Model Landscapes: on the use of GIS in archaeology.

The last ten years or so has seen ever more powerful computers becoming available at relatively low cost. Advances in computational speed and data storage, coupled with a growing awareness and access, has resulted in the almost ubiquitous use of Geographic Information Systems (GIS) for the manipulation and presentation of spatial data in archaeology. Vast quantities of data can be quickly processed, modelled, analysed and presented by computer programs and although they may not be designed for archaeology, being aimed at planning, logistics, oil exploration, and other 'high value' commercial applications, can nevertheless be used to good effect. A recent development in the UK was the presentation of Lidar data within a GIS, the primary purpose of which was to enable flood water studies, but is now revealing many hitherto unknown archaeological features. Like so much in archaeology we borrow and adapt innovation designed for others (fig.1).

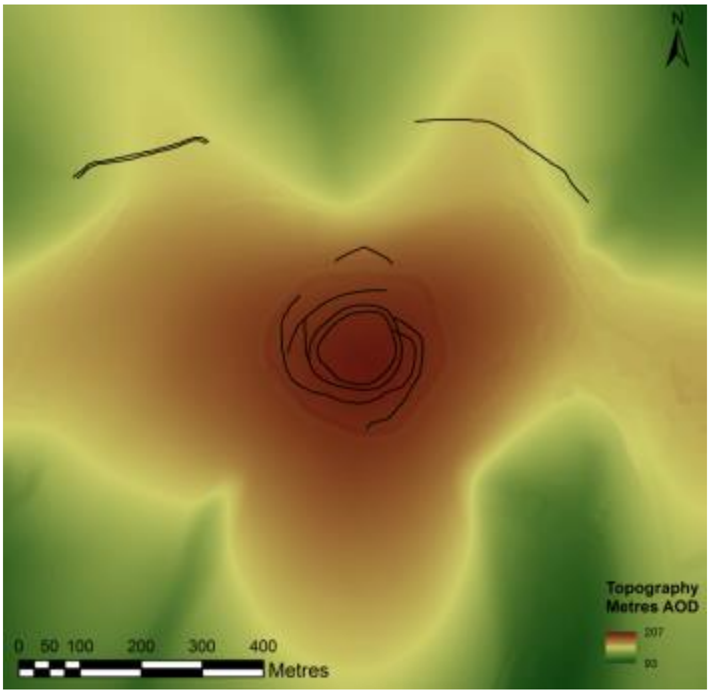

Figure 1 – The Trundle (Sussex)
Lidar data, superimposed on a Digital Terrain Model (DTM) where the higher ground is shown brown and low ground green. This coarse Lidar provides a resolution of 100cm over the Chalk Downs but still clearly shows the contours of the pentagonal Iron Age hillfort. The remains of the early Neolithic causewayed enclosures within the hillfort and the external cross-dykes are less obvious and here are sketched in, based on a combination of field survey and geophysics. The GIS provides the ability to quantitatively relate the causewayed enclosure to the immediate, surrounding and national topography.
Spatial data: Edina Digimap, Crown Copyright/database right 2010. An Ordnance Survey/Edina supplied Service. Lidar data: Geomatics, The Environment Agency

Much (?all) of the data we seek and use in archaeology has some spatial component that we use to build our interpretations. It's a techniques that can be tracked back at least as far as, for example, the work of Pitt-Rivers who presented clear plans and sections locating, in 3D, all the artefacts recovered from his work on Bokerly Dyke (Wheatley & Gillings, 2002). The modern trend towards cartographic presentation can probably be traced back to the 'New Archaeology' of the 1970's and today we see the use of GIS in presenting maps, the distribution of artefacts on a single site, the distribution of trenches over a wider area of interest, monuments across the country and many other applications. Indeed the use of GIS in presenting archaeological data is so common-place that we accept it without even recognising the GIS process that goes in to building the model. And that is how it should be.

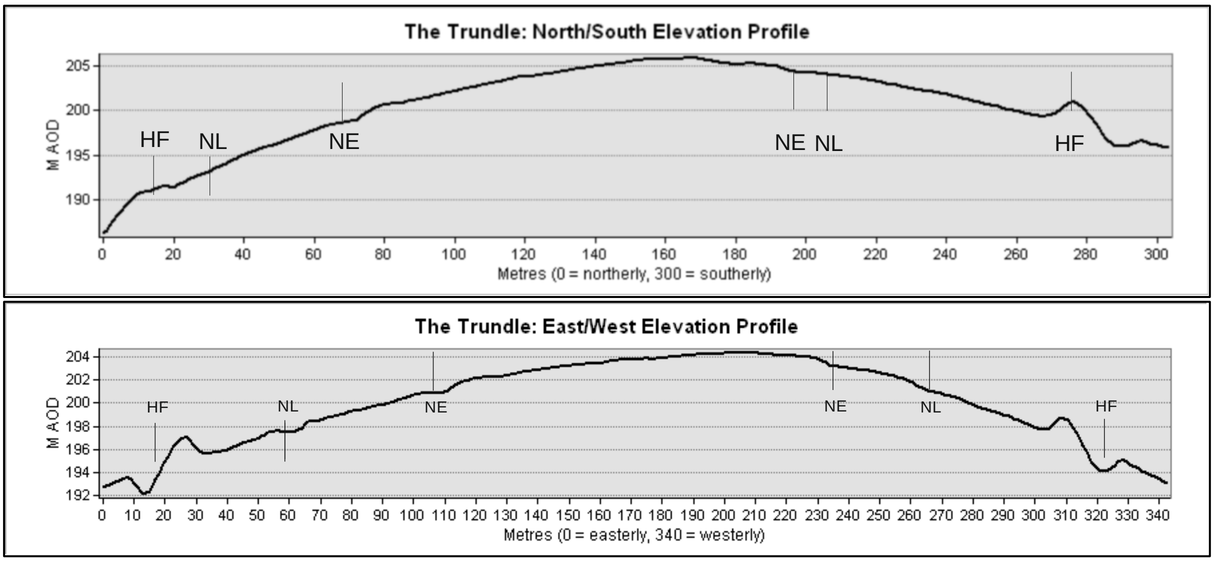

Figure 2: Elevation profiles for The Trundle.
HF, NL, NE: Earthworks associated with the Iron Age hillfort and with the Neolithic linear features and enclosure, respectively. Here the GIS is used to slice through the hillside, itself derived from the Lidar data, to provide a profile in 2 directions. The profile is derived from the same dataset as that in figure 1 but the GIS has allowed the scale to be changed and now shows how the Neolithic components are reflected in the data.
Whilst, in east-west direction, the enclosure is broadly positioned at equal elevations across the brow of the hill, the north to south orientation shows a bias toward the northern aspect.
Spatial data: 1m resolution Lidar data, Geomatics – The Environment Agency

GIS systems range from the free 'open-source' applications like GRASS GIS (http://grass.osgeo.org/) to commercial offerings like ARC GIS (http://www.esriuk.com/) which can cost many thousands of pounds (though are offered for personal non-commercial use at less than £100 per year). All use the same underlying concepts of presenting vector data (points, lines and polygons) and raster data (pictures, built up as 'cell values') and providing mechanisms for storing, manipulating, analysing and modelling these so called 'primitives' and presenting the results, projected to a scale and within a coordinate system, that corresponds to the needs of the user. The difference between the various systems is reflected largely in the user interface, and the power and range of the analytical tools provided. The design of some GIS leans towards either vector or raster data.

This short contribution is aimed at introducing just two analytical techniques used in the archaeological study of landscapes and draws some examples from the authors' current work in researching the landscape context of early Neolithic causewayed enclosures. We shall look first at 'visibility analysis', for example what you can 'see' from a given monument, or where you can see it from (no – it's not always the same) and then 'least cost modelling', that is what is the easiest way of getting from site 'a' to site 'b', or what resources could someone living at site 'a' reasonably exploit.
The results should be considered 'work in progress'!

First we should give some caveats.
Despite the ubiquitous use of GIS in many areas of archaeology the use of the technique in landscape analysis has received criticism in the literature, particularly for its emotional detachment from the landscape it claims to analyse and for its apparent quantitative and mechanistic approach. For example:

GIS provides a dumb, indeed surreal, view of landscape in which everything is equally visible and therefore equally important – which is clearly never the case-and, of course, it can only cope with the visual rather than with other forms of sensory experience. Like any other mathematical technique, it is terribly impoverished and inevitably makes inhuman assumptions in the form of the modelling that is involved. In short it is incapable of providing an embodied encounter with a landscape, or a monument, a feeling for the place in which the place itself exerts its agency, exerts its own powers in relation to human perpetual experience (Tilley, 2010, 477).

And Cummings was equally critical, if more concise: "*Quite simply GIS cannot replicate the experience of being in the landscape so was not used here*" (Cummings, 2009, 127).

Others also recognise that vision is anyway, only one of a number of human senses and have argued that visibility is over emphasised in landscape studies. For example Ingold maintains that a "multi-sensory and kinesthetic dimension" must also both be considered as part of any spatial experience (2000, 158-197) where audio, 'feel' and memory also play key roles.

We might think that with such criticism we are wasting our time with GIS: nevertheless even visibility remains an important facet of most scholarly works of monument and landscape analysis and the same protagonists concern themselves with intervisibility between monuments (e.g. Tilley, 1994, 133-4, 156-159), with astronomical associations (e.g. Bradley, 1993, 52&100-104), whilst others relate a particular monument or monument group to distance landscape topographical features (e.g. Cummings et al., 2005, 47). Llobera (2007, 66) suggests an inability amongst archaeologists to embrace computer based modelling is partly responsible for this stance and like David Wheatley and Mark Gillings (2001, 28-29; 2002) and LK McNamara-Kearin (2013) a decade later, argues that, carefully deployed, GIS can play an important part in such analysis. In particular in extending beyond 'just' the visible and including the quantified topography, geology, and hydrology.

Visibility analysis (viewsheds)

The underlying framework of these studies is the digital elevation model (DEM) which can be mathematically interpolated from contour maps available from, for example, the Ordnance Survey (OS). A model is built up within the GIS where each cell represents a spot height on the ground onto which we place our archaeology. From this we simply look out onto the landscape from our monument (or from the landscape to our monument) and the GIS predicts what is and what isn't visible from a given location.

There are many real problems with this approach which have drawn valid criticism. Interpolating the terrain from the contours is itself a process subject to error. The underlying map data has errors and the mathematical modelling compounds these and introduces more. As such GIS modelling is subject to all the attendant frailties we associate with interpretation: weaknesses which are further compounded by measurement error, model errors, and assumptions made within the input dataset (e.g. Gillings & Wheatley, 2001; 2002, 83-86; McGwire et al., 1996). Not the least of these is the degree to which the modern topography, on which our spatial data is based, is representative of the early landscape. Where we can estimate the difference (e.g. Mercer & Healy, 2008, 7-8; Robinson et al., 2013), we can account for it in the model; however there will be examples where this cannot be estimated with a sufficient degree of confidence.

Other errors relate to the characteristics of the landscape under study. For example an early Neolithic landscape analysis requires a detailed understanding of a landscape, which by definition, is undergoing transition. The improved temporal resolution offered by the statistical interpretation of radiocarbon data (e.g. Whittle et al., 2011) emphasises the rapidity of landscape transition in the period of enclosure construction: this changing landscape is rarely reproducible by the archaeo-environmental record in the landscape 'between the monuments'. Whilst detailed environmental investigation has been carried out at a number of sites, and an environmental record for this period may be provided as a spin-off from other site investigations, the record is patchy and less clear regarding, for example, changes to vegetation, riverine morphology and marine encroachment in the large areas between sites that have not benefitted from such detailed archaeological investigation. The literature has many examples where vegetation, invisible to the GIS, plays a key role in interpreting the monuments environs (e.g. Whittle et al., 1999, 382)

Despite this, I would argue, that GIS based analysis can play an important role in trying to understand the sense of place embodied in the positioning of some monuments within their local environs and whilst it may be unlikely that visibility is the only determinant in positioning, for example, a causewayed enclosure on the summit of a chalk hill, it was surely one factor in the decision making process.

The equal importance argument presented earlier by Tilley can be accounted for, to a small extent, by modifying the visibility model through the introduction of a distance decay function. This shifts the analysis from presenting viewsheds as simple, binary, in-view / out-of-sight models, to one where distance can be represented. Where more distant landscape features are reflected differently to near view ones (Ogburn, 2006). A further refinement can be to reflect contrast, big objects can be treated differently to small ones, or those with high contrast (chalk capped barrows for example) emphasised over the background landscape. These can be accounted for in the mathematical model and reflected differently in the resulting presentation and interpretation (Fisher, 1994). These more complex 'fuzzy viewsheds' overcome some of the shortcomings of the simple binary model.

Intervisibility analysis may be considered on a simple individual pair (single observer and single target), or as an intervisibility network (multiple observer, multiple target) basis. In constructing a visibility model an important consideration is the constraint imposed by distance and hence the dimension of the zone or buffer placed around the observer point. Without such a constraint the model may suggest intervisibilities that are simply not practical.

Case study 1 – Visibility Analysis of Causewayed Enclosures on the Sussex Downs

Figure 1 gives an example of an intervisibility network. The increased geographical range has generated a need for a different dataset for the digital terrain model (DTM) which now has a limit of accuracy corresponding to 10m per cell. That is, if we consider the DTM to be made up of grids of cells, where each cell reflects 10m on the ground, then each cell within the grid has only one value that corresponds to its elevation in the real world. Here the lines between the monuments are indicating the predicted intervisibilities between them, whilst the colour of the lines indicates areas within the landscape that are visible from the 'observer' enclosure at one end of the line. The model predicts that all enclosures intervisible with The Trundle, whilst, for example, the enclosure at Court Hill is only intervisible with The Trundle.

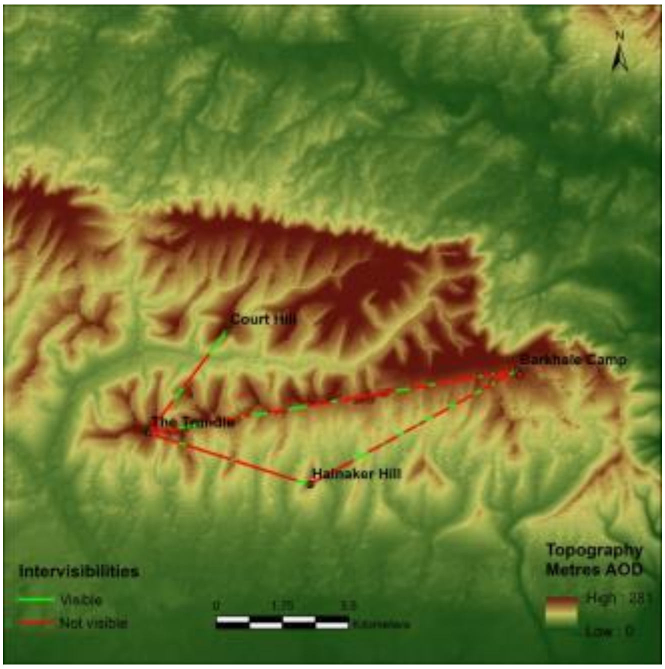

Figure 3.
Visibility network for the cluster of four causewayed enclosures in West Sussex
Spatial data: Edina Digimap, Crown Copyright/database right 2010. An Ordnance Survey/Edina supplied Service.

Figure 4 is an example of two 'fuzzy viewsheds' looking from the highest point within the Coomb Hill and Halnaker Hill causewayed enclosures. The visibility is largely constrained by the immediate topography. In these models, more distance views are shown diffuse (orangey yellow) whilst the more immediate views are more emphatic. Combe Hill is unusual in the Sussex group in having its primary direction of view away from the coast.

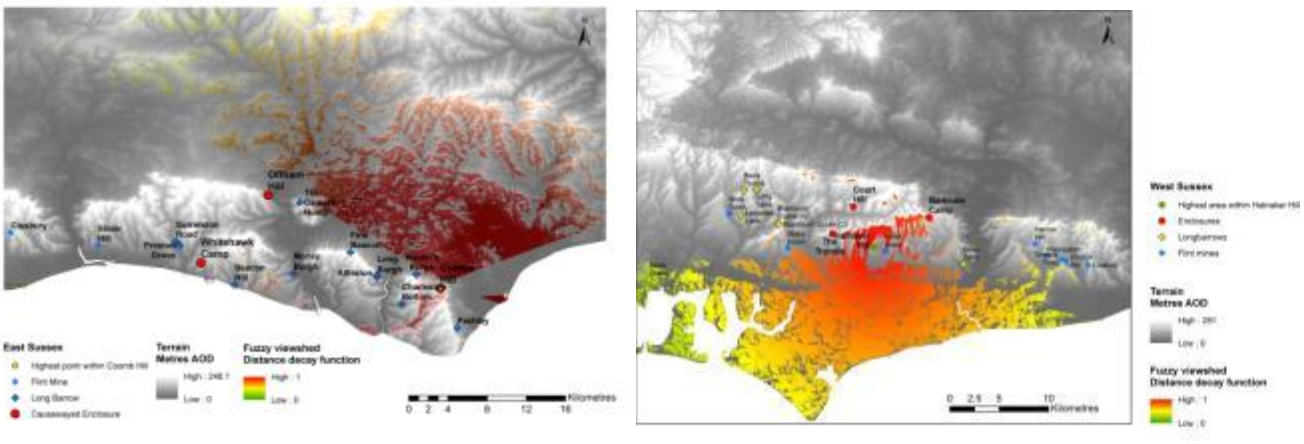

Figure 4.
Fuzzy viewshed for the causewayed enclosures at Combe Hill and Halnaker Hill (Sussex)
Spatial data: Edina Digimap, Crown Copyright/database right 2010. An Ordnance Survey/Edina supplied Service.

Figure 5 takes all four causewayed enclosures of the westerly group, The Trundle, Halnaker Hill, Court Hill and Barkhale Camp. The model, which is a summation of four binary viewsheds, demonstrates how we can combine individual models to establish an 'index of visibility' for the landscape. The resultant analysis shows those areas of landscape that may be visible from none, one, two, three, or all four, of the enclosures. Of notable interest is the relationship with the broadly contemporary long barrows and flint mines, most of which appear to be outside of the visual range of the enclosures. Also noteworthy perhaps is the strong southerly or coastal bias associated with the primary views.

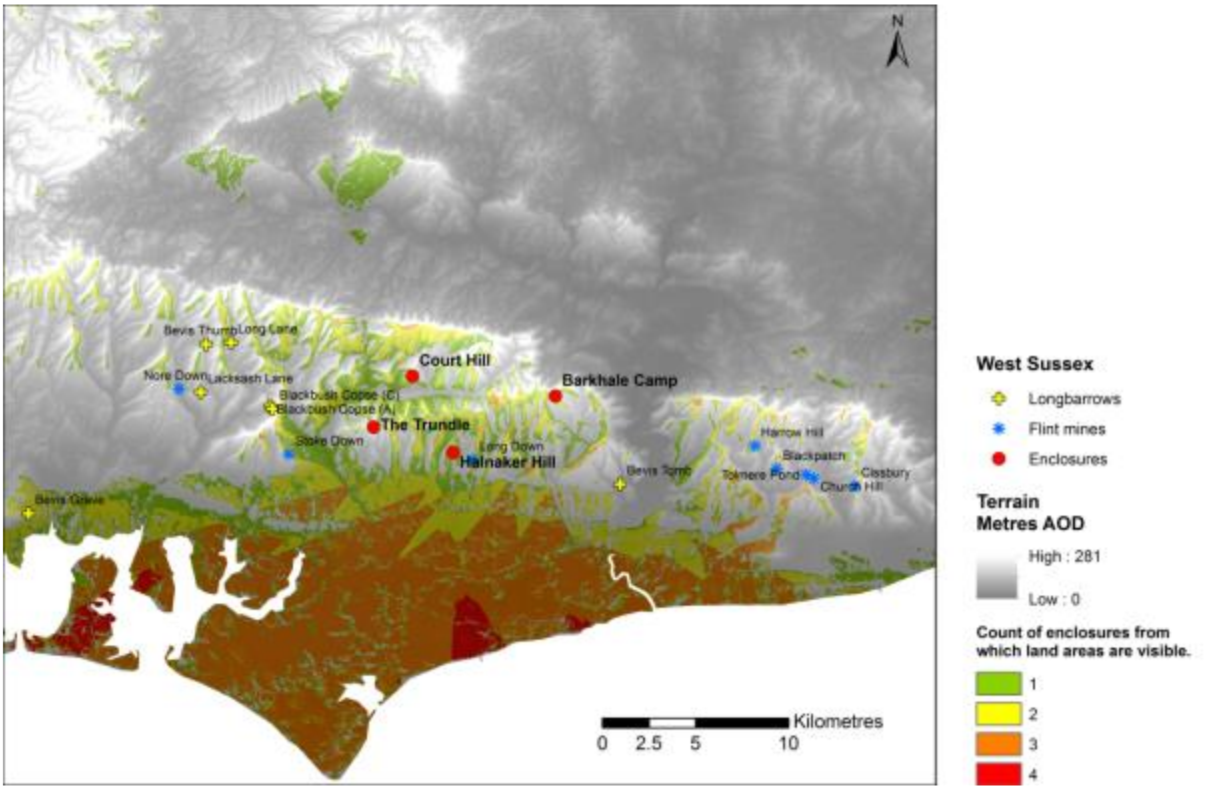

Figure 5.
Fuzzy viewshed for the causewayed enclosures at Combe Hill and Halnaker Hill (Sussex)
Spatial data: Edina Digimap, Crown Copyright/database right 2010. An Ordnance Survey/Edina supplied Service.

Cost modelling.

Here the objective may be to postulate route ways or communication paths between monuments (Bell & Lock, 2000; Lock, 2003) or to estimate the likely areas associated with, in this case, causewayed enclosures. Again the DEM provides the foundation and the mechanics of this technique involve building up a 'cost surface' within the GIS, where the movement between individual cells can be expressed in terms of the human effort required to move between them. The cost surface takes two forms: an isotropic cost surface, useful where the direction of movement does not matter in the calculation and the more normal case where it does, for example in travelling up a slope, down one, or moving along the level. The cost surface hence needs to include aspects of topography such as slope, direction of slope, direction of travel, and elevation, as well as hydrology etc. Account is then taken of these factors according to the degree of effort that may be associated with each variable and mathematical equation that define the overall expenditure of effort. It is important to note that 'cost' or friction surface is an abstract concept rather than a real one and it is most usual to convert this into time taken or energy expenditure.

Again we must make some interpretive assumptions. For example, modern hydrological conditions may not correspond to prehistoric ones. Rivers have been diverted since at least the Roman period, were less canalised than today, and due to modern diminished water tables, may have had origins at higher elevations than today. We may find it more appropriate to model rivers based on topographical characteristics rather than import them from the OS. Energy expenditure can be calculated in different ways. We could model absolute expenditure in Watts or Calories, or, as in the following examples we can calculate relative energy expenditure.

We can use the cost surface to generate least cost pathways, that define the least cost route in travelling between two location, least cost corridors which can indicate the general bounds of a likely route between two locations, or as in the following case study, we can generate so called catchment areas around sites.

Case Study 2 – Relative cost models of selected Sussex enclosures

Figure six gives an example of a relative cost distance model associated with Geological conditions surrounding The Trundle. Here the anisotropic cost distance boundaries are defined according to the manner described by Bell and Lock (2000, 87-90). The inner yellow bounded area defines an area bounded by the minimum cost distance, the red by the mean cost distance and the green by the maximum. Each of the boundary lines defines the same energy expenditure at any point along the line. The shape of each area is defined by the mathematical model and the values we attribute to each variable. The model assumes for example that it is easier to walk along the flat alluvial plains than it is to climb the heights of the South Downs and where superficial (drift) geology overlies bedrock (solid) geology, the bedrock is removed and the superficial used as a (?poor) proxy for soil types.

From this we might make some remarks about the resources enjoyed by Neolithic society in the proximity of the enclosures.

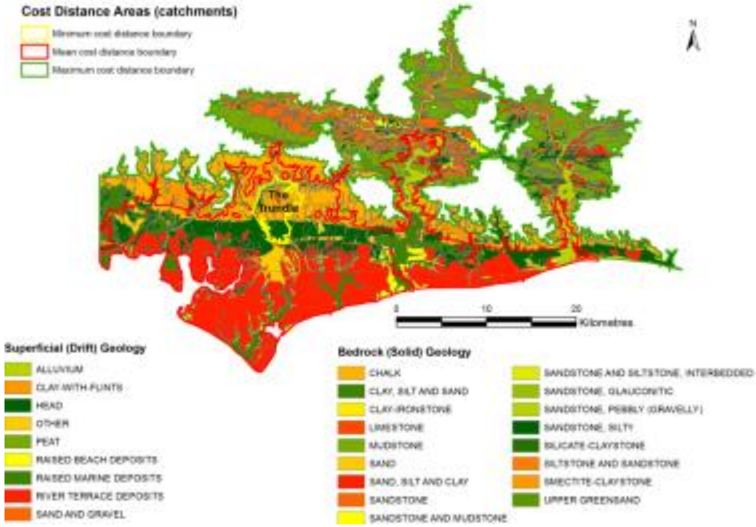

Figure 6.
Cost distance (catchment area) modelling of Geological conditions surrounding The Trundle.
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Figure seven associates the cost distance areas around Whitehawk Camp with the distribution of possible early Neolithic indicators in the form of leaf-shaped arrowheads, polished axes, pits, lithics and ceramic find spots. A speculative leap perhaps in assuming such were contemporary with Whitehawk causewayed enclosure and introducing the normal bias associated with the archaeological record, which in this area is perhaps as much driven by modern commercial developments, PP15, and the consequent quality of the archaeological record. Nevertheless, on a national scale, where such characteristics associated with Whitehawk are later compared with other enclosures then some useful conclusions may be drawn.

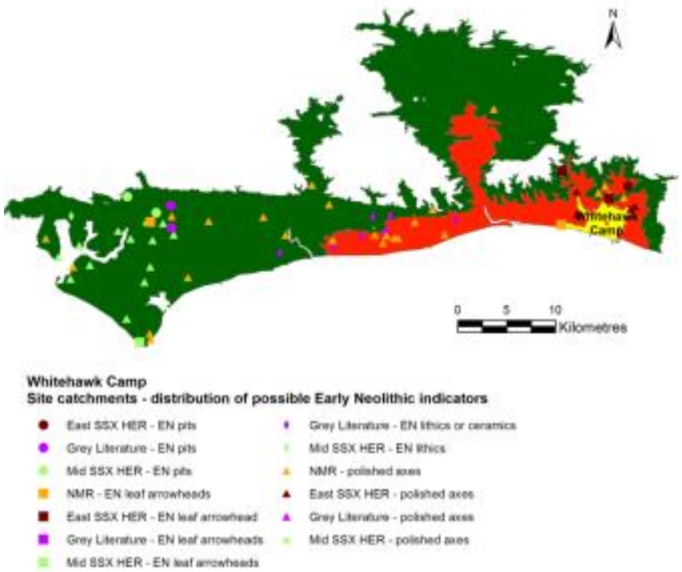

Figure 7.
Cost distance (catchment area) modelling of Whitehawk Camp (Sussex) and the distribution of potentially contemporary indicators.
Spatial data: Edina Digimap, Crown Copyright/database right 2010. An Ordnance Survey/Edina supplied Service.

Various attempts have been made to associate ‘areas’ with causewayed enclosures. From Renfrew (1973), using simple spatial distribution and associations with long barrows, the Wessex enclosures are defined as the centre of territorial chiefdoms. Later, Oswald (2001) defines ‘land use territories’ in terms of common topographical or hydrological characteristics. The GIS model here suggests areas based on the human effort required to access them and the three bounded areas may represent zones of different association. The inner zone where Neolithic activity might be strongly and directly associated with the influence and social functions of the enclosure, a second zone, perhaps the area of a modern parish or large town, where the land was relatively easily accessible and may have exploited to support Neolithic activity in or around the enclosure and a third zone where the influence of the enclosure becomes weaker. This suggests of course that the enclosures were the central place of early Neolithic society, but that’s a consideration for another day.

Summary

If we understand and accept the limitations of GIS, use the GIS to answer specific questions (rather than undertake a high-tech fishing trip) and avoid an interpretation reliant on the apparent precision of the output, we may be able to overcome some of the ‘reservations’ expressed by Tilley and Cummings at the start of this contribution. It is somewhat unfortunate that the technique can be so ‘hard’ to deploy. GIS systems can be awkward and tiresome to ‘learn’, using them for archaeological purposes beyond simple presentation can involve detailed and lengthy processes which can be time consuming and subject to error: even on a modern computer some of the models involve many millions of calculations and can take several hours to run. The mapping data and the Lidar data required to produce the DEM, can be expensive to obtain. If the free sources available for non-commercial purposes at universities etc. aren’t available to the user then this becomes prohibitive. It is possibly these practical problems that restrict the use of GIS, rather than its potential.

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