Environments and Landscape Change

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Abstract and Keywords

This chapter reviews evidence for the nature and magnitude of environmental change in Europe during the Neolithic incorporating evidence of climate change from mires, lakes, and caves as well as event chronology including the use of tephras. Subsequently the chapter reviews spatial approaches to vegetation change and interactions between environmental change and lake, valley, and coastal settlement histories. Finally the chapter introduces two novel aspects of Neolithic environmental change; empty and symbolic spaces including high altitude environments and skyscapes, before discussing how we might start linking environmental change, cultural transformations and cognition.

Keywords: Climate change, events, early agriculture, resilience

Environments, scale, and agendas 6500–2500 BC

THIS chapter considers the 'environment' between 6500–2500 BC, a period which encompasses most of what archaeologists have regarded as 'Neolithic' within Europe. This enormous stretch of time amounts to 40% of the Holocene sub-stage of the Pleistocene. At about 10.2 million km^2, Europe as defined here is also large, equivalent to 7% of the Earth's landmass. It stretches over 35º of latitude and 50º of longitude and from just below sea level to 5633 m in altitude (Mt Elbrus in the Caucasus). Two implications follow; first, this chapter is necessarily an overview and highly selective, and secondly, 'scale' is itself an important issue when dealing with any idea of the European Neolithic.

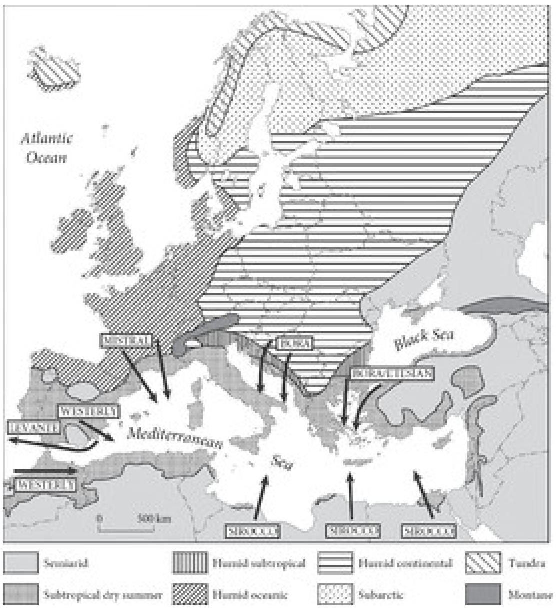

Fig. 2.1. The present climates of Europe with local Mediterranean winds derived from a variety of sources.

The ‘scale’ problem becomes apparent when considering the record of climate change across Europe. Europe has today a wide variety of local climates ranging from the Arctic-Alpine to the semi-desert. The only climates (*sensu* the Köppen climatic classification) it does not have are the sub-polar continental, hyper-arid, and monsoon-dominated wet tropical climates. Local climates are determined by latitude, continentality (effectively longitude), and altitude. This can be illustrated by the variety of local winds which affect the countries bordering the Mediterranean alone (Fig. 2.1). It is, however, possible to identify common forcing conditions (pattern of global pressures and temperatures) for this region due to the underlying importance of the Westerlies and therefore conditions over the north Atlantic. So, for example, even the Mediterranean parts of Europe are under the influence of westerly cyclonic tracks for the delivery of precipitation. The extent to which these air masses penetrate into Europe is controlled through blocking by eastern high pressure systems. The Azores High and (p. 28) North Atlantic High also affect the path of these Westerlies over Europe and this control has been associated with differential climate change in northern and southern Europe. From these synoptic constraints it is apparent that the Holocene climate of Europe would have been closely related to fluctuations in the North Atlantic Oscillation (NAO) index and to both El Nino–Southern Oscillation (ENSO) and the thermohaline circulation (THC), and through these ultimately to global factors such as variations in solar output (so-called sub-Milankovitch forcing) and astronomically forced variations in solar influx (Milankovitch forcing). However, the European landmass is characterized by small–medium altitude mountain ranges especially at about 42º–47º of latitude (Picos de Europe, Pyrenees, Alps, Apennines, Carpathians) which create strong orographic (p. 29) (topographic relief induced) patterning including rain-shadows and local winds, both now and in the past.

Neolithic European Climates from Lakes and Bogs

Over the past 20 years there has been an explosion of research into Holocene climatic change, driven by the need to test global and regional climate models and by the prevailing ideological belief that climate change is the greatest scientific challenge of the present age. Within Europe, appropriate geochemical and biological climate proxies covering this period can be derived from lake sediments, raised mires, and alluvial sequences. Probably the most comprehensive source of palaeoclimatic data is the lake level record, which covers both southern and northern Europe. Within the Global Lake Level Database there are over 700 records from Europe (Prentice et al. 1996) which have been used by the BIOME 6000 project to map vegetation patterns. The Alpine region, being in the centre of Europe, is probably the most valuable. One of the most comprehensive data sets is provided by 26 lakes in the Jura Mountains (Magny 2004), from which 15 phases of higher lake levels were identified, four within the Neolithic (Table 2.1). In a more recent study of Lake Le Bourget in France, Arnaud et al. (2005) have correlated the lake level record with at least three periods of flooding by the Rhone, suggesting that this record is applicable for the entire western Alps region. Studies of lake levels in southern Europe are less common but several crater lakes in Italy have produced long sequences, such as Lago Grande di Monticchio, which shows rather subdued Lateglacial interstadials and Younger Dryas with relative climatic stability in the early Holocene (Allen et al. 2002). This is in contrast to northern Africa where there is abundant evidence of wetter conditions well into the Neolithic (Roberts 1998).

Table 2.1 Climatic shifts (dry in italics, wet in bold) during the Neolithic identified from mire and lake records in Europe.

Sites	Dates BP	Data	Postulated cause	References
Temple Hill Moss, Scotland	*6850* **6650** *6350* **5850** **5300** *4850*	plant macrofossils and testate amoebae	millennial scale climatic periodicities	Langdon et al. 2003
Walton Moss, northern England	**7700–6700** ***c*. 5300**	plant macrofossils	millennial scale climatic periodicities	Hughes et al. 2000, Barber 2007
Bolton Fell Moss, northern England and Abbeynockmoy, Scotland	*c*. **4400–4000**	plant macrofossils	solar forcing	Barber et al. 2003
Mallachie Moss, Scotland	**4450** *4650*	plant macrofossils	wetter climate	Langdon and Barber 2005

Lille Vildmose, Jutland, Denmark and Butterburn Flow, northern England	*c*. **4150**	wiggle–match AMS dating of plant macrofossils and testate amoebae	decline in solar activity	Mauquoy et al. 2008
Jura, France (26 lakes)	**8300–8050** **7550–7250** **6350–5900** **4850–4800**	sedimentological phases dated by 14C, tree-rings, and archaeology	solar activity	Magny et al. 2004

One climatic event during the early Neolithic that has received attention is the so-called 8.2 ka event. Analyses of seasonally laminated varved sediments from Holzmaar in southern Germany provide evidence of differences in duration and onset time of changes in summer temperature and winter rainfall during this event (Prasad et al. 2009). The data show that the onset and termination of the summer cooling occurred within a year, and that summer rains were reduced or absent during the investigated period. The onset of cooler summers preceded the onset of winter dryness by *c*. 28 years and statistical analysis of the varves indicates that the longer NAO cycles, linked to changes in the north Atlantic sea-surface temperatures, were more frequent during the drier periods. This suggests that the event is likely to have been associated with perturbation of the north Atlantic sea surface temperatures. This work is helpful in that it helps us define the magnitude of climatic perturbations which could have affected some early Neolithic communities.

(p. 30) Climatic reconstruction from bog surface wetness (BSW) has the advantage of more reliable and higher resolution dating than can be achieved for most lakes. However, it depends upon the continuous or semi-continuous growth of raised rain fed (ombrogenous) mires (Barber 2006), restricting its application to northern Scandinavia, European Russia, the western seaboard as far south as the southern English lowlands, or mountainous 'outlier' regions as far south as north-west Spain (Cortizas et al. 2002) and mount Troodos in Cyprus (Ioannidou et al. 2008). Most raised mires start as lakes and in the early Holocene become groundwater–fed fens, at some point—most commonly sometime in the Neolithic—going through a fen-bog transition. This means that the number of BSW curves for the Neolithic is restricted temporally and geographically. This work has its origins in the climatic stratigraphy of mires used to formulate the Blytt-Sernander climatic scheme (Sub-Boreal to Sub-Atlantic covering the Neolithic and Bronze Ages) and the overturning of the autogenic theory of bog-regeneration by Barber in 1981 provided the stimulus for many studies of increasingly higher temporal resolution (Charman et al. 2007). The method of using macrofossils of *Sphagnum* spp. and peat humification has been applied in environmental transects (Barber et al. (p. 31) 2000) and combined with other proxies such as pollen, testate amoebae (Hendon and Charman 1997; Charman et al. 1999), and most recently $\partial^{18}O$ and ∂D from plant macrofossils (Brenninkmeijer et al. 1982; Barber 2006). Temporal resolution has been improved by both wiggle-matching and the use of *in situ* tephra deposits (Mauquoy et al. 2004; Plunkett 2006) and at the best sites a decadal resolution is claimed (Mauquoy et al. 2008) which is as fine, if not finer, than the dating of most archaeological sites within the Neolithic.

One reason for generally trusting these climatic reconstructions is the correlation between them and a vast array of other proxies, including later written records from the post-Roman period. Well known historical climatic 'events' often derived from soft data, such as the late Medieval climatic deterioration (Lamb 1977), the Medieval Warm Period, and the Little Ice Age, are also clearly shown in the mire-derived data sets (Barber 1981). For the prehistoric period BSW data has been correlated with a variety of both global and regional proxies, including the European lake level record (Magny et al. 2004), ice drift records from the north Atlantic (Bond et al. 2001), and ocean core proxies for the North

Atlantic Deep Water (NADW) circulation (Chapman and Shackleton 2000). In terms of the causal mechanism, most interest has focused on solar events (van Geel et al. 1996; Mauquoy et al. 2004). However, no such solar episodes have so far been identified in the Neolithic and it is likely that solar activity was moderated or overwhelmed by other factors, particularly ocean circulation, especially in the western European seaboard. Most studies have shown a statistical climatic periodicity in the mid–late Holocene (Aaby 1976; Langdon et al. 2003; Blundell and Barber 2005; Swindles et al. 2007) with values of 200 years (Chambers and Blackford 2001; Plunkett, 2006), 265 and 373–423 years (Swindles et al. 2007), 550 years (Hughes et al. 2000), 560 years (Blundell and Barber 2005), 580 years (Swindles et al. 2007), 600 years (Hughes et al. 2000), and 1,100 years (Langdon et al. 2003). These can be compared with periodicities in other proxy data such as 210, 400, 512 and 550, 1,000, and 1,600 years in tree rings and ocean core-data (Chapman and Shackleton 2000; Rosprov et al. 2001). Although most of the records used in these studies start around the end of the Neolithic or in the Bronze Age (e.g. Charman et al. 2006), it is highly unlikely that these quasi-rhythmic climatic fluctuations started at this time. They probably started prior to the Neolithic in the early Holocene during the re-arrangement of the northern hemispheric circulation system following deglaciation.

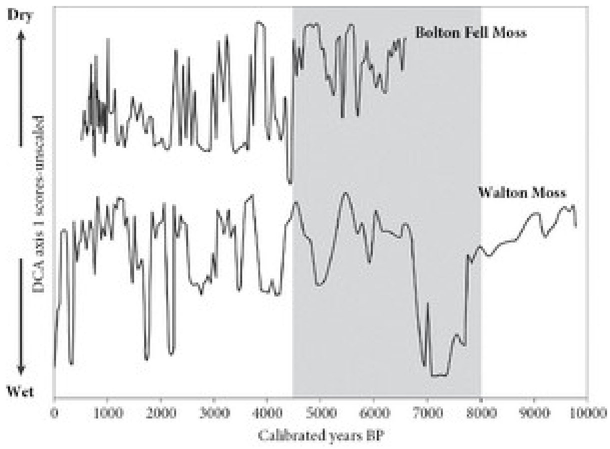

Fig. 2.2. Proxy climatic reconstruction from two raised mires in the UK.

Adapted from Hughes et al. (2000) and Barber et al. (2003).

Traditionally the Neolithic has been regarded as a period of relative climatic stability dominated by the Holocene thermal optimum at *c.* 7500 BP, when temperatures were 1–2ºC warmer than today (Davis et al. 2003), and then a climatic deterioration *c.* 6500 BP (Karlen and Larsson 2007). In the original Blytt-Sernander climatic sub-division of the Holocene the Neolithic spans the later part of the Boreal (10500–7800 BP), the Atlantic (7800–5700 BP), and the early part of the Sub-Boreal (5700–2600 BP). The Boreal Atlantic boundary was largely based on a ‘recurrence’ surface or *Grenzhorizont* (layers of sudden change in peat humification caused by a change in climate) common in Swedish bogs (Barber 1981), whilst the climatic optimum was based upon biostratigraphic data such as thermophilious (warm adapted) vegetation in northern Europe (p. 32) and the occurrence of the pond tortoise (*Emys orbicularis*) outside its present-day breeding range (Stuart 1979). Another classical indicator of the mid-Holocene thermal optimum is high rates of ambient-temperature carbonate or tufa (calcareous spring deposits) deposition (Goudie et al. 1993). Although tufas continue to be deposited outside the mid-Holocene (Baker and Sims 1998), their occurrence is reduced. Tufas can also provide stable isotopic temperature records from a wide range of terrestrial and lacustrine sources throughout Europe, as well as through inferences from floral and faunal remains (Ford and Pedley 1996; Gedda 2006; Davies et al. 2006). Both of these thermal indicators are rather complicated but not invalid, and the concept of the thermal optimum remains valid, although the record of raised mires shows relative BSW stability during the Neolithic at least for north-west Europe. For example, only a few mires such as Temple Hill Moss and Walton Moss show short-lived wet phases (Langdon et al. 2003), (Fig. 2.2). Local variability is shown by the state of Scottish mires before, during, and after the deposition of the Hekla-4 tephra at 2310±20 BC (Langdon and Barber 2004). In the absence of definitive Europe-wide studies of BSW in the sixth millennium BC, it is probably safest to assume a relatively gradual shift to the cooler and wetter conditions during the late Neolithic.

Table 2.2 Major volcanic events in the European Neolithic and some published dated tephras. Data from the tephrabase (Newton et al. 2007) and other sources.

Eruptive source	**Name/ Location recorded from**	**Date**	**Reference**
Southern Italy; Campi Flegrei caldera	Agnano Monte Spina Tephra (AMST)	4690–4300BP	Blockley et al. 2008
Central Anatolian Volcanic Province (CAVP)	Eski Acigol	10 tephra layers between 14,300/11,300 and 8150/5000 years BP	Kuzucuoglu et al. 1998
Iceland	Hekla-4	2350–2250 BC	Pilcher et al. 1996
Iceland	Hekla-5	*c*. 6800 BP (5050 BC)	Smithsonian Institution’s Global Volcanism Program (GVP)
Iceland	Hoy Tephra, Keith’s Peat Bank	5560±90 ^{14}C years BP	Dugmore et al. 1995
Iceland	Lairg tephra A, Sluggan Bog, northern Ireland	6036±20 ^{14}C years BP	Pilcher et al. 1996
Iceland	Lairg tephra B, Sluggan Bog, northern Ireland	5811±20 ^{14}C years BP	Pilcher et al. 1996

Iceland	Mjauvotn A & B, Eidi, Faroe Isles	5910±45 ^{14}C years BP	Wastegard et al. 2001

(p. 33) At the end of the Neolithic, one of the most significant shifts in the climate of Europe occurs. The ‘4.2 Ka event’ has been identified from a number of proxies including the ocean and ice cores (Bond et al. 1997; Brown 2008), from a severe drought event in eastern Africa, and from increased sand movement in coastal dune systems along the eastern Atlantic coast (Gilbertson et al. 1999; Knight and Burningham, 2011). In the British Isles it has been identified as a cool/wet phase from the BSW record of a number of sites in northern England (Chiverrell 2001; Charman et al. 2006; Barber and Langdon 2007) and Scotland (Langdon and Barber 2005), and from combined BSW and chironomid data from Talkin Tarn in northern England (Barber and Langdon 2007).

This climatic chronology will probably be further refined in the next few years with the increasing use of tephra layers, but the broad pattern is unlikely to change. A problem is what these shifts mean in climatic terms and how these bog-proxies relate to other hydro-climatic variables. As Barber (2006) has emphasized, the BSW proxy is a composite measure of past climate, principally because a change to a more continental climatic regime is likely to alter the relative importance of precipitation and temperature. Even for the present oceanic climate of north-west Europe, there is a correlation between temperature and precipitation at least at the mean annual scale (Barber 2006). At the annual scale the linking factor is the correlation between summer precipitation and the winter NAO index (Kettlewell et al. 2003), which is also correlated strongly with changes in mean annual temperature, and on the longer term the THC. Given these complications (p. 34) it is best to regard the BSW record as principally a response to north Atlantic sea surface temperatures transmitted through prevailing synoptic regimes and the resultant summer water deficit. Perhaps more attention should be paid to the dry shifts, which may also have significant, if not greater, archaeological implications.

Two other palaeoclimatic techniques, probably more closely related to variations in precipitation and applicable to the Neolithic, are speleothem (stalagtites, stalagmites, flowstones) luminescence and stable isotope studies. Due to its geological history, Europe is especially rich in limestone cavern systems and speleothem/tufa/travertine deposits. Long-term variations in the intensity of the luminescence under UV light of the growth bands within a speleothem can be related to climate and especially precipitation (Baker et al. 1999), although it is also sensitive to local vegetation change (Baldini et al. 2005). Using data from both mires and speleothems from Sutherland in north-west Scotland, Charman et al. (2001) have shown a correlation between peat humification, speleothem luminescence emission wavelength, and ice-sheet accumulation. The use of speleothems has further potential to produce regional data in areas lacking ombrotrophic mires such as south-west England, north-west Scotland, northern Norway (Lauritzen and Lundberg 1999; McDermott et al. 2001), and southern Europe. Due to the frequent occurrence of annual luminescence laminae this technique has high potential to record annual climatic data, although so far most studies have focused on the short-term fluctuations in climate recorded over the last one to two millennia (Jackson et al. 2008).

Mapping Neolithic Vegetation Change

Many of the lake studies have produced direct evidence of vegetation from pollen and plant macrofossils. During the Late Glacial Maximum (LGM) most of Europe was dominated by *Artemisia* (mugwort) and Chenopodiaceae (goosefoot) steppe, but many refugia existed: evergreen oak (*Quercus ilex)* type woodland survived in Sierra Nevada; Atlantic cedar (*Cedrus atlantica*) and pistachio (*Pistacia* spp) existed in the Apennines and Balkans; and oak, pistachio, and olive survived together in the Levant (van Zeist and Bottema 1991) suggesting re-colonization of Europe from the east. Herb-steppe was replaced in the early Holocene by sub-humid forest sometimes dominated by conifers but more typically by broad-leaved deciduous trees. The xeric (drought tolerant) evergreen forests, shrub, and heathland now typical of the Mediterranean part of Europe are rarely represented in early Holocene pollen diagrams. Attempts to map the Neolithic vegetation of Europe have produced a vegetation pattern closely resembling the climatic pattern shown in Fig. 2.1, but this uniformity is rather misleading since biogeographical, topographic, and edaphic factors pattern vegetation at the regional and sub-regional scale (Skinner and Brown 1999). The composition of the mixed deciduous forest varied from north to south. Oak-birch-hazel dominate its northern limits, lime-oak-hazel the south, and oak (deciduous and evergreen)-hazel-hornbeam the southern fringes. Similarly, the structure of these forests, including the occurrence of natural clearings (p. 35) and openings, reflected the spatially variable disturbance regime, including factors like wind-throw, animal activity (particularly beaver), disease, and snowfall. Indeed, the most well-known Holocene vegetation event in northern Europe, the ‘elm decline’ of around 5300 BP, is now commonly regarded as being due to disease and progressive forest clearance by Neolithic farmers. These allowed the beetle vector, *Scolytus scolytus,* to spread, transforming local outbreaks in to a pandemic (Clark and Edwards 2004; Edwards 2004). It is also clear that Neolithic woodland was not stable, with increasing evidence of mid-Neolithic woodland regeneration in England (Brown 1999), Scotland (Tipping 1995, 2010, 2012), and Ireland (O’Connell and Molloy 2001). At present it is not clear if this was due to declining fertility, agricultural decline, or climatic perturbations, but all these hypotheses are testable. There is also pollen, charcoal, and phytolith evidence of middle Neolithic woodland management, or so-called agro-sylvo-pastoral systems along the middle Rhone Valley (Delhorn et al. 2009). This evidence is clearly of relevance to our views of the mobile or semi-sedentary nature of early Neolithic farmers (Bogaard 2002, 2004), population densities, and their connections to the land and with other groups (Edmonds 1999).

Lake and Wetland Settlement

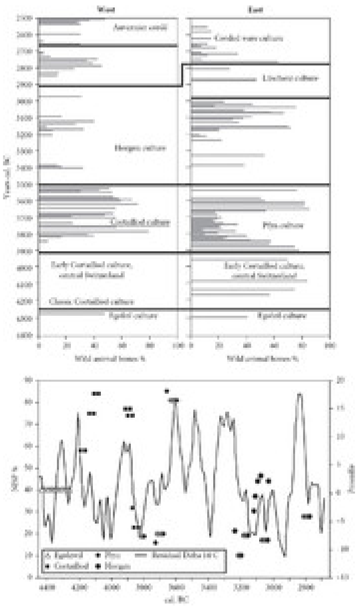

Fig. 2.3. Dendrochonologically dated wild animal bone frequencies and cultures from eastern and western Swiss Neolithic lake villages.

Adapted from Schibler (unpublished) by permission.

One of the most climatically sensitive aspects of the archaeological record is lake and wetland settlement, which, due to high precision dendrochronology dating and good preservation of organic remains (seeds and animal bones), has great potential for investigating the impact of short climatic fluctuations on Neolithic economies and societies. Studies of lakes in the Alpine foreland have shown a remarkable correlation between climate proxies such as the ^{14}C calibration curve and palaeoeconomic data, suggesting that during phases of wet-cold climate wild resources like game were more intensively exploited (Schibler et al. 1997; Hüster-Plogmann et al. 1999; Arbogast et al. 2006; Schibler and Jacomet 2009). Whether this is a result of decreased cereal yields or some other cause is as yet unknown. Even more archaeologically important is that there is *no correlation* between these phases and 'cultures' as defined using pottery (Fig. 2.3). This suggests a disconnection between changes in material culture and changes in food procurement.

Catchments, Valleys, Sediments, and Settlement

European river valley environments span a vast range of topographic and altitudinal settings, encompassing glaciated alpine mountain torrents, terraced river corridors, and extensive low-relief alluvial and estuarine settings on the coastal fringe. Neolithic communities were present in many of these settings, becoming well established in estuarine (p. 36) (p. 37) environments (see below) and extending into relatively high elevation upland localities. Indeed, palynological studies suggest that localized cereal cultivation was occurring from early Neolithic times at altitudes of up to nearly 2,000m above sea level in the alpine valleys of France (Argant et al. 2006; Martin et al. 2008), Switzerland (Welten 1977), and Italy (Pini 2002). In general, however, it is the valley floors in the middle and lower reaches of European river systems that were especially important for Neolithic settlement, offering well-defined and frequently navigable routeways. The Danube and Rhine systems were particularly influential in the dispersal of Neolithic culture across Europe (Roberts 1998; Dolukhanov and Shukurov 2004; Davison et al. 2006). River valleys also offered ready access to freshwater, a rich array of resources, and in many cases low-relief, free-draining Pleistocene river terraces relatively free from flood-risk. Archaeological evidence of Neolithic settlement and especially ritual activities are widely documented on Pleistocene terrace surfaces, for example in valleys of the Trent catchment in the English Midlands (Knight and Howard 2004; Brown 2009a, 2009b), the middle Rhone valley in France (Beeching et al. 2000; Delhon et al. 2009), the Upper Odra basin in Poland (Zygmunt 2009), the Chienti basin in Italy (Farabollini et al. 2009), and the well-known site of Lepenski Vir on the Danube in Serbia (Borić 2002). In both northern and southern England, early Neolithic settlement was apparently initiated from river valley floors and estuarine and coastal lowlands, before late Neolithic and early Bronze Age expansion on to higher elevations and upland terrain hitherto unoccupied or utilized for subsistence activities (e.g. Thomas 1999; Waddington 1999; Garrow 2007; Passmore and Waddington 2012). As well as proving attractive for settlement, fertile and well-drained soils developed on Pleistocene sand and gravel terraces and low-relief catchments developed on loessic plains were favourable localities for pioneering early Neolithic agriculture (which is hence rarely detected on regional-scale pollen diagrams derived from upland peats; cf. Brown 1997, 2008). Although Mesolithic communities are widely thought to have manipulated the early Holocene woodland cover (Brown 1997), the early–mid Holocene temperate forests of Europe seemingly experienced little or no detectable soil erosion (e.g. Bork et al. 1998; Seidel and Mackel 2007). The arrival of Neolithic agricultural systems, embracing both domesticated livestock and arable cultivation, introduced a deliberate process of woodland management, clearance, and tillage that lowered landscape erosion thresholds, thereby creating the first significant possibility of impacting on river catchment sediment and hydrological systems.

The considerable interest in exploring the geomorphological impact of early farming is therefore not surprising. The impact of land-use changes on geomorphological activity in valley systems may be reflected in a variety of contexts, including hillslope erosion and gully development, sedimentation in colluvial and alluvial settings, river channel incision, and elevated water tables (Foulds and Macklin 2009; Fuchs et al. 2010). However, our ability to detect Neolithic land-use activities in the landform and sediment archive of river valleys faces several challenges. These include the often fragmentary preservation (or removal) of sedimentary archives by later erosion, difficulties in establishing accurate chronological controls, and the potential for complex and possibly (p. 38) multiple phases of sediment erosion, transfer, and storage occurring downslope/downvalley of landscapes hosting Neolithic activities (e.g. Lewin and Macklin 2003; Houben et al. 2006; Brown et al. 2009).

These difficulties are perhaps most readily addressed in relatively small catchments or sub-catchments, where archaeological and palaeoenvironmental records can be compared to landform and sediment archives in the immediate vicinity (Hoffmann et al. 2007), and where the potential for intermediate sediment storage and reworking is greatly reduced. Such studies have reported evidence of late Neolithic valley colluviation, as well as alluvial fan and (or) floodplain alluviation linked to the onset of deforestation and localized arable cultivation for localities in Britain (e.g. Brown and Barber 1985; Evans et al. 1993; Bell 1983; French et al. 1992; Collins et al. 2006; see also review by Macklin 1999), western France (Macaire et al. 2006), loess-covered valleys in southern Germany (e.g. Kalis et al. 2003; Lang 2003; Hoffmann et al. 2007; Fuchs et al. 2010), and Poland (Klimek 2003). Neolithic catchment disturbance has also been inferred from accelerated rates of inorganic sediment accumulation in some lake sediment records, including sites in Britain and Ireland (Pennington 1978; Edwards and Whittington 2001), Germany (Zolitschka 1998), and the French Massif Central (Macaire et al. 2010).

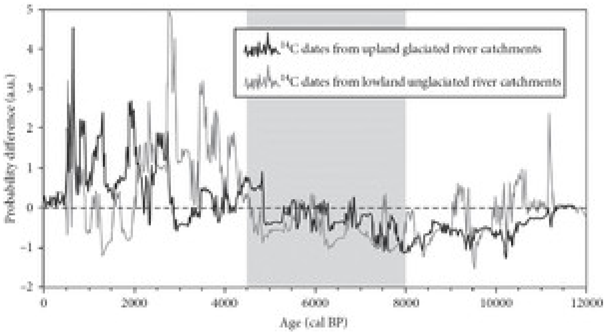

Fig. 2.4. The probability density function of alluvial radiocarbon dates for upland and lowland river catchments in Great Britain during the Neolithic.

Adapted from Johnstone et al. (2006).

A broader perspective on Neolithic interactions with river environments may be obtained from countrywide reviews and comparisons of Holocene valley floor development throughout Britain (Johnstone et al. 2006; Lewin et al. 2005; Macklin et al. 2006, 2009; Brown et al. 2013), Spain (Thorndycraft and Benito 2006), Poland (Starkel et al. 2006), Germany (Hoffmann et al. 2008; Fuchs et al. 2010), and France (Arnaud-Fassetta et al. 2010) (Fig. 2.4). By exploiting the growing number of published and well-dated catchment landform and sediment records and adopting an increasingly robust approach to selecting, interpreting, and analysing ^{14}C-dated colluvial and alluvial sequences (cf. Johnstone et al. 2006; Macklin et al. 2009), these studies indicate that the geomorphological impact of anthropogenic land-use change is seldom widely evident until the marked intensification of woodland clearance and agricultural activity from the Bronze Age and later periods. Rather, Neolithic channel and floodplain environments experienced relatively little direct human intervention, often maintaining a cover of alder-dominated woodland

and wetland habitats (e.g. Knight and Howard 2004; Tipping 1998; Thorndycraft and Benito 2006) amidst meandering (e.g. Starkel 2002; Dambeck and Thiemeyer 2002) or anastomosing (Knight and Howard 2004; Brown 2008) channel systems.

However, countrywide and sub-continental scales of analysis show periods in the early–mid Holocene which experienced broadly synchronous phases of accelerated fluvial activity, and which have been linked to the emerging record of periodic shifts to a cooler and/or wetter climate (Figs 2.2 and 2.4). Macklin and Lewin's (2008) synthesis of the British, Spanish, and Polish records identified four such phases in the Neolithic, centred on 7590 BP (Spain, Poland), 6790–6820 BP (Britain, Poland), 5540–5640 BP (Britain, Spain), and 4840–4860 BP (Britain, Spain, Poland). Enhanced Neolithic flooding was also evident in Poland at 8400, 6250, and 5920 BP, and in Britain at 4520 BP. In German parts of the Rhine, Danube, Weser, and Elbe catchments, Hoffmann et al. (p. 39) (2008) also found broadly corresponding phases of accelerated Neolithic activity centred on 7475 and 5640 BP respectively. An additional early Neolithic activity phase at 8200 BP appeared largely confined to colluvial systems in smaller catchments. The 8.2k event is also evident in French catchments as a period of enhanced frequency and/or magnitude of flooding in the middle Loire, and as increased fluvial activity in the Durant and southern Alps; a similar pattern of activity occurs *c*. 6300 BP, although the record from the southern Alps suggests valley floors here were incising at this time (Arnaud-Fassetta et al. 2010 and references therein).

Both Hoffmann et al. (2008) and Arnaud-Fassetta et al. (2010) found Holocene fluvial activity phases in German and French valley floors, respectively, to show only limited correlation with those identified by Macklin and Lewin (2008) in British, Spanish, and Polish records. This is considered to reflect, at least in part, differing approaches to the classification of ^{14}C dates and the analysis of frequency distributions, but for Arnaud-Fassetta et al. (2010) this contrast in the intensity of fluvial activity between mid-latitude European rivers and those in northern and southern Europe hints at a sub-continental tripartite division of European hydrosystems during the early–mid Holocene.

Current research agendas focusing on multiple scales of analysis (both spatial and temporal) and the quantitative modelling of fluvial system response to environmental change will refine our understanding of these issues (e.g. Arnaud-Fassetta et al. 2010; Hoffmann et al. 2010). What is clear from current evidence is that Neolithic land-use activities were rarely sufficient to promote detectable changes to channel and floodplain environments in the middle and lower reaches of larger European catchments. However, Neolithic communities were accustomed to flood hazard and the inherent rhythms of (p. 40) river channel adjustments, especially with respect to meander migration and occasional channel cut-off. During phases of cooler and/or wetter climate they also witnessed a change in the frequency and magnitude of flooding, alongside a change in the rate and possibly the style of channel and floodplain development.

Changing Coastlines and Coastal Communities

Europe has a strongly maritime character, with heavily indented coastlines and many large peninsulas, offshore islands, and archipelagos. Few areas of Neolithic Europe would have been far from contact with their nearest coastline, even if that contact was an indirect one through trade or exchange over hundreds of kilometres, as evidenced by the movement of the marine bivalve *Spondylus* shell ornaments from the Aegean to Neolithic sites in central Europe (Chapman and Gaydarska, this volume). Coastlines also played an important role as sources of marine food, raw materials, and items of value or decoration; as a medium of communication, travel, and trade by sea; and as sources of inspiration for myth and metaphor.

Marine environmental conditions cover an immense range, from the Arctic to the Mediterranean and from exposed Atlantic coastlines to the protected and tideless basins of the Baltic and the Black Sea. Productivity generally follows a north-west–south-east gradient. Shallow areas of continental shelf, mixing of the water column by tides and storms, and upwelling currents ensure high levels of marine fertility on north Atlantic and North Sea coastlines, and an abundance of marine mammals and fish. The extensive intertidal flats of large river estuaries and inlets support large beds of bivalve molluscs, and rocky shorelines have relatively abundant supplies of limpets and other gastropods. The Mediterranean is much less productive, with limited tidal movement and clogging of major river estuaries by rapid sediment accumulation, although all types of marine resources are available, from top predators such as monk seals and tuna fish to molluscs. Least productive is the eastern Mediterranean, where temperature gradients trap nutrients at a depth beyond the reach of photosynthesis. The Baltic and Black Sea are intermediate, with little tidal movement, but inflow of nutrients from the surrounding land.

Although agriculture is generally regarded as the dominant mode of production, marine resources continued to be widely exploited. Palaeodietary reconstructions based on stable isotope measurements of human skeletons in parts of Britain and Denmark suggest that marine foods were ignored by some Neolithic people in coastal regions (Richards and Hedges 1999). However, the interpretation of the evidence is controversial (Bailey and Milner 2002; Milner et al. 2004, 2006; Hedges 2004; Richards and Schulting 2006), and archaeological sites show continuing exploitation of fish, sea mammals, and shellfish throughout the coastal regions of Britain, Scandinavia (Clark 1983; Lidén et al. 2004; Milner et al. 2004), south-west Europe (Boyle 2005; Milner et al. (p. 41) 2007), and the Mediterranean (Jacobsen 1968; Tagliacozzo 1993). Submerged Mesolithic and Neolithic fish weirs discovered in Denmark show that the Neolithic examples, as at Nekselø, extended several hundred metres out from the seashore and were larger and stronger than their Mesolithic counterparts (Fischer 2007). For many farming communities in coastal regions, marine resources could provide an important alternative during periods of the year when agricultural products were in short supply (Deith 1988; Milner 2001, 2002). Settlements in northerly regions beyond the range of reliable crop agriculture would always have depended on the sea for a major part of their livelihood.

Seafaring played an important role in fishing and sea-mammal hunting, trade, and population movement. At least one pathway of agricultural dispersal into Europe followed the northern shorelines of the Mediterranean, implying seaborne movements. Occupation of Mediterranean islands and the British Isles required the use of seaworthy boats to import crops and animals and exchange raw materials, even if, as now seems likely, Neolithic colonists were not the earliest seafarers in Europe (Anderson et al. 2010). The distribution of megalithic tombs has been linked in some areas to the seasonal movements of migratory fish (Clark 1977). Dugout canoes and skin-covered frame boats were already used in the Mesolithic. The earliest timber-planked boats are recorded from the Bronze Age, but were probably also built in the Neolithic, with the sail most probably in use by the late Neolithic in the eastern Mediterranean (Broodbank 2010).

Much of what might be learned about Neolithic coastal environments may be missing because of sea-level change (Pirazzoli, 1991). At the LGM, 20,000 years ago, the sea level was over 100m lower than present and additional territory amounting to some 40% of the current European landmass was exposed on the continental shelf. The loss of territory as sea levels rose with the melting of the ice sheets after 16,000 years had profound effects on the ecology, demography, and social geography of prehistoric Europe, offset to some extent by climatic amelioration and the opening up of new hinterlands. These changes were especially dramatic in shallow areas such as the North Sea (Coles 1998; Flemming 1998, 2004; Gaffney et al. 2009), with their biggest impacts during the late Upper Palaeolithic and Mesolithic. The eustatic (glacial meltwater) contribution to sea-level change was completed with a final sea-level rise of about 15m between 8,000 and 6,000 years ago according to global estimates from deep sea records (Lambeck 1995, 1996; Lambeck and Chappell 2001; Siddall et al. 2003), which overlaps with the early Neolithic in southern Europe.

Additional geological processes affecting sea-level change likely affected Neolithic coastlines more widely. These processes include coastal subsidence or uplift at a local or regional scale in response to tectonic and volcanic effects, particularly in the eastern Mediterranean, and isostatic rebound or subsidence of coastlines following the melting of the ice sheets, particularly in northern Europe. Geophysical models provide estimates of crustal movement (Lambeck et al. 2006; Peltier and Luthcke 2009), but precise changes can only be established by dating local palaeoshorelines, using evidence of submerged archaeological sites, shoreline biomarkers, or sediments such as peat (Shennan and Andrews 2000; Stewart and Morhange 2009). All these sources show that changes of relative sea level continued to occur in many areas during the Neolithic, with variable (p. 42) impacts depending on local topography and bathymetry, and that an important part of the coastal Neolithic in many regions now lies submerged on the seabed, as for earlier periods (Benjamin et al. 2011).

The most dramatic isostatic effects were in regions close to centres of glaciation. In Scotland and northern Scandinavia there was coastal rebound, with coastlines lifting as much as 200m in northern Norway. Around the southern rim of the North Sea and the southern Baltic, there has been ongoing subsidence, with a corresponding loss of coastal territory and settlements. In Denmark and along the Baltic shoreline of northern Germany, Mesolithic and Neolithic settlements are now submerged in several metres of water (Fischer 2004; Harff et al. 2007). Partially or totally submerged settlements and megalithic sites have been recorded on both the Atlantic and Mediterranean coastlines of France (Geddes et al. 1983; Prigent et al. 1983; Cassen et al. 2011). In the Bulgarian sector of the Black Sea, Neolithic sites submerged by tectonic subsidence have been recovered (Filipova-Marinova et al. 2011). In the eastern Mediterranean, the pre-pottery Neolithic B site of Atlit Yam, Israel, was a coastal village practising farming and fishing and is now submerged in 11m of water (Galili et al. 1993). A Neolithic site on the Aegean island of Aghios Petros, Greece, is partially submerged (Flemming 1983), and recent underwater surveys at Bova Marina on the Calabrian coastline of Italy have drawn attention to the loss of a significant increment of land during the early Neolithic (Foxhall 2005). These changes would also have modified the ecology and configuration of resources available on the local coastline, removed land of potential value for livestock and agriculture, and perhaps influenced Neolithic cosmologies and perceptions of landscape.

More dramatic effects have been claimed in the Black Sea region by Ryan et al. (1997), who used the sedimentary record on the seafloor to infer a catastrophic flood event 7,200 years ago, supposedly resulting from the overtopping of the Bosphorus sill by sea-level rise in the Mediterranean. This in its turn is supposed to have caused widespread dislocation of low-lying settlements on the shores of the Black Sea and triggered the dispersal of farming communities into south-east Europe. However, the geological evidence and the likely human consequences are now not widely accepted. Between 20,000 and 7,200 years ago the Black Sea was a freshwater lake and the water level fluctuated through an amplitude of 90m or more in response to the variable inflow of water from the rivers to the north. However, the sedimentary record in different parts of the basin produces conflicting interpretations about the pattern and timing of these changes, and the re-connection with the Mediterranean may have been more gradual than implied by the 'flood' hypothesis (Yanko-Homback et al. 2007). Overall, the loss of land locally in different areas of Europe, even if not as sudden as claimed for the Black Sea or as extensive as the Mesolithic inundation of the North Sea Basin, most probably had cumulative effects that were recognized within the lifetime of individuals, and the collective memory and oral traditions of many coastal societies likely incorporated stories recalling an earlier time of more dramatic land loss. The marked concentration of megalithic tombs and monuments at the coastal extremities of Britain, in the Orkneys, the Isles of Scilly, and in many other coastal regions of Scotland, Scandinavia, and western (p. 43) Europe—some intended to be viewed from the sea rather than from land—attests to the powerful influence of Neolithic seascapes as an arena for day-to-day subsistence, a place of danger, a source of myth, and perhaps the ultimate resting place of the ancestors (Westerdahl 1992, 2005; Phillips 2004).

Empty and Symbolic Spaces—High-Altitude Environments and Skyscapes

Until recently it has generally been assumed that in the mountainous parts of Europe Neolithic archaeology was restricted to valley floors and the lower slopes (Bocquet 1997). Recent work in the French western Alps at Les Ecrins National Park and the Hauts Ubaye Massif has shown Neolithic activity as high as 3,000m altitude (Walsh and Richer 2006; Mocci et al. 2008; Richer 2009). High alpine grasslands or 'meadows' were not empty spaces and had symbolic/ritual importance (as suggested by rock art) possibly related to their utility for summer hunting (Richer 2009). The environment does not only comprise climate, soil, and vegetation, but includes aspects such as skyscape and subterranean spaces, both of which vary spatially. Monument construction is testament to a growing human interest in, and desire to record, astronomical phenomena (Hoskin, this volume), alongside many other cultural stimuli. Neolithic monuments aligned on astronomical events like midsummer and midwinter sunrise include wood or stone circles and rows, isolated megaliths, and some henges and long-barrows. These Neolithic structures appear to be geographically restricted to northern Europe and this could at least partly relate to variation in the seasonal skyscape, which is a function of latitude (i.e. seasonal variations in the setting/rising positions of the sun and moon). Whilst other factors are clearly also important, both environment and latitude must play a part in the ritualization of the external environment. In wooded areas of moderate relief, the skyscape is only viewable in gaps or clearings and the use of distant horizon markers implies a clear line of sight from the viewing location (Brown 1997, 2001). This association of open, or cleared, areas with Neolithic monumental landscapes (or ritual complexes) appears to hold and the augmentation or manipulation of natural events may have ritual and social importance (Evans et al. 1999; Brown 2001). Studies around Stonehenge on Salisbury Plain, England, suggest partial clearance by the time both Stonehenge and Durrington Walls were being built (Allen 1995). The same is true for ritual complexes on Cranborne Chase in England (French et al. 2005; French et al. 2007) and possibly southern Brittany (Scarre 2001). A fascinating aspect is the extent to which the ritualization of natural phenomena may have been a formative part of tradition, as, for example, with the recent suggestion that the banks and ditches of cursuses monumentalized the tracks of small tornadoes through woodland (Meaden 2009). These environmental phenomena, constraints, and opportunities need to be considered in any attempt to regionalize Neolithic traditions. We also need to explore the possible (p. 44) effects of natural events on the perception and ideology of later Mesolithic and Neolithic peoples (Larsson 2003) in what was still a fundamentally natural vegetation cover until human activities became the dominant driver in the late Bronze Age (Odgaard and Rasmussen 2000).

Linking Environmental Change, Cultural Transformations, and Cognition

Humans do not experience or record climate, but rather daily and seasonal weather, along with the occurrence of extreme events. There is little doubt that early farming communities would have been highly susceptible to extremes of weather including droughts and floods, and the increasing trend towards food storage through the Neolithic, the Bronze Age, and beyond is generally seen as insurance against shortages given sedentary conditions and an increasing population (Halstead 1999; Rosen 2007). Indeed one of the most common Neolithic features across Europe is the storage pit, often found in remarkable numbers (Garrow 2006).

Whilst droughts and floods are the most obvious climatic hazards, others exist even in the relatively benign environment of Mediterranean Europe. These include volcanic eruptions in tectonically active areas, such as southern Italy, Anatolia, and the Greek Isles. Tephras (volcanic ash layers) are known from this period (Table 2.2) and many more fine tephras in the marine record (Lowe et al. 2007) are of high potential for improving environmental chronologies in southern Europe. Likewise, Iceland is the source of tephras found in mires in Scotland, northern Ireland, northern England, the Baltic States, and Scandinavia (Barber et al. 2008; Pilcher et al. 1996; Hang et al. 2006; Boygle 1998). However, even in the Mediterranean there is as yet little evidence for an eruption causing major population dislocation comparable to the Bronze Age Minoan civilization or Roman Pompeii. Essential to that narrative are perceptions of risk along with power, wealth, and opportunity, all of which would have to be included in any model of response at the societal level and below.

One approach to linking environment and human actions in the landscape is through modelling, now common in natural sciences like geomorphology. Modelling has moved away from normalizing, rational, and optimizing economic models towards humans as 'agents' endowed with behavioural attributes, even perceptions, expressed in a logical rule-like fashion. Spatial modelling has in the past largely ignored perception, presenting a 'theoretical model of the culture-environment interaction that takes no account of the cultural preconceptions and consequent constrained interpretations that social actors bring to their physical environment before they interact with it' (Wheatley 1996, 76). Environmental reconstruction can include how past environments looked, felt, and even smelled but, just as with geographical information systems (GIS), environmental (p. 45) models should only be seen as a 'screen on which to project behavioural and cognitive data' (Maschner and Mithen 1996, 302) and part of a wider cognitive approach to archaeology (Renfrew and Zubrow 1997). Parallels exist with recent developments in ecology and geography, where agent-based modelling (ABM) models the behaviour of organisms in the face of changing local conditions (e.g. fishing, Kirby et al. 2004) and incorporates non-normative and humanistic data within an environmental framework (Bithell and Macmillan 2007).

So far, applications include modelling food acquisition (hunting, gathering, basic agriculture) and the resultant soil erosion on limestone terrain around middle Neolithic settlements in southern France (Wainwright 2007), modelling change in the Anasazi culture in northern Arizona (Dean et al. 2000), and Mesolithic hunter-gatherer dynamics in the British Isles (Lake 2000). These studies have included the integration of a digital elevation model (DEM), palaeoenvironmental data, and—crucially—agents with rules of behaviour, agricultural or foraging capabilities, locations, and reproduction/mortality. The crucial point is that modelling does not seek to 'explain' the past or provide just another narrative, but to explore the construction of cultural interaction by challenging existing theories, demanding specification, and throwing up new questions. ABM is part of constructing culture from the bottom up, rather than generalized theorizing from the top down. In it, agents can be autonomous, goal-oriented, reactive, situated, cognitive, social, and capable of reproducing. Consequently, emergent properties can arise (Mithen 2000), a theme currently being explored in geomorphology and ecology (Harrison and Dunham 1999; Slaymaker 2005).

Conclusions

Many of the recent advances in environmental and Quaternary science—such as in sediment-based dating (Brown 2011), bio-markers (e.g. Jacob et al. 2009), soil DNA (Hebsgaard et al. 2009), and multi-element sediment scanning—greatly increase the potential to test competing hypotheses in prehistory. This is particularly pertinent as environmental change is commonly seen as rather less important to human society in Neolithic Europe than during the Bronze Age, Classical, and Medieval periods. This belief is partly a function of the longer time-scale and the dominant domestication-based narrative of Neolithic modernity (Renfrew 2007). This is changing for many reasons, such as the awareness of early domestication and agriculture in other regions (Bellwood 2005) and the remarkable advances in archaeogenetics, which are driving a more contingent, episodic, and non-purposive picture of domestication and agricultural adoption (Zohary et al. 1998). Environmental change has an essential role to play in replacing a functional meta-narrative with regionally differentiated, locally mediated, changing human–environment relations, at least in archaeology. Cognate disciplines such as Quaternary Science, however, appear to be developing in an opposite direction with new meta-narratives of global scale. For instance, Ruddiman's 'early Anthropocene' (p. 46) hypothesis sees the reversal of the expected Interglacial CO_2 and methane trend due to agriculture, particularly rice cultivation in the tropics, effectively forestalling the geological trend towards cooler conditions during the late Neolithic after *c*. 8000 BP (Ruddiman 2005). There is also a rise in deterministic connections between climate and cultural change. As Tipping (2012) has observed, we need to 'stop rejecting deterministic arguments because they are unpleasant, but instead test them, reject them, or revise them' (cf. Coombes and Barber 2005). Both the spatial variation in local climates and climate change must have been a component in cultural and social change, especially in early agriculture or 'Neolithisation' in Europe, but the questions are to what extent and in what ways. The answers can only come from integrated studies of environmental proxies with high-precision archaeological chronologies. This is why the re-dating of Neolithic monuments in Europe is a major advance (Whittle and Bayliss 2007). This will lead to a better integration of social agendas with landscape creation, a theme so actively promoted within environmental archaeology by John Evans (Evans 1975; Allen 2009). We also need to take on board some elements of the post-processual critique of environmental archaeology and work toward a more in-depth, sensual, and embodied view of the external environment of Neolithic agents in the landscape.

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