A visual spatial analysis of Stone Age sites

Milco Wansleeben

Intra site spatial analyses in the Netherlands has applied both visual techniques and statistical methods for some time. The actual characteristics of spatial data in general, and of Stone Age sites in particular, force us to rethink our analytical approaches. New developments in spatial statistics, easily available in modern GIS software, might not solve all the encountered problems. However, GIS also includes powerful methods to visualize the trends on our intra site distribution maps. This study proposes a visual approach, to better support archaeological interpretations, which often require substantial background knowledge to form viable conclusions.

1 ARCHAEOLOGICAL SPATIAL DATA

A recent analysis of the site at Dronten-N23 (Wansleeben and Laan 2012) highlighted how archaeological spatial data contains a number of very specific characteristics which may hamper a spatial analysis. In order to discover regularities and irregularities in the spatial distribution of the archaeological remains, archaeologists produce distribution maps for visual inspection and calculate spatial statistics. Trends, concentrations, voids and outliers offer a way to get insight into the behavior of people in the past, insofar as these patterns did not become too blurred over time by subsequent habitation, geological and soil processes, or by the archaeological discovery process itself. While the distribution patterns of archaeological remains are inevitably faint and faded, a meaningful reconstruction of past behavior is still possible.

Characterizing the spatial distribution on an archaeological map is not self-evident. Spatial patterning has the ability to show different patterns in different spatial scales at the same time. The Dronten-N23 site, discovered in a shielded Pleistocene coversand landscape and dated to the late Mesolithic/early Neolithic period, serves as an example here (fig. 1). This site was excavated in squares of 50 by 50 cm for which the soil was sieved over a relatively fine sieve (2mm mesh size). The distribution of the thus excavated flint artifacts clearly displays a circular patterns of high density squares, which is strongly correlated to the elevation of the natural topography of the coversand ridge. The slightly higher parts of this ridge are much richer in flint than the central depression and surrounding edges. Within the generally wet areas of the Netherlands this is a typical reccurring locational preference.

The presence of a large number of hearths on the ridge confirms the primary context of these finds. Within the circular concentration nine individual concentrations can be recognized, each with a specific size and density. A detailed map of the concentrations VI and VII shows that these concentration are effectively composed of two to three small concentrations of flint artifacts. Zooming in further reveals that even these smaller concentrations are a fusion of little (1 to 1.5m) spots of high density. These tiny rich spots seem to represent individual flint knapping events. It is clear that these activities did not take place at the same time or close to the same hearth. It is simply a large palimpsest of many individual activities over a long period of time, resulting in an almost random collection of concentrations in different sizes, shapes, and densities. Reconstructing the behavior of the Stone Age inhabitants from these patterns is difficult but not entirely impossible. This multi scale characteristic of archaeological distributions has obviously been identified for some time and documented in archaeological literature, with *Confronting Scale in Archaeology* (Lock and Molyneaux 2006) as an excellent example.

Multi scale patterning has not only been discovered in spatial data but also in time series. A well-known example is provided by weather stations in their temperature measurements. The daily cycle of rise and fall of the temperature per hour is bound to the day-night rhythm, effectively the presence/absence of the sun due to the earth's rotation. This rhythm is crosscut by the influence of weather systems by which very irregular fluctuation of high and low pressure seem to result in a randomizing effect on day and night temperatures. This in contrast to much better predictable effects of the seasons (rotation around the sun) on the average daily temperature on a slightly longer timescale. An even longer timescale is considered when studying global warming, in which yearly or even 30-years (running) temperature averages are applied to visualize and discover climate trends. The longer the time span of the unit of measurement (hour, day/night, day, season, year, 30 years) the more general the pattern which can be discovered. At the

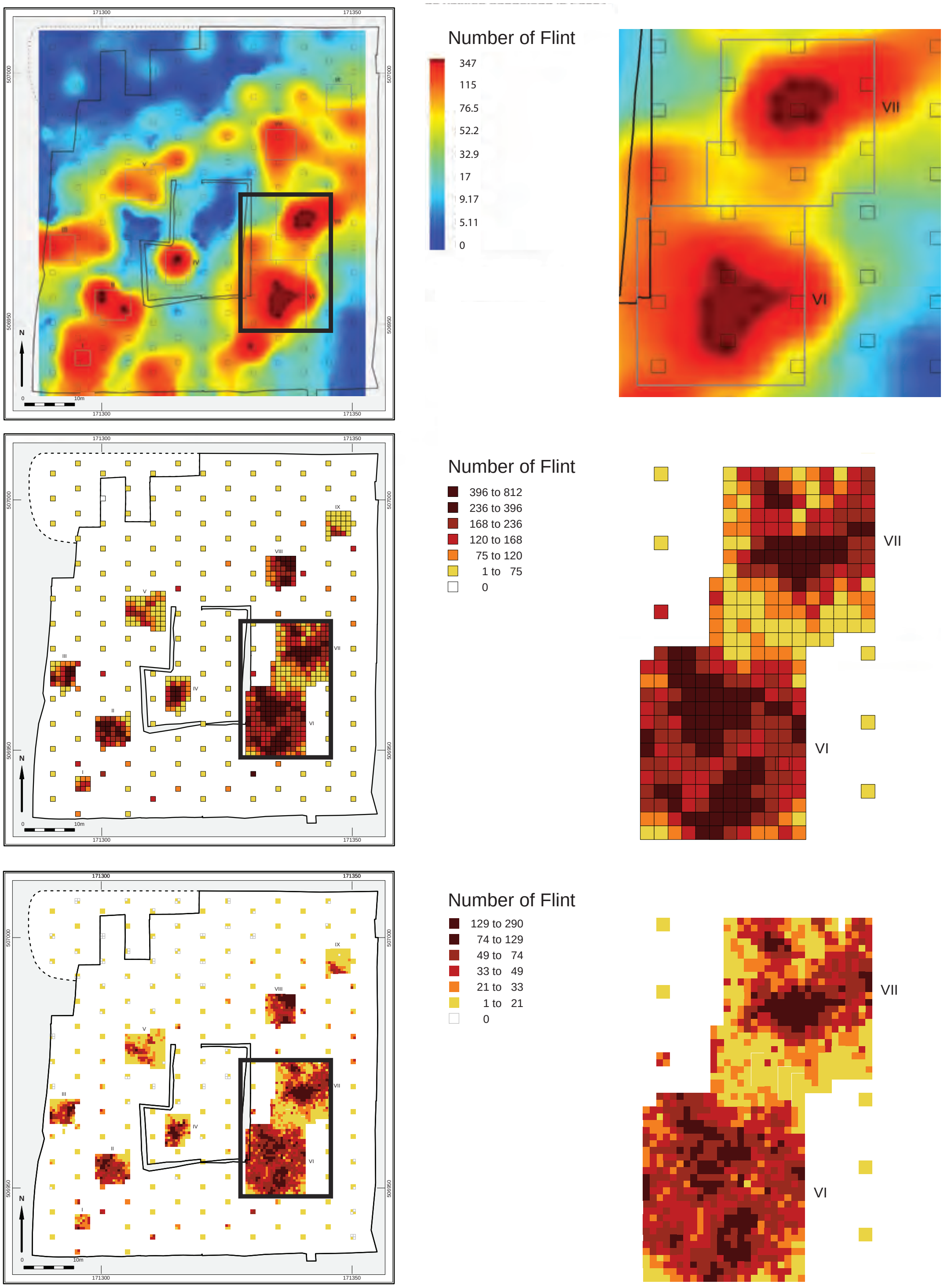

Figure 1 Spatial distribution of Dronten-N23: at different spatial resolutions, the entire site consists of a number of concentrations upon a ring shaped ridge of the coversands (top). The distribution patterns within these concentrations become more and more clear, richer in details and individual deposition events when stepwise zooming in to the 1 by 1 meter (middle) and 50 by 50 cm. grid size level (bottom). Multiple concentrations within a concentrate characterize the multi scale characteristic of (archaeological) spatial data. Details of the concentrations VI and VII are presented on the right

same time this example shows how different time scales have different explanations. The same conclusion applies to archaeology, which is confronted with both a spatial and a temporal component. The way an archaeological site was formed over time also includes temporal *multi scale* effects. A series of daily activities by the Prehistoric inhabitants of the campsite will melt together over the days and weeks into a diffuse pattern over a season. Even a yearly migration with multiple returns to the location, without the certainty that exactly the same activities were performed, will contribute to the seemingly unstructured clustering of flint artifacts across this coversand ridge.

The notion that spatial patterns on archaeological sites have multi scale properties, makes them a bit more difficult to discover. There is however another issues to consider: even at one spatial level the pattern might not be homogeneous across the entire site. At one corner of the excavation the patterns might indicate a clear clustering, while at another corner a much more random or regular pattern might be visible. At the same level of analysis concentrations might be large, round and rich, while interspersed with a lot of small irregular concentrations.

Both these observations, archaeology is confronted with *multi scale* and *non-homogeneous* spatial patterns, should have methodological consequences. This requires rethinking the way we perform a spatial analysis on an archaeological site.

2 Intra site visualization

Spatial data available for archaeological sites is often available as one of two types: point data where we know the exact coordinates of individual objects, or grid data (squares). In the latter only the amount or total weight of the finds is registered in square excavation units of a specific size (for instance at Schipluiden 1 by 1m (Wansleeben and Louwe Kooijmans 2006), at Dronten 50 by 50cm (Wansleeben and Laan 2012) and at Merselo 25 by 25cm (Verhart 2000)). Coordinate data can be reduced to grid data, yet grid data cannot be converted into coordinate data. Based on the exact position of the artifacts recorded in the field, the amount of finds within a square can be calculated afterwards. This approach is often applied to Stone Age sites in order to discover the general trend in the distribution. Many Dutch publications include a distribution map with the count of artifacts per square meter (fig. 2a). This is a broadly accepted visualization that offers some generalization. Methodologically, counting the number of artifacts in squares of 25 by 25cm, 50 by 50cm or even 2 by 2 m is equally valid. A larger square size will result in a more generalized visualization of the distribution pattern. Even the position, shape and orientation of the units used for counting the artifacts is not fixed. Why not use triangular or hexagonal units? The ring and sector method proposed by Stapert (*e.g.* Boekschoten and Stapert 1996) uses slices and segments to count the number of artifacts, expecting the distribution

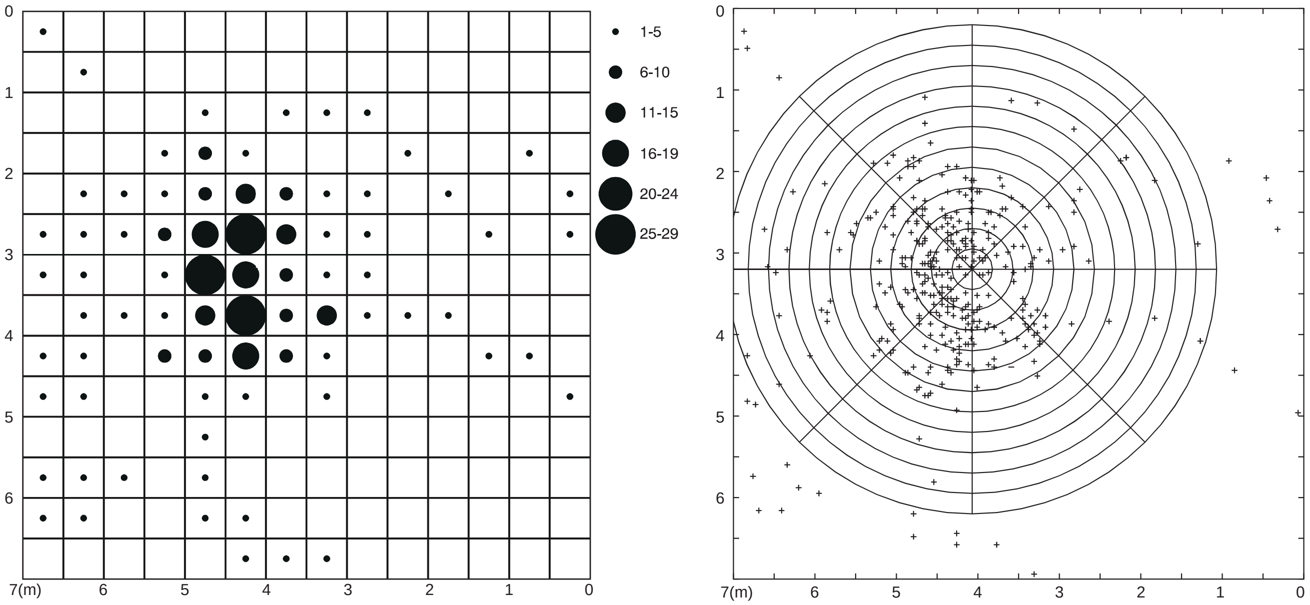

Figure 2 A traditional distribution map of the occurrences of flint artifacts across a Stone Age site, generalized into counts by square unit (2a, on the left). Stapert's ring and sector approach (Boekschoten and Stapert 1996) uses alternative spatial units to count and visualize the spatial pattern (2b, on the right)

pattern to focus on a central hearth (fig. 2b). As long as the area of all the units used for counting is of equal size, the frequency of artifacts can be displayed, if not, the density (corrected for the surface area) will be presented.

Any changes to the shape or size of the units will however lead to another visual image of the distribution pattern, and potentially to another archaeological interpretation. This problem is known as MAUP (=modifiable areal unit problem) (*e.g.* Cressie 1996; Kvamme 1990:269; Lock and Harris 2000:xx-xxi). The results of a generalization of the spatial distribution largely depend on the choice of spatial collection units. In the case of point data this problem can be easily bypassed by calculating counts for squares of 25 by 25cm, as well as 50 by 50cm, 75 by 75cm, 1 by 1m, 2 by 2m, etcetera. The smaller units show a more detailed (*local*) pattern, whereas with larger units a more generalized (*global*) pattern is displayed. Nowadays this can easily be applied in the spatial analysis of Stone Age sites, since GIS software facilitates quick and easy counts for several unit sizes and shapes.

Be aware that counts using units of unequal sizes or shapes across the distribution map, like the ring and sector approach, might create an unwanted side effect, namely that the amount of generalization is unequal as well. Therefore, it seems better to use the same size and shape of the collection units across the entire site, making the interpretation more robust. If a circular concentration exists, with or without different densities in certain sectors, this will certainly show up clearly in a spatial analysis which uses small squares.

If the archaeological excavation collected the artifacts in squares during fieldwork (grid data), the only option left is merging grids into larger units, creating an increasingly more generalized overview. There are no ways to experiment with very small or irregular shaped units.

3 SPATIAL STATISTICS

Which spatial statistics can be applied depends completely on the type of spatial data available. Point data require other techniques and parameters than grid data, although the aim of the technique might be the same. A statistical technique can be applied in order to characterize the spatial distribution into a single numerical parameter that would indicate whether the distribution is random, clustered or regular. In case grid data is available a technique called the Variance/Mean-ratio (V/M) is sometimes applied, whereas for grid data the Nearest Neighbor statistic (R) is available. An introduction to many of the spatial analysis techniques mentioned here, can be found in GIS handbooks, like Conolly and Lake (2006).

Many traditional statistical parameters, however, are not intended for spatial data. Kvamme (1993:92-93) clearly demonstrated that these a-spatial statistics often lead to meaningless results. The statistical assumption that each square is an independent observation is simply incorrect, since spatial data is known to be spatially correlated. If the density of artifacts in one square is high, then very often the squares neighboring it will contain many artifacts as well. This spatial autocorrelation, nearby observation have similar values, is completely ignored by the V/M-ratio, therefor the value of the ratio might be arithmetically correct but archaeologically meaningless. It simply does not give a valuable representation of the spatial distribution.

In addition, these single parameters describe the total distribution pattern across the entire site. This is exactly the same way Census Bureaus used to predicted the behavior of the entire population using a single ‘ideal’ representative, known as Jan Modaal (NL), Joe Sixpack (US) or Otto Normalverbraucher (D). A single representative is simply too crude a simplification of reality. These simple statistical parameters are apparently not very well suited for spatial data after all.

In geography and biology many spatial analysis techniques have been developed that harness the spatial autocorrelation perfectly and are able to recognize trends at different spatial levels. Despite this special characteristic of spatial information, these techniques seem to be able to provide a formal description of a distribution pattern. The development of the *nearest neighbor statistic* might be used as an excellent example here. At first this parameter was calculated with the distance between one artifact and its closest neighbor only. The average “nearest neighbor” distance for all artifacts was compared to a theoretical expectation and expressed into one parameter called R. A value for R of less than 1 would indicate a clustered distribution pattern, whereas a high value pointed to a regular pattern. But this parameter would effectively only take the lowest spatial scale into account. To get around this problem the calculation was extended, not only did it include the first nearest neighbor, but also the average to all second closest neighbors, and third, fourth, fifth, etcetera. With this approach a graph emerges that characterizes the spatial distribution in an increasingly larger area. For instance, clustering at a local scale and random at a higher level. This has been improved further into the Ripley’s L approach (Ripley’s K function). Within an increasing search radius the number of artifacts close by is calculated and matched to a theoretical expectation.

The generic concept behind these techniques is clear: spatial units of an increasing size are used to calculate the same parameter over and over again. Where Ripley’s K is available for point data, a technique called Getis-Ord Gi* (hot spot analysis) is available for grid data. The strength of the spatial autocorrelation is calculated at different spatial distances. Although these alternatives seem to have solved the multi scale problem, the aforementioned non-homogeneity seems to be persistent. Even these techniques ignore the problem that in one corner the pattern might be clustered while elsewhere it is regular.

Additionally one might question what the benefit for archaeologists is with these formal descriptions. Given the nature of archaeological spatial data, what do we gain from a statistical parameter or graph in terms of understanding the human behavior in the past? Archaeologists take so many other things into account then just the bare artifact distribution when interpreting an archaeological sitemap. Take for instance the site at Schipluiden (Wansleeben and Louwe Kooijmans 2006): a small permanent settlement of a Neolithic community on a low dune in the tidal area of the Dutch coast. The central, higher part of the small dune shows very low numbers of artifacts, which is in this case due to a well-known and very simple cause: erosion (fig. 3). The flanks of the dune have probably been enriched due to the

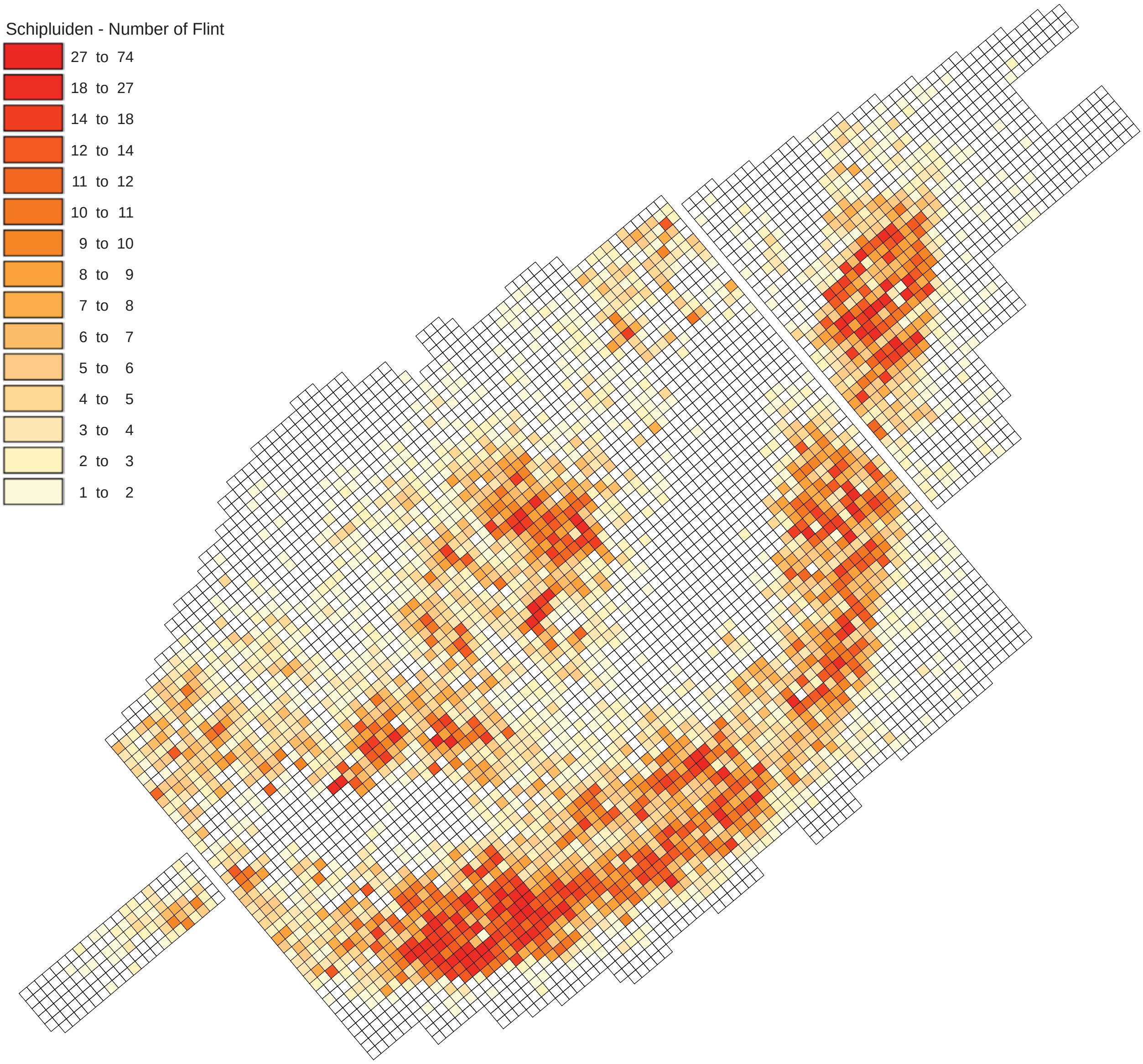

Figure 3 Spatial patterns of the density of flint artifacts as discovered at the Neolithic site of Schipluiden (1 by 1m squares). The center of this site has eroded after the habitation and caused a void in the distribution maps which does not represent human behavior but will be taken into account by spatial statistics (after: Wansleeben and Louwe Kooijmans 2006, fig. 4.10)

same process that took place after the site was abandoned. In the low lying deposits around the dune four concentrations of rubbish dumps could still just be identified, supporting the idea that four small houses were present at the site. A statistical technique would simply take the void in the center as a given fact and the resulting oval shaped ring of high densities would never be properly represented in a numerical value.

4 VISUAL INSPECTION

It seems, to us, that archaeology might be better off with a number of well-chosen spatial visualizations after all. The current GIS software makes it possible to generate many different distribution maps for the archaeological site in a very quick and easy way. As mentioned before, counting the number of artifacts within multiple sized square units is very easy. The visualization can be improved by using geographical approaches like local density and kernel density. The original distribution map of points will be transformed into a map showing the general trends based on (weighted) densities within search radii. The spatial scale, i.e. the degree of the generalization, depends again on the size of the search radius. By calculating multiple kernel density maps, with increasing search radii, the distribution of the artifacts can be effectively analyzed and interpreted, both in terms of multi scale and subareas. With these techniques it is possible to identify clusters within clusters as well as subzones with clusters next to subzones with a regular pattern (fig. 4). For grid data the available counter part of

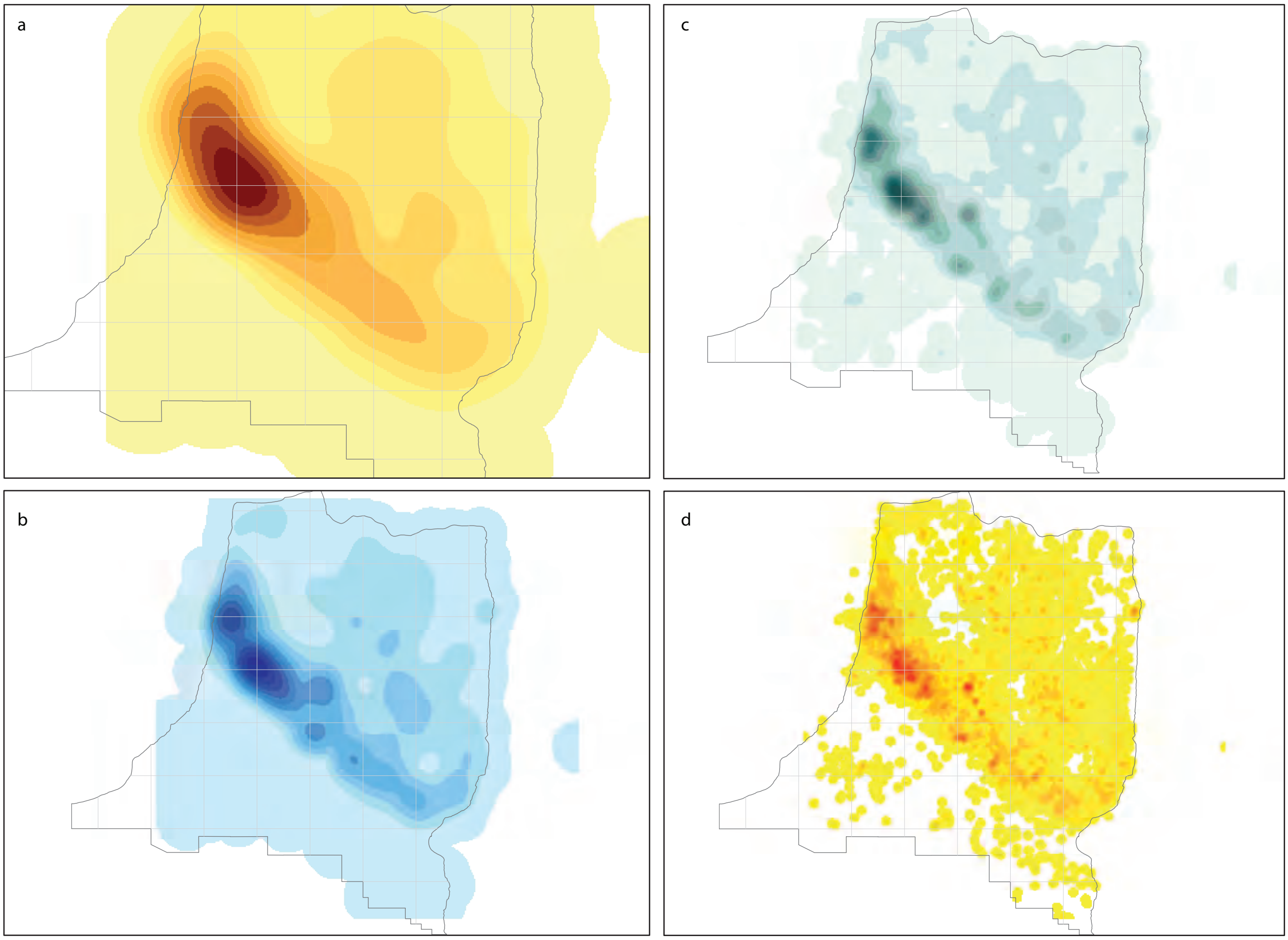

Figure 4 Kernel density-maps of the bone artifacts at Schöningen (Germany) as it was analyzed for different spatial scales and levels of generalization (based on data provided by Böhner, Böhner *et al*. 2015). This visual analysis shows that the artifacts are spread across a relatively narrow band along the former shoreline of a lake (top left). The ideal conservation conditions in the narrow band have played an important role in the perfect survival of the Palaeolithic finds. Within this band a number of large concentrations can be distinguished (bottom left), which clearly consist of smaller concentrations each (top right). At the lowest spatial scale (bottom right) individual butchering events seems to be present. The squares within the excavation represent areas of 10 by 10 meters

kernel density is called moving average. In this technique too, a larger *template* will result in a more general visualization of the find scatter. The Meteorological Office does not use the 30 years moving average for no reason in climate change analyses.

GIS software is very helpful in this approach, as it allows us to generate these trend maps on the fly. This interaction allows us to play with search radii, different ways to calculate the averages, different weights, different color ranges and class divisions, in order to optimize the visual effect. Adjusting these settings makes it possible to emphasize those key characteristics of distribution patterns we consider important for our interpretation of the archaeological site. This may seem less formal ("statistically solid"), but it allows us to incorporate our archaeological knowledge about the site (formation) and the human behavior in the past in a much more coherent manner. A number of well-chosen trend maps, in a well readable map presentation form, will do fine for archaeology.

References

Boekschoten, G.R. and D. Stapert 1996. A New Tool for Spatial Analysis: "Rings & Sectors Plus Density Analysis and Trace Lines". In: H. Kamermans and K. Fennema (eds), *Interfacing the Past.* Computer Applications and Quantitative Methods in Archaeology CAA95. Vol. I (Analecta Praehistorica Leidensia 28). Leiden: Institute of Prehistory, University of Leiden, 241-250.

Böhner, U., J. Serangeli and P.Richter 2015. The Spear Horizon: First spatial analysis of the Schöningen site 13 II-4. In: N.J. Conard, C.E. Miller, J. Serangeli and T. van Kolfschoten (eds), *Excavations at Schöningen: New Insights into Middle Pleistocene Lifeways in Northern Europe*, Journal of Human Evolution, Volume 89.

Cressie, N. A. 1996. Change of support and the modifiable areal unit problem. *Geographical Systems*, 3 (2-3), 159-180.

Conolly, J. and M. Lake 2006. *Geographical information systems in archaeology*. Cambridge: Cambridge University Press.

Kvamme, K.L. 1993. Spatial Statistics and GIS: an Integrated Approach. In: J. Andresen, T. Madsen and I. Scollar (eds), *Computing the Past*. Computer Applications and Quantitative Methods in Archaeology. CAA92. Aarhus: Aarhus University Press, 91-104.

Kvamme, K.L. 1990. The fundamental principles and practice of predictive archaeological modeling. In: A. Voorrips (ed.), *Mathematics and information science in archaeology: a flexible framework, Studies in Modern Archaeology* 3, 297-305.

Lock, G. and T. Harris 2000. Introduction: Return to Ravello. In: G. Lock (ed.), *Beyond the Map: Archaeology and Spatial Technologies*, Amsterdam: IO Press, xiii-xxv.

Lock, G. and B. Molyneaux (eds) 2006. *Confronting Scale in Archaeology: issues of theory and practice*, New York: Springer.

Verhart, L.B.M., 2000. *Times fade away. The neolithization of the southern Netherlands in an anthropological and geographical perspective*, Leiden: Faculty of Archaeology, Leiden University (ASLU 6).

Wansleeben M. and W. Laan 2012. The archaeological practice of discovering Stone Age sites, *Analecta Praehistorica Leidensia* 43/44, 253-261.

Wansleeben M. and L.P. Louwe Kooijmans 2006. The archaeological remains: a critical spatial approach. In: L.P. Louwe Kooijmans and P.F.B. Jongste (eds), *Schipluiden. A Neolithic settlement on the Dutch North Sea Coast c. 3500 CAL BC.*, Leiden: Faculty of Archaeology Leiden University, 67-89.

Milco Wansleeben
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
m.wansleeben@arch.leidenuniv.nl