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3D Data Fusion for the Presentation of Archaeological Landscapes: A Scottish Perspective

Abstract: A 3D presentation can provide a very attractive platform to publish landscape-scale archaeological surveys. Besides eye-catching presentations, what are the research applications of 3D data for landscape archaeologists? This paper (in conjunction with a 3D landscape visualisation) presents a preliminary attempt by the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) to deliver survey data at both landscape and monument scales in 3D. We will also assess some of the research potentials for 3D data publication from a landscape and monument perspective.

Introduction

GIS software in both free and proprietary forms has allowed students, researchers and teachers to present data in 3D format, which "brings landscapes alive". This step change in data presentation has dazzled the archaeological community, but beyond the "wow" factor, what more does 3D data presentation give us (Austin/Stamper 2006)? The first part of this paper outlines the process of creating a 3D visualisation of an area of Scotland that was surveyed as part of a RCAHMS 2005 archaeological landscape survey. It also presents the potential for a monument specific survey within that landscape. The second part of the paper assesses the research potential of 3D data presentations as a tool for landscape archaeologists.

Background

RCAHMS undertook an archaeological landscape survey in 2005 as part of a partnership project with Defence Estates (DE), an Executive Agency of the Ministry of Defence, to provide a baseline survey to enhance the historic component of the Land Management Plan for the Castlelaw and Dreghorn Training Area (CDTA). The survey set out to record all visible archaeological features, including relict military remains.

The CDTA is situated towards the NE end of the Pentland Hills Regional Park, immediately south of Edinburgh *(Fig. 1)*. It measures a maximum of 5 km from north to south by up to 3.9 km transversely and covers an irregular area some 7.9 km² in extent. The area contains a central massif, comprising a series of hills rising to 493 m OD. A narrow ribbon of pasture fields that extends along the southern side of the Edinburgh City bypass marks the northern edge of the CDTA. The southern end of the training area is a patchwork of cultivated and pasture fields. Most of the training area is heather or grass moorland, with a few small patches of woodland and the overall current land-use is sheep farming.

Archaeological Survey

The fieldwork component of the project saw the area inspected on the ground. Features that were not on the Ordnance Survey map were surveyed using a Leica System 1200 differential Global Positioning System (dGPS) with an accuracy of ±2 cm. Features identified from an examination of historic aerial photographs and maps were visited on the ground, to be verified or disregarded. The CDTA is covered by good quality vertical aerial photography, taken in 1947, 1953, 1960 and 1969, and colour photography taken in 1988. The 1st and 2nd editions of the OS 6-inch map of Edinburghshire (1854–5 and 1895–1905) have been valuable sources for understanding the mid 19th and late 19th century landscapes, respectively.

As a result of the documentary research and the field survey, the project generated a large volume of digital data, ranging from coded dGPS line work depicting monuments and landscape features in GIS shapefile format; scanned and geo-referenced Ordnance Survey 1st and 2nd edition maps as TIFF files; aerial photographs as TIFF files, and digital photography as TIFF and JPEG files. This mixture of documentary and survey generated data allows

Fig. 1. Location map of Castlelaw and Dreghorn Training Area. ((DP006980) ©Crown Copyright. All rights reserved, Ordnance Survey Licence Number 100020548 2007)

for a wide variety of presentation options in the 3D environment.

3D Visualisation Production

The fieldwork and documentary research produced data that needed to be judiciously sifted in order that the 3D visualisation conveyed both landscape and monument scale characteristics. It was felt appropriate that visualisation at these different scales would best demonstrate the variation in character between the monument and the landscape. The data sifting produced eight focal sites for the landscape visualisation. Appropriate raster and vector data would be overlain on a backdrop of Getmapping's Nextmap millennium map of Britain, comprising colour photographs with a ground resolution of up to 15 cm per pixel. These vertical photographs were draped over Intermap's digital terrain model (DTM) of the CDTA landscape. The eight foci included 20th century military works and medieval cultivation remains and Bronze Age house platforms, and were used to show datasets in combinations that would

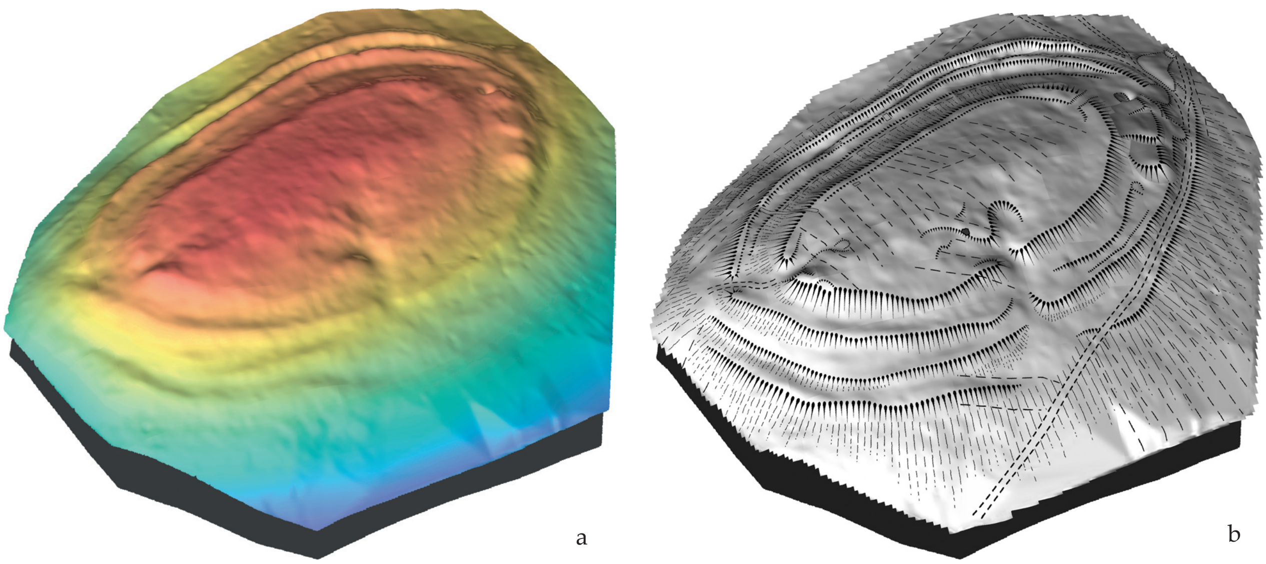

Fig. 2. a. (above left) DTM of Castlelaw fort shows topography derived from the differential GPS survey (SC1059248). b. (above right) Plane table drawing showing Castlelaw fortifications in relief using the DTM heights (SC1059249). (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

convey particular characteristics and changes in the landscape.

The monument specific example used the late 1st Millennium BC Iron Age fort at Castlelaw, in the south-east of the CDTA area, and was chosen to show the range of site-specific data that can be used in 3D site analysis. The data included original excavation plans from the 1930s and 1940s, survey drawings from 1915 and a digitally inked drawing from the RCAHMS 2005 survey. A key element of this monument specific example was to fine tune the height data over which these data elements would be draped. This required the production of a localised digital terrain model (DTM) of the earthwork *(Fig. 2a)*. This DTM was created from 17,000 dGPS spot heights measured across the 140 × 80 m area of the fort to help examine its interior for signs of settlement remains. A complementary plane table survey of the fort produced a hachured plan to demonstrate a conventional 2D survey method and the benefits of its integration within the 3D virtual environment, achieved by draping the plane table survey over the DTM *(Fig. 2b)*. To facilitate the visualisation "flythrough" ESRI's ArcScene 9.1 animation tools were used to create frame-by-frame animation files in Audio Video Interleave (AVI) format for both the landscape and the fort. Orientation on observation, time to view and monument labelling were considered and edited for each of the foci and the fort to demonstrate different research themes *(Figs. 2–7)*.

Vector Data

The line work plotted during the dGPS survey fieldwork and that digitised from aerial photographs represented cultivation, site boundaries, wall lines and individual site features. This line work comprises attributes that are part of the CDTA site database. This vector data included z values (height data) for each survey point node or digitised point. The height data enabled the site features to either sit incongruously against the lower accuracy background, or by attributing the line work directly with the Intermap height data, to form an uninterrupted surface. Most of the foci could easily be recognised and understood using simple 3D polylines. However, it was felt that some sites would benefit from extrusion of polygons created from their line work depiction. This was undertaken to enhance site area extent, wall thicknesses and their probable height above ground level. See, for example, the Bronze Age platforms on Capelaw Hill *(Fig. 6)*.

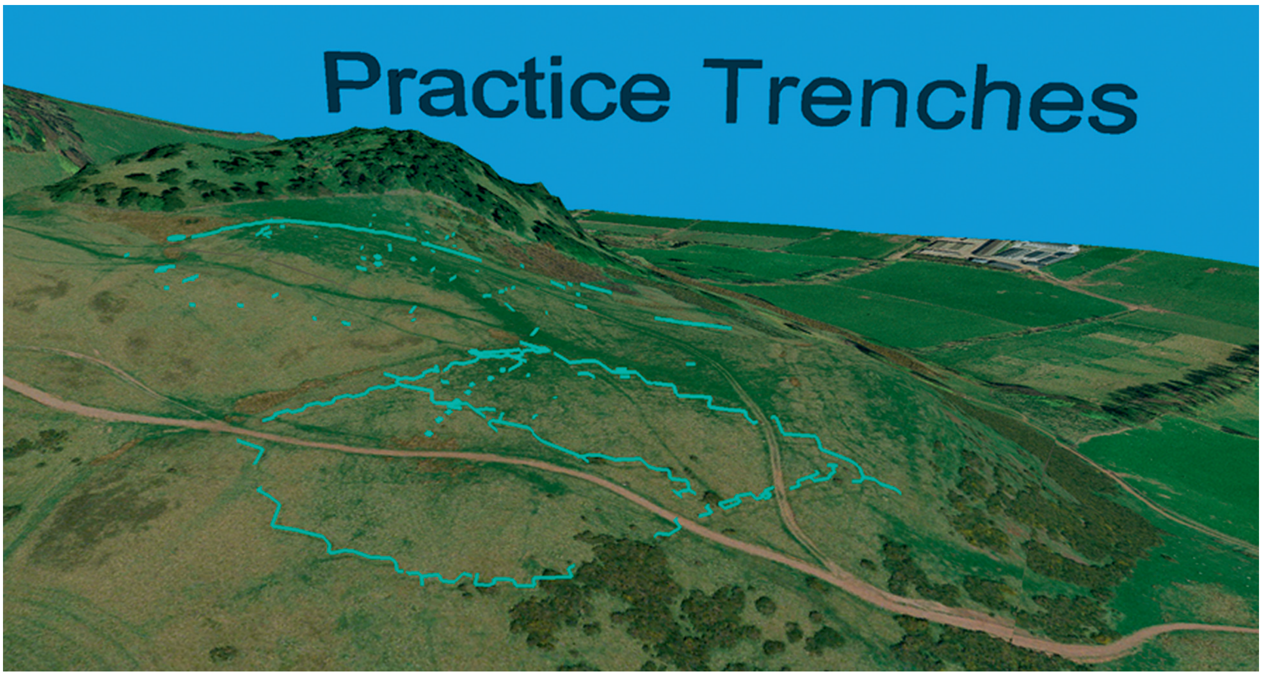

Fig. 3. Survey line-work (vector data) of relict World War I and II military trenches overlain onto the background of Getmapping's draped photography. (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

Raster Data

Maps and drawings were geo-referenced in ArcMap 9.1, as they have none of the distortion associated with oblique aerial photographs. These were rectified and geo-referenced using Aerial 5.31, a software package that can mathematically calculate a pixel-by-pixel rectification, taking into account topographic change across the area of the photograph. The raster data was, in each case, site or locale specific and chosen to be representative of particular types and periods of landscape usage or change. This raster data, when overlain on the Getmapping images, was attributed with the height data of Intermap's DTM. This created a metrically accurate site-specific overlay, viewed against a true background context.

Research Applications and Potential

The researcher can employ an empirical approach to the questions posed to archaeological landscapes and this approach is one that the authors maintain as the most solid of foundations for research utilizing 3D data. Given the complexity and the temporal and spatial extents of archaeological landscapes, the researcher can be faced with vast quantities of data of differing types, media and quality. The following outlines the authors´ experience of using a 3D environment to display, integrate, interrogate and present archaeological landscape data. Once working with data in the 3D environment, the researcher can see the landscape as a palimpsest of preserved topographies, across which there are caches of archaeological data that can be turned on and off at will. Additionally, to provide diachronic understanding of landscape remains, features can be made to fade in and out allowing the user to visualize change. The speed at which the change occurs is clearly not real-time and thus can provide a rather concentrated (speeded up) or telescoped (slowed down) view of landscape change.

The software provides a framework for the integration of data derived from all aspects of landscape studies from geophysics, archive material, survey data (GPS or others), LIDAR scanned landscapes, laser scanned objects and excavation plans (see Wright / Patterson 2007 for an example of a National Park visualisation). However, the authors' experience found that "less is more" when it comes to landscape-scale data. Many more than three datasets superimposed became confused and did not necessarily enhance the focal sites, especially when using the fade tools to provide dynamic change scenarios. The 3D environment is an excellent medium for the interrogation of landscape archaeology, but this is wholly dependent on the quality of the data that is being used. These types of interrogation software allow predictive modelling, which can be tested when field-checked. Other spatial analysis tools, such as viewsheds and altered altitudes of vegetation or sea level can provide modeling sequences to enhance our ability to understand microtopography.

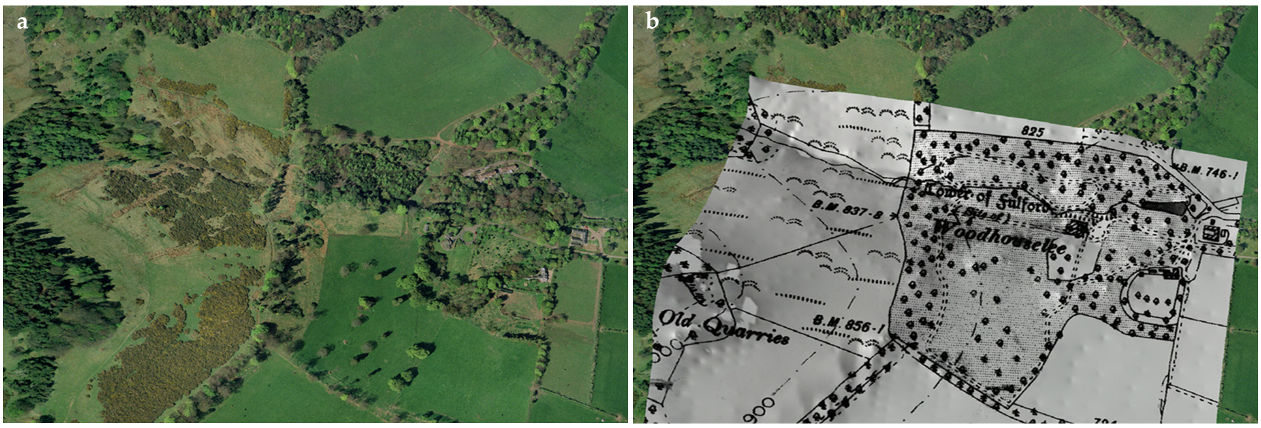

Fig. 4. a. Background photograph of Woodhouselee parkland showing the dispersed, mature trees (middle of image). b. A semi-opaque Ordnance Survey 2nd edition map of Woodhouselee showing the depicted trees with those present in the parkland on the background photograph. (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

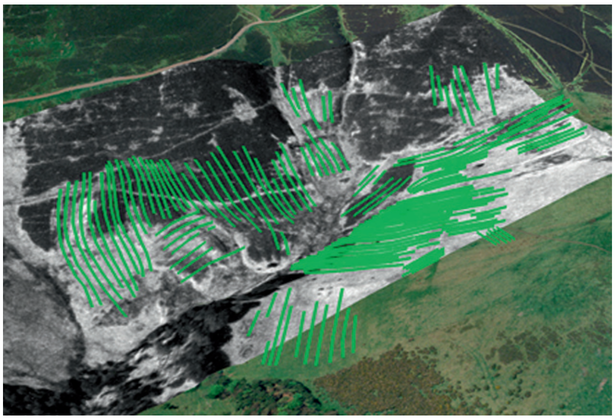

Fig. 5. Part of an archive aerial photograph showing rig and furrow cultivation remains, with survey data overlaid. (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

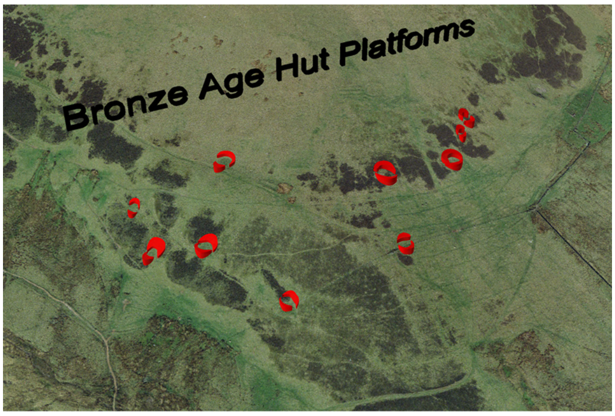

Fig. 6. The Bronze Age hut platforms (commonly termed an unenclosed platform settlement) with their outline extruded to 2 m in height. (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

Visualising Change

Our approach attempted to work at landscape-scale in a rural environment, rather than repeat the plethora of object-based projects (from museum artifacts to structural remains) or urban flythroughs (e.g. Glasgow City Council). At RCAHMS, landscape-scale archaeological surveying has been a central tenant of our remit as a government funded non-departmental public body. However, it was after the data had been gathered in the field that the 3D analysis was undertaken. This enabled us to draw upon the desk-based documentary evidence and combine it with the field-generated data. Our first attempt used all line-work generated in the field and provided a mass of colourful lines, generated through ArcMap files. This included individual furrows between rigs (cultivation remains), which confused rather than clarified the extent of remains, individual monuments and landscape features. So it was decided that we would strip out a large amount of the data in order to create foci within the landscape. These foci could be individual monuments, but more often were a group of monuments, sometimes related in time and space but not always, or combined monuments and landscape features, such as field boundaries. Using Intermap's digital terrain model (DTM) and Getmapping's Nextmap millennium map of Britain photographs as the constant background, we applied seven combinations of data to create the eight foci in the CDTA landscape. The following screen grabs illustrate the different data combinations used in the visualisation.

Research Applications

The 3D visualisation enables us to visit the landscape, move through it and view chosen sites and landscape features. In terms of research applications, the recording of landscape-scale change is the major benefactor. This can be achieved and magnified once combinations of data are overlain on the original background canvas. The combinations present site location, form and context, however, it is with the fade function that change can be illustrated. For example, when combining the OS 2nd edition map with the Woodhouselee estate parklands, the locations of the individual mature trees can be appreciated and their presence or absence recorded *(Fig. 4)*. Similarly, by overlaying the 2nd edition OS map (1895) over the 1st edition sheet (1854) at Capelaw farm we can identify recorded change; for example the farm building is roofed and subsequently unroofed and there are sub-divisions within the enclosure *(Fig. 7)* by the time the farm is depicted on the 2nd edition map. What we do not see are the drivers of change, for example if an estate changes ownership. However, if documentation is available for such events then these can be incorporated into the visualisation. Another example is the analysis of the interior of Castle Law fort. Careful analysis of the fort data using ArcScene's light and vertical exaggeration controls confirmed that the fort had been heavily damaged by 18th/19th century cultivation, which had obliterated any surface

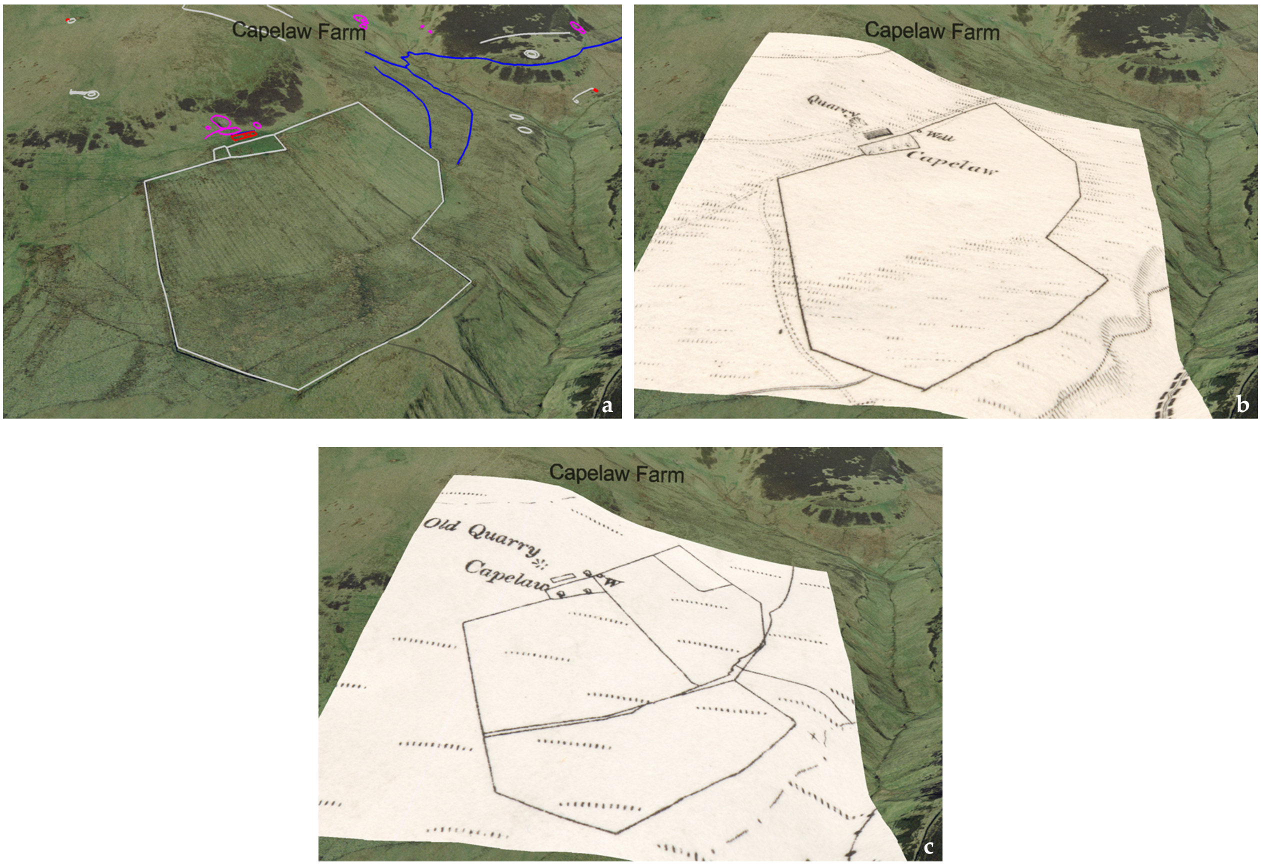

Fig. 7. a–c. Capelaw farmstead and enclosures depicted with survey linework (left), the OS 1st edition map (right) and the OS 2nd edition map (bottom). (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

Fig. 8. The 2005 hachure drawing draped over the dGPS DTM of Castlelaw Fort, set in the context of the Getmapping landscape photography. The drawing shows the 18th/19th century cultivation furrows cutting across the central area of the fort. (©Crown Copyright. All rights reserved. Background images and landscape height model data copyright of Getmapping© and Intermap©)

For a 3D flythrough see http://www.vimeo.com/2039138

evidence of settlement remains in the interior (see furrow lines depicted on *Fig. 8*). The other values of visualisations for research are the potentials for modeling site locations and landscape features and the identification of additional sites, based upon understanding common landscape characteristics and testing them during prospective fieldwork.

Closing Remarks

Working within the 3D virtual environment is both challenging and exciting at landscape-scale. Often visualisations present urban landscapes, with no focus on individual sites or the converse occurs and they remain fixed upon one item. The visualisations presented above enable the landscape archaeologist to undertake data manipulation and analysis, and demonstrate spatial and temporal change at a range of scales. Data fusion models, such as the RCAHMS attempt discussed here, illustrates how datasets must be used judiciously to provide clarity for analysis, from which modeling can be developed to inform future programmes of fieldwork. We have attempted to provide a mixed economy that maintains the landscape-scale and brings out the germane attributes of certain sites.

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