Establishing Optimal Core Sampling Strategies: Theory, Simulation and Practical Implications

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Abstract

Archaeological core sampling is an important surveying tool in the Netherlands. It is used widely to determine the archaeological content and value of the soil record. With the implementation of the Valletta Treaty the demand for this type of survey will even become higher, as it is a relatively cheap tool for site detection. Unfortunately, there is little documentation on the effectiveness of existing core sampling strategies for detecting and identifying specific site types. The paper will focus on the possibility of establishing optimal core sampling strategies for different site types, in particular through the use of simulations to predict the expected cost and benefit of each individual strategy. The simulations will be compared with the actual results of excavations of different site types in order to define the success rate of core sampling when it comes to determining content, size and value of an archaeological find spot.

Introduction

Archaeological core sampling is an important surveying tool in the Netherlands. It is used widely to determine the archaeological content and value of the soil record. Unfortunately, there is little documentation on the effectiveness of existing core sampling strategies for detecting and identifying specific site types.

The Senter agency of the Dutch Ministry of Economic Affairs is co-ordinating a programme of subsidized research projects aiming at promoting the use and development of technological innovations in public archaeology. Within this programme, the development of new, non-destructive ways of prospection is an important issue. In late 2001, RAAP Archeologisch Adviesbureau BV was asked to carry out a study within this programme on the effectivity of core sampling as a prospection technique. The project, that is currently near completion, has tried to gather information on this aspect and provide an assessment of the strengths and weaknesses of core sampling as a prospection technique. This paper focuses on the possibility of establishing optimal core sampling strategies for different site types, in particular through the use of simulation to predict the expected costs and benefits of each individual strategy, using the example of the excavation of Zutphen-Ooijershoek (province of Gelderland, The Netherlands).

Core Sampling: The Basics

Core sampling is not often used outside the Netherlands for archaeological prospection, although it is widely known as a geological survey technique. In areas where a strong accumulation of fluvial or marine sediments is found, core sampling is the only technique available that will provide a quick and cheap assessment of the local stratigraphy. Core sampling is still largely performed by means of manual labour, even though mechanical alternatives are currently being developed. Two basic types of equipment can be used. The auger has a diameter of 7 cm (sometimes 15 cm). It is screwed into the ground and takes small cores per sample (about 15 cm long). It is best suited for dry and sandy soils, and is not frequently used at depths below 2 meters. The gouge has a standard diameter of 3 or 5 cm and is driven with force into humid clayey soils or peat. The core obtained is 1 meter long. This type of core sampling can reach depths of 7 meters or even more, by extending the gouge with metal rods.

Given the fact that the Netherlands are covered by large areas of Holocene fluvial and marine sediments, it is not surprising that core sampling is also considered an appropriate tool for archaeological prospection. In many areas, there is no other way to obtain sufficient information on the (possible) presence of archaeological remains. In fact, its use has resulted in the discovery of some very important archaeological sites, like those found in the alignment of the Betuweroute railway, that runs straight through the river basin of Rhine and Meuse (Asmussen and Exaltus 1993, Asmussen 1994).

Statistical Background

The probability of discovering an archaeological site by means of any method of 'small unit sampling' (other possible methods are test pit sampling and machine trenching) is given by the following equation:

$$P = I \times D$$

where
P = discovery probability;
I = intersection probability; and
D = detection probability.

The intersection probability describes the relationship between the size of the object to be found and the distance between the sampling points. It can be determined using the following equation (Drew 1979):

$$I = A / (i \times s)$$

where
A = the area of the object;
i = the distance between the sampling points in a row; and
s = the distance between the rows.

This equation does not take into account the form and position of the objects. Krakker et al. (1983) have demonstrated that the optimal layout for a sampling grid is an equilateral triangular grid. In this case, the distance between rows s equals ½ i 3. For a standard core sampling survey, with sampling points every 50 meters, this equates to a distance between rows of 43.3 meters. The maximum diameter of a circular object that can be missed by such a grid layout is equal to s + (i2 / 4s), or 57.73 meters in the case of a standard grid (Kintigh 1988).

For elongated (elliptical) objects, the mean intersection probability is the same as for circular objects, but the probability distribution is different, and they may therefore slip through the net more easily (Gilbert 1987). However, when looking for elliptical objects, it is not necessarily useful to change the layout of the grid. Drew (1979) stated on theoretical grounds that using a rhomboid instead of an equilateral triangular grid is only effective when the orientation of the objects is more or less known. However, simulations carried out by ourselves show that there is a small positive effect of finding extremely elongated objects by using a rhomboid grid, even when the orientations are not known.

The detection probability for archaeological artefacts is given by the following equation (Stone 1981, Krakker et al. 1983):

$$D = 1 - e^{-A \times d \times W}$$

where
e = the base of natural logarithms (2.711828);
A = the area of the sampling unit;
d = the density of artefacts per area unit; and
W = the observation probability.

This equation describes a Poisson-distribution, that is appropriate for rare objects that are not very likely to be encountered in a sample. Artefact density determines whether a site may be detected or not, but the observation technique chosen determines whether an artefact will actually be observed. Very little data is available on the effects of sieving versus visual inspection, or of choosing a different sieving mesh. Groenewoudt (1994) showed that about 75 % of the flints found at the site of the Ittersumerbroek excavation were smaller than 4 mm, so choosing a smaller sieving mesh may drastically increase the amount of observed artefacts.

Very little data is available on the actual artefact densities encountered on archaeological sites in the Netherlands. Mean artefact density estimates are given by some authors. Groenewoudt (1994) for example estimated the mean artefact densities for Iron Age en Roman settlements at more than 120 per m2, an estimate obtained by extrapolating data from core samples. It should be noted that the actual detection probability of such a density is not very high when using a standard 7 cm auger (about 37%). For a selection of 79 Stone Age sites from NW Europe (kindly put at our disposal by dr. Willem-Jan Hogestijn) the mean artefact density is 140.4 per m2, but 70.9% of these sites have densities below 50 per m2. In the recent excavation of the Mesolithic site of the Hoge Vaart by Hogestijn and Peeters (2001), mean flint densities of only 18 and 16 per m2 were registered when sieving with a 2 mm mesh. Groenewoudt (2002) also mentions an example of a site with a mean density of only 6.4 artefacts per m2 (sieved with a 4 mm mesh); the site actually contained two house plans.

The observation method used is obviously very important in this respect. Core sampling is based on very small sampling units, the samples are usually thoroughly described, and the soil is sieved with a 1 mm mesh to obtain as many artefacts and other archaeological indicators as possible. Archaeological features are not usually recognized in core samples. During excavations, or even in machine trenching surveys, the features are of primary concern, and artefacts are usually only collected and described if they have diagnostic value. Given the already enormous amounts of artefacts collected in this way (e.g. almost 40,000 in the Malburg excavation; Oudhof et al. 2000), it is very understandable that a full count of all artefacts present per feature or quadrat is not performed. However, this implies that it is impossible to obtain reliable data on the spatial distribution of artefact densities.

Only a few examples could be found of sites that had been consistently sieved for artefacts in quadrats, and all of these concerned small excavated areas with relatively low artefact densities. Simulations performed on these data showed that these sites will be very difficult to discover by means of standard core sampling survey.

Establishing an Optimal Core Sampling Strategy: The Case of Zutphen-Ooijershoek

The Mesolithic site of Zutphen-Ooijershoek[1], for example, was sieved with a 3 mm mesh in 50 by 50 cm quadrats. The resulting flint counts ranged from 0 to 179, resulting in a mean artefact density of 66 per m2, on a total excavated area of 246.75 m2. A strong clustering of the flints was evident; in about two-thirds of the excavated area, the artefact density was below average. For purposes of comparison, the centre of the site was analysed separately from the periphery (see Table 1). The probability of finding the site using standard core sampling strategies was approached by simulating 1,000 hypothetical surveys of the site, using different parameters for grid size and sample diameter. In this way, the costs and benefits of each strategy can be compared. The probabilities given in table 1 should however not be seen as real probabilities of finding the site, as the effect of the observation method chosen has not been incorporated in the simulation runs.

It turns out that for this particular site, increasing the sample volume is a more cost-effective strategy than increasing the density of the sampling grid. However, it should be taken into account that taking a larger sample volume is a course of action that can only be applied once, as augers with a larger diameter than 15 cm are not available.

Conclusions

The results of the simulations, as well as theoretical considerations, point to the conclusion that core sampling is not a

ZUTPHEN-OOIJERSHOEK	centre	periphery	total	cost factor
mean artefact density per m^2	165.84	21.04	66.08	
area in m^2	76.75	170.00	246.75	
discovery probability 7 cm auger				
40 x 50 m	1.6%	0.1%	3.1%	1
20 x 25 m	6.2%	2.8%	7.7%	4
10 x 12.5 m	22.4%	9.2%	33.6%	16
6 x 6.25 m	64.8%	28.5%	73.4%	64
discovery probability 15 cm auger				
40 x 50 m	3.6%	2.3%	5.3%	2
20 x 25 m	11.1%	9.4%	19.1%	8
10 x 12.5 m	43.5%	34.7%	63.8%	32

Table 1 Comparison of the costs of different core sampling strategies for Zutphen-Ooijershoek, based on simulation results. The centre of the site is the area where artefact density is above average. An increase in grid density means a four-fold increase in number of samples, an increase in auger diameter implies a two-fold increase in time needed to take, sieve and describe a sample

very effective technique to discover small archaeological sites when they have a low density of artefacts. Even without the availability of much representative data on artefact densities from excavations, it can be suspected that especially Stone Age (and other briefly occupied) sites run this risk.

However, artefacts are not the only category of indicators looked for and registered in a core sampling survey. In fact, three classes of indicators are registered. The first of these are non-archaeological, like soil type and lithology which can serve as predictors of possible site locations. Secondly, there are (semi-)archaeological indicators with a higher detection probability than artefacts, like charcoal or occupation layers. Even if these indicators are not hard evidence of an archaeological site in the sense that artefacts are, they are almost certainly evidence of human occupation very near to the sampled location. Only in third instance 'real' archaeological indicators come into play, as the final corroboration that we are dealing with an archaeological site. It is only when geomorphological, pedological and archaeological 'predictors' are either absent or too small in size for detection in a standard core sampling survey that low density artefact scatters are likely to escape detection, as there will be no apparent reason to 'zoom in' on a specific location.

The absence of reliable data on the density and spatial distribution of indicators for different types of archaeological sites in the Netherlands makes it difficult to design site-specific prospection strategies. These data can only be obtained by registering the same data in excavations as during core sampling, and will need to be collected in a systematic way during future excavations and trenching campaigns. However, at the moment this is not happening in Dutch public archaeology, also because core sampling and excavation are often carried out by different commercial parties, that may not perceive the mutual benefit that can be obtained from investing time and money in this type of work. It is therefore hoped that the current project will provide the necessary impetus to actually start the comparative research needed for further improvement of archaeological prospection strategies in the Netherlands.

[1] The data of the Zutphen-Ooijershoek excavation was kindly put at our disposal by drs. Jos Deeben, Rijksdienst voor het Oudheidkundig Bodemonderzoek, Amersfoort.

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