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The archaeological practice of discovering Stone Age sites

Milco Wansleeben and Walter Laan

Stone Age sites only rarely show the 'ideal' intra-site spatial distribution pattern of a single round area with one clear concentration of artefacts. The actual spectrum of site variation is so great as to prohibit any realistic modelling of the chance of discovery during a survey. It is well-nigh impossible to calculate one single optimal prospection strategy for finding these archaeological sites as Verhagen et al. (2011) try to accomplish. Despite this, our experience with spatial analysis of various Stone Age sites shows that there are a number of practical steps that can be formulated. These buried sites are indeed difficult to find but with a well-chosen stepwise approach the task can be both possible and economically viable.

1 Introduction

In 2011 the report Rapportage Archaeologische Monumentenzorg (RAM) 197 on the optimal strategies for the detection of Stone Age sites using core sampling in a statistical perspective was published by the State Service for Cultural Heritage (Verhagen *et al*. 2011). This report gave a excellent overview of the spatial distribution of flint on a number of Stone Age sites. The case studies presented are evenly spread over the entire Stone Age period and the various geological landscapes of the Low Countries. Dominant however is a statistical approach, heavily based on publications from the period of the 'New Archaeology'. During one of the first lessons in data analysis we inform our archaeology students that if an author requires a lot of statistics to support his argument, it might cause a feeling of "this is complicated..... it must be correct". This should however be replaced by a critical attitude instead. Why are simple maps and diagrams alone not enough to support the archaeological conclusions?

Archaeological (spatial) data do have very specific attributes and biases. We, as archaeologists, always remain conscious and cautious of this fact. A purely statistical analysis hardly ever pays enough attention to this though. The spatial properties of a Stone Age site cannot be modelled by the ideal of one single diameter and one average finds density. The different finds concentrations within one archaeological site and the variations in form and size between sites are simply too great. Furthermore, a single arithmetic generalization is redundant now that a cartographic abstraction is possible with modern GIS software. Interactive assessment and visual interpretation of a distribution map can, for example, easily take into account the fact that part of the site is affected by erosion and that one part clearly shows clustering and another part does not.

Admittedly, finding an optimal strategy for discovering buried Stone Age sites is no simple matter at all. There are a great number of factors influencing the chance of coming across finds in core samples or small test trenches. On the one hand there are the properties of the archaeology itself: the character of a site as a consequence of human behaviour in the past. 'Measurable' with parameters like the size and shape of the site, the average density and finds clustering. On the other hand we have the characteristics of the sampling strategy such as the distance between sampling points, size of the samples, method of gathering and treatment, form of the area of investigation and distribution of the sampling points. The approach chosen by Verhagen *et al*. (2011) based on a number of actual finds distributions at excavated Stone Age sites is excellent. The effectiveness of different sampling strategies is simulated as if these sites had not yet been excavated. A statistical calculation is made with the aim of a minimum detection chance of 75%, i.e. that the chosen sampling strategy should yield one flint item in one of the corings for at least 3 out 4 sites.

In this article however a more practical sampling approach is proposed based on the known spatial distributions from a number of sites in the RAM 197 report, supplemented by recently excavated sites by the Faculty of Archaeology (Leiden University) and Archol BV. Actually, in practice, many different sampling strategies have already been tried out at these sites. All confirming the theory that the bandwidth of variation of finds patterns is simply too great for one single optimal discovery method. From one location to the next a stepwise approach is necessary. At first a 'coarse' sampling of the area of investigation will give sufficient insight to optimize the next sampling phase(s) in terms of time, cost and increase in archaeological knowledge.

2 Stone Age sites characteristics

In report RAM 197 Verhagen *et al*. make use of two important parameters: the size and average density of finds of the Stone Age sites. Simultaneously the distribution maps presented make it clear that there is a large variation between the sites. Though site size and finds density determine, in their calculations, the chances of discovery, it will be shown that these statistical parameters cannot be determined unambiguously so as to yield realistic statistical modelling.

The character of Stone Age sites is simply too variable for that. On the one hand there are sites such as the river dunes (*donken*), for instance near Hardinxveld-Polderweg (Louwe Kooijmans 2001) and Hardinxveld-De Bruin (fig. 7 in Verhagen *et al*. 2011). Here a waste layer is imbedded in the surrounding clay and bog. A cultural layer that usually has a contiguous character with a relatively high finds density. Only a small portion of these river dunes were excavated (just as at Brandwijk; Van Gijn and Verbruggen 1992). However an extended ring of test trenches and pits have been laid down around the Hazendonk (fig. 1, after Amkreuz in prep.). The entire area of the site of Schipluiden (fig. 2; Louwe Kooijmans and Jongste 2006) was excavated and revealed an almost continuous presence of finds on both the dune and the low lying surrounding marshes. The original find patterns are, through processes of anthropogenic (e.g. trampling) and/or natural (e.g. animals, roots, wind, wave-action) origin, altered to an almost contiguous layer. Sites like A27-Hoge Vaart (Hogestijn and Peeters 2001) and the more recently excavated Dronten-N23 (Archol in prep.) can also be characterized by such rich find layers above the first features level. The amount of homogenization is hard to estimate but it is assumed that the vertical and/or horizontal displacement is limited and that the distribution of finds is still reasonably representative of human behaviour. There is often a clear relationship between the finds density and either the thickness of the cultural layer (e.g. Schipluiden) or the elevation of the river dune (e.g. Dronten-N23).

On the other hand there are sites such as Geldrop-Aalsterhut (fig. 5, Verhagen *et al* 2011) or Sweikhuizen-Groene Paal (fig. 19, Verhagen *et al* 2011) that largely conform to the ‘classic’ idea. In the undisturbed subsoil one isolated, round concentration of flint artefacts with one clear and unambiguous centre was found. This, however, seems to be an exception. Most sites display a succession of concentrations within the excavated area. Examples are Eyserheide (fig. 3 in Verhagen *et al*. 2011), Hempens-N31 (fig. 9 in Verhagen *et al*. 2011), Oudenaarde-Donk (fig. 15 in Verhagen *et al*. 2011), Verrebroek-Aven Ackers 2007 (fig. 23 in Verhagen *et al*. 2011) and A27-Hoge Vaart (fig. 11 in Verhagen *et al*. 2011).

At all these sites there are also sub-concentrations of varying sizes and richness. We can take the excavation at Hempens-N31 (Noens 2011) as an example here (fig. 3). First of all the extent of the excavation is larger than what is shown by Verhagen *et al*. (2011). Test trenches, shovel pits and core samples were part of the excavation strategy as well and these make it clear that there is much more information and spatial variation within this larger area. Alas, Verhagen’s simplification of the distribution maps of other sites too, does not always do justice to the actual spatial distributions. In general the investigators of Hempens-N31 distinguished three concentrations within the main research area of roughly 60 by 35 m. Concentration 1 (north) is smaller, round and less rich than the more elongated concentrations 2 (middle) and 3 (south). The southern concentration is the largest and is in fact composed of two overlapping sub-concentrations (3a and 3b) (see fig. 81, Noens 2011, 137).

It is also clear that a fair amount of flint was found outside this main area in both isolated squares and in small concentrations. This picture also emerges from the original publication of a site like A27-Hoge Vaart (Hogestijn and Peeters 2001). A much larger area was sampled or excavated than the main location of 50 by 20 m (fig. 4). For a substantial part of the, roughly 100 by 120 m, excavation area soil samples were taken with a 20 cm core in a 2 by 2 m grid. On the basis of these results it was decided to not only excavate the whole main area but also many sample squares of 2×2 m (with some extensions) in the periphery. And indeed, in this periphery, small, rich concentrations turned up. The main concentration itself, in general, consists of three concentrations of varying richness and each, again, made up of yet smaller sub-concentrations. Dronten-N23 also shows that the spatial distribution is a palimpsest of individual activities upon each other leading to a distribution pattern with clusters within clusters within clusters (fig. 5). The size and shape of the concentrations are related to the scale of observation (multi-scale spatial model). Sub-concentrations are each composed of one or more sub-concentrations of varying size and richness.

Numbers of finds trail off near the edges of a Stone Age site but almost never completely disappear. A27-Hoge Vaart illustrates perfectly that local concentrations of finds can exist outside the main one, even with an almost comparable high finds density. Off-site patterns (Foley 1981) have been a topic in Stone Age research for some time. Occasionally much time is consciously spent on trying to recover individual artefact in the periphery (Maastricht-Belvédère site N, De Loecker 2004). The idea is an archaeological landscape where sites have no definite end or border: the entire landscape was used in the past after all. Sometimes for activities which have left an enduring material deposit of either high or low density. Sometimes for activities that have left no traces at all.

It is difficult to discern discrete archaeological sites in the discontinuous distribution of flint over the landscape. How big actually is the site of Eyserheide (fig. 3 in Verhagen *et al*. 2011) (see fig. 6, according to fig. 6.3 in Rensink 2010)? Where does it end? Along the edges are grid squares both

Figure 1 Standardized global distribution map of Hazendonk (manual find recovery spade/trowel) (after Amkreutz in prep.).

Figure 2 Standardized global distribution map of Schipluiden (wet sieving 4 mm) (after Louwe Kooijmans and Jongste 2006).

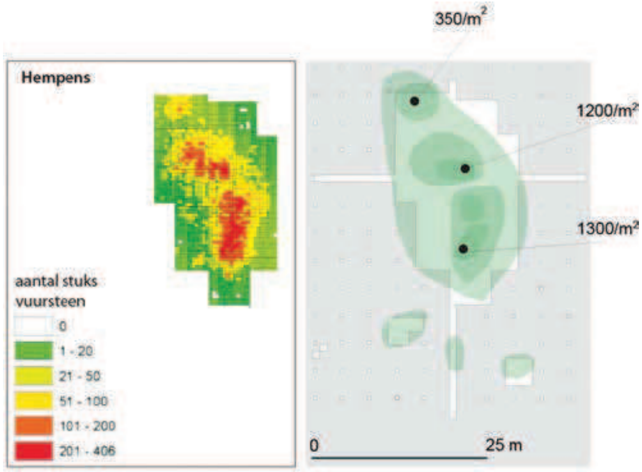

Figure 3 Standardized global distribution map of Hempens-N21 (wet sieving 3 mm) (after Noens 2011 and Verhagen *et al*. 2011).

with and without finds. The archaeological site itself is neither the excavated part nor the grid squares that had one or more finds. The border has a much more diffuse open character, certainly if the results of the test pits of 1×1 m are also taken into account. For our interpretations we usually demarcate a site with a sort of oval on the map, incorporating the general features and leaving the coincidental details to one side. Thus looking at the distribution map with a somewhat 'out of focus view', so to speak. In this manner we can also distinguish smaller clusters within the site. A GIS technique that is very useful for visualization of the 'bigger picture' is the so-called 'moving average technique' (examples are available for Schipluiden and Dronten-N23, respectively Louwe Kooijmans and Jongste 2006; Archol in prep.).

Stone Age sites thus appear not to be clear circles with one neat diameter but rather unpredictable *blobs* with one or several internal peaks of high density (e.g. Verrebroek-Aven Ackers, fig. 7, after Sergant *et al*. 2007). A seemingly simple statistic parameter like the average number of finds turns out

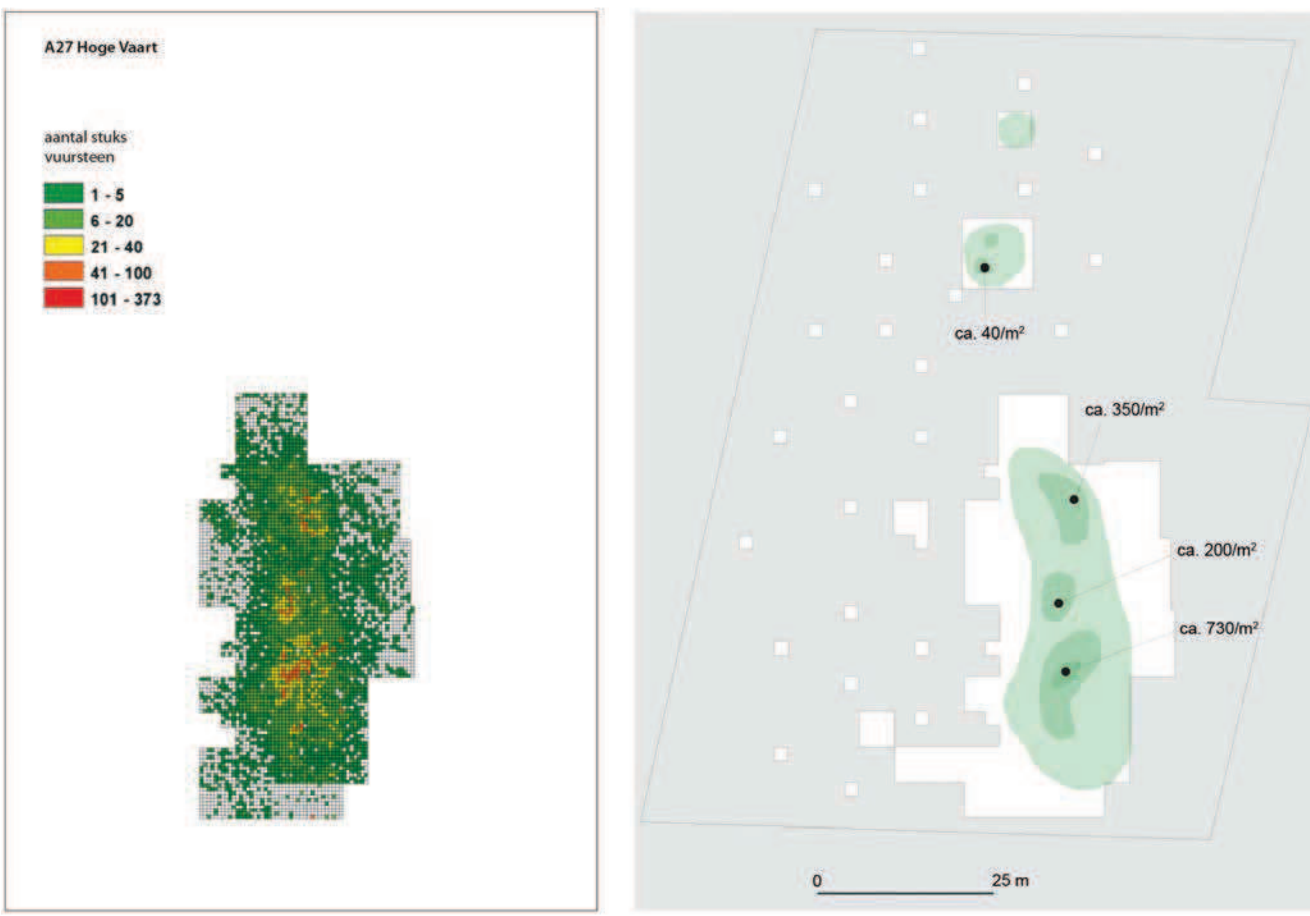

Figure 4 Standardized global distribution map of A27-Hoge Vaart (wet sieving 2 mm, the distribution maps only contain the flint artefacts > 1 cm^2) (after Hogestijn and Peeters 2001 and Verhagen *et al*. 2011).

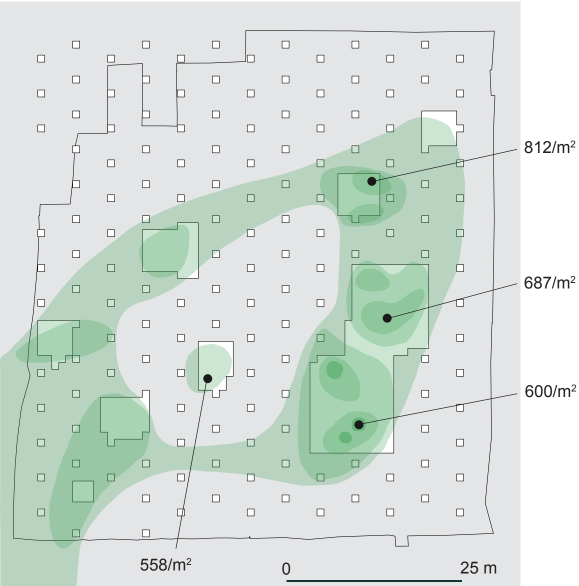

Figure 5 Standardized global distribution map of Dronten-N23 (wet sieving 2 mm) (after Archol in prep.).

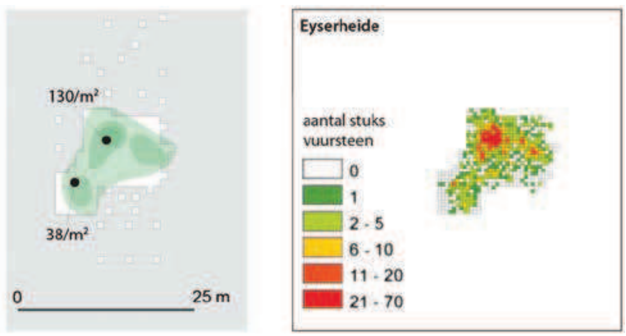

Figure 6 Standardized global distribution map of Eyserheide (trowelling) (after Rensink 2010 and Verhagen *et al*. 2011).

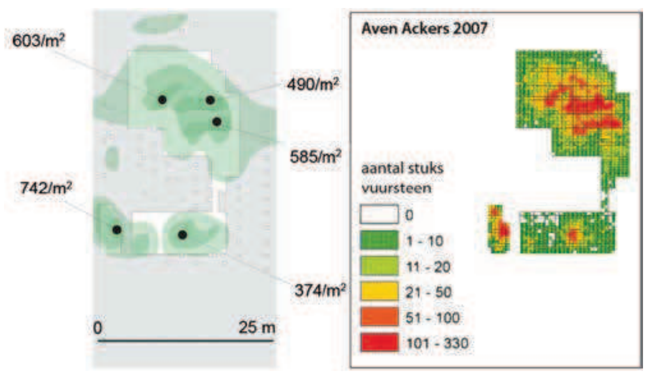

Figure 7 Standardized global distribution map of Verrebroek-Aven Ackers 2007 (wet sieving 2 mm) (after Sergant *et al.* 2007 and Verhagen *et al.* 2011).

not to be so. Indeed the arbitrarily chosen demarcation determines both the size (m^2) and the number of finds within the site. So, other limits will result in different average densities. This makes the statistical calculation of the chances of discovery very troublesome.

To sum up, it can be concluded that the excavated sites, with a few exceptions, have an unpredictable nature with a diffuse open 'limit'. The finds densities have a multi-scale character with multiple, partially overlapping concentrations of differing size, shape and density. Sites were often used for an extremely long period with activities of varying duration, extent and function, in a (partial) spatial overlap (palimpsests). Lastly, landscape and off-site archaeology made us aware that we can expect loose finds and small concentrations in a very wide area around the main concentration(s). These observations have important consequences for the discovery of buried Stone Age sites. The starting point of circular sites with neatly defined diameters and an average finds density is not realistic. The distribution of flint on a Stone Age site does simply not allow such a simplistic description (see the maps of Stone Age sites in this article).

3 Sampling approach

The factors determining the success of a sampling strategy have been well highlighted by Verhagen *et al*. (2011). Whilst the 'statistical' parameters of Stone Age sites do have a positive or negative effect on the probabilities of detection, they are completely beyond our control. As argued above, we cannot assume that Stone Age sites have neat average properties (shape, size, density, clustering etc.). In the following we will attempt to come to grips with the three factors affecting survey sampling over which we can have influence:

- sample size,
- sample treatment and
- sample density.

We should bear in mind that the overarching factor still is the available budget. Of course, one of the best pictures of flint densities is obtained if the entire research area is divided up into a fine grid of 'shovel pits' (25×25 cm squares) and the soil samples are wet sieved over a fine mesh (2 mm).
A much coarser grid of Edelman cores (10 cm diameter) and dry sieving over a more open mesh (5 mm) is considerably cheaper and faster but also gives a less reliable representation of the actual sites.

3.1 Sample size

Here it is assumed that samples are taken from the entire (sediment) layer holding flint artefacts. Therefore the sample size merely has to do with the area sampled. A coring with a diameter of 15 cm samples only 176 cm^2, whereas a 1×1 m test pit has an area of 10,000 cm^2. Since the goal is to estimate the finds density in a square metre such a test pit is no longer a 'sample', since the number of finds is the actual density for that square metre (100% sample). In comparison, the coring is only a less than 2% sample giving a very rough estimate of the actual number of finds. It is very well possible that nothing will be found in the coring when sampling the very centre of a site. Conversely, relatively many finds may mislead as to the richness of the sample square. Research in Dronten-N23 has demonstrated that interpolations from samples can lead to strong over- and underestimates of the actual numbers of finds later excavated (Archol in prep.).

The larger the sample taken, the higher the reliability
Especially with low finds density, a relatively small sample will often result in no finds in the core sample although there are artefacts present in that square metre. Naturally we want to avoid such an underestimation as much as possible, since the site is not discovered! Simply put, a mega-core with a diameter of 20 cm gives a much better result than an Edelman bore of 10 cm diameter. If affordable, a shovel pit of 25×25 cm is better still and ultimately exceeded by a full 1×1 m test pit.

3.2 Sample treatment
The size of flint artefacts on a Stone Age site usually displays a strong skewed distribution. In the sense that very many, really small pieces of flint are found in the sediment (micro-debitage) but that number dips dramatically as the size of artefacts increases. We usually find only a few large artefacts. This means that the method of find recovery has a big influence on the eventual numbers of finds in a square metre. Mechanized recovery yields fewer finds than recovery by hand with a spade, trowelling less than (wet) sieving, and sieving over a 4 mm mesh less than over a 2 mm mesh. In principle, an increasingly finer sample treatment yields (exponentially) more and more finds.

The finer the recovery method used, the higher the reliability
This assumption has a downside however. In practice, searching for micro-debitage, certainly in deposits that naturally contain flint, is very troublesome. The fraction is so small that it becomes increasingly difficult to distinguish pseudo-artefacts from real ones. There are instances where it afterwards became clear that the counts of artefacts in this tiny fraction actually produced a distribution map of the naturally occurrence of river gravel (St. Odilënberg-Neliske, Verhart 2000). A mesh of 1 mm could well produce more 'noise' than an actual anthropogenic signal. A practical lower limit seems to be 2 mm. By the way, with a decrease in mesh size only a small increase in the amount of extra work and costs occurs.

3.3 Sample density
It is obvious that the more samples are taken, the better the insight into the buried flint distribution. With a high core-density the distance between samples is smaller. The discussion about whether a regular or staggered grid performs better (Tol *et al*. 2004) has become less relevant now. With the erratically shaped Stone Age sites the advantage of a staggered grid, theoretically already trivial (Kintigh 1988), is virtually nil. The maximum diameter of a round site that could exactly fit between the core samples is in practice not relevant at all.

What does seem important is that, in general, archaeological spatial data displays a high degree of spatial autocorrelation. That is to say that sample points that are next to each other show reasonably similar results. If we have many finds in a particular square metre then the square metre next to it will very often also have a high density. This autocorrelation can be helpful in discovering sites. We can be fairly sure that when we come across two adjacent samples containing flint that we are homing in on a site.

The question whether an optimal sampling distance between samples exists, considering the irregular character of Stone Age sites, must firmly be answered with a No. These sites (with or without a culture layer) and the off-site concentrations, are indeed so varying in size and shape that any attempt fails to calculate beforehand how distant sample points should be in order not to miss a site. In practice the reverse should be considered: given the sampling spacing, we can reason what minimum size the detected sites have.

The smaller the sample spacing applied, the smaller the detected sites
Here also experience does not fully conform to theory. Flint fragments are found everywhere, but a single artefact in a single coring does not mean we are talking about an archaeological site yet. The existence of an off-site distribution pattern plays, of course, a conscious role in this interpretation. A single, loose find is not usually regarded as significant. Only if relatively high numbers of finds in (adjacent) samples occur is there sufficient motivation to investigate a location more closely. Based on this, our rule of thumb is that a sampling distance of 5×5 m renders a fairly trustworthy insight into sites or concentrations of roughly 10 m size.

4 Discussions
In the detection of buried Stone Age sites the characteristics of the sites themselves play a role. The following plain and simple rules seem to hold:

- the bigger the site the easier it is to find
- the richer the site the easier it is to find
- the less clustered the finds on the site the easier it is to find

At the start of a survey we have no influence on these factors however, as the sites are yet to be discovered. We only know for certain that there will be an extremely wide variation in size, shape and degree of clustering.
Where we do have influence can be seen in the following rules:

- the more samples the greater the chance of detection
- the larger the samples the greater the chance of detection
- the finer the recovery method the greater the chance of discovery

It is, however, unrealistic to expect an unlimited budget needed to apply these rules. At the beginning of a survey we therefore face a choice like: do we set out 10 test pits of 1×1 m or do we carry out 100 coring samples of 10 cm diameter? With the widely spaced test pits there is a big chance of missing sites though; on the other hand, if we actually land on a site then the size of the sample gives great assurance of actual discovery. That is not the case if we work with the small cores. Right in the middle of a site we could still come up with nothing! With smaller samples chance plays a greater role, sample results sometimes will suggest something totally different to the actual situation.

Not only the way of sampling (spacing, type) is important, but also the treatment of the soil sample. The de-facto standard for surveying Stone Age sites is sieving. Depending on the availability of water, wet sieving over a 2 mm mesh seems the most practical and informative approach.

In daily practice the budget determines it all: we try to optimize the archaeological information according to what is available (time, money, personnel). A step-wise approach has already been the common practice in Dutch archaeology. Indeed we don't just open an excavation trench anywhere these days. In the Quality Standards for Dutch Archaeology (KNA) an agreed series of steps is laid out: desk assessment, field prospection, test trenches and the final excavation. This step-wise approach also holds true for the discovery of Stone Age sites.

From our experience over the last years, we therefore propose the following practical approach. First carry out a coring investigation using a relatively coarse grid, gathering the biggest possible samples (e.g. 20 cm mega-core) and sieving over a fine mesh (e.g. 2 mm). The choice of sampling technique is determined by pre-existing knowledge of the research area, for example on the basis of desk assessment or similar research nearby. If we are expecting large, rich Stone Age sites with a cultural layer such as a number at Hoge Vaart sites, then the first phase of the survey can be somewhat coarser. Evaluate the results of that first phase on its merits. Interpret the results in a relative but specific way, just for the present research area. The fact that during another project somewhere else regularly five flint fragments in a coring were discovered is no measure to expect the same at this location. Perhaps the soil conditions or those of preservation were simple better there. Judge the results not only in a quantitative but also a qualitative way. A coring with one arrowhead has a different interpretative value than a coring with a tiny unsure flint flake. And consider not only flint but also other material categories such as charcoal, stone, bone or pottery (for Neolithic sites) for the demarcation of the sites.

The interpretation of the first phase of sampling (see example, fig. 8) guides and triggers the second phase. This next step leads to a denser sample grid and/or enlargement of the samples. In between the existing samples, new (mega) corings are taken or shovel pits/ small test pits are laid down. Where relatively many finds were discovered we go, for

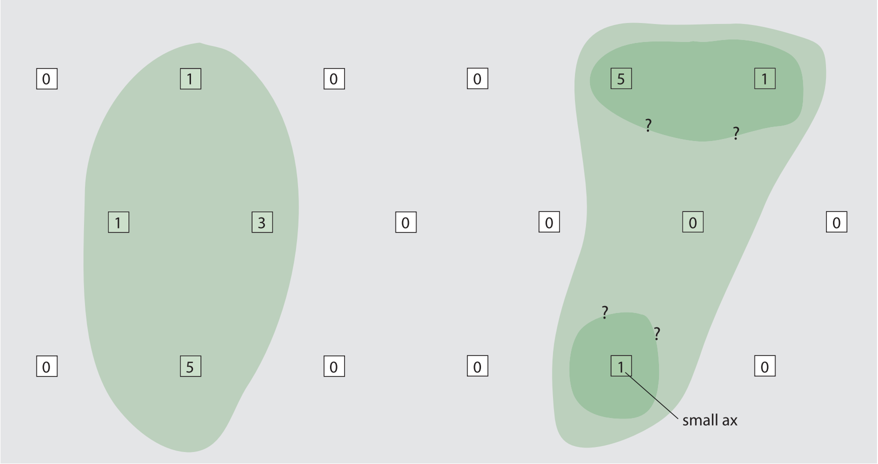

Figure 8 Results of a fictitious first phase coring sampling of a small research area, showing that the demarcation of the archaeological sites, as possibly discovered, is not unambiguous.

example, from a 10×10 m core grid to a 5x5 m grid of shovel pits. The more expensive techniques are thereby applied to a limited extent but in a highly targeted manner.

This proposed step-wise process can happen in multiple steps, an evaluation and interpretation always followed by an even more intensive sampling. So, in the end only the best locations are determined for the time and energy intensive complete excavation.

What we have learned over the years, by trial and certainly error, is that over the entire trajectory of sampling phases, the treatment of the samples should remain constant. Coring samples sieved over a 2 mm mesh and test pits sieved over 4 mm mesh create an extremely difficult to interpret distribution map of flint on a Stone Age site (e.g. Hanzelijn-Oude Land, Wansleeben *et al*. 2011). With one uniform method of sample treatment, we will make it much easier for ourselves (e.g. Dronten-N23, Archol in prep.) to reconstruct past behaviour on the basis of spatial distribution. With that, it does not really make any difference whether we have opted for manual recovery with a spade, for trowelling or for sieving over a specific mesh size. The spatial distribution within a single site is always evaluated relatively: where are the areas with more and fewer finds of a particular category?

In order to make excavated Stone Age sites better comparable with each other it is recommended to oblige researchers, in any case, to give a standardized number of finds from one of the richest areas. The actual artefact counts must be referrable to, for instance, the number of finds per square metre over a 3 mm sieve mesh. Therefore we propose that during an excavation, a limited number of sample units should also be sieved over 3 mm, so that for this site a conversion factor can be determined. 'If we hadn't used manual find recovery, but had sieved over a 3 mm mesh then we estimate that 2.7 times as many finds would have been found'. With this conversion factor the richest areas could have been calibrated to comparable maximum densities. Unfortunately, this was not possible when preparing the maps in figures 1 to 7. This might be a point of attention for the next revision of the KNA.

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