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SOME CRITERIA FOR MODELLING SOCIO-ECONOMIC ACTIVITIES IN THE BRONZE AGE OF SOUTH-EAST SPAIN

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Some Criteria for Modelling Socio-Economic Activities in the Bronze Age of south-east Spain

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14.1 Introduction

Questions relating to prehistoric settlement and particularly the spatial and temporal correlates which articulate human/environment interaction, constitute one of the enduring problems in archaeology. The ubiquity of such studies, however, is not necessarily commensurate with understanding; indeed, there are substantial gaps in our knowledge of basic human ecodynamic processes, especially set within a long-term perspective (McGlade, 1993a). The current status of human ecology with its emphasis on stability and equilibrium, actively misrepresents the non-linear interactions which define the evolutionary dynamics of complex socio-natural systems (Terrada, 1987; McGlade and van der Leeuw, 1994). In this chapter, we shall attempt to show how GIS may be able to contribute, if not to a resolution of such problems, at least to helping resituate them within a more productive spatio-temporal framework.

The growing use and increasing sophistication of GIS methods in archaeology have produced a variety of studies which have demonstrated its tremendous potential for interpretation and interrogation of spatially referenced data (Allen *et al.*, 1990). One of the most obvious uses of this technology has been in the realm of regional settlement studies (e.g. Kvamme, 1989; Madry and Crumley, 1990), and particularly with questions relating to the prediction of archaeological sites (e.g. Brandt *et al.*, 1992; Carmichael, 1990).

It has become clear that GIS is much more than a sophisticated cartographic tool; it not only provides archaeologists with a framework within which to explore spatial problems, but, as we shall argue here, it also has the potential to explore less tractable issues such as those represented by socio-ecological questions.

Mapping the socio-natural environment adequately so as to account for its representation as a true ecology of social space, or what one of us has referred to as 'human ecodynamics' (McGlade, 1993b), is of course, non-trivial. Certainly, it cannot be solved by the extant methods of so-called spatial or settlement archaeology since these generate a problematic distinction between the spatial and the social, and effectively privilege the spatial.

What we are suggesting here, is that the full potential of GIS to address such issues has yet to be explored and in many ways can be viewed as a way beyond the simple representation of spatially referenced data. In this vein, the main function of the present contribution is to attempt to demonstrate the utility of GIS, not simply as a methodological tool, but more importantly, as a means of presenting a series of hypothetical scenarios which are relevant to our understanding of human/environment relationships. This will be done principally through the construction of a 'territorial' model designed to articulate a set of semi-autonomous activity spheres which are said to be implicated in the reproduction and organization of a specific archaeological locus, or settlement. Finally, we shall argue for the inclusion of GIS, and especially a time-referenced GIS, as an integral element in theory building within the domain of experimental archaeology.

14.2 GIS and Archaeology

Geographic information systems have, over the last fifteen years, effectively revolutionized the way in which disciplines such as geography, land resource management, ecology and archaeology handle and interpret spatially referenced data sets. Such systems provide a means of manipulating complex, multivariate observations within relatively flexible, interactive computer environments.

Archaeological uses for GIS technology have been expanding since their first appearance in the early 1980s (see Kvamme, Chapter 1), when they began to be used within the context of regional spatial analyses. Despite a number of theoretical issues which have yet to be addressed, one clear advantage which GIS brings to archaeological research is its power of visualization: settlement distributions in two and (pseudo-) three dimensions are by now well known and utilized methods of data representation. In addition, geographical information systems are adept at calculating both distances and surfaces of spatially referenced phenomena in relation to specific geographical features; this fact in conjunction with the possibility of analysing intervisibility by means of digital elevation models (DEMs), has resulted in increasing utilization of GIS methods by archaeologists.

In spite of such developments and the increasing availability of PC and Macintosh compatible user packages which allow easier access, the application of GIS within archaeology has largely been directed at the production of new ways to visualize data, often as a means of verifying environmental determinist models. In short, it has largely been concerned with representation and description (van Leusen, 1993), and for this reason, its use as a potential interpretive tool has yet to be explored (but see Gaffney and Stančič, 1992). For example, while geological or soil characteristics can be represented with some degree of spatial accuracy, the use of geometric polygons is clearly an inappropriate way to deal with spheres of social interaction and their boundaries, since they are characteristically 'fuzzy' (Burrough, 1990; Castleford, 1992). Furthermore, the locational details of archaeological sites are superimposed on present-day geography, and in doing so we create potentially misleading and even spurious correlations. In short, we cannot explain the past by back-projecting the present.

There are, however, more serious problems, when we turn to the theoretical contexts, or the lack thereof, within which GIS systems operate (Wheatley, 1993). The charge that GIS have often assumed a kind of 'theoretical neutrality' in many ways reflects the investment of time and energy in the technological aspects of their development. It is clear that any meaningful discussion on the nature of space (and here we must emphasize that it is not a neutral category, it is socially constructed) demands explicit discussion of the theoretical assumptions within which the particular problem is situated. It is to such issues that GIS methods must now turn their attention, if they are to be more fully integrated into a mature socio-spatial theory.

14.3 Time, Space and GIS

14.3.1 Introduction

As we noted at the outset, understanding regional settlement systems is conventionally perceived as a problem to be set within the context of spatial archaeology. A fundamental, and frequently cited referent in this activity, is said to be the designation of the resource exploitation zone, and this is viewed as constituting the site catchment.

This model, whose underpinnings are borrowed from economic theory, and now widely used in archaeology, presupposes that the activities of food production can be reduced to rational economic behaviour. Thus, human groups are assumed to be interested in 'least cost' energetics. An important corollary states that the closer an area is to a settlement location, then the more intense will be its exploitation. We thus employ terms such as 'optimum resource exploitation zone'.

Perhaps the worse failing of site catchment strategies is their inability to acknowledge adequately the social, cultural and ideological contexts within which human settlements are situated and which structure the day-to-day routine activities such as the procurement, production and processing of food, as well as the array of social and cultural activities involved in the reproduction of society. What we have in fact, is a functional, systemic description in which the social is abruptly disaggregated from the natural. In summary, this model attempts to superimpose an abstract, atemporal Cartesian geometry onto a reality that is fundamentally reflexive, subjective and contingent (Castro *et al.*, 1993; McGlade, 1993b).

14.3.2 Timing space

In addition, this systemic view is articulated within spatial and temporal frameworks which distort the true nature of societal relationships with the environment. This is principally brought about through the separation of time and space, which are often represented as independent entities. In fact, much of the theoretical discourse surrounding archaeology assumes implicitly that time is unproblematic; it is somehow self-evident. Conventionally, it is seen as an abstract container of events supported by chronometric props. Time is presented as sequence and interval; it is objective and quantifiable (Shanks and Tilley, 1987).

Within this abstract framework, the multiple periodicities which make up and define societal existence and reproduction, can, so it would seem, be compressed (smoothed over) and reduced to a sequence of datable events. We can thus make a ladder of history on whose rungs past events are placed. This is the key to understanding, and is rooted in a search for order, for the reduction of difference. What we are arguing is that the seductive logic which underpins this type of archaeological reasoning is both dangerous and pernicious: dangerous, because it privileges a single dimension of time as continuous and linear; and pernicious because it promotes a fictive view of human endeavour and the way in which time is constituted in social praxis (González Marcén, 1991; Picazo, 1993).

The conventional use of space is equally problematic, since it assumes that space as a 'physical' entity can be separated from time and expressed as an absolute value, e.g. as a bounded territory with measurable dimension. In a sense, spatially motivated archaeology and its variants such as 'settlement archaeology' assume that spatial structure is something independent from its social context; there is little appreciation that space is in fact, not a neutral Cartesian concept, but is socially constructed (Lefebre, 1974; Soja, 1980).

The problems posed by the artificial separation of time and space are manifestly obvious, and become especially acute with respect to socio-natural interaction. Here the disaggregation of human ecological processes effects a distortion which severely compromises our ability to interpret the reciprocal dynamic which defines human societal reproduction. If we are to move towards a true ecology of social space, what we have earlier referred to as human ecodynamics, then this must have as a central premise, an emphasis on and an understanding of temporality as a fundamental constituent of the socio-spatial dialectic.

This temporal understanding of space (time–space) demands that we map human societal processes with their individual, engendered, seasonal, generational time-scales onto the array of periodicities and time-scales which define evolutionary environmental phenomena. We thus encounter human ecodynamics as co-evolutionary; humans do not adapt to the environment as is conventionally held in human ecology and archaeology—rather, they are embedded in landscape evolution as a continuous structuring and restructuring of time–space, one that implies no teleological directive. Humans are not passive recipients of environmental information; they are conceived as actively involved in the creation of their environment (Touraine, 1977; McGlade, 1993b).

14.3.3 The territorial map: a time–space description

If we are to come to terms with a true human ecodynamic description of extinct settlement systems, then this requires a conceptual structure upon which analytical and interpretive models can be based: one which is able to address the need for a dynamic ecology of social space. Following Crumley and Marquardt (1990) we shall argue that two types of structures are implicated in the representation of social space: socio-historical structures and biophysical structures.

The first of these structures (socio-historical) is involved with relations of production, inheritance, class, political liasons, defence, trade/exchange and laws, while the second structure (biophysical) includes those natural, geological, pedological, topographical and climatic factors which provide the enabling and constraining features which generate human settlement. Societal organization and its reproduction is thus the product of the reciprocal, mutually reinforcing relations between these two structural spheres. The locus of their time–space intersection we shall refer to as 'territory'.

Thus, we propose that the most appropriate way to view settlement dynamics within a human ecodynamic context is to replace the concept of 'site' or 'settlement' with such a time–space construct; settlement is seen as the interpenetration of multiple coexisting territorial domains (McGlade, 1993b).

Territory here defined is not synonymous with a simple spatial referent; thus the socio-spatial configuration which constitutes for example, the Argaric universe of the Vera Basin, represents the time–space intersection of multiple activity spheres: social, political, ecological and ideological. Collectively, these constitute a web of human–environment interactions in time and space. An additional part of our definition of territory embodies the concept of a field of knowledge and is taken here to mean the locus of particular historical and culturally bound social and natural knowledge-bases, i.e. the intersection of natural phenomena and lived experience. What we have, in effect, are semi-autonomous activity spheres in a specific space–time configuration, implicated in the reproduction of the social group.

As we have previously noted, an important property in presenting such a scheme is the representation of time, or rather temporalities. Time cannot be relegated to the realms of the abstract, nor can there be any single unifying 'time', there is no present moment; rather, time is to be grasped in relation to the particular sets of biological, social, economic, political and ideological processes which articulate societal reproduction. Thus we can say that every social act which takes place within its territorial domain, implicates different temporalities. Moreover, within these territories, we encounter a substantial (as opposed to abstract) time—an arena in which continuous, discontinuous and cyclical periodicities meet.

In order to give these concepts a more concrete realization, a set of fundamental domains has been arrived at, and are regarded as representing a primary set of socio-natural descriptors which may be said to encompass the dynamics of societal reproduction. A more complete elaboration of these ideas is set out elsewhere, particularly with respect to temporal issues (McGlade, 1993c). For our present purposes, we shall present a reduced description of the basic terms of reference:

- The domain of **human reproduction and maintenance activities** is conceived as representing the basic production modes upon which society is constituted and maintained. This territory is structured by the domestic unit, which is defined as the social group or segment that effects control over the day-to-day routinization of household tasks and other activities related to the construction and maintenance of domestic structure.
- The domain of **food production** includes all the fundamental activities connected with gathering, hunting, crop production and animal husbandry. From a temporal perspective, what we have is the superimposition of sets of social temporalities on the natural temporalities of the environment, e.g. the times of soil preparation, of planting, cultivation and harvesting, as well as the imposition of human action on animal reproduction (stock breeding) and behaviour.
- The domain of **material technology production** deals with the extraction, manipulation and transformation of raw materials, and the necessary technological processes which affect these transformations. The temporalities involved here encompass the duration of the different activities involved in the fabrication process.
- The domain of **raw material and artefact transactions** includes all inter- and intra-group transactions, whether equal or unequal. Spatially, this domain is distinguished by its incorporation of other social groups and their territories. This domain is also an important carrier of information across cultural boundaries and thus is involved—either implicitly or explicitly—in the dissemination of myth, ritual, or other specialized knowledge.

- The domain of **political and administrative organization** acts to facilitate the organizational structures, both enabling and constraining, which provide the basis for the perpetuation and legitimation criteria for societal reproduction. Inscribed in this domain are the collection of institutional structures and codified rules and regulations which form the vital underpinning for all social activities and their enforcement. This domain is the locus of control and power.
- The domain of the **ancestors,** by its existence, implies the active participation of the dead in the symbolic reproduction of the living. In this domain are religious and/or ritual practices and the organization of their spaces. It may, in some cases, be identified with a cosmological conception of territory. From a temporal perspective, this domain is unique in that it transcends time as a measurable phenomenon; it is concerned with trans-temporal associations and activities.

Clearly, within this time–space territorial description, not all territorial domains are archaeologically visible (e.g. territories of women differentiated from those of men, territories of ritual, etc.), nor can they be readily accessed via GIS; this however is no reason to ignore or to relegate them as epiphenomena. What we are arguing is that we can make a beginning in terms of addressing some of these issues, and set out some possible interpretive modelling approaches which can be operationalized within a GIS framework. In line with our previous argument, there can, of course, be no privileged model representation of any territory or its domains; what we must work towards is the realization of multiple levels of description, i.e. and assemblage of different interpretive modes, from which 'meaning' can be negotiated. Additionally, as complexes of symbols and meaning structures, the territorial realization that we refer to as a specific archaeological site, incorporated, not simply a set of physical and material criteria, but reflected sets of values as to how space should be perceived and experienced.

14.4 The Vera Basin: the socio-natural context

14.4.1 The natural environment

In order to contribute towards the task of resituating GIS within a more productive archaeological context, one which recognizes the need to generate new ways of articulating human/environment relationships, we shall now focus on an interpretive approach to model building within the context of the Vera basin.

The south-east Iberian peninsula, in which the Vera basin is situated, is the most arid region of Europe. From a climatic perspective, it is characterized by high temperatures and extremely low rainfall (*c.* 250–300 mm per annum), though it is not so much the paucity of rain that is significant here, but rather its intensity and irregularity and the way in which these events are involved in structuring the landscape. The region is broadly defined by the river plains of the Almanzora, Antas and Aguas rivers, and is bordered by the mountain ridges of the Sierra Cabreras to the south, the Sierra de Bédar to the west and the Sierra de Almagro and Sierra Almagrera to the north (Figure 14.1). These mountain ranges are largely composed of metamorphic rock, while the river plains are covered by sedimentary and volcanic deposits from Tertiary and Quaternary contexts. The soils in the mountainous areas tend to be shallow and prone to erosion, and while the river plains tend to have

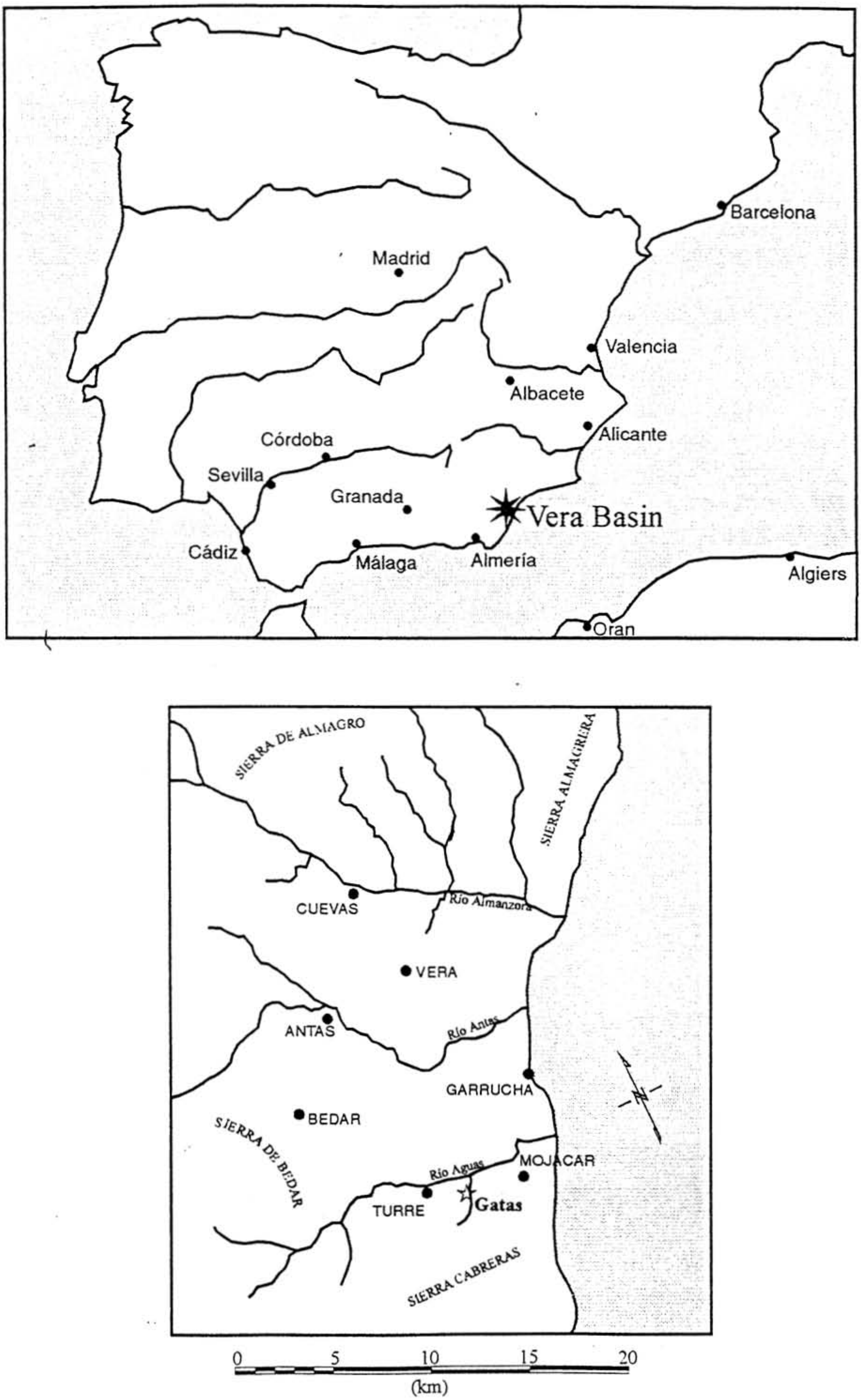

Figure 14.1 The location of the Vera Basin

better soils for agricultural exploitation, they are also prone to lateral erosion by the river channels as well as to salinization (Proyecto Lucdeme, 1988–91).

Although the vegetation cover we observe today is that of species adapted to semi-arid conditions, dominated for example by *Artemisia* or *Lygeum spartum*, it is not clear to what extent these are indigenous species, since in more remote areas which have had minimal human interference, we see examples of light forest cover of *Pinus halepenis* and *Pistacia* (Ruiz *et al.*, 1992). One of the primary aims of the EC-funded ARCHAEOMEDES project is to address such questions within the context of the Holocene period, so as to provide a more rigorous approach to environmental reconstruction focused especially on the role of social and cultural factors and the way in which they have co-evolved to generate the historical trajectory of the Vera Basin.

Preliminary results of the ARCHAEOMEDES investigations have shown that immediately prior to the arrival of humans, the area seems to suggest a less dynamic geomorphological regime than today; a landscape characterized by a smoother topography than we see currently, along with a slow infilling of the low lying regions and the presence of lagoons and marshes both near the coastline and inland (Gili *et al.*, 1993).

14.4.2 The archaeological context

While the specific sets of dynamic processes structuring the palaeo-environments of the Vera Basin are difficult to specify with any degree of precision, what is clear is that the area has been continuously inhabited since *c.*4000 BC. The first Neolithic exploitation of the basin is archaeologically translatable as a pattern of low intensity and high diversity and is consistent with what appears to be undifferentiated socio-economic organization. Geomorphological change during this period resulted in the entrenchment of river beds and there are signs of the beginnings of erosion as is indicated by coastline studies (Hoffman, 1988). Speculations on the causes of such change point to tectonic activity, rather than to climatic factors.

With the ensuing Chalcolithic period (3000–2300 BC), human settlement in the basin shows a significant increase and we have higher levels of productivity and population density especially in the riverine areas. Significantly, the archaeological settlement pattern data shows differentiation based on size and on craft specialization, and this is reinforced by burial data which demonstrate unequal access to material goods.

Around 2300 BC, a radical change in the pattern of human occupation occurred with the beginning of the Argaric period, and is accompanied by a shift from the lowland areas to higher ground, as well as large population concentrations in a few large centres. The radical nature of this change lies both in the rapidity with which it took place, and in the drastic modification in the subsistence base which accompanied it. Additionally, the social discontinuity is clearly reflected in burial practices which now are located inside the settlements and are moreover focused on individual interment. A marked differentiation in grave goods is now evidenced, and this has led to the establishment of a hierarchical model of social stratification with elite control and a possible state level organization (Lull, 1983; Lull and Estevez, 1986). What the available archaeological data demonstrate unequivocally, is that there is no continuity between the preceding Chalcolithic and the ensuing Argaric.

Speculation has arisen as to the possible role of climatic factors in inducing such social and cultural discontinuity or alternatively the role of soil exhaustion as a result of the cumulative effects of long-term cultivation practices in the lowlands. What is interesting, however, is that initially, the change in social organization is not reflected in subsistence practice; it is only after *c*.1800 BC with the full development of Argaric society that we see a transition to barley monoculture. It seems that this change is coeval with a general trend to more arid conditions and the exhaustion of lowland riverine soils, something corroborated by the decline of hydrophytic species in the charcoal and pollen evidence. The available archaeological evidence suggests that this exhaustion seems to have been accompanied by population increase, and this may have forced a shift towards intensive monoculture so as to maintain the existing social and political organization.

This situation seems to have lasted for about 200 years, after which the Argaric system collapsed with the abandonment of the larger settlements and a general contraction of population throughout the region. The resultant dismantling of the close knit Argaric exchange system allowed, for the first time, access to materials from other parts of the Iberian peninsula and from a wider Mediterranean context generally. In addition, the relaxation of hierarchical control seems to have produced a more diversified subsistence economy, in many ways a reversion to the earlier Neolithic exploitation strategies.

The precise causal nature of this system collapse, or rather transformation, has provoked a variety of hypothetical explanatory models (Chapman, 1978; 1990; Lull, 1983; Mathers, 1984; Gilman and Thornes, 1985), which range from the primacy of environmental factors to the determining role exerted by political centralization and social stratification.

Debate on such questions continues apace, and their resolution is thought to reside in the results of future excavations. While it is true that the availability of further data can help to provide better corroboration for particular hypotheses, what we are arguing here, is that:

(a) there is yet a great deal of latent information resident in existing data, and
(b) it may be possible with the use of GIS methods to generate alternative ways of interrogating these data sets.

14.5 The role of GIS in the Vera Basin project

14.5.1 Introduction

The primary aim of the Vera Basin project with respect to GIS, is to provide a means of combining and cross-referencing archaeological, historical and environmental data so as to understand better the way in which socio-natural dynamics have evolved over the long term. Of particular importance is the role of differing socio-political strategies in generating the conditions within which human communities persisted during the period of the later Holocene. What we are attempting to define are the temporal, spatial and social criteria contributing to the array of human ecodynamic relationships which have structured the prehistoric and historic landscape.

The GIS developed for the project is based on a 1:100000 scale. Topography, geology and soil maps were manually digitized, as was a land-use map dating from 1978. More recent land-use data were obtained from the CORINE database (Commission of the European Communities, 1992). In addition, the locations of archaeological sites and present-day mining activities as well as farms were digitized. A DEM with a resolution of 200 × 200 m was obtained from the Spanish National Geographic Institute. A further selection of statistically treated data on sites was added so as to create a working geographical database in GRASS and INFORMIX. Ecological and historical data are currently being added.

From both theoretical and methodological perspectives, an important goal of the research is to go beyond the purely statistical treatment of data and provide a more useful frame of reference within which previously constructed hypotheses might be addressed, reassessed and reconstructed, as well as advancing alternatives.

14.5.2 An integrative, multiscalar framework

In order to work towards such a goal, we have devised an iterative model structure which links the divergent data sets and the GIS with a hierarchical interpretive framework (Figure 14.2). From the figure, we can see that there are three principal levels of 'knowledge' which can be accessed, forming three levels of data transformation. These represent different scales of inquiry or interrogation and range from a mode of representation at the first level, to a mode of description at the second level of transformation to an interpretive/analytical level at the final level of transformation. It is important to point out here that the framework is not simply goal directed to the third level of enquiry, but rather exists as a continuum in which different questions and problem sets can be tackled at a particular level or combination of levels; the feedback loops in the diagram illustrate this point by demonstrating the reciprocal relationship between data and any chosen level of representation or transformation.

14.5.3 The representational level

At this first level of transformation we have conventional statistical treatments of the various databases, i.e. climate, geology, soils, vegetation, etc., as well as historical documentation and the archaeological data from both surveyed and excavated sites spanning prehistory to early historic times. The difficulty of generating accurate spatial representations of the archaeological data lies in the fact that although artefacts are geo-referenced, the spatial dimensions of the organization of their production, distribution and acquisition are unknown. Similar problems beset the environmental data: while the location of pollen samples is known, the precise spatial distribution of the pollen producing species remains obscure. Our third category of information, consisting of historical documents, is equally problematic. Although they provide valuable data on the agricultural properties and their subsistence base, the exact location of the territories of production remains unknown.

With these caveats in mind, the manipulation and cross-referencing of this information can nevertheless generate useful spatial representations at a coarse-

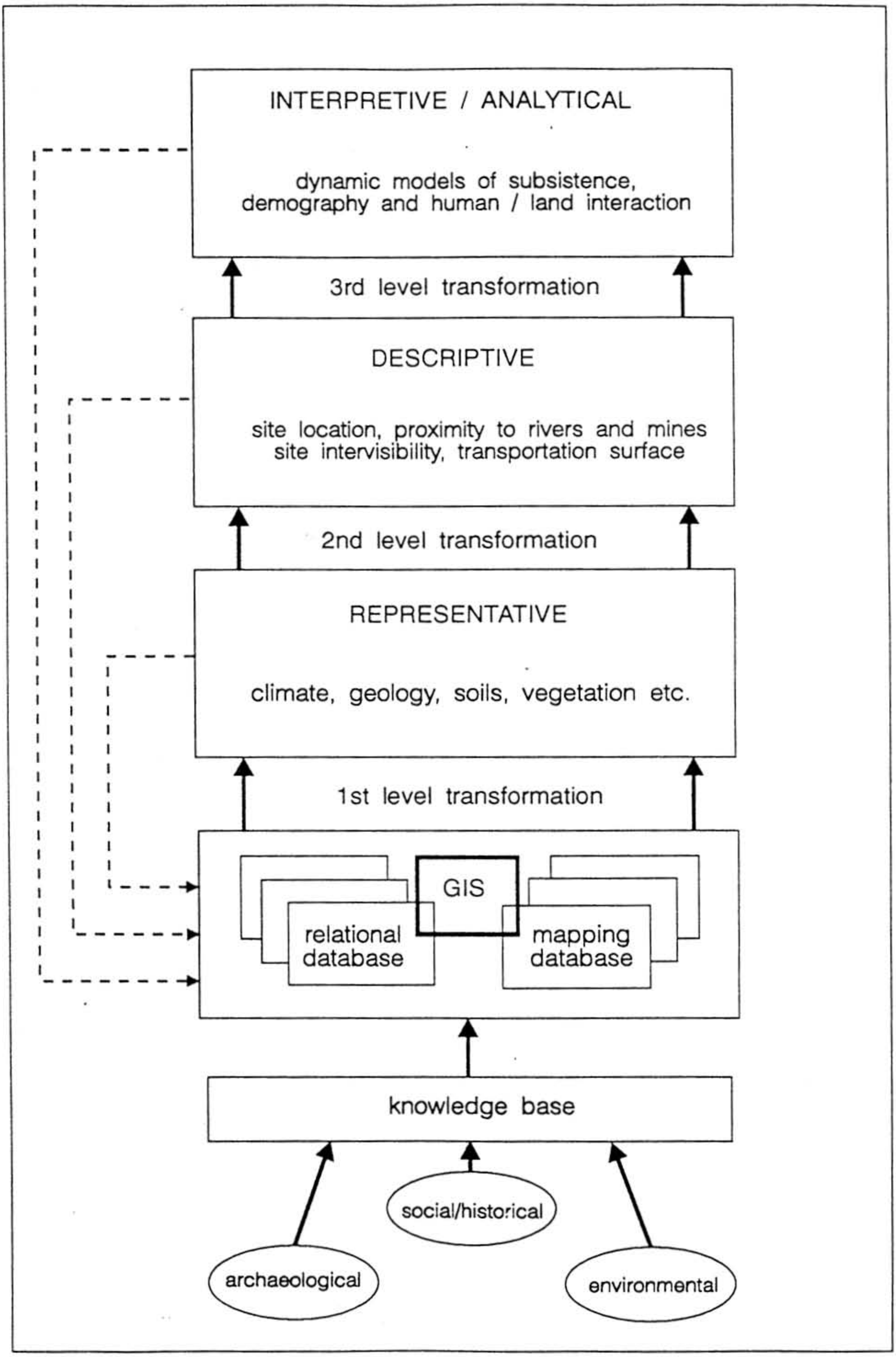

Figure 14.2. Vera Basin integrative model structure.

Figure 14.2. Vera Basin integrative model structure.

grained level. With this knowledge, we can move to the second level of transformation—the descriptive.

14.5.4 The descriptive level

At this level, the geological, topographical and archaeological characteristics of site locations have been subjected to univariate statistical treatments in an effort to isolate different site distribution patterns. It should be pointed out here that these patterns are superimposed on present-day ecological conditions and thus caution should be exercised in any proposed correlation with prehistoric conditions. Following this evaluation of sites at the locational level, the next step is to seek non-random associations at the inter-site and regional level, based on an analysis of the immediate surroundings of the sites. To this end, three separate types of analysis have been undertaken:

1. **Distance analysis** For all settlements distances were calculated to *ramblas* (dry river beds), to the coastline, to the nearest neighbouring contemporaneous site, and to the nearest present-day mine with copper, iron or lead (the latter being considered an indication for the presence of silver). The distances calculated are straight line distances, and the actual distances may have been much larger in rugged terrain. To account for the change of coastline over the last 6000 years, the palaeogeographic reconstructions of Hoffman (1988) were used, although the accuracy of these reconstructions remains a matter of debate. Not all of these calculations were useful: the availability of metals cannot be very relevant for the Neolithic period, nor will iron have been of much importance to the Chalcolithic and Argaric cultures.
2. **Analysis of the surroundings of each site** For all settlements the geological, pedological and land-use data were quantified within a 2 km radius from the settlement. This radius of 2 km is a rather arbitrary one and is not to be confused with site catchment analysis, critiqued above. Rather, it serves as a first description of the area around a settlement, and can be used for comparison of the conventional resource environment with the territorial model suggested above. The same technique can be applied for palaeo-botanical and palaeo-faunal data, especially since the locus of deposition and sampling does not correspond to the spatial extent of vegetation or animal foraging areas.
3. **Visibility analysis** As it is assumed that the Argaric society was highly organized and had a state-like character, the analysis of intervisibility can be used to test that hypothesis. Questions like, 'were the most important settlements located in positions where they could see all others?' and 'could the other settlements always see the capital settlements?' can be answered by creating a viewshed around each site, and then calculating the number of visible sites in this viewshed.

Even these relatively simple analyses can add to the verification of archaeological hypotheses. To illustrate this, we shall focus on Gatas, one of the most important recently excavated Argaric sites in the Vera Basin (Chapman *et al.*, 1987; Buikstra *et al.*, 1989, 1992; Castro *et al.*, 1989; 1993; Ruiz *et al.*, 1992). The distance calculations suggest that Gatas' nearest neighbour is the site of Barranco de la Ciudad at a distance of roughly 3100 m. From the visibility analysis however it is clear that the two do not have visual contact. In fact, from Gatas one can see almost all of the

Vera Basin, but to the south-east the view is blocked by the Sierra Cabreras. How can we make the distance calculations reflect this lack of direct contact between the two sites? One of the options is to create a cost-surface around Gatas using slope as a friction factor, and see if we can create a route from Gatas to Barranco de la Ciudad by executing at least cost path. The route that this method provides does not go over the Sierra Cabrera, but descends into the valley, following the Río Aguas almost to the second nearest Argaric site of Cabezo de Guevara, and then follows the coastline before reaching Barranco de la Ciudad. The total distance of this route comes to 8600 m. There is of course no proof that such a route existed (cf. Madry and Crumley, 1990), and the path is not a very efficient one because it first descends and then goes up again. A logical step would be to follow the contour lines, by means of a cost-surface based on the difference in elevation between Gatas and the rest of the area. A route from Gatas to Barranco de la Ciudad using this method is only 4400 m.

When using this last procedure from Gatas to Cabezo de Guevara, a junction is found at the point where the path to Barranco de la Ciudad crosses the ridge of the Sierra Cabrera. The route to Cabezo de Guevara descends following the ridge, the one to Barranco de la Ciudad continues to follow the contours on the other side of the sierra (Figure 14.3). It is interesting to observe that the distance to Cabezo de Guevara is not changing very much using either method: the straight line distance is 4800 m, the distance using the slope map is 5400 m and the distance following the ridge is 5000 m. This suggests that the method to be used is very much dependent

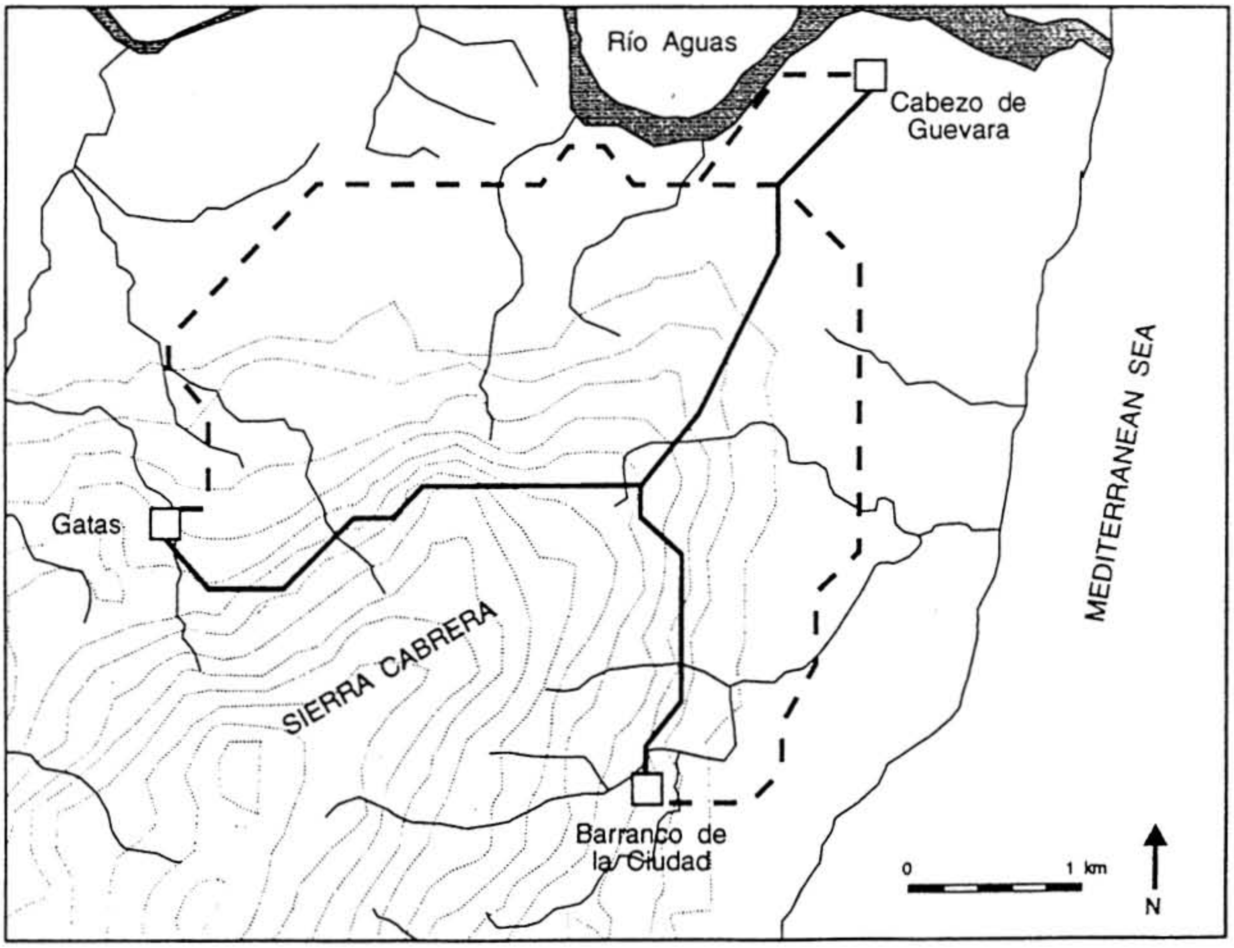

Figure 14.3 Least cost paths from Gatas to Barranco de la Ciudad and Cabezo de Guevara using gradient (dashed line) and elevation difference (black line) as friction factors.

upon the type of terrain and the position of the settlements in this terrain. Both methods however indicate that there was no direct link between Gatas and Barranco de la Ciudad, and that the site of Cabezo de Guevara must have played an important role in their relations.

It seems that the construction of least cost paths can be helpful in finding possible routes of transportation and produces more relevant results for distance calculations, even when used with a relatively crude DEM like the one here. In fact, any factor can be included in the friction map that is used, e.g. vegetation, the presence of water, or for that matter, the location of taboo or proscribed areas. Caution should be applied however with the interpretation of the paths; in fact this little exercise shows that the levels of representation, description and interpretation of GIS derived data are *all* needed in order to tackle our questions.

14.6. An explicative example

14.6.1 Introduction

We shall now attempt to situate some of these ideas with respect to a specific set of issues pertinent to the Vera Basin. Although we feel that it should be possible to apply the methods discussed here in any study of settlement territories, we will be focusing on the possibilities of reconstructing agricultural territories around settlements. One of the most urgent problems to address when reconstructing past land use is the extent of the territories used for farming. Methods like distance buffering and Thiessen polygons have often been used to create settlement territories, but these are not very satisfactory. Of the GIS methods available, cost surfaces made from slope or elevation maps offer the best possibility to obtain non-linear representations of the landscape (Wheatley, 1993). A good example of the application of cost surfaces to create radii of hours' walking is found in Gaffney and Stančič (1992). Although the approach is site-centred, just like the traditional distance buffering, and takes a rather arbitrary cut-off point, it gives a fairly good idea of the accessibility of the terrain around a settlement. We suggest that a different approach can be used by reversing the process and concentrating on the area around the sites first before determining the settlement hinterland. First we will try to find the zones where farming was actually possible, and then make an estimate of what portion was needed to sustain the population of the settlement.

For this approach two issues have to be tackled. First, a comprehensive system for land evaluation is needed from which estimates can be made concerning the productivity of soil types for different crops. Both qualitative and quantitative methods are available and will have to be tested (MacRae and Burnham, 1981) using ecological characteristics of the cultivated crops such as slope, relative humidity and salt tolerance. In south-east Spain, an area which has suffered severe erosion, present-day soil maps can only be used as a guideline for past agricultural potential, since their relationship to the palaeo-environment is exceedingly complex and potentially misleading. Data on soil erosion and a detailed study of palaeosols will be necessary to provide a more accurate picture of past soil types.

Second, demographic estimations are needed, in addition to information on diet, the distribution of resources and the socio-economic organization in general. Clearly, the greater our knowledge on these aspects, the greater will be our ability to generate plausible estimates of the amount of suitable land that is needed for food production for a given community.

14.6.2 Estimating agricultural potential

In order to assess the viability of this approach, we need to make a comparison between the available methods. First, we will consider two of the traditional approaches: distance buffering and walking time. Although the use of cost surfaces will give a more accurate representation of the settlement's surroundings, in level terrain the two methods coincide: a one-hour walk will approximately be the same as a distance buffer of 4 km. The maps of walking time can be created using a slope map in combination with distance buffering, and by applying a rule of thumb that assumes that a healthy person can walk 4 km per hour horizontally, and that each 400 m uphill or 800 m downhill will cost one hour extra. Taking the average of 600 m vertical movement per hour, the maps in Figure 14.4 were created. As we pointed out earlier, these maps cannot account for the effect of walking with the contour lines in mountainous areas. A simple comparison can be made between the 2 km radius from the descriptive analysis and these radii. The soil maps 1:100 000 from the Proyecto Lucdeme (1988–91) provide enough information to roughly assess the agricultural productivity of the area around Gatas, Barranco de la Ciudad and Cabezo de Guevara. Of the soil types mentioned in Table 14.1 and Table 14.2 the *Lithosols* offer very little potential for agricultural use. The best soils

Table 14.1 Distribution of soil types in ha within a two km buffer zone

	Gatas (ha)	Bco. de la Ciudad (ha)	Czo. de Guevara (ha)
Lithosols	405	754	229
Regosols	738	216	217
Vertisols	108	—	149
Xerosols	—	—	28
Solonchaks	—	—	257
Fluvisols	—	60	112
Total	1251	1030	992

Table 14.2 Distribution of soil types in ha within a one-hour walking zone

	Gatas (ha)	Bco. de la Ciudad (ha)	Czo. de Guevara (ha)
Lithosols	209	593	417
Regosols	951	140	598
Vertisols	128	—	264
Xerosols	—	—	454
Solonchaks	—	—	309
Fluvisols	4	68	313
Total	1292	801	2355

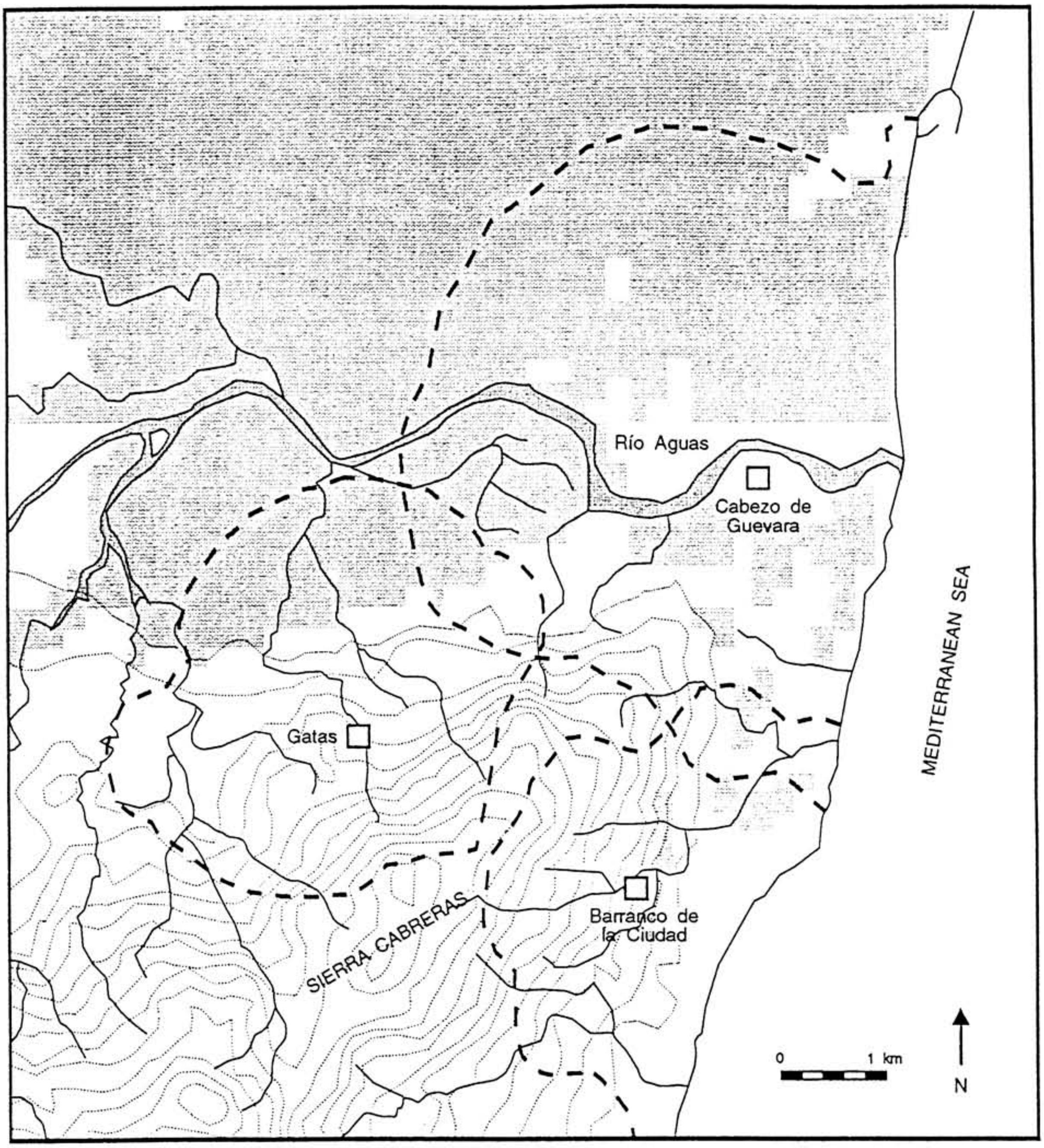

Figure 14.4 Radii of a one-hour walk from Gatas, Barranco de la Ciudad and Cabezo de Guevara. The shaded areas denote soils that have reasonable agricultural potential.

in the region are without any doubt the *Fluvisols* that nowadays are widely used for irrigated horticulture. In fact, irrigation in some areas has been so intense that locally these soils have suffered from salinization and turned into *Solonchaks*. The *Xerosols* are generally well suited for dry farming, while both *Regosols* and *Vertisols* are very much prone to erosion and are only used for terraced agriculture. However, it may well be that these soils have had a much higher agricultural potential in the past.

Both tables show us that the area around each of the three sites has a very different agricultural capability. The mountainous site of Barranco de la Ciudad is clearly dominated by *Lithosols*, so agriculture cannot have been of primary importance to its inhabitants. The site of Cabezo de Guevara shows a completely different picture: a wide diversity of soil types offers many possibilities for both irrigated and dry farming. The proximity of this site to the Río Aguas, however, suggests that the environmental conditions could have changed greatly through the existence of marshes or alternatively, coastline changes as Hoffmann (1988) has suggested for the Antas and Almanzora rivers.

Gatas seems to have an intermediate position with a large proportion of soils that now cannot be considered very well suited for farming, but may have been much better in the past. The main difference between the tables lies in the size of the territory and the relative proportion of the soil types. For Barranco de la Ciudad, the area available is considerably reduced, but the proportion of the soil types stays about the same. For Gatas, however, not much change in the extent of the hinterland is observed, but the amount of *Lithosols* is sharply diminished in favour of the *Regosols*. When we look at Cabezo de Guevara, we see that the catchment becomes 2.5 times as large, with a marked increase in *Xerosols*. The territory of Cabezo de Guevara not surprisingly now approaches a 4 km radius around the site, with the exception of the sea. The comparison shows that the use of this method has a marked effect on the descriptive level of the analysis and over-emphasizes the areas of easy access. It also shows that the nature of this effect is not only dependent upon the methods used, but also on the position of the settlement in the landscape and can give rise to a different interpretation of the site catchments (Wheatley, 1993).

Assuming, for example, that the Argaric settlements were heavily dependent on barley cultivation, at least in the final phase (Ruiz *et al.*, 1992), we might consider Cabezo de Guevara to be the most important site, due to its high potential agricultural land, as opposed to Barranco de la Ciudad. Although neither of the two sites has been systematically excavated, if we take into account the total area of artefact deposition and the quality and quantity of archaeological material collected during intensive field survey, the contrary seems to be the case. Moreover, many of the most important Argaric settlements show no clear preference for areas with large amounts of first-class agricultural land.

14.6.3 Reconstructing the domain of food production

Now we shall attempt to make a hypothetical reconstruction of the domain of food production for the Argaric settlement of Gatas. The domain of food production is modelled as a system of mixed agro-silvo-pastoral land use, i.e. a natural type of landscape organization, incorporating cereal cropping, olives, oak groves and animal pasture as a diversified single system. Similar systems of natural land management (*dehesas*) have been identified from palynological remains for the period 4000 BC–AD 1900 for south-west Spain (Stevenson and Harrison, 1992), although as yet there is no reliable evidence for the south-east due to the problems of pollen sampling in semi-arid environments.

Our point of departure involves population estimates. The problems related to the estimation of prehistoric population size and demographic factors generally has been the subject of much debate within archaeology and anthropology (Hassan, 1981; Schacht, 1981). While acknowledging the complexity of this issue, it is not our intention to enter this debate, but rather to use existing population estimates as the basis for calculating a minimum potential area (hectarage) which would be needed to cope with the subsistence requirements for the Argaric settlement of Gatas.

We shall begin with a population estimate of *c*.300, calculated by Chapman (1990) on the basis of burial and settlement area. We can now consider the basic food needs for such a population by utilizing available data on caloric and protein requirements as suggested by World Health Organization statistics (WHO, 1974). Taking an average consumption level of 3000 calories per day, then the human needs for one year become *c*.1 million calories or 1 SNU (standard national unit). One kilogram of wheat or barley will mill down to 900 g of grain, which will produce *c*.3100 calories. This is equivalent to $\frac{1}{3}$ tonne and interestingly, correlates with Roman military rations which allowed each soldier $\frac{1}{3}$ tonne of corn per annum (Mercer, 1981). Using this figure as a minimum requirement per person, the hypothetical Gatas population of 300 would have required 90 tonnes of barley per year.

Yield estimates for prehistoric crops vary enormously depending on soil fertility and climate. In the absence of hard empirical data, most estimates have been based on analogies with classical and medieval sources or from experimental evidence (Gregg, 1988; Mercer, 1981). From these sources it is possible to generate an average yield for barley of between 1.05 and 1.85 tonnes/ha, with a mean of 1.45. Next we must allow for the effects of spillage, disease or rotting and this can reasonably be calculated at around 20 per cent. A similar reduction must be factored in our calculations to account for seed for next year's crop. We thus have reduced the original yield figures by around 40 per cent, giving a new range of 0.63–1.11 tonnes/ha (mean = 0.87). Comparing these estimates with present-day data on land used in the Vera Basin shows that yields for barley are between 0.8 and 0.9 tonnes/ha in favourable years (Ministerio de Agricultura, Pesca y Alimentación, 1982) but on less suited soils the yields may be as low as 0.3–0.5 tonnes/ha. The estimates mentioned before may therefore be too high for south-east Spain. Yields for cereals can however be as high as 1.0–1.5 tonnes/ha when irrigation is applied. We can therefore take two figures for our estimation of the hectarage needed: the original estimate with a mean of 0.87 when irrigation is applied, and the second one with a range between 0.18 and 0.54 tonnes/ha when irrigation is absent. The figure of 0.54 will be more appropriate for well-suited soils like the *Xerosols* and *Fluvisols*, whereas 0.18 tonnes/ha will be a valid estimate for areas with abundant *Regosols*.

Applying these figures to our Gatas example, we can estimate the total hectarage needs, with irrigation, as ranging between 81.1 ha and 142.0 ha with a mean of 103.5 ha. An important assumption we will make is that not all arable land was cultivated. Probably one-third was left fallow, thus we need to increase our hypothetical hectarage at least by this figure, giving new values between 185.6 and 105.4 ha (mean = 134.6). Non-irrigated agricultural estimates give much larger values ranging from 221.7 to 665.0 ha. The subsistence system we are dealing with was not, of course, dependent on cereal crops alone. The available faunal evidence from Argaric sites in the Vera Basin show that both sheep and goats formed a prominent feature of the economy. Our food production domain, therefore, needs to accommodate the additional spatial requirements for these animals. It is known that sheep and goats need *c*.0.7 ha of pasture per animal, thus if we suggest for the settlement of Gatas a mixed flock of 50 sheep and goats, then we need around 35 ha of browse and pasture to accommodate them.

From Table 14.2 it is clear that the amount of arable land within one hour's walking from Gatas is more than sufficient, even when taking the most conservative estimate of 665 ha. This arable land is largely constituted by *Regosols* and *Vertisols*, soil types that are not very well suited for dry farming with yield figures under

0.6 tonnes/ha that do not lend themselves to easy irrigation. When we look at the 1982 land-use map, we see that downhill from Gatas cereals are grown in some places, but only 21 per cent of these areas are actually cultivated and the rest is left fallow. There are, however, some indications that in the past the situation may have been more favourable. Inside the area with *Vertisols* and *Regosols*, patches of *Cambisols* and *Xerosols* are found, soil types that are much more suited for growing cereals. These areas are very much prone to erosion due to the considerable gradient and the unconsolidated material that underlies the soils, so we can assume that the *Cambisols* and *Xerosols* have been much more common in the past, especially in the lower portions of the area. The agricultural potential of the area may have been much larger in the Argaric period. Furthermore, the area around Gatas offers almost unlimited possibilities for goats and sheep. With this knowledge we can construct a map of the hypothetical food production domain of Gatas (Figure 14.5) using the estimate of 221.6 ha for agriculture, located downhill, and 35 ha for livestock uphill. This map can be used as the basis for a dynamic modelling system.

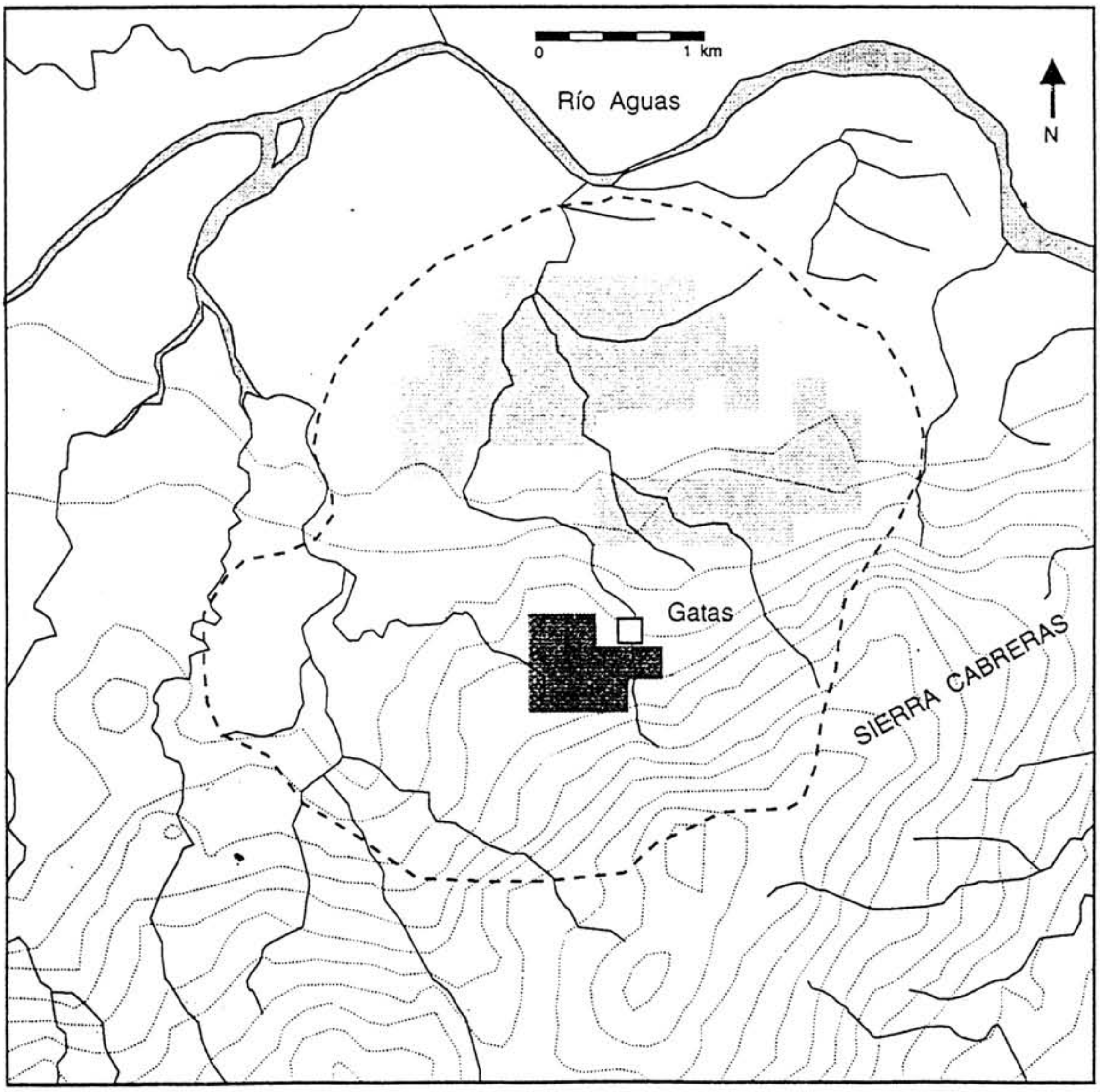

Figure 14.5 Hypothetical territories around Gatas for agriculture (lighter grey) and husbandry (darker grey). The radius of one hour's walking is given for reference.

The GIS offers the possibility to experiment with a number of parametric estimates for our subsistence model, and can provide a representation of possible settlement territories through time. Population changes, erosion or climatic factors can be introduced into the simulation to test some of the hypothetical dynamics concerning the socio-natural evolution of the Vera Basin. The GIS also offers tools for spatializing palynological and other palaeo-ecological data, and the interdisciplinary collaboration which this implies is a prerequisite for a better understanding of spatial interactions. Thus, it is this third level in our original scheme, i.e. the interpretive/analytical one, that can reach further levels of sophistication, demonstrating the fruitful interaction of GIS and dynamic modelling for future archaeological research.

14.7 GIS: towards an integrated model of social space

What the foregoing model building and discussion has shown, is that there is a great deal that GIS methods can contribute by way of demonstrating the utility of an interrogative multiscalar framework. The iterative nature of this model allows formal data to interact with less formal, qualitative knowledge and provides a format within which a variety of social, historical and environmental questions can be posed. A critical dimension in this process is that the model structure is non-hierarchial and pluralistic, such that there is no 'privileged' hierarchical classification of variables. It thus facilitates the construction and reconstruction of a wide variety of possible model, depending on the specific problem or interrogative process desired.

Perhaps one of the most interesting aspects of this scheme, which is still being developed, is the way in which the GIS technology provides statistical and descriptive data which can form the basis for dynamic simulation modelling of prehistoric subsistence practices. While this novel, interactive capacity is still under development, the success of current preliminary models based on data from the ARCHAEOMEDES project in the Vera Basin is encouraging, particularly in the integration of a temporal dimension; it thus suggests a way out of the oft quoted 'static' impasse which GIS is often accused of inhabiting (e.g. Castleford, 1992). Clearly there is much that is yet to be done if we are to move towards a true spatio-temporal GIS: one in which space is not simply a container of events, but the locus of socially defined practices and perceptions.

By way of summary, perhaps the primary implication of the foregoing discussion is the need for a conceptual 'retooling' if we are to realize the potential of GIS not simply as a method of *representation*, but rather as a means of generating sophisticated spatio-temporal *interpretive* models. In this way, archaeology can move to a new level of integrated modelling driven by GIS, and thus its goal of coming to a more complete understanding of the long-term development of human-modified environments, can potentially be realized.

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