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Patterning Human Behaviour in Chalcolithic Southern Palestine: Differing Scales of Analysis

Abstract: The Chalcolithic period in the southern Levant shows a marked increase in evidence of human behaviour that was not present either before or after. In the northern Negev desert very few remains have been found of Neolithic or Bronze Age date, but more than 400 Chalcolithic sites have been identified. The widely accepted explanation of this phenomenon has been the so-called Mid-Holocene Climatic Optimum, a sub-interval of more humid conditions roughly 7000–5000 years ago. Mixed farming, primarily based upon the cultivation of grain on alluvial flats in the wadis of the Negev, is thought to have supported this Chalcolithic population during a period of wetter winters than are presently the case. The aim of our study is to use differing scales of physical and environmental analysis to test the validity of the theory of alluvial farming in the Negev desert. Cost-distance analyses of sites showing evidence of human behaviour in the Negev within this landscape of farming / grazing have shown how sites relate to the environment. These results and a series of autocorrelation tests show that large scale analyses support the theory of site clustering around resources, while small scale site distribution shows a random patterning of settlement suggesting short-term settlement by groups separated within the landscape.

Introduction

The study of the Chalcolithic period (4700–3900 BC) started more then 80 years ago, with the discovery of Teleilat Ghassul in the late 1920s by Mallon (Mallon 1929; Neuville / Mallon 1931). At approximately the same time Macdonald discovered and published information about several Neolithic-Chalcolithic sites in the Negev (MacDonald 1932). Ever since these discoveries and thanks to an intensive program of excavation and survey, especially in the Negev area, a mass of data and research continues to accrue. Roughly, these fields of research may be divided between questions about society and social structure, technology, cult and ritual, mortuary practices, settlement practice and structure, and about environmental/ecological change.

It should go without saying that all of these must be seen to be closely interrelated, but some are more accessible to research. The question of what has been termed "cultural ecology" is most obviously open to investigation and several specific studies have been undertaken (Butzer 1989; Crumley 2001; Vayda 1969; Levy 1983). More recently, studies of climatic change in the Southern Levant point towards significant changes occurring during the Chalcolithic (Bar-Matthews et al. 1996; Bar-Matthews / Ayalon 2001; Bar-Matthews et al. 2003; Ayalon / Bar-Matthews / Kaufman 2002; Schilman et al. 2001; Vaks et al. 2003; Goodfriend 1988, 1991). These studies have reached roughly similar conclusions, although with varying interpretations, degrees of certainty, and within differing chronological frameworks: that the Chalcolithic saw climatic conditions more favourable to settlement and agriculture than has been the case since.

Studies of settlement distribution, practice and structure have been limited (Alon / Levy 1980; Cohen 1986, 1999; Gilead 1986, 1988, 1994; Levy 1983; Levy / Alon 1987; Perrot 1984; Gophna / Portugali

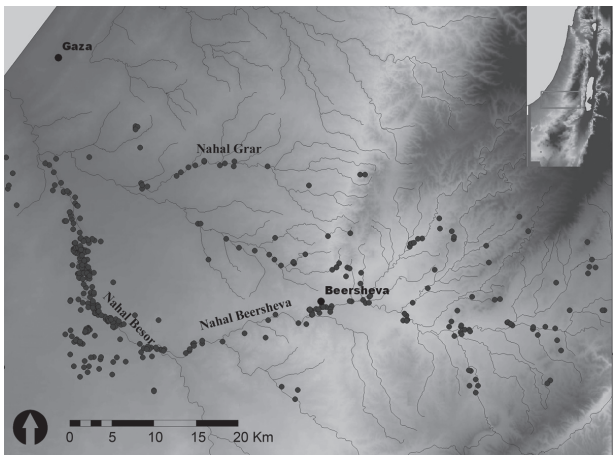

Fig. 1. Settlement location in the Chalcolithic Northern Negev.

1988). Settlement in the Negev is well known to be constrained by environmental factors, the most important of which are access to water and sufficient rainfall. It has been noted many times that Chalcolithic settlement is concentrated around the edges of wadis and water courses in the Negev *(Fig. 1)*. In fact, more than 65% of known Chalcolithic sites – at this stage some 403 sites – in the northern and central Negev are within 500 m of a water course and about 80% are within 1 km, 88% within 2 km.

The Data and Prospects for its Use

Probably the most important set of data we have is the locations of Chalcolithic sites. These have been identified in the landscape, usually accurately. One cannot overstate the value of this data. In an area of only 60 x 70 km, we have a wealth of site data; there are few archaeological regions in the Mediterranean in which one can find such a well documented settlement distribution for one period. In addition to the locations of these sites, the IAA has recorded brief descriptions of the sites which indicate estimations of size and impressions of the nature of each site. Such records are unauthenticated and must not be treated with too much confidence, but possessing such data is beneficial, and must be used. We also have environmental data consisting of detailed geological, hydrological and topographical maps, even if we must take these also as rough and unauthenticated for the reasons set out above. The DEMs we have are accurate to 25 m squares, a precision that allows us to derive other maps – of slope, visibility, cost-distance, derived hydrology and so on – with confidence. Since even the smallest sites identified by IAA and university surveys are about 40 m by 40 m, possessing a DEM accurate to 25 m means that every site can be placed within the present topography with assurance. Studies of climate in the mid-Holocene, have given us data suggesting more humid conditions in Israel during the Chalcolithic period. When combined with the study of vegetation history in Israel (Baruch 1994; Bottema / van Zeist 1981) and general environmental studies (Butzer 1978), they can allow us the opportunity to construct tentative climate simulations for the past.

We have undertaken a study of the Northern Negev in the Chalcolithic period that uses a multitiered approach. This involves the use of present environmental and topographical data and derived, speculative environmental and topographical conditions in combination with archaeological data.

1. Create different climate scenarios (the first being the present climate)
2. Map water distribution, flows, and husbandry scenarios
3. Reconstruct possible environments and vegetation maps
4. Use DEM, slope and soil maps to produce possible agricultural zones in wadi alluvial areas
5. Use agricultural zones, water distribution and vegetation maps with cost-distance analysis to derive agriculturally productive zones, access to water, Mediterranean maquis and grazing;
6. Use cost-distance / visibility analysis to assess separation between sites.

1. Create different climate scenarios

This is in fact rather more difficult than it may seem (Issar / Berlin 2004). While we may adjust rainfall levels by pushing mean annual lines (isohyet) further to the south, by assuming a pattern of rainfall similar to that of wet years in Israel, we must also account for humidity and evaporation rates. Rainfall maps show how a wet year can bring roughly twice the annual mean to most areas of the Negev. If we can assume such a pattern of rainfall over a long period of time, the conditions for agriculture alone are vastly different. Although studies have consistently shown that Israel probably had a higher rainfall in the mid-Holocene, during what season the rain fell is also important, as are temperatures, evaporation rates and humidity conditions. For example, it is considered likely that in the period of 5000 to 7000 years ago summers were warmer in the northern hemisphere (North America, Europe) but that winters were cooler and the tropics were cooler (Ganopolski et al. 1998; Hewitt / Mitchell 1998). It is possible that this area saw conditions of warmer summers and cooler winters with higher rainfall during the winter (Gilead 1988, 407–8 and references).

2. Map water distribution, flows, and husbandry scenarios

The mapping of water distribution involves much more than just the outlining of stream and river beds in the landscape. Using the rainfall patterns proposed above and derived watersheds for any particular site, we can show how much water could potentially reach that site.

3. Reconstruct possible environments and vegetation maps

Using modern rainfall patterns, environmental factors and vegetation distributions we have also made possible alternative vegetation patterns for the Chalcolithic Negev. This was done by taking present maps of vegetation (both Mediterranean maquis and grasses) and noting rainfall, humidity, evaporation, soil type, slope, hillshade and aspect for every 25 x 25 m square. These factors were recorded for each classification of vegetation when that vegetation is present in the modern landscape and calculating mean and standard deviations for these factors. The idea is thus to record the environmental conditions currently suitable for vegetation growth in the modern landscape. Then, taking the rainfall, humidity and evaporation patterns which we are here assuming to have been indicative of a possible rainfall pattern during the Chalcolithic (based upon meteorological data for a wet year in southern Israel), we then took each 25 x 25 m square upon the map and when the environmental values were within 1 sigma STD of the mean for a given vegetation type (calculated above) we placed that vegetation type on the map.

4. Use DEM, slope and soil maps to produce possible agricultural zones in wadi alluvial areas

Studies have shown that settlement in the Chalcolithic period was concentrated around the wadi slopes (eg. Levy 1983) and that this was almost certainly related to the use of alluvial flats for agriculture (Rosen 1999; Rosen / Rosen 2001). But no study has actually tried to relate accessibility of alluvial flats and settlement patterns. As a first step towards such an analysis one must identify such alluvial flats. On the assumption that alluvial flats have not altered significantly since the Chalcolithic period – a reasonable assumption based on the evidence – one may use the DEM, soil maps (alluvial soils) and a slope grid to identify such flats. The size of these alluvial flats varies and their positions are not in any way uniform along the wadi courses. These flats, particularly where water was available at high altitudes, were presumably suitable for farming after seasonal floods. One cannot assume that all of these – or even most – were used for farming: 42% of those identified in the Northern Negev are not within 5 km of a known Chalcolithic site (though 94.3% of all sites are within 5 km of such flats, and 78% within 2 km).

5. Use agricultural zones, water distribution and vegetation maps with cost-distance analysis to derive agriculturally productive zones, access to water, maquis and grazing

Using the assumption that settlement sites are chosen on the basis of access to agricultural fields (food), rivers and streams (water), grazing lands (flocks), Mediterranean maquis (fuel, among other things) and loess slopes for the construction of underground constructions known along Nahal Beer Sheva, it should be possible to produce a map of ideal settlement areas. This was done by producing cost-distance maps from the source of each of these necessities. The value of the cells of the raster datasets decreases with the distance/difficulty of movement from these sources. The combination of all these datasets will give a raster that shows the ideal settlement area. It was found that the vast majority of sites fitted into the predictive high value zone. Indeed, of the 403 sites, 41% are found in the highest classification and 77% in the highest two classifications. If we consider that 310 sites are in these two

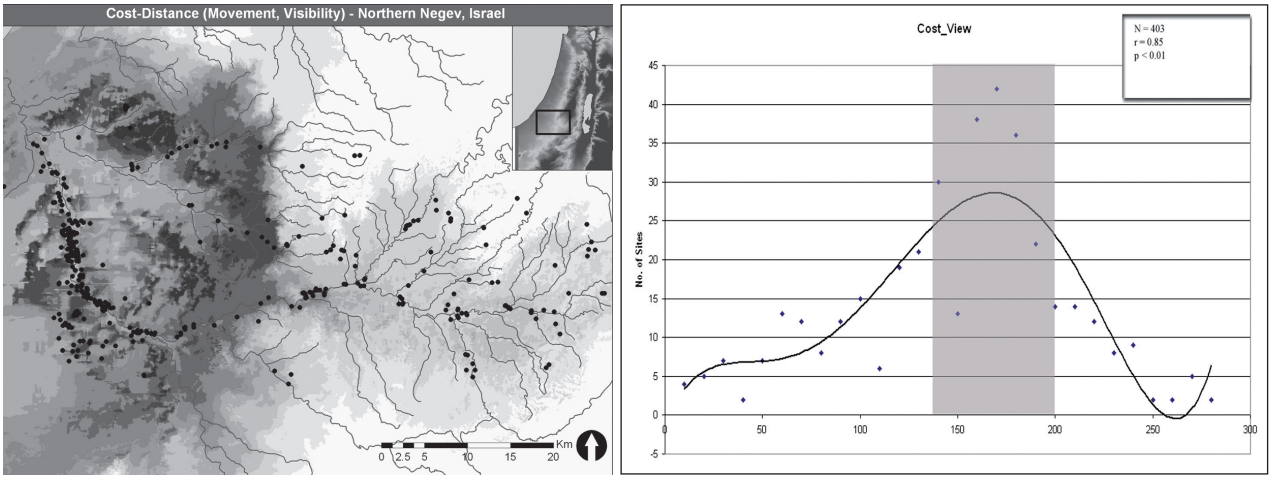

Fig. 2. Sum total of cost-distances/visibility from sites (white: high, black: low) and preferred cost-distances/visibility zone.

high classifications and 84 of the 403 sites have been described as 'camp sites' – and all of these are in the lowest classification – then 51.4% of the sites may be said to be in the highest level of predictability and 97.2% in the two highest.

6. Use cost-distance/visibility analysis to assess separation between sites

While this may be a satisfying result, it does not allow us to determine what factors were most important, nor what combination of factors resulted in those sites which are positioned less advantageously in regard to resources. To demonstrate the point, in the Nahal Beersheva (as in all areas of the Negev) there are sites which are not as close as possible to the alluvial flats, or the water, or to other resources, but are positioned somewhat incongruously away from them, though almost always near to them.

We may assume that access to resources is of the highest importance in selecting settlement sites, however, human beings also select site locations on the basis of accessibility to other sites of human activity. With this in mind, we have produced three raster databases which are: 1. The sum of the cost-distances (i.e. the ease/difficulty of travel) between all the sites in the Northern Negev; 2. The sum of the visibility maps from all sites; and 3. The sum of the combination of both cost-distance and visibility from all sites.

Regression analysis for access to farming, water, grasslands and maquis in terms of cost-distance give r values of between 0.8 and 0.9 ($p < 0.01$) in a straightforward linear regression model, but for cost-distance / visibility the results are not linear and strongly suggest a cost-distance / visibility weight between 140 and 200. We shall call this cost-distance / visibility weight the "CVf" factor or factor of effective separation (FES). The number of sites in this CVf zone 140 to 200 shows that there was a preference for sites being neither too close (or visible) nor too far away (or not visible). This preferred CVf zone is equivalent to a distance of 5.2–9.0 km on a flat surface. The reality, however, shows that the preferred distance between sites will vary according to the visibility factor and may be considerably less.

The concept of a 'preferred zone' shown in the CVf may require some explanation. Because the regression analysis shows quite clearly that the CVf model has a peak number of sites between 140 and 200, with numbers diminishing rapidly on either side of this zone, it is reasonable to presume that this is the value of distance and visibility that was preferred in the Chalcolithic period. Such values show that although sites were often very close to each other on a two-dimensional basis, the actual distance between them and their visibility to each other was most likely to be equivalent to a separation of about 5–9 km. Such a division, albeit of sites of uncertain chronological separation, is very common in the archaeological record for Pre-modern settlement, whether for market towns in Medieval Europe or for so-called 'service centres' in Roman Britain (Hodder / Orton 1976, 57-9; Drury 1972, 8). In the context of the Negev, it is also very close to what Levy calls the maximum distance for pastoralists taking their flocks from water, 5–8 km (Levy 1983, 22), and for zones for hunter-gatherers, 10 km (Levy / Alon 1987). This distance is, in fact, well documented. A set of standard threshold distances for settlement sites of 5 km (thus 10 km between sites), for settled pastoralists also of 5 km and for hunter-gatherers of 10 km was proposed by Higgs and Vita-Finzi almost 40 years ago (Higgs / Vita-Finzi 1972; Chisholm 1968; Lee 1969).

Autocorrelation

By using the indices of autocorrelation, Moran's I, Getis-Ord, as well as average Nearest Neighbour, we are in a position test the degree of clustering in settlement distribution during the Chalcolithic in the Northern Negev, and to do so at varying scales. In order to make such a test one must prepare the

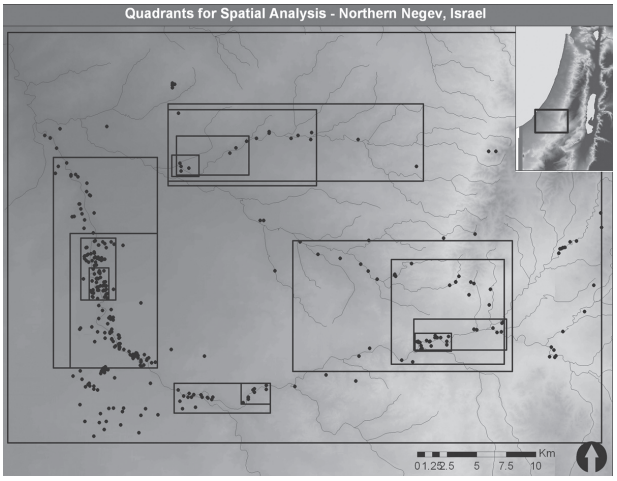

Fig. 3. The rectangles used for autocorrelation test in the Northern Negev.

data so that it may be used by the autocorrelation tools. The indices used require that events on a map have both a position and a 'population'. In order to make these tests the 'population' field was created in ArcGIS as rasters with grid sizes of 250 x 250 m and 500 x 500 m in each of which grids the density of settlement was used as the 'population' value. Different scales of analysis were achieved by using different areas *(seen in Fig. 3)*. The selected area of the Northern Negev in the largest scale encompassed some 1,725 km^2, the large blocks in the Nahal Besor, Nahal Grar, Nahal Beersheva were 150–200 km^2, the medium blocks in the same areas about 80 km^2, the small blocks (including Shiqmim) 15–20 km^2, and the smallest blocks around 4 km^2.

The sites in the largest rectangle, taking up most of the map in *Fig. 3*, showed in all indices of autocorrelation and for both the 250 m and 500 m rasters the highest possible indications of clustering. Such a result is hardly surprising. It has already been demonstrated that settlement patterns in the Northern Negev during the Chalcolithic were predicated upon access to resources, such that sites were located along the wadi slopes and beds. With a pattern of settlement along the water-courses, clustering is a result that is to be expected. However, what is somewhat surprising is that autocorrelation indices for rectangles smaller than the entire Northern Negev indicate that settlement patterns were random: there is in smaller scale analyses no discernable pattern.

While these indices of autocorrelation would seem to be present clear evidence of a lack of patterning in settlement in the Chalcolithic Northern Negev, one must be cautious in interpreting their significance. There are two major problems with an analysis based upon the settlement data we have: it takes no account of either the real distance between sites (in terms of topography) or of chronological changes in settlement. Furthermore, if one looks at the distribution of Chalcolithic evidence in the Negev, one notices that it is by no means regular. In the Nahal Besor, for example, there is a very high density of evidence in comparison with the Nahal Beersheva, Nahal Grar and Nahal Patish.

The first of these problems is caused by the fact that indices of autocorrelation are calculated on the basis of a straight-line distance between sites on a two-dimensional map. In reality, sites are located in a landscape in which topography can have a crucial effect; if two sites are separated by several kilome-

Rectangles	Morans I 250	Getis Ord 250	
Northern Negev	0.08 (10.4sd)	0 (8.4sd)	Very Clustered
Besor - Large	-0.03 (-0.7sd)	0 (1.7sd)	Random
Besor - Medium	-0.04 (-1sd)	0 (1.1sd)	Random
Besor - Small	-0.07 (-1.1sd)	0 (-0.3sd)	Random
Besor - Vsmall	-0.07 (-0.3sd)	0 (0.4sd)	Random
Beersheva - Large	-0.07 (-0.8sd)	0 (2.2sd)	Random
Beersheva - Medium	-0.09 (-0.8sd)	0 (1.2sd)	Random
Beersheva - Small	-0.11 (-0.7sd)	0 (0.9sd)	Random
Beersheva - Vsmall	-0.12 (-0.5sd)	0 (0.4sd)	Random
Grar - Large	-0.07 (0sd)	0 (0.2sd)	Random
Grar - Medium	-0.08 (0sd)	0 (-1.3sd)	Random
Grar - Small	-0.04 (1sd)	0.02 (1sd)	Random
Grar - Vsmall	-0.37 (-1.2sd)	0.04 (-1.2sd)	Random
Shiqmim - Small	-0.13 (-0.7sd)	0 (1.1sd)	Random
Shiqmim - Vsmall	-0.25 (-0.4sd)	0.03 (0.4sd)	Random

Tab. 1. Indices of autocorrelation in the Northern Negev for specified rectangles.

tres on the two-dimensional plane, the presence of a mountain between them will be significant. This can, however, be overcome by adding a factor for terrain in the population field for the autocorrelation calculations. The second problem, that of the chronological distribution of the sites, cannot be surmounted with such ease. It would seem obvious that an analysis of how individual sites, or clusters of sites, relate to each other can only be achieved if such sites can be shown to have been settled at the same time. However, with the data as we have it for the Northern Negev during the Chalcolithic, it is rarely possible to quantify the number of sites that we can consider to be simultaneous. Our analysis, therefore, can only be seen as applicable to, and dependent on, factors that affected site location for the whole of the Chalcolithic period; the analysis is valid only insofar as it shows how sites were located regardless of synchronicity. This does not mean that any analysis of settlement patterns in the Northern Negev for the Chalcolithic period is pointless. The question of scale in chronology is very similar to that of scale in spatial terms; different scales give different results. The chronological scale for analysis of the Northern Negev for the Chalcolithic may be forced upon us, but so long as we are dealing with a cultural unit, which we are since the changes before and after were significant, the analysis remains valid. A simple example of how such a process may have operated is to imagine the historical presence/absence of sites in a region that affected decisions to use a particular piece of land. Put simply, a site may have been used with the knowledge that other sites had been used in the vicinity or, conversely, that no sites were in the vicinity or known to have been nearby.

Adding a factor for topography can, however, deal with the question of real distance with some ease. By calculating the cost-distance and the visibility properties to every other site, a cost-distance-visibility factor (CVf) is attained for each and every site. This factor is added to the density raster and new autocorrelation indices calculated.

The results for the Moran's and Getis-Ord autocorrelation tests are unchanged, giving clustered results for the Northern Negev as a whole and slightly clustered for the larger rectangles, but with the same random pattern for the smaller rectangles. However, as can be seen from *Tab. 2*, the Nearest Neighbour test, even if the least reliable of autocorrelation tests, does show some interesting results. Perhaps the most important indication is that larger

	Near Neighbour	Near Neighbour (CVf)	Without CVf	With CVf
Northern Negev	0.49 (-18.8sd)	0.42 (-23.1)	Very Clustered	Very Clustered
Besor - Large	0.72 (-5sd)	0.66 (-7.2)	Very Clustered	Very Clustered
Beersheva - Large	0.85 (-2.4sd)	0.61 (-4.9)	Clustered	Clustered
Grar - Large	1.17 (2sd)	0.9 (-1.8)	Clustered	Random-clustered
Besor - Medium	1.28 (2.5sd)	0.8 (-4.0)	Clustered	Random-clustered
Beersheva - Medium	0.69 (-3.7sd)	0.63 (-4.1)	Clustered	Random-clustered
Grar - Medium	0.72 (-0.3sd)	0.72 (-2.1)	Clustered	Random-clustered
Besor - Small	0.94 (-0.5sd)	1.09 (1.3)	Random	Dispersed
Beersheva - Small	1.15 (1sd)	0.73 (-2.3)	Clustered	Random
Grar - Small	0.96 (-0.4sd)	0.91 (-0.5)	Random	Random
Shiqmim - Small	0.71 (-2.1sd)	0.83 (-1.4)	Random	Random
Besor - Vsmall	0.91 (-0.5sd)	1.3 (3.1)	Dispersed	Dispersed
Beersheva - Vsmall	0.76 (-1sd)	0.98 (-0.2)	Random	Dispersed
Grar - Vsmall	1 (0sd)	0.77 (-1.0)	Random	Random
Shiqmim - Vsmall	1.06 (0.3sd)	0.72 (-1.6)	Random	Random

Tab. 2. Indices of autocorrelation (Nearest Neighbour) in the Northern Negev for specified rectangles.

scales show clustered patterns and at smaller scales there are random or dispersed patterns, but that the medium sized rectangles show uncertain random-to-clustered results. What this shows is that at the scale of the medium rectangles there is a shift and that at this scale Nearest Neighbour patterning becomes uncertain. Thus between the scales of 80 km² and 20 km² or between rectangles that have dimensions of >10 km by >6 km and <7 km by <3 km there is a shift between the clustering around resources and the randomness (or dispersion) of small groups of sites. We might infer from this – and from an analysis of cost-distance and visibility which has shown an optimal separation distance between sites in the Chalcolithic in the same area of about 5–9 km (cartesian) – that settlement, although clustered around resources, was essentially randomly distributed in groupings that separated themselves by effective distance-areas that can be approximated as a distance of 6–10 km.

What can this tell us about settlement during the Chalcolithic? There are three points:

1. Chalcolithic settlement in the Northern Negev was clustered around the wadis as a means of access to resources;
2. At scales of less than 20 km² settlement would appear to have been randomly situated;
3. Spatial analysis of the settlement pattern shows that the distances between neighbouring sites or groups of sites are important, which becomes manifest when focusing on areas greater than 20 km².

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