SETTLEMENT OF THE FIRST FARMERS IN THE BELGIAN LOESS BELT

The edaphic factor

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ABSTRACT

The first farmers to settle in the Belgian loess belt belong to the Linearbandkeramik Culture (LBK), formerly Danubian Culture, and the Blicquy/Villeneuve-Saint-Germain group. As elsewhere in Europe, these populations preferred settling on loess soils. We can distinguish three patterns when they reached Belgium. Firstly, they settled only at the southern and eastern fringe of the loess belt. Secondly, the village occupations lasted only about one generation (some 25 years). Thirdly, after 2 to 3 centuries the occupation ends, leaving a hiatus before the next period of settlements. Several hypotheses are proposed to explain this particular behaviour, such as a research hiatus, contact with the hunter-gatherers that lived in the area, and heredity rules. In this paper attention is paid to the impact of the edaphic factor, an essential element besides climate when it comes to crop production. From archaeopedological research on LBK sites, it appears that the soilscape in this European Atlantic biogeographical area was similar to the soils that occur today in the 50 km² tall Sonian Forest. Exceptionally, this area situated in the middle of the Belgian loess belt, has never been cleared for agricultural purposes and the soils have very low chemical and physical fertility. This status provides a plausible explanation for the particular behaviour of the first farmers reaching the Belgian loess belt. Simple shifting cultivation, as practised in the equatorial forest, was not sustainable in this temperate climate and therefore whole villages would have to move. Obviously, the workload for these Neolithic farmers was too severe and they abandoned the further colonisation of the Atlantic loess belt.

KEYWORDS

LBK farmers, loess, Belgium, soil fertility, crop production, Sonian Forest, shifting village

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1. Introduction

Some 7300 years ago (= cal BP) the first farmers arrived in Atlantic (Western) Europe through a vast migration that started around 8100 in Anatolia (Mazurié de Keroualin, 2003, 91, 153). The settlement occurred in the Atlantic period, the climatic optimum of the Holocene, i.e. the warmest and most humid period of this interglacial, with dominance of oak, lime, elm, ash, hazel and alder (Damblon, 2013).

This movement occurred in two main directions (Toussaint, 2013; Hauzeur and Jadin, 2013, 17):

- One through the Balkans and further West through Central Europe, which resulted in the development of the 'Linearbandkeramik' Culture (LBK), formerly called the 'Danubian' Culture.
- One along the Mediterranean and further north from southern France, resulting in the 'Cardium' Culture. It is still under discussion as to whether a few sites in the loess belt of Belgium, attributed to the Blicquy/Villeneuve-Saint-Germain group, belong to this movement.

In Central and Western Europe, many of these LBK settlements are located on soils with silty texture, mostly associated to loess deposits of the Last Ice Age (Weichsel) (Hauzeur and Jadin, 2013, 19). This sedimentation ended latest around the transition period from the Pleniglacial to the Late Glacial, some 15,000 years ago (Haesaerts et al., 1981; Haesaerts et al., 2016; Rousseau et al., 2018). In Belgium, all Early Neolithic sites are located on such loess soils.

Originally these sediments contained variable amounts of calcium carbonate. In Belgium and northern France about 10 %; in other regions such as along the Rhine and Danubian rivers, these amounts can go up to 25 % (Rousseau et al., 2018).

When studying the behaviour of these populations along their migration route, we can distinguish three patterns when they reach Belgium.

- Surprisingly, this vast population movement didn't colonise the whole loess belt, but settled in relatively small territories in the southern, south-eastern and eastern fringes (Fig. 1) (Meylemans et al., 2018, 9; Hauzeur and Jadin, 2013).
- The duration of the village occupation was much shorter in this region, mostly what can be considered as one generation period, or 20-25 years (Hauzeur and Jadin, 2013, 22), while in the Central European loess area, several phases of house reconstruction can be observed (Lüning, 1982, 18).
- After some two to three centuries, the local occupation stops. The villages are abandoned and no new settlements are detected between the end of the Early Neolithic and the first traces of the middle Neolithic Michelsberg Culture (Damblon, 2013, 16; Jadin, 1999; Hauzeur and Jadin, 2013, 33).

The interaction of various causes is mentioned to explain this particular conduct, for example, a hiatus in the present-day research (Meylemans et al., 2018, 8), contact with local population of hunters/gatherers (Vanmontfort, 2008), the impoverishment of an acid soil (Damblon, 2013, 12, 16), a climatic impact (even if, according to Damblon (2013, 12), the climatic conditions appear to be stable), heredity rules and disintegration of the social fabric (van de Velde and Amkreutz, 2017).

In this paper we focus on the edaphic factor, an item not so important when discussing cattle raising and meat production, but crucial when it comes to crop production.

2. The edaphic conditions in the Early Neolithic

The soil types these farmers met in the Belgian loess belt, are the result of four main soil-forming factors: soil parent material, age, erosion and climate, since pedogenesis started.

2.1. SOIL PARENT MATERIAL

In Middle Belgium, the loess sediment came mainly from the North Sea region which was largely dry, because of the 100 – 120 m lowering of the sea level (Sima et al, 2009; Rousseau et al., 2018, 5). Soils are developed here in sediments of the last period of accumulation, between about 25,000 and 15,000 uncal BP (Haesaerts et al., 2016), labelled as 'Brabantian loess formation'. According to the Belgian Quaternary lithostratigraphic units (Gullentops et al., 2001) this is a Late Weichselian (Mis 2) 'member' (GxB) of the Gembloux 'formation' (Gx) that contains all loess units of Middle Belgium deposited during the periglacial stadials of Middle and Upper Pleistocene. The particle size of this dust is dominated by silt (0.002 - 0.050 mm), some 10-15 % clay (size less than 0.002 mm) and a few per cent of very fine, and fine sand (0.050 – 0.250 mm). The 'silty region' ('région limoneuse' -fr., 'leemstreek' -nl) of Belgium (Fig. 1) is characterized by a nearly continuous cover of this sediment. The deposit was homogeneous, very finely stratified but without contrasting strata. The lime content was relatively stable, between 8 to 11 %. Besides the lime, the sediment is dominantly composed of quartz with minor amounts of feldspars, chlorite, amphiboles and glauconite. Latter mineral originates from the erosion in the landscape of the Tertiary marine sediments that occur as substratum in Middle Belgium. The clay fraction is dominantly smectite and some mica and kaolin, quartz, feldspars and interstratified minerals (Van Ranst, 1981; Van Ranst et al., 1982).

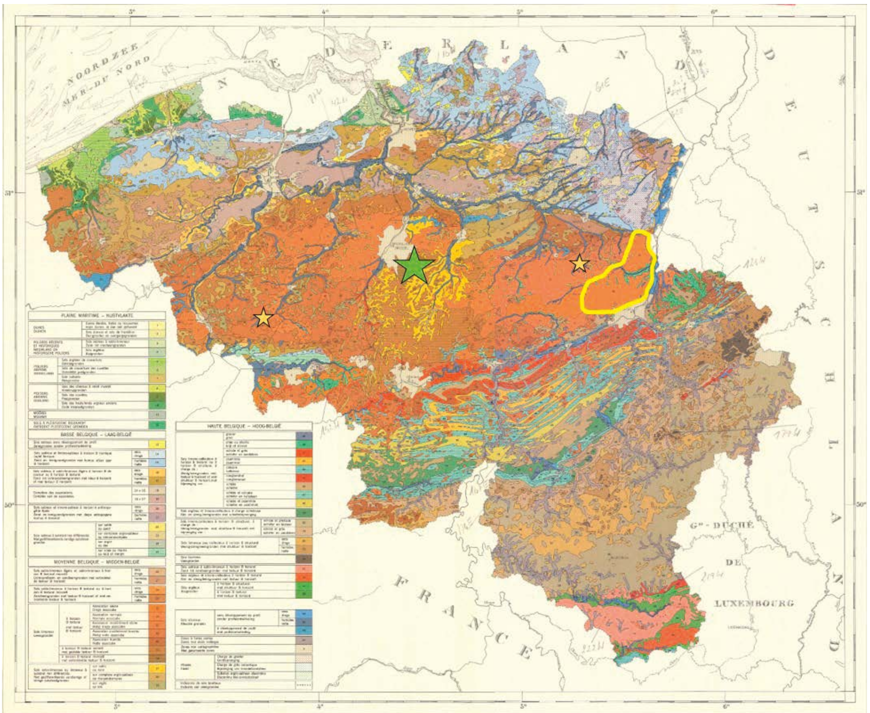

Figure 1. Soil Association Map of Belgium (Marechal and Tavernier, 1971). The brown colours correspond to silty (= loess) soils. The yellow stars and the yellow delineation indicate the Early Neolithic LBK site areas. The green star is the site of the Sonian Forest.

2.2. AGE

At the transition from the Pleniglacial to the Late Glacial, some 15,000 years ago, the climate shifted from severe periglacial to Boreal, coinciding with the end of the loess input and the development of permanent forest vegetation stabilizing definitively the soil surface in the loess belt. This can be considered as the start of the loess soil evolution (the 'age' of the soilscape). Accordingly, the first farmers cultivated soils that evolved already since some 7000 to 8000 years. This hypothesis is in opposition to the ancient view that pedogenesis started only in the beginning of the Holocene. (e.g. Louis, 1955; Tavernier and Louis, 1971; Modderman, 1988, 81; Gullentops and Corrijn, 2009, 29).

2.3. EROSION

Except for all human interventions, just one 'natural' erosion (Soil Survey Staff, 1951, 251-253) period is recorded since the start of the soil evolution in the Belgian loess belt. This process, very limited in extent, affected only some steep valley slopes and valley bottoms (Sanders, 1981; De Corte, 1982; Cruzado, 1982; Baes, 1985; Langohr and Sanders, 1985a; Sanders et al. 1986). The resulting remodelling of the relief is specific for processes active in a periglacial environment with in some areas a water flow over frozen ground during snowmelt. Such events occur today in cold Atlantic climate areas such as Atlantic Canada (Bernsdorf et al., 1995) and southern Norway (Øygarden et al., 2006, 10). In other areas of the loess belt, the erosion occurs as local landslides on segregation ice along valley slopes (Gullentops and Corrijn, 2009, 22, 29; Langohr, 2008, 74). According to the soilscape characteristics in both the eroded and non-eroded areas, this particular climatic event occurred most probably at some moment in the Younger Dryas when the soils were already well developed with the presence of a clay accumulation horizon.

2.4. CLIMATE

Throughout the 15,000 years of pedogenesis, climate changed considerably during several periods. For the soil evolution in the Belgian loess belt, three phases are important.

There is first the strong leaching boreal climate dominating in the Late Glacial Bølling and Allerød periods (12,500-11,000 uncal BP) (e.g. Langohr and Marcelino, 2012; Bos et al., 2017, 2018). During this period, lime was leached in the loess soils down to at least 1.2 m, a clay-accumulation horizon (Bt) developed between 25/45-100/120 cm depth and the surface horizons became very acid and N-poor.

In the last phase of the Late Glacial, or Younger Dryas (ca. 11,000-10,000 uncal BP), soils underwent a severe periglacial climate, with permafrost. The strong desiccation and the growth of ice blades within the permanently frozen soil created a fragipan horizon between 25/40-100/120 cm (Mackay, 1974; Van Vliet and Langohr, 1981; Langohr, 1983; Langohr and Sanders, 1985a; Payton, 1992). This development was responsible for strong physical soil deterioration, as roots can only penetrate the deeper horizons through a set of vertical streaks displaying a polygonal pattern and representing less than 10 % of the soil volume.

The last important climatic period is the Holocene with, in Atlantic Europe, a relative stability and dominance of a moist temperate Atlantic climate. For soils, the main climatic impact is the frequent excess of precipitation over evapotranspiration, inducing further acidification and the dissolution of calcium carbonate, if present.

2.5. CONCLUSION ABOUT THE SOIL DEVELOPMENT

At present, the loess belt is known for its 'fertile' soils of the Luvisol (World Reference Base for Soil resources, 2014) type (Fig. 2 and 3). However, this fertility is the result of centuries of soil amelioration through manuring, liming and fertiliser applications (Langohr, 2001). The previous paragraphs clarify the status of the Belgian loess soilscape when the LBK farmers reached the area. Instead of fertile soils, they were facing very acid and nutrient-poor soils down to at least 1 m depth. In addition, these soils had a very low physical fertility due to a compact fragipan horizon, with an upper limit at only a few decimetres from the soil surface.

3. Rationale in the search for a present-day representative of the Neolithic soilscape

Detecting a site today with a soilscape that would be identical, or at least close to the edaphic conditions Early Neolithic farmers were facing in Atlantic Europe, sounds utopic. Particularly in Europe, where human impact on nature is widespread for thousands of years, except for some areas in western Scandinavia. Evidently, priority will go to sites that are under forest. However, the majority of forests today are located on less favourable soils for crop growth, such as steep slopes, sandy soils and soils with a rock substratum close to the surface. Loess soils, and silty soils in general, are considered by farmers as being potentially advantageous, often because a good chemical fertility and certainly because the silt texture, versus sand and clay, is optimal for water supply to plants. Despite this priority to silty soils for crop production, some forests of Western Europe grow on such soils. Yet two factors may reduce the potential to find out the fertility of these soils in the Neolithic: many of these forest sites have been once under agriculture and others have previously been intensively grazed. Both management types have an impact on soils, mainly by increasing the chemical and physical fertility. The input of fertiliser, mainly manure and lime, may vanish when the site is reforested in an area with an excess of precipitation over evapotranspiration. However, some elements such as phosphorous can remain as they are not soluble in well-drained soils. Such modification, increasing the chemical soil fertility, is traceable for several thousands of years (e.g. Georges-Leroy et al., 2014). But the most important impact of former crop production or grazing is at the level of increased physical fertility. Diminishing the soil acidity and the carbon/nitrogen ratio

Figure 2. The present-day slightly undulating landscape on the LBK site of Darion, in the Eastern fringe of the Belgian loess belt. This area has been under continuous agriculture since at least the Roman period (see also Fig. 3).

Figure 3. The characteristic homogeneous soil on the old agricultural land at the site of Darion. As a consequence of centuries of manuring, and fertilising associated with intense tunnelling activity of earthworms and moles, this soil has today a high chemical and physical fertility.

by liming, manuring and by the input of excrements and urine by grazing cattle, will raise the soil faunal activity, mainly of deep burrowing earthworms like Lumbricus terrestris, and dung beetles. This soil fauna is important nutriment for moles that drill through the soil in search of food. All this soil bioturbation increases the soil porosity down to several decimetres, thus favouring the plant rooting depth. Here the Sonian Forest, south of Brussels and situated in the middle of the Belgian loess belt, has to be mentioned (Fig.1 and 4). This 50 km² tall forest has never been cleared for cultivation since loess soils started to develop some 15,000 years ago. In addition, as this Royal Forest represented an important financial input through timber and charcoal production (Tack et al., 1993, 93-94), it is not a surprise that the owners tried to regulate the right of free grazing. Several other forests in the Belgian loess belt present limitations in this research.

- The Meerdaal Forest, 1700 ha large, west of Leuven, was probably under agriculture in the Iron Age and Roman Period (Vawalleghem et al., 2004; Langohr 2008).
- The Halle Forest, 552 ha large, west of the Sonian Forest, but not a Royal Forest, has been under many different ownerships throughout the last 1000 years. The soils show characteristics for intensive grazing during some periods (https://www.hallerbos.be/en/history, Baeté, 2003).
- Part of the 210 ha Bertem Forest, west of Leuven, has a comparable soilscape to the Sonian Forest, but the limited surface does not include all geomorphic positions.

Figure 4. A characteristic view of a beech stands in the Sonian Forest. Since the initial stability of the soil surface, at the end of the loess dust deposition some 15,000 years ago, no erosion has occurred except in the small valley bottoms.

- The Terrijst Forest, 25 ha large, west of Brussels, was probably cultivated during at least the Roman Period (Langohr, 2007).
- In NW France, the large Mormal Forest (9163 ha), on loess soils, has probably never been cultivated, but was intensively grazed (Dubois, 1973; Duceppe-Lamarre, 2011). It has, in addition, a groundwater table relatively close to the soil surface.

A source of information in this search for crop productivity on the original Neolithic soilscape, are the experimental sites. However, a review study of nine of such sites in Europe (Louwagie and Langohr, 2005) has shown that none of them has a database sufficiently elaborated to check if the experimental sites are situated on a soilscape that has not already been influenced by past human activities.

From the above review, we can conclude that the Sonian Forest seems to be the most appropriate site for the research about Neolithic farming in the Belgian loess belt.

5. Potentials and limitations for crop growth on the Belgian loess soils by the LBK farmers

The LBK farmers, migrating from the Balkan through Central Europe towards the Atlantic area, settled preferentially on the loess soils (e.g. Clark, 1952, fig. 45; Lüning, 1982, Barker, 1985, 141-143; Lefranc, 2007, fig. 1, Saile and Posselt, 2007, 55, Mordant, 2008, 120-121). Whether the cultivation was of the shifting type, or more permanent, is discussed for example by Barker (1985, 141-143) and Bogaard (2002). Evidently, this choice must have been done according to the soilscape characteristics. Large areas along the Danube and Rhine valleys have a climate with little or no excess of precipitation over evapotranspiration, corresponding to an annual precipitation of about 550 to 650 mm/year or less. On the soil map of Europe (European Soil Bureau Network, 2005) Chernozems, Phaeozems and Luvisols (World Reference Base for Soil resources, 2014) are today very common soils in these regions. Yet, although some changes occurred since the start of cultivation, these soil types were also present in the Neolithic period (Lüning, 1982; von Suchodoletz et al., 2019). Within rooting depth, these soils are either calcareous or have at least a high base saturation. Also, the fragipan horizon, a physical barrier for root penetration, was not present in these soils. Hence people could grow crops year-in, year-out, with not much need of extra mineral fertilisation except the input of manure. This is evidenced by, for example, long-lasting settlements with successive reconstruction of several generations of houses (e.g Lüning, 1982, 18). From the biogeographical point of

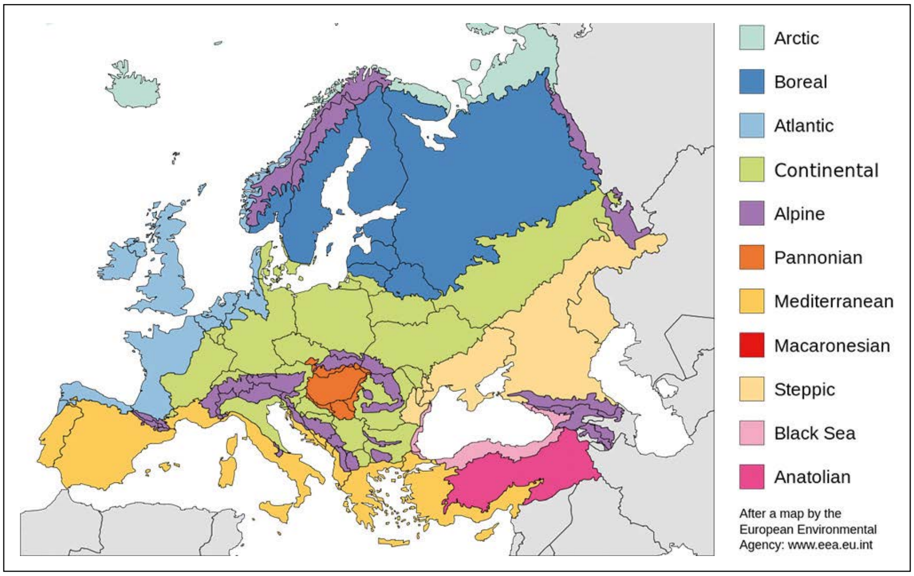

Figure 5. Biogeographical Regions of Europe (European Environmental Agency, 2017). The Atlantic region coincides with strongly acidified loess soils, an area that the LBK farmers colonised only partly (see Figure 1) and abandoned after a few centuries.

view, these areas fit in the European 'Continental region' (EEA Report 1/2017, 24-26, Fig. 5) encompassing central and eastern Europe. When progressing more westwards, the LBK farmers reached around 7250 years ago (eg. Lanting and Van der Plicht, 1999-2000) the 'Atlantic region' (EEA Report 1/2017, 24-26, Fig. 5), where soils had undergone a leaching climate since several millennia. Here the silty soils, still convenient for the construction of the characteristic large LBK houses (Fig. 6) were very acid and presented a physical barrier for root penetration (the fragipan) from a few decimetres' depth, all restraining severely the crop production (Langohr, 1990).

This hypothesis is sustained by archaeopedological investigations of Early Neolithic LBK sites in the Belgian loess belt (Pieters, 1986, 97-127; Langohr and Sanders, 1985b) showing that 7200 years ago, the soils were very similar to the present day soilscape of the Sonian Forest (Fig. 7 to 11). Moreover, this status is supported by the growth, on the harvested parcels, of acid-tolerant plants such as heather (Calluna vulgaris) (Heim, 1985, 36, Fig. 12). Under such edaphic conditions, it is impossible to grow crops permanently. After clearing and burning the forest, one crop growth is possible thanks to the supply of the wood ash and its soluble mineral plant nutrients. Unfortunately, under the climatic conditions of Central Belgium, with an important excess of precipitation over evapotranspiration, this input of soluble nutrients is rapidly lost through the leaching process. This process is even more intensive in an open field, with much less interception and transpiration of the crop versus a tree stand. Consequently, one can expect that most of the soluble ash elements that were not taken up by the crop and associated weeds, leached out within one to two years. Subsequently, in order to supply the village with sufficient food, it will be necessary to clear a new forest parcel within at least two to three years. This slash-and-burn type of shifting cultivation, as practised in tropical areas with nutrient-poor soils, represents a very important labour effort for the LBK farmers. In addition, under the hypothesis that within 10 to 20 successive forest clearings, the whole area in the neighbourhood of the village would have gone through this process, the new clearing and burning of the forest growing on the first parcel will not be enough to guarantee a correct crop production. Indeed, versus the tropical areas, plants grow in this country only during 6 months, temperatures are lower and the total precipitation is less. Consequently, one can expect a forest stand of only 15 to 20 m tallness, not enough for a sufficient supply of ash. This is in contrast with the tropics where after 20 years of fallow, one can expect a 30-40 m tall forest, allowing a sustainable shifting cultivation around the village (Fig. 13).

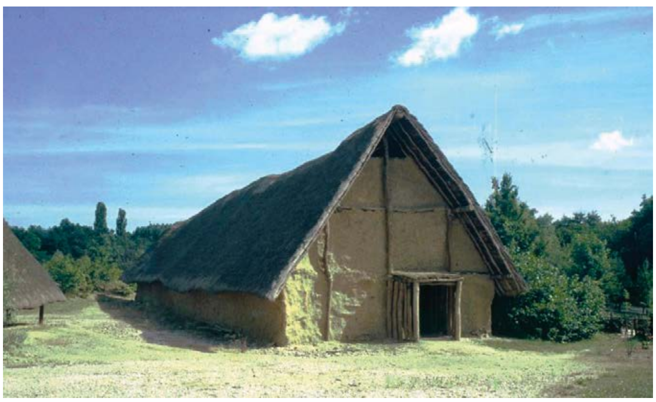

Figure 6. A reconstructed typical LBK house. The walls are made of adobe. Silty (loess) soils associated with straw provide excellent material for such construction.

Figure 7. A characteristic loess soil of the Sonian Forest. The very thin humiferous surface horizon (a few cm) is characteristic for soils with very limited bioturbation by burrowing animals. Down to 35 cm is a biologically active horizon with many roots. This part of the soil is very acid and nitrogen-poor. From 35 to 110 cm depth, is a clay accumulation horizon with vertical light-coloured streaks that form a polygonal pattern in horizontal section. All roots are situated in these streaks that represent less than 10 per cent of the soil volume at this level. This pattern is typical for a fragipan horizon, a soil characteristic that develops under permafrost conditions. This part of the soil is acid.

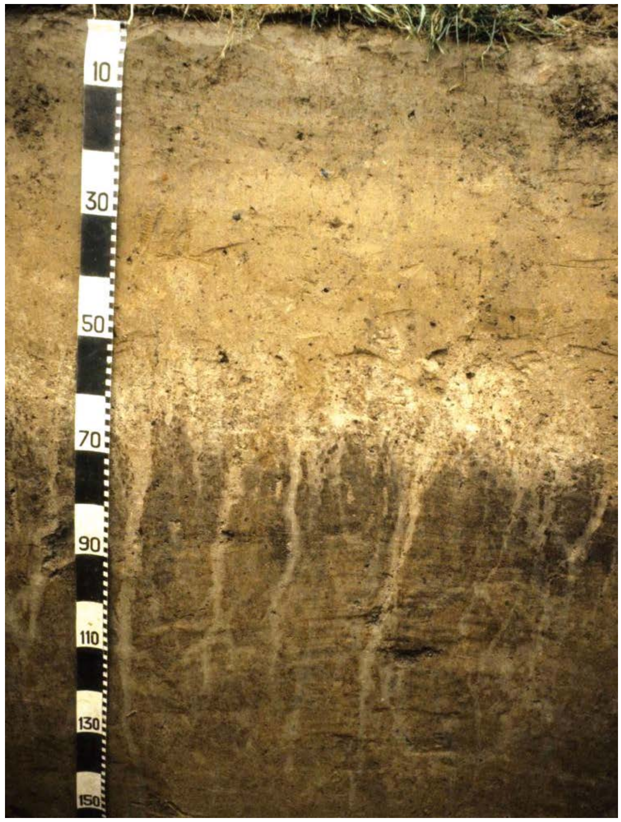

Figure 8. Darion LBK site. Buried soil profile under 30/40 cm colluvium just below the archaeological site. This buried soil is morphologically very similar to the soil profile of the Sonian Forest (Fig. 7).

Figure 9. Darion site. The LBK settlement was surrounded by a ditch, at least 2.5 m deep. The palynological study of the sediments at the bottom of this ditch indicate the presence of heather (Calluna vulgaris) on the surrounding cropland in the early phase of fallow.

Figure 10. Darion site a and b. In the lower part of the ditch fill occur fragments from the upper horizons of the original soil. These fragments are identical to the horizons at 60 to 90 cm deep of the buried soil at Darion shown in Figure 8, and 35 to 60 cm of the soil profile from the Sonian Forest (Fig. 7). Similar observations were made by Bosquet et al. (2004) at the site of Remicourt-en Bia Flo II.

Figure 11. Example of heather (Calluna vulgaris) growing today on the very acid soils of the Sonian Forest.

Figure 12. Shifting cultivation in the tropical forest of the Amazon (Yurimaguas area, Peru). After some 20 years of fallow, the forest regrowth is reaching a height of about 40 m as seen on the background parcel. The slash and burning of such parcel allows a sustainable crop growth. Similar conditions didn't exist in Atlantic loess belt 7000 years ago, as forest regrowth after 20 years would reach a height of only 15 to 20 m. This is not sufficient for a new slash and burn cycle. In the Neolithic, the shifting of the village to a new neighbouring virgin forest area would allow it to survive, but at the expense of a very intense effort.

6. Conclusions

The problem of crop production on chemically and physically poor loess soils in the European Atlantic belt, is a plausible explanation for a set of particular behaviours of the LBK farmers:

- Why these Early Neolithic farmers frequently moved their villages, which probably lasted less than 20-25 years.
- Why this initial colonisation, after migrating through Europe from East and South, did not move further into the loess belt and remained limited to its southern and eastern fringes.
- Why these farmers abandoned to settle in the Dutch and Belgian loess belt area after about two to three centuries, leaving a hiatus before the next period of settlements - the Michelsberg Culture period in the second half of the fifth millennium (Meylemans et al., 2018).

From this data we conclude that in this area, farmers were most likely not applying just a 'shifting cultivation', but rather a 'shifting village' rotation, better adapted to a harsher edaphic stress as compared to growing crops in the so said 'poor' tropics. It is not excluded that the clusters of settlements (e.g. Bakels, 1982) correspond to the shifting of one village in a limited area.

Thanks to the minimum human impact on its soilscape and the very limited faunal perturbation, the Sonian Forest represents a unique site (Langohr, 2009a, b) to discover the land and soilscape the first farmers, after crossing Europe from East and South, were facing some 7300 years ago in the Atlantic belt of Europe. The loess soils of this permanently forested site are very similar, morphologically, chemically and physically, to the at present detectable, remnants of the soils on which the LBK farmers established.

In the future, the Sonian Forest offers a unique opportunity to set up experimental sites in order to test the constraints of growing crops on soils identical to those the LBK farmers were facing 7300 years ago.

Both soilscape and geomorphological configuration of the 50 km² large Sonian Forest display exceptionally well-preserved characteristics that predate the Holocene. Hence this site represents a unique heritage for earth sciences and deserves to be considered as a UNESCO Global Geopark Site (www.unesco.org/geoparks/) or, on a larger scale, a UNESCO World Heritage Site (https://whc.unesco.org/).

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References

Baes, R., 1985. Pedological study of toposequences through the dry valley along the Schone Eikweg in the Zonien Forest (loess belt of middle Belgium). Unpublished MSc-dissertation. Ghent University. 104 pp.

Baeté, H., 2003. Excursie boomsoortenproeven in Zoniënwoud en Hallerbos, 24 september 2003. Unpublished report. 5 pp.

Bakels, C.C., 1982. The settlement system of the Dutch Linearbandkeramik. *Analecta Praehistorica Leidensia,* XV, 31-43.

Barker, G., 1985. *Prehistoric farming in Europe*. Cambridge University Press, Cambridge.

Bernsdorf, B., Richter, G. and Schmidt, R.G., 1995. Die Kartierung der Schneeschmelz-Erosion – Probleme un Möglichkreiten der Felderhebnung. *Forschungsstelle Bodenerosion – Universität Trier*, Heft 14, 80 pp.

Bogaard, A., 2002. Questioning the relevance of shifting cultivation to Neolithic farming in the loess belt of Europe: evidence from the Hambach Forest experiment. *Vegetation History and Archaeobotany*, 11: 155, 168.

Bos, J.A.A., De Smedt, Ph., Demiddele, H., Hoek, W.Z., Langohr, R., Marcelino, V., Van Asch,N., Van Damme, D., Van der Meeren, T., Verniers, J., Boeckx, P., Boudin, M., Court-Picon, M., Finke, P., Gelorini, V., Gobert, S., Heiri, O., Martens, K., Mostaert, F., Serbruyns, L., Van Strydonck, M. and Crombé, P., 2017. Multiple oscillations during the Lateglacial as recorded in a multi-proxy, high-resolution record of the Moervaart palaeolake (NW Belgium). *Quaternary Science Review*, 162, 26–41.

Bos, J.A.A., De Smedt, P., Demiddele, H., Hoek, W.Z., Langohr, R., Marcelino, V., Van Asch, N., Van Damme, D., Van der Meeren, T., Verniers, J. and Crombé, P., 2018. Weichselian Lateglacial environmental and vegetation development in the Moervaart palaeolake area (NW Belgium); implications for former human occupation patterns. *Review of Palaeobotany and Palynology*, 248, 1-14.

Bosquet, D., Fock, H., Goffioul, C., Marchal, J.P. and Preud'homme, D., 2004. La néolithisation en Hesbaye (Belgique): apports des fouilles récentes (1996-1999) sur le tracé oriental du TGV et le site de Ans, à Alleur. *BAR International Series,* 1303, Oxford, 81-94, Oxford.

Clark, J.G.D., 1952. *Prehistoric Europe – the Economic Basis*. Methuen, London.

Cruzado, G.V., 1982. The relation between the geomorphology, the loess-cover thickness and soils in the Zonien Forest, Province of Brabant-Belgium. Unpublished MSc-dissertation. VUB-Ghent University. 60 pp.

Damblon, F., 2013. L'environnement végétal de l'homme néolithique en Belgique. In: *L'archéologie en Wallonne. Le Néolithique*, 7-16. Carnets du Patrimoine, Institut du Patrimoine Wallon, Namur.

De Corte M., 1982. Study of the influence of slope orientation (E-W) and slope gradient on soils developed in Weichsel loess (Forest of Zoniën, Central Belgium). Unpublished Master thesis. Ghent University. 121 p.

Dubois, J.J., 1973. Influences humaines sur l'évolution des paysages et des limites de la forêt de Mormal. *Hommes et Terres du Nord*, 2, 73-106.

Duceppe-Lamarre, F., 2011. *Chasse et pâturage dans les forêts du Nord de la France. Pour une archéologie du paysage sylvestre* (*XIe-XVIe siècles*). L'Harmattan, Paris.

European Environment Agency, 2017. *Climate change, impacts and vulnerability in Europe 2016. An indicator-based report*. European Environment Agency Report No 1/2017, 419 pp. url: https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016/do.-accessed on 22.06.2019.

European Soil Bureau Network, 2005. *Soil Atlas of Europe*. Office of the Official Publications of the European Communities, Luxembourg.

Georges-Leroy, M., Bock, J., Dambrine, E., Dupouey, J.L. and Laffite, J.D., 2014. Parcellaires et habitat antiques des forêts du plateau de Haye en Lorraine : bilan et perspectives. Les parcellaires conservés sous forêt. Paris, France, 27 pp. url: https://hal.archives-ouvertes.fr/hal-01067845 -accessed on 22.06.2019.

Gullentops, F., Bogemans, F., De Moor, G., Paulissen, E. and Pissart, A., 2001. Quaternary lithostratigraphic Units (Belgium). *Geologica Belgica*, 2001 4/1-2, 153-164.

Gullentops, F. and Corrijn, M., 2009. Steen, zand, water, sneeuw, ijs en stof. In: *Miradal, Erfgoed In Heverleebos En Meerdaalwoud*, (Eds. H. Baeté, M. De Bie, H. Martin, P. Van Den Bremt), 13-30. Davidsfonds Leuven.

Haesaerts, P., Juvigné, E., Kuyl, O., Mucher, H. and Roebroeks, W., 1981. Compte rendu de l'excursion du 13 juin 1981, en Hesbaye et au Limbourg néerlandais, consacrée à la chronostratigraphie des lœss du Pléistocène Supérieur. *Annales de la Société Géologique de Belgique*, 104, 223-240.

Haesaerts P., Damblon F., Gerasimenko N., Spagna S, Pirson S., 2016. The Late Pleistocene loess-palaeosol sequence of Middle Belgium. *Quaternary International*, 411, A, 25-43.

Hauzeur, A., Jadin, I., 2013. Le Néolithique ancien de nos régions. In: *L'archéologie en Wallonnie. Le Néolithique*, 17-33. Carnets du Patrimoine, Institut du Patrimoine Wallon, Namur.

Heim J., 1985. Recherches sur l'environnement paléobotanique du village rubané de Darion par l'étude des pollens et des restes de diaspores (graines). *Bulletin de la Société Royale belge d'Anthropologie et de Préhistoire*, 96, 31-48.

Jadin, I., 1999. Trois petits tours et puis s'en vont… La fin de la présence danubienne en Moyenne Belgique. Unpublished PhD-dissertation. Université de Liège.

Langohr, R. 1983. The extension of permafrost in Western Europe in the period between 18,000 and 10,000 years B.P. (Tardiglacial): information from soil studies. In: *Permafrost, Fourth International Conference Proceedings*, National Academy Press, Washington D.C., 68388.

Langohr, R., 1990. The dominant soil types of the Belgian loess belt in the early Neolithic. In: Rubané et Cardial (Eds. D. Cahen, M. Otte), 117-124.

Langohr, R., 2001. L'anthropisation du paysage pédologique agricole de la Belgique depuis le Néolithique ancien – Apports de l'archéopédologie. *Étude et Gestion des sols*, 8-2, 103-118.

Langohr, R., 2007. Bos Ter Rijst. Rapport Bodemprospectie. Unpublished report. Instituut voor Natuur- en Bosbeheer, Vlaamse Overheid, Geraardsbergen. 59 pp.

Langohr, R., 2008. Bosreservaat Pruikenmakers (Meerdaalwoud). Rapport Bodemprospectie. Unpublished report, Instituut voor Natuur- en Bosbeheer, Vlaamse Overheid, Geraardsbergen. 104 pp.

Langohr R., 2009a. La forêt de Soignes, site unique pour les sciences de la terre et l'archéologie. In: *La forêt de Soignes, Connaissances nouvelles pour un patrimoine d'avenir*, 181-195, Mardaga, Wavre.

Langohr, R., 2009b. *The Zonian Forest. A unique site for Earth Science and Archaeology. Understanding soilscape evolution in the Belgian loess belt; the edaphic factor in the Sonian Forest ecosystem – a review of 30 years research*. Excursion German Soil Science Society – Soils Science Society of Belgium, 12 September 2009. 38 pp. Lab of Soil Science, Ghent University, Association for the Diffusion of Sciences, Brussels.

Langohr, R. and Marcelino, V., 2012. Origin of the calcium carbonate of the bog marl deposit of the Moervaart Depression in the cover sand area of NW Belgium. Micromorphological evidences of decarbonation and clay migration under a permanent groundwater table in sand ridges. Poster presentation, 14th International Meeting on Soil Micromorphology, 8-14 July 2012, Lleida, Spain.

Langohr, R. and Sanders, J., 1985a. The Belgian Loess belt in the Last 20.000 Years: Evolution of Soils in the Zonien Forest. In: *Soils and Quaternary Landscape Evolution.* (Ed. Boardman), 359-371. John Wiley & Sons.

Langohr, R. and Sanders, J., 1985b. Etude pédologique du site de Darion: données préliminaires. *Bulletin de la Société. Royale belge d'Anthropologie et de Préhistoire*, 96, 17-30.

Lanting, J.N. and van der Plicht, J., 1999-2000. De 14C chronologie van de Nederlandse pre- en protohistorie, III: Neolithicum, *Palaeohistoria* 41/42, 1-110.

Lefranc, P., 2007. L'habitat rubané de Bischoffsheim «Afua» (Bas-Rhin). Premiers résultats. *Archaeologia Mosellana*, 7, 99-111.

Louis A., 1955. Waarnemingen betreffende de degradatie der bosprofielen in het Zoniënwoud. *Natuurwetenschappelijk Tijdschrift*, 37, 113-118.

Louwagie, G and Langohr, R., 2005. Relevance of Archaeological Experiments in Crop Productivity for Evaluating Past Land-Use Systems (Die Bedeutung archäologischer Gewächsproduktivitätsexperimente für die Bewertung vergangener Bodennutungssysteme). *Materialhefte zur Archäologie in Baden-Württemberg*, Band 73 („Zu den Wurzeln europäischer Kulturlandschaft -Experimentelle Forschungen", Wissenchaftliche Tagung Schöntal 2002 - Tagungsband), 57-66.

Louis A., 1955. Waarnemingen betreffende de degradatie der bosprofielen in het Zoniënwoud. *Natuurwetenschappelijk Tijdschrift*, 37, 113-118.

Lüning, J. 1982. Research into the Bandkeramik settlement of the Aldenhoverner Platte in the Rhineland. *Analecta Praehistorica Leidensia* XV, 1-29.

Mackay, R.J., 1974. Reticulate ice veins in permafrost, Northern Canada. *Canadian Geotechnical Journa*l, 2, 230-237.

Marechal, R. and Tavernier, R., 1971. Associations des sols – Pédologie; Pedologie, Bodemassociaties. *Atlas de Belgique*, Planche 11B, Institut Géographique Militaire.

Mazurié de Keroualin, K., 2003. *Genèse et diffusion de l'agriculture en Europe*. Errance, Paris.

Meylemans, E., Cordemans, K., Vanmontfort, B. and Van Gils, M., 2018. *Erosiegevoelige sites: Nederzettingen van de Bandkeramiek in Vlaanderen: inventaris en problematiek van beheer*. Onderzoeksrapport agentschap Onroerend Erfgoed nr. 102, Vlaamse Overheid. 59 pp.

Modderman, P.J.R., 1988. *The Linear Pottery Culture : Diversity in Uniformity*. Berichten van de Rijksdienst voor Oudheidkundig Bodemonderzoek. 140 pp.

Mordant, M., 2008. En France du Nord. In: *Archéologie de la France. Le Néolithique*, 120-142. Picard, Paris.

Øygarden, L., Lundekvam, H., Arnoldussen, A.H. and Børresen, T. 2006. Norway. *In : Soil erosion in Europe* (Eds. J. Boardman, J. Poesen). Wiley.

Payton, R. W. 1992. Fragipan formation in argillic Brown earths (Fragiudalfs) of the Milfield Plain, North-East England; I, Evidence for a periglacial stage of development. *European Journal of Soil Science* 43(4), 621-644.

Pieters, M., 1986. Ontwikkeling en toepassing van bodemprospectietechnieken voor archeologische sites van de Belgische zand- en leemstreek. Unpublished MSc-dissertation, Laboratory of General Pedology, Ghent University, 139 pp.

Rousseau, D.D., Derbyshire, E., Antoine, P and Hatté, C., 2018. *European loess records*. Reference Module in Earth Systems and Environmental Sciences, Elsevier., 17 pp.

Saile, G.A. and Posselt, M., 2007. Un maître d'œuvre qualifié pour le néolithique ancien de Basse-Saxe ? prospections magnétiques sur les places centrales du rubané. *Archaeologia Mosellana*, 7, 55-64

Sanders, J., 1981. Het gebruik van geomorfologie in de bodemkartering – toepassing aan de hand van veldprospectie en luchtfotointerpretatie in het Zoniënbos (België). Unpublished MSc-dissertation. Ghent University. 188 pp.

Sanders, J., Baes, R. and Langohr, R., 1986. Micromorphology of dry flat-bottomed valley soil in the Zonien Forest, loess belt of Middle Belgium. *Pedologie* 36(3), 277-602.

Sima, A, Rousseau, D.D., Kageyama, M, Ramstein, G., Schulz, M., Balkanski, Y., Antoine, P., Dulac, F. and Hatté, C. 2009. Imprint of North-Atlantic abrupt climate changes on western European loess deposits as viewed in a dust emission model, *Quaternary Science Reviews*, Volume 28, Issue 25. 2851-2866.

Soil Survey Staff, 1951. *Soil Survey Manual*, U.S. Department of Agriculture, Handbook 18. U.S. Government Printing Office, Washington, D.C.

Tack, G., Van Den Bremt, P. and Hermy, M., 1993. *Bossen van Vlaanderen. Een historische ecologie*. Davidsfonds, Leuven.

Tavernier, R. and Louis, A., 1971. La dégradation des sols limoneux sous monoculture de hêtres de la forêt de Soignes (Belgique). *An. Int. St. Cerc. Pedol.*, 38, 165-191, Bucarest.

Toussaint, M., 2013. Introduction. In: *L'archéologie en Wallonne. Le Néolithique, 3-6*. Carnets du Patrimoine, Institut du Patrimoine Wallon, Namur.

van de Velde, P. and Amkreutz, L., 2017. A world ends: the demise of the northwestern Bankeramik. *Analecta Praehistorica Leidensia* 47, 35 pp.

Vanmontfort, B., 2008. Forager-farmer connections in an 'unoccupied' land: First contact on the western edge of LBK territory. *Journal of Anthropological Archaeology* 27, 149-160.

Van Ranst, E., 1981. Vorming en eigenschappen van lemige bosgronden in Midden- en Hoog België. Unpublished Ph.D. thesis. Ghent University. 561 pp.

Van Ranst, E., De Coninck, F., Tavernier and R. Langohr, R., 1982. Mineralogy in silty to loamy soils in Central and High Belgium in respect to autochtonous and allochtonous materials. *Bulletin de la Société belge de Géologie*, 91-I, 27-44.

Van Vliet, B. and Langohr, R., 1981. Correlation between fragipan and permafrost – with special reference to Weichsel silty deposits in Belgium and northern France. *Catena*, 8, 137-154.

Vanwalleghem T., Verheyen, K., Hermy, M., Poesen, J. and Deckers, J. 2004. Legacies of Roman land-use in the present-day vegetation in Meerdaal Forest (Belgium) *Belgian Journal of Botany*, 137 (2), 181-187.

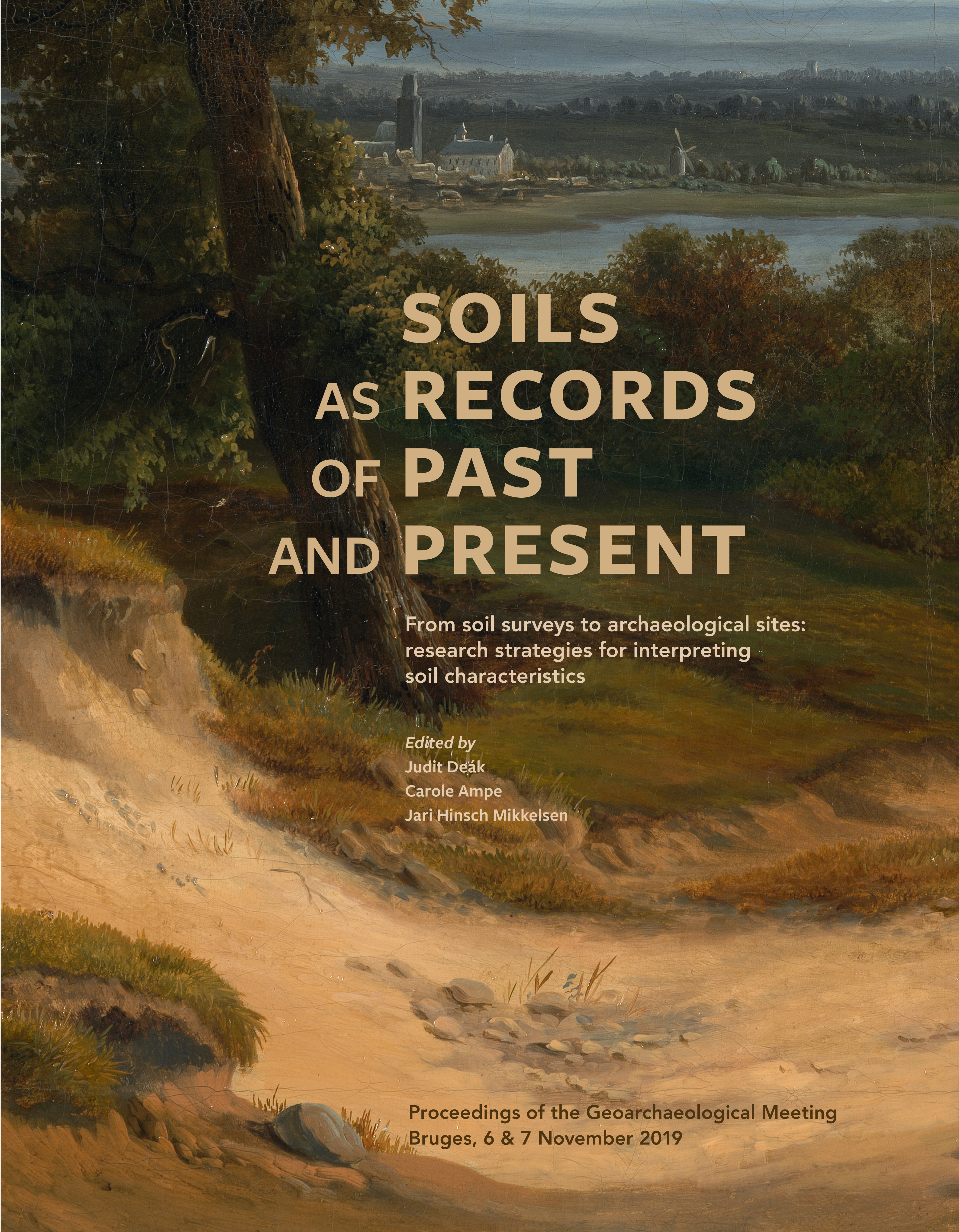
von Suchodoletz, H., Tinapp, C., Lauer, T., Glaser, B., Stäuble, H., Kühn, P. and Zielhofer, C., 2019. Distribution of Chernozems and Phaeozems in Central Germany during the Neolithic period. *Quaternary International*, 511, 166-184.

World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. *World Soil Resources Reports* 106, FAO, Rome.

https://www.hallerbos.be/en/history – accessed on 22.06.2019.

https://www.unesco.org/geoparks/ – accessed on 22.06.2019.

https://whc.unesco.org/ – accessed on 22.06.2019.



SOILS AS RECORDS OF PAST AND PRESENT

From soil surveys to archaeological sites: research strategies for interpreting soil characteristics

Edited by
Judit Deák
Carole Ampe
Jari Hinsch Mikkelsen

Proceedings of the Geoarchaeological Meeting
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