Continuous multi-signal EMI survey in geoarchaeological research: a 90 ha dataset

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Abstract

The archaeological evaluation of project sites is often solemnly based on extensive trenching programmes complemented with auger surveys. However, these methods lack spatial continuity, which can make detected structures difficult to interpret. A mobile multi-signal electromagnetic induction (EMI) survey was therefore incorporated in the archaeological evaluation of a large polder site in the north-west of Belgium. Using a mobile multicoil EMI instrument enabled us to map of both the apparent electrical conductivity (ECa) as well as the apparent magnetic susceptibility (MSa) of different soil volumes of the study area. This study illustrates the potential of multi-signal EMI prospection for geoarchaeological research.

Keywords: mobile multi-signal EM survey, electrical conductivity, heritage management, geoarchaeology

Introduction

Geoarchaeological evaluation of large project sites for heritage and environmental management, is becoming more common as government regulations on infrastructure development are increasing. Common methods to support these evaluations, are still mostly limited to traditional surveys such as extensive trenching programmes complemented with augerings (Verhagen & Borsboom, 2009). Although these techniques offer a high local resolution, their time- and energy-consuming nature often results in a low sampling density. As up to 90% of study areas is left unexcavated, lateral connection between sample locations depends mostly on interpolation. Moreover, archaeological features can remain undetected, leading to incorrect evaluation of the archaeological potential of the site (Verhagen & Borsboom, 2009).

Mobile proximal soil sensing techniques enable a more continuous and rapid mapping of the subsurface. When both the pedology and the archaeology of a site are investigated, techniques based on electromagnetic induction (EM) offer the potential to combine high resolution soil mapping with accurate information about material properties. Soil features with different texture and composition can be identified and, for example, metal or even burnt objects can be pinpointed.

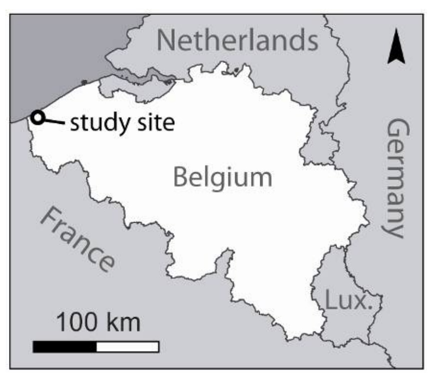

Figure 1. Location of the study site in Belgium

For the archaeological evaluation of a planned golf course, located within a 90 ha polder site in the north-western part of Belgium (Fig. 1), a mobile multi-coil EM survey was included in the prospection campaign. Apart from the cost-time benefit of a mobile survey, the high groundwater levels and the possible presence of unexploded war ammunition excluded large-scale trenching as a primary prospection method. The high clay content of the area combined with the need to gather both archaeological and pedological data, made EM based proximal soil sensing an efficient way to guide further fieldwork. This intensive survey unveiled archaeological traces relating to medieval periods and objects related to World War I events. It also allowed a detailed reconstruction of the site's palaeohydrology as a buried river system was detected and could be traced throughout the entire study area.

Material and methods

The study area is situated in the western part of the Belgian coastal plain (Fig. 1) and is characterised by Pleistocene sand overlain with clay sediments (Baeteman et al., 1999).
To map the ECa and MSa of different soil volumes of the entire area, we used a multicoil Dualem-21S EM sensor (Dualem, ON, Canada). In this instrument, four receiver coils are combined at fixed distances of 1, 1.1, 2 and 2.1 m from a transmitter coil. The receiver coils placed at 1.1 and 2.1 m form coil pairs in a perpendicular loop orientation (1.1 and 2.1 *PERP*). Those placed at 1 and 2 m from the transmitter coil form pairs in a horizontal coplanar loop orientation (1 and 2 *HCP*). As the depth of exploration (DOE) of each coil pair, is determined by the intercoil separation and their orientation, the Dualem sensor enables measuring four different soil volumes simultaneously. With a DOE of 0.54 and 1.03 m beneath the surface, the 1.1 and 2.1 *PERP* coil pairs give information about the upper soil layers. The 1 and 2 *HCP* configurations give information about deeper sediments with DOE's of 1.55 and 3.18 m (Saey et al., 2009). By combining this multi-signal configuration within a mobile setup, four bulk conductivity values and four MSa measurements were taken every 0.2 m, i.e. eight measurements per second. At the same time, soil temperature was measured to allow conversion of the ECa data to a reference temperature of 25°C. We drove along parallel lines with a 1.75 m separation to obtain a nearly complete lateral coverage of the study area, measuring an average of 0.75 ha per hour. These field data were then interpolated with ordinary kriging using Vesper (Whelan, McBratney & Viscarra-Rossel 1996) to create four ECa and four MSa maps.
Based on both the EMI survey data, auger data and available historical data, four main excavation zones were selected where the topsoil was removed. The archaeological traces and structures were then drawn and digitized. In this paper, we focused on the ECa dataset.

Results

The four ECa maps clearly revealed both the archaeological and pedological complexity of the site. In Fig. 2 A, the ECa measurements from the 1 *HCP* configuration are shown while Figs. 2 B-E show all four ECa measurements within one of the excavation areas (EA1). Here, clayey infillings of features allowed delineating ditch systems, parcel boundaries, and a moated site next to several small palaeogullies incised through the sandy substrate (Fig 2 B-E). Apart from locating these structures, we precisely predicted their depth by combining the ECa signals (Saey, 2011). After excavating this zone and validating the ECa data with the archaeological field data, a high correlation was found between the excavation results and the ECa maps exemplified in Fig. 3.

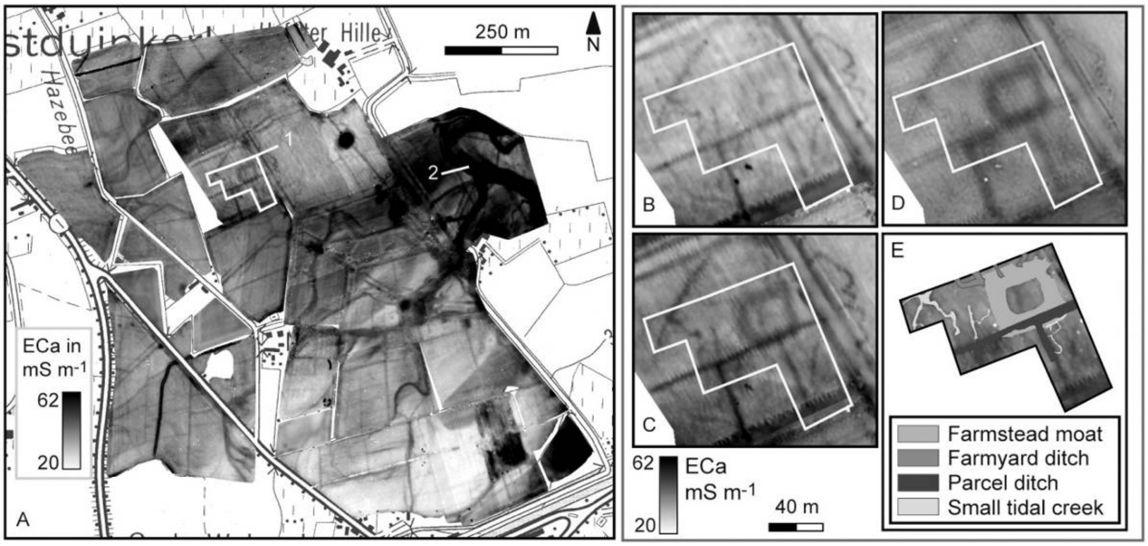

Figure 2. 1HCP ECa map of the entire study area, with excavation area 1 (1) and the large palaeochannel (2) (A), and detail of the ECa measurements of EA1 in 1.1P (B), 2.1P (C), 2 HCP configuration with the excavation data plotted on the 1HCP ECa plot (E).

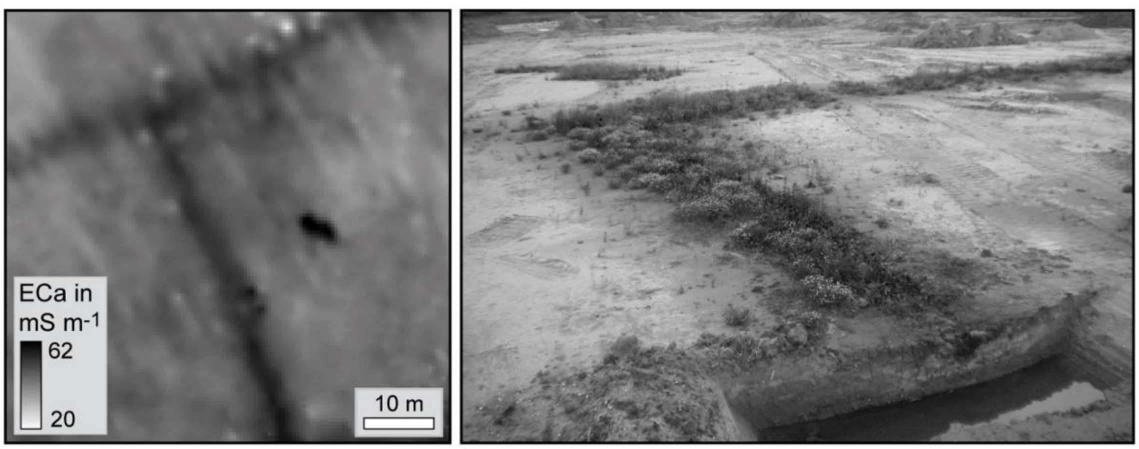

Figure 3. Detail of a ditch system in the 1HCP ECa measurements (A) and the excavated ditch system, showing vegetation on top of the organic clay infillings after 2 weeks (B).

In a second zone, a large branch of a palaeochannel was detected. Again, the clayey infillings of this features caused high ECa values. Here, the ECa measurements were combined to accurately reconstruct the channel's morphology (Saey, 2011) giving important information about flow direction and discharge capacity (Fig.4).

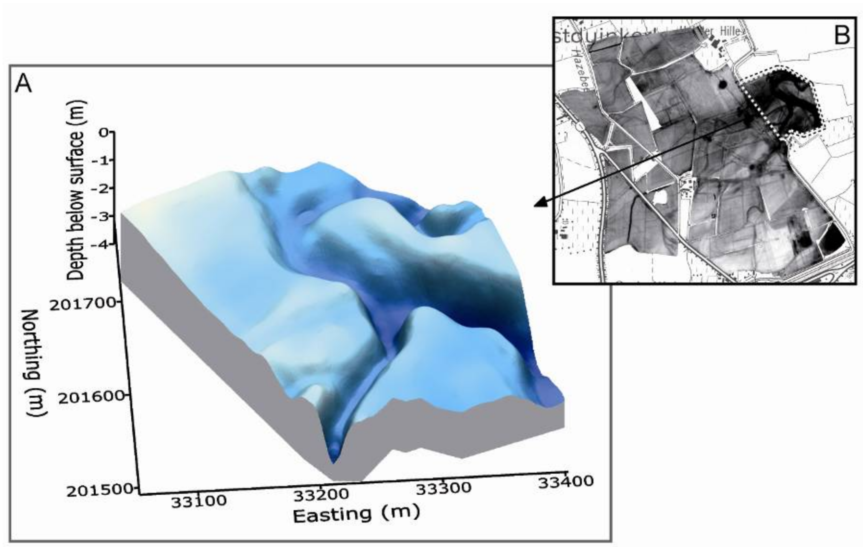

Figure 4. Depth model (A) and location (B) of the large palaeochannel segment.

Conclusions

By mapping ECa variations, the site's main archaeological features were detected and the buried palaeolandscape could be reconstructed. As the combination of multiple signals adds vertical discriminating potential to the high measurement density of a mobile EMI survey, features can be described in three dimensions. Although these data need to be complemented with augerings and limited trenching, this survey method offers a data continuity which is seldom achieved in traditional preliminary archaeological prospections. Especially when large areas have to be evaluated, integrated proximal soil sensing techniques can provide valuable information to researchers studying every aspect of present or past landscapes.

References

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