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Historical ecology of lowland forests: Does pedoanthracology support historical and archaeological data?

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ABSTRACT

Historical ecology is a cross-disciplinary approach which uses various sources to reconstruct past ecosystems and landscapes, and their interactions with human activities. Here we assess the potential contribution of soil charcoal analysis to the understanding of the dynamics of forest-human relationships in a temperate deciduous forest of North France since the Roman times. We conducted a soil charcoal analysis in three contrasted forest stands and soil types (podzol, cambisol and luvisol) using two sampling techniques (pit and auger), and subsequently compared the results to archaeological and historical data, including LiDAR imagery. We show that (i) combining two sampling techniques can more readily reflect the local charcoal assemblages than the traditional pit sampling alone; (ii) the vertical distribution of charcoals cannot be taken as a surrogate for temporal vegetation changes, as a probable consequence of biological mixing among soil horizons; (iii) once dated, soil charcoal assemblages provide support to an early medieval forest colonisation of formerly cultivated sites, the subsequent maintenance of open-canopy forests until the 18th century, and a recent canopy closure. We conclude that pedoanthracology solely cannot solve the question of forest vegetation changes over time, but can provide support to hypotheses made from other approaches such as field archaeological surveys.

1. Introduction

Today's biodiversity is a legacy of the interactions between natural processes and human activities (Swetnam et al., 1999). At local to landscape scales, past human land-uses are increasingly recognized as important drivers of modern vegetation patterns and ecosystem functioning (Fraterrigo et al., 2006; Dambrine et al., 2007; Plue et al., 2008). In this context, there is a growing interest in the recently emerged sub-discipline of historical ecology, which aims at tracing the relationship between humans and the ecosystems and landscapes they live in, charted over the long term (Swetnam et al., 1999; Egan and Howell, 2001; Szabò, 2015). Historical ecology relies on various sources, among which historical documents, archaeological data, present biodiversity surveys (Egan and Howell, 2001), and also paleo-ecological data (Elias, 2007). For the recent history, aerial or terrestrial photographs (Miller, 1999; Boucher et al., 2009), satellites pictures (Song et al., 2015) and oral interviews (Gimmi and Bürgi, 2007) are privileged resorts. Written accounts such as management plans, tax registers, land survey records and various thematic maps contain valuable information about vegetation, the amount of livestock and population, and thus land use (Dahlström, 2008; Yang et al., 2014). Since historical sources are chronologically and regionally unevenly preserved, the reconstruction of landscapes and vegetation over several centuries needs to combine different sources (Petit and Lambin, 2002; Nielsen and Odgaard, 2004). Precious information about past land uses can be provided by archaeological contexts, which benefit from aerial photographs (Agache, 1979) and, more recently, airborne LiDAR data for archaeological prospection in forests (Kraus and Pfeifer, 1998; Georges-Leroy et al., 2011).

Biological archives contained in soils or sediments have been widely used to reconstruct past land use over various time scales. Pollen analyses are probably the most widely used proxy for reconstructing past plant communities and their relationships with human activities (Edwards and MacDonald, 1991; Brun, 2011), but

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other proxies are increasingly used, such as ancient DNA (Schlumbaum et al., 2008), molecular biomarkers (Lavrieux et al., 2012), plant macroremains (Warnick et al., 2014) and charcoal assemblages (Thinon, 1978, 1992; Knapp et al., 2015; Robin et al., 2015).

Soil charcoal analysis addresses ecosystems that have supported, at least temporary, woody plants (Nelle et al., 2013). It allows reconstructing past fire events (Fesenmyer and Christensen, 2010; Robin et al., 2013a) and the identification of the associated burnt woody material (Talon, 2010). Following a fire, charcoals are fragmented with time, buried and preserved over millennia, hence are a ubiquitous proxy in past environment studies (Ritchie, 1995; Robin et al., 2013b). However, the representativeness of charcoal assemblages and their potential for past ecosystem reconstruction are biased by several filters. Firstly, forest fire experiments showed that the post-fire spatial distribution of soil charcoals was highly variable (Ohlson and Tryterud, 2000), suggesting that assemblages from pedoanthracological studies may depend on the sampling location. Therefore a multisampling strategy is more reliable for better capturing the heterogeneity of charcoal assemblages at a stand scale (Touflan and Talon, 2009). This first filter is specific to pedoanthracological studies while others such as combustion and post-depositional disturbances are shared with taphonomic processes encountered in archaeological contexts (Théry-Parisot et al., 2010). The conversion of woody biomass into charcoals is a species-specific process but is also controlled by heating conditions such as temperature, length of exposure, heating rate (Braadbaart and Poole, 2008), factors like humidity, wood density, bark thickness and trunk diameter (Rossen and Olson, 1985; Fréjaville et al., 2013), as well as local environmental conditions (Théry-Parisot et al., 2009). The last filter consists of post-depositional processes leading to burying, fragmentation (Chabal, 1994; Chrzavzez, 2013) and mixing of charcoals by soil biota (Carcaillet, 2001; Schwartz et al., 2005), so that pedoanthracological studies can hardly resolve the temporal sequence of vegetation changes.

Due to pros and cons of each discipline, reconstructing past land use and landscape is more efficient when several approaches are combined (Spek, 1998; Knapp et al., 2013; Yang et al., 2014). In this study, we compared the results from a soil charcoal analysis to historical records and local archaeological data for three contrasted sites of a lowland temperate forest, in order to reconstruct landscape changes since the Roman times. More specifically, we question whether combination of soil charcoal assemblages and archaeological data are consistent and complementary to understand the relationships between human societies and their environment in lowland forests.

2. Study site

We conducted this study in the Compiègne state forest (49°24′54″N, 2°49′23″E, altitude: 31–152 m), which is located in northern France and extends over ca. 14,000 ha at the confluence between the Oise and the Aisne rivers. The climate is sub-oceanic with mean annual temperature and annual rainfall of 10 °C and 610 mm, respectively. The forest covers a vast plain and several small mounts (outliers) towards the eastern and southern edges. The geological substrate mainly consists of Paleocene and Eocene sand and limestone, locally covered by quaternary loess or drift sand. The soils are mostly cambisols, luvisols and podzols (FAO classification) and, to a lesser extent waterlogged soils. The current vegetation is a temperate deciduous forest dominated by common beech (*Fagus sylvatica* L.) and oaks (*Quercus robur* L., *Quercus petraea* L.), with several planted Scots pine (*Pinus sylvestris* L.) stands.

Human occupation of the area is evidenced from the Neolithic period onwards (Woimant, 1995). A high density of archaeological sites, mostly in the south half part of the forest, also evidences the extensive Gallo-roman occupation (Fig. 1-a), which concentrated nearby streams and along a Roman road (Doyen et al., 2004). These Roman habitats are connected with ancient parcel boundaries as revealed by LiDAR pictures (Horen et al., 2015). During the Roman times, the forest should thus be limited to a few islets on the top of the mounts, whilst the vast majority of the plain was cultivated. Following its abandonment by Gallo-Romans, the plain probably became spontaneously afforested since the fifth century AC (Woimant, 1980; Talon et al., 1995). The forest was first mentioned by Grégoire de Tours in 561 as “forest of Cuise” (Guizot, 1823). Close to the royal *villae* of Compiègne, from the Merovingian period (Hennebicque, 1979; Barbier, 1985), the forest was used for royal hunting and remains as such until recently. The forest continuity is thus attested from the early Middle Ages onwards. Though the forest was used for royal and imperial hunting, grazing by livestock and horses was a common practice of local people. During the 12th century these informal practices became use rights, which were preserved until the 17th century. Based on written sources, it has been estimated that the livestock pressure within the forest reached more than 7600 pigs and 3800 cattles during the 15th century, together with an undeterminated number of sheeps (Bocquillon, 2000). In addition, some cultivation rights were also granted and people were allowed to collect firewood and sometimes even trees and shrubs for fences, tools or carpentries (Bocquillon, 2000). Local users of the forest include villagers, industries such as glass furnaces (Sautai-Dossin, 1973), monasteries, abbeys and hospitals, which were implanted inside or nearby the forest (Fig. 1-b). More distant hospitals and abbeys, located along the Oise valley and in Paris, were also allowed to raise their livestock into the forest (Carlier, 1764, Bocquillon, 2000). These use rights were maintained until the Colbertian reformation of 1661, whereby they were drastically reduced; at this time the forest boundaries were the same as today, as revealed by the first map of the forest, drawn in 1662 (*Archives Nationales 0/1/3800*). Medieval and early modern writings suggest that the forest was much more open than today. The forest likely remained an open woodland due to the severe climatic conditions of the Little Ice Age (Buridant, 2008), the grazing of livestock, and the many storms that occurred during the 18th and early 19th centuries. Moreover, game damages were frequently mentioned in the registers of grievances of local populations (Harlé d’Ophove, 1968). A map from 1728 shows that one quarter of the forest consisted of heathlands or marshlands, which were subsequently reforested (Fig. 1-c). Since the late 18th century, many plantations occurred over about half of the forest area, leading to a gradual closure of the canopy (Fig. 1-d) (Buridant, 2008). These were oak plantations at the beginning, followed by conifer plantations during the 19th century. The forest is now managed as a regular high forest of beech and sessile oak. It is currently a closed-canopy forest composed of *Fagus sylvatica* (46%) *Quercus robur* (27%), *Quercus petraea* (7%), *Pinus sylvestris* (7%), other broadleaved (10%) and conifer (3%) species. Since 1970, the American black cherry (*Prunus serotina* Ehrh.) is reported as an invasive tree species, but its first introduction would date back from the mid 19th century; it currently occurs in ca. 80% of the forest area, as single trees to pure stands, especially on nutrient-poor soils (Javelle et al., 2011).

3. Material and methods

3.1. Site selection

Three sites were selected within closed-canopy forest stands, accounting for contrasted soil types, themselves inherently associated with contrasted historical land uses (Fig. 1):