

Using airborne LiDAR intensity to predict the organic preservation of waterlogged deposits

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1 Introduction

Airborne remote sensing techniques have traditionally been employed to great effect in mapping the cultural archaeology and to a lesser extent the geomorphology of valley floor landscapes. Archaeologists have largely focused their attention on the comprehensive mapping of cropmarks and other features of the archaeological landscape revealed from aerial photographs (eg. Riley 1980; Whimster 1989), and large areas of England have been comprehensively mapped as part of the National Mapping Programme undertaken by English Heritage (Bewley 2003). Aerial photographs have also been employed in mapping geomorphology in alluvial landscapes, for example in extensive studies of the valleys of the Rivers Trent (Baker 2003; Garton and Malone 1998) and Thames (Lambrick 1992; Robinson and Lambrick 1994). Such mapping of fluvial geomorphology provides a context for past cultural landscapes and assists in identifying topographical features of high archaeological potential (for example relict river channels) and isolating areas of past river erosion where little in the way of archaeological material might be expected to survive (*cf* Brown 1997). The systematic reconnaissance, mapping and classification of aggregate bearing valley floor landscapes in this way has played a significant role in the strategic management of the geoarchaeological resource and intimately associated archaeological remains (e.g. fishweirs, bridges, platforms, trackways, etc.) in the face of growing impacts from aggregate extraction and other development pressures (Bishop 2003). More recently, information relating to former fluvial regimes is also being increasingly used in understanding wider issues of floodplain management, particularly with respect to assessing the impacts of changing flood frequency and magnitude with respect to future climate.

While the two dimensional record of air-photography provides an approach to mapping the quantity of archaeological material (both cultural and geoarchaeological) within aggregate bearing landscapes, it provides no indication of the state of preservation of that material or the associated cultural evidence. In particular, aerial photography provides no indication of the moisture level and the potential for the preservation of organic sediments. This is a significant shortfall in the usefulness of the data, since the presence of moist,

organic-rich sediments may greatly increase the archaeological value of deposits.

In contrast to photography, airborne lidar provides access to high resolution, high accuracy terrain information and as a secondary output a laser “image” of the land surface derived from measurements of the intensity of reflection of each laser pulse. A typical airborne lidar is able to record multiple returns for each laser pulse (Figure 1) enabling the recording the top of the vegetation canopy and the underlying ground surface. In most systems intensity is taken as being the measurement of the amplitude of the returned pulse, and is usually recorded on an 8-bit digital scale. To date, archaeological applications of Lidar have focused largely on its ability to provide a high resolution record of terrain variation, allowing the detection and mapping of subtle archaeological features (Bewley *et al*, 2005), mapping of fluvial geomorphology (Challis 2005 and 2006) and due to its unique ability to penetrate vegetation cover to map archaeological earthworks under vegetation (Devereux, *et al*, 2005). Laser intensity measurements have largely escaped attention, and indeed do not form a part of the standard data product supplied by Environment Agency (EA: Brown *et al*, 2003) the chief instigator of lidar survey in the UK (although intensity data is collected on each EA flight and can be accessed by reprocessing original flight data).

The lidar system used by EA, NERC and many UK-based commercial lidar providers (an Optech Airborne Laser Terrain Mapper) utilises a laser that operates in the near infra-red (NIR: 1047nm) and so backscattered intensity is in-effect a record of the reflectance of earth surface materials at this wavelength. While it is recognised that other airborne remote sensing techniques (ATM, CASI, etc.) may be equally or more effective than lidar at detecting geoarchaeological and anthropogenic features, our present study focuses on lidar for a number of reasons. Principally lidar has been chosen as the basis of this study because it is an emerging technology, still poorly understood within the archaeological community. There is a growing demand for and supply of commercial lidar providers. National agencies such as EA already operate lidar, while Ordnance Survey are actively investigating a move into ownership or a lidar system for data acquisition to assist national mapping. Some good work has been done of understanding the parameters of

lidar terrain mapping required for archaeological purposes (Challis 2005, Crutchley, pers comm) and so archaeologists are equipped to specify such work when commissioning survey. However, little or no work has been undertaken to investigate intensity, which until now has been largely ignored both by archaeologists and by the lidar industry as a whole.

2 Researching Lidar Intensity

Initial examination of backscattered laser intensity data by the applicants (Challis, 2006) suggests that a fall-off in the intensity of the reflected light corresponds with the position of sediment filled landform features such as palaeochannels (Figure 2). Variations in the reflectivity of various earth surface materials to laser light are well-documented (Wehr and Lohr 1999, 74) and damp soil conditions are known to reduce reflectivity. It is possible that the increased soil-moisture associated with palaeochannels, and perhaps other associated variations in soil and vegetation properties, are responsible for the reduced reflection of the laser pulse. This phenomenon is largely untested but demands further examination as if reflected laser intensity is closely related to soil moisture it may provide a useful means of identifying areas of preferential organic preservation. The rigorous examination of lidar intensity data, both to identify geoarchaeological and anthropogenic features and to remotely determine wetness and other soil and sediment properties forms the core of the research described here.

In most aggregate-rich areas the *greatest* potential for organic preservation is usually associated with palaeochannels, whose position within the landscape is already known from the analysis of aerial photographs and historic maps. Information gained from analysing lidar data is unlikely to identify new areas of organic preservation, but may help in the rapid assessment of valley floor corridors, preventing the need for costly investigations prior to the submission of planning proposals and provide an indication of the preservation potential and degree of waterlogging.

Our on-going research has two components: firstly aimed at determining the soil properties characterized by backscattered laser intensity through use of terrestrial laser scanning; secondly at systematic investigation of the backscattered laser intensity component of airborne laser scanning.

3 Terrestrial Lidar and Intensity

The initial stage of the research investigated the land cover and properties influencing laser intensity. Since mobilisation of an airborne system is both costly and time consuming, with no guarantee that data can be collected to suite specific soil and vegetation conditions, work on this stage of the project made use of a NIR terrestrial lidar with appropriate deployment and data manipulation to simulate airborne lidar. Work was undertaken both to investigate the extent to which intensity data might allow

identification of buried archaeological remains through their physical expression at the earth surface as crop or soil marks (including those not otherwise evident in the visible portion of the spectrum), and to examine and quantify the aspects of land cover, soil and sediment properties affecting intensity values.

The project investigated the impact of ground conditions and vegetation on lidar intensity through examination of a variety of ground cover types. Briefly, work was undertaken to collect intensity data for sites with bare earth such as ploughed fields, equating to conditions where archaeological soilmarks may be evident, growing crops, where light crop cover is unlikely to give any indication of buried features using conventional techniques, and areas of mature crop where cropmarks might be expected to form. Areas of permanent pasture were similarly investigated to determine to what extent archaeological remains may be detected and analysed through lidar backscatter in such conditions.

Information on weather conditions prior to each survey were collected from the nearest Metrological Office ground station so that some attempt at gauging impact of prevailing conditions on soil properties may be made. Fieldwork collected laser backscatter data using a NIR terrestrial lidar to scan the ground surface at selected test sites (Figure 3). The use of a ground-based lidar allowed collection of dense data (100s points / m²) that were resampled to reflect typical point densities for airborne lidar at varying resolutions. Use of a highly mobile ground-based lidar allowed rapid collection of multiple data on each survey visit to allow for example, the investigation of factors such as scan direction, angle of incidence, and short term environmental conditions on intensity values. Intensity data were compared with simultaneously collected information on land cover, soil and sediment properties. This included analysis of the physical properties of soils through the analysis of sediment samples from each test site in order to assess organic content, moisture, geochemical signature and particle size. Initial results, which take into consideration measurements of volumetric soil moisture only, show a weak inverse relationship between soil moisture and intensity (Figure 4). This suggests that areas of low laser intensity may act as a reliable indicator of damp soil conditions. Further analysis will determine the extent to which other soil properties affect intensity, and the contribution of each recorded property to the overall intensity reading.

4 Airborne Lidar and Intensity

Subsequent stages of the research aim to determine to what extent the properties of lidar intensity predicted though use of a terrestrial laser system hold true for airborne lidar. Airborne data for test sites will be collected and similar calibration with land cover, soil and sediment properties undertaken as for stage one. In order to avoid the cost of new commissioned flights the team

will liase with the EA airborne remote sensing facility and with commercial lidar providers to identify areas that

will be flown in the future and co-ordinate field data collection with over flights in appropriate areas.

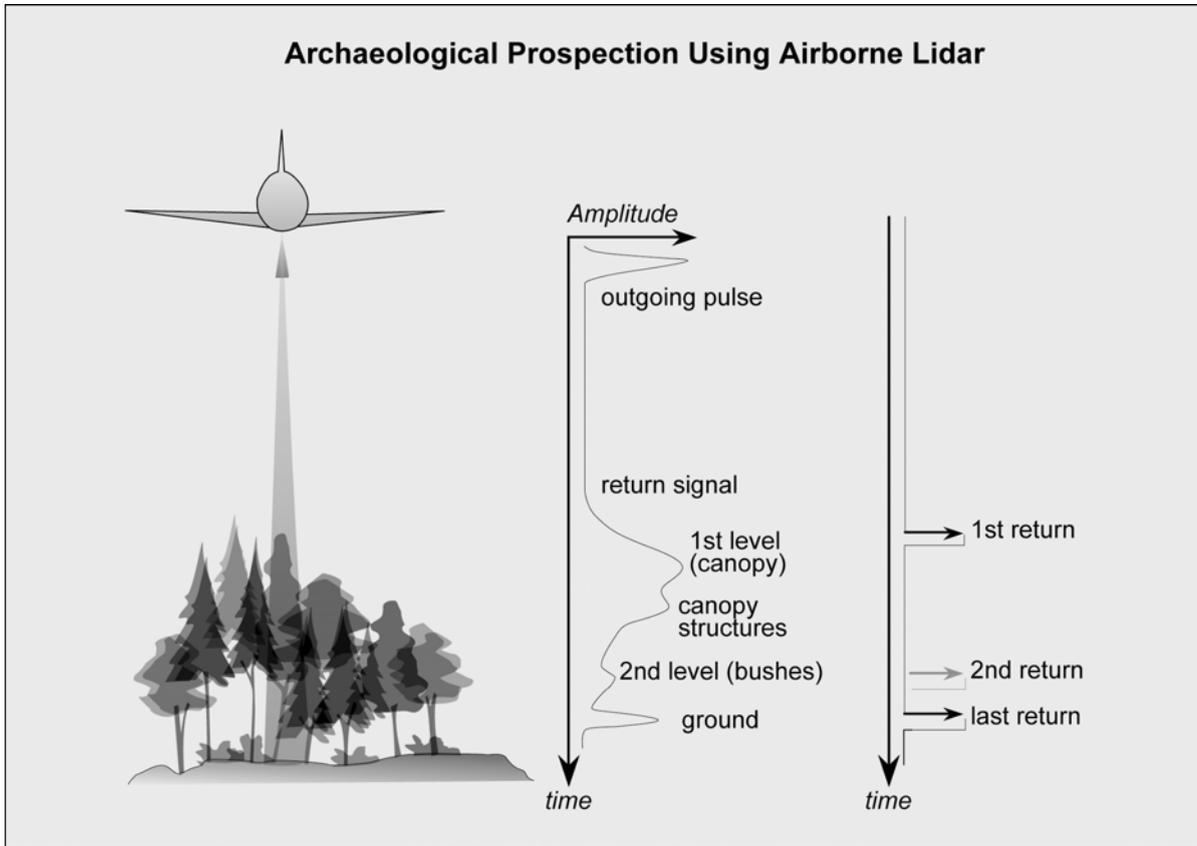


Figure 1 Diagram showing a typical airborne lidar. Typically, each pulse is reflected from a number of objects on the earth's surface, generating multiple returns that are captured digitally as discrete pulses by the data logging system. The amplitude of each return is logged as the intensity value.

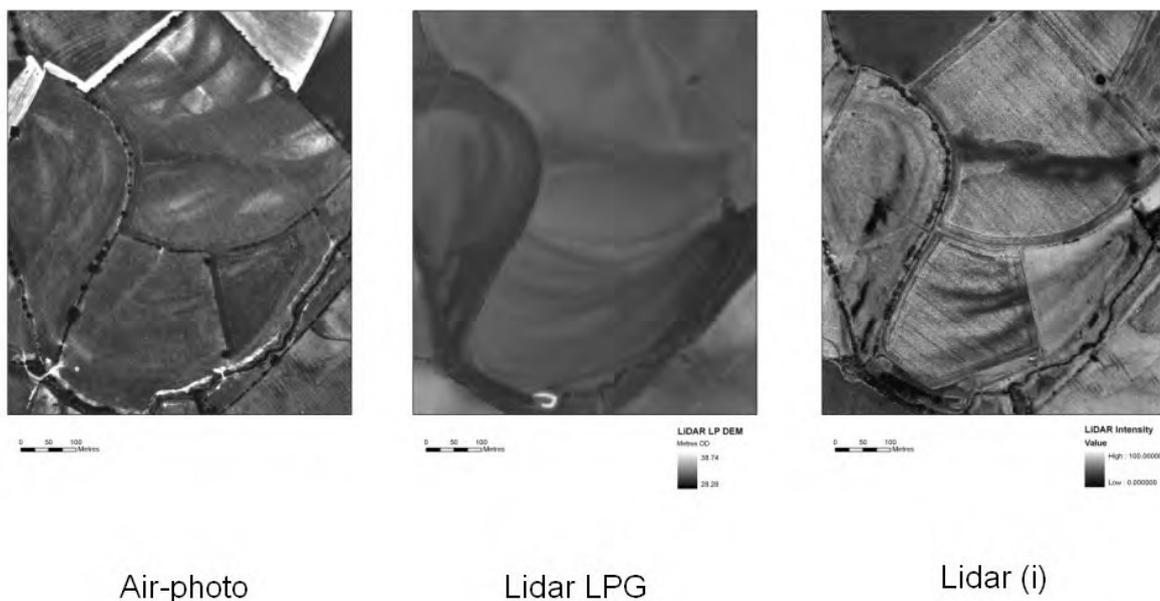


Figure 2 Comparison of air-photographic evidence, lidar last pulse surface model and last pulse intensity for a part of the Lockington test site. Note that the same palaeochannels are evident to different degrees in each data source.

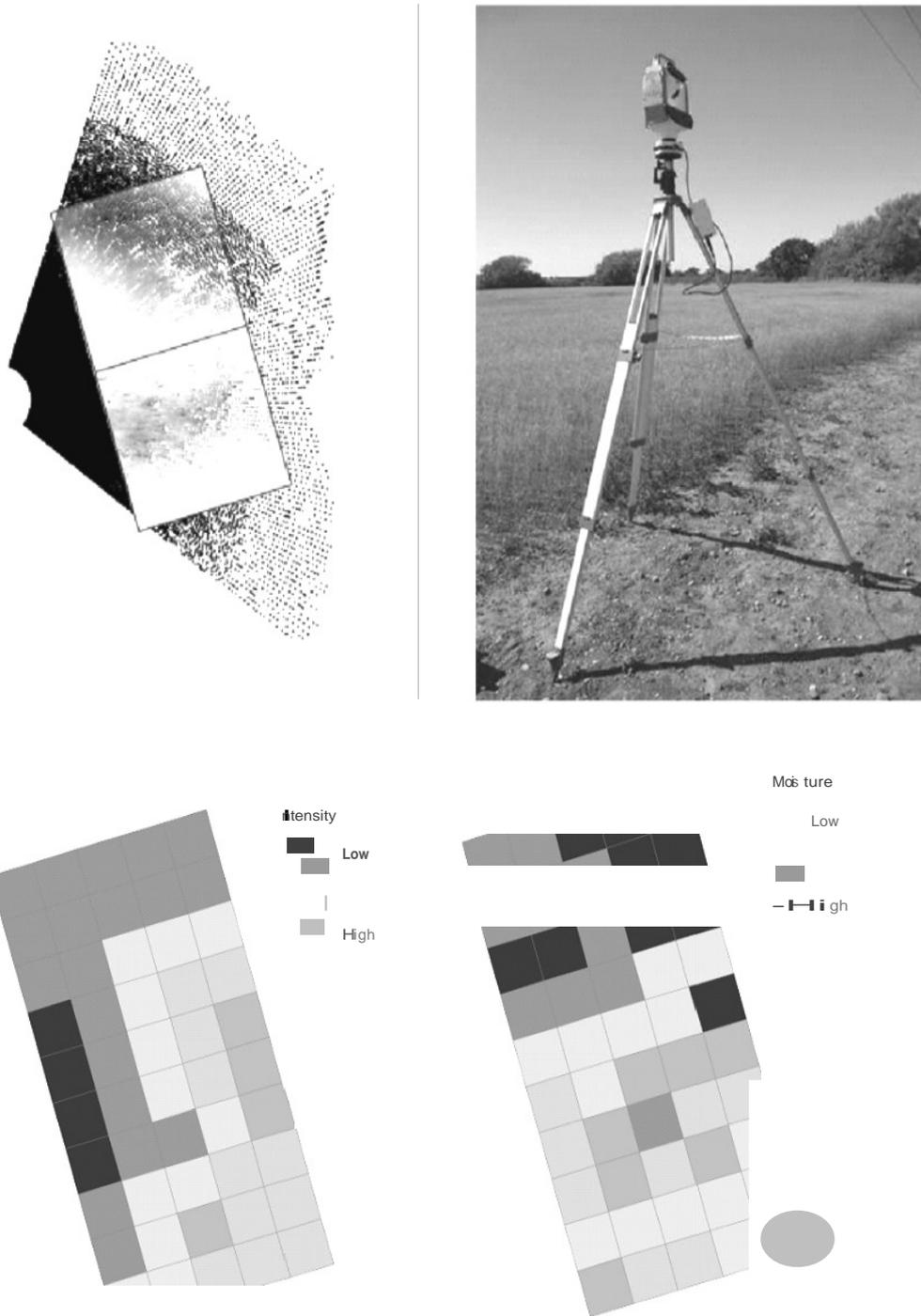


Figure 3 Terrestrial laser scanning in use to simulate airborne lidar, showing: (top) MDL Laser Ace laser scanner mounted on 4m tripod and scanned point-cloud data with two 20x20m sample areas extracted (bottom) intensity values (aggregated by 4m square, extracted from the scanned point-cloud data) and field collected volumetric soil moisture for the two 20x20 sample areas.

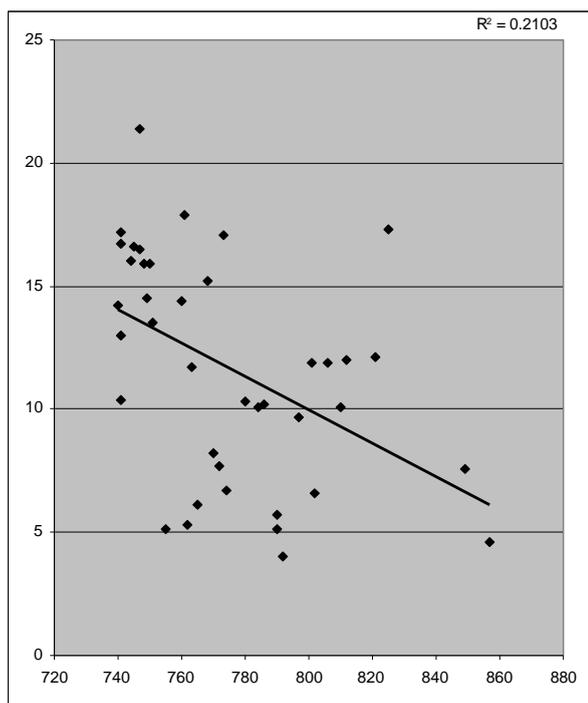


Figure 4 Scatter plot showing the relationship between intensity and volumetric soil moisture in the two 20x20m sample areas show in figure 3. The R^2 value of -0.21 suggests a weak negative correlation between intensity and soil moisture.

Investigation of newly collected lidar data will be supplemented by examination of intensity data from archive lidar surveys held by EA and others. A number of problems are anticipated in examining airborne intensity data. Most notably, intensity data from Optech airborne systems has a number of recognised but undocumented issues each of which will require careful investigation and consideration. Intensity values are not constant as sensors may be adjusted from flight to flight to provide different data collection parameters. Within any single flight, intensity values vary markedly depending upon the direction of the flight path so that for example, adjacent flight paths may exhibit different intensity values for similar earth surface materials. Since this means that intensity values are not recorded on an absolute scale and vary across or even within flights analysis will focus on change of intensity value within individual survey flights, and within flights on analysis of intensity values within individual flight lines.

5 Conclusions

The on-going research described in this paper is intended to culminate in a good practice document relating to airborne lidar intensity aimed at those in the archaeological and development control community who might be called upon to commission or interpret lidar surveys. It is hoped that the research will inform the commissioning of future lidar surveys to take into account the potential of intensity data to provide a qualitative assessment of the archaeological resource and

encourage the reassessment of existing, archive, intensity data.

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