Elsevier Editorial System(tm) for Journal of Anthropological Archaeology
Manuscript Draft

Manuscript Number: YJAAR-D-13-00114R2

Title: Understanding the impact of socio-economic activities on archaeological charcoal assemblages in temperate areas: comparative analysis of firewood management in two Neolithic societies in Western Europe (Belgium, France).

Article Type: Full Length Article

Keywords: archaeobotany; charcoal analysis; Neolithic; domestic firewood; Western Europe; life paths; socio-economic activities; wood gathering areas.

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Abstract: This paper presents archaeological charcoal assemblages from two clusters of Neolithic sites in temperate Europe, which reveal differences in the choice of firewood acquisition areas. We advance and test the hypothesis that there is a link between firewood gathering areas and daily travelled itineraries, using two comparable, but temporally and spatially distinct, case studies. The first of these is the Hesbaye in central Belgium where the Early Neolithic occupation is made up of two settlement phases from between 5200 and 5000 BC (Linearbankeramik culture). The second is the Late Neolithic occupation of the French Jura pile-dwellings in eastern France. In Hesbaye, the firewood supply area is restricted, favouring the rapid development of light-demanding species, while this area appears to be more extensive in the Jura where there is no clear development of light-demanding taxa. We postulate that there is a close spatial convergence between firewood gathering areas and potential cultivated land in Hesbaye and the French Jura. This case study therefore addresses the potential links between firewood management and the socio-economic context and demonstrates that the concept of daily itineraries enhances our understanding of charcoal assemblages and their palaeoecological interpretations.

Highlights :

-to understand the impact of socio-economical activities on archaeological charcoal assemblages.

-to show the importance of cultivated lands location on the expansion of wood gathering areas during the Neolithic.

-to highlight the value in comparing two distant regions showing a comparable settlement pattern and pioneer farming system.

Understanding the impact of socio-economic activities on archaeological charcoal assemblages in temperate areas: a comparative analysis of firewood management in two Neolithic societies in Western Europe (Belgium, France).

Abstract

This paper presents archaeological charcoal assemblages from two clusters of Neolithic sites in temperate Europe, which reveal differences in the choice of firewood acquisition areas. We advance and test the hypothesis that there is a link between firewood gathering areas and daily travelled itineraries, using two comparable, but temporally and spatially distinct, case studies. The first of these is the Hesbaye in central Belgium where the Early Neolithic occupation is made up of two settlement phases from between 5200 and 5000 BC (Linearbankeramik culture). The second is the Late Neolithic occupation of the French Jura pile-dwellings in eastern France. In Hesbaye, the firewood supply area is restricted, favouring the rapid development of light-demanding species, while this area appears to be more extensive in the Jura where there is no clear development of light-demanding taxa. We postulate that there is a close spatial convergence between firewood gathering areas and potential cultivated land in Hesbaye and the French Jura. This case study therefore addresses the potential links between firewood management and the socio-economic context and demonstrates that the concept of daily itineraries enhances our understanding of charcoal assemblages and their palaeoecological interpretations.

Key-words: archaeobotany, charcoal analysis, Neolithic, domestic firewood, Western Europe, life paths, socio-economic activities, wood gathering areas.

Introduction

Archaeological charcoal remains from domestic firewood are widely used to reconstruct the composition of local woodlands and to interpret the transformation of these environments as the result of climatic change or human impact. Indeed, past firewood resources are mainly conditioned by biomass, species diversity and the availability of standing or dead woods. However, the choice of species for cooking or lighting and the selection of building timber can be interdependent,as previously demonstrated for Neolithic periods (*e.g.* Asouti and

Austin, 2005; Asouti 2012; Dufraisse, 2008, 2012; Out, 2010). Moreover, wood diameter is at least as important a criterion for firewood selection as the choice of the species for effectively managing a fire with regard to specific fireplace use (Chabal, 1994; Dufraisse and Garcia-Martinez, 2011). In this respect, human practices involving domestic firewood gathering for heating, defense, light, cooking, and the production of goods also depend on economic activities, like the location and the range of the territories covered for pastoral and agricultural activities, as well as the socio-cultural context (Asouti and Austin, 2005; Dufraisse et al., 2007; Picornell-Gelabert et al., 2011; Zapata et al., 2003). The development of a more coherent framework including the complex ecological and cultural processes affecting species availability and firewood management is required. The new challenge for current charcoal analysis consists in modelling wood acquisition strategies based on human behavioural ecology (Marston, 2009; Shackleton and Prins, 1992). In this paper, we propose to test the concept of "the carrying capacity of terrestrial space time" proposed by Carlstein (1980) for pre-industrial societies. This can be defined as "the limited ability of a given area to accommodate space-demanding people, organisms, artefacts, materials and the activities associated with them" (Carlstein, 1980, p. 19-20). More specifically, the notions of "daily itineraries" and "life paths" (Carlstein 1980) could serve as a descriptive framework for understanding interactions between past societies and the environments where resources, including firewood, are not concentrated in one place but are scattered and often mobile across the surface of the catchment area. In order to test and use the concept of "daily itineraries" or "life paths" to analyse charcoal assemblages and thus, to advance hypotheses about past firewood acquisition strategies, solid datasets based on well-understood archaeological contexts are required. This paper is based on two summaries of research carried out as part of a PhD thesis on two geographically distant Neolithic communities: early Neolithic groups (5200-5000 BC) on the Hesbaye plateau, in Belgium, and late Neolithic groups (3200-2700 BC) at Chalain Lake, in the French Jura (Dufraisse 2005, Salavert 2010).

The two regions studied here concern comparable sedentary human communities from both a technical and economic point of view (Tabl. 1). Firstly, the Neolithic groups of Hesbaye and the Jura are farming communities practising livestock herding but also, to a lesser extent, hunting and gathering. Secondly, in Hesbaye, the LBK people seem to have settled in areas previously unexploited by late Mesolithic groups (Vanmonfort, 2008). Likewise, the settlement pattern could be of pioneer type in the Jura, as implied by the scarcity of archaeological evidence of human occupation prior to the late Neolithic period around Lake

Chalain (Pétrequin 2005). In most cases, the Neolithic villages were built on the lakeshore and the rest of the valley was only slightly affected by temporary clearances (Richard 1997). Therefore, even if the Neolithic sites of the two regions are temporally distinct, the occupation process is comparable, that is to say, pioneer Neolithic groups settling in woodland that has been subjected to very low human impact. Furthermore, in both regions, the datasets may yield reliable information on exploited forest formations throughout time. The charcoal fragments studied in the two regions come from domestic deposits accumulated throughout time that correspond to different episodes of combustion and are therefore, suitable for palaeoenvironmental interpretation (Chabal, 1994, 1997). Moreover, the two regions present a similar potential of temperate wood species (Tab. 1).

The most significant differences between the two datasets are the time resolution. The main reason for this is that the mode of preservation of archaeological sites may have an influence on absolute dating methodologies. In Hesbaye, due to erosion, only the imprints of houses (postholes) and detritus pits are preserved. The age assessment of the site is based on radiocarbon dating conducted on carbonized macro-remains, seeds and charcoal (Bosquet and Golitko, 2012). The duration of house utilisation is thus not accurately known. In central Belgium, the whole LBK period is estimated at around two centuries (Jadin, 2003). In the French Jura, the littoral sites are preserved in stable anaerobic conditions conducive to excellent wood preservation. Dendrochronology was thus used to accurately date the duration of the village which can be estimated between 12 and 25 years, depending on the period (Viellet, 2007). Another difference lies in the farming system of the two societies. In Hesbaye, the LBK people cultivated permanent plots (Bogaard 2004), which means that field fertility could have been maintained over a long period of time. In the Jura, settlements are permanent but with a short life span (12-25 years). The Neolithic people may have managed fields in a semi-intensive way (Lundström-Baudais, 1986).

The aim of this paper is thus to compare the charcoal dataset from two areas of pioneer Neolithic occupation in western temperate Europe in order to highlight the processes affecting charcoal assemblage composition. We postulate that firewood acquisition strategies could be linked to socio-economic and cultural contexts in these two Neolithic societies.

Socio-economic settings and charcoal results

Early Neolithic sites from Hesbaye (central Belgium)

The Hesbaye is located in the eastern part of central Belgium. It is a gently hilly plateau region, roughly demarcated by the River Geer to the north, the Meuse to the south and the Méhaigne to the west. The Early Neolithic sites are at about 150 m a.s.l. (Fig. 1). The oceanic and temperate climate is characterized by relatively cool and wet summers. Average temperatures range from 3.1°C in January to 17.7°C in July. The average rainfall is 804 mm per year (source: Royal Meteorological Institute of Belgium). Today, the forest is highly fragmented, as the thick loess cover is favourable to extensive agricultural activities in Hesbaye. The rare natural woodland zones are mainly dominated by *Quercus robur* and *Fraxinus excelsior* (Tabl. 2), which compose 70 to 90 % of the forest, and, to a lesser extent, *Fagus sylvatica*. *Corylus avellana* and *Sambucus nigra* dominate the shrub canopy. The alluvial forest is composed of four main species: *Alnus glutinosa*, *Fraxinus excelsior*, *Ulmus minor* and *Prunus padus*. The riparian flora is also represented by *Salix* and *Alnus* species (Noirfalise, 1984).

The sites are attributed to the Linearbandkeramik (LBK) culture, which corresponds to a pioneer front of Neolithic colonisation from central Europe to the Paris Basin. In Belgium, the occupation extends between 5200 and 5000 BC (Jadin 2003). The typo-chronology of ceramic, lithic raw material, the spatial distribution of houses, AMS radiocarbon dating and charcoal analysis (see below) indicates the presence of two successive phases of occupation within the LBK culture (Bosquet et al., 2008; Bosquet and Golitko, 2012; Salavert, 2008; Salavert et al. in press). Both these phases are visible at the site (Fig. 2). To date, we have not ascertained whether we are dealing with two distinct phases of colonisation, meaning that two separate LBK groups arrived at two different times, or whether the secondary stage is an extension of the first installation, involving time continuity between both phases. Houses seem more numerous during the second settlement phase than during the first, in which pioneer houses appear to be isolated. However, the area excavated during rescue operations did not provide an overview of the whole built-up area (Bosquet et al., 2008). Data relating to animal husbandry are very scarce, due to the poor conservation of bones in loessic soil. A narrow range of crops has been identified, composed mainly of *Triticum dicoccum*, *Triticum monococcum*, *Pisum sativum*, *Lens culinaris*, *Linum usitatissimum* and maybe *Papaver somniferum* (Salavert, 2011). There is little evidence of fruit gathering, possibly because of the preservation mode of macro-remains (carbonization). The most common species are *Corylus avellana* and *Malus sylvestris*. The comparison of modern weed assemblages from experimental plots with archaeological weed assemblages from several LBK sites indicates the presence of permanent fields, intensively ploughed on a household scale (Bogaard, 2002, 2004, 2005).

Due to erosion the occupation level, which is the stratigraphic layer on which human activity has occurred, has not been preserved. Only two combustion structures are preserved at Alleur (Collin et al., 2000). Sediments for charcoal analysis were recovered from the thick rubbish layers that filled LBK house lateral pits and isolated pits which therefore do not display a direct connection with any household. The fragments of charcoal are mixed with waste from daily life (potsherds, lithics, carbonized seeds, burnt earth, fragments of grinding stones), and may essentially correspond to remains from emptying domestic fireplaces. The combined analysis of charcoal and pottery indicates that they were generally indirectly discarded in the pits after a long period of accumulation on the floor (Bosquet et al., 2010). Seven sites and ten settlement phases have been studied at Hesbaye. Four belong to the first LBK phase (13 structures) and six to the second one (86 structures). The total number of samples studied (n = 273) allows us to judge the reproducibility of the results at both site and regional scales and thus to gauge the representativeness of the charcoal analysis. Sediments were washed on a 0.5 mm mesh sieve. We consider that the examination of up to 50 charcoal fragments each time a new species is identified per sample is sufficient in order to gain an overview of past vegetation in temperate areas (Salavert et al., in press). Salavert conducted most of the charcoal analyses (2008, 2010, Salavert et al., in press). Deligne (2005) identified the Podrî Cortri (PDC) charcoal. Buydens and Damblon (2001), as well as Figueiral (2004), studied some of the Alleur (ALL) structures.

The combination of charcoal assemblages attributed to the first phase displays relatively low species diversity (Fig. 3). Most often, only four or five taxa were identified, mainly *Quercus*, *Fraxinus* and *Corylus.* They are present at every site and almost at every structure and make up 73 % of the charcoal assemblage. Fragments of *Ulmus* and *Tilia* were generally present in small quantities, except at Vinâve (WV) where *Ulmus* made up 9 % of the identified taxa and in Podrî l'Cortri (PDC) house I where *Tilia* comprised nearby 15 %. These two taxa were respectively identified in four and three sites and in less than half of the 13 structures. Maloideae and *Sambucus* are both represented by a single fragment at Podrî l'Cortri (PDC). The charcoal assemblage attributed to the second phase of settlement presents more diversity (up to 14 taxa). *Quercus* (35 %) and *Fraxinus* (24 %) are the two main taxa, accompanied by Maloideae and *Corylus* (about 14 % each). These four taxa are present at each site and in more than two-thirds of the 86 structures attributed to the second LBK phase. Prunoideae, *Ulmus* and *Sambucus* are also regularly identified and make up less than 10 % of the assemblage. *Salix/Populus*, *Acer*, *Tilia, Betula, Ligustrum* and *Cornus* are marginal and are only present at one or two sites (Salavert et al., in press).

Late Neolithic sites from Lake Chalain (eastern France)

The lakes of Chalain and Clairvaux are located on the left bank of the Ain River, in the Combe d'Ain and are 12 km apart (Fig. 4). The altitude of the region ranges from 450 m a.s.l. in the valley to 750 m a.s.l. on the first plateau. In the Combe d'Ain, the mean annual temperature is about 10 °C and varies with altitude. The area is protected from westerly winds and receives less precipitation than the surrounding regions (about 1,300-1,400 mm). In this part of the Jura, topography and soil (silt, limestone, marl, moraines, etc.) give rise to wide floristic diversity. From the River Ain to the glacio-lacustrine terraces of the Combe d'Ain, various woodland assemblages are represented, such as *Salix* along rivers, *Alnus* in marsh zones, *Acer-Fraxinus* on recent alluviums and along rivers, and *Quercus-Fraxinus* on colluviums with a high degree of soil water retention. Below 600 metres, *Quercus* woodlands mainly represent the hillside vegetation, whereas *Fagus* woodlands, associated with *Quercus*, cover the sub-mountainous zones, between 600-750 metres (Beaufils 1986).

The French Jura pile dwellings represent a chronological sequence stretching from 3800 to 2400 BC. The dendrochronological study of house posts revealed the existence of three settlement cycles. In this paper, we focus on cycle 2, for which the ceramic typo-chronology, as well as the chronological and spatial evolutions of the villages, are well known (Pétrequin 2005). Cycle 2 corresponds to the Late Neolithic occupation (3200-2960 BC) at Lake Chalain, whereas cycle 1 (3550-3250 BC) is characterized by the complete absence of lakeshore settlements at Chalain due to a major phase of climatic deterioration. Cycle 2 can be divided into two phases (Arbogast et al., 1999; Giligny et al., 1995), with the Horgen culture from 3200 BC to 3100 BC (phase 1), and the Ferrières culture followed by the Clairvaux group from 3040 BC to 2960 BC (phase 2). These two phases are separated by a phase of minor climatic deterioration (around 60 years) (Pétrequin and Bailly, 2004). These two habitation phases can be closely correlated with population density, as shown by the rise in the number of villages. Phase 1 corresponds to a period of low density (4 villages) and phase

2 to a period of higher village density (15 villages) (Arbogast et al., 1999; Pétrequin et al., 1999). The evolution of a meat-based diet could be correlated with village population densities. Deer hunting, cattle and pig farming characterized phase 1, whereas demographic growth, an increase in hunting and more diversified exploitation marked phase 2. Farming plays a more minor role and compensates for hunting supply shortages (Arbogast and Pétrequin, 1993). During the late Neolithic, the proportion of cultivated plants is significant, with *Triticum dicoccum*, *Triticum aestivum*/*duru*m, *Hordeum vulgare*, *Pisum sativum, Linum usitatissimum* and *Papaver somniferum.* However, fruit remains of *Malus sylvestris*, *Corylus avellana*, *Rubus fruticosus* and *Fragaria vesca*, which indicate gathering activities, are considerable (Baudais et al., 1997), probably because of waterlogged preservation conditions. According to K. Lundström-Baudais (1986), the weed assemblages indicate the presence of permanent fields in a context of villages with a short life span. Some of these weeds are representative of gardens and weeded crops, which evoke semi-intensive gardening activities. "Pasture-meadow" species suggest the presence of livestock and the use of manure (Lundström-Baudais 1986).

At Lake Chalain, studied charcoal fragments come from the occupation levels. Each domestic unit has a fireplace. Trash, including charcoal remains, was discharged into water, both under and around the houses. Collective garbage dumps were also identified. Several studies concerning the dispersal of the archaeological artefacts, carried out at Chalain 3 (Arbogast et al., 1997), Clairvaux III (Pétrequin, 1986) and Clairvaux la Motte-aux-Mangins (Pétrequin and Pétrequin, 1989), indicate a close spatial relationship between clay lenses issued from repairing fireplaces, heated stones and charcoal fragments. Easily recognizable fire levels in the field were thus excluded and no remnant of handcrafted activities inside the village was identified. Thus, the studied charcoal fragments unquestionably derive from cleaning fireplaces and were consequently produced by domestic activities. When possible, each occupation level was sampled following a systematic pattern. In addition, when excavations were not in progress during sampling, samples were taken by coring along a line perpendicular to the lakeshore (Dufraisse, 2002). The charcoal fragments were washed on a 2 mm mesh sieve and air-dried. The minimum number of charcoal fragments to be identified is defined by the use of “saturation curves” (Asouti and Austin, 2005; Chabal, 1997). Altogether, results from the Jura lakeshore settlements are based on the charcoal analysis of three sites and seven occupation phases. Dufraisse conducted most of charcoal identifications (Dufraisse 2005) while Lundström-Baudais (1997) identified charcoal from Chalain 3 (CH 3).

The number of identified taxa fluctuates between 7 and 20 depending on the sites (Fig. 5) and is not correlated with the occupation phases. *Fraxinus* is the major species exploited during both phases, especially during phase 1 (Horgen), characterized by low village density at Chalain 3 (CH3) and Chalain 19 (CH19). Unlike *Fraxinus*, *Fagus* and *Quercus* are mainly attested during phase 2, at a time of high village density. With the exception of Chalain 4 (CH4), level G, *Fagus* is generally more abundant than *Quercus*. The percentages of *Acer* spp. are more or less constant during both phases while Rosaceae (Maloideae, Prunoideae) and shrub species, such as *Ligustrum* and *Cornus,* are minor.

Comparison of charcoal assemblages and vegetation dynamics from Hesbaye and the Jura

At the time of arrival of the first Neolithic groups in Hesbaye (phase 1), the charcoal assemblages are characterized by a low number of taxa, in general two to five per structure (*Quercus*, *Fraxinus*, *Corylus*, *Ulmus*, *Tilia*). This indicates the exploitation of *Quercus*-*Fraxinus* woodlands. We assume a more or less homogeneous mixture of both species in woodland plots as is the case today in Hesbaye (Noirfalise 1984). Riparian taxa, including *Alnus*, are missing, implying that riverbanks may have been ignored during firewood gathering. The absence of shrubs, medium-sized trees and heliophilous taxa is noteworthy and indicates that the forest may have been relatively closed, at least in the vicinity of the archaeological sites, at the time of arrival of the first LBK groups. In the Jura, during phase 1 (3200-3100 BC), species diversity is higher than in Hesbaye. The number of taxa varies from twelve to twenty per occupation level. The floristic list indicates the predominant exploitation of *Fraxinus* woodlands which, associated with *Acer* and according to current phytosociology (Beaufils 1986), could be part of a discontinuously flooded riparian forest. The presence of shrubs and medium-sized trees such as *Salix*, *Populus*, *Corylus* and Maloideae may indicate the exploitation of transitory vegetal formations from the riparian vegetation around the lake to the hillside forests.

Thus, in Hesbaye, during the second LBK phase, the charcoal assemblages are characterized by a significant increase in the number of taxa (from three to ten per structure), and the appearance of heliophilous and shrub species, such as Maloideae, Prunoideae and *Sambucus*. These taxa are characteristic of forest edges. The *Quercus-Fraxinus* woodland is still the only exploited biotope. *Alnus* and other potential riverside species remain absent. In the Jura, during the second phase (3040-2960 BC), the number of taxa does not increase significantly between the two phases. *Fraxinus* woodland is still widely used. *Fagus,* associated with *Quercus* at Chalain 19 (CH19), could point to the exploitation of sub-mountainous vegetation (between 600-750 metres). Similarly, shrubs characteristic of woodland edges, such as *Corylus,* Maloideae and Prunoideae, do not increase and their proportions remain minor.

For both datasets, the floristic list of the two temperate areas is consistent with past vegetation reconstructed from the pollen data (Salavert et al., in press; Dufraisse, 2005). The main differences in charcoal results between both Neolithic areas lie in:

- The number of taxa between phase 1 and phase 2. It increases in Hesbaye while it remains stable in the Jura.

- The change in the main plant community exploited during phase 1 and phase 2. It remains stable in Hesbaye (*Quercus-Fraxinus*) while it partly changes in the Jura (from *Fraxinus-Quercus* to *Fraxinus-Quercus* and *Fagus-Quercus* woodlands).

- The proportion of typical edges species, such as Maloideae and Prunoideae, during phase 2. These taxa are important in Hesbaye where the percentage of Maloideae can reach 30 % in some sites (Salavert et al., in press), while it clearly remains marginal in the Jura.

Discussion

Vegetation response to firewood collection

Firstly, it is relevant to question whether the low number of species in phase 1 at Hesbaye reflects species diversity in the exploited forest or if it is the result of marked selection. In Western Europe, very few current references concerning the taxonomic composition of forests allude to the "original naturalness" that existed before any significant human influence (Peterken, 1996: 11). In Hesbaye, we observe that in the multiple phase 1 archaeological sites, the list and frequencies of species are reproducible and in accordance with modern ecology, which argues in favour of the environmental representativeness of charcoal assemblages. Furthermore, according to several records, forests “can be poor in terms of number of plant and animal species in temperate zones” (FAO 2006:40), in particular for the group of vascular plants, because the dense canopy was not conducive to the development of shrubs and heliophilous trees (Paillet and Bergès, 2010). Thus, we assume that the species diversity recorded in charcoal assemblages from phase 1 in Hesbaye, and more generally, in Neolithic settlements in Belgium and France as a whole, reflects the diversity of species in the exploited woodlands, even if some of the secondary species are not necessarily exploited for firewood (Dufraisse, 2012). Differences concerning species diversity between Hesbaye and the Jura could be mainly linked to topographic and edaphic conditions. These are more contrasted in the Jura where woodlands are more varied than on the Hesbaye plateau.

Consequently, species diversity, combined with the morpho-ecological characteristics of the taxa, provide information concerning the nature of the forest when Neolithic groups arrived in both regions. In Hesbaye, phase 1 charcoal assemblages indicate a rather closed canopy and woodland with low species diversity. During phase 2, a transformation of woodland composition occurs, involving an opening of the forest landscape, characterized by heliophilous taxa, namely Maloideae species, which could have developed on forest edges. The increase of *Corylus* in Hesbaye between phases 1 and 2 is not noticeable. Given that the entire LBK period lasted around 200 years in Hesbaye (Jadin, 2003), the transformation of the landscape, from a closed canopy to more open woodland, occurs within a short time span. This may be due to human pressure concentrated around the habitat, which would have led to the rapid development of forest edges, well defined by the composition of species (Alignier, 2010).

In the Jura, woodland composition was more diversified when the first Neolithic groups arrived, due to the spatial organization of the vegetal communities from the lakeshores to the glacio-lacustrine terraces. Due to their autecological and phytosociological characteristics, heliophilous species, such as Rosaceae and *Sambucus*, could also be considered as potential markers of woodland opening in the Jura. Maloideae is identified in phase 1 and could thus have developed during phase 2, promoting the opening of the vegetation. Indeed, after a short period of lakeshore abandonment, the number of contemporaneous villages increased from 5 to 15 in less than 40 years. However, during phase 2 at the Jurassian sites, heliophilous species were scarce and species diversity was stable between both occupation phases. The anticipated vegetation dynamic and landscape transformation - that is to say, the increase in the percentage and ubiquity of Maloideae linked to Neolithic activities, is not observed in charcoal assemblages from the Jura. Furthermore, in Neolithic as well as Protohistoric northwestern and central Europe, as is the case in Hesbaye, the development of the Maloideae sub-family often accompanies woodland clearing and is therefore indicative of increased human impact on the landscape (Castelletti and Stäuble, 1997; Damblon and Hauzeur, 2006; Jansen et al., 2013; Pernaud, 1997; Salavert et al., in press).

Firewood gathering areas

In Hesbaye, the use of firewood is confined to *Quercus-Fraxinus* woodlands and does not extend to other biotopes throughout time, such as the riparian forest. The rapid transformation of the woodlands is evident, especially through the swift development of post-pioneer heliophilous taxa such as Rosaceae (Maloideae, Prunoideae). Therefore, the wood gathering areas must have been very close to the LBK sites located on the plateau and may have been maintained near the sites throughout the entire occupation (phases 1 and 2). In the Jura, the spatial extension of the exploited territories evolves over time. During phase 1, the presence of *Fraxinus* associated with *Quercus* and/or *Acer* reflects the exploitation of the riparian woodlands located on glacio-lacustrine terraces. Then, the floristic list indicates the extension of firewood gathering areas to sub-mountainous *Fagus-Quercus*, associations currently found on the upper Jura plateau (Fig. 6).

Therefore, in Hesbaye and the Jura, charcoal assemblages indicate two different landscapes at two periods of human occupation. These two pictures can be interpreted in terms of vegetation dynamics between settlement phases 1 and 2. In Hesbaye, the rapid development of Maloideae due to woodland canopy openings could be related, on one hand, to the maintenance of firewood gathering areas near LBK settlements and, on the other hand, to the intensification in human pressure on woodlands due to the increase in the number of houses and possibly villages from phase 1 to phase 2. Furthermore, in Hesbaye, the sustained exploitation of forest edges species could point towards particular gathering strategies of firewood resources (Burrel and Baudry 1995; Ellenberg, 1988). The importance of Maloideae could also indicate wild fruit tree management at forest edges. In this regard, *Malus sylvestris* fruits are regularly identified in LBK carpological assemblages (Salavert, 2011). If we adhere to this hypothesis, the use of pruning waste or old trees as fuel could explain the presence of Maloideae charcoal in archaeological sites. In the Jura, the extension of firewood gathering areas could be correlated with both the progressive increase in the number of houses in the village and the number of contemporaneous villages on the lakeshore. We do not observe the development of post-pioneer heliophilous species. Maloideae and *Corylus* are not well represented in charcoal assemblages despite the high quantities of *Malus* (apples) and *Corylus* (hazel nuts) present in archaeological sites. Neolithic communities may have exploited forest boundaries at different phases of ripeness or pruning by-products may not have been used as fuel. Then, the low representation of *Malus* and *Corylus* could imply that forest fringes were not managed in the same way in the Jura.

Impact of the socio-economic context on firewood management

According to our results, a link may exist between firewood acquisition areas and the location of potential economic territories, or catchment areas (access to water for cultivated fields, pastures, water, raw materials).

In Hesbaye, charcoal analyses indicate an increase in Maloideae species during phase 2 of the LBK occupation, demonstrating the rapid development of forest borders. This could be linked to a marked anthropogenic impact on vegetation on a local scale. Furthermore, the list of weeds highlighted in Hesbaye (Salavert, 2011) is consistent with the hypothesis formulated by A. Bogaard (2002, 2004, 2005), that is to say, permanent fields in the landscape maintained over a long period and managed on a household scale. This agricultural system points towards the spatial limitation of "daily itineraries" and "life paths" (Carlstein 1980), and thereby suggests restricted firewood gathering areas. Finally, the proximity of at least partly contemporaneous LBK sites on the Hesbaye plateau may limit the potentially exploited economic territories. Thus, in Hesbaye, firewood acquisition areas are restricted, and may be located near LBK sites. The exploitation of fringes could define living spaces, whether for crops, habitats or possibly for livestock pasture and fruit gathering areas. This could be a means of limiting travel distances.

In the Jura, charcoal assemblages indicate the extension of firewood areas correlated with the progressive increase in the number of contemporaneous villages on the Chalain lakeshore. At the same time, the analysis of timber house foundations indicates the use of long *Fraxinus* trunks with a small diameter and circular cross-section during phase 1 (Horgen culture) and large *Quercus* trees prepared by splitting (subtriangular cross-section) during phase 2 (Ferrières and Clairvaux cultures) (Pétrequin 1996). Thus, the timber wood supply territories change from a young secondary forest near the lakeshore during the first phase to a mature forest environment, possibly even in a primary forest, during the second one. The exploitation of twigs for litter is also characterised by an extension of the acquisition areas with the exploitation of *Ulmus*, *Fraxinus* and *Viscum* during phase 1 and the exploitation of *Abies alba* during phase 2. Other disciplines such as fauna, ceramic and lithic material studies also suggest extensive economic territories during the Late Neolithic around the Chalain lakeshore (Pétrequin 2005). Whereas timber wood studies indicate that local forests could have been subject to human impact, dendrochronology charcoal assemblages (Viellet 2007) and pollen data (Richard 1997) do not indicate a decrease in wood resources. Therefore, the persistent low percentage of fringe species could indicate an extensive exploitation of woodlands which could be correlated with the short life span of villages and the mobile economic territory of Neolithic groups between lakes Chalain and Clairvaux.

Conclusion

Some resources, such as firewood, are so basic and vital that it is essential to minimize the distance travelled to procure them. An analytic approach to the *chaine opératoire* of fire production in current farmer populations using non-mechanized agriculture and managing firewood collection at a household scale, indicates that firewood gathering depends mainly on socio-economic organization (Dufraisse, 2012). Firewood resources are contingent on the distances which have to be travelled, estimated at a radius of 5 km to 10 km, depending on the authors (Bakels, 1978; Higgs and Vita-Finzi, 1972). The collection of firewood could be conducted along the daily travelled territory, depending on the activities performed within the area. This mode of operation is widely recognized and practised by current populations (Carlstein, 1980).

The comparison of two datasets from temperate Western Europe indicates that firewood management areas could reflect socio-economic organization. In this paper, we propose that agricultural practices could be one of the main factors influencing the expansion of firewood gathering areas in agro-sylvo-pastoral populations. Indeed, this activity required an important labour force during most of the year. Our hypothesis is that there is a close spatial convergence between firewood gathering areas and potential cultivated land in Hesbaye (Salavert et al., in press) and the French Jura (Dufraisse 2006, 2008). In Hesbaye, we note an intensive farming system localized in a small area near the sites while in the Jura, extensive agriculture with permanent fields is associated with villages with short life spans. In the same way, firewood “catchment areas” seem restricted around sites, while they appear to be extensive and mobile in the Jura. Nevertheless, other economic activities may also impact firewood acquisition areas, such as water, raw material supplies and husbandry management.

The detection and interpretation of woodland clearing evidence depends on the enlargement and intensification of firewood acquisition areas. In our case study, obvious differences in species diversity, forest edge management and the expansion of firewood gathering areas between Hesbaye and the Jura are observed. Thus, firewood management can be thought of in terms of “daily itineraries” and “life paths”, and firewood acquisition areas may be linked to a more general economic context. This case study comparing the charcoal assemblages of two Neolithic site clusters in Belgium and eastern France shows the efficacy of charcoal analyses in providing solid evidence for understanding the socio-economic organization of Neolithic groups in temperate areas.

Acknowledgments

We thank the three anonymous reviewers for helpful suggestions and comments. We also thank the Direction de l’Archéologie du Service public de Wallonie, especially D. Bosquet, for providing most of the charcoal material studied by A. Salavert in her PhD Thesis. We thank the French Ministry of Education and Research for financing A. Dufraisse’s PhD thesis.

Figure 1: Location of Early Neolithic sites in central Belgium (5200-5000 BC, Hesbaye). White circles: pioneer phase (phase 1), black circles: phase 2, black and white: phases 1 and 2.

Figure 2: Plans of Remicourt-En Bia Flo II (RBF, left) and Fexhe-le-Haut-Clocher-Podrî l'Cortri (FPC, right) with the location of houses from phases 1 and 2.

Figure 3: Anthracological diagram of phases 1 and 2 of the LBK occupation of Hesbaye, n: number of charcoal fragments identified, str.: number of structures, tax.: number of taxa.

Figure 4: Location of lakeshore Neolithic sites (circles) of Lake Chalain (eastern France, Jura). Black circles: sites studied (CH: Chalain).

Figure 5: Anthracological diagram of the Late Neolithic occupation of Chalain Lake (CH) in the French Jura, n: number of charcoal fragments identified. H: Horgen, F/C: Ferrières/Clairvaux,. Ca: early Clairvaux.

Figure 6: Firewood gathering areas around the two clusters of Neolithic sites presented in this paper. Notes: in Hesbaye (left), the areas are maintained near the sites during both habitat phases (see fig. 1 for site abbreviations). In the Jura (right), there is a change in the firewood gathering areas between phase 1 and phase 2.

Table 1: Comparison of the two Neolithic areas discussed in the text: central Belgium and eastern France.

Table 2: Latin and common names of taxa mentioned in the text.

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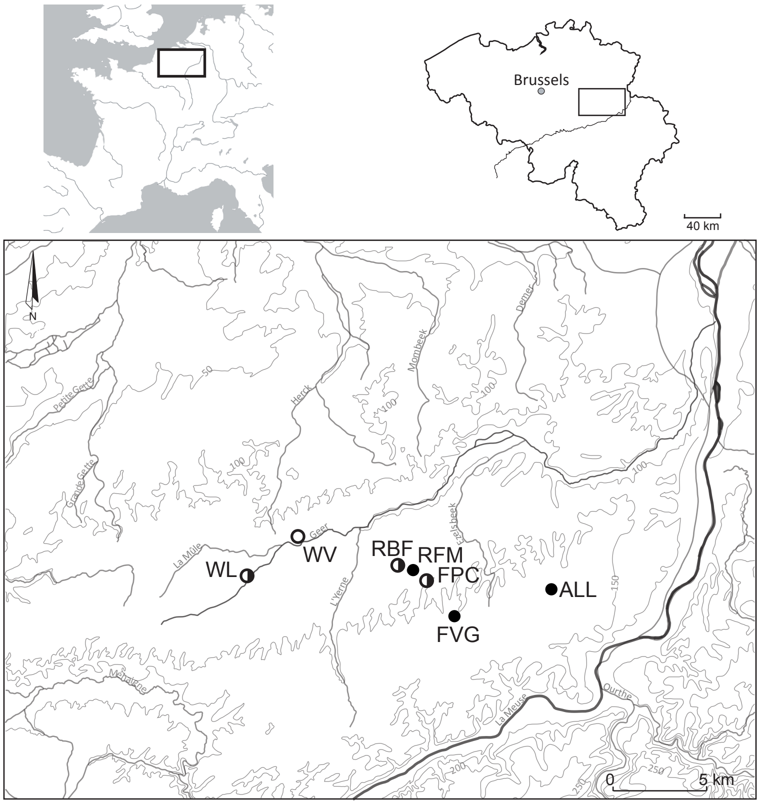
Table

		HESBAYE (central Belgium)	JURA (eastern France)
Present environment	**Altitude**	150 m	500 m
	Topography	Mildly hilly	Montainous
	Climat	Oceanic, temperate	semi-continental, temperate
	Annual average temperature	10,4°C	9°C
	Pluviometry (mm/year)	804 mm	1000 à 1500 mm
	Main vegetal association	*Quercus-Fraxinus/Quercus* groves	*Fagus/Quercus-Carpinus*
	Riparian association	*Salicion-albae/Alno-padion*	*Alno-padion/Alnion glutinosae/Aceri-fraxinetum*
Archaeology	**Dating**	5200-5000 BC	3900-2700 BC
	Cultures	Early Neolithic (Linearbankeramik)	Recent Neolithic (Horgen, Clairvaux ancien)
	Settlement dynamic	Pioneer front of colonisation	Marginal area on lake banks, pioneer front possible
	Duration of the cycle of habita	200 years, no cultural changes	300 years, cultural changes
	Village localisation	Plateau	Lake banks, plateau
	Life of the village	Less than 200 years (low chronological resolution)	10 to 25 years (high chronological resolution)
	Architecture	Large wooden houses	Large wooden houses
	Rubbish management	Floor and pits	Floor, in the water
Economy	**Agriculture**	Garden cultivation. Permanent fields. High labor input	Semi-intensive garden cultivation, mobile fields
	Crops	*Triticum dicoccum, T. monococcum, Pisum sativum, Linum usitatissimum,* (maybe *Papaver somniferum)*	*Hordeum vulgare, Triticum aestivum, T. dicoccum, Pisum sativum, Linum usitatissimum, Papaver somniferum*, *Vicia*
	Gathering	*Corylus avellana*, *Malus sylvestris*, *Prunus spinosa*, *Rubus idaeus, Sambucus racemosa*	*Rubus fruticosus, Fragaria vesca, Rosa canina, Malus sylvestris, Prunus spinosa,Corylus avellana, Crataegus, Quercus, Physalis alkekengi*
	Husbandry	Cattle, sheep/goat, pigs. Herd management unkown	Deer hunting, cattle and pig farming
Anthracology	**Sampling location**	Rubbish pits	Occupation floor
	Context	Domestic firewood	Domestic firewood
	Sites	7	3
	Occupations levels	10	7

Table

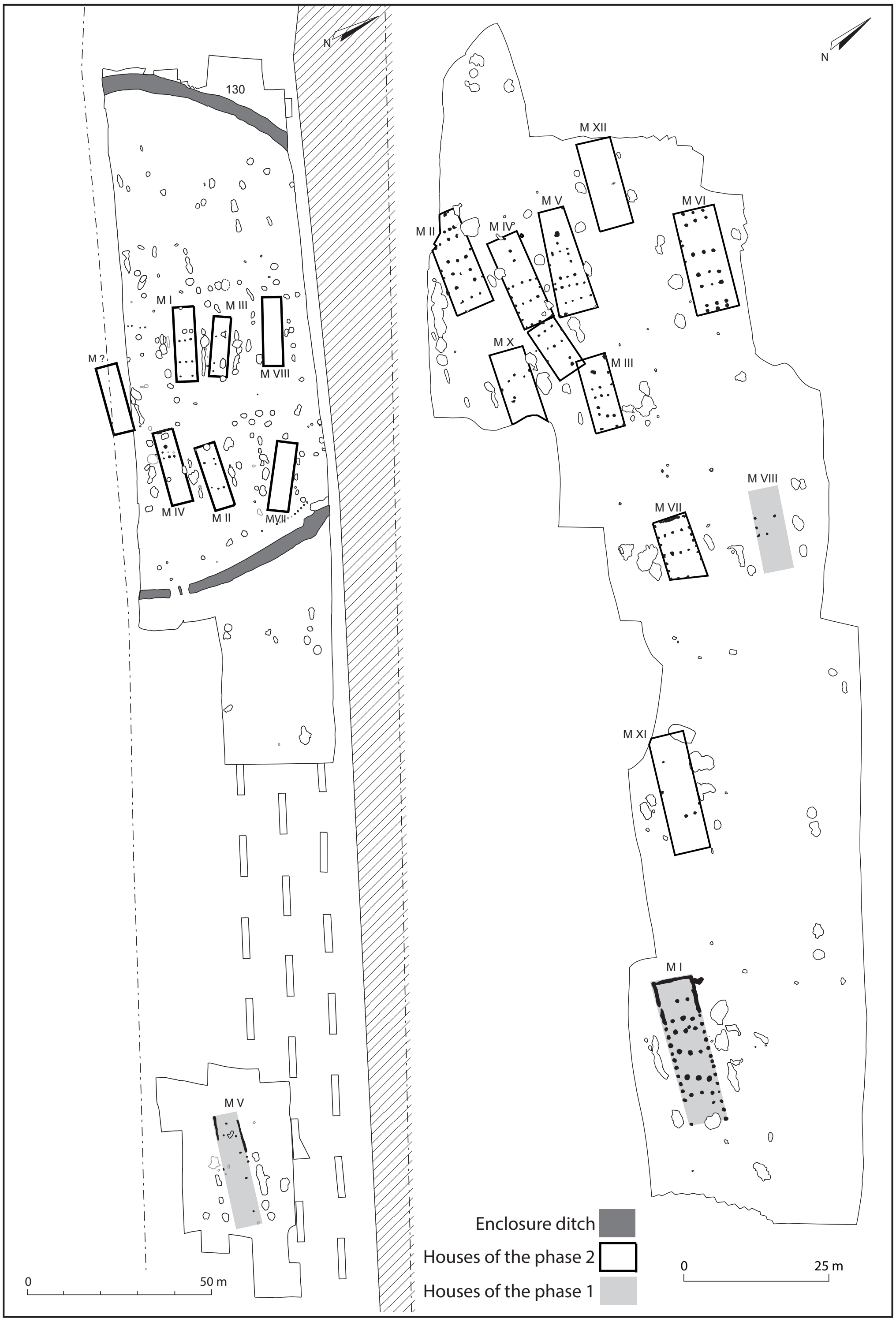
Latin name	Common name
Abies alba	Silver fir
Acer campestre	Field mapple
Acer platanoides	Norway maple
Acer pseudoplatanus	Moutain mapple
Alnus glutinosa	Black Alder
Betula	Birch
Carpinus betulus	Common hornbeam
Cornus cf. *sanguinea*	Midwinter dogwood
Corylus avellana	European hazelnut
Crataegus	Hawthorn
Fabaceae	Family of pea,beans, lentils, broom tree...
Fagus sylvatica	Common beech
Fragaria vesca	Woodland strawberry
Fraxinus excelsior	European ash
Hippophae rhamnoides	Common sea-buckthorn
Hordeum vulgare	Barley
Ilex aquifolium	Common holly
Lens culinaris	Lentil
Ligustrum vulgare	Wild privet
Linum usitatissimum	Common flax
Maloideae	Sub-family of apple, hawthorn, and rowan trees
Malus sylvestris	Crabapple
Papaver somniferum	Opium poppy
Physalis alkekengi	Bladder cherry
Picea abies	Common spruce
Pisum sativum	Common pea
Populus	Poplar
Prunoideae	Sub-family of plum and cherry trees
Prunus padus	Bird cherry
Quercus robur	Pedonculate oak
Rosa canina	Dog rose
Rosaceae	Family of Maloideae and Prunoideae
Rubus fruticosus	Backberry
Salix	Willow
Sambucus nigra	Black elder
Taxus baccata	European yew
Tilia platyphyllos	Large-leaved lime
Tilia cordata	Small-leaved lime
Triticum aestivum/durum	Free-threshing wheat
Triticum dicoccum	Einkorn
Triticum monococcum	Emmer
Ulmus cf. *montana*	Wych elm
Ulmus minor	Field elm

Figure



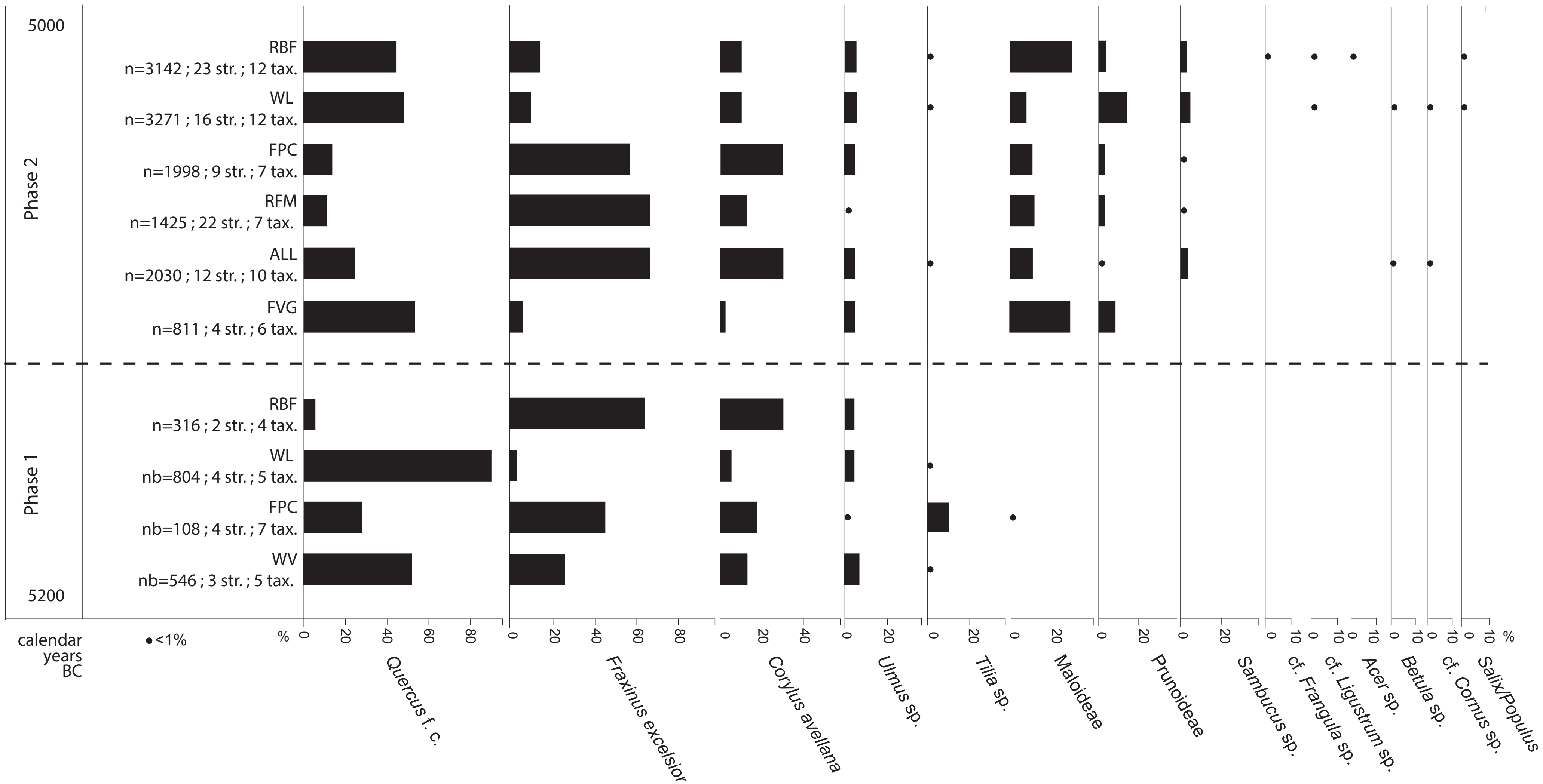
WL: Waremme-*Longchamps*; WV: Waremme-*Vinâve*; RBF: Remicourt-*En Bia Flo* II; RFM : Remicourt-*Fond de Momalle*; FPC : Fexhe-le-Haut-Clocher-*Podrî l'Cortri*; FVG : Fexhe-le-Haut-Clocher-*Voroux Goreux*; ALL : Alleur.

Figure



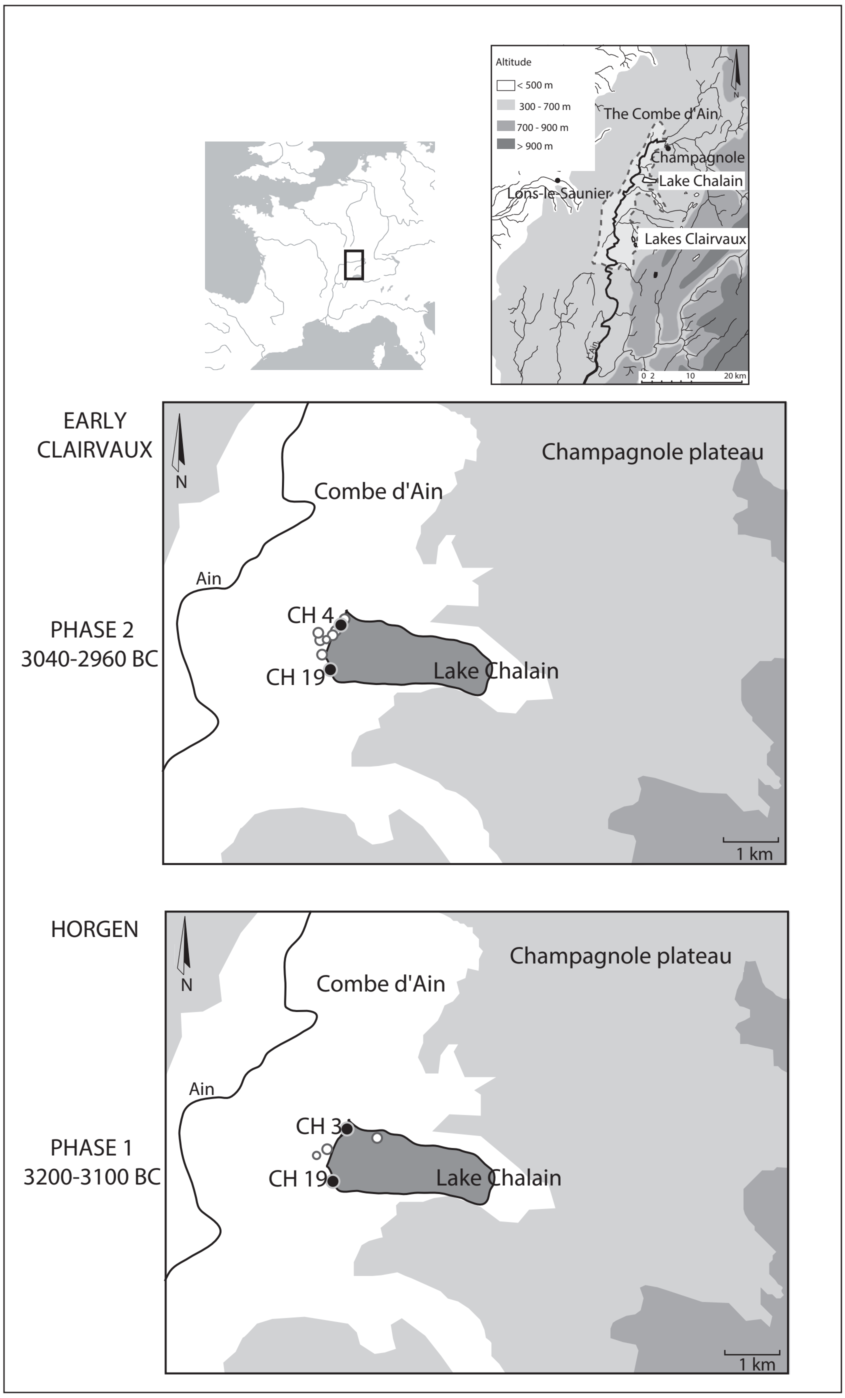
N
130
M I
M III
M VIII
M ?
M IV
M II
M VII
M V
0
50 m
N
M XII
M V
M VI
M II
M IV
M X
M III
M VIII
M VII
M XI
M I
Enclosure ditch
Houses of the phase 2
Houses of the phase 1
0
25 m

Figure



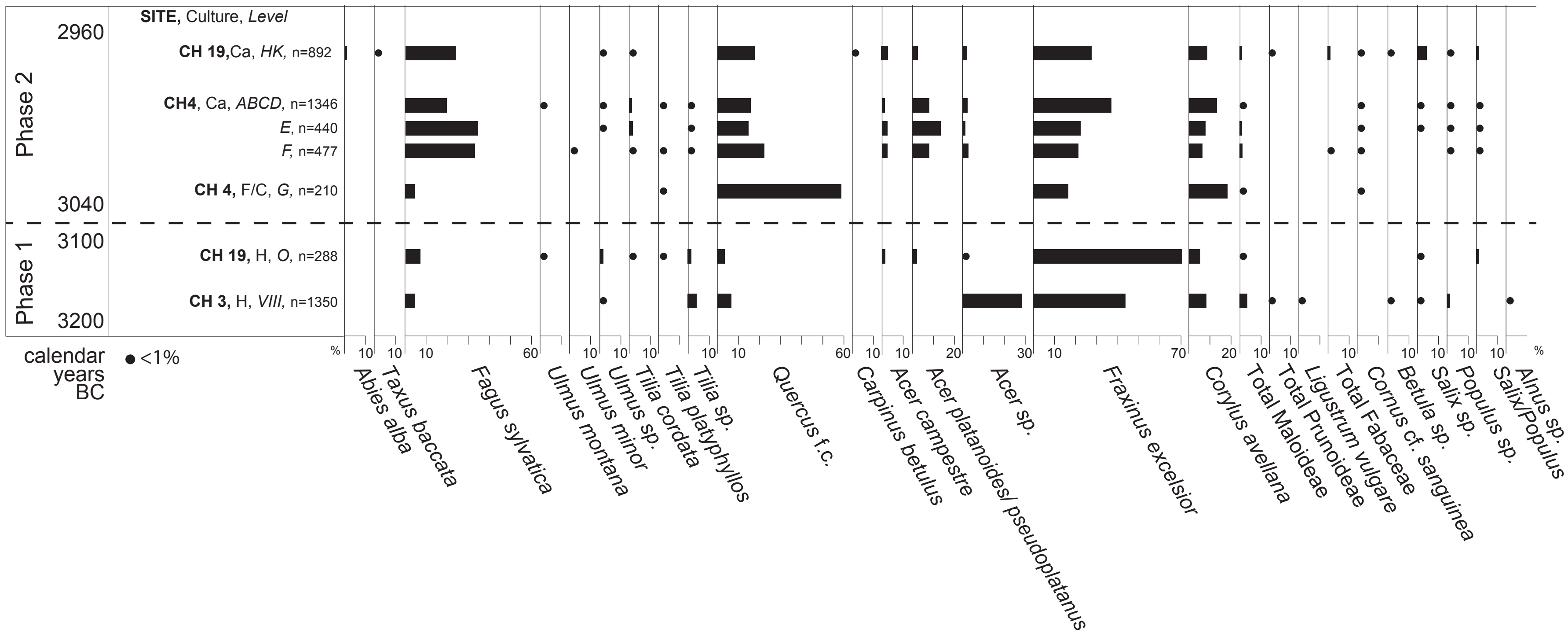
5000
5200
Phase 2
Phase 1
RBF
n=3142 ; 23 str. ; 12 tax.
WL
n=3271 ; 16 str. ; 12 tax.
FPC
n=1998 ; 9 str. ; 7 tax.
RFM
n=1425 ; 22 str. ; 7 tax.
ALL
n=2030 ; 12 str. ; 10 tax.
FVG
n=811 ; 4 str. ; 6 tax.
RBF
n=316 ; 2 str. ; 4 tax.
WL
nb=804 ; 4 str. ; 5 tax.
FPC
nb=108 ; 4 str. ; 7 tax.
WV
nb=546 ; 3 str. ; 5 tax.
calendar years BC
• <1%
%
Quercus f. c.
Fraxinus excelsior
Corylus avellana
Ulmus sp.
Tilia sp.
Maloideae
Prunoideae
Sambucus sp.
cf. Frangula sp.
cf. Ligustrum sp.
Acer sp.
Betula sp.
cf. Cornus sp.
Salix/Populus

Figure



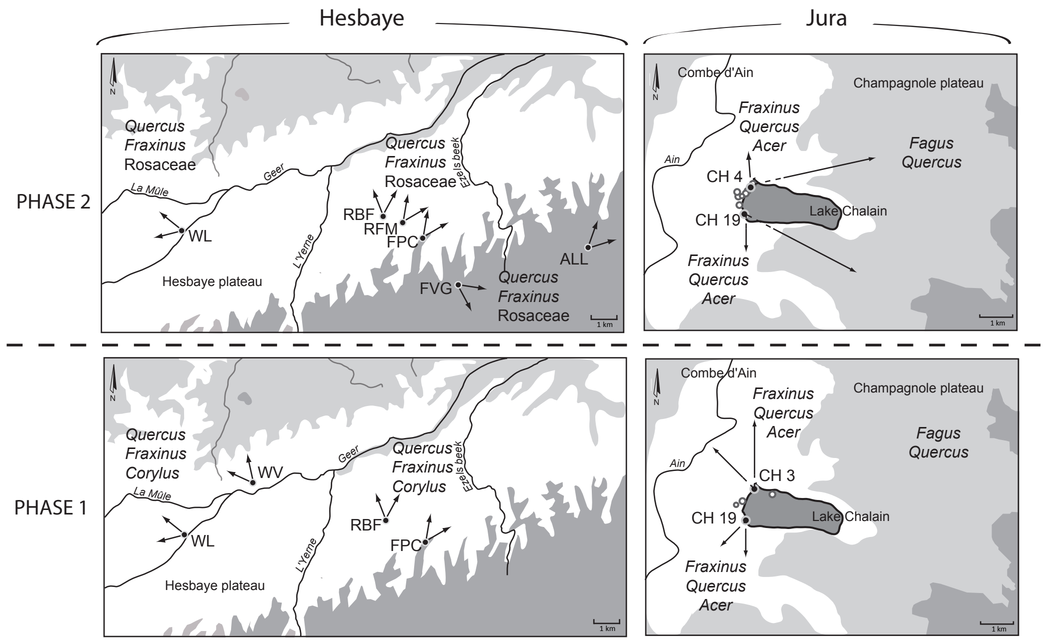
Altitude
< 500 m
300 - 700 m
700 - 900 m
> 900 m
The Combe d'Ain
Champagnole
Lake Chalain
Lons-le-Saunier
Lakes Clairvaux
20 km
EARLY
CLAIRVAUX
PHASE 2
3040-2960 BC
Champagnole plateau
Combe d'Ain
Ain
CH 4
CH 19
Lake Chalain
1 km
HORGEN
PHASE 1
3200-3100 BC
Champagnole plateau
Combe d'Ain
Ain
CH 3
CH 19
Lake Chalain
1 km

Figure



SITE, Culture, Level
Phase 2
Phase 1
2960
3040
3100
3200
CH 19,Ca, HK, n=892
CH4, Ca, ABCD, n=1346
E, n=440
F, n=477
CH 4, F/C, G, n=210
CH 19, H, O, n=288
CH 3, H, VIII, n=1350
calendar years BC
<1%
Abies alba
Taxus baccata
Fagus sylvatica
Ulmus montana
Ulmus minor
Ulmus sp.
Tilia cordata
Tilia platyphyllos
Tilia sp.
Quercus f.c.
Carpinus betulus
Acer campestre
Acer platanoides/ pseudoplatanus
Acer sp.
Fraxinus excelsior
Corylus avellana
Total Maloideae
Total Prunoideae
Ligustrum vulgare
Total Fabaceae
Cornus cf. sanguinea
Betula sp.
Salix sp.
Populus sp.
Salix/Populus
Alnus sp.

Figure



Hesbaye
Jura
PHASE 2
PHASE 1
Quercus
Fraxinus
Rosaceae
La Mûle
Geer
WL
Hesbaye plateau
L'Yerne
RBF
RFM
FPC
FVG
ALL
Ezels beek
Combe d'Ain
Champagnole plateau
Fraxinus
Quercus
Acer
Fagus
Quercus
Ain
CH 4
CH 19
CH 3
Lake Chalain
Corylus
WV
1 km