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The importance of flat archaeological sites in the Age of Empires and new digital methods for their identification and analysis

A case study from the Peshdar Plain in Iraqi Kurdistan

In the Age of Empires of the first millennium BCE when large, major urban centres dominated the plains of Mesopotamia and the coastal regions of the Mediterranean, the rural landscape began to transform, with settlements often located away from traditional, mounded sites. Finding these sites can be challenging but is not impossible. However, the mountainous regions in Iraq and the neighbouring areas present special methodological challenges. Many sites occupied were flat and low, making them less visible in surveys and even in satellite-based remote sensing data. Machine-learning techniques and the use of point pattern analysis of stone debris offer the possibility of finding the typically less detectable flat sites using drone (UAV) imagery. Once detected, flat sites offer the considerable advantage that street networks and urban zones can be more easily mapped by using geophysical prospection. This provides advantages in understanding movement within such sites using graph analysis and can help provide insight into social behaviour in the use of urban zones and land use more easily than Bronze Age mounded sites. This paper explores both these issues and discusses their usefulness in Iraqi Kurdistan and beyond.

1. Introduction

Archaeology in Mesopotamia has mostly focused on mounded sites, which are typically highly visible in the landscape. While many such sites warrant this kind of attention, during the first millennium BCE, including in the Neo-Assyrian period, settlements shifted to new areas, often leading to the construction of sites in areas previously unoccupied.[2] In such cases, these settlements often appear flat or have generally low gradients and slopes (e.g., less than 5%). Given their imperceptibility, even when using satellite imagery, this presents a key

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problem in the detection of such sites. Furthermore, it has become evident that the quantities of ceramics from sites in some of the regions in Iraqi Kurdistan are generally much smaller than those observed elsewhere in Mesopotamia, further complicating site detection.[3] Thus, the development of entirely new methods is necessary in order to find relevant archaeological sites that are not only flat but also, in many cases, date to the first millennium BCE and later.

While typical pedestrian survey methods are not likely to detect relatively flat sites with sparse ceramics coverage, the use of unmanned aerial vehicles (UAVs; drones) in archaeology has become common, with techniques in image interpretation greatly assisting in the identification of the types of archaeological sites that became increasingly common in the first millennium BCE. Ideally, thermal or multispectral cameras would be used in UAVs; however, even visible light type images have the potential to be highly useful for site detection. In such cases, machine-learning techniques, including supervised and unsupervised classification, along with identification of spatial patterning of stones could be highly effective in detecting the kinds of settlements we expect to find in the mountainous regions of Iraqi Kurdistan.[4] In particular, as such sites used stone as their primary building material, remains of these stones may be more common than ceramics or other artefacts, indicating that such material should be used for the detection of ancient sites that typically date to the first millennium BCE and later. The advantage of finding relatively flat sites is that they can be more easily studied for their urban structure and layout, as geophysical techniques can be more easily applied; the limited stratigraphic sequences also implies a greater possibility for obtaining snapshot views of large areas of sites. Flat sites are therefore advantageous for research focussed on understanding spatial urban organization.

After identifying relatively flat sites, and once they can be mapped using geophysical prospection, other methodologies can provide insight into the likely location of first millennium BCE public spaces, including markets and social gathering points such as temples. In this case, graph analysis, in which mapped streets are studied for their connectivity, could be used to indicate areas where traffic was likely to have concentrated relatively more in relation to other streets.[5] These techniques also fall within space syntax studies, in which graphing results are used to anticipate likely areas of greater traffic. Combining site detection methods to find relatively flat archaeological sites and with graph analysis on street networks determined through geophysical prospection can, therefore, begin to change our understanding of Iron Age (and later) settlements. While finding relatively flat sites can be frustrating for archaeologists, such sites have the advantage of revealing more about urban morphology than mounded sites which take decades to properly excavate.

This paper discusses two methodologies. The first is used to find archaeological sites in relatively flat or unmounded areas, including cases where minimal ceramics are present. In addition to site detection, the second method applies graph analysis to the results of a street network determined by geophysical prospection in order to demonstrate the likely relevant importance of urban spaces in a first millennium BCE site. This chapter begins by presenting a case study from Iraqi Kurdistan, the site of the Dinka Settlement Complex (DSC) in the Bora Plain. The method for detecting such sites is then presented, demonstrating how sites in mountainous regions or areas that utilise stone for construction, could be located.

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3   Altaweel et al. 2012.
4   Altaweel and Squitieri 2019.
5   Boeing 2019; Altaweel and Wu 2010.

The graph analysis technique, encompassed within a GIS tool developed by the author, is also discussed. Results of the stone detection method are presented as well as a graph analysis of DSC's roads, which demonstrates how flat archaeological sites may offer greater understanding of past social phenomena in the first millennium BCE. The conclusions of this work discuss the benefits of the methodologies and possible future research directions.

2. Background

2.1 Flat sites and surface stones

Surface surveys in the Middle East have mostly focused on mounded and relatively easily-visible sites either from eye-level[6] or from remotely sensed images.[7] Such sites have understandably attracted considerable attention given their visibility, and the fact that many of the great capitals and socially significant sites of the Bronze and Iron Ages are located on major mounded sites. However, both standard, visible light aerial imagery from drones (UAVs) and satellite data often do not easily distinguish sites with low slopes (e.g., < 5%) or low gradients (e.g., < 0.1 m), making the detection of such sites difficult. While the definition of what exactly constitutes a "flat" site is not always agreed on,[8] as most surfaces are not truly flat, it is clear that sites with relative low slopes are not easily distinguished using the standard imagery and field survey techniques applied by most archaeologists.
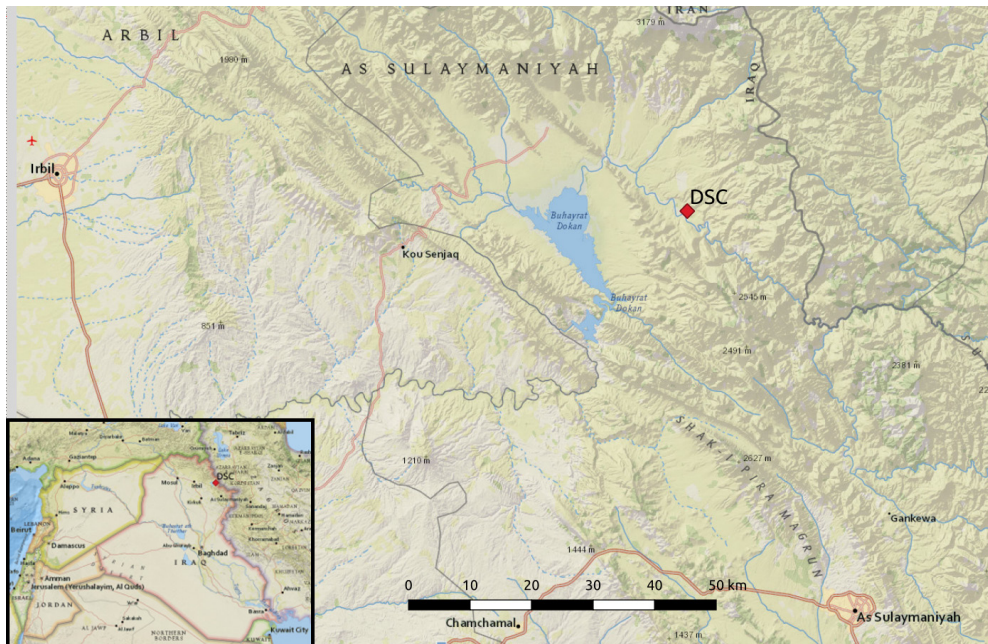

Fig. 1. The location of the Dinka Settlement Complex in Iraqi Kurdistan.

6   Adams 1981; Gibson 1972; Finkbeiner 1991.
7   Kouchoukos 2001; Kennedy 1998.
8   Hofmann 2012.

Additionally, the low number of ceramics finds further complicates the discovery of archaeological sites. Alternative approaches may be needed to detect sites with minimal accumulated debris and relatively low ceramic density.

Flat sites are common in the first millennium BCE in the Near East,[9] including in Iraqi Kurdistan at the Dinka Settlement Complex in the Bora Plain, located about 60 km north of Sulaymaniyah (Slemani) (Fig. 1). Both at the DSC and in other regions in the province of Sulaymaniyah,[10] low ceramics concentrations make settlements more difficult to detect using surface survey techniques.

However, one benefit offered by the mountainous zones of Iraqi Kurdistan is the abundant availability and use of stone for building architecture. Unlike in the plains of northern Mesopotamia, stone is often found in high concentrations on site surfaces, which potentially makes the ancient settlements more visible. However, distinguishing between natural stones and those used for architecture (and thus stones that were transported by human activity) is not always easy. But as has been noticed in regions such as western Syria,[11] human transportation and deliberate construction are likely to be revealed by patterns and concentrations of stone that differ from the wider background distribution of stones. The presence and distribution of surface stones can, therefore, potentially be used to distinguish archaeological sites, with concentrated patterns revealing clear clusters that are distinct from the wider distribution of stones and thus indicating that human occupation was likely in a given area.

2.2 Case study: Dinka Settlement Complex

To demonstrate the utility of these advanced methods, this paper presents a case study using the Dinka Settlement Complex. Excavations and geophysical prospection have revealed an archaeological settlement at the DSC sprawling across 60 ha.[12] The settlement consists of an eroded natural hill, called Qalat-i Dinka, which rises about 40 m above the plain, with the lower Zab river flanking it on the west. Another part of the site is Girdi-i Bazar, which is a small mound of less than 1 ha that is both naturally relatively higher on the plain but also has some accumulated human occupation. The remainder of the site spreads across the alluvial Bora plain, with Cretaceous limestone ridges to the east of the site.

Initial field observations in 2015 did not suggest the existence of a wide site that spread across the plain, as the ceramic surface survey only revealed 776 diagnostic sherds over 60 ha, a number generally low by Near East standards.[13] At the beginning of the excavations, only the area within and around Girdi-i Bazar was believed to have been occupied, with evident Iron Age remains. However, first confirmation of the presence of an extended archaeological site was obtained by the geoarchaeological trenches excavated between Girdi-i Bazar and Qalat-i Dinka in 2015.[14] The geoarchaeological studies confirmed that the surface stones at the DSC were transported in antiquity for use as building materials and were not natural stones found on the surface. Excavations at Girdi-i Bazar and later also in DLT2 and DLT3 further confirmed the existence of occupational and structural remains. Juxtaposing

9   Wilkinson 2000.
10   Altaweel et al. 2012.
11   Philip et al. 2002.
12   Radner et al. 2018; Fassbinder et al. 2017; 2018.
13   Giraud 2016.
14   Altaweel and Marsh 2016.

the geophysical results, the archaeological trenches and the ceramic remains observed indicated that the settlement extends over a much wider area than initially thought (Fig. 2).

While the Peshdar Plain Project was fortunate to have found this extended settlement site, it opens up the question of how such a site could be identified without geophysical survey and
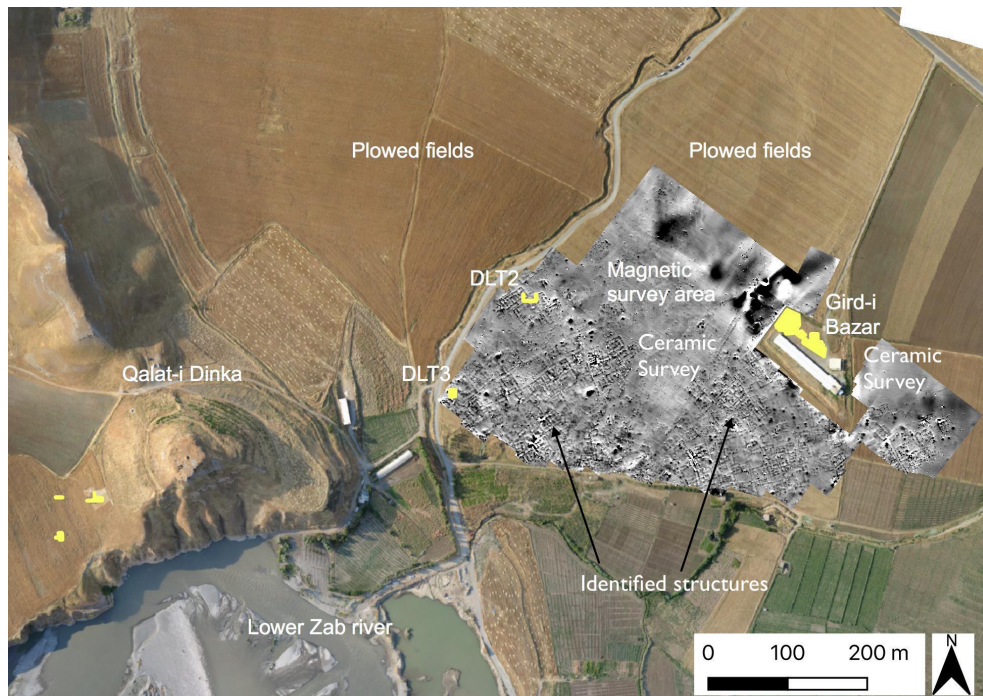

Fig. 2: The site of the Dinka Settlement Complex spread across the Bora Plain showing areas of different archaeological work.

geoarchaeological trenches, as these are not generally part of most surveys, nor can they be easily applied across many sites. As archaeological survey data and geophysical results are available for DSC, these data can be used to determine how well an approach that integrates UAV imagery manages to identify built-up areas underground. The results of this case study can then be applied to identify other sites in regions similar to that of DSC.

3. Methods

3.1 Imagery and K-means cluster

With the paper of Altaweel and Squitieri (2019) providing full details on the methods used, it will therefore suffice to summarize these methods briefly here. To map DSC, a DJI Phantom 4 Pro drone (UAV) was used during the autumn 2018 season to capture imagery at a height of 80 m, using a CMOS 20 mega-pixel sensor. Ideal conditions for image recovery include clear skies to ensure good lighting and minimal vegetation cover. The images were then

processed using Agisoft Photoscan to create orthophotos. After this, ENVI 5.5 software was used to conduct a machine-learning unsupervised k-means cluster analysis consisting of 24 identified classes with two iterations. Open source tools, including deep learning and artificial intelligence tools such as Python Keras (2020)[15] or Scikit-learn (2020),[16] can potentially also be used. Regardless of which tools are used, the k-means cluster analysis used here distinguishes between features in the orthophotos that include natural and anthropogenic elements.[17] Where possible, roads and wadis, including recently built features, were excluded from our analysis to minimize signal interference.

Once the k-means clustering method has been applied, features such as rocks or other items can be distinguished by the classes determined by this unsupervised classification method. One class distinguishes rock features evident on the surface of the site, and this class was exported as a shapefile to QGIS for analysis. In order to test the validity of this identification of stones, nine random 40 × 40 m squares on the orthophotos were sampled. With over 9,000 stones sampled from the k-means cluster analysis, true positives and false positive readings were measured, resulting in a positive predictive value (PPV; true positives/(true positives+false positives)) of 0.96. This indicates that we achieved a precision level of about 96% in identifying stones, suggesting that this technique is indeed sufficient for identifying stone features on site surfaces.[18] With this confirmation, the full analysis of stones was then assessed.

3.2 Regression analysis and point pattern analysis

The results from the k-means classification can then be taken and compared to the surface ceramics survey and the results of the geophysical survey. This allows us to see how well the surface stones match architecture as determined by geophysics, while also comparing this result to ceramics picked up during the pedestrian survey. A simple linear regression can be used to determine how well the k-means classification determined the mapping of surface stones to architecture identified by the geophysical survey.[19] With this, we now have outputs from the analysis that demonstrates how well the surface ceramic survey compares to the mapping of surface stones for site detection.

Additionally, a k-nearest neighbour point pattern analysis (PPA) is run to determine the concentration of stones that represent an ancient site.[20] PPA helps to distinguish the approximate level of stone concentration that one could reasonably use to indicate whether an archaeological site is present. The PPA analysis provides an output that demonstrates whether identified points (stones in this case) are likely to be randomly or non-randomly distributed, with less random distribution suggesting the presence of human activity.

Furthermore, contrasting between on-site and off-site PPA indicates what level of variation is possible between these two types of areas, which can demonstrate whether an archaeological site is likely to be present. The presence of an archaeological site should result in a higher stone concentration than a non-archaeological area. The Nearest Neighbour Index (NNI)

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15   https://keras.io/. Last accessed 18 May 2020.
16   https://scikit-learn.org/stable/. Last accessed 15 May 2020.
17   Altaweel and Squitieri 2019; Wu 2012; Richard 2013.
18   Brenning 2009.
19   Fassbinder et al. 2017; 2018; Giraud 2016.
20   Illian 2008.

can be used as output values for on- and off-site measurements for PPA, demonstrating where stone distributions are likely to be the result of human activity rather than the result of random distribution.

3.3 Graph analysis

While the case study presented here compares geophysical data and how it maps to stones found using UAV imagery, this was only done for validation purposes. The main reason one would want to carry out an assessment of surface stones using UAV imagery is to find a site without having first done a geophysical survey. In fact, the expected order would be to find a site using UAV imagery, using the k-mean and PPA analysis demonstrated here, and then to carry out a geophysical survey to map any architectural features. This technique offers the potential of identifying many more single-period sites than are currently known.

The benefit of finding single-period or short-lived sites, including flat sites, is that they can reveal clear architectural features using geophysical analysis, including magnetometry. Street networks can be more easily mapped, enabling one to see a footprint of ancient streets and their relation to different neighbourhoods or architectural features in urban contexts. In turn, mapping streets enables the identification of key areas where public spaces or important buildings and institutions, such as markets and temples, may have been located. This make flat sites potentially important for understanding Near Eastern social institutions and urban contexts, as relatively few settlements have been fully mapped.

With the methods advanced earlier for finding flat sites, the method demonstrated here then permits researchers to better understand urban social spaces by studying movement patterns using space syntax graph analyses.[21] Different graph analyses, including centrality measures such as betweenness, closeness, degree, efficiency, and straightness could be utilised.[22] All of these centrality measures are used in an analysis based on a GIS tool created by the author, which was first developed during a fellowship held at LMU Munich's Center for Advanced Studies (CAS[LMU]) in autumn 2018.[23] In summary, the centrality measures offer different ways to determine central areas or places likely to be the most trafficked, based on the connectivity of streets to each other. Betweenness centrality measures the influence of a node in connections between other nodes (i.e., how important a node is for moving between different places). Closeness centrality measures the inverse distance of nodes; degree centrality measures the number of connections a node has. Efficiency and straightness centrality measure the importance of a node to a network based on its removal and how straight a given path is between nodes respectively.

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21   Jiang and Liu 2009.
22   Liu et al. 2015; Crucitti et al. 2006.
23   https://plugins.qgis.org/plugins/StreetAnalysis/; the tool can be downloaded from QGIS (www.qgis.org/) by searching for Street Analysis (2020).

4. Results

4.1 Site detection

Fig. 3 demonstrates results from the k-means cluster analysis, where identified stones are in-dicated, along with 40 × 40 m sample squares used for PPV. Overall, 24 classes, as identified using the k-means cluster assessment, were used in the analysis. From these classes, only one was deemed relevant: class 23. This class shows stones that are marked on Fig. 3, with over 82,000 stones shown in the figure. Two iterations of the k-means cluster assessment were sufficient to yield the results shown. Next, an NNI index was applied using stones identified in the known on-site areas (the area covered by geophysical survey) and off-site areas from the DSC. Areas such as wadis, roads, and the modern chicken farm that occupies part of Gird-i Bazar were removed from the analysis to prevent interference in the results, as these are either modern or clearly intrusive.
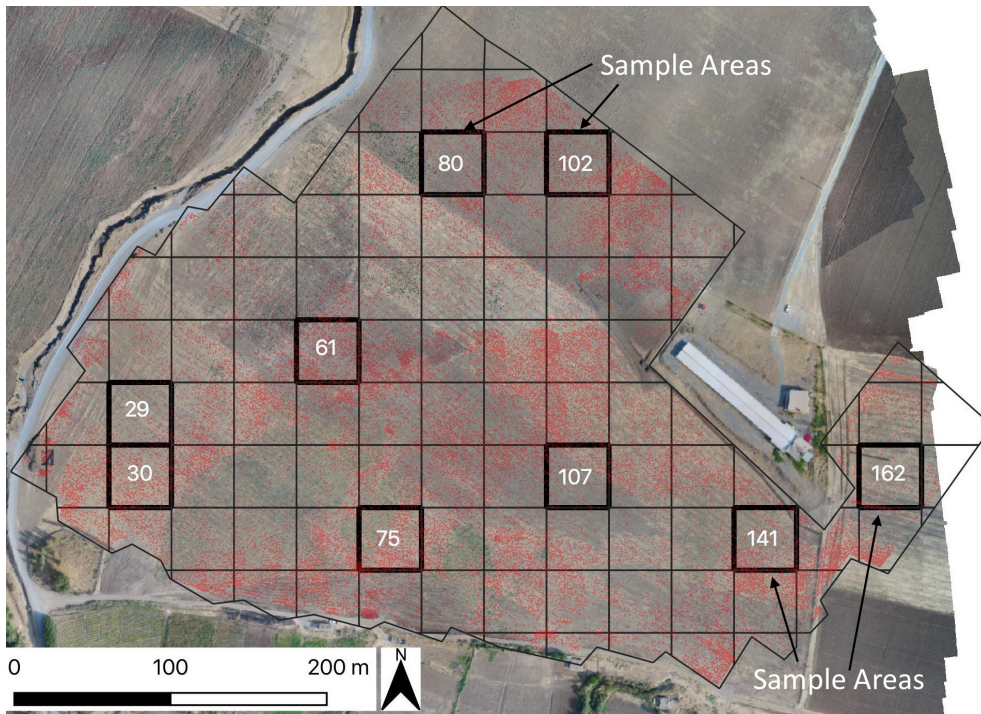

Fig. 3: Identified stones across the Dinka Settlement Complex and sample squares for PPV.

Fig. 4 and Table 1 demonstrate results of the NNI analysis along with observed and expected mean distance. The mean distance reflects mean distance between stones, which indicates a much tighter clustering of stones in the on-site areas. Overall, the NNI results indicate that stone concentrations are much more pronounced in the geophysical, on-site areas, with the NNI value lower there than the off-site areas. Values closer to 0 suggest a tightly-clustered distribution, indicating that the on-site stones are not only more closely clustered together

but are also likely to be less random in distribution, which is one would expect from a more natural distribution. The NNI values, in other words, suggest that such a value is what can be expected for an ancient settlement having stone architecture, with the remains of this architecture evident on the surface.
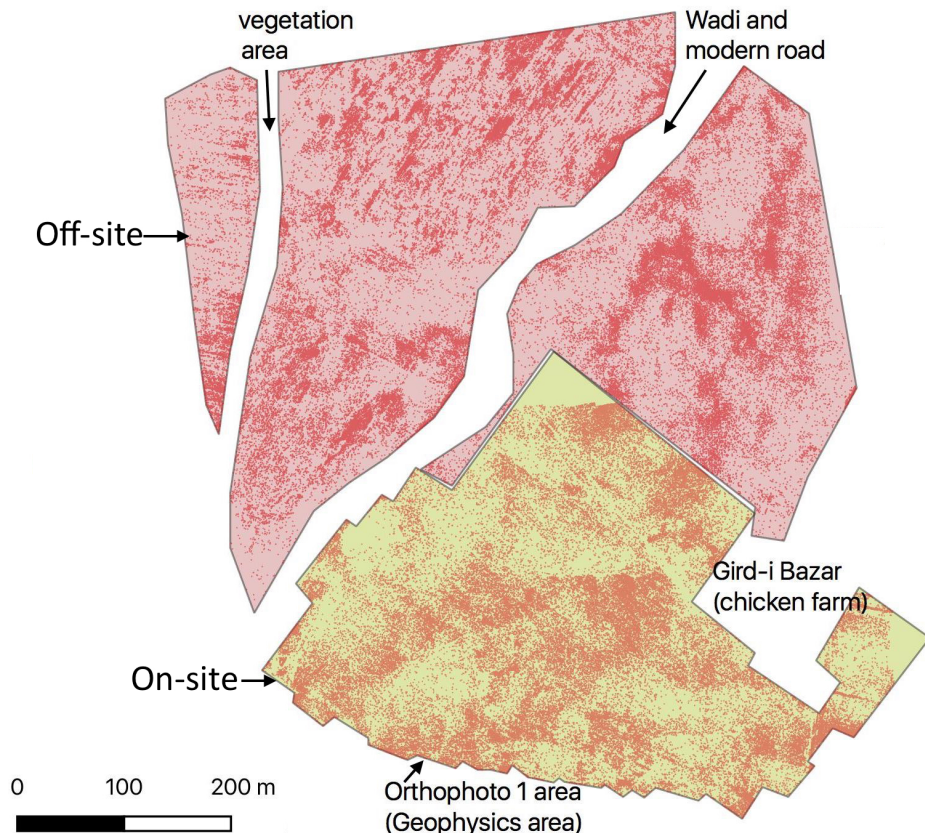

Fig. 4: Area covered on- and off-site, which are characterized by areas covered in geophysics for on-site. Stone concentrations are denser in the geophysical areas.

Table 1. The NNI results and mean distances observed for the two divided areas.

Place	Observed Mean Distance	Expected Mean Distance	NNI
Off-Site	0,3893	0,8962	0,4344
On-Site	0.0155	0.5155	0.0302

While the above analysis was carried out to demonstrate which imagery signatures demonstrate the clear presence of surface stones and where they are concentrated, the utility of this approach is made evident when compared to the surface ceramic survey. Fig. 5 reflects areas where diagnostic sherds were found in the DSC and its surrounding area. This output can be taken and a regression analysis can be carried out that compares the architectural remains, using built area from the identified features in the geophysical results, and the ceramic surface survey. Then the stone counts from the k-means cluster, surface ceramics, and identified architecture can be compared in a regression.

Table 2 shows the sherd count along with the stone count and built area for the pottery collection zones used in survey. The three measurements - ceramic count, stone count, and architecture area - allow a regression to be applied for all three values, indicating how ceramic sherd count and stone counts demonstrate goodness-of-fit relative to built-up areas. In other words, the values help to demonstrate whether pottery sherds or stones act as a better fit to built-up areas in this case. This helps to establish whether stone counts might prove to be a better indicator of settlement.
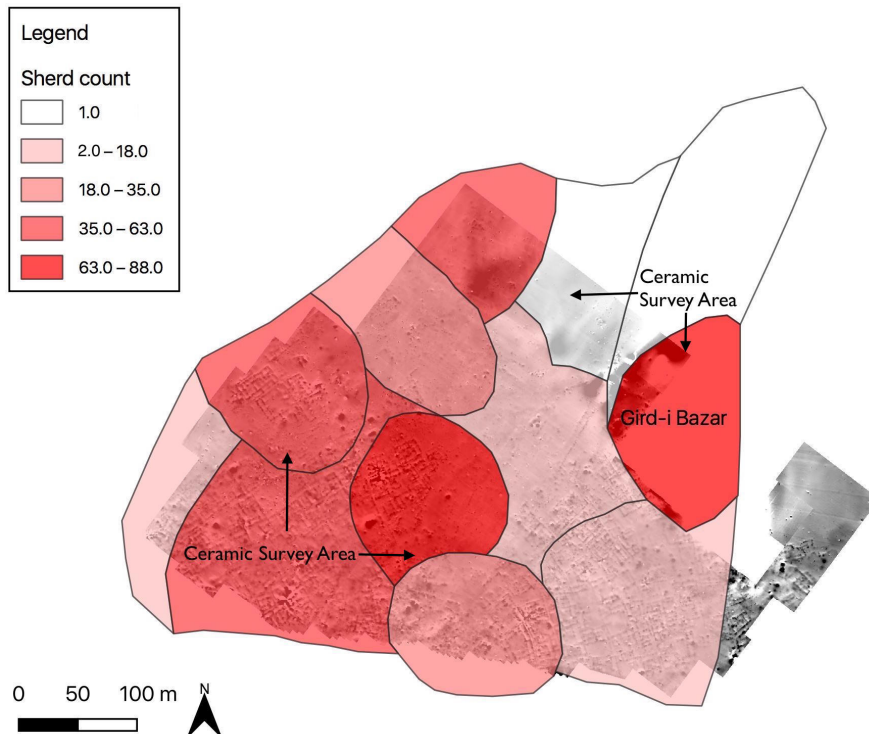

Fig. 5: Areas (outlined) where a ceramic surface survey was conducted in DSC (after Giraud 2016).

Table 2. Sherd count, built area, and stone count for given survey collection areas.

Area ID	Sherd Count	Built-up Area (m²)	Stone Count
1282	1	0	1635
1284	48	4070	3670
1285	42	0	3964
1286	35	1686	3603
1287	18	746	2043
1288	30	3626	9829
1290	10	9184	10593
1291	77	3896	12155
1292	1	0	5404
1298	63	8712	15477
1299	9	4009	13651

Fig. 6: Regression applied across 150 × 150 m sample squares across DSC that compared normalized ceramic and stone remains to evident architecture. The values indicate r^2 results, showing the strongest fit is between stones and built area.

Fig. 6 reflects a regression carried out within 150 × 150 m squares divided across DSC and clipped to the area of the site and survey areas. In this case, it is clear that the fit is stronger between stone architecture and surface stones, while the fit is weaker between ceramic sherds and stone architecture. The fit of the surface ceramics to architecture, determined by geophysics is $r^2 = 0.31$, which is a relatively weaker fit than that of the stones found on the surface of DSC.

In fact, r^2 improves to 0.77 (Fig. 7) for surface stones and built-area from geophysics if sampling areas do not have a standardized 150 × 150 m measure but are simply divided into regions with architecture based on geophysics and areas with virtually no architecture, with only five sample regions used in this case (Fig. 8). Overall, this generally indicates that surface stones have a stronger relationship to architectural site remains determined by geophysics.
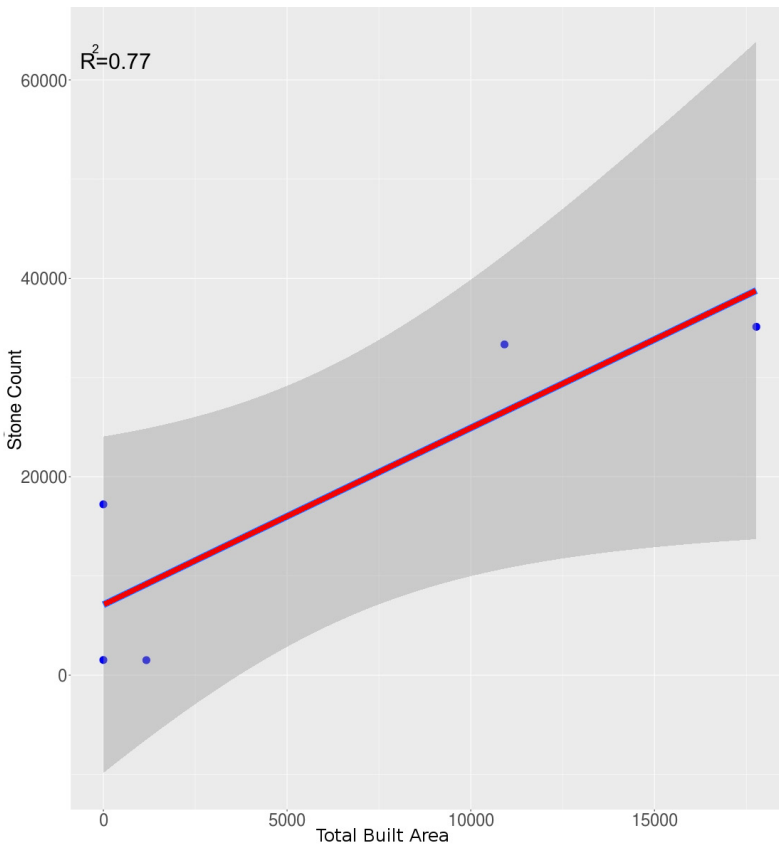

Fig. 7: Regression showing goodness-of-fit for five areas across DSC, including areas with and without architecture.
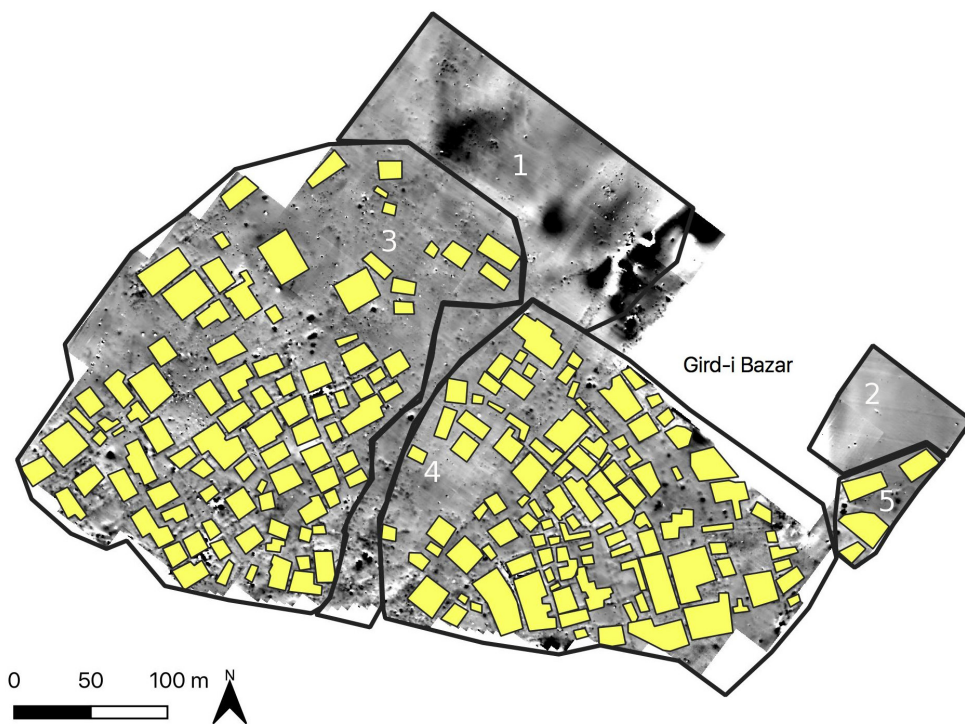
Fig. 8: Division of sample areas (numbered) used in the coarser regression for areas with built architecture and areas with minimal or no clear architecture.

4.1 Graph Analysis

The graph analysis discussed in the methods, using the StreetAnalysis tool,[24] was applied to the DSC based on the results of the geophysical survey discussed above. These results help to map streets and indicate given routes within the DSC. Results of the graph analysis of the streets and routes are shown in Fig. 9, which provides betweenness, closeness, efficiency, and straightness centrality measures.

These measurements are used to identify the streets that are most connected to other streets, where the most-connected streets are also likely to be streets with the highest levels of traffic. The results here are very similar, indicating the main east-west road and routes to the northeast and southwest in the site are likely to have the most traffic. The results show that accessing the various identified streets throughout the DSC requires heavy use of the street segments identified. These areas could be expected to include markets, temples, or some form of public buildings. While excavation results have not verified this, the geophysical survey shows some potentially large buildings along the routes with the likely or suspected busiest traffic levels.[25]

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24   https://plugins.qgis.org/plugins/StreetAnalysis/ (last accessed 8 May 2020).
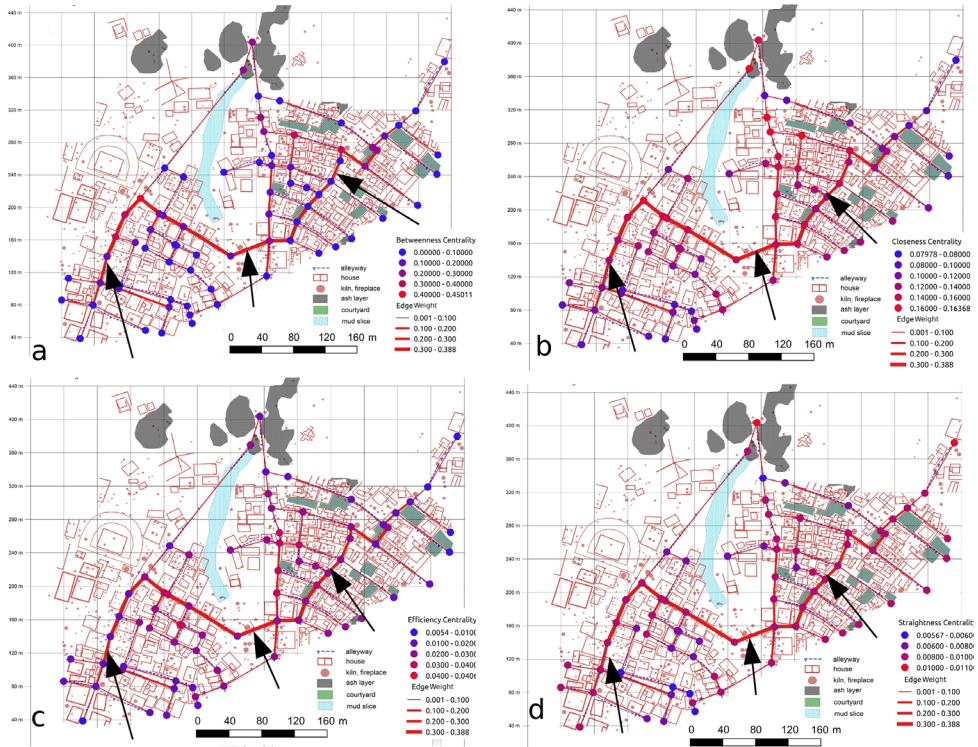25   Fassbinder et al. 2017; 2018.

Fig. 9: Results of betweenness (a), closeness (b), efficiency (c), and straightness (d) centrality using the
QGIS Street Analysis tool created. Degree centrality results are not indicated because they are
very similar to the displayed results. Arrows indicate areas of high relative traffic as deter-
mined by the graph analyses. For feature interpretations, see Fassbinder et al. 2018

Based on these results, core samples from both the potentially busiest streets and streets
deemed to be less busy in the past are currently being analysed by Eileen Eckmeier at LMU
Munich. Investigation of street-level sediments may demonstrate proxies for greater or less
traffic. This is similar to a study conducted earlier at Kerkenes Dağ in Anatolia, which com-
bined modelling and geoarchaeology to demonstrate which urban streets likely had more
ancient traffic.[26] In this case, smaller-sized sediment particles suggested greater levels of
trampling and the streets suggested to be the most trafficked in the modelling approach
matched the streets with the smallest sediment particles. We hope similar results could be
demonstrated for the DSC, potentially indicating the benefit of studying flat sites which may
also then give us insight about where important urban structures may have been located.

26   Altaweel and Wu 2010.

5. Discussion and conclusions

The first millennium BCE is distinct in Near Eastern archaeology in that many new sites were established on relatively flat landscapes. In Iraqi Kurdistan, this also means often that minimal levels of ceramics are found on the surface. Detecting such sites is difficult using traditional pedestrian survey techniques, or even when satellite remote sensing data are used. However, using images that show surface stones, even without the benefit of thermal cameras or multi-spectral sensors, can enable the detection of sites, particularly in regions where stone architecture is likely to have been common. Machine-learning techniques can distinguish stones, while PPA techniques help to distinguish concentrations of stones relative to the background noise in a region. Values that show large differences in PPA between areas that can be designated as sites and those areas outside of sites could be the critical output for identifying whether a site is detected. This approach could substantially aid in the recovery of first millennium BCE and later sites which, up to now, are under-represented in the archaeological record, even though they likely form an important urban component in a period of large empires and states. New methods such as the ones presented here are needed if we are to improve the recovery of such sites. Sites with NNI values lower than 0.1 for identified stones suggest the likely presence of intentionally-deposited stones in regions where stone dispersion is more random or less likely. Other values are possible, but generally values well below 1 will show dense concentrations of stones that we would not expect in regions where relatively few surface stones are typical. The value for detecting sites may need to be adjusted, however, in regions that have a higher concentration of naturally occurring surface stones (e.g., in the case of water transported stones). In the case of the DSC, it can be demonstrated that surface stones generally appear primarily as a result of human activity.[27]

While the objective of site recovery, by itself, is sufficient to warrant more research on the use of machine-learning, there is another reason why it is worthwhile to identify specifically flat sites. Once detected, flat sites can provide insights not normally available to us when dealing with long-lived, multi-layered sites. Specifically, geophysical surveying allows us to more easily map flat sites than settlement mounds and this is enormously useful to reconstruct urban street networks. With urban street networks, graph analyses permit a space syntax approach for determining likely street nodes and edges where higher levels of traffic may have traversed in the past. As the results of this analysis are currently being tested in the DSC, for now the graph analyses outputs indicate that public spaces and large-scale building structures (potentially sanctuaries or markets) may have concentrated near a main thoroughfare running east-west or northeast to southwest. Archaeological excavation will need to validate whether such buildings were indeed present in the areas along this route.

However, already the results presented here highlight the great potential offered by a tool that can identify the locations of important buildings within a site. Overall, the work presented in this paper has demonstrates, firstly, the usefulness of a machine-learning and PPA approach for detecting sites in areas that are detrimental to their easy identification by using the methods typically applied in the Middle East, and secondly, the potential of an analytical technique that can serve to reveal important spaces within ancient settlements.

27　Altaweel and Marsh 2016.

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