Virtual Neanderthals : a study in agent-based modelling Late Pleistocene hominins in western Europe

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3. CASE STUDY: THE LATE PLEISTOCENE IN WESTERN EUROPE

3.1 Introduction

This chapter provides a background to the core elements of the case study implemented in this research. Introduced are the topography of the research area, the environment during the simulated period in that area and the Neanderthals that inhabited Late Pleistocene Europe and whose presence is attested by the archaeology. Details of the model are given in the chapters that follow. The topographical area in this case study covers the part of Western Europe between latitudes 41.3 and 51.5 and between longitudes -6.3 and 8.5. This area includes more or less the area currently known as France. This area is well suited for agent-based modelling because it is enclosed by natural borders: in the south by the Pyrenees mountains and the Mediterranean Sea, in the west by the Atlantic Ocean and the Channel, in the north by the Ardennes hills and in the east by the Rhine river and the Alpine mountain ranges. The area includes different landscape elements like mountains, hills, plains and coastal areas.

Neanderthals lived here in the Late Pleistocene and archaeology attests to their occupational history. The area is selected also because archaeological research intensity is probably highest here if compared to the wider Neanderthal range, with the greatest density of observation points. Another reason why this area is particularly useful in this study is that according to the archaeology there are parts with a more or less continuous occupation in the south whereas in the north large areas seem to become depopulated when the climate deteriorated. The variation in population density through time and space combined with the relatively high number of archaeological sites provides a unique opportunity to investigate responses of the local hominin population to a changing environment.

HomininSpace simulates hominins moving through a reconstructed and dynamic landscape for an extended period of time. The components and the data flow in the simulation system are visualized in the schema presented in Figure 2. During execution output data is generated for further analysis and illustrative purposes. These include topographical (GIS) display of the simulation and simulation results. Archaeological data resulting from past hominin behaviours is used to compare simulation results against in order to explore hypotheses on those behaviours.

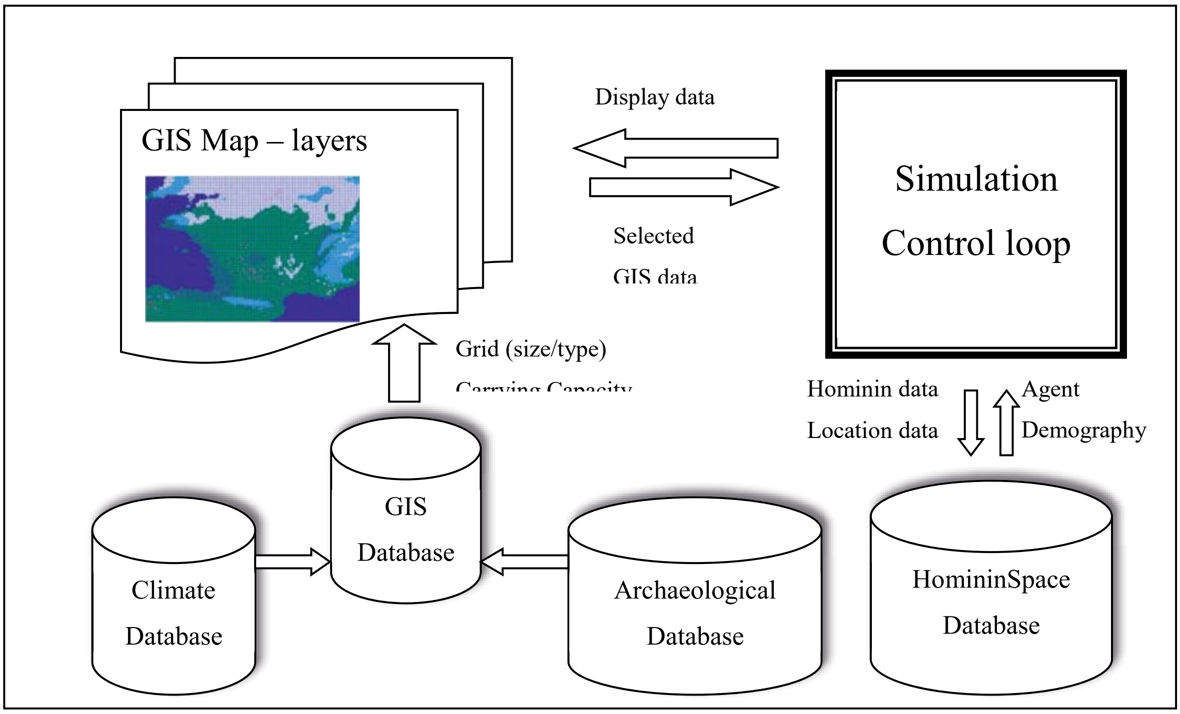

Figure 2: Components and data flow in the HomininSpace simulation system.

The simulation period for all experiments in the case study starts at 131,000 years ago and ends at 50,000 ago. Each thus starts at the end of Marine Isotope Stage (MIS) 6 and encompasses MIS 5, MIS 4, and ends in MIS 3[9]. This time frame is selected to ensure that the archaeology used in the simulations is exclusively produced by Neanderthals (Higham *et al.* 2014; Tsanova 2006; Hublin 2015; Roussel *et al.* 2016), which is important for the interpretation of the simulation results. The environment for the selected area and time period is discussed in Section 3.2. Not only the varying climate and the effect thereof on flora and fauna in the simulation area are illustrated but also the effects of advancing and retreating glaciers and associated fluctuating sea levels on the topography itself. The hominins that populated this changing environment are presented om more detail in Section 3.3.

3.2 The environment: climate and topography

One of the most important parameters defining the natural environment is the local climate. Climate is the long-term pattern of weather conditions in a particular area, and includes temperature, air pressure, humidity, precipitation, sunshine, cloudiness and wind fluctuations[10]. Climate in the research area is influenced to a large extent by the fact that the Atlantic Ocean, limiting the area to the west, provides a relatively warm sea climate.

[9] MIS stages after Lisiecki and Raymo (2005) (cf. Richter *et al.* 2013).
[10] Definition from http://www.dictionary.com/browse/climate, accessed 16 January 2018.

Further to the east a land climate prevails while in the south the Mediterranean Sea produces warmer climates year round. The mountain ranges which include the Pyrenees and the Alps have their influence on the climate also and to the north glaciers advance when the temperature drops.

In temperate western Europe the fluctuating climate during the latter part of the Quaternary (Cohen and Gibbard 2011) may have had major effects on the spread of flora and fauna. The cyclic changes in the global climate of the Quaternary have been described as dramatic (Guiot *et al.* 1989). Ice and deep sea cores give compelling evidence for sometimes rapid climate change (Sanchez Goñi and Harrison 2010). During glacial and interglacial cycles climate change causes geographic distributions of plants and animals to shift and for all species the changing environment influenced the use of refugia, speciation, range sizes and latitudinal patterns (Dynesius and Jansson 2000; Hewitt 1996). These shifts are caused by differences in the energy levels received and stored in the landscape. The general effect of these changes on the flora is that forest is replaced by woodland and, with increasing aridity and seasonality, in turn by grassland in northwest Europe (Janis *et al.* 2000). Cold and dry conditions in colder periods like the Last Glacial Maximum (LGM) favoured extensive tundra and steppe. Northern hemisphere forest biomes were displaced southward. Boreal evergreen forests (taiga) and temperate deciduous forests were fragmented, while European and East Asian steppes were greatly extended (Prentice *et al.* 2000).

The Late Pleistocene is generally seen as a colder period. But it is initiated by a warm stage, the Eemian. The Eemian Interglacial in Europe is characterized by high pollen abundances of oak (*Quercus*), hazel (*Corylus*), alder (*Alnus*), beech (*Fagus*), hornbeam (*Carpinus*), and other temperate woody taxa with differences among sites likely reflecting interregional differences in Eemian climates as well as variation in substrate. After the last interglacial, the proportion of treeless vegetation increased, with high pollen abundances of grass (*Poaceae*), sagebrush (*Artemisia*), chenopods (*Chenopodiaceae*), pine (*Pinus*), and juniper (*Juniperus*) reported from records spanning the last glacial period (Allen *et al.* 1999). This suggests that summer precipitation, at least, was insufficient to sustain forest (Prentice *et al.* 1992; Prentice *et al.* 2000). What came into existence in large parts of continental Eurasia is referred to as the Mammoth Steppe.

The Mammoth Steppe is a landscape remarkable for its unusual combination of mammal species: woolly mammoths, bison, horses, lions, camels and many more (Guthrie 1982, 309; Guthrie 1990; Stewart 2007). The environment was very productive and characterized by a very diverse flora and fauna with a large variety in species[11]. The ecosystem of the Mammoth Steppe disappeared during the Pleistocene – Holocene transition and was replaced by the modern tundra, taiga, and steppe environments.

In the Mediterranean area of France the climate was completely different, with a humid and warm climate at the beginning of the Late Pleistocene. When it becomes colder in the north, the south turns more arid (and only slightly colder), causing the landscape to open (Montuire and Desclaux 1997). These phases alternated until the end of the Late Pleistocene when also the southern parts become more colder and more open.

While climate has changed the landscape drastically for people living during the Quaternary, the topography itself changed relatively little (van Gijssel 2006). The landscape in western Europe was shaped in the last 200,000 years by two major processes: glaciation and sea level change. Other processes changed the nature of the landscape and include earthquakes, erosion and sedimentation systems, and volcanic and tectonic activities. Events with lasting impact are diversions of major river systems (for instance the Thames) and creation of volcanic plateaus and mountains (like the Chaîne des Puys in the Massif Central region, around 70 ka).

The area of this case study was hardly affected directly by glaciations, with the Weichselian arctic glaciers reaching no further south than Denmark and covering part of England (see Figure 3). Only the Alpine glaciers (and to a lesser extent those from the Pyrenees) have left their traces but the extent of their glaciers is limited and in the grid scale of the simulations their effects are ignored. The effects of a glaciation extend however much further than the area of the main body of ice. Besides influencing the local climate, glaciers can physically block and divert existing river systems and create new ones due to melt. The weight of the ice depresses the land and can aggravate the above mentioned processes. Rebounding surfaces effect the area long after the ice has gone, influencing local sea levels and again diverting river systems.

[11] See for instance the Stage 3 database on identified faunal remains, on-line available through http://www.esc.cam.ac.uk/research/research-groups/oistage3, verified 26 April 2011.

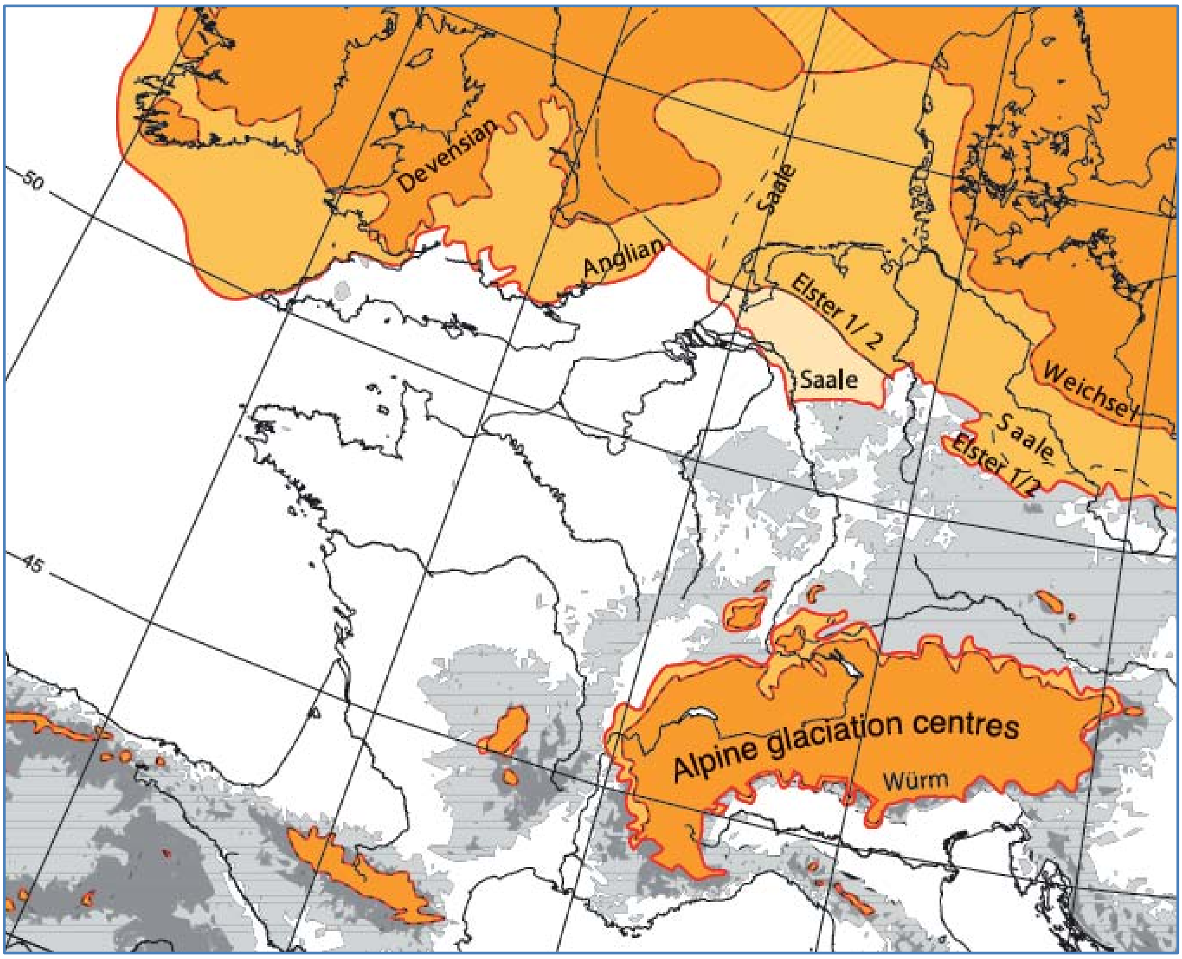

Figure 3: Maximum ice sheet coverages (adapted from van Gijssel 2006, Figure 3.4). The solid red line follows the maximum limits of the Pleistocene glaciations.

A good example illustrating the influence of ice sheets is the Channel area between modern day England and France during the severe cold stages of the Quaternary. Here, the accumulation of sweet water in glaciers encroaching from the North made the sea level drop as much as 130 meter, opening a land bridge from main land Europe to the British Islands (Gupta *et al.* 2007). The main river systems in the larger area, including the Thames, the Rhine and the Meuse were diverted into these newly exposed land areas. The huge river system, additionally fuelled with melting waters from the ice, might have posed a formidable obstacle for any hominin trying to reach across (Gibbard 1988). But nevertheless Neanderthals reached the shores of England later during the early phases of MIS stage 3 (White 2006).

Due to the importance of coastal areas (Cohen *et al.* 2012) reconstructing past sea levels is essential for understanding dispersals of species and interpretation of the stratigraphy of geological sequences (Cohen *et al.* 2012). Kelly (1983) separates production environments with many marine resources from those with only terrestrial influences. Sea level changes influence the landscape in a more or less dramatic way. Sea levels on a global scale are influenced mainly by the presence of glaciers, where more water stored as ice in the glaciers means a lower sea level (Grant *et al.* 2012).

Sea level rise and fall had significant effects on people in the past as well. Due to the diversity of available resources, occupation densities near water bodies were generally high. Lowering of the sea level by growing ice-sheets exposed new lands, while former beach areas became part of the inland ecology. Climate associated with the land-sea border will shift and communities will have to respond. Accordingly, sea level rise forced populations to relocate, causing local population densities and movement which had to be resolved. In some cases rising local sea levels might have been rapid and unexpected, removing communities in the process. Rates of mean sea-level rise reached at least 1.2 meter per century during all major episodes of ice-volume reduction (Grant *et al.* 2012).

Figure 4 presents the bathymetry of the European tectonic plate with in pink those landmasses that emerge when the global sea level drops 120 meters, the assumed global level drop for the LGM (Fairbanks 1989). This map is constructed by Smith and Sandwell (1997) and illustrates what landmass might have been accessible during the simulations.

Figure 4: Topography for western Europe, sea level lowered with 120 meters. Pink areas are now submerged. Adapted from http://topex.ucsd.edu/marine_topo/mar_topo.html, accessed 8 April 2013.

3.3 The hominins: Neanderthals

The Neanderthal[12] phylogenetic lineage arises somewhere around 500 ka (Meyer *et al.* 2016). In Europe these hominins were typically sturdily built, with short but robust limbs and a specific cranial shape (Weaver *et al.* 2016). Through time they displayed more and more typical Neanderthal features (Hublin 2009; Klein 2009a). The species disappeared around the time that *Homo sapiens* (modern humans) appeared in Europe in the areas previously occupied by Neanderthals (Hublin 2017). The possible replacement of Neanderthals by modern humans is one of the most important questions of palaeoanthropology (Hublin 2017;Hajdinjak *et al.* 2018). They are unarguably the best researched extinct hominin but many aspects of Neanderthal daily life remain poorly known (Anwar *et al.* 2007, 250).

To obtain food Neanderthals frequently hunted some of the largest and most dangerous prey animals of their time (Bocherens *et al.* 2005; Hoffecker and Cleghorn 2000; Roebroeks 2006). These include large herbivores like horse (*Equus* sp.) red deer (*Cervus elaphus*), woolly rhinoceros (*Coelodonta antiquitatis*), woolly mammoth (*Mammuthus primigenius*) and bison (*Bison priscus*). Even when smaller animals are more abundant, it is rather more cost effective to hunt these larger animals in terms of return rates for procurement effort (Kelly 1995, 86-87). Most dietary protein (up to 80%) were obtained from terrestrial animals (Naito et al 2016). Animal species were locally hunted both selectively (i.e. equids) as well as unselectively (i.e. cervids) (Marín *et al.* 2017). Research suggests that Neanderthals were quite capable and successful in obtaining and using biogeographical information on hunted resources (Adler *et al.* 2006; White *et al.* 2016).

Mobility, the sum of small scale movements through larger geographic and temporal scales, enables hunter gatherers to survive (Kuhn *et al.* 2016). Binford (1980) demonstrated that the character of mobility depends on the environment. He used effective temperature to illustrate the relation between environment and different settlement strategies. He reduced earlier schemes (e.g. Murdock 1967) into two main types of mobility: collectors and foragers, where foragers would move the group around looking for resources and collectors would leave the group at one specific location and collect resources on individual or task-specific forays to bring them back to the group. For a

[12] Throughout this work the terms *Homo neanderthalensis* and Neanderthal are synonyms and taken to denote the same species. They are used interchangeably. The species name is written with an 'h' as in the original spelling. As much as possible individual Neanderthals are consequently referred to as 'he'. Wherever applicable this should be taken to mean both male and female hominins of any age.

discussion see Kelly (1995) who found that larger distances were covered in colder climates(117). Environmental productivity steers hominin residential moves (Kelly 1983, 292) and influences population density with most productive and thus most habitable areas being colonized first (Codding and Jones 2013). Occasionally, hunter-gatherer groups become more sedentary, and cease to move residentially as a group while increasing individual logistic mobility (Kelly 1995, 148).

Individual mobility in the form of migration can be tested with strontium analysis (Bentley 2006). Such analysis suggests that at least some Neanderthals were very mobile, albeit not over very large distances (Richards *et al.* 2008). If relative tibial rigidity reflects adaptation to terrestrial mobility Neanderthals were walking or running to a far greater degree than any modern human of today (Shaw and Stock 2013). Used raw material sources and transport may also provide a proxy for past mobility and seem to suggest that Neanderthals in only few instances moved material over large distances (Adler *et al.* 2006; Féblot-Augustins 1999; Féblot-Augustins 2009; Soressi and Hays 2003; Slimak and Giraud 2007).

Gamble and Steele (1999) calculated that areas used by Neanderthal groups could be relatively large (2025 km^2 for Grotte Vaufrey VIII). But daily travelled distances for Neanderthals are likely to have been relatively short (Verpoorte 2006), supported by the fact that more than 90% of the raw material was transferred less than 20 km from its source (Féblot-Augustins 1999). This could suggest that most groups were not migrating over larger distances or that lithic artefacts were not taken along, and that the exceptional artefacts were either exchanged between Neanderthal groups or transported over longer distances by some individuals or groups.

Neanderthals disappeared from the archaeological record around the time modern humans arrived in Europe. It is currently assumed that modern humans arrived in western Europe not before 50,000 years ago (Appenzeller 2013; Higham *et al.* 2014; Tsanova 2006; Hublin 2015; Roussel *et al.* 2016; Teyssandier 2008). The presence of the first modern humans is attested by physical remains and via association with sites and lithic assemblages attributed to the Aurignacian culture family. The distribution of the different Aurignacian technologies appears to trigger the transition from Middle to Upper Palaeolithic. This process often includes transitional industries and seems to temporally coincide with the eventual disappearance of the Neanderthals.

The earliest appearance of these archaeological cultures is around 43-42 ka (Higham *et al.* 2011). For some, most notably the Châtelperronian, a Neanderthal origin is inferred

(Hublin *et al.* 2012; Roussel *et al.* 2016; Ruebens *et al.* 2015). The presence of modern humans is likely a direct (Mellars 1992) or indirect (through stimulus diffusion of culture) cause for the Neanderthal demise (Roussel *et al.* 2016). Due to geological processes (like low sedimentation rates), periglacial processes (like cryoturbation), and due to poorly recorded excavations there are quite a few interpretive problems for sites dating to the transition period around 50-35 ka (Ruebens *et al.* 2015). To prevent incorrect assessment of the Neanderthal record in this study by potential mixing of early modern human influences the upper boundary of the simulations is set to 50 ka.