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RESEARCH ARTICLE

Comparative analysis of settlement change across Mesopotamia: exploring a large Iraqi archaeological dataset with aoristic analysis

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ABSTRACT

In memory of Amir al-Hamdani, this paper utilises a large Iraqi archaeological dataset to explore settlement patterns between 6000 BC and 1900 AD. The dataset includes a refined version of Amir's 'Digital Database for Archaeological Sites in Iraq', as well as thousands of other sites collated as part of the 'Endangered Archaeology in the Middle East and North Africa' project. Splitting Iraq into north, central and south zones we apply aoristic analysis to our preliminary Iraq dataset. We seek to explore: 1) how site numbers fluctuate over time; 2) whether there are regional differences; and 3) how they relate to general trends such as climate, increasing social complexity and the emergence of cities, states and empires. Our analysis effectively plots changes in site numbers, and demonstrates clear regional differences. Climatic and socio-political changes explain many of the observed trends, but higher-resolution data is needed for more detailed and nuanced plots.

Keywords: *Iraqi archaeology, settlement patterns, aoristic analysis, Amir al-Hamdani, Endangered Archaeology in the Middle East and North Africa (EAMENA), digital databases, site density, regional differences, climate change, social complexity, urbanization, Mesopotamian empires*

1. INTRODUCTION

We are honoured to offer this paper, which reflects the convergence of two streams of Amir's archaeological work, as a tribute to our colleague and friend. We were delighted to have Amir work at Durham University as Training Manager on the Endangered Archaeology in the Middle East and North Africa (EAMENA) project, and to lead on our collaboration with the State Board of Antiquities and Heritage (SBAH) that sought to train staff in the identification, mapping and condition assessment of archaeological sites using satellite imagery. One long-term aim of this project is to create a digital national inventory of archaeological sites in Iraq. A preliminary version, known as the *Digital Database for Archaeological Sites in Iraq,* was developed by Amir, and given to the SBAH in 2018. This included the results of his pioneering surveys undertaken in the marshes of southern Iraq. As a member of the EAMENA project, Amir shared this dataset with the project team so it could be enhanced through revision and updating, and by the inclusion of additional datasets. Since then, EAMENA has worked to extend Amir's original dataset and improve its locational accuracy; we have currently mapped around 18,000 sites across Iraq, with more still to be added.

As well as Amir's archaeological database, EAMENA is in the process of collating site data from a wide range of sources, including a range of historic documents and published research. We hope that when complete this dataset will be of value to the SBAH in protecting the globally significant archaeology of Iraq. In this tribute to our late friend and colleague we analyse a preliminary version of the dataset to compare changes in settlement patterns in northern, central and southern Mesopotamia from 6000 BC to 1900 AD.

Settlement patterns have been studied in Mesopotamia for almost a century (Braidwood 1937; Adams 1965). The precise research questions they are used to address – issues such as social complexity, urbanisation, agricultural development, demography – may vary, but understanding the number, size and distribution of sites over time and space remains a crucial component for understanding past societies (Marchetti 2024; Lawrence et al. 2021; Algaze 2017). In this paper we analyse our preliminary archaeological dataset to better understand settlement patterns in Mesopotamia. Three key questions are central to our approach:

1. How did site numbers fluctuate over the course of the study period?
2. Can we see regional differences in these fluctuations?
3. How do these changes relate to general trends, including climate and, at a millennial scale, increasing social complexity and the emergence of cities, states and empires?

2. Materials and Methods

2.1 Iraq archaeological database

2.1.1 EAMENA and Amir's Archaeological Database in Iraq

Prior to working with Durham, Amir had carefully compiled a database of over fourteen thousand archaeological sites and possible sites, creating what he called the *Digital Database for Archaeological Sites in Iraq* (al-Hamdani 2015a). Several hundred of these sites he discovered during his own surveys in the Southern Marshes (al-Hamdani 2014; 2015b). He was extremely keen to share his hard work with colleagues to help protect and publicise the archaeology of Iraq. Amir's dataset has provided the foundation to the Iraq dataset presented here, refined and augmented by the addition of several additional published datasets.

2.2 Data sources

Nine primary data sources have been used to create the current dataset, although there is a considerable degree of overlap between these, both in their spatial coverage, and in the individual archaeological sites that they include. The level of detail and locational accuracy varies considerably between, and sometimes within, these datasets, which has made the process of collating and combining this information quite demanding.

Table 1: the main sources used to populate the Iraq dataset.

Dataset	Data	Notes
Digital Database for Archaeological Sites in Iraq	Point and toponym data for 14,500 sites and possible sites	Dataset created by Amir, but derived from a variety of sources, including his own fieldwork (al-Hamdani 2015a).
Atlas of Archaeological Sites in Iraq	Point and toponym data for 6,607 sites	Directorate General of Antiquities (1976, now the SBAH), all 136 maps have now been digitised
Archaeological Sites in Iraq	Toponym, period and administrative area data for 6,701 sites	Directorate General of Antiquities (1970, now the SBAH), translated to English

Archaeological Map of Iraq	Point, period and toponym data for 253 major sites	Directorate General of Antiquities (1967), digitised map
Carrie Hritz	Polygons and period data for 4,796 sites	From her PhD (Hritz 2005), in which she digitised the maps and gazetteers of surveys undertaken by Adams (1981, 1972, 1965), Gibson (1972) and Wright (1981)
Elizabeth Stone	Point, toponym, dimension and looting condition assessment data for 2,056 sites	Described in two papers on looting (Stone 2008; 2015), derived from Adams' (1981) and Wright's (1981) surveys, as well as Amir's marsh data (al-Hamdani 2014).
Olof Pedersén	Point and toponym data for 1,682 sites	Ancient Near East dataset (2007)
Jaafar Jotheri	Point data for 7,824 sites	Remote sensing survey data from his PhD (Jotheri 2016)
North Jazira Project	Polygon, toponym and period data for 184 sites	Tony Wilkinson's survey data, (Wilkinson & Tucker 1995), collated and digitised as part of the Fragile Crescent Project (Wilkinson et al. 2014)

It is not uncommon for a single site to appear in multiple datasets. However, the exact location (i.e. the coordinates) of the site will often vary between datasets. This is because they are ultimately derived from maps that were created, annotated, scanned and georeferenced to varying levels of accuracy, and at varying scales, by different projects. The identification and accurate location of sites, the removal of duplicate entries (cases where the same site has been placed in slightly different locations by different projects) and efforts to ascertain and collate the most accurate information for each individual site, proved quite time-consuming. The process is not yet complete, but the master dataset currently includes data on over 18,000 sites located across Iraq. Over 8,000 of these sites currently have associated period data, and so, while not yet complete, there is already sufficient data to support the examination of broad temporal changes in settlement patterns. We aim to add more recent survey work, especially from the Kurdistan Region of Iraq to our master dataset in the near future.

3. Data Modelling

3.1 Aoristic analysis

We use an aoristic approach to explore our dataset. Aoristic analysis was originally developed in the field of criminology to handle the temporal analysis of crimes for which no exact time was known, but that could be placed within a specified time-period. For example, consider a house burglary that took place over a two-week period when the occupants were away from home. While the exact date of the incident is not known, we do know that it took place at some point within the two-week period and for which it is possible to define start and end dates. Such an approach is useful if an analyst wants to see whether house burglaries follow a particular temporal pattern, although to generate the necessary data the analyst will have to create a dataset which will require the aggregation of data from hundreds, or even thousands, of separate events, some of which can be dated exactly and others only broadly – as with our two-week period (Ratcliffe 2002; 2000; Ratcliffe and McCullagh 1998). The probability of each event is distributed evenly across its individual timespan; to apply this to our burglary, all we know for certain is that it could have taken place at any point within the two-week period – we cannot be more precise than that. The probabilities from all events (those which can be dated precisely and those which can only be placed within a broader time-period) are then added together, and the resulting 'aoristic weight' is plotted on a graph – showing event likelihood over time. The applicability of this technique to archaeology, which usually deals with periods rather than absolute dates, was recognised quickly (Johnson 2004), and the precise methodology within the field has evolved since (Crema 2012; Müller-Scheeßel and Hinz 2018). It has already been applied successfully to better understand regional variation in settlement patterns over time in the Near East (e.g. Palmisano et al. 2021), and in Southern Mesopotamia (Marchetti 2024), as well as the possible timing of damage to cultural heritage in conflict situations (Mamo et al. 2022).

With period data derived from so many different datasets, it would be difficult to analyse our Iraq dataset using a single approach. A simple bar chart setting out site counts for the main periods would involve excluding the more generalised periods that were often used in in some older sources (e.g. 'Bronze Age' or 'Islamic') but would also risk masking the finer resolution offered by more precise dating (e.g. 'Ur III' or 'Late Abbasid'). Using an aoristic approach, it is possible to use temporal data across a range of resolutions. In practice, better-defined period data will contribute more to the probability of a specific time block than broad dating information, but both will be integrated into the final plot.

This approach does have its drawbacks. Overlapping periods can lead to artificial anomalies in the plot, at least in the absence of a more complex weighted model (Müller-Scheeßel and Hinz 2018). It can also be difficult to visualise and interpret period data categories with greatly differing timespans. As our chronological periods tend to get shorter as we move closer to the present-day, mainly because material culture changes more quickly than was the case in prehistoric periods, so temporal resolution improves. The method can also 'flatter' a dataset – producing impressive looking plots from low-quality or mixed data. The length of the time blocks used makes a substantial difference to the final distribution, and there is no mathematically defined approach for selecting a time block length to produce the best model. We have used a time block of 50 years as it produced the best visualisations, but this was an arbitrary decision. As with any analytical tool, these issues must be kept in mind when using it. However, taken as a whole, aoristic analysis provides an excellent means of extracting the maximum amount of information from a large, diverse and uneven archaeological dataset.

3.2 Mesopotamian zones

To provide a degree of inter-regional comparison, Iraq was broken up into three zones: South, Central and North Mesopotamia. The northern zone forms the Iraqi part of the fertile crescent – where dry farming is the predominant strategy. The central zone represents the boundary between the north and the main southern flood plain, where the Tigris and the Euphrates move away from each other. Its southern boundary runs through Baghdad, and its northern limit cuts diagonally across Iraq, roughly on the line between Hamrin Dam and the confluence of the Little Zab and the Tigris. The southern zone consists of the main southern plain and marsh zone all the way to the coast. Whether it is appropriate to delimit a Central Mesopotamian zone is debatable but we felt that, at this early stage in the analysis, it was worth examining the data from this zone as a separate unit, in order to better understand regional trends in settlement. Traditionally North and South Mesopotamia have been identified as the two main entities, but the boundary between the two is not well defined. Topographically there is no clear border, and isohyets are unreliable over long time periods as rainfall fluctuated significantly in the past (Hewett et al. 2022). In terms of subsistence, in this boundary area presumably neither dry farming nor irrigation would predominate, with the relative importance of each fluctuating over time depending on variation in environmental conditions and local political organisation. A Central Mesopotamian zone accounts for these difficulties, and should make the distinctive signatures of the northern and southern zones more clear by removing exceptional or boundary cases. It also provides an interesting research question as to whether this zone is more similar to the North or South, and whether its alignment with other regions varies over time.

We have included the southern and western desert from the southern and central zones although our current dataset has very few datable sites in this area, and we accept that new survey work in the region may change the picture substantially. However, it is important to understand that settlement in this area would have looked very different from that occurring in the core agricultural zones, as has been demonstrated clearly in the case of arid peripheries in other parts of southwest Asia (e.g. Philip and Bradbury 2010; Rosen 2017). Although they have been included for geographical completeness, the very low number of sites recorded in the arid zones means that their contribution is so small that they will not impact significantly upon the overall patterns. Future research might treat the desert as a separate entity, but with the current low number of sites, doing this would not yield meaningful results.

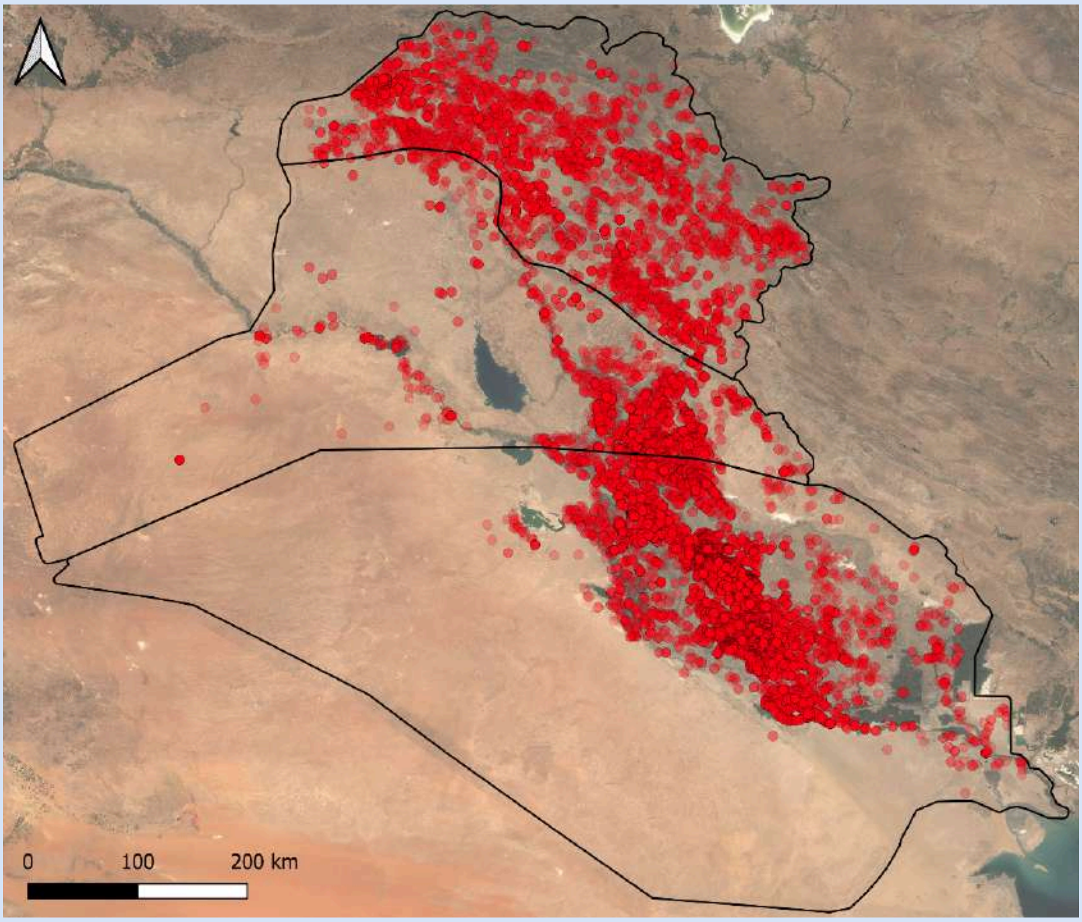

Figure 1: Mesopotamia zones and the preliminary dataset of datable archaeological sites in Iraq (Sentinel-2 imagery courtesy of the ESA).

Although datable sites are not evenly distributed numerically across the three zones, each zone has produced sufficient data to generate meaningful individual aoristic analysis plots (Table 2).

Table 2: Mesopotamia zone site counts and percentages.

Zone	Site Count	Percentage
North Mesopotamia	2,588	32.2%
Central Mesopotamia	1,271	15.8%
South Mesopotamia	4,178	52.0%

It should also be noted that sites are not distributed evenly within zones with, for example, the North Jazira Project data (Wilkinson & Tucker 1995) represent an unusually dense, and well-dated, pocket of sites within the wider North Mesopotamian zone.

3.3 Analytical parameters

The zone and periods of occupation of each site were listed in a spreadsheet for aoristic analysis. This was carried out in R using the aoristAAR package using fifty-year time blocks throughout. Because the major criterion for dating in all of the datasets used here was pottery, we have included all Neolithic or later sites listed in our sources within our dataset, setting the boundaries of the analysis to between 6,000 BC and 1900 AD. This spans the period from the appearance of Neolithic pottery types that can be readily dated, through to the end of the Ottoman period. Sites with period data but which lacked geographical coordinates were excluded from the analysis[1].

As well as making visual comparisons, Pearson and Spearman correlation coefficient statistics are used to compare plots.

4. Results

'Aoristic weight' (AW) shares the total number of sites from each period of occupation across every overlapping fifty-year time block, and then adds up all the values for each period. The overall AW plot, calculated across the entire Iraq dataset, reveals that site frequency changes significantly over time. There are clear peaks and troughs, but with a general upward trajectory across the timespan of our study period (Figure 2).

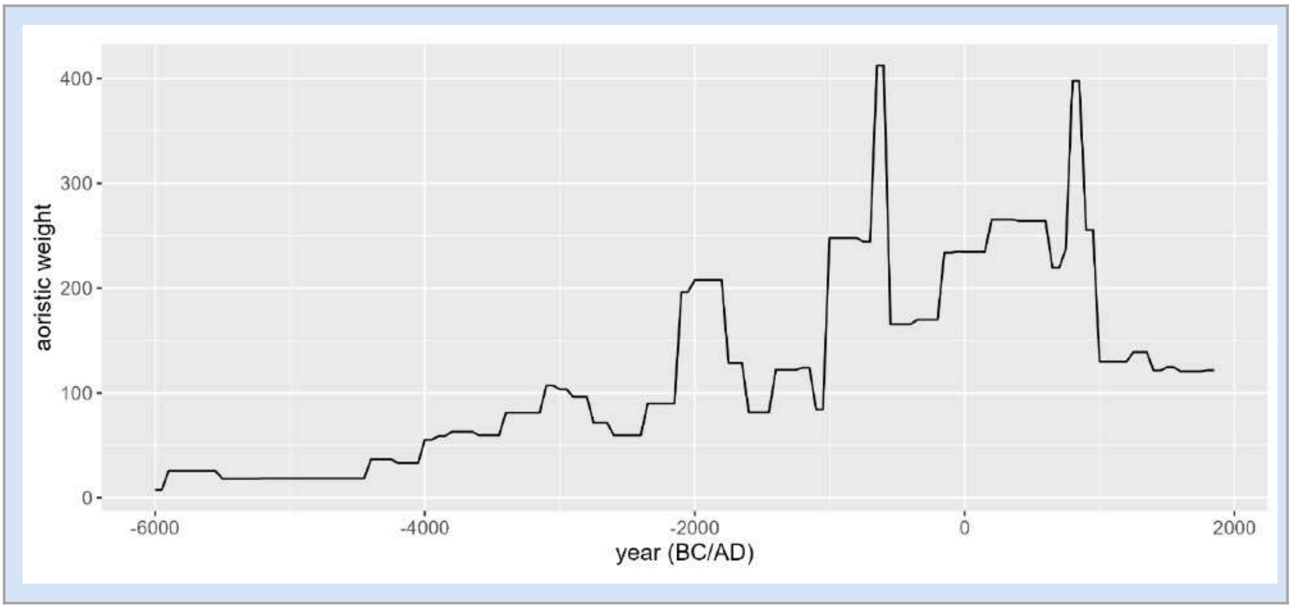

Figure 2: aoristic weight calculated across the entire datable Iraq dataset, showing site frequency over time.

Utilising this data to explore settlement patterns over time becomes more straightforward after we introduce the zone classification, as this allows us to treat north, central and south Mesopotamia separately, and then begin to compare the evidence from the different regions. The individual AW plots demonstrate that each zone has a distinct 'signature' for site frequency over time (Figure 3).

[1] Numbering fewer than 800, these are all *Archaeological Sites in Iraq* (Directorate General of Antiquities 1970) sites which could not be matched with data from other sources. This publication does not include maps or site coordinates, only outdated administrative areas. However, aoristic analysis comparing the book's locatable and unlocatable sites showed a strong correlation, so their omission is very unlikely to have greatly altered our results.

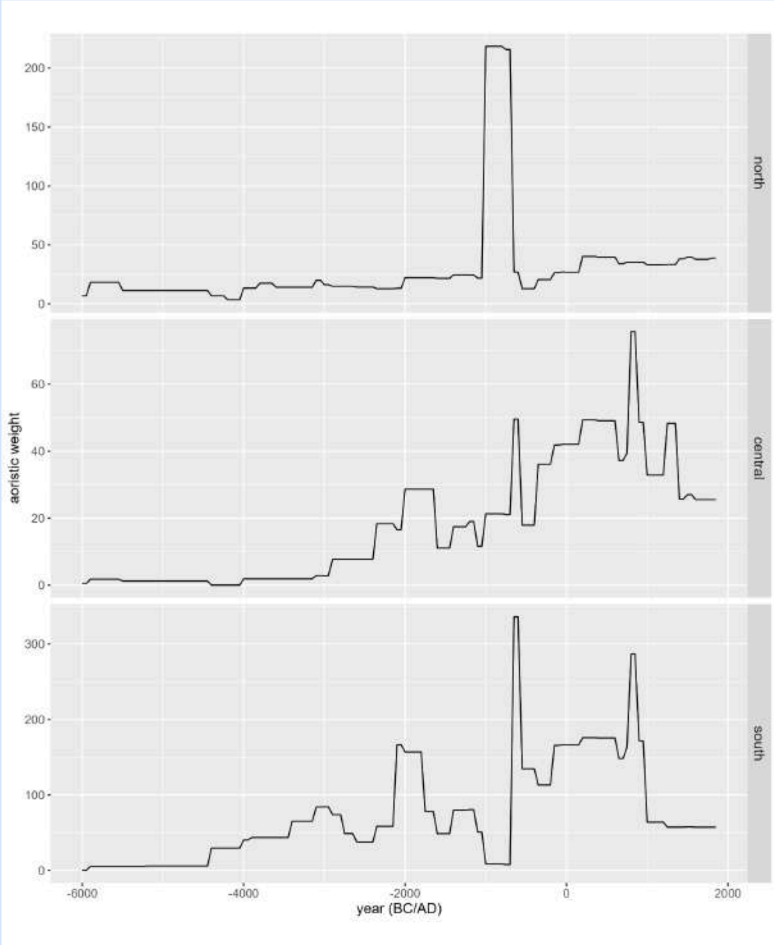

Figure 3: aoristic sum plot for north, central and south Mesopotamia.

To allow direct comparisons on the same graph, a 'normalised aoristic weight' (NAW) was calculated by dividing the AW values by the total number of datable sites in each zone (Figure 4).

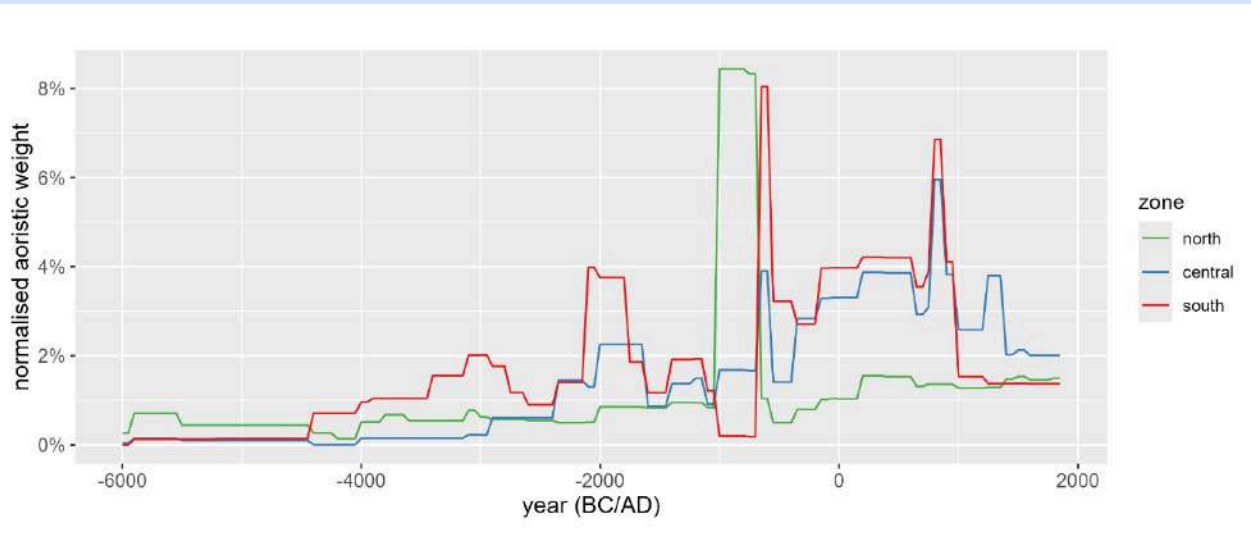

Figure 4: NAW plots showing site frequency over time for each zone.

A simple visual comparison indicates that there were several significant fluctuations in the north over time, but all are dwarfed by a major peak in sites during the first half of the 1st millennium BC. The south shows limited activity prior to the 4th millennium BC and then significant variability over time. Central Mesopotamia appears to show a combination of peaks and troughs from north and south – which raises the question of whether this zone should be treated as a separate unit. The correlation coefficients suggest weak correlation between settlement trends in the north and south – which is interesting in itself – a slightly stronger correlation between the north and central zones, and a strong correlation between southern and central zones (Table 3).

Table 3: correlation coefficients for zone pairs.

	Pearson	Spearman	Correlation
North-South	null	0.53	none/weak
North-Central	0.23	0.85	weak/middling
Central-South	0.80	0.81	strong

This could suggest that the central zone is an artificial construct formed by combining sites/sub-regions most of which relate to patterns characteristic of the southern unit, with a smaller number relating to patterns in the north. However, comparison of the central zone with a combined north/south dataset indicates that while there is strong overall correlation (PCC = 0.83, SCC = 0.88), there are particular periods during which the central zone demonstrates patterns of settlement that are distinctive from the larger regions (Figure 5). Instances include the 4th millennium BC, when the central region does not demonstrate the contemporaneous increase in settlement that is evident in both the north and south, and, of course, the markedly higher site numbers during the Islamic period. These points indicate that the central region does show some genuinely distinctive characteristics.

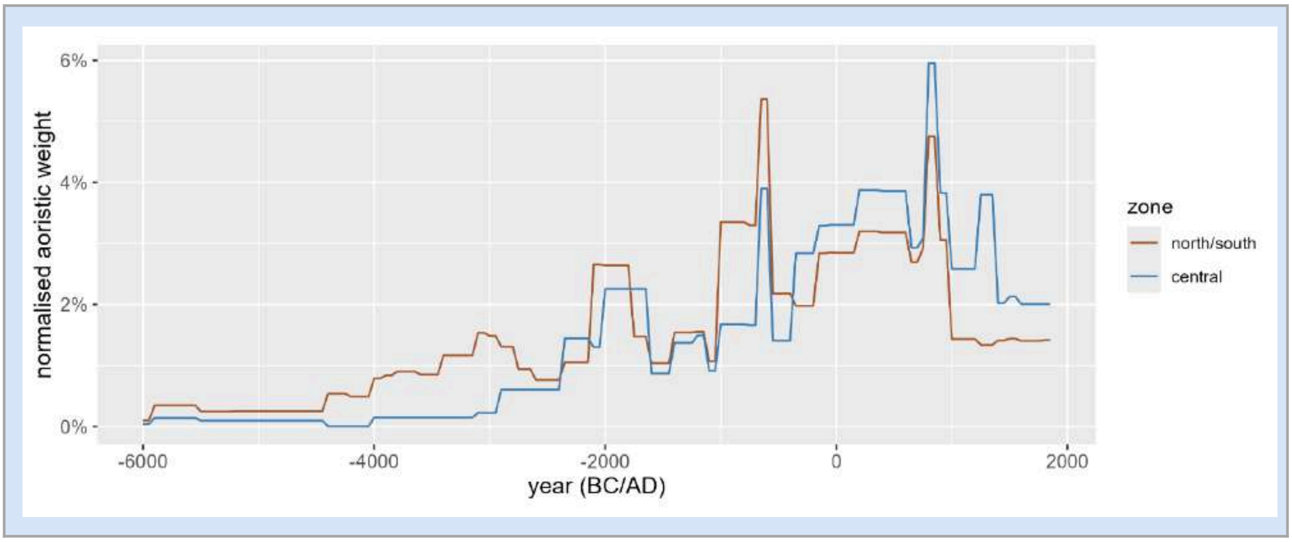

Figure 5: comparing site frequency over time in the central and combined north/south zone datasets.

Before more detailed analysis is undertaken, it is worth gauging the extent to which this analysis reflects archaeological reality rather than historic research biases. An analysis of two subsets of the data from Southern Mesopotamia – the Directorate General of Antiquities (DGA, now the SBAH) dataset versus the Adams/Gibson/Wright (AGW) surveys from the 1960s and 1970s – is illuminating in this respect (Figure 6).

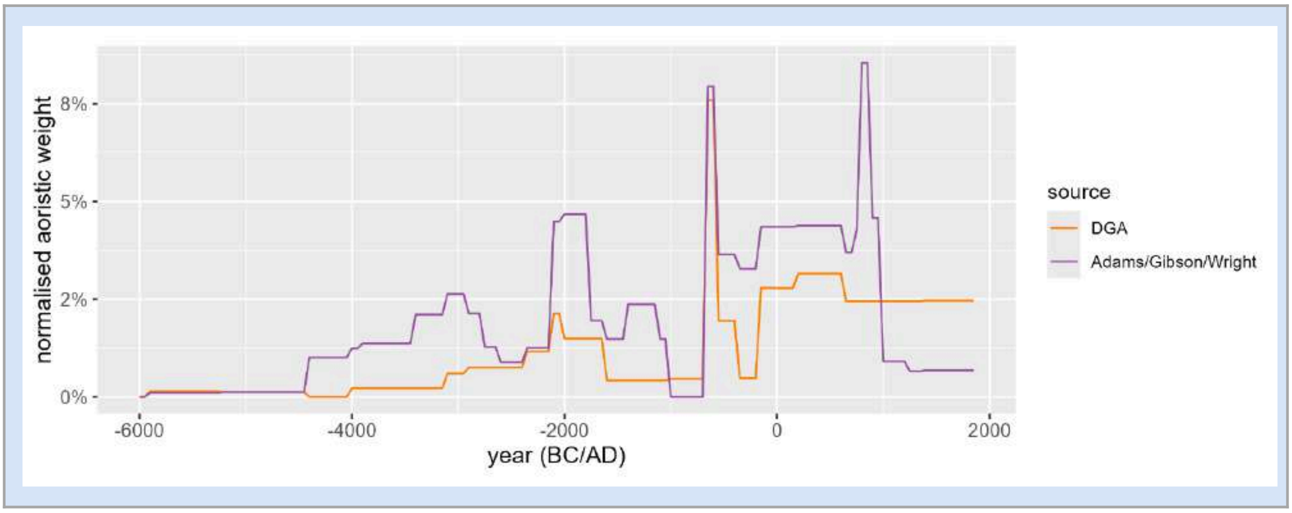

Figure 6: comparing site frequency for DGA and Adams/Gibson/Wright datasets from the south zone.

A comparison of the temporal patterning exhibited by these two datasets indicates that methodological and research biases are clearly present. Despite making every effort to address the Islamic periods the AGW plot shows a much lower level of site occupation after the Abbasid period than the DGA data. This is explained by the fact that, unlike the AGW surveys, the DGA data doesn't distinguish between Islamic periods. Grouped together as a single block, Islamic sites make up a similar overall percentage in both datasets. The AGW surveys also seem to have been much more proficient in distinguishing Uruk, Jemdet Nasr, and Middle Babylonian sites than the broadly contemporary DGA data. This is probably linked to the ability of the teams concerned to identify clear ceramic diagnostics for particular periods. Generally, though, correlation between these two datasets is reasonably strong (P = 0.67, S = 0.58). While peaks and troughs vary in magnitude, broadly speaking they rise and fall in concert. This suggests that while the overall dataset has been impacted by methodological and research biases, these can be identified, and once acknowledged, it should still be possible to piece together the reality on the ground.

5. Chronological patterns

Detailed analysis of our results should allow us to identify the main chronological patterns in the data. To this end the data has been broken into four broad epochs encompassing the different periods as defined in North and South Mesopotamia (Table 4). These four epochs broadly correlate with levels of social complexity from pre-state, through states and early empires, to major territorial empires and Islam.

Table 4: broad epochs used to analyse chronological patterns in the data.

Epoch	Absolute Dates	Main Periods (north)	Main Periods (south)
Neolithic to Early Chalcolithic	6000 to 3900 BC	Samarra/Halaf, Ubaid, Late Chalcolithic 1-2	Ubaid
Late Chalcolithic to Bronze Age	3900 to 1000 BC	Late Chalcolithic 3-4, Early Bronze Age, Middle Bronze Age, Late Bronze Age	Uruk, Jemdet Nasr, Early Dynastic, Akkadian, Ur III, Old Babylonian, Isin-Larsa, Kassite
Iron Age to Late Antiquity	1000 BC to 650 AD	Neo-Assyrian, Neo-Babylonian, Achaemenid, Hellenistic, Parthian, Sasanian	
Islamic	650 to 1900 AD	Umayyad, Abbasid, Ilkhanid, Late Islamic	

To facilitate analysis, the settlement frequency NAW plots (Figure 4) have been clipped to the temporal boundaries of each epoch. Summary tables with the most significant periods for each epoch are also presented.

5.1 Neolithic to Early Chalcolithic – invisibility and stability?

Settlement numbers are generally very low during this epoch – only after 4000 BC does NAW ever surpass 1% in any of the three zones (Figure 7). The north and central zones show a very similar pattern but at differing scales, while the south is entirely distinct. A small but significant number of Samarra/Halaf sites are present at and before 6000 BC in the north and centre, an artificial peak in the data at 5900-5500 BC is caused by an overlap with the Ubaid period (Table 5) – site numbers did increase but not as dramatically as the plot suggests. There is a drop-off in both zones after 4400 BC crossing from Ubaid to Late Chalcolithic 1 and 2, with numbers picking up again at the end of the epoch with the start of the Uruk. The pattern in the south is very different. No sites are known prior to the Ubaid, and then growth is apparent at every stage through Ubaid 3-4, Early Uruk and the onset of the Middle Uruk at the end of the epoch.

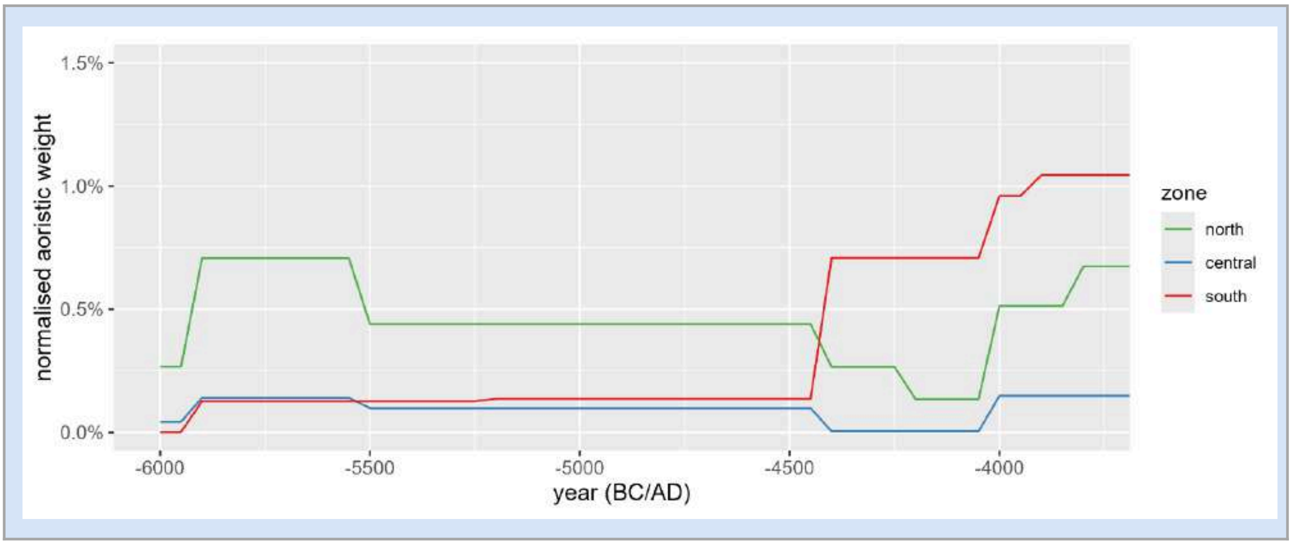

Figure 7: NAW plot for the Neolithic to Early Chalcolithic epoch, note the condensed scale of the y-axis.

Table 5: period summary table for Neolithic to Early Chalcolithic epoch, only the most abundant periods are included.

	from	to	north		central		south	
			sites	percent	sites	percent	sites	percent
Samarra/Halaf	7000 BC	5500 BC	207	8.0%	16	1.3%		
Ubaid	5900 BC	4400 BC	338	13.1%	36	2.8%	116	2.8%
Ubaid 1-2	5900 BC	5200 BC					17	0.4%
Ubaid 3-4	5200 BC	4400 BC					26	0.6%
Early Uruk	4400 BC	3900 BC					293	7.0%
Late Chalcolithic 1	4400 BC	4200 BC	27	1.0%				
Late Chalcolithic 2	4200 BC	3800 BC	27	1.0%				

The overall low site numbers are at least partially due to low data resolution – very long periods tend to yield somewhat featureless aoristic plots. The north-central/south divide is almost certainly a result of differing geography – in the massive flood plain of the south, prehistoric sites in particular are likely to have been eroded, or buried under many metres of alluvium (see Altaweel et al. 2019) or by extensive later occupation. It is also possible that prior to the construction of substantial irrigation channel systems, settlement was constrained to major river channels which restricted the number of viable settlement locations and even limited potential population size. The apparent northern and central decline between 4400 and 4000 BC, is probably related to issues around ceramic recognition and periodisation. Until the clear definition of the Late Chalcolithic I-III at the Santa Fe conference (Rothman 2001), it was believed that the Ubaid was the direct antecedent of the Uruk. The transition was dated around 4000 BC in the 1980s (Adams 1981: 60; Porada et al. 1992: 100 and Vol. II Fig. 3), and even earlier in the 1970s (Redman 1978: Fig. 8.1). On the basis of material obtained through surface collection, surveyors assigned their later prehistoric sites to either the Ubaid or the Uruk (e.g. Wilkinson and Tucker 1995). In the case of the Ubaid the key diagnostic was the distinctive painted pottery, meaning that the plain wares that are characteristic of the Late Chalcolithic received little attention on surface collections. As a result, when the end of the Ubaid was pushed back to its current mid-5th millennium BC position, legacy data will reveal an apparent decline in settlement activity that is probably methodological in origin. Overall, the data reveals low, stable levels of settlement in central and northern Mesopotamia, and the stark invisibility of Neolithic sites in the south.

5.2 Late Chalcolithic to Bronze Age – muted peaks and troughs

There is a significant increase in settlement frequency moving into the Late Chalcolithic and Bronze Age across all zones, but with considerably more variability across the epoch (Figure 8). During the fourth millennium, the south shows a steady increase, peaking during the Jemdet Nasr (Table 6), while the north and centre show more modestly consistent settlement numbers, highest towards the end. There is interesting divergence in the third millennium. The centre shows general growth through the Early Dynastic, Akkadian and Ur III, while the north shows a lull across all three, and the south an Early Dynastic decline followed by an Akkadian rebound and an Ur III explosion in settlement numbers. The second millennium has two distinct halves. All three zones show consistently high site numbers during the Isin-Larsa/Old Babylonian periods, followed by a drop – very modest in the north, substantial in the centre and south – after 1600 BC with the onset of the Kassite/Middle Assyrian. The peak apparent in all three plots at 1400-1000 BC is caused by the overlap between this period and the Middle Babylonian.

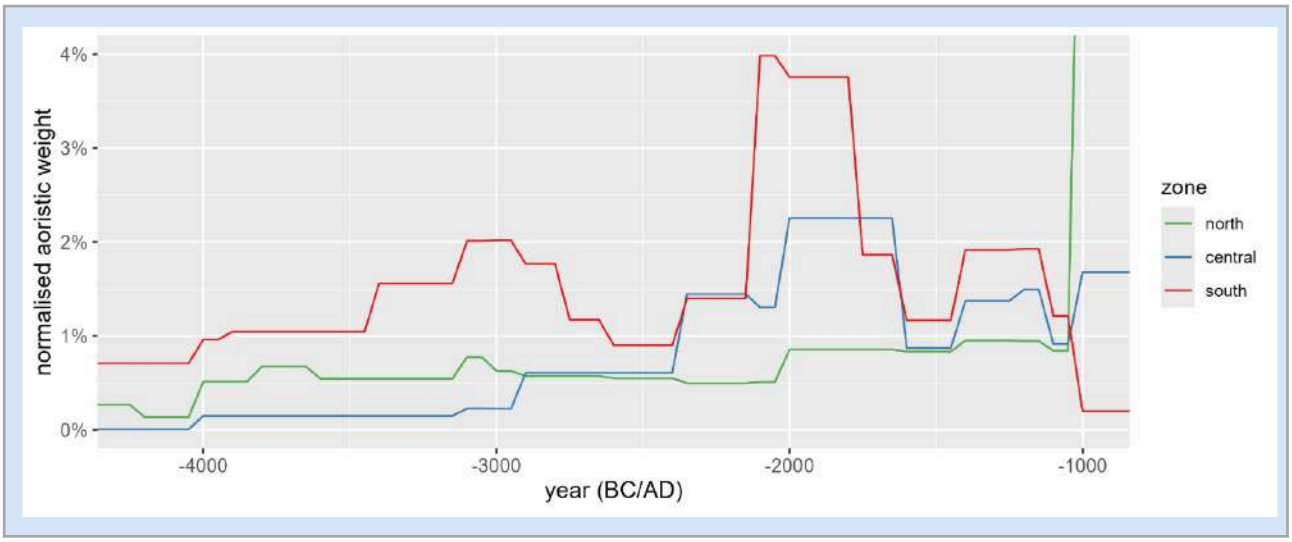

Figure 8: NAW plot for the Late Chalcolithic to Bronze Age epoch.

Table 6: period summary table for the Late Chalcolithic to Bronze Age epoch, only the most abundant periods are included.

	from	to	north		central		south	
			sites	percent	sites	percent	sites	percent
Uruk	4000 BC	3100 BC	175	6.8%	33	2.6%	186	4.5%
Middle Uruk	3900 BC	3400 BC					328	7.9%
Late Uruk	3400 BC	3100 BC					325	7.8%
Late Chalcolithic 3	3800 BC	3600 BC	30	1.2%				
Late Chalcolithic 4	3600 BC	3300 BC	25	1.0%				
Late Chalcolithic 5	3300 BC	3000 BC	25	1.0%				
Jemdet Nasr	3100 BC	2900 BC	55	2.1%	11	0.9%	332	7.9%
Early Dynastic	2900 BC	2350 BC	136	5.3%	84	6.6%	244	5.8%
Early Dynastic I	2900 BC	2750 BC					151	3.6%
Early Dynastic II	2750 BC	2600 BC					77	1.8%
Early Dynastic III	2600 BC	2350 BC					72	1.7%
Akkadian/Ur III	2350 BC	2000 BC	76	2.9%	17	1.3%	128	3.1%
Akkadian	2350 BC	2100 BC	1	0.0%	79	6.2%	195	4.7%
Ur III	2100 BC	2000 BC	1	0.0%	8	0.6%	279	6.7%
Ur III/Isin-Larsa	2100 BC	1600 BC			100	7.9%	63	1.5%
Isin-Larsa/Old Babylonian	2000 BC	1600 BC	139	5.4%	145	11.4%	565	13.5%
Isin-Larsa	2000 BC	1750 BC					394	9.4%
Middle Bronze Age	2000 BC	1600 BC	27	1.0%	2	0.2%		
Kassite/Middle Assyrian	1600 BC	1000 BC	217	8.4%	130	10.2%	575	13.8%
Middle Babylonian	1400 BC	1100 BC			32	2.5%	166	4.0%

The onset of urbanisation in this epoch brings with it a step change in site frequency from the Uruk period onwards. Almost certainly, the more substantial sites are much more visible in the landscape, resulting in a recovery bias. Overall, the Bronze Age is characterised by a pattern of relatively muted peaks and troughs. This may suggest the existence of a structural Bronze Age ceiling tied to the nature of the economy. Similar ceilings – proposed on the basis of productive capacity and settlement size – have been demonstrated for North Mesopotamian urban forms (Wilkinson 1994). The Jemdet Nasr settlement peak in the south may attest to real growth or be due to the easily identifiable and distinctive pottery produced during this period, or a combination of these two. The southern drop-off during the Early Dynastic may be attributable to the nucleation of settlement resulting in fewer, larger sites (Adams 1981). This pattern appears to change during the Akkadian period. Overall, the north shows a much less variable plot, likely partly the result of the same issue with ceramic identification as described for the Late Chalcolithic, but also as the signal is significantly attenuated by the dominance of Neo-Assyrian sites in the zone's dataset. The greater stability in the north compared to the south may partly be the result of its contrasting agriculture. Northern settlements with good access to land and water would tend to stay occupied with limited viable alternatives, while in the south the existence and abandonment of irrigation channels might lead to greater settlement mobility. Interestingly there is no evidence of settlement disruption with the 4.2k climate event (contra Weiss et al. 2017; Kaniewski et al., 2018), but this could be the result of a lack of sufficient resolution in the period data before and after this point in time. The drop-off in the central and southern zones with the onset of the Kassite period is not attested in the north which rather witnesses a modest stability over the course of the Late Bronze Age (1600-1200 BC). The southern and central lull is aligned with a 3.2k event decline apparent in other

Southwest Asia and Mediterranean datasets in the centuries either side of 1000 BC (e.g. Knapp and Manning 2016; Cline 2014), suggesting that political and economic disruption may have impacted quite widely across the region.

5.3 Iron Age to Late Antiquity – imperial boom and bust

The Iron Age brings an intriguing pattern of boom and bust in site frequency (Figure 9). The north shows an incredible Neo-Assyrian explosion – with well over half of all sites occupied during this period (Table 7). The contrast with the south is stark – here settlement numbers plummet to their lowest level since the fifth millennium. Conversely, with the Neo-Babylonian period, southern settlement reaches a major peak, but drops in the north to a level similar to the Bronze Age average. Positioned between the two, unsurprisingly, the centre is much more stable throughout. Following this, all three zones show a general trend of increasing settlement numbers to the Sasanian period, except for a minor lull in the south over the Hellenistic period.

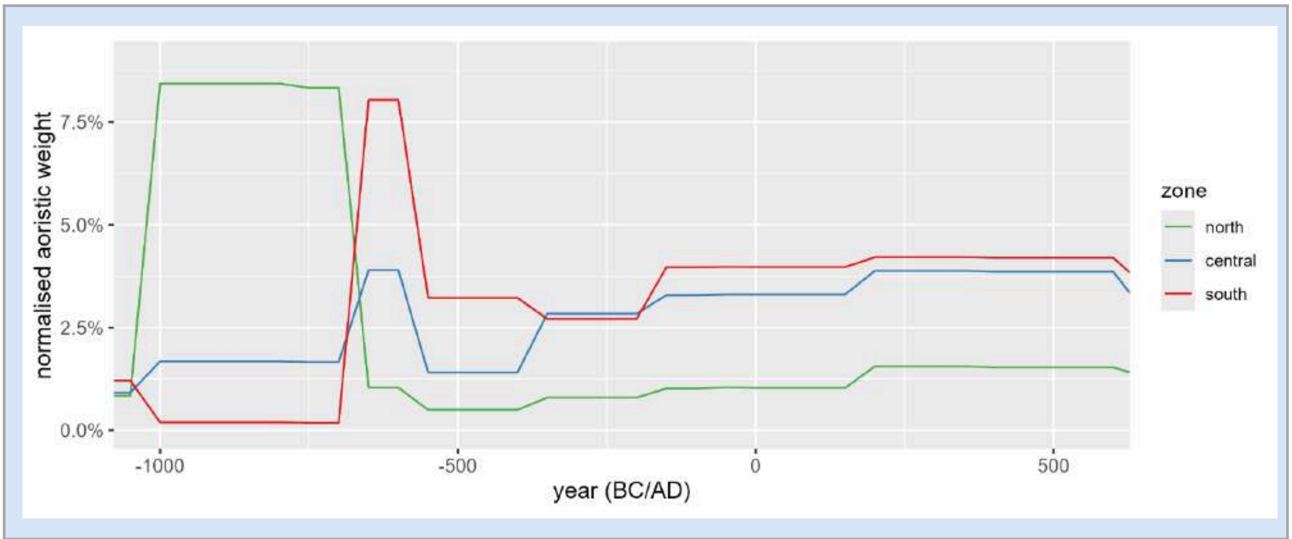

Figure 9: NAW plot for the Iron Age to Late Antiquity epoch.

Table 7: period summary table for Iron Age to Late Antiquity epoch, only the most abundant periods are included.

	from	to	north		central		south	
			sites	percent	sites	percent	sites	percent
Neo-Assyrian	1000 BC	650 BC	1501	58.0%	147	11.6%	52	1.2%
Neo-Babylonian	650 BC	550 BC	52	2.0%	98	7.7%	665	15.9%
Achaemenid	550 BC	350 BC	49	1.9%	71	5.6%	496	11.9%
Achaemenid/Hellenistic	550 BC	150 BC					79	1.9%
Classical	350 BC	650 AD	18	0.7%	8	0.6%	45	1.1%
Hellenistic	350 BC	150 BC	77	3.0%	142	11.2%	402	9.6%
Parthian	150 BC	200 AD	175	6.8%	289	22.7%	1140	27.3%
Sasanian	200 AD	650 AD	347	13.4%	437	34.4%	1556	37.2%

Perhaps more than any other, this epoch requires careful interpretation to distinguish the research and interpretative biases from the archaeological reality on the ground. The sheer dominance of Neo-Assyrian settlements in the north is difficult to fully account for. Likely it results from a combination of an archaeological reality, with major investment in irrigation systems and a policy of settlement dispersal enabling a boom in Neo-Assyrian sites (Wilkinson and Rayne 2010; Wilkinson et al. 2005), and a strong research bias in this early dataset towards Neo-Assyrian sites in northern Mesopotamia. There is a similar, exaggerated Neo-Babylonian peak in the south. This is likely the result of the brevity of the period – a partially artificial disconnect between the historical and archaeological evidence –and a highly distinctive material culture – for example including bricks stamped with the name of Nebuchadnezzar (Abraham 2012) – combined with intensive imperial investment and building projects. Some of these sites should probably be partially redistributed to cover the major 1000-650 BC void, smoothing out the plot. The same is probably true for the centre, which otherwise shows a lull in the Neo-Assyrian period – surprising given the unparalleled strength of the northern signal, and possibly suggesting that the Neo-Assyrian heartland was highly localised (Altaweel and Squitieri 2018). It is also likely that there was a need for intensified rural settlement to support major concentrations of population in the Neo-Assyrian and Neo-Babylonian imperial capitals.

The signatures of the succeeding imperial periods are much less dramatic. The Achaemenid period represents a significant lull in the north and central zones but gives a much stronger signal in the south. Possibly *laissez-faire* Achaemenid imperial governance might have resulted in more localised ceramic assemblages that surveys have struggled to identify and date accurately, but this could also be explained by merely less centralised pottery production. The same is likely true of the minor lull over the Hellenistic period in the southern zone – striking given that Seleucia, the first Seleucid capital, lies inside it, albeit near its northern limit. The Sasanian period provides a strong, sustained signal across all three zones. Sasanian imperial economic development and reorganisation of the landscape – especially irrigation infrastructure – could well lead to significantly greater settlement numbers, even with settlement nucleation, and perhaps a larger population (Wilkinson and Rayne 2010; Simpson 2022; Adams 1981). Beyond the obvious issues with the data, overall this epoch shows a marked development in settlement and population distribution with both following the political centre of gravity. This is particularly clear in the Neo-Assyrian period in the north, the Neo-Babylonian in the south and the Sasanian period across Mesopotamia. This is partly due to these states/empires investing in infrastructure projects, but also wholesale population transfers and perhaps the development of marketisation.

5.4 Islamic – low resolution and underrepresentation

The Islamic plot is somewhat featureless (Figure 10), as the "Islamic," covering the entire epoch, is by far the most common period (Table 8). The most obvious exception is the significant Abbasid spike in the south and centre in the eighth to tenth centuries AD. The second is a peak in the Ilkhanid period seen only in the central zone centring around 1350 AD.

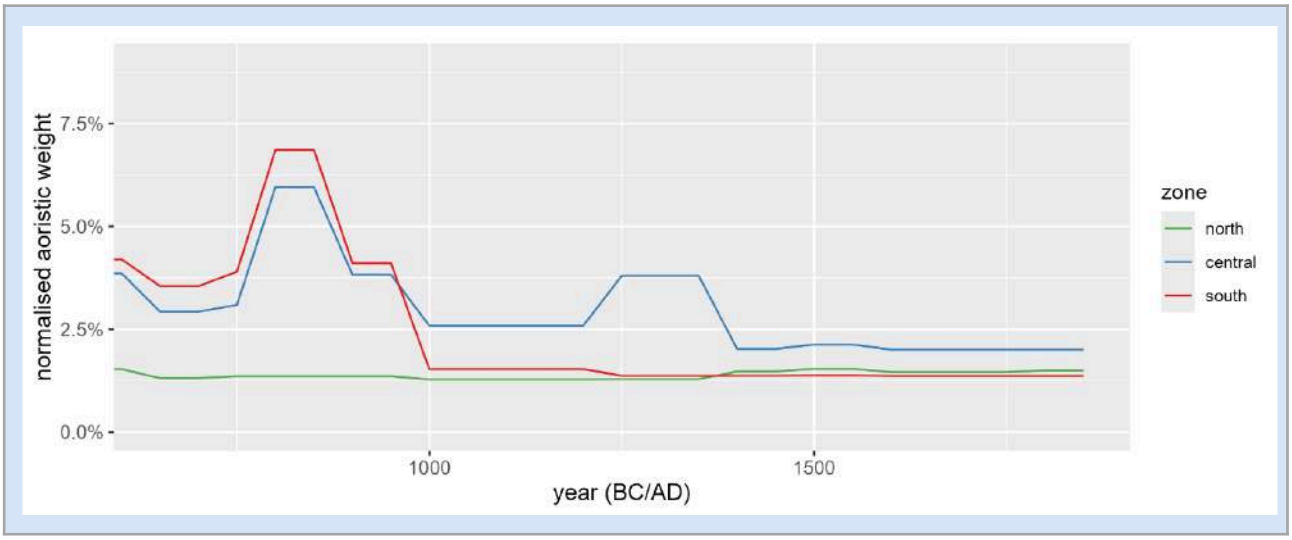

Figure 10: NAW plot for the Islamic epoch.

Table 8: period summary table for Islamic epoch, only the most abundant periods are included.

	from	to	north		central		south	
			sites	percent	sites	percent	sites	percent
Islamic	650 AD	1900 AD	772	29.8%	511	40.2%	936	22.4%
Early Islamic	650 AD	1000 AD	14	0.5%	110	8.7%	752	18.0%
Umayyad	650 AD	750 AD	2	0.1%	2	0.2%	6	0.1%
Samarran	800 AD	900 AD			72	5.7%	245	5.9%
Abbasid	750 AD	1250 AD	22	0.9%	31	2.4%	117	2.8%
Middle Islamic	750 AD	1250 AD					60	1.4%
Late Abbasid	900 AD	1250 AD			65	5.1%	61	1.5%
Ilkhanid	1250 AD	1400 AD	5	0.2%	82	6.5%	59	1.4%
Late Islamic	1400 AD	1900 AD	58	2.2%	46	3.6%	195	4.7%

Given that the Abbasid caliphate was based in southern and central Iraq during what is commonly known as the Golden Age of Islam, it is unsurprising that there is a significant settlement spike. Both Islamic archaeological research interests and contemporary investment in settlements, architecture and infrastructure are likely to leave a high-water mark at this point. The second, smaller Ilkhanid local maxima is less expected. This is probably the result of contrasting datasets – with the central zone having a much higher relative proportion of detailed Islamic data than the other two zones due to two large surveys covering part of the area (Adams 1965; 1972). The northern zone represents the other extreme – around a third of sites are recorded as having some Islamic occupation here, but only a small fraction has detailed period information – leading to a flat aoristic plot. Overall, the relatively modest number of Islamic sites compared to some earlier periods is due to a lack of focused research of the settlement of the period, perhaps exacerbated by sites lying beneath – or incorporated into – present-day settlements.

6. Discussion

The aoristic analysis of our preliminary dataset has revealed some interesting patterns in settlement frequency over the last eight millennia. Overall, there was consistent growth across all zones from the 6th millennium BC to the start of the Bronze Age, as is to be expected with the onset of urbanism. The modest peaks and troughs present in the Bronze Age plots perhaps suggest the existence of a structural constraint on settlement during the Bronze Age, particularly in the dry-farming areas, related to the nature of the landscape and economy (Wilkinson 1994). The boom and bust apparent in the Iron Age and Late Antiquity could also be rooted in differing imperial economic policies – with centralised, high-investment empires contrasting with laissez-faire, regionalised control. This contrast is also augmented by varying imperial scale and the location of the empires' centres-of-gravity – within or outside Mesopotamia. The strong, steady, but very much muted, settlement numbers in the Islamic period seem mainly to demonstrate a lack of research and high-resolution dating evidence in Iraqi Islamic archaeology despite its inarguable global significance. North, Central and South Mesopotamia show their own distinct settlement signature, although certainly linked at points, with the Central zone often aligning itself to whichever neighbour is showing the strongest signal at any given point in time.

Several interesting points related to Iraqi archaeology emerge from this exploration of settlement data. The question of whether it is worth distinguishing Central Mesopotamia from the North and the South remains open, and if so where the boundaries should be drawn. The total lack of a Southern Mesopotamian Neolithic also remains a future research opportunity. Identifying such sites that have not been eroded, with many others almost certainly buried under metres of alluvium (Altaweel et al. 2019) would undoubtedly be a challenge, although new research in the western desert may suggest that the desert fringe may be the best place to look (Jotheri 2024). The lack of archaeological sites falling with the Islamic period demonstrates a lack of research in this phase of Iraqi settlement, despite the global archaeological significance of Islamic Iraqi archaeology. Recent research suggests that this is beginning to change (Northedge and Kennet 2015; Brown 2022; Deadman et al. 2024), but clearly this huge research potential is not yet being sufficiently explored. The extent to which this gap can be accounted for by modern villages, first founded in the Middle or Late Islamic, not being counted in archaeological surveys is not well understood. In contrast to the Islamic period, the staggering extent of the Neo-Assyrian spike in northern Mesopotamia also merits further discussion. To what extent does this reflect the archaeological reality or past research biases favouring this particular period? The significant numbers of modern archaeological surveys in Iraqi Kurdistan should help answer this question (Ur 2021; Mühl and Nieuwenhuyse 2016; Bonacossi and Iamoni 2015). More broadly, the extent to which site dating data based on an incomplete understanding of the ceramics can be profitably used to explore settlement patterns requires further exploration. Does the 'boom and bust' pattern in the Iron Age to Late Antiquity epoch at all genuinely reflect settlement patterns? To what extent do the aoristic plots genuinely reflect variation in ceramic visibility and identifiability over time? It could plausibly be the result of top-down imperial economic policy yielding more standardised and identifiable ceramic types, while a laissez-faire governing approach may tend towards diverse, regionalised ceramics that are harder to identify and date. The relatively low site numbers in Achaemenid and Seleucid versus the Sasanian period in Southern Mesopotamia could indicate this. Alternatively, it could reflect the relative strength of marketisation and exchange networks across the region, enabling a more standardised material culture. Ultimately of course, there is a need for better stratigraphic data to refine ceramic dating, but also for a better understanding of ceramic production and distribution on a regional basis.

This analysis also raises some methodological issues in the use of aoristic analysis with large legacy datasets. Northern Mesopotamia offers an extreme example of the difficulties in using aoristic analysis – the dominance of Neo-Assyrian period sites attenuating the signal for all other periods and making analysis difficult. One approach may be to calculate and plot percentage rank, alongside aoristic weight. This calculates the rank of each fifty-year time block for each zone in terms of their aoristic weight – the highest will be at or near 100%, the lowest at or near 0% and the median at or near 50%. This generates a much more readable graph for northern Mesopotamia (Figure 11). It much better illustrates, for example, the significance of the Sasanian and Islamic periods in the north.

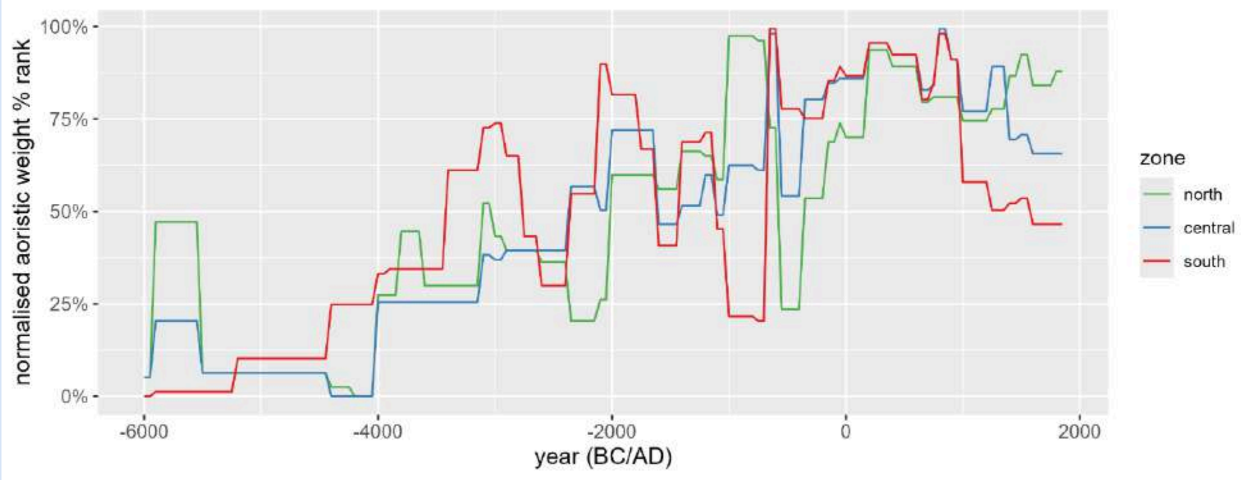

Figure 11: percentage rank of the aoristic sum, grouped by zone.

Another major issue is integrating data quality into the plot. Aoristic analyses can produce graphs that flatter the original dataset, making accurate assessments of settlement patterns more difficult. One means of indicating the data quality, without the need for an accompanying table, would be to include a second line showing the contribution made by low-resolution data – for example ‘Bronze Age’ or ‘Islamic period’ records. An example for the Islamic epoch in northern and central Mesopotamia demonstrates this – the central zone has a much higher proportion of high-resolution period data (Figure 12). This is favourable to eliminating low-resolution entirely, which would mean, for example in this case, removing almost all of the data for the north zone during the Islamic period.

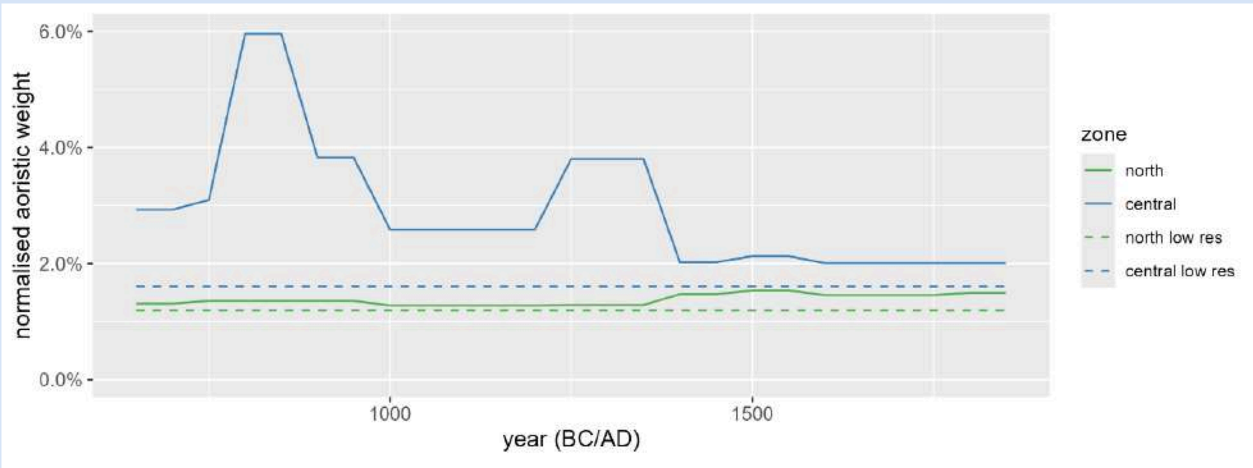

Figure 12: NAW plot for north and central zones in the Islamic epoch including low-resolution contribution lines.

A further refinement that could be explored is the reinterpretation of the published dating for particular sites and periods. The false peak in the north and central zones in the sixth millennium (Figure 7) is caused by an overlap between the Ubaid period and the Samarra/Halaf. When the vast majority of these sites were identified, the phasing of the Ubaid period had not been adequately mapped (cf. Crawford 2010), and so they could only be assigned to the overarching period. In reality, in north and central Mesopotamia the ‘Ubaid’ is contemporary with the southern Mesopotamian 3-4, preceded by a Halaf-Ubaid transition and followed by the Late Chalcolithic 1 (Akkermans 1988; Campbell 2007). Thus, the dating of many of these north and central sites can be refined, as perhaps ‘Northern Ubaid,’ without the need for re-examining ceramic assemblages. Making these sort of period refinements would improve the accuracy of the aoristic plots when working with older legacy data. In other cases, high-resolution data may need to be downgraded.

Unsurprisingly, given the seminal nature of his work, issues have been raised with some of Adams' ceramic chronologies, with particular type fossils being misassigned (Wells 2015; Simpson 2022).

Conclusion

We set out to utilise our preliminary Iraqi dataset to explore three questions related to settlement patterns in Mesopotamia. Despite its shortcomings, aoristic analysis has proven highly effective at plotting changes in site numbers over the course of the study period. Regional differences between southern and northern Mesopotamia are clearly apparent, while the central zone broadly corresponds with the south except in a few phases. Many of the trends observed in the data can be related to shifts in climate and socio-political organisation, but higher-resolution data is required to map these out in greater detail.

The exploration of settlement patterns presented in this paper are preliminary – further work will undoubtedly enable augment our understanding of Mesopotamia over the long durée. More sites and period data need to be added to our database, especially from the many recent surveys in northern Mesopotamia. The existing period data should also be carefully reinterpreted, where possible, to update it in line with a contemporary understanding of ceramics. Adopting a Bayesian aoristic approach (Crema 2024), which attempts to deal with some of the issues with the methodology, could also prove fruitful. Comparisons with other big data datasets could also be illuminating – including diachronic climate data (Hewett et al. 2022) and frequency distributions of radiocarbon dates from wider southwest Asia (Palmisano et al. 2021).

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التحليل المقارن للتغير الاستيطاني عبر بلاد الرافدين: استكشاف مجموعة بيانات أثرية عراقية ضخمة باستخدام التحليل الأورستي

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الملخص

إحياءً لذكرى عبد الأمير الحمداني، تقصت هذه الورقة الأنماط الاستيطانية بين عامي 6000 قبل الميلاد و1900 ميلادي بالاعتماد على مجموعة بيانات أثرية عراقية ضخمة. وتتضمن مجموعة البيانات نسخة منقحة من "قاعدة البيانات الرقمية للمواقع الأثرية في العراق" التابعة لعبد الأمير، بالإضافة إلى آلاف المواقع الأخرى التي جُمعت كجزء من مشروع "الآثار المهددة بالانقراض في الشرق الأوسط وشمال أفريقيا" (EAMENA). ومن خلال تقسيم العراق إلى ثلاث مناطق: شمالية، ووسطى، وجنوبية، نطبق التحليل الأورستي على مجموعة بياناتنا الأولية الخاصة بالعراق. ونسعى من خلال ذلك إلى استكشاف: 1) كيفية تقلب أعداد المواقع بمرور الوقت؛ 2) ما إذا كانت هناك اختلافات إقليمية؛ 3) كيفية ارتباط هذه التقلبات بالاتجاهات العامة مثل المناخ، والتعقيد الاجتماعي المتزايد، وظهور المدن والدول والإمبراطوريات. ويرسم تحليلنا بفعالية التغيرات في أعداد المواقع، ويظهر اختلافات إقليمية واضحة. وفي حين تفسر التغيرات المناخية والسياسية-الاجتماعية العديد من الاتجاهات الملحوظة، إلا أننا بحاجة إلى بيانات ذات دقة أعلى للحصول على مخططات أكثر تفصيلاً ودقة.

الكلمات المفتاحية: علم الآثار العراقي، الأنماط الاستيطانية، التحليل الأورستي، عبد الأمير الحمداني، مشروع الآثار المهددة بالانقراض في الشرق الأوسط وشمال أفريقيا (EAMENA)، قواعد البيانات الرقمية، الكثافة الموقعِية، الاختلافات الإقليمية، التغير المناخي، التعقيد الاجتماعي، التوسع الحضري، إمبراطوريات بلاد الرافدين.

