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## CHAPTER FIVE

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# Models of Changing Environments

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*'It is impossible to suppose that by chance or design the whole of the woods on a given rock over a very considerable extent of country have been replanted with the same species, other than the natural ones; especially when it is observed that on a neighbouring rock, producing a different kind of soil, quite a different type of wood is found, while in another part of the country, on a rock belonging to a different geological formation but lithologically similar and producing the same soil as the first one, the same type of wood occurs as in the first case.'*

Moss, Rankin and Tansley (1910: 117).

### ABSTRACT

This chapter describes one possible 'way forward' through the apparent *impasse* caused both by the biases in the archaeological record discussed in chapter two, and the limitations of ecological and ethnographic analogies discussed in chapters three and four. The most constructive approach appears to be to develop a better understanding of changes in the nature and distribution of different environmental types, which may then provide a firmer context for interpreting changes in the archaeological record. Changes in woodland types and distribution are clearly a key issue, determining changes in available resources from tree nuts, such as hazelnuts, to large game, such as deer. Present interpretations of these changes are also the major influence on interpretations of changing populations. Equally, serious limitations with the evidence for marine environments, make terrestrial environments a more informative context to focus on and it is an exploration of changes in these environments, particularly changes in woodland types, which form the basis of this chapter. A model of most likely dominant woodland types in northern England is constructed using carefully considered evidence for past environments. The implications of this model in terms of changes in vegetation, including the description of three main phases of forest development, are then outlined. Finally, in order to address the reliability of the model, the limitations and possible variations are discussed. The development of this large scale picture of environmental changes opens up the door to studies of their potential impact on human populations, and these issues, alongside the significance of these changes for ideas about population changes are addressed in the following chapter (chapter six).



## INTRODUCTION

As argued in previous chapters, there are serious problems with our current interpretations of Mesolithic adaptations. For one thing, it was clear in chapter two that ‘top down’ interpretations of the archaeological evidence for settlement systems are affected by biases in the distribution of recorded sites. For another, chapters three and four demonstrated that ‘bottom up’ interpretations are limited by a lack of understanding of the nature of Mesolithic environments (which have often been interpreted through misplaced modern analogies). The preconceptions about Mesolithic subsistence and settlement described in chapter four have also given rise to ‘fixed’ concepts of Mesolithic economy and organisation (especially where the archaeological record is not sufficient to refute these interpretations).

Taking on board the limitations outlined in the previous chapters, this chapter describes one possible way of ‘moving forward’. There are of course a number of options, for example it would be worthwhile to explore the nature and causes of variability in subsistence and settlement among known hunter-gatherer groups, or the ‘real’ patterns of site distributions identifiable in the archaeological record through fieldwork or more effective sampling strategies. However, it is the environmental basis of Mesolithic adaptations which has consistently provided the baseline for interpretations. Thus in any re-evaluation of changes in Mesolithic population and settlement, environmental change is an obvious starting point.

## MESOLITHIC ENVIRONMENTS

Addressing the wide range of changes in Mesolithic environments in detail is a problem of immense proportions. The effects of changing climates and rising sea-levels are complex, with many variations in the subsequent adaptations of different vegetation communities and terrestrial and marine fauna. There are also very real limits to the evidence available for certain zones, with almost all early Mesolithic coastlines, alongside evidence for available resources and settlement patterns, having been submerged. Changes in resources in riverine or terrestrial environments are also far from simple. There *is*, nevertheless, a much greater body of evidence for changes in terrestrial environments from environmental studies, and for their effects on human populations from the archaeological record. Because of these considerations, the model introduced in this chapter concentrates on only terrestrial environments and particularly on changes in woodland types, which largely determine large scale changes in environmental zones. Changes in the character of woodlands is also the context for interpretations of gradually increasing populations (as discussed in chapter one) that provide the focus of this investigation.

What follows illustrates the development of one possible model to describe the main changes in terrestrial environments, specifically in terrestrial vegetation (effectively woodland composition), in the Mesolithic of northern England, as well as the possible nature of subsequent adaptations.

## THE NATURE OF TERRESTRIAL ENVIRONMENTS

Although there may be more evidence available for terrestrial rather than marine environments, the path from environment to Mesolithic adaptations is still one that is strewn with hurdles (as described in chapter four). In fact, even with a perfect knowledge of environments and resources, the best we can hope for is to define the most likely options for adaptations. What we have is far from ‘a perfect knowledge’. The evidence for past vegetation is largely limited to proxy records from pollen cores, but more than this, present environmental reconstructions are also limited in their relevance to the archaeological record because of their scale. Large scale generalisations such as ‘a change from coniferous to deciduous woodland’, as described in the last chapter, tend to be over-simplistic and moreover misrepresent the main changes taking place. The only alternatives are detailed reconstructions, based on ‘on the spot’ interpretations from pollen cores, which are generally at too localised a scale to relate to large scale changes in population or settlement.

There is clearly a need to reconstruct the large scale spatial nature, and changes in the extent, of different types of terrestrial environments, and specifically of inland vegetation communities. Such a knowledge of the nature and extent of *changes* in different environmental zones will provide information about changes in the structure of the resource base which should constitute a better basis for understanding changing adaptations than current static analogies.

*How can we go about reconstructing this type of picture of changing vegetation?*

The most obvious source of evidence for past terrestrial vegetation is that from studies of pollen cores.

### Pollen Based Evidence for Changing Woodland Distributions

Pollen cores would appear to provide a wealth of information for past vegetation types. There are, however, three main problems with using data from pollen sequences to interpret large scale changes in terrestrial environments in the Mesolithic - the limited availability of dated cores, difficulties in interpretation and, as mentioned above, the restricted spatial scale of reconstructions based on pollen analytical evidence.

Although many pollen cores have been analysed throughout the whole of the British Isles, pollen cores are only rarely adequately dated, with dated sequences depending at best on interpolation between a few widely spaced dates. This method is very problematic, not only because rates of sedimentation may vary through time, but also because ‘real’ calendrical dates are affected by the shape of the radio-carbon calibration curve, not necessarily having a strict linear relationship to other dates in the sequence. Birks (1989) in fact could only find 135 pollen cores in Britain (20 in northern England) suitably well dated to be used to determine the date of presence of different tree types (and very few are from lowland areas).

Additionally, whilst pollen cores can be used to determine the presence of any tree type with reasonable reliability, it is very difficult to determine the relative importance of different tree types, since different species contribute varying amounts of pollen to the pollen rain, and because pollen may travel different distances before being deposited. Lime has only relatively recently been recognised as a major component of past woodlands, as lime rich pollen spectra are often treated as suspect, since lime pollen is robust and therefore tends to be preferentially preserved (Grieg 1982: 26). Simmons *et al* (1996: 25) also discuss the problems of differentiating between 'open-ground' pollen, travelling some distance from communities above the tree line, and pollen from undergrowth within upland forests, since similar plants characterise both locations.

However, the most fundamental limitation to the use of pollen data to understand broad changes in woodland distribution is the issue of scale. Pollen cores represent a very local record of woodland composition which is difficult to relate to large scale regions. Although general woodland characteristics over a large scale conform to broad generalisations about the most common types, the woodland within any small area is governed not only by local topography, geology and sedimentology, but also by factors such as the history of tree spread and chance events such as woodland fires or freak storms (Smith 1978; Webb 1987). In fact, Turner, Innes and Simmons' (1993) analysis of 11 cores from a 350m stream section in the North York Moors demonstrates substantial variation in the Mesolithic period even within this small area (with the occurrence of peat inception varying within three millennia). The authors attribute some of this variation to the influence of human interference, nevertheless substantial local variability is as typical a feature of Holocene pollen cores as of unmanaged woodlands today (especially those in the uplands). Essentially, while pollen cores provide valuable information on the environmental context of a single site, interpolating woodland composition between cores can be extremely misleading, especially given the huge areas, particularly in the lowlands, without dated cores.

## APPROACHES TO LARGE SCALE CHANGES IN VEGETATION

Unfortunately, since the 'dots' on pollen maps of northern England are few and far between, 'joining them' may give us a very biased picture of the changing distribution of vegetation zones. To address changes in large scale vegetation zonation demands an alternative approach, and since there is insufficient 'hard' evidence, this approach will have to take the form of a *model* of changing vegetation zones. Any model based on ecological principles, however, depends on past vegetation zones being predictable, the factors governing vegetation being definable and evidence available for these factors in the past being available. Fortunately ecological studies in the present suggest that we can have at least some optimism about the first of these requirements, whilst the latter two are more problematic.

## ECOLOGICAL DETERMINANTS OF WOODLAND DISTRIBUTIONS

Local vegetation history is complex and much influenced by small scale variation and changes in local conditions (such as topography, drainage and underlying geology), but over the large scale certain trees (or associations of vegetation) *will* tend to be dominant under specific conditions of soil, climate and competition from other species. The factors determining the distributions of woodland types were an important component of early botanical studies. Early this century Moss, Rankin and Tansley (1910) explored the main determinants of dominant woodland types in Britain in detail (see quote at the start of this chapter). They concluded that climatic differences across the country at a constant elevation had little effect on the 'general nature of woodland types' (although climatic differences did affect the nature of undergrowth associated with different woodland types), the main determinants of woodland type being the *climatic effect of altitudinal differences*, and the effect of *substrate (soil) types*.

The reasons for the patterning that Moss, Rankin and Tansley observed is essentially that certain tree types are better adapted than others to grow on specific soils or in specific climatic conditions, and so tend to become dominant in these situations. Alder, for example, is adapted to soils which are often waterlogged, so it is particularly common in riverside locations. On the other hand, birch competes poorly with most other tree types, but being tolerant of relatively cooler climates, is dominant at high elevations. Both the general preferences of individual trees in Britain (as described for example by Moss, Rankin and Tansley 1910; Tansley 1939; Godwin 1975; Rackham 1980; Grime, Hodgson and Hunt 1988; Stace 1990; Rieley and Page 1990; Ingrouille 1995, and the locations where particular woodland compositions are found (Rodwell 1991) are relatively well understood. The reliability with which we can characterise the type of woodland expected under particular conditions of soil and climate will be an important component of any model of expected woodland types.



Fortunately, the behaviour of tree types at a coarse scale tends to be relatively predictable compared to behaviour at finer scales. Since the preferences of different trees and the modern climate and soil conditions are well known, it is possible to map specific regions where certain tree types ought to be dominant. Models of 'natural potential vegetation' (the vegetation that would characterise an area unaffected by human influence) have been developed for some years (Box 1981) although applications are growing rapidly in response to a need to understand the effects of global warming on plant communities (for example Davis and Botkin 1985; Leemans 1991; Prentice *et al.* 1993; Davis 1989; Davis and Zabinski 1992; Huntley *et al.* 1995; Sykes *et al.* 1996). Many models have been quite successful at predicting present potential natural vegetation from sample data, including the distribution of woodland types (Davis and Goetz 1990, Fischer 1990, Brzeziecki, Klenast and Wildi 1993). In fact, dominant tree types under known conditions can be predicted with a good degree of certainty for today's environments. Brzeziecki, Klenast and Wildi (1993) used 12 different environmental factors (divided into the three main factors of soil, precipitation and climate), coupled with detailed evidence for the environmental correlates of different forest types, to successfully map predicted woodland in Switzerland (according to 71 forest community types, with up to 85% accuracy) at a scale as fine as 1km resolution. Thus, in principle, the prospects for predicting *past* vegetation look good. However, in practice, the situation is somewhat more complex.

## PREDICTING PAST VEGETATION - IN PRINCIPLE

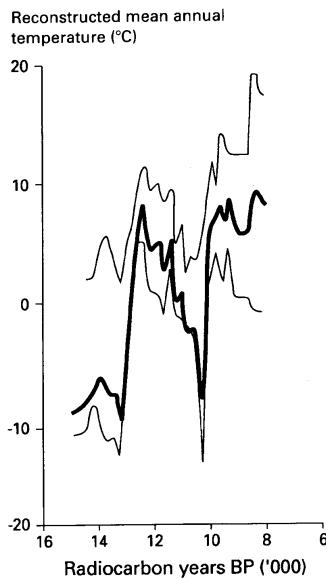
Given the main influences on woodland types described above, determining the woodland types at any location in the past should be merely a matter of using the soil type and climate to suggest which of the range of tree types available in the region will be likely to have been most competitive. The main limitation however, is that although very detailed information is available both on present soil and climate and on the environmental correlates of modern vegetation communities (as in the case of present day Switzerland), no such detailed information is available for past environments. The evidence which is available for each of the determining elements, climate (both in general terms, that is at sea level, and the variation of climate with altitude) and soil types, is discussed below. Since different tree types colonised the British Isles at different rates at the end of the last ice age, then the *presence* of tree types will also be an important component. Even before reviewing these elements in detail, it is clear that the resolution of the model (both spatially and temporally) and the nature of the predicted vegetation types will be limited, especially in comparison with similar models for present vegetation communities. The effect of uncertainties in the controlling variables on limitations to the resolution of the model are also discussed, although the potential implications of such uncertainties on the model results are discussed at a later stage. Nonetheless, it is clear that in comparison with models of present vegetation, that for past environments will have to be 'coarse-grained and careful'.

## EVIDENCE FOR THE DETERMINING FACTORS

### Climates

We can be certain that at the end of the last ice age climates in Britain were very different from those of today, much cooler, and also more continental (as low sea levels exposed large areas of land surface). By the end of the Mesolithic, climates fairly similar to those of today had been reached (Simmons, Dumbleby and Grigson 1981; Bell and Walker 1992; Atkinson, Briffa and Coope 1987; Mayewski *et al.* 1996; Stuiver, Grootes and Braziunas 1995). An understanding of the way in which climates changed between these two points is obviously very important in any model. Fortunately, the evidence available for climatic changes has increased enormously in recent years, particularly since only fifteen to twenty years ago our understanding of climatic changes was largely derived from pollen evidence. Major revisions from the contemporary thinking of a decade ago have recently been made as much more sensitive proxy sources have become available. These revisions have implications for our understanding of environmental changes and human adaptation as well as for any model of changing vegetation types.

Since in most areas of Britain the spread of tree types recorded in pollen cores appears to follow a similar sequence after the end of the last ice age, this sequence was seen as a good indicator of changing climates. Changing pollen frequencies have even been taken to represent datable sequences, particularly prior to radio-carbon dating, which is why Clark (1936: 30), refers to the importance of changing



**Figure 5.1** Temperature changes in the British Isles reconstructed from beetle remains, after Atkinson, Briffa and Coope (1987: figure 2). The bold line represents the most probable palaeotemperature for the coldest months of the year, finer lines the limits of the mutual climatic range of the dated fauna.

woodland in terms of *'the chronological value of its sequence of internal phases'*. In upland environments, such as the North York Moors, this sequence typically begins with herbaceous communities after the last glaciation, with early tree arrivals being juniper and birch, and after some changes during cold phases these communities are joined by hazel and pine in the early Holocene, with later arrivals being elm and oak (Simmons *et al.* 1993: 20-22; Pennington 1981), possibly followed by lime at low altitudes. Certain marker tree types still denote transitions from one phase to another, with the rise of alder pollen denoting the start of the Atlantic period, for example (West 1977; Simmons *et al.* 1993: 22). The gradual sequence of changing woodland types and the apparently gradual climatic changes were an important inspiration for archaeological interpretations of gradual changes in human communities. Subsequent changes in ideas about climate change are thus also important for a re-evaluation of archaeological interpretations.

The upheaval in ideas about climate change came about during the late 1980s when researchers began to recognise that environmental changes after the end of the last ice age may have been much more marked than the evidence from pollen cores appeared to suggest. Atkinson, Briffa and Coope (1987: **figure 5.1**), demonstrated from analysis of proxy temperature records, derived from beetle species (coleopteran data) from 26 sites in the British Isles, that temperature changes in the early Holocene were more rapid than had previously been supposed. This inference was possible because different species of beetle are very specific to certain environmental conditions (being limited to relatively narrow ranges of temperatures for example) and their presence is thus a good proxy record for climate. The reason why tree types changed only very slowly in response to environmental changes is that most tree species did not

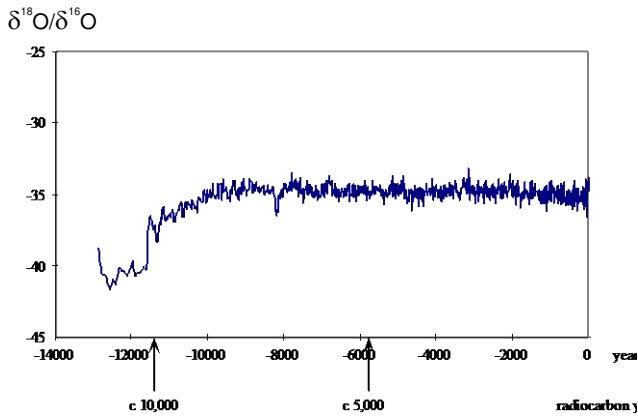
survive in northerly regions through the last glaciation and thus trees had to 'spread' from warmer regions, or 'glacial refugia'. Other plant species are somewhat more mobile than tree species (most undergrowth plants for example), and may have shown somewhat less of a 'time lag' in expansion after climatic change, not only because they can mature more quickly and produce seeds after a single season (Bennett 1986: 528), but also because their seeds are often lighter and more easily dispersed. However the suggestion of a more rapid temperature rise from the pollen of undergrowth species was not recognised in the early climate reconstructions partly because this pollen is less well represented in pollen cores, but also because undergrowth species tend to be given less attention than tree species, considered the 'dominant' component of vegetation.

The analysis of beetle distributions also confirmed the rapid cooling during the Younger Dryas cold phase which preceded the sustained warming in the early Holocene. Interestingly, the first appearance of Early Mesolithic industries in the British Isles is approximately contemporary with the end of the Younger Dryas and the subsequent initiation of sustained warmer conditions.

One limitation of using beetle species as an indicator of temperature is that habitable environments for beetles depend not only on temperature but also on humidity, soil development and the presence of particular plant species. Beetles may be a good indicator of certain types of *environment*, but not necessarily temperature alone. In fact other lines of evidence suggest that, comparable to tree pollen, the response of beetles to climate change may also be subject to a 'time lag'. Though derived from much farther afield, records of climatic change from polar ice cores appear to suggest an even more rapid change in temperature in the early Holocene than the beetle data, and have the advantage of not being affected by lags in plant or animal spread. In fact analyses of a number of 'cores' of polar ice (of which the most famous are the GRIP and GISP2 cores) have revolutionised ideas about the variability and rate of past climate change. Year by year climatic records for up to 130,000 years are available because proxy measures of past climates have been preserved in certain situations where tiny pockets of air have been trapped in ice which accumulates regularly each season. Over time, a sequence of ice has been deposited in which annual layers are distinguishable. The pockets of air can be dated by reference to the number of annual layers accumulated, and the components, indicative of the components of air in the atmosphere at the time of deposition, can be analysed. Several of these components hold a clue to changing temperatures during the Holocene. The most commonly cited is the relationship between different isotopes of oxygen -  $\delta^{18}\text{O}$  and  $\delta^{16}\text{O}$  (**figure 5.2**). Since the proportion of the lighter isotope ( $\delta^{16}\text{O}$ ) in the atmosphere increases with increased evaporation of water sources, the ratio of the two isotopes serves as a proxy record for temperature (Bell and Walker 1992: 38). This record shows even more marked warming after the 'Younger Dryas' cold phase than the beetle record.

Sources disagree about how relevant changes in temperature in polar regions are for changes in northern Europe (Petet 1995 for example discusses how 'global' a picture is recorded





**Figure 5.2**  $\delta^{18}\text{O}/\delta^{16}\text{O}$  ratio recorded in the GISP2 ice core (Meese *et al* 1994; Stuiver *et al* 1995), years before present (2000AD) plotted with a 50 year rolling mean.

in the ice cores). However, both the local evidence from coleopteran species and the suggestions from the ice core data make it clear that, *contra* initial interpretations from tree species, temperatures in the early Holocene rose rapidly. The picture of climate change derived from the presence of tree species is thus a very misleading one (Walker 1982: 419-420). Far from gradually and imperceptibly ameliorating climates, early Holocene human populations are likely to have experienced rapid temperature changes, both before and after the Younger Dryas. The exact nature of these changes is, however, uncertain, and, though bearing in mind the concerns expressed above, for a reliable local record the beetle data (since it is from the British Isles) is probably a better source.

### Altitudinal Limits to Tree Growth

Temperatures get progressively colder at higher elevations, and thus tree growth is limited at a certain elevation depending on the tree type (Hengeveld 1985). Aside from the *appearance* of tree species (discussed below) the main effect of warming climates will have been a rise in the *altitudinal limits* of different tree species (that is, the maximum elevation at which they successfully grow) as upland environments become warmer. The altitudinal limits of different tree types and how these change through time will clearly be an important component of any model. The altitudinal limits of modern species is an obvious starting point, since these limits can be altered to give past altitudinal limits by taking into account past climates. Fortunately, detailed studies have also been made of the altitudinal zonation of tree species in mid-Holocene environments in one region of northern England (Tallis and Switsur 1983; 1990), which comply with modern differences in elevation of dominant tree species, and therefore provide a reasonable basis for estimating the differences between the limits to tree growth of different tree species in the past.

Even with a knowledge of approximate elevation limits to the growth of different trees, the spatial distribution of different tree types demands further information. The locations of different elevation limits 'on the ground' (or in

effect the contours) will also need to be a component of any model. Present topographic data is readily available to use in any model. Past topographies (and the extent of land cover) will, however, have also been affected by sea level change. The melting of glaciers, increase in volume of sea water, and subsequent isostatic recovery of land areas, are very complex processes. Fortunately, recent models for sea levels through the Holocene, taking into account the readjustments of the mantle from as far afield as North America, are available (Lambeck 1995) although at low resolution.

The altitudinal limits are slightly more problematic than they might at first appear since although average temperatures appear to have been the most influential component of changing climates, rainfall (Simmons 1996: 11) and seasonality (the relationship between summer and winter temperatures) were also clearly variable during the Holocene (Bell and Walker 1992). The precise nature of these climate changes remains unclear, and, alongside changes in temperature, these factors may also have imposed constraints on the relative competitiveness of different tree species, particularly at higher elevations. These factors are difficult to incorporate. Nonetheless, differences in rainfall today largely affect only different woodland *composition* (such as between the west and east of the British Isles) but not the dominant tree types (Rodwell 1991). In any case, any model must be constructed on the basis of temperature as the main constraint on growth at different altitudes, at least until more information is available.

### The Presence of Tree Types

The date of arrival of different tree species in the British Isles will obviously be an important component of any model. The arrival of different species ought, in principle, to be predictable on the basis of the *rates of spread* of different tree types and the *locations of glacial refugia*. However, the factors influencing the *rate of spread* of individual trees are very complex. Prentice (1986) and Bennett (1986; 1993) discuss time lags and vegetation responses to climatic variation in more detail. Climate changes enabled the range expansion of forest trees, but since trees spread at different rates from refugia, their appearance (in sequence) in the British Isles is more a reflection of differing rates of spread than of the contemporary climate (Bennett 1985; 1986; Birks 1986; 1989). Different dispersal rates (windblown or animal dispersal, for example), time taken to reach maturity, and opportunities for seedling establishment in canopy gaps influence the rate of expansion of different trees. However climate, soil development and topographic barriers may also have constrained arrival times and patterns and rates of spread in certain circumstances. Lime is today one of the few trees whose presence in lowland Britain is limited by climate. Lime trees have never spread north of the north of England (Pigott and Huntley 1978; 1980) and, even though these trees may be present in the north today, temperatures are rarely high enough for successful pollination (Pigott and Huntley 1981). Pennington (1986) suggests that lags in the spread of tree birch into Britain in the Late Glacial may be a result of slow soil development after the scouring of soils by glacial activity, possibly also affected by only gradually rising levels of precipitation. Willis *et al.* (1997) note that rapid maturation of soils to a level sufficient to maintain deciduous forest, of the order of a hundred years, is

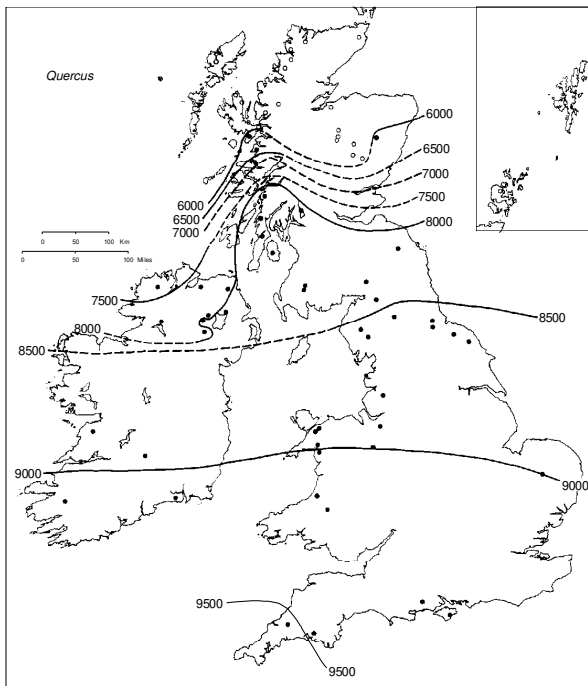


Figure 5.3 Isochrone map of the rational limit of *Quercus* pollen in the British Isles. The isochrones are based on data from the sites indicated by dots and are shown as radiocarbon years BP. Sites where there is no pollen-analytical evidence for local presence are shown as open circles.

**Figure 5.3** The spread of oak in the British Isles (after Birks 1989: 512).

documented in Eastern Hungary (although this process does depend on parent rock and climate). The spread of different trees is also complicated by relationships between species, such as the spread of one species enabling or preventing the spread of another. There has also been an increasing appreciation of the importance of chance or random factors in colonisations (Birks 1989; Smith 1978; Webb 1987). It is thus not surprising that as Bennett (1993: 72) notes that '*Re-running the Holocene with as close to the original starting position as possible would not necessarily produce the same outcome*'.

The *location of glacial refugia* also has a major influence on the date of arrival of different species to England. The precise locations of these refugia are not always clear, particularly since the location of refugia varies among different tree types. Pine, for example, appears to have survived the last glaciation in selected refugia in the northwest of Britain, while the glacial refugia for hazel and oak were in south-west Europe and those for later arrivals such as lime and elm were in central, southern or south-east Europe. Trees may also have survived in locations some distance from the main refugia. The presence of limited numbers of trees in certain locations beyond the typical geographical limits (too few to be picked up in analysis of pollen cores) which spread as climatic constraints were lifted, may also influence rates of spread (Bennett 1986).

Birks (1989) analysed the evidence for the spread of individual tree types into the British Isles and the influence of spread rates and the location of glacial refugia. He constructed his maps of the spread of each individual taxon<sup>1</sup>

<sup>1</sup> Pollen in cores dated to the early Holocene is not necessarily identifiable to species level, so the broader term of taxon (plural - taxa), the taxonomic subgroup, is usually employed.

by interpolating between dated pollen cores where tree types can be seen to be consistently present. **Figure 5.3** shows the constructed 'map' for the spread of oak. Birks (1989) notes that even the rates of spread of tree seeds dispersed by animals are remarkably fast. Huntley and Birks (1983) obtained rates of up to 2000 m per year for taxa in Europe, and Birks (1989: 525) obtained rates of spread which varied from 690 m per year for hazel, to 90 m per year for pine in Scotland. Although the spread of woodland trees into Britain took millennia, the changing appearance of woodland landscapes would still be very noticeable in a human lifetime. More importantly from the point of view of modelling woodland changes, it is clear from the maps that the rate of spread of different tree types is very individualistic, as tree types have spread at different rates and from different refugia and are affected by a complicated set of related factors. It has even been suggested that hazel was deliberately, or even accidentally, spread more quickly through human activities (Eriksen 1996: 109), although this is by no means clear. It has also been suggested that a dominance of hazel in many locations in the early Holocene may have been encouraged by human clearances (Simmons 1979; Simmons 1981; Smith 1970; Boyd and Dickson 1986), although Birks (1989, following Rackham 1980; Edwards 1982 and Edwards and Ralston 1984) argues that there is little evidence or ecological support for this, and Huntley (1993) concludes that climate was likely to be the primary cause of high hazel frequencies. Hence as can be seen, the chronology of tree spread may be similar over many areas, but the timing of this sequence is influenced by many complex factors such that climate, or temperature, play a relatively minor role.

Ideally, any ecological model would be based on the rate of spread of different tree types, however the factors governing the spread of different trees are clearly very complex, and partly determined by random factors of chance dispersals (or even possibly by human activity). Attempting to model tree spread based on first principles would thus be prone to huge inaccuracies (Bennett 1993). Given the difficulties with using such a model, Birks' (1989) maps provide an important source of evidence for changing vegetation (see **figure 5.3**). A further benefit of the use of this source would be that the problem of potential constraints on rate of spread imposed by soil development or climatic factors would be reduced.

Birks' (1989) maps (or a model of the rate of spread of different taxa for that matter) however only show the *presence* of tree taxa and not their importance in local woodland. In fact, of the tree taxa present in any area, only a limited number will be a significant component of the forest canopy. These maps *could* nonetheless be combined with soil and climatic evidence to generate a model of the important tree types in a region, as long as the limitations of the dataset are kept in mind.

## Soils

Determining the character and distribution of past soil types is potentially quite difficult. Obviously for areas now submerged under the North Sea and Irish Sea, the rising sea-levels since the early Holocene have made past soil types almost impossible to assess. Although the bottom sediments of the North Sea are mapped, they are largely produced by





deposition of sediment by ocean currents rather than being any reflection of past soil types. On the other hand, even the land based evidence for past soils is not straightforward. Although British geology is accurately recorded, present soil types are a very poor analogy for past soil types, particularly for the early Holocene. The presence of woodlands, the accumulation and decomposition of leaf litter, and millennia of leaching of upland soils have had major effects on soil types (Iversen 1958; Pennington 1981; Birks 1986; Rieley and Page 1990). Lowland deciduous woodlands, especially those dominated by oak, have through time encouraged the thin soils (lithosols) present at the start of the Holocene to develop into deep soil profiles with a nutrient rich humus. Conversely, increasing waterlogging and leaching in the uplands turned early and middle Holocene soils into deep gleyed peat with pronounced iron pans.

While Bennett (1989) was able to use modern soil types in his model of the dominant woodland types of 5,000 years ago, modern soils would be a poor source of evidence for earlier periods. Fortunately, it is the rock type which is the major determinant of 'young' soils developing on rocks scoured by glacial activity, although soil characters change with increased weathering, leaching and through the effect of vegetation. Any model of past forest distribution would be more pragmatically based on the most probable soil types on the basis of rock types than on present soil distributions. There are some limitations to this approach, as we have only an imperfect knowledge of the process of soil development, and the *importance* of the stage of soil development in governing vegetation cover. Nonetheless, a map of rock types is a reasonable basis for the model (and thus the typical soils developed on these rocks, such as described by Curtis, Courtney and Trudgill 1976), with the addition of alluvial soils near major rivers.

### Soil Preferences

The dominant tree taxon on any soil type of course depends on which tree taxon were present and how individual trees compete in different situations (the 'biotic' factors, in contrast to the above 'abiotic' factors). Whilst definable in the present, the past *preferences* or optimum environments of different tree types are potentially problematic. Although modern tree species preferences can be determined, the environmental preferences of past woodland types may have been subtly different, and current ideas about preferences are based on evidence from modern woodlands. These modern woodlands are either deliberate plantations or associations of species suited to present ecological conditions, thus potentially a poor analogy for Mesolithic forests (as discussed in chapter four). In fact many ancient woodland types have no modern counterparts (Bennett 1993), for example early colonising hazel probably existed as a tree rather than a shrub species - although it is not seen in this form today.

Despite these considerations, although the behaviour of tree taxa on certain soils and under certain climates, and in competition with other taxa, may have varied subtly from the present behaviour, Prentice (1986) points out that the behaviour would not have been fundamentally different, with even the many millennia since the early Holocene being insufficient for marked evolutionary changes. Bennett (1989)

uses modern tree preferences in his model of dominant woodland types 5,000 years ago. Whilst taking the limitations on board, the preferences of modern tree taxa, and the way in which they compete with each other in different environments, seem the best basis on which to model the most likely dominant woodland in earlier periods.

## THE RESOLUTION OF THE MODEL

Clearly building a successful model of past vegetation will depend on adopting a pragmatic approach, for example using present evidence for the timing of arrival of different tree types rather than a model based on principles of spread rates and refugia. This means that there will be limits to the resolution of the model - the level of detail of expected woodland composition and the spatial and temporal resolution of the woodland distributions and successions. Also, given uncertainties in the input factors, any model should be designed so that these factors, such as the effects of climate changes on altitudinal limits, can be modified. The implications of the chosen set of factors, and confidence in these factors should also be carefully assessed.

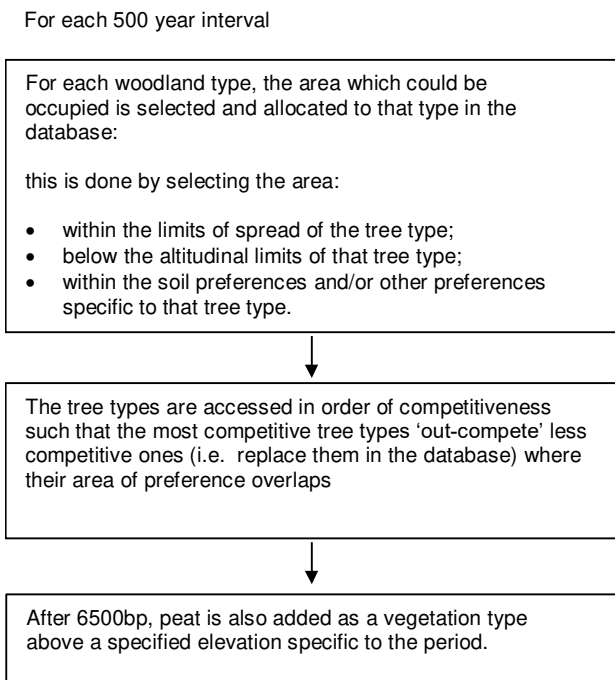
### The Resolution of Woodland Composition

Where detailed information is available for present environments, it is possible to predict specific woodland compositions or even phytosociological associations (Rieley and Page 1990; Rodwell 1991). Given the limitations of evidence for past environments, a single probable dominant woodland type may be a more pragmatic approach (with an option to introduce secondary tree taxa determinations if known), especially as any more complex categories would undoubtedly misrepresent the confidence in any model. Whilst the 'dominant tree type' in any woodland only gives us a simple indication of the woodland composition, changes in dominant tree types are still a valuable record of past ecological changes and *would* undoubtedly have been a major factor governing changes in resource availability for past human exploitation.

### The Spatial and Temporal Resolution of the Model

Last of all, the issue of the spatial and temporal resolution of the model will be a critical one. A major limitation imposed by using Birks' (1989) maps as a basis for the presence of tree types is that the resolution of this analysis, both spatially and temporally, is very coarse. The maps of tree spread are only generated for 500 year intervals, and, given only 135 cores across the British Isles, have a low (although not stated) spatial resolution.

In terms of *temporal scales*, although climatic data of high resolution from ice cores are available, the potential effects of small scale climatic changes on vegetation in northern England are unclear. It is important to consider that the effects of both short and long term climatic changes are largely *indirect*, being mediated by time lags in the response of different elements of the ecosystem. Because of this, short term climatic variability has effects on ecological successions (Prentice 1986), but it is the long term changes in climate which will cause a displacement of vegetation



**Figure 5.4** The construction of the model.

zones. Thus it is long term changes which will have had the major effect on *long term adaptations* of human populations.

This is not to say that short term climatic oscillations did not have an effect on vegetation or on human adaptation, but that these effects are difficult to define and identify, and moreover, act at a different scale than that of the questions addressed here. Even the most extreme of short term environmental changes, such as volcanic eruptions, rarely have direct effects identifiable in the archaeological record of mobile groups (Borrero 1996: 349). Dust from volcanic eruptions, for example, probably created several year long periods of decreased temperatures in the early Holocene due to reduced solar radiation (Zelinski *et al.* 1994; Mayewski *et al.* 1996), but archaeological evidence for any specific response to these short term changes is unlikely to be recognisable.

Given that the radio-carbon dating record for Mesolithic sites is notoriously poor, with dated sites associated with 150 year standard deviations being comparatively 'accurate' and many standard deviations being over 400 years, only a model of very coarse temporal resolution (of the order of the 500 years mapped by Birks) would be appropriate to compare to the archaeological evidence for long term adaptations.

Finally, in terms of *spatial scales*, a better spatial resolution of tree presence would undoubtedly improve the model. However, the resolution is still adequate to address large scale regional differences in vegetation types.

Evidently, given the limitations discussed, the model of past dominant vegetation types cannot hope to describe the complexity of local vegetation histories and will at best describe only a general picture of the types of changes taking place across the period. Nevertheless, a model using the factors described must provide a better context for

interpreting Mesolithic adaptations than all-embracing generalities or small scale local histories. The method by which to build such a model is the only factor left to address.

## CONSTRUCTING THE MODEL

A choice had to be made of an appropriate platform to use for the model and method by which to use soils, climate and tree types to determine woodland distributions for each period. Creating a time sequence of models by combining each of these factors for each period would be extremely time-consuming by hand, and computerising the process is an obvious step. GIS (Geographical Information Systems) were chosen as the appropriate computer software to use since they have been designed to enable many different layers of information to be combined and analysed and the results plotted<sup>2</sup>.

The method essentially consisted of using GIS to combine a series of base maps (described below) of soils, topography (to determine the altitudinal limits to tree growth) and the time of arrival of each tree type, to produce a map with a large number of units, with information on soil types, etc., for each unit stored in a database. A program designed within the GIS package (listed in Appendix B) used the soil and climate preferences of each tree type, along with information on the climate and presence of tree types for each phase, to select the most probable dominant tree type<sup>3</sup> for each unit (for each 500 year period), as illustrated in **figure 5.4**. This is done by running through two nested 'loops', the outer cycled through each date or period for which the model was being run, the second went through the mapping of each different possible woodland type allocating a dominant type for each unit. The program in fact generated a new attribute in the database (defining probable dominant woodland) for each of the units (**figure 5.5**).

The model was constructed to allow the components to be easily varied. These components are detailed below.

<sup>2</sup> Since the input data is line (vector) based, the analysis was carried out using vector based techniques (in ArcInfo version 7.0) to avoid the distortions created by converting between formats, plus the spatially referenced database produced could be analysed with more flexibility than through combining raster based layers.

<sup>3</sup> That is to say the species that would be expected to be the most competitive under the conditions defined, and that therefore ought to be the most frequently occurring species in the woodland.



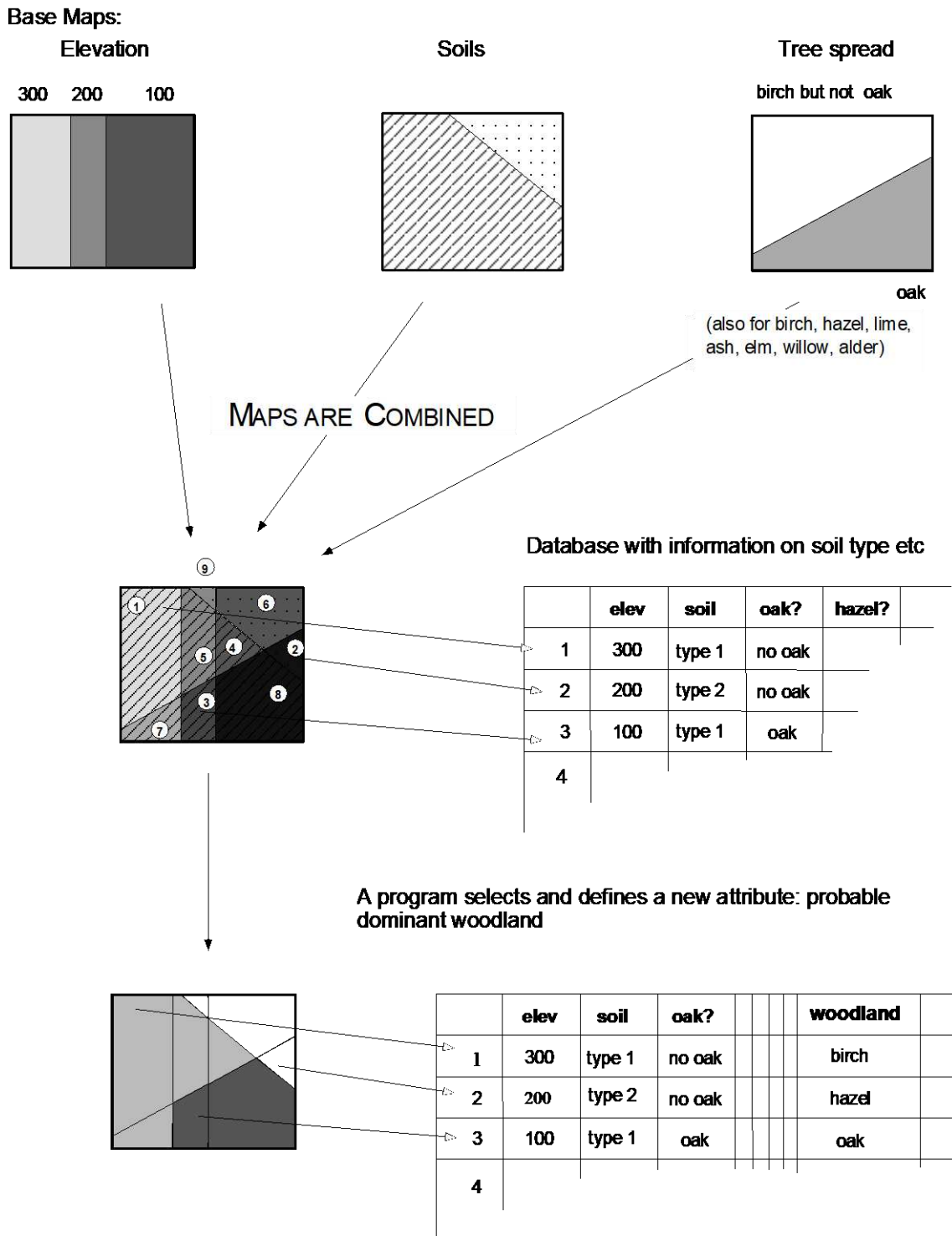
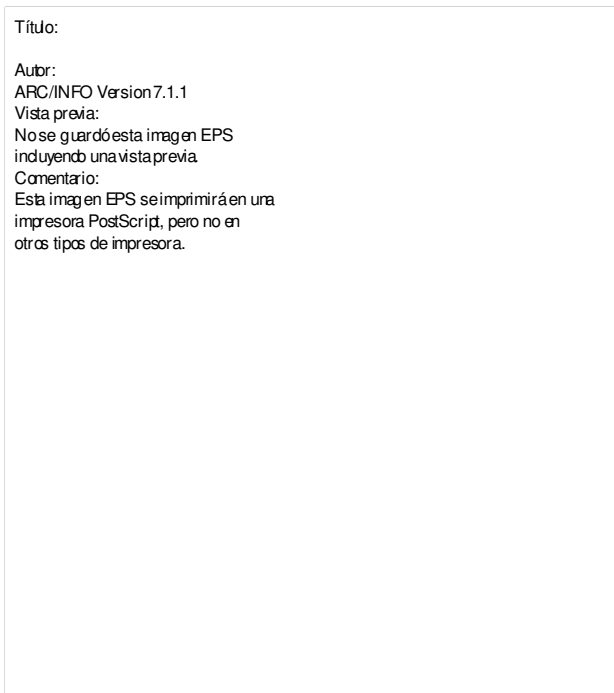


Figure 5.5 Assigning probable dominant vegetation.

**The Maps Used**

The past *soil types* used in this model were based on rock types, and were grouped into the following major classes (figure 5.6): very shallow soils (1 - on slates and greywacke, mica schists, volcanic rocks and granites); calcareous soils (2 - on chalk, oolitic and similar limestones, massive and also

metamorphic limestones); wet basic soils on clays and loams (3 - on clays, mudstones and shales); well-drained basic soils (4 - on friable sandstones); and variants of the latter two soil types (5 and 6) where rocks also include a limestone component. The location of present day major rivers (shown



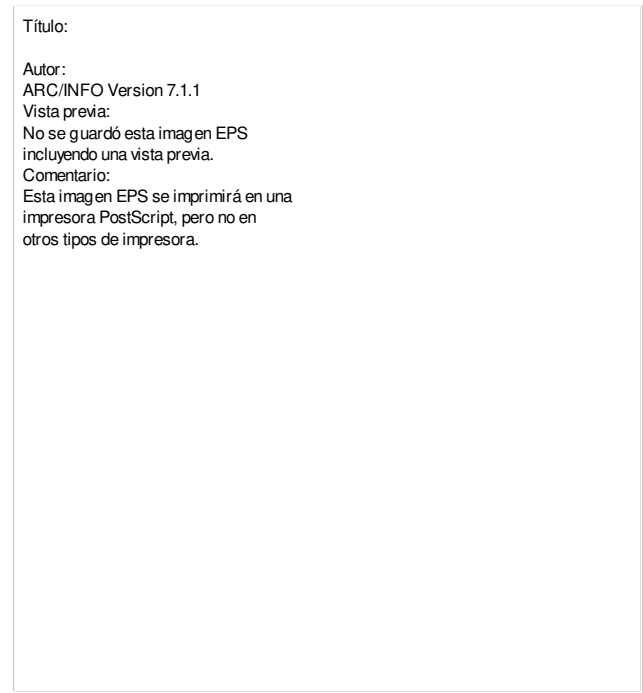
**Figure 5.6** Soil preferences base map.

in **figure 5.7**) was used to determine the likely location of wetland soils.

In order to define the altitudinal limits for each tree type for each 500 year interval, a topographic map was used. This was based on digitised 100m contours for the area (**figure 5.7**), which were then interpolated to 50m contours (by creating a surface model which was sampled at 50m intervals to generate contours). The change in *climate* (based Atkinson, Briffa and Coope's 1987 analysis) affects the distribution of tree types via the change in altitudinal limits with rising temperatures. That is to say that the altitudinal limits for each taxon are determined by the effective temperature at defined elevation bands (with a 0.6°C fall in temperature for each 100m above sea level, Simmons, Dimpleby and Grigson 1981: 91), with the altitudinal limits rising in each intervals according to the rise in temperature.

The contemporary *coastline* was taken from Lambeck's (1995) model which took into account complex modelling of glacio-hydro-isostatic rebound. Although mapped on a very large scale, the coastlines defined in this study are more accurate than previous models and give a good correlation with profiles of sea depth changes at sites around the British Isles. Interestingly, Lambeck's model generates a very different picture of the past area of land surface than those generated by simply exposing land according to sea-depth data (such as Verhardt 1995), a fact which has wider repercussions for studies of changing marine environments in the Mesolithic. The edge of the coastline was interpolated at 1000 year intervals (from a model generated of the time sequence of coastlines on the basis of Lambeck's 1995 maps which are at 2000 year intervals) to give a general picture of changing coastlines through the period.

Finally, the known *presence of tree types* (taken from Birks 1989) was used to define the limit of spread of each tree type



**Figure 5.7** Topography base map.

for each 500 year interval. This evidence covers eight main tree types which may have been dominant under certain conditions, i.e. birch, hazel, pine, willow, oak, ash, alder and lime, and also elm, which though included in the model does not figure as a dominant tree. The earliest Mesolithic radio-carbon date for northern England is from Star Carr (9,700±160bp (OxA-1176)) and latest Mesolithic date is from March Hill (Hearth B at 5190±45bp, (OxA-6306)). These dates provide a broad indication of the span of Mesolithic occupation in the region and thus the model spans the period from 10,000bp to 5,000bp.

In the 'run' of the model described, even using the above quite coarse scale maps, a large number of individual units - 12,168 - were created when the soils, topography and tree spread maps were combined (the average size of each unit being 3.9 km<sup>2</sup>)<sup>4</sup>.

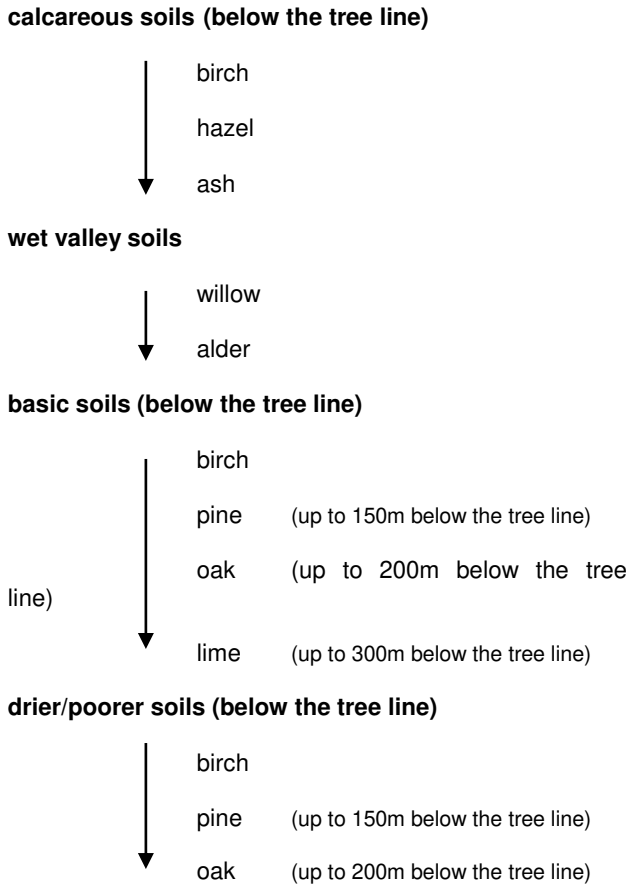
### The Relative Competitiveness of Tree Species

The *altitudinal* and *soil preferences* of different tree types have been derived from several publications (e.g. Moss, Rankin and Tansley 1910; Tansley 1939; Godwin 1975; Rackham 1980; Grime, Hodgson and Hunt 1988; Stace 1990; Rieley and Page 1990, Ingrouille 1995, most notably Rodwell 1991 with particular reference here to discussions of altitudinal zonation in Tallis and Switsur 1983; 1990 and preferences of past tree types in Bennett 1989).

The most probable dominant woodland on any soil at any time was selected on the basis of which of those tree types present is most competitive under the specific conditions of soil substrate and altitude. In general terms, the earliest tree

<sup>4</sup> Given processing and memory requirements, a raster based model may be required for any more detailed model (although such a model would be more limited in the way in which selections could be made from within the database).





**Figure 5.8** Vegetation succession used in the model.

type to arrive at any location will be dominant (as long as conditions allow growth) until this tree type is replaced by more competitive tree types, and the resultant sequence of woodland types forms a *vegetation succession*. Different vegetation successions will characterise different substrate types. Prior to the spread of any other trees, juniper/aspen scrub would characterise most areas and would be the ‘first’ vegetation type in any succession. The vegetation successions following this ‘scrub’ vegetation that were used in the model (for four main types of soils) are shown in **figure 5.8**.

The calcareous components of both basic loams and poorer soils determine the presence of hazel as a secondary component of the woodland.

The temperature changes were used to approximate the altitudinal limit of *the tree line*. The treeline was set to initially limit tree growth (at 10,000bp) to below the present 100m OD contour, rising quickly to 300m OD by 9,500bp and more slowly to 600m OD by 7,000bp. The initial rise in temperature (at 500 year intervals) was taken from (Atkinson, Briffa and Coope 1987), which provided a more local record than the Greenland ice core data, with a more gradual increase following this initial rapid rise. These altitudinal limits for tree growth were based on the present ecological limits adjusted for lower temperatures and reduced sea level on the basis of a steady effective fall in temperature with elevation (0.6°C per 100m, Simmons,

Dimbleby and Grigson 1981). The altitudinal limits of different tree types were based on those proposed by Tallis and Switsur (1983; 1990), with the relative altitudes remaining the same whilst absolute altitudes changed with warming temperatures and the rise of the tree line. The maximum elevation of birch, hazel, and willow were set as the treeline itself, that of pine was set at 150m lower than the treeline, upland forest (the limits of oak and elm) at 200m below and lowland forest (essentially the limit of lime) at 300m below (based on Tallis and Switsur 1983; 1990). These elevations were somewhat limited by being restricted to 50m intervals (because of the topographic map used), a more detailed topographic base could have been used to enable altitudinal zonation to be modelled in more detail.

*Peat formation* was also added to the model. A representation of peat formation was introduced very simply, as a spread starting at the higher elevations (550m OD and above) at 6500bp and reaching a lowest elevation of 400m OD at 5000bp. Very early dates exist for peat inception, such as within the 9<sup>th</sup> millennium bp at North Gill, North Yorkshire (Turner, Innes and Simmons 1993), but dates around the Boreal-Atlantic transition are more typical (Tallis 1991). In fact, Tallis (1964) and Taylor (1983) cite characteristic dates for basal peat deposits or the tree remains in at around 6000bp.

## PREDICTED PATTERNS OF CHANGES IN VEGETATION

Before discussing the limitations of the model, it will be useful to review the main changes recorded in the model. In general terms the model describes the phase of the glacial-interglacial cycle (from 10,000 to 5,000 bp, i.e. 11740 (11200, 11180, 11110) 11000 1 $\sigma$  cal bp – 5900 (5730) 5620 1 $\sigma$  cal bp, Stuiver and Reimer 1993) when shade intolerant species and opportunistic species such as birch spread into northern England, gradually being replaced by shade tolerant species such as oak and lime. Note that the woodland types in the model only represent the most likely dominant tree types in the region given the soils and climate. As well as considerable variability within any woodland, the ‘population front’ of tree types and altitudinal zonation would in reality be markedly ‘blurred’ and patchy.

The sequence of vegetation changes described by the model can be summarised in three main phases:

### 10,000bp to 9,000bp (Figures 5.9 to 5.10)

11740 (11200,11180,11110) 11000 (9980) 9910 1 $\sigma$  cal bp

The period from just prior to 10,000bp to 9,000bp illustrates the initial colonisation of un-wooded areas by opportunistic tree species, with rapid changes in the extent of lowland woodland as the altitudinal limits to tree growth rose to higher elevations. Birch probably spread to the British Isles from the East (across the North Sea plain) a few centuries before 10,000bp. By 10,000bp it had already expanded rapidly onto existing scrub (willow and juniper-aspen) and grass vegetation (Birks 1986) in the lowlands. The model shows birch forests only extending up to a low elevation, partly because the effective altitude of the uplands would have been higher due to the low sea-levels and also because climates would have been several degrees cooler. A rise in the height of the tree line by 9,750bp is illustrated as being relatively rapid with tree lines reaching approximately present levels by 9,000bp and the extent of lowland woodland increasing as a result. A further significant change illustrated by the model is the spread of hazel over northern England from the west (from 10,000 to 9,500 bp), flourishing under the light shade of birch woodlands and also existing as pure stands of hazel woodland. With an open canopy the birch forests would have had a substantial hazel component.

This period is thus, in general, characterised by a lowland landscape dominated by birch and hazel forests, with willow in wetter areas and juniper in the upland fringes.

### 9,000bp to 7,500bp (Figures 5.11 to 5.12)

10040 (9980) 9910 - 8370 (8310, 8220, 8220) 8140 1 $\sigma$  cal bp

During this time interval the changes illustrated in the model describe the opportunistic but shade intolerant species (such as birch) being pushed to a higher altitude as shade tolerant and more competitive species come to dominate the lowlands. From 9,000bp oak *and* pine gradually move northwards into northern England displacing lowland birch. Shade tolerant trees such as oak would have formed a denser forest canopy than previous woodland types, although shade intolerant species remain as initial colonisers of canopy gaps (Peterken 1981) at too small a scale to be included in this

model. The spread of shade tolerant species also generates an altitudinal zonation in the uplands as different tree types are more or less competitive at different altitudes. This zonation becomes apparent in the model from 9,000bp, with a higher proportion of oak in the lower uplands (with oak coming to dominate most soils in the lowlands after 8,500bp), a narrow band of pine coming to dominate slightly higher elevations, and birch even higher still (with juniper-aspen scrub above the treeline). From 8000bp the model shows alder becoming more common than willow on wetter soils. The effects of rising sea levels in causing large areas of the North Sea plain to be flooded is also evident in this phase.

By 7,500bp the lowland landscape would have been dominated by oak forests, with alder in wetter areas, hazel on calcareous soils and an altitudinal zonation of oak-pine-birch in the uplands.

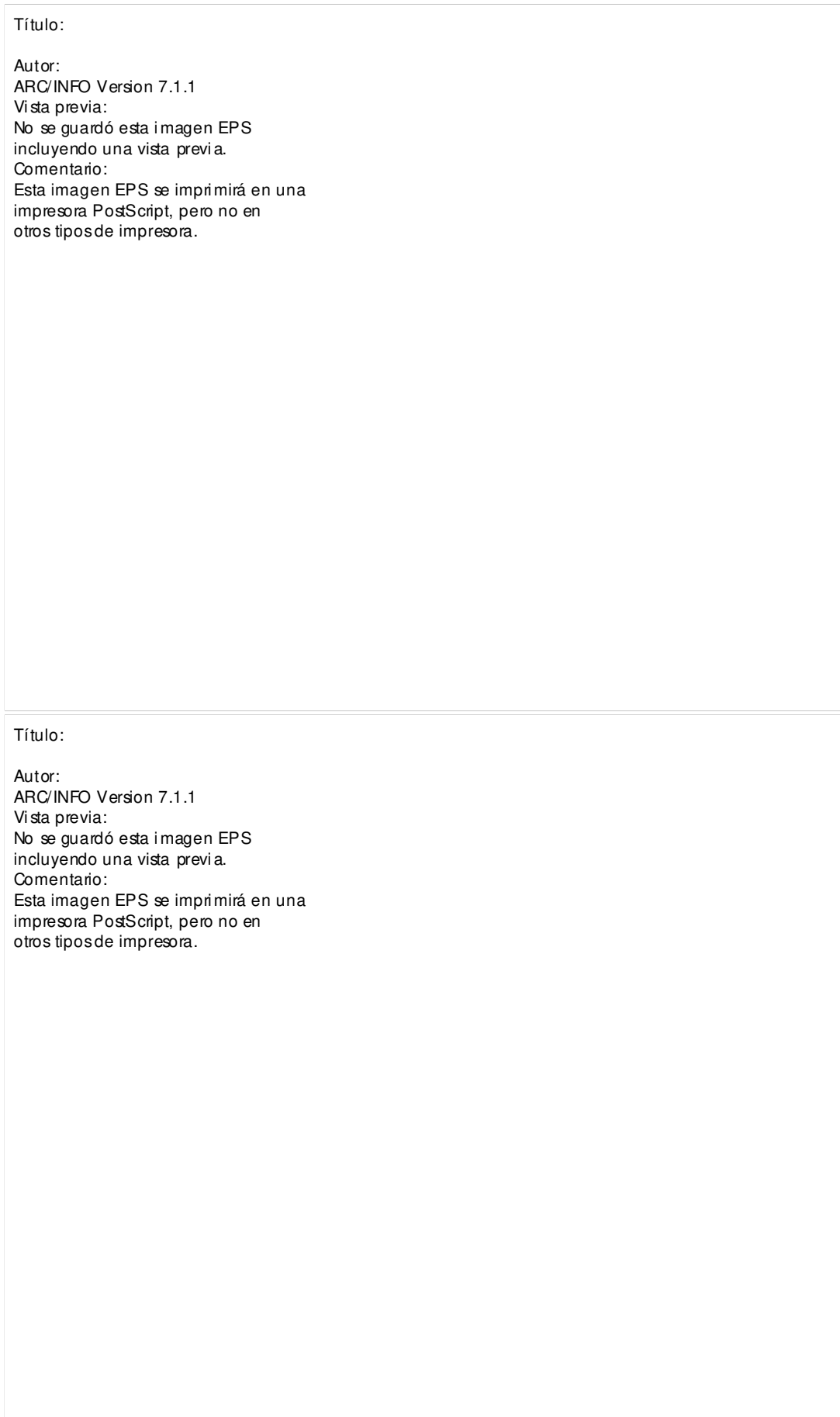
### 7,500bp to 5,000bp (Figures 5.12 to 5.14)

8370 (8310, 8220, 8220) 8140 - 5900 (5730) 5620 1 $\sigma$  cal bp

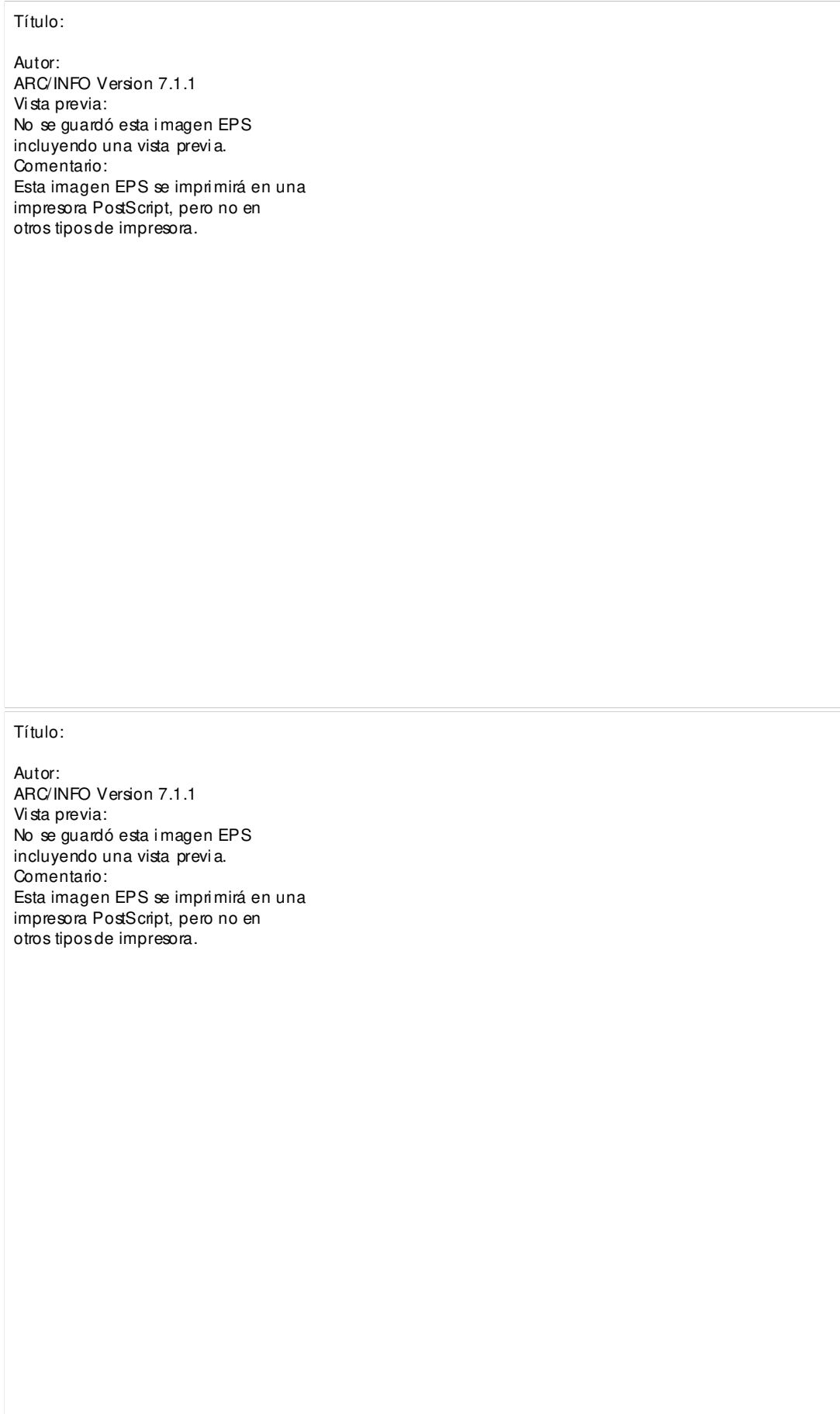
This period is characterised by the spread of slower moving tree types - lime and ash - and the subsequent development of a relatively stable woodland composition. Oak was gradually replaced by lime after about 7,500bp, particularly in the south-east and on the richer soils (Bennett 1989), once again changing the character of the lowland forest. Ash also spread onto calcareous basic soils (replacing hazel) a little later (after 7000bp). By about 6,500bp the woodland composition is shown as relatively stable, with the maximum northwards extension of lime occurring at 6000bp (see Piggott and Huntley 1978; 1980; 1981 for a discussion of the past and present limits of lime woodland). The North Sea plain by this time has been completely inundated, with coastlines reaching approximately present day levels at 5500bp.

The stable period (from about 6,500bp) is characterised by a broad area of lowlands (especially in the south) dominated by dense lime forest and a stable altitudinal zonation in the uplands. The only further changes in the model are brought about by the spread of blanket peat from flat or gently sloping high altitude plateaux starting in the model from 6,500bp.





**Figure 5.9** Model of Probable Dominant Woodland Types at 10,000bp (above) and 9,750bp (below).



**Figure 5.10** Model of Probable Dominant Woodland Types at 9,500bp (above) and 9,000bp (below).





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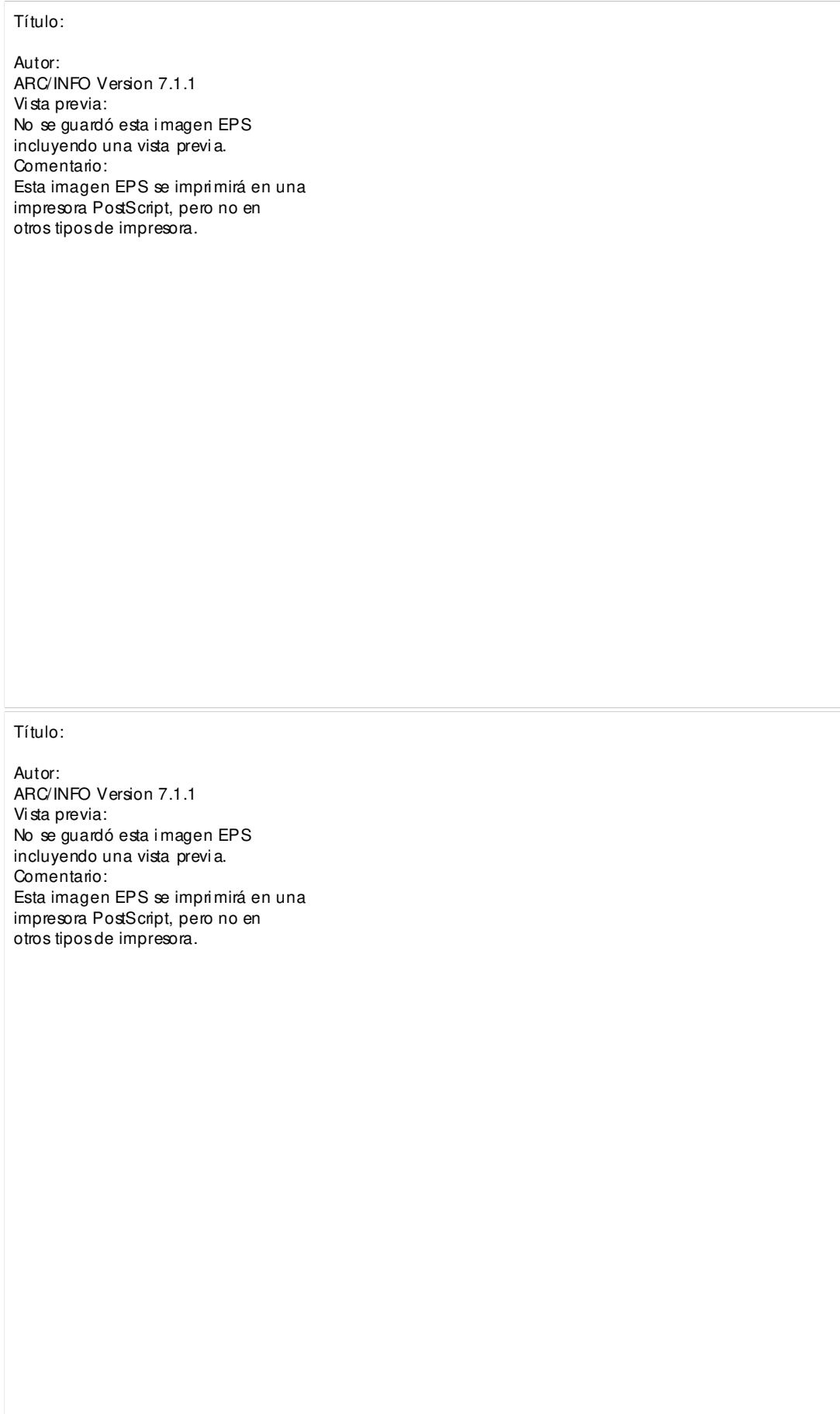
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**Figure 5.11** Model of Probable Dominant Woodland Types at 8,500bp (above) and 8,000bp (below).



**Figure 5.12** Model of Probable Dominant Woodland Types at 7,500bp (above) and 7,000bp (below).



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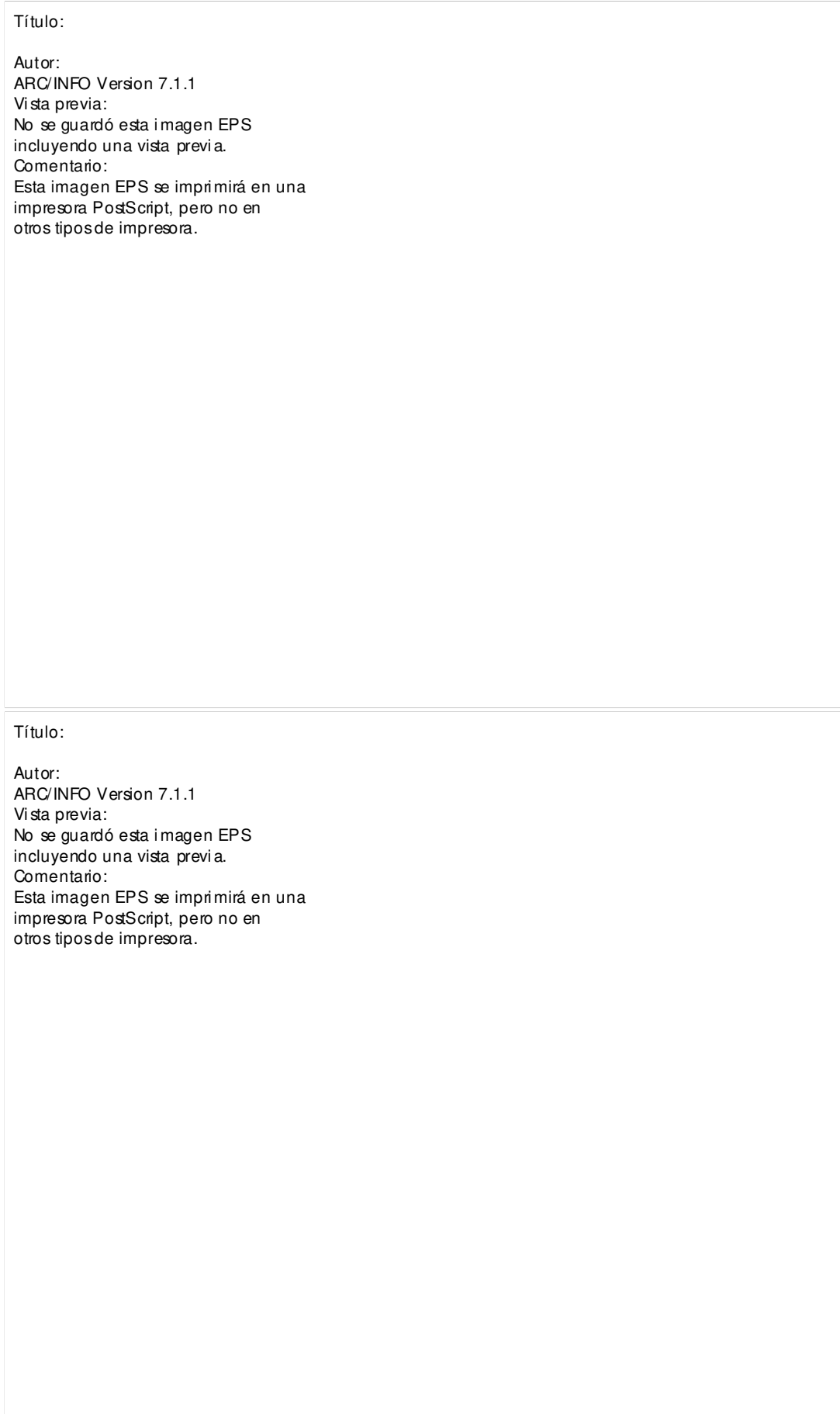
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**Figure 5.13** Model of Probable Dominant Woodland Types at 6,500bp (above) and 6,000bp (below).



**Figure 5.14** Model of Probable Dominant Woodland Types at 5,500bp (above) and 5,000bp (below).

