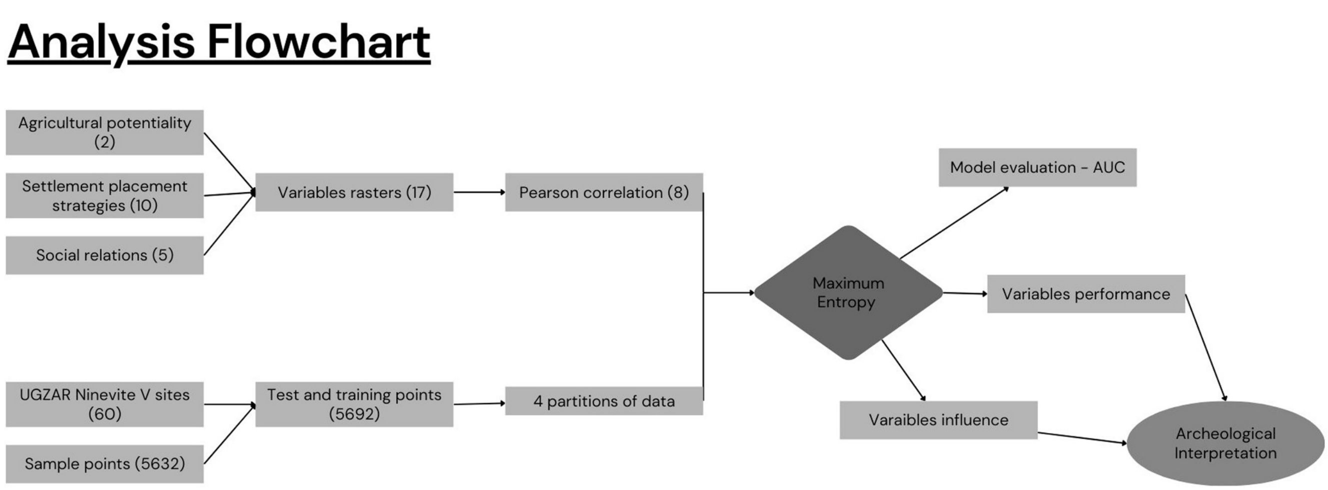

Fig. 3. Analysis flowchart.

reflecting environmental and social factors—and the points or locations to be analysed. In this study, the points consist of archaeological sites and sample locations, where information to compare with the archaeological points will be collected. Typically, in MaxEnt modelling, a separate set of sample points is unnecessary, as the method automatically generates background points across the study region. However, to ensure an accurate representation of the study area, a preselected set of equidistant sample points, as described earlier, was supplied to the model (Phillips et al., 2006).

This approach is particularly relevant for MaxEnt, as it treats background points differently from most similar methods. In MaxEnt, background points are considered pseudo-absences—locations where no archaeological sites have yet been detected but could potentially be discovered in the future. This contrasts with the concept of true absence points of other methods, where no settlements could ever exist—a claim that is challenging to substantiate in archaeology (Yaworsky et al., 2020). MaxEnt modelling was chosen for this study because the research region has demonstrated uneven coverage in terms of archaeological investigations. Despite multiple campaigns of surface surveys and excavation efforts, there remain significant disparities in the extent and quality of the data collected.

However, the MaxEnt method, like other methods that rely on iterative data processing, has some drawbacks. One significant issue is its tendency to overfit the data, meaning it often creates overly complex models that are difficult to interpret and understand (Hastie et al., 2017). To address this, it is necessary to filter the data before the modelling process, particularly by discarding variables that are highly correlated. Highly correlated variables can lead the model to identify “false” relationships that do not contribute meaningful information to the final results. To achieve this, a Pearson correlation test was applied to the sample points data to identify and exclude highly correlated variables, ensuring that only the most relevant variables were included in the modelling process.

The MaxEnt modelling process produces two principal outputs. First, it provides a graphic that shows the importance of each variable as a percentage of its individual influence on the model. Second, it generates a set of graphs, one for each variable, illustrating the relationship between the values of the individual variables and their probability of influencing point presence in the model (Harte, 2011). The first output highlights how the different variables contribute to the model and identifies those with the greatest impact. The second output explains how each variable operates individually and which values are most strongly associated with site presence. In this study, the first output identifies which environmental or social factors have the most influence on settlement patterns, while the second explains the specific ways in which these factors affect the location of archaeological sites.

Two additional steps were taken to ensure the model’s performance, as these types of processes are not self-sufficient in terms of performance verification and result evaluation.

1. **Four-Fold Cross-Validation:** A four-fold cross-validation of the data was conducted. The 60 archaeological sites and the 5,632 sample points were randomly divided into four equal parts (approximately 15 archaeological site points and 1,408 sample points per part). Each subset was processed separately using the MaxEnt tool. This approach aimed to ensure the robustness of the results by reducing spatial autocorrelation between the training and testing points in the models (Fielding & Bell, 1997).
2. **Area Under the Curve (AUC) Analysis:** The models’ overall performance was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC). This threshold-independent measure provides a value estimating how effectively the model discriminates between archaeological locations and sample points (Fielding & Bell, 1997; Phillips et al., 2006). AUC evaluates the model’s ability to correctly identify locations where archaeological sites are likely to be found, offering a robust metric for model performance.

5. Results

As mentioned earlier, a Pearson correlation test was applied to the raster variables using the values extracted from the sample points. This test revealed significant correlations (>0.50) among three groups of variables (Fig. 4).

1. **Geographical Morphology Variables:** Most of the geographical morphology variables were highly correlated (e.g., Height at site, Mean height in buffer, Slope at site, Mean slope in buffer, and Mean solar radiation in buffer). As a result, all of these variables were removed except for “Height at site,” as it is derived from the original raster from which the others were calculated.
2. **Visual Relationship Variables:** Three of the five rasters related to visual relationships among sites (Total sites in view, Size 1 sites in view, and Size 2 sites in view) also showed significant correlation. Only the “Total sites in view” raster was retained because it provided the most comprehensive data for the modeling process. Consequently, the “Size 3 sites in view” and “Size 4 sites in view” rasters were also removed, as their utility was limited without their

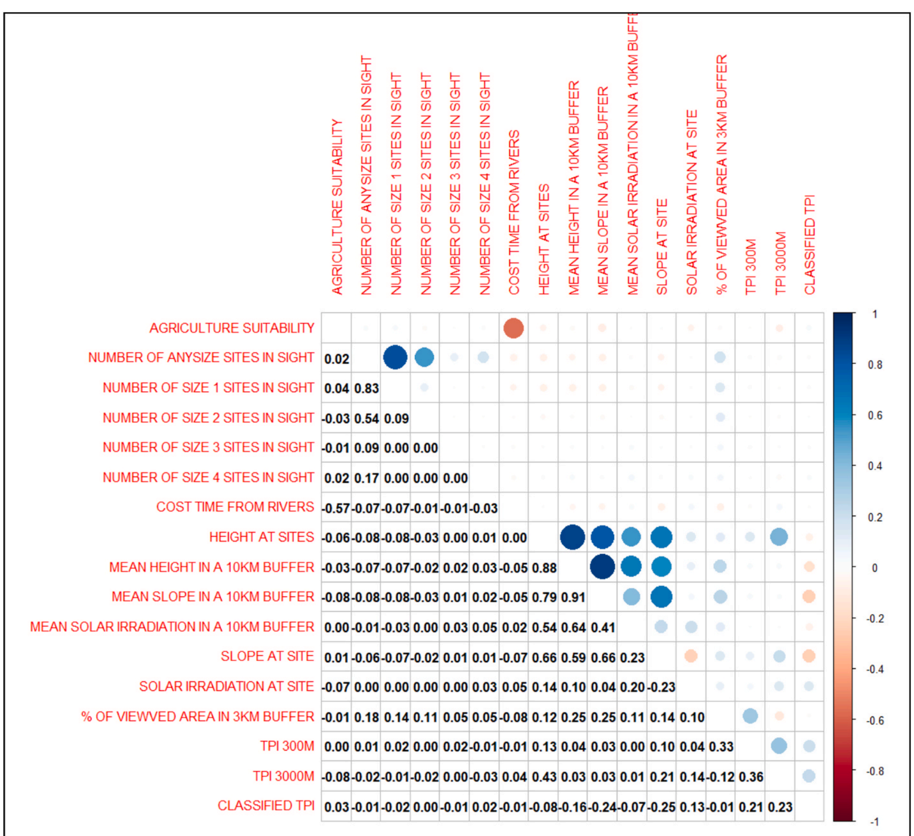

Fig. 4. Pearson tests for collected variables.

counterparts and their low values were expected to have minimal impact on the model.

3. **Cost Distance and Agricultural Suitability Variables:** Lastly, a correlation was observed between the "Cost distance from rivers" and "Agricultural suitability" rasters. This result was unsurprising, as both variables ultimately depend on similar geographical features, such as flatness and proximity to rivers. In this case, the "Cost distance from rivers" raster was retained because it quantified the environmental feature in a more precise, quantitative manner rather than a qualitative one.

With the eight remaining variables, the MaxEnt modelling process was conducted on the four data partitions, all of which produced similar results (Fig. 5). Across all models, over 50 %–60 % of the model's performance is attributed to the "Cost from rivers" raster, with the "Total number of sites in view" raster contributing approximately 20–30 %. The "Height at site" raster accounts for around 10 % of the influence, closely followed by the "Percentage of view area" raster, which always has a similar but slightly lower influence than the previous one. Except for the model from the data partition 3, where the raster "Classified TPI" ranks third with an influence of 10 %. The remaining rasters vary in their rankings and influence across the models, but have anegligible impact on the overall study.

Individual Behaviour of Variables:

A consistent pattern emerges regarding the behaviour of the key variables in all four models (Fig. 6):

- The **"Cost from rivers"** raster demonstrates the highest prediction power at its lowest values.
- The **"Total sites in view"** raster exhibits its strongest influence at its highest values.
- Similarly, the **"Height at site"** raster shows predictive power at lower values, while the **"Percentage of view area"** raster is most influential at higher values.
- Uniquely, the **"Classified TPI"** raster shows a slight concentration of power prediction at its middle values
- The remaining rasters behave consistently across all four models but contribute minimally to the outcomes.

Model Performance:

The AUC values for all four models exceed 0.89, indicating excellent performance (Fig. 7). The overall results align with expectations, as proximity to rivers is a well-known attractor for settlements in the Near East. However, one notable aspect is the strong influence of visual relationships with other settlements, making this the second most significant factor. This finding highlights a clustered settlement pattern, further supported by the relevance of the third and fourth variables. The "Classified TPI" also has expected values with the categories where data is concentrated on those representing flat zones, which is the norm in the region under study.

In contrast, no evidence of a hierarchical organization of sites was observed. This is noteworthy, given that such organization is typical in the later phases of the Ninevite 5 culture (Garcia-Ramis, 2024). This lack of hierarchy can be attributed to the solitary presence of a single Size 4 site in the UGZAR region and the prior exclusion of the individual "Sites in view" rasters.

No other significant patterns were observed, reinforcing the conclusion that environmental variables remain the primary drivers of

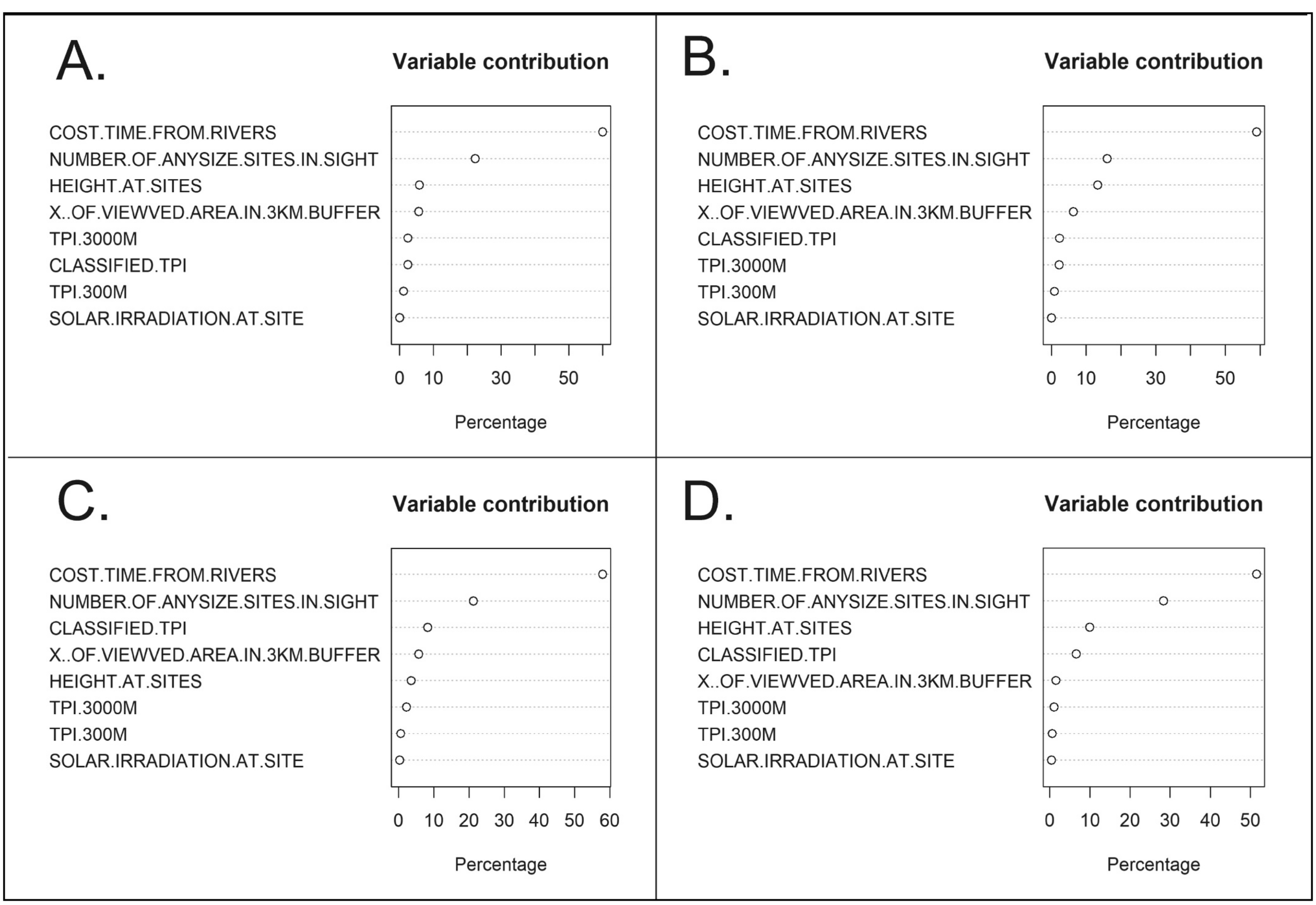

Fig. 5. 4 MaxEnt models results (A. Partition of data 1, B. Partition of data 2, C. Partition of data 3, D. Partition of data 4).

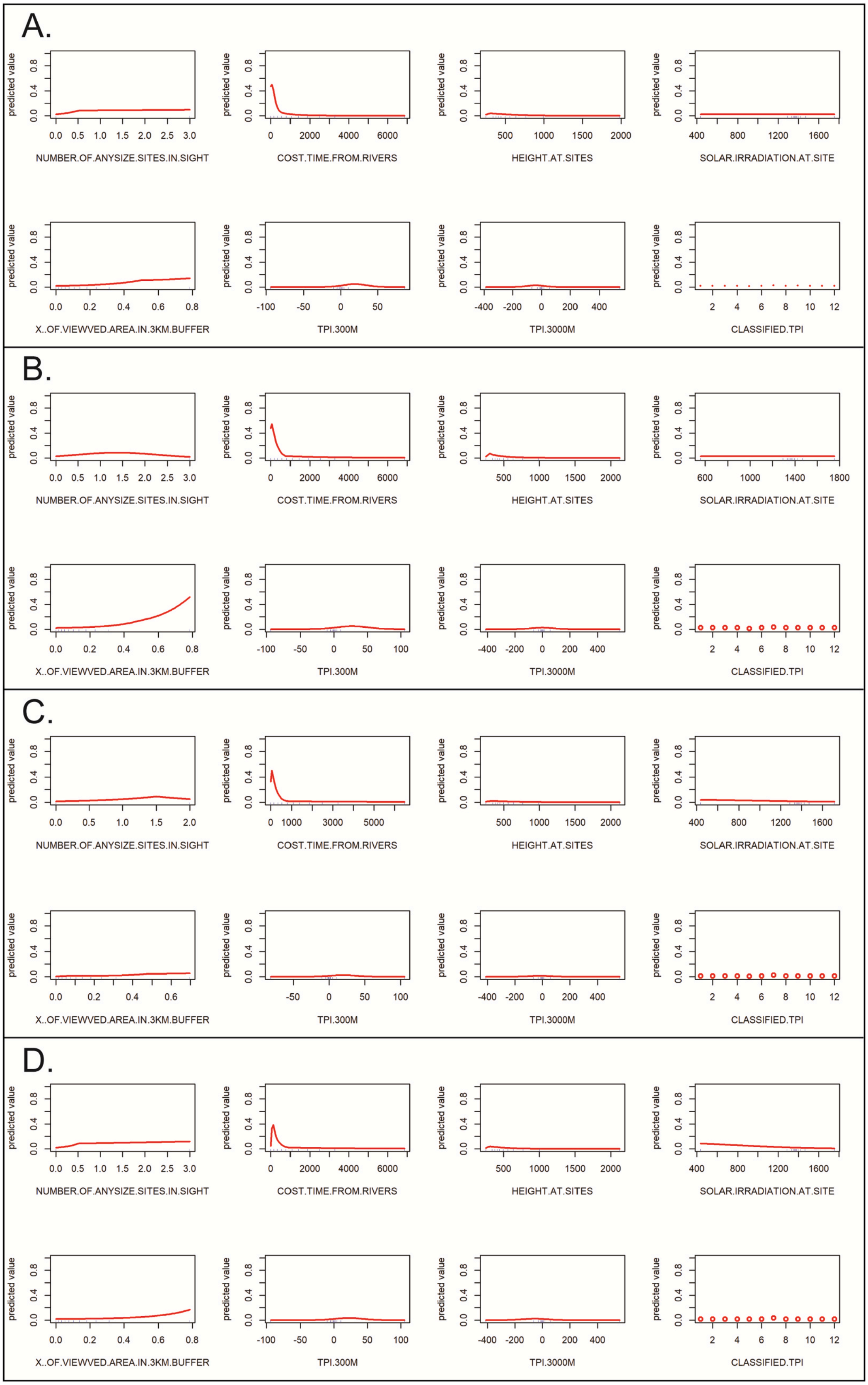

Fig. 6. 4 MaxEnt models variable's response (A. Partition of data 1, B. Partition of data 2, C. Partition of data 3, D. Partition of data 4).

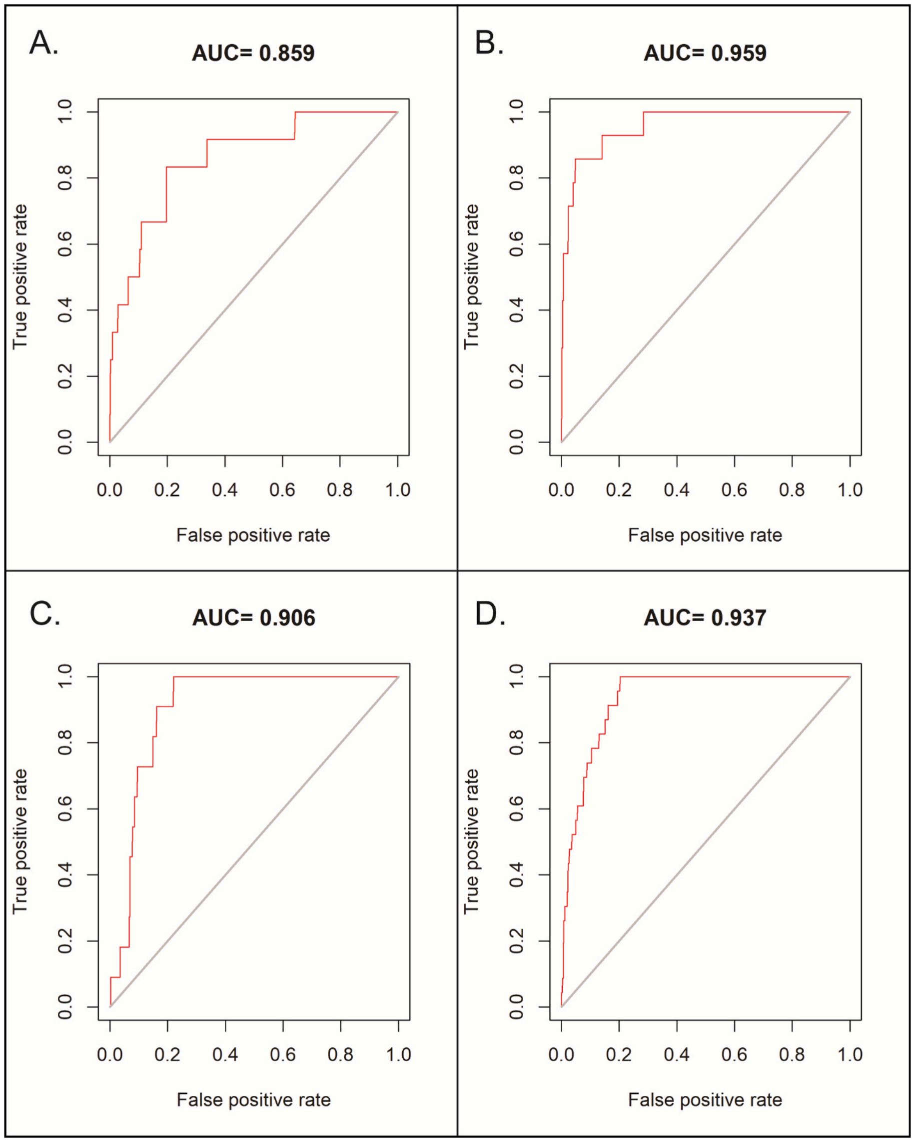

Fig. 7. 4 MaxEnt AUC values and graphics (A. Partition of data 1, B. Partition of data 2, C. Partition of data 3, D. Partition of data 4).

settlement organization in the region under study.

6. Conclusions

The analysis of settlement patterns through MaxEnt modelling has shown interesting results, thus allowing us to establish a comprehensive study that takes into account multiple variables. However, the present study is only a first approach to determining the settlement pattern of the Ninevite 5 communities, as this analysis considers only a small portion of the entire Ninevite 5 region, which we hope to be able to address in the near future.

In this way, this methodology has allowed us to identify a possible settlement pattern within the Ninevite 5 culture in the UGZAR region. The modelling process may show that the sites are not randomly distributed across the landscape, but that environmental factors may have caused them to cluster around rivers. In this way, the possible settlement pattern described earlier as a possible hierarchical relationship between settlements as a general feature in the pattern of the whole culture is not detected at all in the UGZAR region. This may be related to the lack of large settlements and the absence of variables that could inform us about these possible hierarchical relationships. Nevertheless, this clustered structure around rivers must be determined by the management of agricultural land and available resources, even without the presence of larger settlements that could act as production organisers and redistribution centres.

As a consequence, the specific political conditions that led to this arrangement are not clarified by the MaxEnt model in the UGZAR region, and complementary studies are needed. However, as opposite to the Late Ninevite5 period, evidence from the excavated Early Ninevite 5 period examples does not yet show a clear hierarchy. First, the urban settlements were much smaller, and the sites scattered throughout their hinterlands do not appear to follow any clear hierarchical arrangement. This settlement pattern could fit well with the UGZAR region, since this specific region did not show any hierarchy or arrangement clearly focused on political reasons. Nevertheless, this does not deny, for the moment, the possible application of the hierarchical model to other regions, but it evidences that this hierarchical model is not applicable to the entire core area of the Ninevite 5 culture.

Nevertheless, the clustering of sites is evidenced by the tests performed in this article, but a political hierarchy does not seem to be a reasonable explanation for this specific region during the Early Ninevite 5 period. In fact, the absence of a larger regional center and the apparent lack of political intent in the arrangement of sites make this statement highly unlikely.

For that reason, we consider that this analysis cannot support or debunk by itself the vision of a hierarchical pattern to explain the arrangement of sites during the Ninevite 5 period due to two main reasons. The first one is that the hierarchy is clearly visible only during the late Ninevite 5 period, and the studied region yielded probably an early Ninevite 5 occupation that, otherwise, has revealed no evident hierarchy in any of the areas of distribution of this culture. The second reason is that the clustering in the case of the UGZAR regions seems to hold no similarities with the clustering observed around large late Ninevite 5 centers in Syria: while settlement pattern around these later populations are clearly structured around central urban sites, the clusters in the UGZAR, given the available evidence, seem to be largely conditioned by the exploitation of natural resources rather than the relative positions of other sites exploiting similar resources, primarily suitable agricultural lands and riversides. In this sense, as previously shown, the highest concentration of sites is found in the largest valleys surrounding mountainous ranges, while the narrower river valleys tend to be less populated and, subsequently, the sites are much less clustered in the landscape (Fig. 2). That features would align well if the main reasons behind the settlement pattern of the Early Ninevite 5 period in the region was the agricultural exploitation of the most fertile lands.

Additionally, the agricultural orientation of settlements attested in the UGZAR region is not unique to this area, and many other regions seem to be displaying a pattern focusing on the presence of water sources and agricultural fields. Moreover, excavations at sites in the middle Khabur region, Syria and at the Eski-Mosul Dam have shown granary compounds and other evidences proving the importance of the agricultural resources during the first quarter of the Early Bronze Age (Fortin 1998; Schwartz 2015). Perhaps the pattern shown by the statistics allows us to see a planned urban development centred on the exploitation of agricultural and grazing resources of the surrounding landscape, but further analysis on other regions are required.

As stated before, this is just an initial attempt to acknowledge the settlement pattern of the Ninevite 5 culture. Therefore, we look up continuing this field of work and expanding our analysis to more locations that may help us determine the ruling factors in the overall settlement pattern of the Ninevite cultures. In this way, we would also want to persist in the research on the reasons behind these patterns, as no computational method can help us make any hypothesis in this way.

Statements and Declarations.

The authors confirm that there are no conflicts of interest.

CRediT authorship contribution statement

Biel Soriano-Elias: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Francesc Xavier Garcia-Ramis:** Writing – review & editing, Writing – original draft, Investigation, Data curation, Conceptualization. **Miquel Molist Montañà:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization.

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Declaration of generative AI and AI-assisted technologies.

During the preparation of this work the authors used **Chat.openai** in order to improve the language and readability of the final paper. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Appendix A. Supplementary material

All the code and data to be able to reproduce the results of the present article can be found here: https://github.com/Bielsoel28/Ninevite-V-Settlement-pattern-MaxEnt.

Data availability

The data is freely available online and its referenced on the text

References

Abu al-Soof, B., 1968. Distribution of Uruk, Jamdat Nasr and Ninevite V Pottery as Revealed by Field Survey Work in Iraq. *Iraq* 30 (1), 74–86. https://doi.org/10.2307/4199840.

Abu al-Soof, B., 1970. Mounds in the Rania Plain and excavations at Tell Basmusian. *Sumer* 26, 65–104.

Akçay, A., 2017. A Late Uruk-Early Bronze Age Transitional Period Cemetery in the Upper Tigris Region: Aşağı salat. *OLBA* 25, 49–90.

Arrivabeni, M., 2010. Early Bronze Age Settlement in the Tell Leilan Region; a Report on the ceramic Material of the 1995 Survey. *KASKAL. Rivista Di Storia, Ambienti e Culture Del Vicino Oriente Antico* 7, 1–49.

M. Arrivabeni (2019). Pottery. In E. Rova (ed.). Associated Regional Chronologies for the Ancient Near East and the Eastern Mediterranean (ARCANE). Volume 5 - The Tigridian Region. (pp. 45-129) Turnhout: Brepols.

Algaze, G., Hammer, E., Parker, B., 2012. The Tigris-Euphrates Archaeological Reconnaissance Project. Final Report of the Cizre Dam and Cizre-Silopi Plain Survey Areas. *Anatolica* 38, 1–115. https://doi.org/10.2143/ANA.38.0.2186349.

Algaze, G., 2018. Entropic Cities. The Paradox of Urbanism in Ancient Mesopotamia. *Curr. Anthropol.* 59, 1, 23–54. https://doi.org/10.1086/695983.

L. Alwi Muttaqin, S. Heru Murti & B. Susilo (2019). MaxEnt (Maximum Entropy) model for predicting prehistoric cave sites in Karst area of Gunung Sewu, Gunung Kidul, Yogyakarta. In S.B. Wibowo, A.B. Rimba, A.A. Aziz, S. Phinn, J.T. Sri Sumantyo, H. Widyasamratri, & S. Arjasakusuma (eds.), *Sixth Geoinformation Science Symposium* (p. 3). SPIE. DOI: 10.1117/12.2543522.

M.R. Behm-Blancke (2003). Northern Frontiers: Early Ninevite 5 Contacts with Southeastern Anatolia. In E, Rova, & H. Weiss (eds). *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX*. (pp. 481-492). Turnhout: Brepols.

Castiello, M.E., Tonini, M., 2021. An Explorative Application of Random Forest Algorithm for Archaeological Predictive Modeling. A Swiss Case Study. *J.Comput. Appli. Archaeol.* 4 (1), 110–125. https://doi.org/10.5334/jcaa.71.

Conati Barbaro, C., Iamoni, M., Morandi, B.D., Moscone, D., Qasim, H.A., 2019. The Prehistory and Protohistory of the northwestern region of Iraqi Kurdistan Preliminary results from the first survey campaigns. *Paléorient* 45 (2), 207–229. https://doi.org/10.4000/paleorient.778.

Fielding, A.H., Bell, J.F., 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environ. Conserv.* 24 (1), 38–49. https://doi.org/10.1017/S0376892997000088.

Fortin, M. (1998). L'habitat de la station commerciale de Tell 'Atij, sur le moyen Khabour, au IIIème millénaire av. J.-C. In M. Fortin & O. Aurenche, O (eds.). *Espace naturel, espace habité en Syrie du Nord (10e - 2e millénaires av. J.-C). BCSMA*, 33, 229-242.

Fukai, S., Horiuchi, K., & Matsutani, T. (1974). *Telul eth-Thalathat, Vol. III, The Excavations of Tell V, The Fourth Season* (1965). University of Tokyo.

Garcia-Ramis, F.X., 2024. *Spatial Analysis of the Ninevite 5 Culture in Northern Mesopotamia (3000-2500 BCE)*. Universitat Autònoma de Barcelona [Unpublished PhD Thesis]. Departament de Prehistòria.

Gavagnin, K., 2016. The Land of Nineveh Archaeological Project: A Preliminary Overview on the Pottery and Settlement Patterns of the 3rd Millennium BC in the Northern Region of Iraqi Kurdistan. In: Kopanias, K., MacGinnis, J. (Eds.), *The Archaeology of the Kurdistan Region of Iraq and Adjacent Regions*. Archaeopress, Oxford, pp. 75–85.

Gillings, M., Haciguzeller, P., & Lock, G. (2020). *Archaeological Spatial Analysis: A Methodological Guide*. London: Routledge. DOI: 10.4324/9781351243858.

Hammer, E., Ur, J., 2019. Near Eastern Landscapes and Declassified U2 Aerial Imagery. *Adv. Archaeol. Pract.* 7 (2), 107–126. https://doi.org/10.1017/aap.2018.38.

Harte, J. (2011). Maximum Entropy and Ecology: A Theory of Abundance, Distribution, and Energetics. Oxford: University Press. DOI: 10.1093/acprof:oso/9780199593415.001.0001.

Hastie, T., Tibshirani, R., Friedman, J.H. (Eds.), 2017. The Elements of Statistical Learning: Data Mining, Inference, and Prediction (second Edition). *Springer Series in Statistics*. Springer, New York.

Hijmans, R.J., 2020. terra: Spatial Data Analysis. Available at. https://doi.org/10.32614/CRAN.package.terr a.

Hijmans, R.J., Phillips, S., Leathwick, J., & Elith, J. (2024). dismo: Species Distribution Modeling (Versión 1.3- 16) [Software]. https://cran.r-project.org/web/packages/dismo/index.html.

Jaynes, E.T., 1957. Information Theory and Statistical Mechanics. *Phys. Rev.* 106 (4), 620–630. https://doi.org/10.1103/PhysRev.106.620.

Jones, E.E., 2017. Significance and context in GIS- based spatial archaeology: A case study from Southeastern North America. *J. Archaeol. Sci.* 84, 54–62. https://doi.org/10.1016/j.jas.2017.05.009.

Killick, R. & Roaf, M. (2003). The Relative Chronology of Ninevite 5 Sites in the Tigris Region and Beyond. In E. Rova, & H. Weiss (eds.). (2003). *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX* (pp. 73-82) Turnhout: Brepols.

Kolinska, X., Kolinski, R., & Laweka, D. (2024). *Material Studies, Pottery, Lithics: Prehistory. Settlement History of Iraqi Kurdistan. Volume II/I. Ninevite 5*. Wiesbaden: Harrassowitz.

Kolinski, R., 2017. Settlement history of Iraqi Kurdistan: an assessment halfway into the project. *Polish Archaelogy in the Mediterranean* 26 (1), 579–590.

Kolinski, R., 2018. In: An Archaeological Reconnaissance in the Greater Zab Area of the Iraqi Kurdistan (UGZAR) 2012–2015. Harrassowitz, Wiesbaden, pp. 13–26.

Kolinski, R. (2020). *Catalogue of Archaeological Sites Navkūr Plain Kārbk Stream Basin. Settlement History of Iraqi Kurdistan. Volume 4*. Wiesbaden: Harrassowitz.

Laweka, D., 2016. Ninevite 5 – culture or regional pottery style? In: Kopanias, K., MacGinnis, J. (Eds.), *The Archaeology of the Kurdistan Region of Iraq and Adjacent Regions*. Archaeopress, Oxford, pp. 181–187.

Laweka, D. (2019). Architecture and Settlement Trends. In E, Rova (ed.). *Associated Regional Chronologies for the Ancient Near East and the Eastern Mediterranean (ARCANE). Volume 5 - The Tigridian Region*. (pp. 139-164). Turnhout: Brepols.

Lebeau, M. (1993). Tell Melebiya: cinq campagnes de recherches sur le Moyen-Khabour 1984-1988. *Akkadica Supplementum* 9. Peeters.

Lebeau, M. (ed.). (2012). *Associated Regional Chronologies for the Ancient Near East and the Eastern Mediterranean (ARCANE). Volume 1 - Jezirah*. Turnhout: Brepols.

Lebeau, M. (Ed.), 2014. *Associated Regional Chronologies for the Ancient near East and the Eastern Mediterranean (ARCANE). Volume-IR 1 - Ceramics*. Brepols, Turnhout.

Lyonnet, B. (ed.). (2000). *Prospection Archeologique Haut-Khabur Occidental (Syries du N. E.). Volume I. Bibliotheque Arqueologique et Historique* 155. IFPO.

Lloyd, S., 1938. Some Ancient Sites in the Sinjar Province. *Iraq* 5, 123–142.

Mallowan, M.E.L. (1936) The Excavations at Tall Chagar Bazar, and an Archaeological Survey of the Habur Region, 1934-5. *Iraq* 3 (1), 1-59 + 61-85.

Mallowan, M.E.L. (1937). The excavations at Tell Chagar Bazar and an archaeological survey of the Habur region. 2nd Campaign, 1936. *Iraq*, 4 (2), 90-154.

Mayo, D. & Weiss, H. (2003). The beginning of the Ninevite 5 sequence at Tell Leilan. In E. Rova, & H. Weiss (eds.), *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX*. (pp. 25-41). Turnhout: Brepols.

Meijer, D.J.W. (1986). *A Survey in Northeastern Syria*. Nederlands Historisch-Archaeologisch Insitut voor het Nabie Oosten.

Monchambert, J.Y., 1984. Le Futur lac du Moyen Khabour: rapport sur la prospection archéologique menée en 1983. *Syria* 61 (3–4), 181–218. https://doi.org/10.3406/syria.1984.6852.

Murrieta-Flores, P., 2014. Developing computational approaches for the study of movement: assessing the role of visibility and landscape markers in terrestrial navigation during Iberian Late Prehistory. In: Polla, S., Verhagen, P. (Eds.), *Computational Approaches to the Study of Movement in Archaeology: Theory, Practice and Interpretation of Factors and Effects of Long Term Landscape Formation and Transformation*. De Gruyter, Berlin, Boston, pp. 99–132. https://doi.org/10.1515/9783110288384.99.

Noviello, M., Cafarelli, B., Calculli, C., Sarris, A., Mairota, P., 2018. Investigating the distribution of archaeological sites: Multiparametric vs probability models and potentials for remote sensing data. *Appl. Geogr.* 95, 34–44. https://doi.org/10.1016/j.apgeog.2018.04.005.

Ökse, A.T., 2019. Ilısu Barajı Inşaat sahasının arkeologik potansiyeli (in Turkish). *Turkish Journal of Ancient near Eastern Studies* 1, 42–61.

Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10 (1), 439–446. https://doi.org/10.32614/RJ-2018-009.

Pebesma, E. & Brivand, R. (2023). *Spatial Data Science: With Applications in R*. New York: Chapman and Hall. DOI: 10.1201/9780429459016.

Pfälzner, P., Qasim, H.A., 2018. Urban developments in northeastern Mesopotamia from the Ninevite V to the Neo- Assyrian periods: excavations at Bassetki in 2017. *Zeitschrift Für Orient-Archäologie* 11, 42–87.

Phillips, S.J., Anderson, R.P., Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190 (3–4), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026.

Postgate, J.N., 1994. How Many Sumerians per Hectare? – Probing the Anatomy of an Early City. *Camb. Archaeol. J.* 4 (1), 47–65. https://doi.org/10.1017/S0959774300000962.

Ristvet, L., 2005. Settlement, Economy, and Society in the Tell Leilan Region, Syria, 3000–1000 BC. Faculty of Oriental Studies, King's College, University of Cambridge, PhD.

Roaf, M., 1984. Excavations at Tell Mohammed 'Arab in the Eski Mosul Dam Salvage Project. *Iraq* 46 (2), 141–156. https://doi.org/10.2307/4200223.

Rova, E., 1988. *Distribution and Chronology of the Nineveh 5 Pottery and of its Culture*. Contributi e materiali di Archeologia Orientale II, La Sapienza.

Rova, E. (2003). Tell Karrana 3: Ceramic Evidence for the Late Uruk/Ninevite 5 Transition. In E. Rova, & H. Weiss (eds) (2003). *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX* (pp. 11-21). Turnhout: Brepols.

Rova, E. (ed.). (2019). *Associated Regional Chronologies for the Ancient Near East and the Eastern Mediterranean (ARCANE). Volume 5 - The Tigridian Region*. Turnhout: Brepols.

Rova, E., Weiss, H. (Eds.), 2003. *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX*. Brepols, Turnhout.

Salman, I. (1976). *Atlas of the archaeological sites in Iraq*. Baghdad.

Sağlamtimur, H., Batıhan, M., Aydoğan, I., 2020. Between the plains and the mountains: A brief look at Upper Tigris region in the Post-Uruk period according to data from Başur Höyük. In: Restelli, F.B., Cardarelli, A., Di Nocera, G.M., Manzanilla, L., Mori, L., Palumbi, G., Pittman, H. (Eds.), *Pathways through Arslantepe Essays in Honour of Marcella Frangipane*. Sette Città, Roma, pp. 435–447.

Schwartz, G.M., 1987. The Ninevite V Period and the Development of Complex Society in Northern Mesopotamia. *Paléorient* 13 (2), 93–100.

Schwartz, G.M. (2015). *Rural Archaeology in Early Urban Northern Mesopotamia: Excavations at Tell Al- Raqa'i. Monumenta Archaeologica 36*. Los Angeles: University of California.

Starková, L., 2020. Toward a High-Definition Remote Sensing Approach to the Study of Deserted Medieval Cities in the Near East. *Geosciences* 10 (9), 369. https://doi.org/10.3390/geosciences10090369.

Thomson, R.C. and Mallowan, M.E.L. (1933). The British Museum Excavations at Nineveh, 1931-32. *Annals of Archaeology and Anthropology*, 20, 71-186, pls. XXXV-CVI.

Tobler, W., 1993. Three Presentations on Geographical Analysis and Modeling: Non-Isotropic Geographic *Modeling. Tech. Rep.* 93, 1–25.

Ur, J., 2002. Surface Collection and Offsite Studies at Tell Hamoukar, 1999. *Iraq* 64, 15–43. https://doi.org/10.2307/4200517.

Ur, J., 2010. *Urbanism and Cultural Landscapes in Northeastern Syria: The Tell Hamoukar Survey, 1999-2001*. Oriental Institute, Chicago.

Ur, J., Babakr, N., Palermo, R., Creamer, P., Soroush, M., Ramand, S., Novácek, P., 2021. The Erbil Plain Archaeological Survey: Preliminary Results, 2012-2020. *Iraq* 83, 205–243. https://doi.org/10.1017/irq.2021.2.

Ur, J. & Wilkinson, T.J. (2008). Settlement and Economic Landscapes of Tell Beydar and its Hinterland. In M. Lebeau, & A. Suleiman (eds.), *Beydar Studies 1. Subartu 21*. (pp. 305-327). Turnhout: Brepol.

Urbanek, S. (2024). rJava: Low-Level R to Java Interface (Versión 1.0-11) [Software]. https://cran.r- project.org/web/packages/rJava/index.html.

Valentini, S., 2012. Scavi di salvataggio a Kuriki Höyük (Turchia) (in Italian). In: Mazzoni, S. (Ed.), *Studi Di Archeologia Del Vicino Oriente. Scritti Degli Allievi Fiorentini per Paolo Emilio Pecorella*. University Press, Florence, pp. 275–298.

Wei T, Simko V (2024). *R package 'corrplot': Visualization of a Correlation Matrix*. (Version 0.95), https://github.com/taiyun/corrplot.

Weiss, A. D. (2001). *Topographic position and landforms analysis*. Poster Presentation. ESRI User Conference, San Diego.

Weiss, H. (2003). Ninevite 5 Periods and Processes. In E. Rova, and H. Weiss (eds.). *The Origins of North Mesopotamian Civilization: Ninevite 5 Chronology, Economy, Society. Subartu IX* (pp. 593-624). Turnhout: Brepols.

Weiss, H. (2013). Tell Leilan and the Dynamics of Social and Environmental Froces across the Mesopotamian Dry-Farming Landscape. In D. Bonatz & L. Martin (eds.). *100 Jahre archäologische Feldforschungen in nordost-Syrien – eine Bilanz. Schriften der Max Freiherr von Oppenheim-Stiftung 18* (pp. 101-116). Wiesbaden: Harrasowitz.

Wilhelm, G. & Zaccagnini, C. (eds.), (1993). *Tell Karrana 3, Tell Jikan, Tell Khirbet Salih. Baghdader Forschungen* 15 (pp. 37-136). Verlag Philipp von Zabern.

Wilkinson, T.J. & Tucker, D.J. (1995). *Settlement development in the North Jazeera, Iraq. A Study of the Archaeological Lanscape. Iraq Archaeological Reports* 3. British School of Archaeology in Iraq Department of Antiquities & Heritage.

Yang, X., Fox, N., Van Berkel, D., Lindquist, M., 2024. Viewscape: An R package for the spatial analysis of landscape perception and configurations in view sheds of landscapes. *SoftwareX* 26, 101662. https://doi.org/10.1016/j.softx.2024.1016.

Yaworsky, P.M., Vernon, K.B., Spangler, J.D., Brewer, S.C., Codding, B.F., 2020. Advancing predictive modeling in archaeology: An evaluation of regression and machine learning methods on the Grand Staircase-Escalante National Monument. *PLoS One* 15 (10), e0239424. https://doi.org/10.1371/journal.pone.0239424.