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Building theory into GIS-based landscape analysis

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17.1 Current theories

Discussion has taken place over the last four years on the issue of theory in archaeological GIS. It has been debated whether the most common general theoretical orientation in existing applications of GIS to archaeology is functionalism (Gaffney *et al.* 1995; Wheatley 1993) and whether the label of 'environmental determinism' can justifiably be applied (Gaffney & van Leusen 1995). Research agendas in archaeological GIS have begun incorporating contextual theories into GIS-based analysis of viewsheds and cost surfaces (Gaffney & Stančič 1991; Gaffney *et al.* 1995; Lock 1995; Ruggles *et al.* 1993; Wheatley 1993). They have demonstrated that GIS can offer the wider archaeological community a tool for visualising what an individual in the past may have seen. They have provided case examples of GIS elucidating site location decision making based on land control, with assumptions of differentiated power in the past based on control of that land. These works are also indicative of a trend toward explanation of site location in terms of ritual and symbolic systems employed in the past by people to consolidate socio-political power. Most recently, a call to embrace both the more processual and the more post-processual of these approaches has been made (Kvamme 1997). What has been missing are explicit alternatives to a functional or environmentally deterministic theoretical stance, and concrete suggestions of how such alternative theoretical perspectives would affect GIS studies in archaeology.

I would like to redress this by examining the application of ecological and phenomenological theories to archaeological GIS. Ecology is 'the scientific study of the interactions between organisms and their environment' (Begon *et al.* 1990). Phenomenology is the study of the forms and varieties of consciousness. Though ecology is traditionally aligned with a processual axis in archaeology and phenomenology is associated with a more post-processual axis, both approaches share foci on time depth, scale, and human agency. For example, recent archaeological applications of these two approaches emphasise change through time and space, scale, and landscape as a phenomenon created by, and creating, human cultures and individuals (Crumley 1994a; Tilley 1994).

17.2 Ecology

Landscape ecology, human ecology, cultural ecology and historical ecology are four branches of this discipline which explicitly focus attention on human actions. Landscape ecology is defined as:

> the scientific basis for the study of landscape units from the smallest mappable landscape cell to the global ecosphere landscape in their totality as ordered ecological, geographical, and cultural wholes (Naveh & Lieberman 1990, pp. xii–xiii)

Human ecology focusses on humans in their environments, but often treats environmental variables as static backdrops to human action (Winterhalder 1980). Cultural ecology, begun by the archaeologist and ethnologist Julian Steward, focussed attention on culturally constructed beliefs which structured human interaction with particular physical environments (Netting 1986; Steward 1973). Most recently, historical ecology has been introduced as the study of past ecosystems by charting the change in landscapes, including anthropogenic changes, over time (Crumley 1994a).

Biologists, climatologists, geographers, historians, and others influenced the development of ecology and its application to archaeology (*e.g.,* Bryson & Padoch 1980; Butzer 1982; Harding 1982; Lamb 1981). This multi-disciplinary perspective ensures that humans are treated as mobile, observant, communicative animals adapting to and instigating environmental change. Environment is treated as both a culturally-mediated and mediating dynamic suite of variables. In historical ecology particularly, environment is interrelated with society, therefore changes that occur through space and time in both society and environment are necessary components in any study. The dichotomy between 'cultural' and 'natural' becomes a barrier to thinking in terms of historical ecology, and is thus discouraged (Crumley 1994a; Ingerson 1994).

Ecological approaches seem particularly relevant to topics addressed by GIS practitioners including locational modelling, viewsheds, and friction surfaces. This is because the relationship of environment

Modern environmental data
- vegetation
- land capability for agriculture
- elevation/slope/aspect
- soil type/depth/moisture capacity/drainage
- precipitation/temperature/growing degree days
- bedrock type/depth
- land management strategies

Paleoenvironmental data
- location of archaeology sites
- pollen from archaeological contexts
- beetles from non-archaeological contexts
- geomorphology

Models of change through time in variables
- community succession models
- Energy balance climate model (EBM)
- soil erosion model

Models of change across space in variables
- plant competition models
- climate controls on vegetation

Theories linking changes in variables
- plant succession theories
- population ecology theories
- climatic change theories
- anthropogenic impact theories
- soil degradation theories

Table 17.1: Sample suite of variables suitable for using GIS in an ecological framework.

Modern environmental data
- Local residents' knowledge and views
- Scientific knowledge and views
- Visitors' observations

Paleoenvironmental data
- Contextual analysis of archaeological site location
- Environmental proxy data (*e.g.,* pollen, land snails)

Models of change through time in variables
- Ethnographic analogy
- Historical texts
- Scientific models

Models of change across space in variables
- Ethnographic analogy
- Historical texts
- Scientific models

Theories linking changes in variables
- Action of gods/goddesses/spirits
- Social relations: taxation, landscaping
- Climate change: glaciation, flooding

Table 17.2: Sample suite of variables suitable for using GIS in a phenomenological framework.

and environmental change to human economies, settlement patterns, and social relationships has been demonstrated repeatedly (*e.g.,* Bowden *et al.* 1981; McGovern 1994; Parry 1978, 1981). A variety of theoretical discussions of human/environment relationships have developed from environmental archaeology (Bell & Walker 1992; Bowden *et al.* 1981; Chambers 1993; Goudie 1992; Harding 1982), but formal testing of derived hypotheses in specific regional contexts has been confined mainly to periods for which historical documents exist (*e.g.,* Lamb 1981; McGhee 1981; McGovern 1994; Parry 1978, 1981). Part of the reason prehistoric applications have been more limited is that our uncertainty about past environments increases with time, and without powerful modelling tools it is impossible to adequately consider all the variables.

Zubrow (1990, pp. 67-68) has noted:

> Archaeology's theory, methodology and tools are devised to show how human behaviour changes over time. Geography's theory is often synchronic and is clearly not geared toward diachronic and historical studies which cover exceptionally long time spans. What is true of geography is even more true of GIS.

Since the discipline of ecology has produced a body of theory well suited to the study of people and their relationships with their surroundings through time, this is a powerful framework in which to begin theorising archaeological GIS. An added benefit of ecology as a theoretical framework is that a variety of methods and case studies are available from which to begin.

17.3 GIS and historical ecology

In this section references are provided to the extensive literature which has developed around ecology, environment, and social change in the archaeological literature. Suggestions are made about suitable data for GIS analysis within an ecological framework (Table 17.1). This is not intended to be an exhaustive literature review but rather one that suggests many possibilities in an effort to stimulate discussion within the archaeological GIS community.

A GIS analysis influenced by the theoretical underpinnings of ecology, especially historical ecology, must include information relating to change through time and space in cultural and physical environments and also information about the interrelationship of the cultural and physical spheres. One starting point, already included in most GIS analyses, is a modern environmental baseline or backdrop from which to work. Modern environmental data such as vegetation distribution, land capability for agriculture, elevation, slope, aspect, soil descriptions and distribution, weather, and geology are all good starting places for depicting the physical environment. Population, land-use, and political boundaries are frequent starting points for depicting the modern cultural environment.

In order to understand change through time in a landscape, any available palaeoenvironmental data for a region should also be incorporated as GIS coverages. Examples include geomorphology, macrofossils, peat, phytoliths, pollen, seeds, species distributions, and the location and size of archaeological sites. Data could come from archaeological reports but are more likely to come from reports prepared by specialists in other disciplines (*e.g.,* Bell & Walker 1992; Bintliff *et al.* 1988; Blackford 1993; Butzer 1982; Chambers 1993; Foster & Smout 1994; Needham & Macklin 1992; Robinson 1990; van der Veen 1992).

Changes from past conditions to modern conditions are rarely understood fully for any given region. This compels the archaeologist using GIS within an ecological framework to explore models of change. Examples include community competition and foraging models, climate models, soil evolution/erosion models, palaeoenvironmental modelling from pollen records and other proxy data sources, models of climatic controls on lakes or vegetation, models of communication fall-off distances and models of cultural change (*e.g.,* Adams 1978; Barnett 1953; Bradshaw 1991; Bryson 1985; Crowley & North 1991; Davis 1983; Ericson & Earle 1982; Preucel 1991; Smith 1991; Wise & Thorme 1995).

The data and models mentioned above are all potential puzzle pieces for understanding changes through time and space in a region. Theories have been developed to explore relationships between models and data in particular regions (Webb *et al.* 1987). Theories linking models and data can be usefully drawn into archaeological explanations of landscape change. For example, earth's orbital variations correlate closely with changes in monsoonal rainfall. These orbital variations also affect the climate of high latitudes but do not seem to correlate as closely with environmental fluctuations, so other factors would need to be given primacy.

Depending on the region in which one works modern environmental data may be accessed and easily digitised or even purchased in digital form. Palaeoenvironmental data is often available for regions but is more difficult to obtain as it is distributed in published and unpublished work across many disciplines. In less studied areas it may be necessary to design field research projects to collect missing environmental data and, of course, not all types of data will be available for every region. The growth of digital archiving facilities worldwide (*e.g.,* the Archaeology Data Service, NCAR, *etc.*) should increase the availability of these types of data.

Framing a GIS analysis in ecology can structure data collection and modelling to enable a wider range of spatially referenced questions to be answered. For some, however, this ecological framework will be too empirical and divorced from the realm of social phenomena. A phenomenological framework may prove more helpful in such cases.

17.4 Phenomenology

Some phenomenological studies emphasise similarities of human perception across space and through time, while others emphasise differences between individuals within similar social contexts (Table 17.2). Tilley (1994) uses modern ethnographic examples to illustrate the importance of place and landscape for modern groups. He then embodies past landscapes with cultural meaning by postulating that places would have had names, people would have known stories about significant places, there would have been customary patterns of movement across the landscape between important places. Finally he illustrates these living past landscapes by discussing possible experiences had by people in the past. A phenomenological approach to landscape stresses the observations and experiences of individual people or groups of people. No particular parcel of space is important or significant until people imbue it with meaning and transform it into place.

Phenomenology is a powerful theoretical framework for archaeological GIS because it actively disables our learned tendencies toward functional analysis and requires 'truth' to be located in human experience. This is different from ecology in which the physical world, past or present, is described and explained. Consequently, a phenomenological approach to GIS would be harder to implement than an ecological approach.

A GIS analysis influenced by phenomenology would require a different suite of variables for landscape studies. For phenomenology, the human experience should be at the centre of data collection, conceptualisation and analysis. In phenomenology human thought should be given primacy. Human experiences of landscape are thus more important than scientifically defined soil types or accurate spatial coordinates for water sources. GIS analyses that take account of viewsheds or difficulty of movement across landscapes begin to provide information about the ways in which past humans may have experienced their landscapes. But two problems occur. First, the past environment is often inadequately represented in GIS databases. Second, too much emphasis is placed in many archaeological GIS analyses on the interrelationships between constructed places (what Tilley calls architectural space). The pattern and layout of spiritual, non-constructed, or so-called 'natural' places are rarely analysed. Cultural places may become meaningful in conjunction with or in opposition to such places.

This is a radical departure from functional approaches as it removes authority from scientifically collected information. Ethnographically recording the experiences, thoughts, and feelings of landscape inhabitants provides a more fruitful point from which to begin a landscape analysis in a phenomenological framework than do decontextualised digital maps. For example, an informant's perception of the distribution of important plant species could be digitised and coded by some index of the degree of familiarity the informant has with the region. These coverages would potentially be numerous and very large because of the number of environmental variables that could be considered important by the informant.

While useful for collecting a modern baseline, ethnography is obviously not a very useful approach to the palaeoenvironment. The most direct way to represent locations meaningful to people in the past is probably to present a coverage of the locations of archaeological sites within a region. The distribution of environmental resources in the past, in the form of pollen, plant macrofossil, insect and other data, would provide some contextualisation for the human experience of a past place. But for a phenomenological theoretical framework the description of past distributions is meaningless without contextualisation in socio-cultural terms as well.

Models of change through time in the way people experience their environment might be drawn from ethnographic analogies with those who have experienced similar types or scales or tempos of change. Often a wealth of historical textual data on these issues is available for the archaeologist. Themes such as ethnicity, economic importance of raw resources, the meaning of social and physical boundaries, and power relationships would all be important. In a phenomenology of landscape based on a GIS analysis, a mechanism for incorporating the perceived actions of gods, goddesses, and spirits would be essential. For example, a reading of the *Tain Bo* suggests that watery places such as stream fords sometimes held special spiritual significance for medieval Irish people. Fordable stream locations thus might be an informative variable in a GIS designed for evaluating some Irish/Celtic site locations.

Models of how these variables change through space and time, and theories about the human perception of these variables could be obtained initially from anthropological, sociological, historical, aesthetic and economic texts or by interviewing informants from other cultural settings or who subscribe to different intellectual paradigms (road protesters, Green activists, hikers, or planning officers). The meaning of vegetation would thus richly vary as a source of food, healing materials, dyes and fibres; a source of visual and aural beauty; enspirited places for ancestral souls; and a variably profitable and protectable economic resource.

17.5 Discussion

Though the data necessary for incorporating ecological and phenomenological frameworks is already often incorporated in GIS analyses, two problems exist. The first is a tendency to base palaeoenvironmental coverages in GIS databases on modern data only. Thus archaeological site locations are evaluated in relation to 'past vegetation' but the 'past vegetation' is often a conflation of modern vegetation and modern land capability for agriculture and little else. This substitution of modern environmental data for past environmental data removes the element of change through space and time. A modern agricultural productivity coverage purchased from the Ordnance Survey, or other mapping agency, does not equal a coverage showing land suitability for agriculture in the past. It definitely says nothing about actual past land-use patterns. Even when modern vegetation maps are overlain with coverages for agricultural productivity, soil type, soil drainage, and soil depth we really aren't saying anything about the past. As a corollary, GIS viewshed analyses based on modern vegetation, land use, and topography are very limited in their ability to reproduce past human experiences. Local forestation in the past would have constrained or expanded viewsheds as much as individual variations in height, or motivation to climb on top of things like roofs, fences, hay bales, and trees. Besides inadequately modelling the past environment, GIS analyses based on modern environmental coverages do not incorporate any information about the scale, duration, tempo, or magnitude of past landscape changes.

The second problem is that the trend in archaeological GIS is to present the environment as a passive background on which humans act. For example, site location coverages might be overlaid on an environmental coverage and site selection criteria inferred as the union of these two variables. A rigid dichotomy between 'humans' and 'environment' is thus reproduced, and the inter-relationships of cultural and physical phenomena is ever more difficult to conceptualise. Theoretically based archaeological GIS approaches to landscape studies need to be multidisciplinary, experimental, flexible, and creative.

Informed by ecology, an archaeological GIS application would focus on multi-causal landscape changes at a variety of spatial and temporal scales. It would incorporate the actions of humans, past and present, and their changes to the landscape as well as forces like climate, glaciation, erosion, and sedimentation. Such a GIS analysis would be based on the knowledge that the modern landscape is not a pristine analog for the past. The data and models available to us for understanding these changes would be incorporated and questions like 'what caused this environmental change and what were its repercussions' could be addressed.

Informed by phenomenology, an archaeological GIS application would focus on people's differing perceptions of the landscape. This information might be drawn not from digital maps, but from interviews with local residents about important local features like hills or lakes or caves, or the correct time of year to plant wheat and the best way to prepare fields for crops. Information about which plants bloom when, and the extent and beauty of purplish heathery coverage, would be incorporated. These sets of personal experiences of the landscape would be used to build up coverages of important places and the times/ways in which those places have meaning to specific people. Similar information could also be gleaned from historical texts and traveller's accounts or by ethnographic analogy. The possible benefits to phenomenological studies in archaeology by the use of GIS would be the ease of comparing, contrasting, and combining individual's perspectives and the ability to quantify this information using spatial statistics.

In both the ecological and phenomenological approaches presented, GIS is an extremely valuable tool. This is because it provides an environment for exploring the overlap and gaps among existing data sources, models, and theories. The data structure of GIS is already good for model calculations and for storing model results, as is shown by the routine use of these programs by geologists to model hydrology, run-off, and soil moisture in regions. The data structure of GIS is also relevant for modelling change in both cultural and physical environments and their interrelationships. The quick and flexible modelling capabilities of GIS can be turned to exploring scenarios derived from theoretical positions like gender studies or Marxism as easily as ecology or phenomenology.

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