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Technical aspects

You know it's summer in Ireland when the rain gets warmer: analysing repetitive time-lapse earth resistance data to determine 'optimal' survey climate conditions

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The purpose of this paper is to determine whether there are temporal changes/variations observable in time-lapse earth resistance surveys carried out in Ireland, how important those variations are and whether geophysicists can be confident of interpreting data from such surveys undertaken all year round in Ireland. Temporal or 'seasonal' weather changes impact the results of earth resistance surveys by altering rainfall and temperature, which influence the amount of net moisture entering the soil. It is known that these changes influence the moisture contrast of archaeological features, which can be quantified via repetitive time-lapse earth resistance surveys over a given study area. The timetable of most development-led assessments (and many research programmes) is not conducive to the use of earth resistance surveys at the 'optimum' time of year (if there is an optimum time of year). However, if levels of confidence for the detection of archaeological features can be achieved throughout the year, then geophysicists and curators can be made aware of the potential limitations of the technique for a given set of climatic conditions. It is important to establish the impact of temporal variations on earth resistance data to determine how effective such a survey will be for a given climate.

Extensive time-lapse studies on archaeological features and the near surface have been performed across Europe (Al Chalabi and Rees 1962; Hesse 1966; Clark 1980; Coombes 1991; Cott 1997; Parkyn 2012; Fry 2014), but the impact of temporal variations on the archaeological prospection of Irish soils has not been examined. Annual average precipitation in Ireland exceeds evapotranspiration by over 500 mm (Walsh 2012). Average annual rainfall figures are approximately 1230 mm. To determine the influence of this climate, a 14 month time-lapse investigation was designed to review, investigate and test the temporal variables that impact the success or failure of earth resistance geophysical surveys.

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LOCATION OF THE TIME-LAPSE SURVEY

The time-lapse research site at Kilcloghans, Tuam, Co. Galway was adjacent to a proposed road scheme, the excavation of which (McKinstry 2008; 2010) revealed a ringfort enclosure ditch, half of which was excavated within the road scheme, while the remainder was persevered beyond it. Subsequent geophysical investigations (Bonsall and Gimson 2007) determined the presence of a second larger enclosure adjacent to the ringfort and demonstrated that both were suitable for an earth resistance assessment.

The time-lapse surveys were carried out over a 40 m x 40 m survey area located across each of the curved enclosure ditches. The survey area was located 5 m beyond the area of excavation, upon undifferentiated limestone, overlain by limestone tills and well drained soils, which are representative of the most frequent soil types found across Ireland. The ringfort enclosure ditch was 1.25–1.45 m deep, 2.06–3.58 m wide and V-shaped in profile. The larger enclosure has not been excavated and is only known from the earlier geophysical survey (Bonsall and Gimson 2007).

TIME-LAPSE SURVEY METHODOLOGY

The time-lapse study used Twin-probe, Square and Wenner arrays (Table 1) to determine which obtained the most/least favourable outcome. The earth resistance surveys were conducted once a month for 14 months; all of the data were collected on the same day per month.

Table 1. Method of data capture in a 40 m x 40 m survey area at Kilcloghans

Instrumentation	Probe separation	Sample interval	Traverse interval
Square array (alpha and beta)	0.75 m	1 m	0.25 m
Twin-probe array	0.5 m	1 m	0.5 m
Wenner array	0.5 m	1 m	0.5 m

DATA ANALYSIS

Three different methods were used to analyse the data.

Can archaeological features be visualised in earth resistance data throughout the year? Geophysicists carrying out a single assessment on one occasion will need to make informed interpretations on the basis of the data collected, as well as climate-induced influence. To determine this, greyscale images of each earth resistance dataset (per month, per array) were visually inspected at ±2 standard deviations to determine whether the two enclosure ditches were clearly appreciated in the data. The data from each earth resistance array were also compared to climate extremes to examine the differences in earth resistance response between the driest and wettest periods studied.

The mean apparent resistivities of each dataset were corrected for temperature variations using the Keller and Frischknecht (1966: 31) method and were compared to the net moisture change in the ground per month. This allowed for an investigation of the influence of climate on the earth resistance surveys to determine which array(s) are most/least affected and what impact can be expected for a given weather history.

Apparent resistivity values were corrected to a standard temperature equivalent, which is an important variable to account for intime-lapse studies (Keller and Frischknecht 1966; Scollar *et al.* 1990; Hayley *et al.* 2007). A standard reference temperature of 10.9° C was selected, which represents the average annual soil temperature and compares well with the reference temperatures used by other recent studies (Parkyn 2012; Pellicer *et al.* 2012) and the annual mean of 11° C for Ireland (García-Suárez and Butler 2006).

RESULTS

The most favourable time for an earth resistance survey (using any array) was found to be between March and July (a period when net moisture was considerably lower than rainfall, caused by spring/summer temperatures and moderate evapotranspiration, which for this study happened to occur between March and July).

The least favourable period was found to be between December and February (a period when net moisture and rainfall are very similar, caused by cold winter temperatures and low rates of evapotranspiration, which for this study happened to occur between December and February).

While the Twin-probe array returned lower contrasts for archaeological features (which was expected), it was found to be less influenced by weather changes throughout the year than the Wenner or Square arrays.

In practical terms, a Twin-probe array (the industry default) may normally be more than adequate, but it is quite possible that other arrays would be applicable (or preferable) across variable landscapes, particularly with reference to survey speed (i.e., an articulated Square array) and ease of movement across areas of rough terrain or dense vegetation (i.e., a Wenner array). The most appropriate array for a given survey area must make allowances for ground conditions as well as the best temporal or 'seasonal' response.

An important variable highlighted by the study of contrast factors is the correction of apparent resistivity data for soil temperature. This strongly suggests that apparent resistivity data should be routinely corrected for soil temperature and that it is particularly important for surveys that may occur over several days or weeks.

CONCLUSION

Temporal changes in Ireland do not conform to those established elsewhere. The results from Kilcloghans differ from those from other studies and much of this can be attributed to the local and regional weather patterns in the west of Ireland compared to those in other countries. This unexpected outcome validates the research and highlights the importance of carrying out time-lapse studies in different regions and countries in response to local climates and soils. This also has implications for earth resistance surveys in the short term, which currently occur on the assumed limitations based on previous (non-local) research that could be irrelevant depending on the location of the survey.

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