Archaeological Prospection
Archaeol. Prospect. **24**, 101–117 (2017)
Published online 27 November 2016 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/arp.1552

Reassessing Surface Artefact Scatters. The Integration of Artefact-Accurate Fieldwalking with Geophysical Data at Medieval Harbour Sites Near Bruges (Belgium)

JAN TRACHET[1]*, SAMUËL DELEFORTRIE[2], MARC VAN MEIRVENNE[2], BIEKE HILLEWAERT[3] AND WIM DE CLERCQ[1]

[1] *Historical Archaeology Research Group, Department of Archaeology, Ghent University, Sint-Pietersnieuwstraat 35, B-9000 Ghent, Belgium*
[2] *Research Group Soil Spatial Inventory Techniques, Department of Soil Management, Ghent University, Coupure links 653, B-9000 Ghent, Belgium*
[3] *Raakvlak, Intercommunal Service for Archaeology in Bruges, Komvest 45, B-9000 Bruges, Belgium*

ABSTRACT Archaeological fieldwalking is particularly used to detect sites within a landscape, rather than to assess the internal structure of a site itself. Contributory to this trend is that surface artefact patterns collected by pedestrian field survey are rarely seen as valuable archaeological data for intra-site research. In recent decades, they have been overtaken by other non-invasive prospection methods, which seem to be more efficient and time-effective. This paper aims to reassess fieldwalking as a valuable intra-site prospection method and explores its added value when used in a multidisciplinary framework. The medieval lost harbour site of Monnikerede near Bruges (Belgium) is used as a first test-case. The site was subjected to a grid survey in 1985 and recently acted as the location for an intensive artefact-accurate fieldwalking survey as well as an extensive geophysical survey. Comparing the recent global navigation satellite system (GNSS)-underpinned fieldwalking survey results with a 10 m × 10 m grid survey from 1985, demonstrates the gain in knowledge and detail using the former method. The combination of both fieldwalking and geophysics showed both significant positive and negative relations between surface artefact scatters and subsurface anomalies, hence pointing to the complementary nature and added value of the methods being jointly applied. In addition, the combination of both techniques was tested on a second lost harbour site near Hoeke, to further evaluate the potential of the applied methodology. The results demonstrate that, although the sites have been heavily ploughed for decades, the lateral displacement of artefacts is limited and confined to the original medieval allotment. Finally the integration of surface artefacts with geophysical anomalies enabled to enhance the spatio-temporal interpretation of both sites. Copyright © 2016 John Wiley & Sons, Ltd.

Key words: Fieldwalking; intra-site; artefact scatter; ploughsoil; electromagnetic induction (EMI); survey

Introduction

Traditionally, the ploughsoil of an archaeological site is seen as an intermingled and archaeological valueless agricultural layer (Binford *et al*., 1970; Navazo and Díez, 2008; Yorston *et al*., 1990). Hence, today's archaeological practice mechanically removes the ploughsoil in order to rapidly reach the intact 'archaeological stratum' (Orton, 2000). However, studies on the relation between surface artefact scatters, ploughsoil finds and subsoil archaeological features, have shown the value of integrating all three strata (Bowden *et al*., 1991; Evans *et al*., 2014; Hawkins, 1998; Pogue, 1988; Redman and Watson, 1970). Visual inspection through pedestrian survey is considered the standard technique to register such surface artefacts (Banning, 2002) and has been discussed in the seminal works of Lewarch and O'Brien (1981); Haselgrove *et al*. (1985); Schofield (1991); Sullivan (1998) and Francovich and

* Correspondence to: Jan Trachet, Historical Archaeology Research Group, Department of Archaeology, Ghent University, Sint-Pietersnieuwstraat 35, B-9000 Ghent, Belgium. E-mail: Jan.Trachet@ugent.be

Received 19 May 2016
Revised 18 August 2016
Accepted 21 August 2016

Patterson (2000). Several observations emerge from this state of the art. First, the bulk of studies on archaeological fieldwalking seem to be confined in terms of scale and period. The scale is predominated by extensive regional surveys aimed at finding sites within a landscape, the period is focussed on prehistoric and Classic Mediterranean sites (Dieudonné, 1989). A second observation is the apparent standstill in fieldwalk-methodology. As Gaffney suggested in 2000 "[…]the basic data collection techniques, such as gridded intensive and extensive collection strategies combined in a variety of sampling designs, are now likely to remain the mainstay of data capture" (Gaffney, 2000: 29). Moreover, it seems that other survey techniques, such as geophysical methods and metal detecting, have gradually gained the upper hand in archaeological prospection while fieldwalking is barely even used in northwest-European context of both academia and heritage management. Consequently, intensive fieldwalking and the methodology to study intra-site surface scatters did not keep up with technological advances in field registration. Indeed, although Riordan already in 1988 stated that "Ideally, the recording of exact provenience for each artefact is the best method for surface collection" (Riordan, 1988: 6), and Terrenato (2000) tested and praised its potential, surprisingly few studies abandoned rigid gridded survey in favour of artefact-accurate recording. Yet, those few studies who registered individual surface artefacts, produced highly detailed artefact patterns that probably would not have emerged through gridded survey (Araujo, 2001/2002; Brooks *et al*., 2009; De Clercq *et al*., 2013).

In Flanders too, fieldwalking has been predominated by large-scale extensive surveying. Following the 1980s trend of *Landesaufnahme*, a scheme was set up to combine extensive fieldwalking with archival research and aerial photography, which resulted in the prospection of more than 75 municipalities (Nenquin *et al*., 1990). Also the community of Oostkerke, near Bruges in West-Flanders, was thus extensively fieldwalked (Hillewaert, 1984). In additional research, an intensive gridded survey was performed on the site of Monnikerede, which was more precisely located during the extensive survey of 1984. Pedestrian line and grid-survey in the Flemish Polders was further positively assessed through the prospections in the central coastal plain (Deckers, 2014; Dyson *et al*., 2006) and the polders of western Zeeuws-Vlaanderen (Gelorini *et al*., 2006).

The goals of the present study are: (1) to evaluate the potential of intensive intra-site fieldwalking as a means to assess and validate intra-site morphologies; (2) to appraise its possible role within the modern-day toolkit of complementary non-invasive prospection techniques; (3) to build a more sophisticated view on the spatio-temporal evolution of the site by correlating artefact scatters with geophysical anomalies. To attain these goals, first, the 30 year-old data of the grid survey at Monnikerede was post-processed. Next, we conducted new intensive fieldwalking campaigns in which the *XYZ*-coordinates of every collected artefact were recorded with a real-time kinematic global navigation satellite system (RTK-GNSS). Finally, we performed an extensive geophysical survey using electromagnetic induction (EMI) (Figure 1).

Materials and Methods

Harbour sites as case study: Monnikerede and Hoeke

The sites of Monnikerede and Hoeke have a similar history. Both harbours developed on the left bank of a large tidal inlet that connected the medieval city of Bruges with the North Sea. Soon after their first attestation in written sources, they received city and staple rights from the Count of Flanders and the city of Bruges in the third quarter of the thirteenth century. Under influence of Bruges' thriving economy via the Zwin-inlet, the settlements rapidly evolved from fishing villages to miniature harbour cities. When shipping became increasingly problematic due to the silting up of tidal channel, the downside of the integration into the Bruges medieval port network prevailed. The harbours were not able to reconvert their economies and officially ceased to exist in 1594. Monnikerede slowly disappeared from the landscape, a process that was accelerated by the construction of two canals through the harbour and the centre of the site. Hoeke did not vanish completely but shrank into a small rural hamlet. Only the church and the surrounding farms continued to exist. The economic heart, where the harbour was located, was deserted and transformed into arable land and pastures. Both sites have a limited research history. Only the archaeological surveys of the mid-1980s are worth mentioning for Monnikerede. Next to the gridded fieldwalking survey in the north of the site, a microtopographical survey was executed in the south (Hillewaert, 1986). Both surveys were followed by a small test trench. The site at Hoeke has never been subjected to any systematic research at all, but has a promising number of chance-find reports. Both sites offered possibilities for extensive non-invasive research, resulting in a

DOI: 10.1002/arp

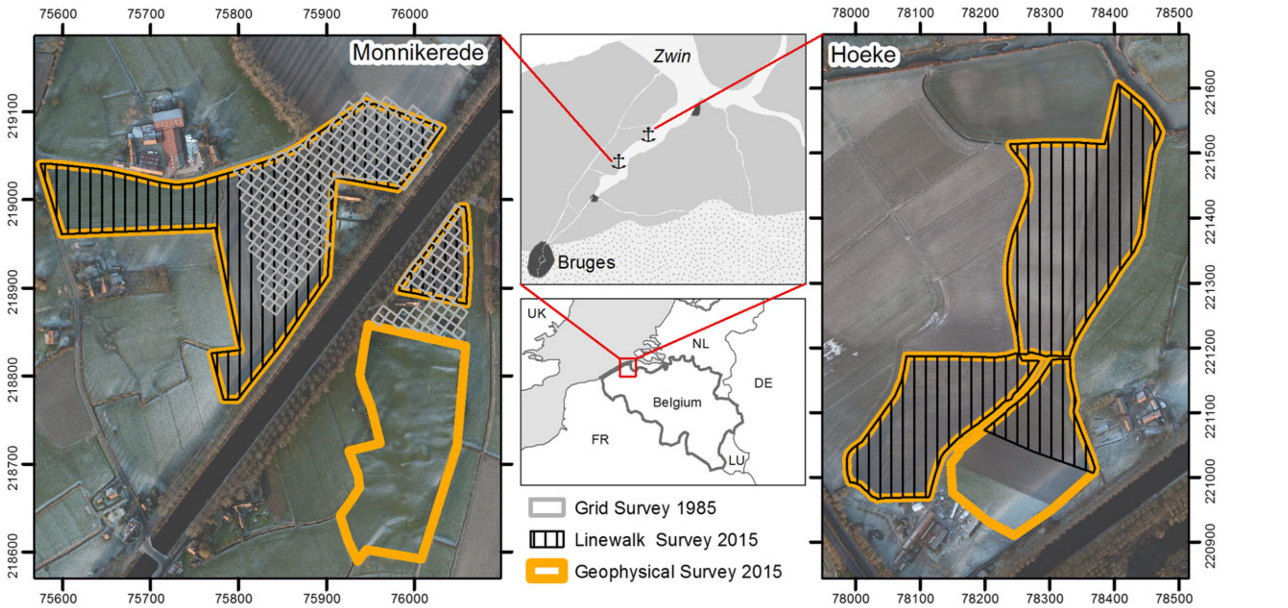

Figure 1. The sites of Monnikerede (left) and Hoeke (right) with indications of the research areas, localized within a reconstruction of the medieval Zwin-region (above) and present-day Belgium (below). Coordinate system: Belge Lambert 72. [Colour figure can be viewed at wileyonlinelibrary.com]

selection of 15 hectares for pedestrian field surveys and 25 hectares for EMI-surveying.

Collection of artefacts through fieldwalking

The factors and processes influencing the study of a surface artefact scatters are manifold, but generally concern (1) behaviour on the site during deposition, (2) post-depositional processes and (3) registration of the artefacts. The debate on depositional and post-depositional factors is sufficiently attended by Lewarch and O'Brien (1981); Haselgrove *et al*. (1985); Schofield (1991) and Francovich and Patterson (2000). Although a detailed reflection on these processes is beyond the scope of the present paper, relevant explanatory theories will be included in the discussion. The registration of artefacts is the only controllable process in the methodology and therefore requires special attention. Registration in fieldwalking can be subdivided in three phases: (i) fieldwork, (ii) laboratory work and (iii) data processing, and will be discussed in detail. Indeed, research design and fieldwork approach determine which part of the surface population is recorded. Therefore, modifications in fieldwalk-strategy and accompanying workload-effects will also be described. The archaeological properties of a surface record are characterized by (a) abundance, (b) composition and (c) distribution (Shott, 1995) and will be assessed using quantitative and spatial-analytical techniques. The focus of this paper is on the distributional characteristics of the surface ensemble.

Grid survey – 1985

The gridded survey intended the recuperation of all artefacts within a 10 m × 10 m grid. In what was thought to be the centre of the city, an area of 3.25 ha was selected for intensive fieldwalking. The orientation of the grid system was aligned with the nineteenth-century canal and therefore most probably discordant with possible medieval patterning. Because the original survey data were never fully processed or published, the present post-processing comprised the georectification and digitalization of the plans in a geographic information system (GIS) and the digitalization of the forms in Excel, after which the cells were colour-coded to visualize density patterns. The initial aim – the full recuperation of all surface artefacts – could not been held as the overall applied methodology and three zones with different levels of recuperation and registration, are discerned: a full recuperation in zone 1, the non-recuperation of ceramic building material in zone 2, and the non-recuperation of pottery in zone 3 (Figure 2a).

Artefact-accurate survey – 2015

The point of departure of this field prospection was to collect and register the exact provenance of each artefact found on the site of Monnikerede, as suggested by Riordan (1988) and Ebert (1992). Such a full recuperation had been performed in the grid survey and would generate a complete, potentially ideal, dataset.

DOI: 10.1002/arp

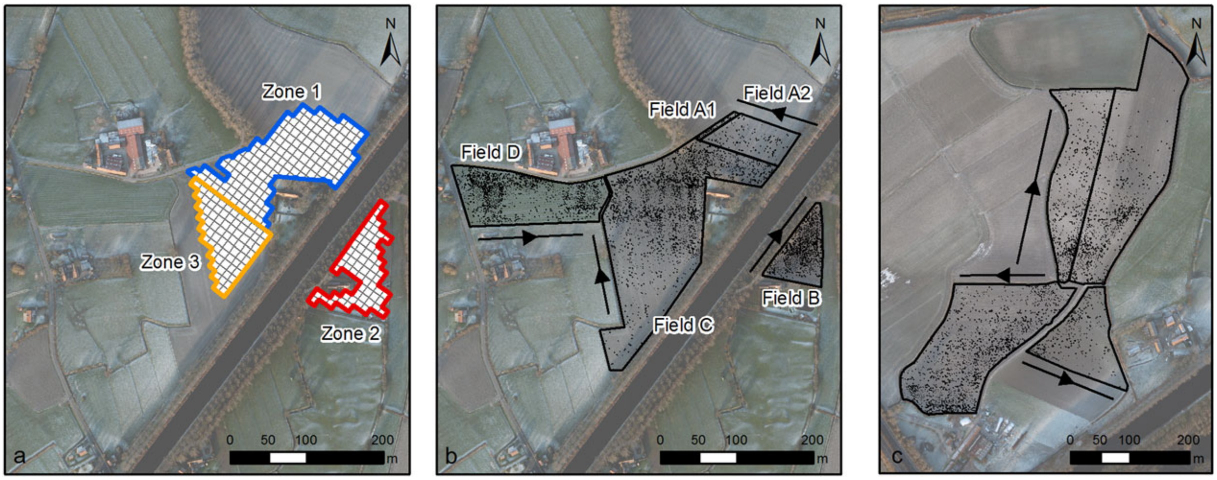

Figure 2. Delineation of areas fieldwalked in the 1985 grid survey in Monnikerede (a) and the 2015 artefact-accurate survey in Monnikerede (b) and Hoeke (c), with display of the artefact scatter (black dots) and indication of ploughing and fieldwalking direction (arrows). [Colour figure can be viewed at wileyonlinelibrary.com]

However, post-processing of Hillewaert's fully recuperated zone showed a harvest of 57,540 finds per hectare. Therefore, Field B was used to test (1) if such numbers were still present 30 years later and (2) how an optimal artefact-accurate registration could be applied. The prospection was conducted by a fixed team of students with a basic knowledge of medieval material culture. Only Field D was prospected by a team of professional archaeologists. To introduce the students with the material culture of this site, a small strip (Field A1) was prospected for one hour. The prospectors line-walked the site with an interdistance of approximately 1.5 m in order to achieve a full visual coverage of the surface. Every single non-recent artefact was registered using a Trimble R10 GNSS with RTK correction and bagged by the prospectors. This fieldwork procedure was tested on Field B in order to fine-tune the methodology.

A first observation was that the site was again scattered with a huge amount of material, rendering full recuperation unfeasible. Lewis (2012) suggests three options to restrict a fieldwalking sample when confronted with large quantities: (1) restrict the time allowed for collection, (2) restrict the range of finds to be collected, or (3) restrict the area to be searched. Considering the fixed site size, we decided to restrict the range of artefacts to be collected on Field B by two measures. A first adaptation was to abandon the full recovery of the abundant and relatively heavy building material (natural stone, brick and tiles) and organic material. The grid-survey in Monnikerede's zone 1 proved that these categories covered 67% of all artefacts and could therefore considerably reduce the workload (Figure 3a). A second corrective measure was to leave out all artefacts smaller than a €1-coin or younger than AD 1800. Next, a post-survey evaluation of Field B urged for further modification of the methodology. Although the first set of corrective measures decimated the registrations to 5678 finds/ha, the method still incurred an unsustainable 213 man-hour/ha. Quantification of the fully recuperated ceramics on Field B show that 59% of the ceramics consist of body sherds; 80% of those belong to local greywares or redwares, which are the most difficult to attribute chronology or usage to. We therefore decided to further restrict the recovery and registration of artefacts diagnostic for activity or chronology, as suggested by Walker (1985) and Mattingly (2000). Thus, only rim, handle and base would be recovered for local redwares and greywares, whereas diagnostically decisive ceramics were to be fully registered.

This methodological strategy is mainly inspired by the focus on distributional patterns, demanding a sufficient, yet processable, amount of ceramics to retrieve spatial patterning. Although we do not deny that quantification of the collected sample is valuable, it does not fit easily within the standard quantification techniques (Orton and Hughes, 2013). It is clear that surface assemblages, which are characterized by high levels of fragmentation and low possibilities of refitting, are not suitable for using the more complex methods such as EVE or MNI (Millett, 2000; Winther-Jacobsen, 2010). Weighing might have been a possible quantification method, but was rejected for practical and time-consuming reasons. Therefore, counting sherds prevailed as the method that offered the best possibilities to quantify this specific surface sample. We suggest to count the samples in two ways: (i) the

DOI: 10.1002/arp

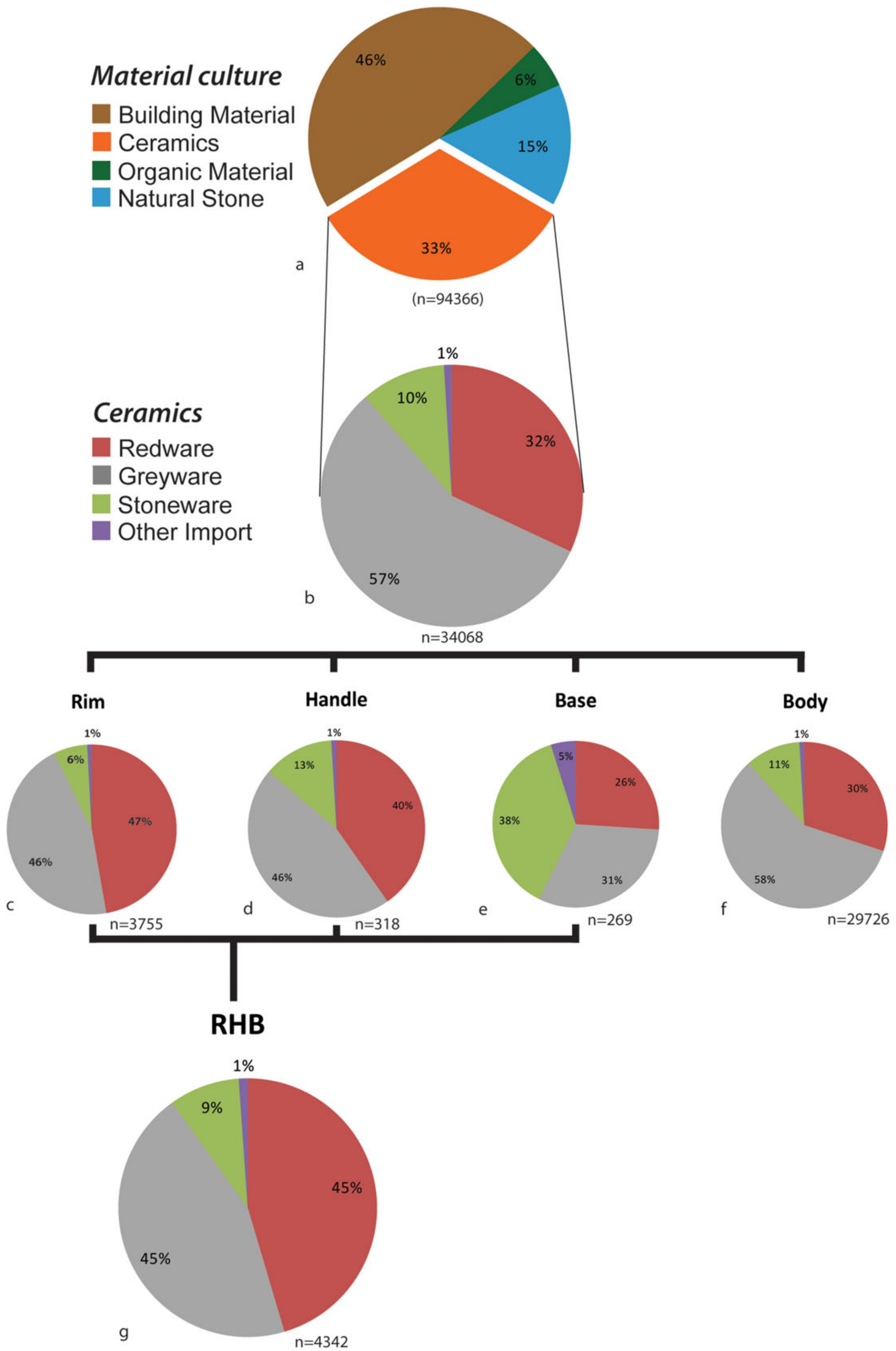

Figure 3. Quantification of the 1985 grid survey with relative proportions of the material culture (a); all ceramics (b); rim, handle, base and body fragments separately (c-f); and rim, handle and base fragments grouped as RHB. [Colour figure can be viewed at wileyonlinelibrary.com]

DOI: 10.1002/arp

quantification of rim fragments to approach the MNI method, and (ii) the quantification of diagnostic fragments [rim, handle and base (RHB) fragments], to approach a total count. Quantification of the 'complete' 1985 surface sample indicates that the relative frequency of the summed RHB fragments seems to be sufficiently close to that of the total count (Figure 3b and g), supporting us to adopt the artefact-accurate recuperation of diagnostic (AAD) fragments, as our standard fieldwalking strategy.

The 'lab-phase' of the survey consisted of washing, drying and sorting the artefacts. A basic determination for artefact category, ceramic fragment, ceramic type, date and origin was entered in a spreadsheet, allowing quantitative and spatial analyses.

The artefact densities were calculated at every find location by counting the amount of neighbouring artefacts in a 10 m radius. This calculation was repeated for the different categories derived after determination (thirteenth-century artefacts, fourteenth-fifteenth-century artefacts, rims, handles, metals, etc.). To produce robust and comprehensible grids (for visualization and spatial analysis), Natural Neighbour interpolation was applied. This method is executed by assigning weights to data points neighbouring the desired location(s). The neighbours and weights are calculated based on the Voronoi tessellation of the discrete, spatial data. Since the basis is linked with the spatial distribution of the data it is an objective method that is well suited for heterogeneous data sets (in the spatial distribution sense). It is noted that if the acquired dataset is small, simply visualizing the scattered data (and colour coding these data if desired) might be a more suitable alternative instead to interpolating.

EMI-survey

EMI instruments produce a time-varying electromagnetic field, thereby inducing electromagnetic fields in the subsurface. Transmitter coil(s) produce a primary field with known waveform, while receiver coil(s) pick up the both the primary (H_p) and induced field (H_s). During measurement, the resulting field is sampled for the quadrature-phase (QP) and in-phase (IP) components, which are expressed as the ratio H_s/H_p.

The QP response is converted to apparent electrical conductivity (ECa), expressed as milli Siemens/metre (mS/m), using the low-induction-number (LIN) approximation as formulated by McNeill (1980). Generally, subsurface conductivity is influenced by the hydrology, mineralogy, porosity and presence of man-made materials. In the survey area, variations in electrical conductivity (EC) of the shallow, unconsolidated Quaternary sediments are presumably mainly due to variations in clay content and presence of anthropogenic disturbances.

The IP response, expressed as parts per thousand (ppt), is proportional to magnetic susceptibility. Elevated magnetic susceptibility is caused by ferrimagnetic enrichment (Fassbinder *et al.*, 1990; Le Borgne, 1955), anthropogenic disturbance of top soils (Gaffney and Gater, 2003), or the heating of soil (Le Borgne, 1960). In the survey area, variations in IP are presumably mainly due to anthropogenic disturbance (e.g. presence of bricks and soil displacement). Due to geometrical effects, an elevated susceptibility at a given depth may give rise to a positive or negative (elevated) IP response (e.g. De Smedt *et al.*, 2014).

Multi-receiver, frequency domain EMI data were collected using a DUALEM 21S sensor in a mobile set-up. The sensor has four coil configurations; two perpendicular (PRP) coil configurations and two horizontal coplanar (HCP) coil configurations with intercoil spacings of ~1 and ~2 m (1HCP, 1PRP, 2HCP and 2PRP). This allows for the recording of four different subsurface volumes. The sampling frequency was 8 Hz and the data were collected along parallel lines, 1 or 2 m apart, at a speed of ~8 km/h. Geographic coordinates were logged using a differential global positioning system (dGPS) system. The *XY* accuracy of the dGPS was around 10 cm (slightly larger than RTK GNSS *XY* accuracy). Whilst the positional *XY* accuracy of the geophysical measurements can be hard to quantify in the presence of spatial and temporal offsets (see Delefortrie *et al.*, 2016), the average error is likely less than 20 cm. After collection, all measurements were corrected for the spatial offsets between the global positioning system (GPS) antenna and the coil configuration midpoints according to Delefortrie *et al.* (2016) as well as a time lag, and corrected for signal drift according to Delefortrie *et al.* (2014). The processed data were interpolated to grids (0.2 m × 0.2 m) using natural neighbour interpolation.

Methods to correlate fieldwalking and geophysics

The scarce research that discusses the correlation between surface artefacts and subsurface (electro)magnetic anomalies has been using visual overlay (Brooks *et al.*, 2009; De Clercq *et al.*, 2013; Deckers, 2011; Heron and Gaffney, 1987; Music *et al.*, 2000; Peterson *et al.*, 2014). However, the large quantity of surface finds and extensive geophysical prospection offered possibilities to quantify their correlation, and was tested using two different techniques. The first technique consists of correlating the EMI values with the artefact

DOI: 10.1002/arp

densities at each artefact location. Geometrical effects were not considered. This results in a correlation matrix in which Pearson coefficients indicate how the position of the artefacts correlate with the EMI-values. The Pearson coefficient indicates how strong the linear correlation between two measured variables is and varies between −1 and 1 (perfect negative and positive correlation) (Pearson, 1895).

The second technique consisted of classifying the EMI data grids and counting the number of artefacts in each class. In order to remove outliers and allow more solid classification, the EMI grids were smoothed using a median filter (with a square 4 m × 4 m window). Next, the data were reclassified in deciles and the amount of artefacts were counted within every decile and divided by the acreage of the decile. The obtained values represent the artefact density per square metre for each class. Pearson coefficients for the reclassified EMI-layers and related densities were also calculated. Whereas the first technique questions the direct relation of the artefact location with its subsoil electromagnetic value, the second technique aims to enlarge the scale and look into broader patterning. Both correlation analyses were performed on (i) all ceramics, and the good-datable, mostly imported (ii) thirteenth-century ceramics[1] and (iii) fourteenth-fifteenth-century ceramics[2] (Hillewaert, 1987; Verhaeghe, 1983).

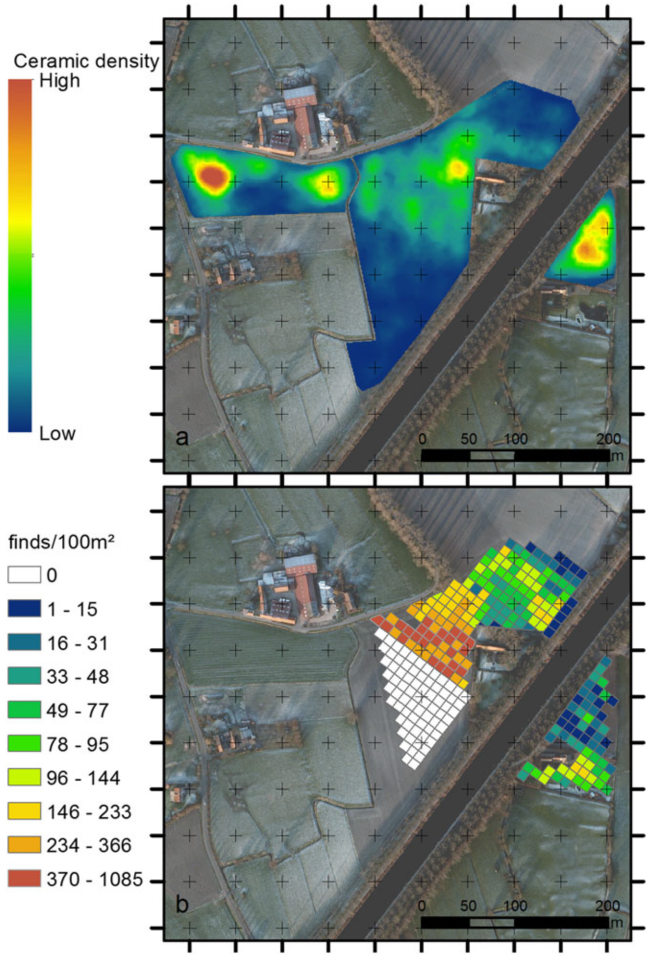

Figure 4. Ceramic density maps using the artefact-accurate method (a) and the grid method (b) in Monnikerede. [Colour figure can be viewed at wileyonlinelibrary.com]

Results

Processing surface artefact patterns

The grid survey and AAD density maps representing all ceramic finds are visualized in Figure 4. The increase in detail using the AAD method is striking, facilitates the interpretation of the site, and allows a more precise delineation.

The ceramic clusters resulting from the density analysis can be interpreted as 'positive' and 'negative' features. The positive features are related to the zones of habitation and are defined as separate clusters, whereas roads are rather characterized as negative features in the density maps. The southern part of the main dike in Hoeke is still in use as a track, the northern part has been ploughed-in since the 1970s and can be discerned as a linear low-density feature that represents the medieval border between reclaimed-land and tideland (Figure 5b). In Monnikerede, the road had been ploughed-in in the middle of the nineteenth century and is only vaguely outlined as a low-density zone (Figures 2b and 5a). The maintenance of historical relevant patterning is further confirmed when datable artefacts are clustered separately. At both sites, the distribution of thirteenth-century fragments is confined to a nucleus (Figures 5c and 5d), whereas the fourteenth and fifteenth-century fragments show a lateral extension (Figures 5e and 5f). Thus, the clusters emerging from the density analysis allow us to discern separated zones of habitation along the historical road network and provide a first indication on how the settlements developed over time (Figures 5g and 5h).

Interpreting EMI

Whereas the surface artefact scatters produce vaguely delineated zones of habitation, elevated IP responses outline well-defined disturbances of the subsoil

[1]The thirteenth-century ceramics chiefly comprise: Saintoinge ware, Scarborough ware, Proto-stoneware and Highly decorated ware
[2]The fourteenth and fifteenth-century ceramics chiefly comprise: so-called stoneware from Langerwehe and Siegburg and Iberian wares.

DOI: 10.1002/arp

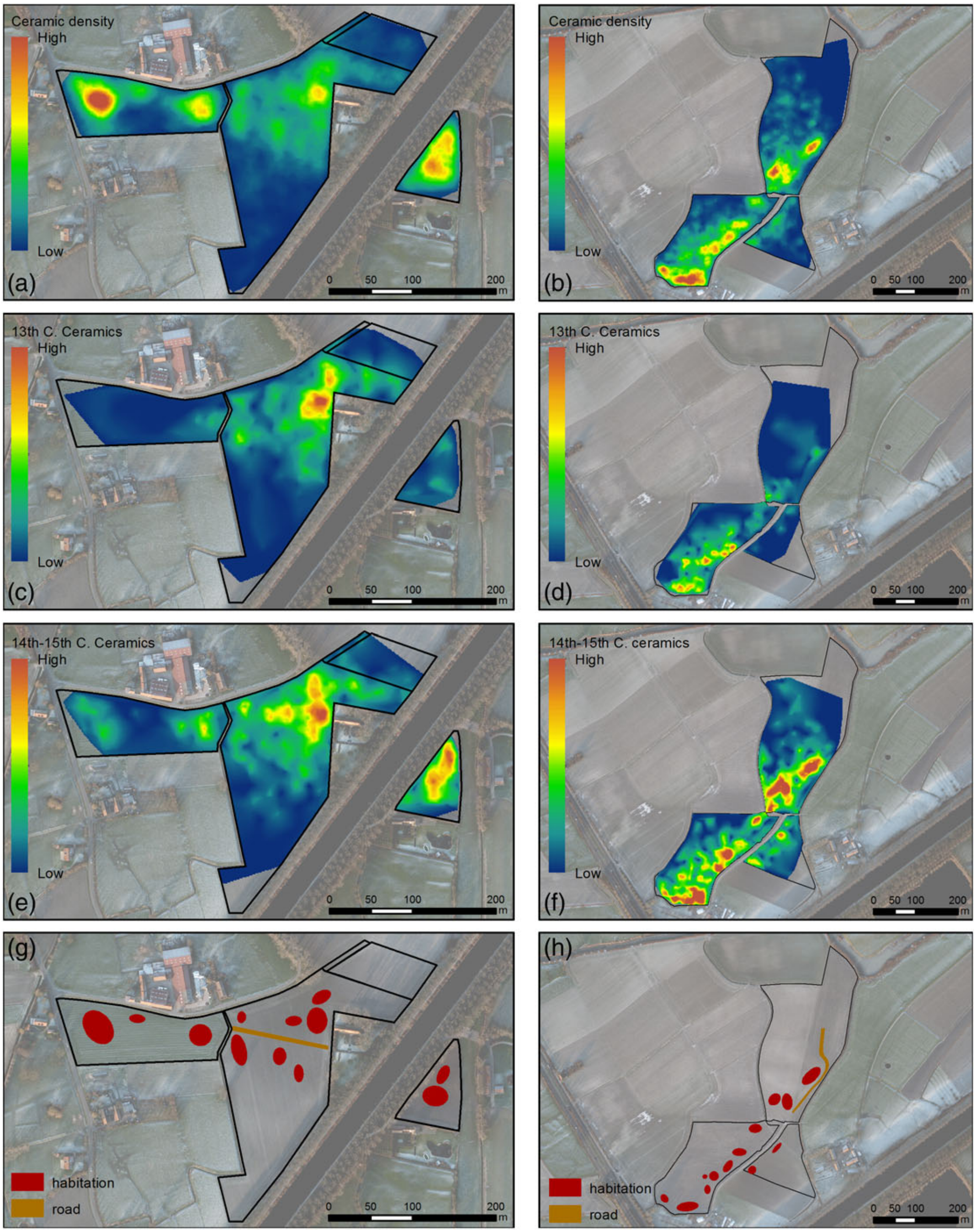

Figure 5. Ceramic densities in Monnikerede (a) and Hoeke (b), with subclassification of thirteenth-century ceramics (c, d) and fourteenth-fifteenth-century ceramics (e, f) and interpretation of the distribution development: from thirteenth-century core to fourteenth-fifteenth-century expansion (g, h). [Colour figure can be viewed at wileyonlinelibrary.com]

(Figures 6a and 6b) and are most probably related to zones of habitation or human activity. Many of these zones are interpreted as a system of parcellation that could date back to the late-medieval occupation of the sites. Linear zones of lower magnetic susceptibility seem to characterize the medieval road network. Roads that were situated on a dike, such as the roads on the most northern part of Hoeke and the most southern part of Monnikerede show as sharp-edged anomalies. The east-west running road in Monnikerede is less defined, but can be recognized by the ditches parallel to it.

DOI: 10.1002/arp

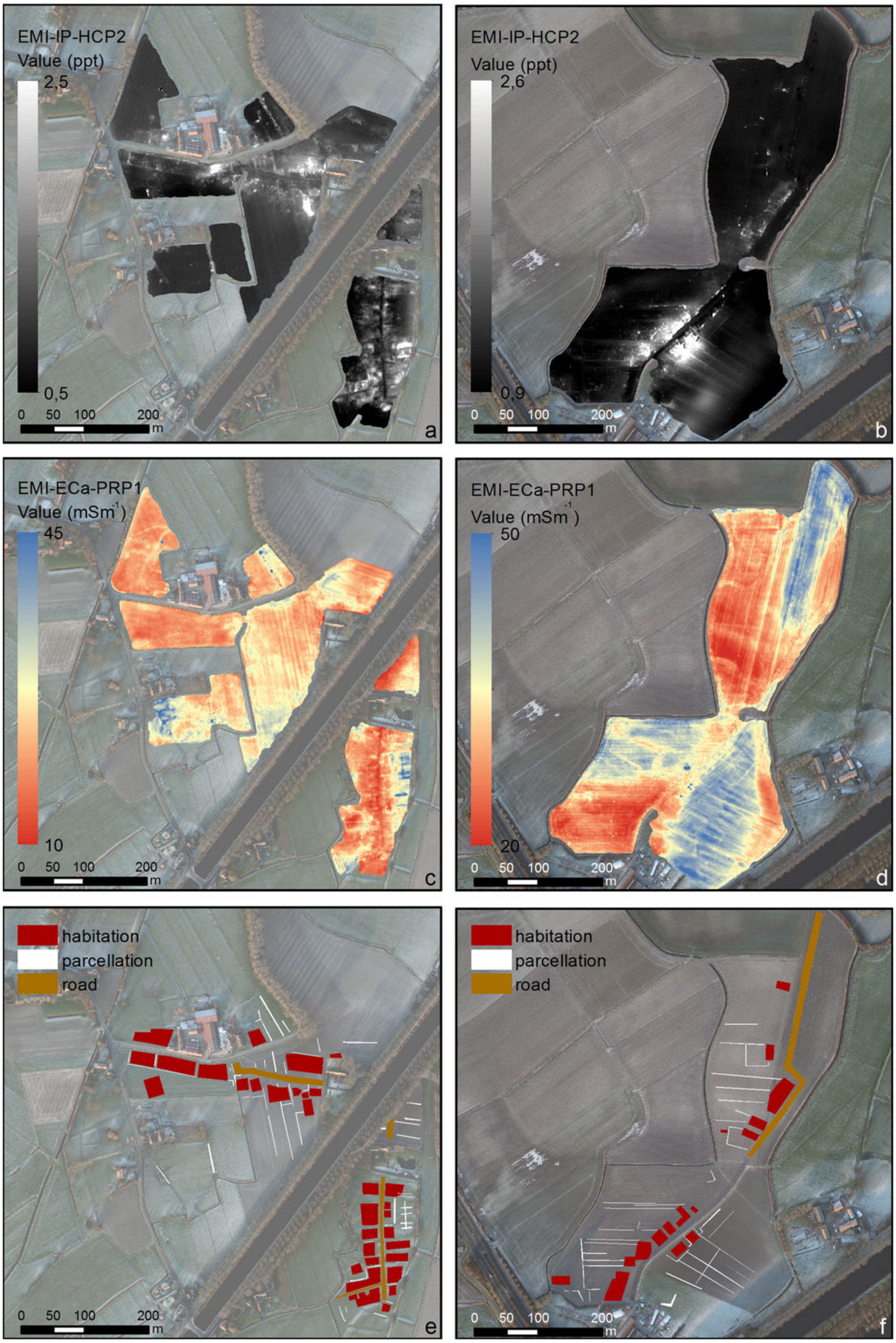

Figure 6. Results of the electromagnetic induction (EMI) survey-soil scan with visualization of the 2HCP in-phase (IP) response and 1PRP apparent electrical conductivity (ECa) in Monnikerede (a, c) and Hoeke (b, d), with interpretation of the geophysical data. [Colour figure can be viewed at wileyonlinelibrary.com]

Although some of the earlier-mentioned features, such as the dike/road in southern Monnikerede, also stand out in the ECa, these layers inform us on sedimentological characteristics of the sites. In Monnikerede, the soil variability is rather limited. Only the old north-south oriented dike indicates the former boundary between dryer sandy soils in the west and the edge of the tidal inlet in the east (Figure 6c). Hoeke however, shows a more variable sedimentology. The reclaimed land on the west side of the dike shows sandy and clayey soils. The land outside (east of) the medieval dike is again characterized by more conductive sediments, representing the medieval tidal inlet (Figure 6d). Remarkably, both sites show activity zones outside the dikes, which could indicate the occupation of these former tidelands in a later phase of the settlements. Thus, the EMI response patterns not only confirm the image of habitation or activity zones being aligned with the road network, they also provide a more precise delineation of these zones (Figures 6e and 6f).

Integrating ceramics and geophysics

From a site-perspective, both sites show a similar trend (visually) in which zones with positive magnetic anomalies yield more ceramics on the surface and thus sharply contrast with 'empty' zones. When zoomed in to individual allotments, the same is still valid; individual concentrations of ceramics mostly coincide with delineable parcels, whereas interparcelar boundaries and roads produce less ceramic finds. Although a closer look into the internal structure of individual allotments broadly followed the earlier pattern, the opposite pattern of seemingly contradictory relations appeared too. At some locations, subtle magnetic anomalies were covered with large quantities of ceramics (Figures 7d-7f), while areas of strong magnetic anomalies had a low-cover ratio (Figures 7b, 7c and 8).

In order to statistically underpin these visual observations, Pearson correlation coefficients were calculated. When relating individual artefact locations to the subsoil magnetic (IP) and conductivity (ECa) values, IP-values generally have a weak correlation, whereas ECa-values produce slightly higher values (Table 1). When total artefact populations are counted within the reclassified EMI-values, a much stronger correlation prevails in both IP and ECa-values (Table 1). Most relevant from a methodological point of view is that all three IP-layers have high coefficients. In Monnikerede, the correlations with EC-values seem less strong when the whole site is taken into account. However, a different picture appears when Field B is separated from the rest. Field B generally has very weak correlation coefficients from which we may conclude that artefacts are more randomly spread. When the data from Field B are excluded, an even stronger correlation appears at the rest of the site. Separate calculations of thirteenth and fourteenth-fifteenth-century fragments in Hoeke follow the trend of strong IP- and ECa-correlations. In Monnikerede however, weaker correlations between thirteenth-century fragments and ECa-values appear, suggesting that soil conditions were not that decisive in Monnikerede's earliest occupation. Concluding, the statistical analyses confirm what the visual comparison between ceramic densities and EMI shows. A direct correlation based on point locations at the scale of individual features cannot be proved. When the perspective is widened to zones of similar EMI-values, a strong structural correlation appears.

Quantifying surface assemblages

The 'complete' collection of both RHB and body fragments in the 1985 gridded survey allowed to assess the impact on the quantification of the surface assemblage if sampled differently, and helped to adjust our 2015 survey methodology (see Figure 3). General comparison between the recent surveys in Monnikerede and Hoeke produce similar relative frequencies, in which local redwares clearly outnumber the other ceramic categories. When rim-counts are compared with RHB-counts, the latter shows a reduced proportion of redwares, in favour of an increased share of stonewares (Figure 9). This pattern could also be discerned in the 1985 dataset, yet to a lesser degree. The only discrepancy between both datasets is the greyware/redware ratio, in which the 2015 survey apparently under-represents the greywares.

Workload of artefact-accurate fieldwalking

In order to assess the time-efficiency of the various fieldwalking strategies, all man-hours of fieldwork were registered and related to the applied method, field surface area and number of finds (Table 2). The most important feature of Table 2 are the implications of the methodological adaptations. Especially note the decline of finds per hectare and related man-hours per hectare from registering all artefacts (Field B) to registering only diagnostic artefacts (Fields C and D). Because of the small amount of covered area and/or artefacts, Fields A1 and A2 should be neglected in the overall comparison of methods. Using the AAD-method, the densely artefact-

DOI: 10.1002/arp

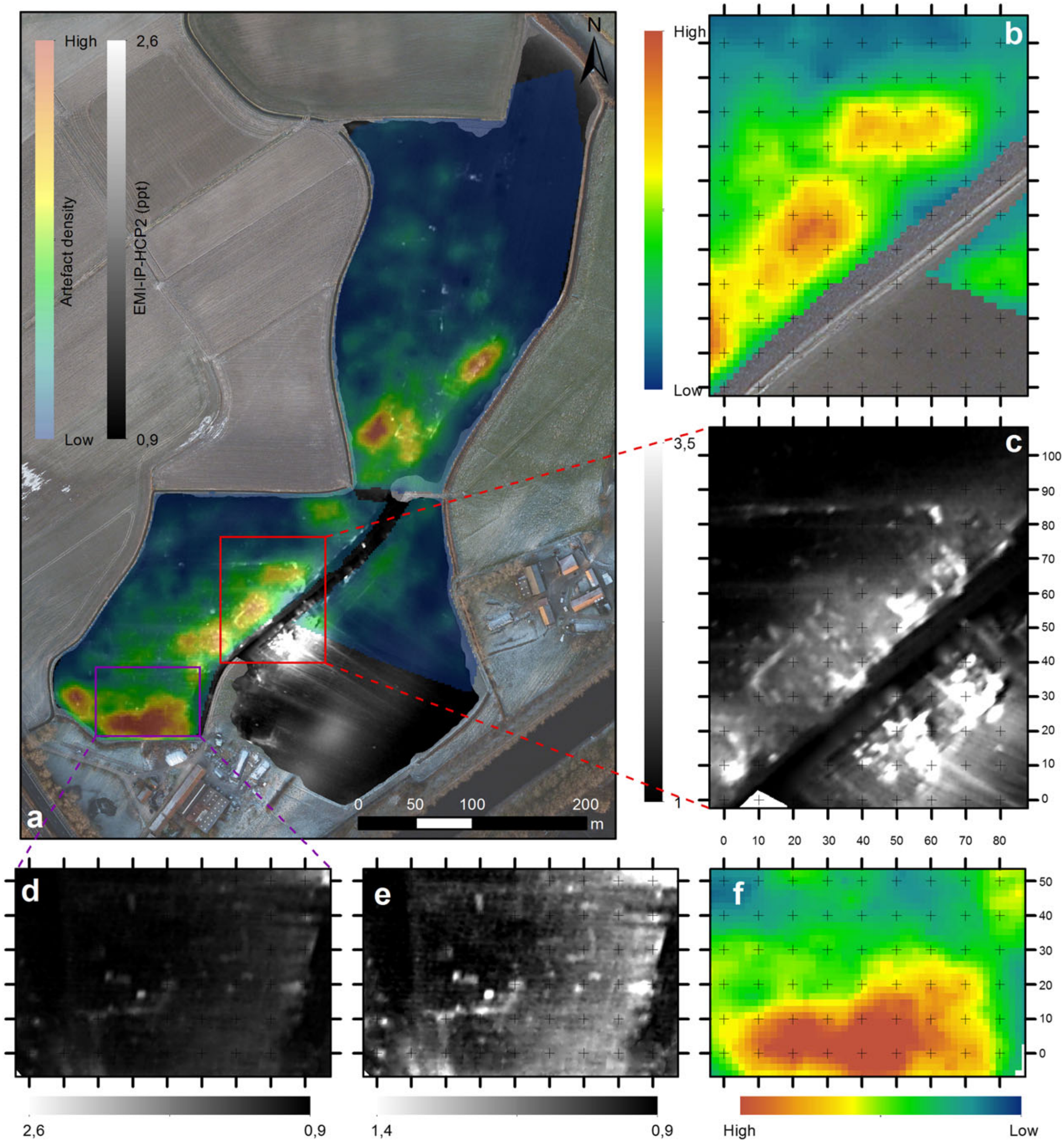

Figure 7. Overlay and visual comparison of geophysical anomalies and artefact densities in Hoeke with indication of special zones of interest. Purple zone (d)-(f) has a weakly elevated magnetic susceptibility (d, e) with high artefact densities, whereas red zone (b) and (c) combines strong anomalies (c) with low artefact densities (b). [Colour figure can be viewed at wileyonlinelibrary.com]

scattered Monnikerede thus approximately needed 38.6 man-hour/ha to survey. The survey in Hoeke was fully prospected using this method and resulted in 27.4 man-hour/ha. This discrepancy is due to the lesser foreknowledge on the delineation of the site at Hoeke which resulted in larger 'empty' areas being fieldwalked. Averaged over both sites, the workload amounts to 30.5 man-hour/ha. Although the workload of the EMI-survey was not strictly kept, the average survey speed of 8 km/h would result in 1.25 man-hour/ha. Yet, this estimation does not take into account the amount of surveyors (usually more than one) nor the time required for setting up and dismantling the configuration (±1 hour).

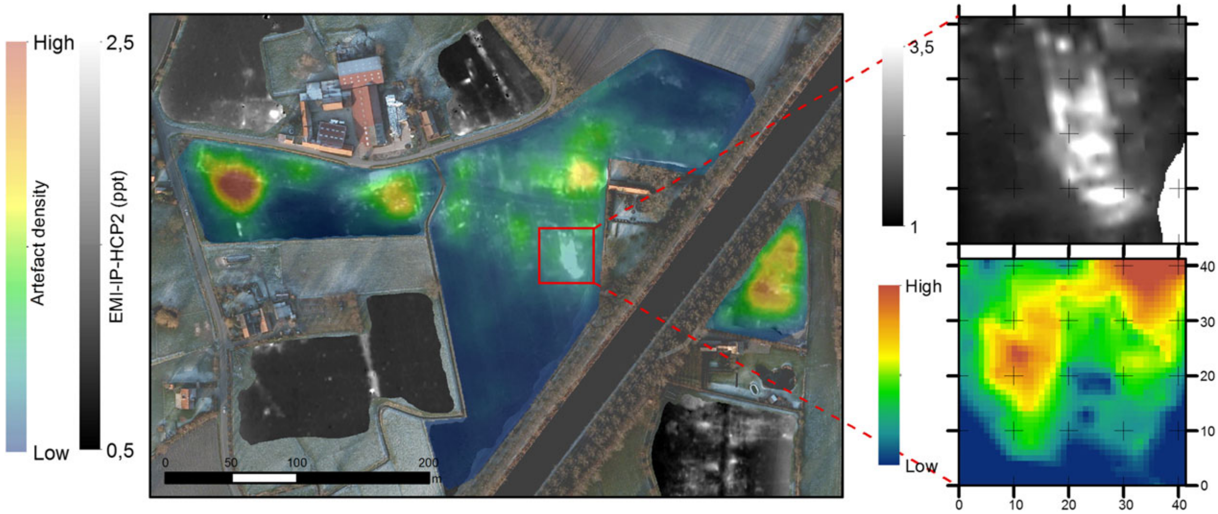

Figure 8. Overlay and visual comparison of geophysical anomalies and artefact densities in Monnikerede with indication of a zone in which strong susceptibility anomalies are exceptionally not covered by a high artefact density. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1. Overview of the workload resulting from the 2015 linewalk surveys for the various methodologies at both sites.

		IP			ECa			
Method 1: individual		IP_PRP1	IP_HCP1	IP_HCP2	ECa_PRP1	ECa_PRP2	ECa_HCP1	ECa_HCP2
Monnikerede	all ceramics	−0.05415	0.44768	0.026765	−0.44369	−0.3776	−0.2529	−0.09823
	Thirteenth century	−0.3417	0.58033	0.45089	−0.19252	−0.41175	−0.53996	−0.4447
	Fourteenth-fifteenth century	−0.41634	0.528997	0.441673	−0.34277	−0.39052	−0.34841	−0.07137
Hoeke	all ceramics	−0.18315	0.286686	0.179173	−0.34826	−0.40785	−0.44168	−0.37451
	Thirteenth century	−0.25427	0.349493	0.209484	−0.37765	−0.45108	−0.49047	−0.44269
	Fourteenth-fifteenth century	−0.16794	0.263512	0.182918	−0.27375	−0.30749	−0.33102	−0.2972
Method 2: reclassified			IP				EC	
	AAD-fields	−0.97244	0.980274	0.947713	−0.98529	−0.92693	−0.95047	−0.85321
	Field B	0.170936	0.955665	0.094648	−0.37618	−0.38951	−0.41452	−0.35321
	all fields	−0.95937	0.971159	0.925245	−0.95845	−0.89853	−0.67324	−0.22049
	Thirteenth century	−0.93579	0.885064	0.952535	−0.14889	−0.45602	−0.77331	−0.47893
	Fourteenth-fifteenth century	−0.95316	0.987549	0.953154	−0.67558	−0.78952	−0.90013	0.106142
Hoeke	all ceramics	−0.84249	−0.84249	0.821338	−0.93571	−0.87557	−0.83274	−0.88461
	Thirteenth century	−0.79115	0.888824	0.691774	−0.87272	−0.84908	−0.79986	−0.88273
	Fourteenth-fifteenth century	−0.85047	0.945356	0.818299	−0.8693	−0.86467	−0.8117	−0.86968

Discussion

The relation between surface artefacts and subsoil magnetic anomalies can be evaluated at three scales: the feature, the parcel and the site. At the level of the individual features, recognized as magnetic anomalies (IP), there seems to be no strong statistical correlation. A phenomenon that can be aligned with the seemingly contradictory relations of intraparcelar visual comparison (Figures 7 and 8). Depositional and post-depositional processes that influence the ploughsoil can explain this weak correlation. A depositional clarification could be the spatial separation between habitation zone and adjacent, but clearly separated waste disposal zones. Such a pattern has repeatedly been recognized where ploughsoil concentrations were compared with excavated subsoil features (Bowden *et al.*, 1991; Fellner, 2013; Heron and Gaffney, 1987). A post-depositional explanation for the absence of surface artefacts above anomalies lies in the intactness of the subsoil feature. If agricultural plough-activities do not affect the structure, less material will be included in the ploughsoil. Conversely, when features are intensely affected by ploughing, the combination of dense artefact scatters above weak IP-anomalies can be expected.

Although this complex combination of both positive and negative relations obscures the correlation coefficients of point locations, statistical analysis of reclassified EMI-values reveals a far better correlation.

DOI: 10.1002/arp

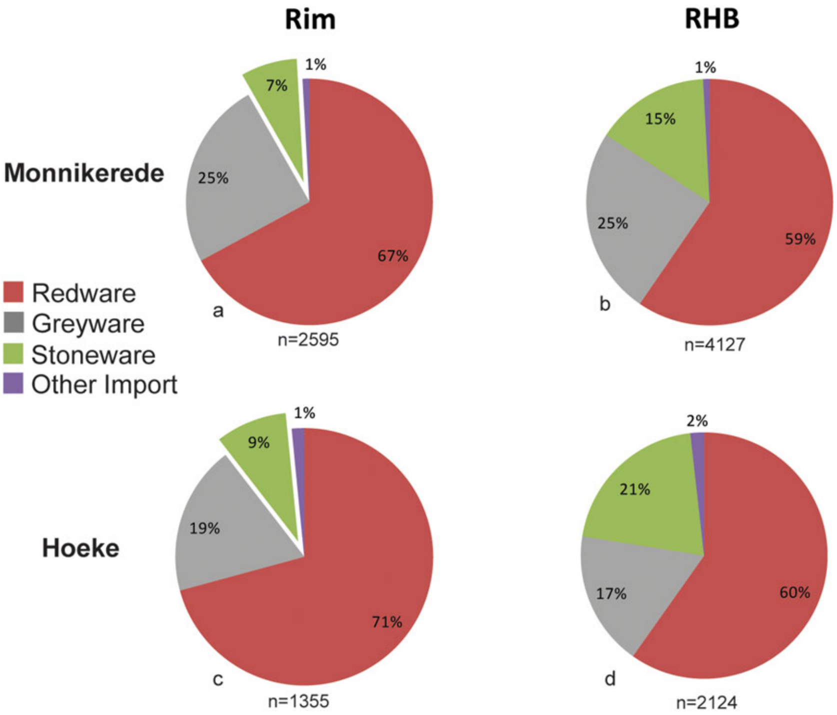

Figure 9. Relative proportions of the rim (a, c), and grouped RHB (rim, handle and base) (b, d) for the artefact-accurate survey in Monnikerede (above) and Hoeke (below). [Colour figure can be viewed at wileyonlinelibrary.com]

Table 2. Pearson correlation coefficients for Monnikerede and Hoeke, subdivided for correlation method (individual versus reclassified), site (Hoeke versus Monnikerede) and period (all ceramics versus thirteenth-century ceramics versus fourteenth-fifteenth-century ceramics).

	Method	Man-hour/field	Surface (ha)	Number of finds	Finds/ha	man-hour/ha	m^2/person-day
Field A1	all ceramics	5	0.04	117	3031.09	129.53	579
Field B	all ceramics	102	0.48	2720	5678.5	212.94	352.21
Field C	AAD	109.5	2.98	2935	984.9	36.74	2041.1
Field D	AAD	52	1.2	2178	1815	43.33	1730.77
Field A2	AAD	9	0.48	140	293.5	18.87	3975
Method all ceramics	all	102	0.48	2720	5678.5	212.94	352.21
Method AAD	AAD	161.5	4.18	5113	1223.21	38.64	1941.18
Total	combined	277.5	5.17	8090	1564.8	53.68	1397.3
Monnikerede	AAD	161.5	4.18	5113	1223.21	38.64	1941.18
Hoeke	AAD	294	10.75	3851	358.23	27.35	2742.35
Total	AAD	455.5	14.93	8964	600.4	30.51	2458.29

Indeed, a more zonal approach of both datasets is preferable and indicates that for example areas of higher IP systematically reveal more surface artefacts. Likewise, visual comparison of artefact densities and IP-anomalies suggests a strong correlation on the scale of the historic allotment. In both Monnikerede and Hoeke, the estimated artefact clusters coincide with the delineation of distinct allotments in the magnetic response and are thus in line with results from Brooks *et al*. (2009); De Clercq *et al*. (2013); Deckers (2014); Music *et al*. (2000), and Peterson *et al*. (2014). The debate on horizontal displacement of ploughsoil artefacts is fundamental in archaeological survey and generally has two sides; those who acclaim that the displacement is confined to several metres (Ammerman, 1985; Lewarch and O'Brien, 1981; Odell and Cowan, 1987; Redman and Watson, 1970; Riordan, 1988; Roper, 1976) and those who believe that the displacement by ploughing is more far-reaching (Navazo and Díez, 2008; Yorston *et al*., 1990). Obviously, muddy plough conditions or the use of agricultural machines such as a drag-harrow can result in an extreme displacement of some surface artefacts. However, an overall view on the ceramic clusters, magnetic susceptibility and

DOI: 10.1002/arp

correlation coefficients at Monnikerede and Hoeke show that these extreme displacements are limited and that the majority of artefacts cluster in the historical allotment.

When the artefact densities and geophysical properties are analysed at the scale of the site, more general conclusions can be drawn. First, the correlation coefficient of thirteenth-century artefacts and EC-values indicate a preference for sandy and dry soils in earliest occupation phase in Hoeke, whereas such a preference is absent in Monnikerede. Being at the forefront of economic activity and living at the most favourable location from a sailor's point of view, could indeed overrule less favourable soil conditions. In the case of Monnikerede, the more sandy soils were located in the west of the city, in the direction of nearby Oostkerke. The link between ceramic densities and soil use is more clear in Hoeke, where the less conductive (drier) soils show both magnetic anomalies and high artefact densities, whereas the more conductive (wet) zones, remain empty of these human activity indicators. Moreover, both sites demonstrate that thirteenth-century artefact densities are more confined to a nucleus, where we consequently could suspect the earliest harbour facilities and the core of the settlement. The fourteenth-fifteenth-century artefacts, however, visualise the expansion of the settlements to economically more peripheral grounds. The high density of redwares in the western corner of Monnikerede finally affirms this pattern and could be an indicator of Monnikerede's reorientation towards Oostkerke once the harbour activities in the east of the settlement declined.

Sampling in this survey was primarily focussed on discovering spatial patterning of surface artefacts, yet entailed sample restrictions less favourable for quantification. The most fundamental restriction was the exclusion of red and grey body sherds from the survey sample. Although the 1985 gridded survey showed that body fragments best represent the overall population of the ceramic surface ensemble (Figures 3e and 3f), they are generally of little diagnostic value for further analysis. Moreover, including these fragments into the sample would make up half of the workload. Rims, on the contrary, are more diagnostic, but constitute a relative low fraction of the surface ensemble. Consequently, just sampling these fragments would not yield a sufficient amount of artefacts to visualize the spatial patterns of well-datable, yet small-numbered ceramics, such as Saintonge or Majolica wares. Moreover, when the quantification of rims is compared to the RHB-count, it seems that rims tend to under-represent stonewares and over-represent redwares. These apparently stable differences can probably be attributed to the narrow-necked and thin-rimmed morphology of the stonewares on the one hand, and the often open-shaped and solid-rimmed redwares, on the other hand. Conversely, counting base fragments tend to over-represent stonewares, that have more solid stems, and under-represent redwares, that often have sagged bases that are difficult to distinguish from body fragments (Figure 10). Ears and handles, then again, are often indicative of usage and chronology for redwares and remarkably well represented in the total 1985 survey-sample. Therefore, we believe that adding bases and handles to our rim-count, can give a better representation of the surface population, and can account for the standard 'total' count.

Yet, when RHB-stoneware counts from 1985 and 2015 are compared, there seems to be an over-representation of redwares and stonewares in 2015, a bias that can also be explained by another factor: visibility. Indeed, one should take into account that the relatively inexperienced team of students were more inclined to pick up well visible redware and stoneware, overseeing greywares that tend to blend in with the surface. Hillewaert, however, was better trained in discerning greywares after two years of extensive field prospection in the area. A second factor that influences the disparity is the exact delineation of zones that are compared. When the delineation of grid survey zone 1 is applied to the 2015 dataset, a more equal greyware/redware ratio appears (1.05 in 1985 against 0.95 in 2015). The large quantities of redwares in the western corner of the site contribute to this bias.

The increased accuracy in data-registration also resulted in a lower workload and a higher resolution output, allowing a more detailed spatial interpretation. Indeed, applying the AAD-method led to a vast

Figure 10. Examples of a stoneware jug (a), a redware bowl (b), and a frying pan (taken from De Groote, 2008, figures 273, 209 and 291). [Colour figure can be viewed at wileyonlinelibrary.com]

DOI: 10.1002/arp

increase in detail, but does it also imply an increase of costs? We believe not. Framing the workload of the AAD-prospections is not straightforward, as such data are not frequently published. Exceptionally, Riordan (1988) accurately published the workload for the intensive survey on a seventeenth-century Mill Field site in St Mary (Maryland, USA). With a total of 7784 artefacts scattered over 6.8 ha, this site has a similar density to that of Monnikerede. The survey was executed in 3 m × 3 m grids and resulted in 150 man-hour/ha (converted from 57.3 man-hour/acre). Celuzza and Fentress (2000: 44) equally needed 150 man-hour/ha (converted from 20 person-days/ha) for their 5 m × 5 m gridded survey of a Roman villa. The adopted AAD-method for fieldwalking in Monnikerede and Hoeke resulted respectively in 38.4 and 27.4 man-hour/ha, averaging at 30.5 man-hour/ha for both sites and thus decreasing the workload by a factor of five. Orton (2000) calculated the relative costs of survey techniques in m^2 per person-day and reports 1000–2500 m^2 as surface-coverage when a field is line-walked with 3 m interdistance. Even with an 1.5 m interdistance, the surveys of Monnikerede and Hoeke had surface-coverages of respectively 1941 m^2 and 2742 m^2, averaging at 2458 m^2/person-day.

Conclusion

This paper assesses the added value of fieldwalking in current field-survey strategies, and argues that the methodology of intensive intra-site fieldwalking surveys can be improved by measuring the exact location of every individual artefact, rather than collecting bulk surface material in grids. Not only is the artefact density registered with a much higher resolution, also time-efficiency can be significantly enhanced. To keep artefact-accurate survey manageable on densely scattered sites, we argue that diagnostic fragments generate a pottery sample that is sufficiently representative for the total pottery population on the surface of the site.

This paper also shows how the combination of fieldwalking and geophysics as non-invasive prospection techniques are complementary in the spatio-temporal analysis of the site. The geophysical techniques delivered a clear-cut delineation of the topographical morphology. The surface artefact densities coincided with this pattern on the scale of the historic allotment. At the level of the site, the combination of both techniques helped to clarify the development over time. The oldest ceramics indicate where to find the earliest nuclei of the harbour-towns, whereas the younger ceramics show how the settlements expanded to economically less interesting zones.

Furthermore, we believe this research rehabilitates the value of fieldwalking as an intra-site survey technique, next to its use to discover sites within a landscape. Ploughing obviously disrupts the archaeological stratum, but it seems that unearthed artefacts shape a meaningful cluster within their historic parcel rather than being redistributed over the entire field in a random pattern. Getting a grasp on the internal structure of an historical parcel falls beyond the possibilities of the applied methodology. For that purpose, all the ceramic building material, natural stones and organic material should possibly be collected too. Moreover, a wide range of depositional and post-depositional processes obscures the exact interpretation of such micro-scaled research and can only be clarified by excavation.

It should also be stressed that the results of the applied methodology depend on the characteristics of the site. Both sites were densely populated, had a short lifespan and produced a relatively robust material culture. Furthermore, the flat microtopographical surface of the sites reduces the erosive impact on the horizontal displacement of the surfaced artefacts.

The spatio-temporal analysis based on geophysical and fieldwalking survey will be further elaborated by the integration of proto-cadastral documents reaching back to the middle of the fifteenth century. Because the southern zone of Monnikerede is used as a meadow, traditional fieldwalking was not possible. This gap is being filled with a microtopographical unmanned aerial vehicle (UAV)-survey (De Reu *et al*., in press for publication) and the integration of archaeological material found at a molehill-survey (Trachet *et al*., in preperation for publication). Finally, the archaeological interpretation of the observed anomalies will be verified through specific augering.

Acknowledgements

This research was conducted as part of the Research Foundation Flanders (FWO)-funded project, *Medieval Bruges and its outer ports. A landscape-archaeological contribution to the Zwin debate* (3G004013). The authors would like to thank Jan Tilleman and Jacques Strubbe, as well as the family Van Wassenhove proprietors and cultivators of the fields in, respectively, Hoeke and Monnikerede, for their cooperation in this research. The authors would also like to thank Dr Koen De Groote and Maxime Poulain for their help with the determination of the medieval ceramics and Dr Jeroen De Reu, Dr Dave Herremans, Dr Lieven Verdonck and Dr Jeroen Verhegge for their input and corrections.

DOI: 10.1002/arp

References

Ammerman AJ. 1985. Plow-zone experiments in Calabria, Italy. *Journal of Field Archaeology* **12**(1): 33–40. DOI:10.2307/529373.

Araujo AGM. 2001/2002. Destruído pelo arado? Arqueologia de superfície e as armadilhas do senso comum. *Revista de Arqueologia* **14/15**: 7–28.

Banning EB. 2002. *Archaeological Survey*. Kluwer Academic/Plenum: New York.

Binford LR, Binford SR, Whallon R, Hardin MA. 1970. Archaeology at Hatchery West. *Memoirs of the Society for American Archaeology* **24**: i–91. DOI:10.2307/25146704.

Bowden MCB, Ford S, Gaffney VL, Tingle M. 1991. Skimming the surface or scraping the barrel: A few observations on the nature of surface and sub-surface archaeology. In *Interpreting Artefact Scatters: Contributions to Ploughzone Archaeology*, Schofield AJ (ed). Oxbow Books: Oxford; 107–113.

Brooks A, Bader H-D, Lawrence S, Lennon J. 2009. Ploughzone archaeology on an Australian historic site: A case study from South Gippsland, Victoria. *Australian Archaeology* **68**: 37–44.

De Clercq W, De Smedt J, De Reu J, *et al*. 2013. Unravelling a complex of enclosures. An integrated prospection approach for a deserted historic farm-complex at Kleit, Maldgemem (Flanders, Belgium). In *Archaeological Prospection. Proceedings of the 10th International Conference*, Neubauer W, Trinks I, Salisbury RB, Einwögerer C (eds). Ludwig Boltzmann Institue for Archaeological Prospection and Virtual Archaeology: Vienna; 123–125.

De Groote K. 2008. *Middeleeuws aardewerk in Vlaanderen : techniek, typologie, chronologie en evolutie van het gebruiksgoed in de regio Oudenaarde in de volle en late middeleeuwen (10de–16de eeuw)*. Vlaams instituut voor het onroerend erfgoed: Brussel.

De Reu J, Trachet J, Laloo P, De Clercq W. in press. From low cost UAV survey to high resolution topographic data: developing our understanding of a Medieval outport of Bruges. *Archaeological Prospection*.

De Smedt P, Saey T, Meerschman E, De Reu J, De Clercq W, Van Meirvenne M. 2014. Comparing apparent magnetic susceptibility measurements of a multi-receiver EMI sensor to topsoil and profile magnetic susceptibility data over weak magnetic anomalies. *Archaeological Prospection* **21**(2): 103–112. DOI:10.1002/arp.1467.

Deckers P. 2011. Leffinge-oude Werf. In *Prospectie met ingreep in de bodem, 30 augustus–24 september 2010*. Vrije Universiteit Brussel: Brussels.

Deckers P. 2014. Between Land and Sea. In *Landscape, Power and Identity in the Coastal Plain of Flanders, Zeeland and Northern France in the Early Middle Ages (AD 500–1000)*. Vrije Universiteit Brussel: Brussels.

Delefortrie S, De Smedt P, Saey T, Van De Vijver E, Van Meirvenne M. 2014. An efficient calibration procedure for correction of drift in EMI survey data. *Journal of Applied Geophysics* **110**: 115–125. DOI:10.1016/j.jappgeo.2014.09.004.

Delefortrie S, Saey T, De Pue J, Van De Vijver E, De Smedt P, Van Meirvenne M. 2016. Evaluating corrections for a horizontal offset between sensor and position data for surveys on land. *Precision Agriculture* **17**(3): 349–364.

Dieudonné N. 1989. La prospection au sol: étude bibliographique. *Revue archéologique du Centre de la France* **28**(2): 217–228.

Dyson L, Heppell E, Johnson C, Pieters M. 2006. *Archaeological Evaluation of Wetlands in the Planarch Area of North West Europe*. Open access: Maidstone.

Ebert JI. 1992. *Distributional Archaeology*. University of Utah Press: Salt Lake City, UT.

Evans C, Tabor J, Linden MV. 2014. Making time work: Sampling floodplain artefact frequencies and populations. *Antiquity* **88**(339): 241–258. DOI:10.1017/S0003598X0005033X.

Fassbinder JWE, Stanjekt H, Vali H. 1990. Occurrence of magnetic bacteria in soil. *Nature* **343**(6254): 161–163.

Fellner R. 2013. Intrasite spatial analysis of the early medieval hamlet of Develier-Courtételle, Switzerland. *Medieval Archaeology* **57**(1): 183–197. DOI:10.1179/0076609713Z.00000000019.

Fentress E. 2000. What are we counting for? In *Extracting meaning from ploughsoil assemblages*, Francovich R, Patterson H, Barker G (eds). Oxbow Books: Oxford; 44–52.

Francovich R, Patterson HX. 2000. *Extracting Meaning from Ploughsoil Assemblages: The Archaeology of Mediterranean Landscapes, volume 5*. Oxbow Books: Oxford.

Gaffney C, Gater J. 2003. Revealing the Buried Past. In *Geophysics for Archaeologists*. Tempus: Stroud.

Gaffney V. 2000. Ceramics and the site: is survey enough? In *Extracting Meaning from Ploughsoil Assemblages*, Francovich R, Patterson H, Barker G (eds). Oxbow Books: Oxford; 29–43.

Gelorini V, Lehouck A, Vanslembrouck N, Mulder J, Thoen E, Jelier V. 2006. Interdisciplinair onderzoek naar verdwenen cultuurlandschappen in het grensgebied van Vlaanderen en Nederland: problemen, nieuwe mogelijkheden en toepassingen. In *VOBOV 64*, (Themanummer Grensgevallen: bijdragen tot het grensoverschrijdend archeologisch onderzoek in Vlaanderen en Zeeuws-Vlaanderen); 2–19.

Haselgrove C, Millett M, Smith I. 1985. *Archaeology from the Ploughsoil: Studies in the Collection and Interpretation of Field Survey Data*. Department of Archaeology and Prehistory, University of Sheffield: Sheffield.

Hawkins RA. 1998. Coming full circle: Plowzone assemblages and the interpretation of fort ancient settlement structure. In *Surface Archaeology*, Sullivan API (ed). University of New Mexico Press: Albuquerque, NM; 91–110.

Heron CP, Gaffney CF. 1987. Archaeogeophysics and the site: Ohm Sweet Ohm? In *Pragmatic Archaeology: Theory in Crisis?* Gaffney VL, Gaffney CF (eds). BAR British Series, 167. Bar Publishing: Oxford; 71–81.

Hillewaert B. 1984. *Oostkerke-bij-Brugge*. Archeologische Inventaris Vlaanderen: Gent.

Hillewaert B. 1986. La petitte ville de Monnikerede: analyse du reliëf et étude microtopographique. *Scholae Archaeologicae* **4**: 5–48.

Hillewaert B. 1987. Laatmiddeleeuwse importceramiek te Brugge. In *Brugge Onderzocht. Tien jaar Stadsarcheologisch onderzoek*, De Witte H (ed). VZW Archeo-Brugge: Brugge; 123–139.

Le Borgne E. 1955. Susceptibilité magnetique anormale du sol superficial. *Annales de Geophysique* **11**: 399–419.
Le Borgne E. 1960. Influence du feu sur les propriétés magnétiques du sol et sur celles du schiste et du granite. *Annales de Geophysique* **16**: 159–195.
Lewarch DE, O'Brien MJ. 1981. Effect of short term tillage on aggregate provenience surface pattern. In *Plowzone Archaeology: Contributions to Theory and Technique*, O'Brien MJ, Lewarch DE (eds). Publications in Antrhopology: Vanderbilt University, Nashville, TN; 7–50.
Lewis C. 2012. A practical guide to investigating medieval rural settlements. In *Medieval Rural Settlement Britain and Ireland, AD 800–1600*, Christie N, Stamper P (eds). Windgather Press: Oxford; 288–307.
Mattingly D. 2000. Methods of collection, recording and quantification. In *Extracting Meaning from Ploughsoil Assemblages*, Francovich R, Patterson H (eds). Oxbow Books: Oxford; 5–15.
McNeill JD. 1980. *Electrical Conductivity of Soils and Rocks*. Geonics Ltd: Mississauga.
Millett M. 2000. Dating, quantifying and utilizing pottery assemblages from surface survey. In *Extracting Meaning from Ploughsoil Assemblages*, Francovich R, Patterson H, Barker G (eds). Oxbow Books: Oxford; 53–59.
Music B, Slapsak B, Perko V. 2000. On-site distributions and geophysics: The site of Rodik-Ajdovscina. In *Extracting Meaning from Ploughsoil Assemblages*, Francovich R, Patterson H, Barker G (eds). Oxbow Books: Oxford; 132–146.
Navazo M, Díez C. 2008. Redistribution of archaeological assemblages in plowzones. *Geoarchaeology* **23**(3): 323–333. DOI:10.1002/gea.20201.
Nenquin J, Van Moerkerke J, Semey J, Bourgeois J. 1990. *Het project 'Archeologische inventaris Vlaanderen' in Oost-Vlaanderen – Archeologie en luchtfotografie in Binnen-Vlaanderen, meer dan 15 jaar onderzoek*. Vobov-info: Belsele; 38.
Odell GH, Cowan F. 1987. Estimating tillage effects on artifact distributions. *American Antiquity* **52**(3): 456–484. DOI:10.2307/281594.
Orton C. 2000. *Sampling in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press: Cambridge.
Orton C, Hughes M. 2013. *Pottery in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press: Cambridge.
Pearson K. 1895. Notes on regression and inheritance in the case of two parents. *Proceedings of the Royal Society of London* **58**: 240–242.
Peterson CE, Xueming L, Drennan RD, Zhu D. 2014. *Hongshan Regional Organization in the Upper Daling Valley*. University of Pittsburgh Centre for Comparative Archaeology: Pittsburgh, PA.
Pogue DJ. 1988. Spatial analysis of the King's Reach Plantation Homelot, CA. 1690–1715. *Historical Archaeology* **22**(2): 40–56. DOI:10.2307/25615690.
Redman CL, Watson PJ. 1970. Systematic, intensive surface collection. *American Antiquity* **35**(3): 279–291. DOI:10.2307/278339.
Riordan TB. 1988. The interpretation of 17th century sites through plow zone surface collections: Examples from St Mary's City, Maryland. *Historical Archaeology* **22**(2): 2–16. DOI:10.2307/25615688.
Roper DC. 1976. Lateral displacement of artifacts due to plowing. *American Antiquity* **41**(3): 372–375. DOI:10.2307/279527.
Schofield AJ. 1991. *Interpreting Artefact Scatters*: *Contributions to Ploughzone Archaeology*, Oxbow monograph, volume 4. Oxbow Books: Oxford.
Shott M. 1995. Reliability of archaeological records on cultivated surfaces: A Michigan case study. *Journal of Field Archaeology* **22**(4): 475–490. DOI:10.1179/009346995791974062.
Sullivan API (Ed). 1998. *Surface Archaeology*. University of New Mexico Press: Albuquerque, NM.
Terrenato N. 2000. Surface thought: Future directions in Italian field surveys. In *The Future of Surface Artefact Survey in Europe*, Bintliff J, Kuna M, Venclová N (eds). Sheffield Archaeological Monographs, Sheffield Academic Press: Sheffield; 21–28.
Trachet J, Poulain M, Delefortrie S, Van Meirvenne M, De Clercq W. in preperation. Making a mountain out of a molehill? A low-cost and time-efficient molehill survey on the lost medieval harbour site of Monnikerede (Belgium).
Verhaeghe F. 1983. Medieval pottery production in coastal Flanders. In *Ceramics and Trade. The Production and Distribution of Later Medieval Pottery in North-west Europe*, Davey P, Hodges R (eds). Department of Prehistory and Archaeology, Univerity of Sheffield: Sheffield; 63–94.
Walker L. 1985. Survey of a settlement: A strategy for the Etruscan site at Dognella in the Albegna Valley. In *Archaeology from the Ploughsoil: Studies in the Collection and Interpretation of Field Survey Data*, Haselgrove C, Millett M, Smith I (eds). Department of Archaeology and Prehistory, University of Sheffield: Sheffield; 87–107.
Winther-Jacobsen K. 2010. From Pots to People. A Cermamic Approach to the Archaeological Interpretation of Ploughsoil Assemblages in Late Roman Cyprus. In *Babesh Supplement Series*. Peeters: Leuven.
Yorston RM, Gaffney VL, Reynolds PJ. 1990. Simulation of artefact movement due to cultivation. *Journal of Archaeological Science* **17**(1): 67–83. DOI:10.1016/0305-4403(90)90015-W.

DOI: 10.1002/arp