Zooming Patterns Among the Scales: a Statistics Technique to Detect Spatial Patterns Among Settlements

Alessio Palmisano
Univeristy College London, United Kingdom

Abstract:
The present paper aims to offer an overview of the existing statistical approaches to settlement patterning in Archaeology by one multi-scalar method (Ripley's K function) and to show both problems and potentiality of such technique dealing with spatial data. I will use as case study the Iron Age I period archaeological sites located in the actual West Bank (or Cisjordan) in order to show how point pattern analysis can help us to detect spatial patterns and investigate if phenomena of attraction or repulsion among settlements are mainly related to the first or second order of effects. With the term "first order of effects" I mean that the observations throughout a study area "vary from place to place due to the changes in the underlying properties of the local environment" (O'Sullivan and Unwin, 2003, 79). The second order of effects, instead, is due to the local interaction between the observations. Therefore, I am going to investigate through this particular method how the environmental variables (first order of effects) and the direct interaction between the settlements themselves (second order of effects) can determine different spatial patterns (cluster, even or random distribution of settlements).

Keywords:
Spatial Analysis, Iron Age I Period, Southern Levant, Settlement Pattern, Landscape Archaeology, West Bank (Cisjordan)

1. Introduction

During the last years digital technologies have been used in Archaeology for the documentation, the management and the representation of archaeological data. A consequence of this phenomenon is the increasing popularity of Geographical Information Systems (GIS) as powerful tool for the organization and the visualization of archaeological data in relation with the correspondent spatial information, while less attention is paid to the application of spatial statistics for detecting specific patterns of such datasets.

Recently, however, GIS has been used by archaeologists not only for data management, but also for analysing data and their spatial references. Thus, researchers can detect particular patterns from archaeological data collected through archaeological surveys or excavations by carrying out statistical spatial analyses. It is important to point out that statistics and spatial analysis have the power to detect and explain even the most vague and complex aspects of the world (Shennan 1997, 3). Researchers, by using statistics, can discern the presence or the absence of any pattern in the archaeological data, and detect the relationships between the spatial and the attribute datasets (Conolly and Lake 2006, 122). Many foundations of spatial analyses were established by geographers in the 1950's and 1960's, and then adopted and modified by archaeologists in the 1970's and 1980's (Hodder and Orton 1976). In the past 20 years there have been several important advances and a renewed interest in the application of spatial statistics techniques to the study of the past human behaviour (Williams 1993; Beardah 1999; Premo 2004; Crema et al. 2010; Ladefoged and Pearson 2010; Bevan 2012).

This paper focuses on a set of point pattern and process models that now put archaeologists in a position to return to the analysis of spatial pattern and process with renewed ambition, especially with regard to distribution maps. Therefore, the first section offers an overview of the existing statistical approaches to settlement patterning in Archaeology by one multi-scalar method (Ripley's K function) and shows both problems and potentiality of such technique dealing with spatial data. The subsequent section focuses on one particular case study (the Iron Age I settlements in the actual West Bank or Cisjordan[2]), which highlights some important conceptual issues and new analytical opportunities.

2. Spatial Statistics and Settlement Patterns

Archaeologists frequently use points for representing the location of artefacts, sites, particular features, etc. The analysis of point distribution can be an important tool for understanding, interpreting and explaining the spatial configuration of our observations in a given study area. There are three idealised point distributions: random, clustered and regular. Nevertheless, these states rarely occur so clearly in reality and settlement patterns are more complex above all if we consider that the scale of analysis can change the spatial configuration of a spatial pattern. A regular distribution of sites can reflect a form of competition among settlements, the existence of agricultural catchments or both (Hodder and Orton 1976, 54-85). Clustering of sites may be due to a localized distribution of sources or to the presence of polities and regional centres. On the other hand, random distributions have been usually treated as null-hypotheses, although this kind of spatial pattern can be determined by specific environmental and social variables (Bevan and Conolly 2006, 218). The most known technique in Archaeology for detecting spatial patterns among settlements is nearest neighbour analysis, which was originally designed by Clark and Evans (1954) for ecological purposes. The widespread of this technique among archaeologists is due to the fact that it is simple to calculate and it provides an easy coefficient to interpret. Nevertheless, this technique considers only the first nearest neighbour, it is not multi-scalar and its result is strongly affected by the size of the analysed area.

At this point, I will propose a multi-scalar spatial statistics technique known as Ripley's K function, designed to detect spatial patterns of aggregation or segregation of point data at different scales (Ripley 1976). In this section I will try to identify the possible interactions between settlements distributed in a given study area by carrying out point pattern analyses to investigate if phenomena of attraction or repulsion are mainly related to the first or second order of effects. With the term "first order of effects" I mean that the observations throughout a study area "vary from place to place due to the changes in the underlying properties of the local environment" (O'Sullivan and Unwin 2003, 79). The second order of effects, instead, is due to the local interaction between the observations. Therefore, in the present paper, I am going to investigate how the environmental variables (first order of effects) and the direct interaction between the settlements themselves (second order of effects) can determine different spatial patterns (cluster, even or random distribution of settlements). In practice, it is important to point out that it is not easy to distinguish the first/second order effects in the point pattern simply by observing as the intensity of a process varies across space. In fact, any points distribution documented in a given study area can be thought as the result of one or more underlying processes. Moreover, in many real world examples, it is probably that different spatial patterns (cluster, even or random distribution of points) are due to multiple processes behaving differently in different parts of a specific study area. Therefore, is it important to make a distinction between the first order effects as factors and phenomena affecting the intensity of points across a region, and the second order effects that describe different patterns of interaction among points such as attraction and segregation.

In this section I will use two different point pattern analyses for investigating if the spatial patterns of the Iron Age I settlements are due to the direct interaction among them or to the environmental variables: homogenous and inhomogeneous Ripley' K functions. I will also investigate two different kinds of homogenous Ripley's K functions: global and local.

The homogeneous Global Ripley's K function describes the second order properties of a point pattern by using measures based on distances between all events in the study area (Lloyd 2007).

Corresponding author: a.palmisano@ucl.ac.uk

[2] The West Bank is a landlocked territory bordering Jordan to the east and Israel to the west, north and south. Since the Oslo peace's accords in the 1993, parts of the West Bank are under full or partial control of the Palestinian Authority. Actually, 164 nations refer to the West Bank, including East Jerusalem, as "Occupied Palestinian Territory".

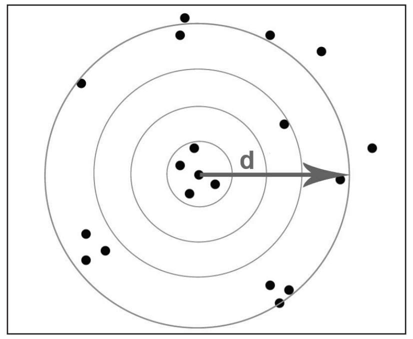

Figure 1. *Number of events within the circle with radius d centred on location x.*

The K function for distance d is given by the following formula:

$$K(d) = \frac{\#(C(x,d))}{\lambda}$$

where #(C(x,d)) indicates the number of events in the circle C(x,d), with radius d centred on location x (Fig. 1) and λ is the average intensity (M= N(a)/A) of the process. This global function examines spatial dependence over small spatial scales by assuming homogeneity and isotropy over the scale of analysis (stationary point process) (Lloyd 2007, 177). The K function is obtained by counting the number of point within radius d of an event and calculating the mean count for all events; then, the mean count is divided by the overall study area event density. We can repeat the same procedure at different scales by modifying the values of the radius d around each event.

The local K function is similar to the global K function, but only pairs of points that have a given point i as one of the members of the pair are included (Lloyd 2007, 186-187). A local K function of distance d is defined by the following formula:

$$K(d) = \frac{|A|}{n}\frac{N(C(x_i,d))}{\lambda}$$

where counts are of all points within distance d of point i and |A| indicates the area of the window analysis. Unlike the Global Rypley's K function, the local K function allow us to show the spatial distribution of clustering at each spatial scale by plotting the K value for all artefacts at each bandwidth in turn.

Nevertheless, the homogeneous Ripley's K function has some weaknesses: it supposes homogeneous space and is characterized by a stationary point process, where the intensity function λ[3] is constant throughout the whole study area (Marcon and Pluech 2003, 2). If an initial analysis suggests that a pattern is not characterized by a constant intensity over the study area, the homogenous K function does not allow further analyses (Baddeley et al. 2000, 330).

Inhomogeneous point pattern could arise if, for instance, we detect that our observations are distributed according to environmental variables such as soil fertility, water source proximity and so on. Therefore, the inhomogeneous K function is a non-parametric second order analysis, which allows us to analyse point patterns distributed in a heterogenic space. This is possible by creating a predictive surface including the environment variables as covariates (Baddeley and Turner 2005, 23). Therefore, an inhomogeneous K function will not only depend on the distribution of points in a study area, but also on the underlying intensity function, so that to de-trend the first order of effects (Comas et al. 2008, 390).

3. Study Area and Dataset

My study focuses on past human settlement in Southern Levant, particularly in the West Bank highlands (Cisjordan). This area (coordinates: 32°00′N 35°15′E) has a total extension of 5,860 km² and an average altitude of 600 m. The highest and best known peak is Tall Asur (1,016 m), a mount located 10 km North-East of Ramallah, while the lowest point is located in the Dead Sea (- 408 m).

The peak settlement that took place in the West Bank highlands, during the Iron Age I period (12th-11th centuries B.C.), is one of the most controversial and discussed topics in the history of the land of Israel. Many scholars have studied this stormy period with different points of view: the biblical interpretation (Albright 1939; Dever 1992; Thompson 1992), historical research and archaeology (Finkelstein 1996; Finkelstein 1998; Finkelstein and Mazar 2007). Most of them assumed, in their researches, the presence of a unique ethnical group living in this region during Iron Age I period: the proto-Israelites. Instead, in this paper I will generally speak about Iron Age I settlers without assuming any ethnical boundary but assessing how in this region the environmental features, related to cultural-socio-economic aspects, may have affected the human decision-making process and the settlement distribution of Iron Age I people.

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[3] The intensity is given by the following formula λ=N/A, where N indicates the number of events and A is the overall area of the window analysis.

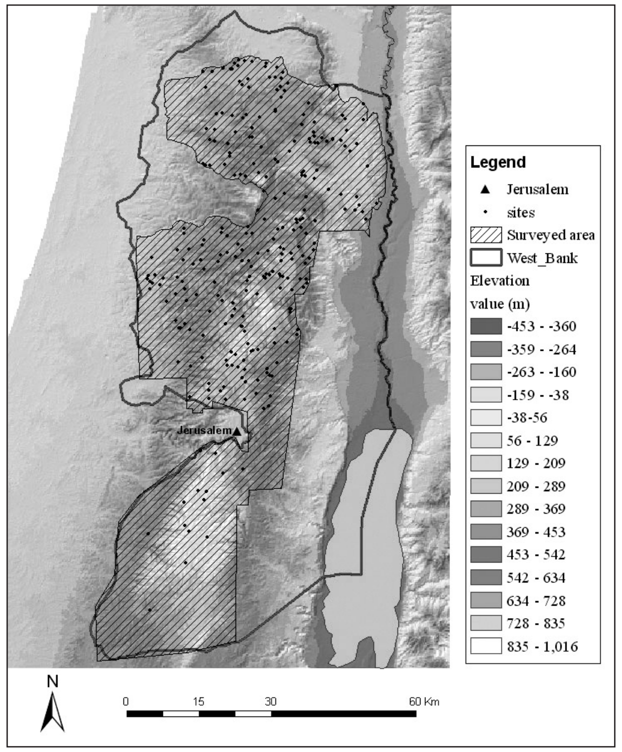

Figure 2. *Map showing the West Bank boundaries (in black) and the total surveyed area.*

The principal archaeological surveys throughout the West Bank have been carried out in the north by A. Zertal between 1978 and 1988 (Zertal 2004) and by Finkelstein, Lederman and Magen between 1980 and 1988 (Finkelstein and Lederman 1997; Finkelstein and Magen 1993); in the south by M. Kochavi in 1967-68 and A. Ofer in early 90's (Kochavi 1972).

The methodology of the surveys consisted of making a grid of a selected region and then spreading out in a line and walking throughout the whole area looking for all traces of ancient remains. The archaeologists carefully recorded any natural (topography, distance from water sources, soil typology, elevation) and archaeological feature (wall lines, buildings remains, potsherds, etc.) in order to detect the nature of ancient occupation. After surveying all sites, maps of each archaeological period were drawn to show the location and distribution of sites recorded by size and typology. I managed to identify and locate 270 sites distributed throughout the whole area in the Iron Age I by gathering the data coming from the archaeological surveys that I have above mentioned (Fig. 2).

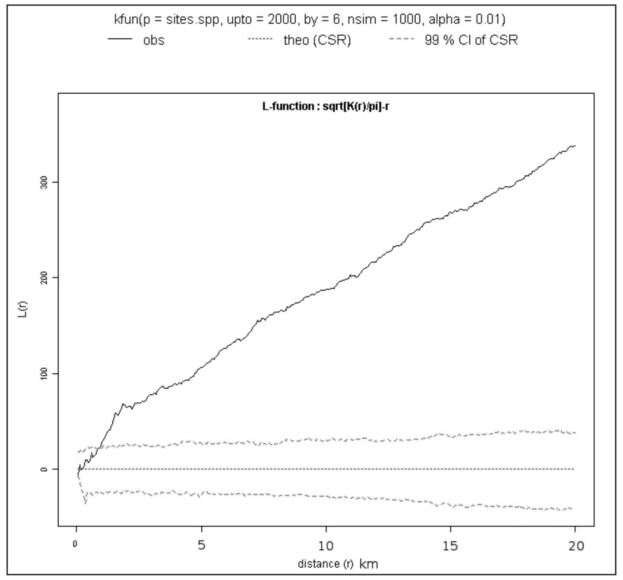

Figure 3. *Global homogeneous Ripley's K function for Iron Age I settlements.*

4. Analyses and Results

I carried out an univariate global Ripley's K function for all 270 settlements by using an interval of 60 metres (the minimum nearest neighbour distance between the settlements) and a maximum bandwidth of 20 Km.

The resultant K function plot shows the cumulative frequency distribution of average point intensity at set increments (equal to 60 m) of r. I used Monte Carlo simulations of points random distributions to estimate local confidence limits of the null hypothesis of complete spatial randomness (CSR) and obtained 99 percent confidence interval by carrying out 1000 iterations (Bevan and Conolly 2006, 220). These estimates are, then, compared to the observed values of K (L) in order to provide a statistical robust measure of a clustered or regular point distribution in our study area (Conolly and Lake 2006, 166). The Ripley`s K plot (Fig.3) shows a strong positive deviation from the confidence

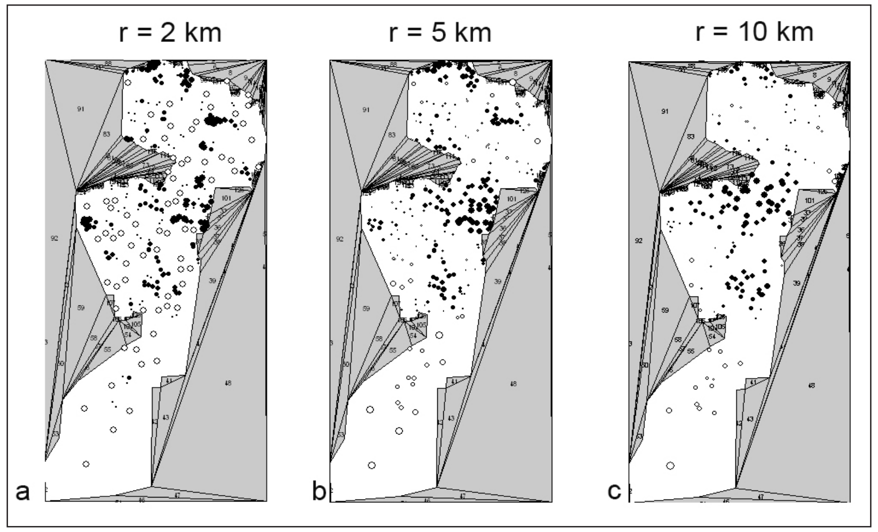

***Figure 4**. Local Rypley's K values for all settlements at bandwidth 2, 5 & 10 Km.*

interval and indicates that from a distance (r) greater than 1 Km sites cluster into statistically significant groups (p<0.01) indicating that there are more neighbours than expected at almost all distances r.

Unlike the univariate Global Rypley's K function, the local K function allow us to show the spatial distribution of clustering at each spatial scale by plotting the modified K-distribution (L) function value for all settlements types at each bandwidth in turn. At this point, I created different plots of all 270 settlements at bandwidth 2, 5 and 10 km in order to detect different local patterns. I would like to point out that there is not an ideal bandwidth's value because this kind of spatial statistics technique is multi-scalar and its results depend on the scale adopted. So, in this case I have used three different bandwidths for showing the common general trends occurring in my study area at different scales.

In my plots the dimension of black circles represents the degree of aggregation of a site, while the dimension of white circles represents the degree of segregation of each point. So, the greater is a black circle the more clustered are the corresponding sites. If we look at the local clusters of all sites at bandwidth equal to 2km (Fig. 4a) we can see that some small clusters are distributed mainly on the eastern and north-western ridges of the West Bank. Instead, at bandwidth 5 (Fig. 4b) and 10 Km (Fig. 4c), the clusters appear greater than the cluster obtained by using a bandwidth equal to 2 km. That means that the results change according our scale and that there is not an ideal bandwidth to use for detecting the spatial distribution of clusters in our study area. Thus, we can compare the different results obtained by making use of different bandwidths either for detecting general trends occurring in any scale or for inquiring particular pattern at a given scale. The results of local Ripley's K function, by looking at the three outputs obtained with three different bandwidths, tell us that the settlements were generally clustered in the Central West Bank and in the northern edge of the study area. The inhomogeneous K function, as we have previously said, allows us to detect the interaction between the sites by de-trending the first order of effects (environmental factors) through the creation of an-inconstant intensity surface underlying all our study area.

We can therefore build some formal point process models to consider what environmental affordances could have significantly affected the distribution of settlements in the West Bank highlands. We begin by considering, as examples, six related environmental factors: elevation, slope, aspect, ridge-top landforms, distance into/out of the dolomite geological typology and topographic wetness in a local catchment (Figures 5a-f)[4].

This selection is prompted in part by many commentators' informal impressions that rugged topography and hydrology were important factors behind settlement locations in this region and period, for a variety of practical reasons (e.g. Zertal 1988; Gibson 2001).

If we now run a multivariate regression and select the best combination of these six variables via stepwise comparison (minimising an Akaike Information Criterion), we find that that elevation, distance into/out of the dolomite and the aspect are not particularly good predictor of the intensity of sites across the landscape, that the other three variables are all significant (p<0.05 or better), and that this new model with a first-order trend is substantially more effective that a null, random hypothesis (Fig.6). We can then create a predicted first-order intensity surface (Fig.7) by implementing covariates that are good predictors: slope, topographic wetness index and ridge-like landforms. I performed Monte Carlo simulations of random points distribution to estimate local confidence limits of the null hypothesis of complete spatial randomness (CSR) and I obtained 95 per cent confidence interval by carrying out 500 iterations. Unlike the homogenous Ripley's K function, the random points created at each iteration are distributed according the highest values of the intensity surface.

If we look at the inhomogeneous K function plot of the 270 settlements (Fig. 8), we can see that the sites are randomly spaced at small distances r (lower than 1 km) and they tend to be clustered at a distance approximately greater than 1km. These results reflect the same pattern that we have when we perform a homogeneous Ripley's K function and they tell us that the environmental variables (first order of effects) implemented in our model could have not strongly affected the spatial distribution among the Iron Age I settlements in the West Bank highlands. So, the phenomena of aggregation or repulsion among the sites could be due either to socio-cultural factors or to other environmental factors not included in the model.

The analyses' results could be framed into a long term study including a time span from the Chalcolithic period (fourth millennium BC) to the Iron Age II (first millennium BC). It would be worth investigating the cyclic mechanism of alternating processes of sedentarization and nomadization of indigenous groups in response to the changing political, economic, and social circumstances. This could be done through the study of the faunal assemblage of the sites, where pastoral communities will yield more sheep/goats remains and sedentary society more cattle remains. In fact, there were three peaks of settlement with two intervals of collapse in the West Bank in the third and second millennium BC. The peaks of settlement occurred in the Early Bronze Age I (3300-3000 BC), in the Middle Bronze Age (ca. 1750-1550 BC) and in the Iron Age I (ca. 1200-1000BC), while the demographic collapses occurred in the Intermediate

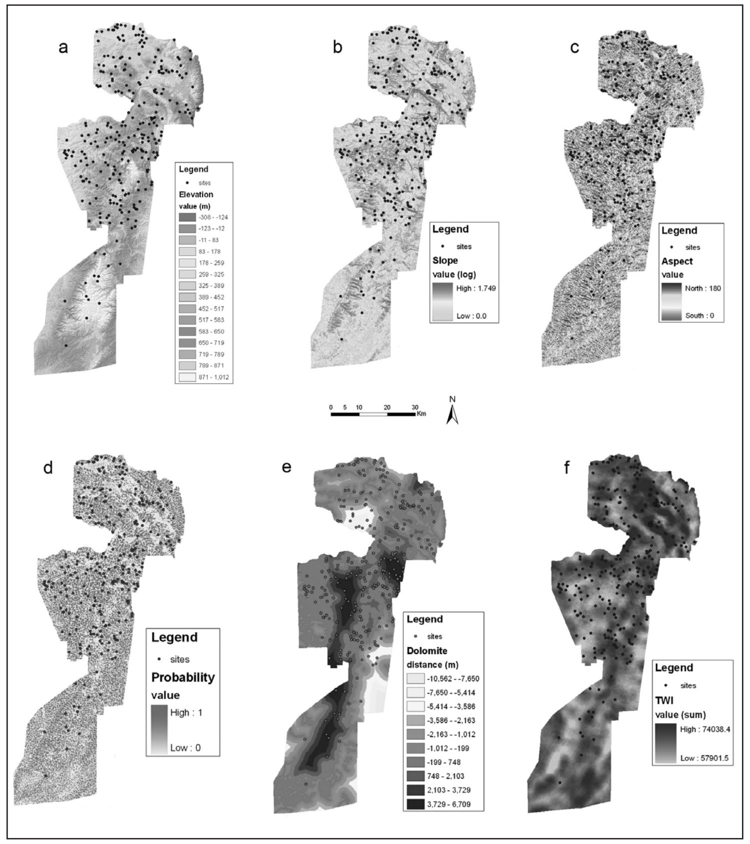

***Figure 5**. Iron Age I sites in the West Bank and six possible first-order covariates: (a) elevation (light to dark ranges from - 306 – 1012 m ASL), (b) slope map, (c) aspect map, (d) ridge landforms (darker is more likely to be geomorphometrically classified as a ridge), (e) Map of the study area showing the distance into dolomite (positive values) and the distance out of the dolomite (negative values),(f) topographic wetness index summed over a local neighbourhood (darker is wetter).*

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[4] The digital elevation model (DEM) used here is NASA's 30m ASTER dataset. Ridge-like landforms were defined from the DEM via a fuzzy feature classification across focal filter scales from 3x3 to 11x11 cells (Fisher et al. 2004). Catchment-based topographic wetness was calculated via focal filtering of a standard topographic wetness index surface (itself derived from the DEM) in a way that summed all values within a circular neighbourhood of 1.5 km radius (the average of the nearest neighbour distance of the Iron Age I sites). The slope and aspect maps were derived from the DEM. After carrying out a chi-squared test (p-value : 0.02813) I assessed that there was a spatial correlation between the settlements distribution and the geology type, and more than expected sites were located in dolomite geological category. Therefore, I created a raster surface indicating the distance of each pixel into and out of dolomite.

variables	Pr (>|z|)	p-value
Slope	**1.21e-09**	**1.936202e-10**
Elevation	0.267	0.2654711
Wetness index	**0.0145**	**0.014**
Distance from dolomite	0.367	0.3651802
Ridges	**2.73e-14**	**2.109424e-15**
Aspect	0.527	0.5270893

Figure 6. *Top. P(r) and p-values from multivariate logistic regression of the settlement distribution.*

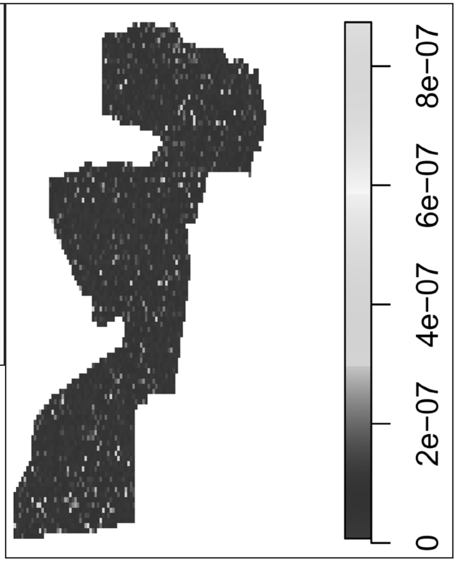

Figure 7. *Right. Prediction surface based on the three significant covariates (lighter is higher point intensity).*

Middle Bronze Age (ca. 2200-2000 BC) and in the Late Bronze Age (ca. 1550-1200 BC). Therefore, in a future research it would be worth investigating and comparing the different settlement patterns occurred in the area across the millennia in order to have a better understanding of the phenomena causing this cyclic settlement process.

5. Conclusions

In this paper I have analysed how the first and the second order of effects may have affected the distribution of Iron Age I settlements in the West Bank highlands. The results of the global and local univariate homogenous Ripley's K function indicate that the settlements are clustered at almost all scales. Nevertheless, the results of these analyses have to be analysed carefully because the homogeneous K function assumes the stationarity of the point process and that the space is homogeneous. These assumptions cannot be valid for the West Bank highlands, a large study area characterized by environmental heterogeneity, geological and topographical properties that can determine inhomogeneous structure. This does not mean that it is useless investigating settlement patterns regarding the second order of effects. In addition, the local Ripley's K has revealed that the settlements were mainly located in the central West Bank and along the northern edges of the study area. This could reflect spatial patterns also connected with different environmental conditions and subsistence strategies.

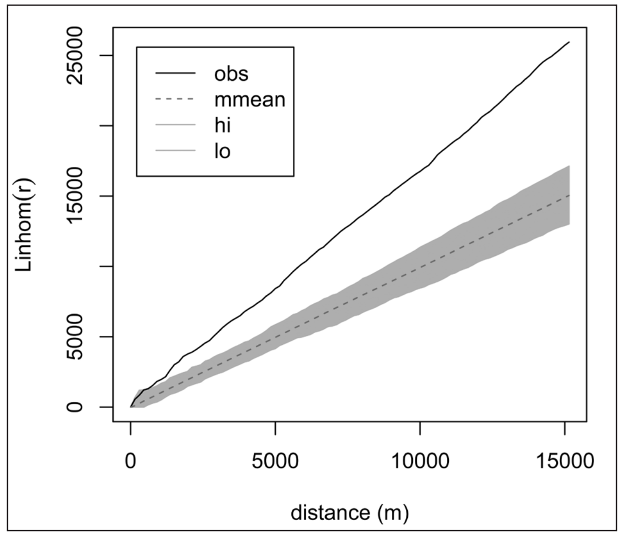

Figure 8. *Global inhomogeneous Ripley's K function for Iron Age I settlements.*

As I have formerly pointed out, the homogenous K function shows some weaknesses and it is not completely reliable for our purposes. For this reason I carried out the inhomogeneous Ripley's K function analysis by de-trending the first order of effects. The results of this analysis indicate that at a distance greater than 1km the Iron Age I settlements are significantly clustered, by indicating that in this particular study area the environmental factors (first order of effect) could have not affected the spatial pattern among the settlements. Therefore, the homogeneous and inhomogeneous Rypley's K analyses should be used complementarily in order to detect both the environmental and the cultural factors that could have affected the settlements patterns in the West Bank highlands during the Iron Age I period.

It is interesting to notice that about 70 % of the settlements were located on the ridges, suggesting that this environmental feature was the privileged location where to settle. The results of the analyses make us state that the settlements were located on the top hills for a series of reasons such as the building of agricultural terraces, and the visibility. Most Iron Age I settlements were small and medium unfortified agricultural villages specialized in a horticulture-oriented economy including the industrialization of orchard's products. Considering this aspect, the agricultural terraces were the most striking man made features dominating the highland landscape of the West Bank. The terraces were built to guarantee additional ground space dedicated to the cultivation of fruit trees and other crops. The terraces were located on the slope of hills, on sloping plateau areas and over gullies and valleys. In this context the proximity of water sources and land suitable for cultivation played an important role. In fact, the sites were mainly located on the ridges bounding green and fertile intermountain valleys, where the agricultural productivity was higher. The northern and central West Bank, with vast fertile intermountain valleys and a relatively moderate topography were suitable zones for the proliferation of small sedentary rural communities.

Therefore, some archaeological features such as the plastered cisterns, the pillared room houses and the agricultural terraces mirror the socio-economic conditions of Iron Age I settlers to adapt and exploit the hilly landscape and not the cause that favoured the peak of settlements over the region.

The eastern flank of the west Bank, instead, characterized by the presence of steppes and the proximity to the desert fringes, was more suitable for animal husbandry and dry farming (in flat and open areas) undertaken by nomadic or semi-nomadic communities.

Another important aspect is that I have identified several clusters distributed on the western and eastern edges of my study area and in some intermountain valleys in the central highlands. These clusters are mostly composed by settlements not located on the ridges but mainly distributed over intermountain valleys (central and western West Bank) and steppes (eastern West Bank). This could suggest that the position of settlements on the ridges may reflect the need of segregation of the "highlanders", while the settlements located in the valleys and in the steppes tended to be more clustered.

The vacuum of power following the Sea People advent and the end of Egyptian domination, may have turned the relationships of various groups within highlands into a form of competition among villages resultant in the raise of "totemic" and "local" identities (Faust 2006, 229). This determined the proliferation of many rural and small communities spread over large areas and divided into several local "factions".

In the end, I conclude by stating that perhaps the "proto-Israelites" were not a unique ethnical group living in the West Bank highlands, but one of the several communities that inhabited the region in the Iron Age I.

References

Albright, W. F. 1939. "The Israelite conquest of Canaan in the light of Archaeology." *Basor* 74.

Baddeley, A., J. Moller and R. Waagepetersen. 2000. "Non-and semi-parametric estimation of interaction in inhomogeneous point patterns." *Statistica Neerlandica* 54: 329-350.

Beardah, C. 1999. "Uses of multivariate kernel density estimates." In *Archaeology in the age of the Internet: Computer Applications and Quantitative methods in Archaeology 1997*, edited by L. Dingwall, S. Exon, V. Gaffney, S. Laflin and M. van Leusen. Oxford: Archaeopress.

Bevan, A. 2012. "Spatial methods for analysing large-scale artefact inventories." *Antiquity* 86(332): 492-506.

Bevan, A., and J. Conolly. 2006. "Multiscalar Approaches to Settlement Pattern Analysis." In *Confronting Scale in Archaeology*, edited by G. Lock, and B. L. Molyneaux, 217-234. New York: Springer.

Clark, P. J., and F. C. Evans. 1954. "Distance to Nearest

Neighbour as a Measure of Spatial Relationships in Populations.” *Ecology* 35: 444-453.

Crema, E., A. Bevan, M. Lake. 2010. “A probabilistic framework for assessing spatio-temporal point patterns in the archaeological record.” *Journal of Archaeological Science* 37 (5): 1118–1130.

Comas C., M. Palahí T. Pukkala, and J. Mateu. 2008. “Characterising forest spatial structure through inhomogeneous second order characteristics.” *Stochastic Environmental Research and Risk Assessment* 23 (3): 387-397.

Conolly, J., and M. Lake. 2006. *Geographical Information Systems in Archaeology*. Cambridge: Cambridge University Press.

Dever, W. G. 1992. “How to tell a Canaanite from an Israelite. “In *The Rise of Ancient Israel* edited by H. Shanks. Washington: Biblical Archaeology Society.

Faust, A. 2006. *Israel`s Ethnogenesis: Settlement, Interaction, Expansion and Resistance*. London: Equinox.

Finkelstein, I. 1996. “Ethnicity and Origin of the Iron I Settlers in the Highlands of Canaan: Can the Real Israel Stand Up?” *The Biblical Archaeologist* 59 (4): 198-212.

Finkelstein, I. 1998. “The Rise of Early Israel Archaeology and Long-Term History.” In *The Origin of Early Israel, current debate*, edited by A. Shmuel and E. D. Oren. Jerusalem: Posner & Sons Ltd.

Finkelstein, I. and Z. Lederman. 1997. *Highlands of many cultures. The Southern Samaria Survey*. Jerusalem: Graphit Press Ltd.

Finkelstein, I. and Y. Magen. 1993. *Archaeological Survey of the Hill Country of Benjamin*. Jerusalem.

Finkelstein, I. and A. Mazar. 2007. *The quest for the historical Israel*. Atlanta: Society of Biblical Literature.

Gibson, S. 2001. “Agricultural Terraces and Settlement Expansion in the Highlands of Early Iron Age Palestine: Is There Any Correlation Between The Two?” In *Studies in the Archaeology of the Iron Age in Israel and Jordan*, edited by A. Mazar. Sheffield: Sheffield Academic Press.

Hodder, I., and C. Orton. 1976. *Spatial Analysis in Archaeology*. Cambridge: Cambridge University Press.

Kochavi, M. 1972. *Juda, Samaria and Golan. Archaeological Survey 1967-68*. Jerusalem.

Ladefoged, T. N. and R. Pearson. 2000. “Fortified castles on Okinawa Island during the Gusuku Period, AD 1200-1600.” *Antiquity* 74: 404-412.

Lloyd, C. D. 2007. *Local Models for Spatial Analysis*. London: Taylor & Francis Group.

Marcon, E. and F. Puech. 2003. *Generalizing Ripley’s K function to Inhomogeneous Populations.*

O’Sullivan, D. and D. J. Unwin. 2003. *Geographic Information Analysis*. Hoboken: John Wiley & Sons.

Premo, L. 2004. “Local spatial autocorrelation statistics quantify multi-scale patterns in distributional data: an example from the Maya Lowlands.” *Journal of Archaeological Science* 31: 855-866.

Ripley, B. D. 1976. “The Second-Order Analysis of Stationary Point Process.” *Journal of Applied Probability* 13: 255-266.

Shennan, S. 1997. *Quantifying Archaeology*. Edinburgh: Edinburgh University Press.

Thompson, T. L. 1992. *Early Hystory of the Israelite People From the Written and Archaeological Sources*. Leiden: Brill.

Williams, J. T. 1993. “Spatial autocorrelation and the Classic Maya collapse: one technique, one conclusion.” *Journal of Archaeological Science* 20: 705-709.

Zertal, A. 1988. “The water factor during the Israelite Settlement Process in Canaan”. In *Society and Economy in the Eastern Mediterranean (c. 1500-1000 BC)*, edited by M. Heltzer and, E. Lipinski, 341-52. Leuven: Peeters.

Zertal, A. 2004. *The Manasseh hill country survey. Vol. I-II*. Leiden, Boston: Brill.