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Reconstruction and semi-quantification of human impact in the Dijle catchment, central Belgium: a palynological and statistical approach

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A B S T R A C T

Reconstructing and quantifying human impact is an important step to understand how, when and to what extent humans have changed the landscape during the Holocene. In this study we present a reconstruction of vegetation changes throughout the Holocene based on palynological data of six study sites in the Dijle catchment, located in the Belgian loess belt. A reconstruction of human impact in the catchment is extracted from the palynological study based on statistical analyses (cluster analysis and non-metric multidimensional scaling (NMDS)). The NMDS analysis on the pollen data do not detect large-scale Mesolithic or Neolithic human activities on the Dijle catchment. In these periods, human impact in the catchment was probably limited to local disturbances and small-scale forest clearances. Only from the Bronze Age onwards (ca 3900 cal a BP) human impact was clearly detected in the pollen records and vegetation gradually changed. Human impact further increased from the Iron Age onwards, except for a temporary halt between ca 1900 and 1600 cal a BP, possibly coupled with the Migration Period in Europe. The general vegetation development and increasing human impact are rather similar at the catchment scale, beside some local variations in timing and intensity of the human impact in the different subcatchments. The applied methodology, cluster analysis and NMDS, proves to be a useful tool to provide semi-quantitative insights in the temporal and spatial vegetation changes related to increasing human impact.

1. Introduction

From the Neolithic period onwards, human impact increased in many catchments in NW Europe through deforestation and the development of agriculture (e.g. Kalis et al., 2003; Dotterweich, 2008). As one specific result, sediment fluxes within the landscape changed (for an overview, see e.g. Notebaert and Verstraeten, 2010), and sediment supply from the hill slopes to the river systems increased and floodplain geomorphology and ecology changed (e.g. Kalis et al., 2003; Houben, 2007; Lespez et al., 2008; de Moor and Verstraeten, 2008; Broothaerts et al., 2013).

Although the general framework of changes in sediment fluxes in relation to anthropogenic land cover changes during the Holocene is now established, many uncertainties still exist. For instance, we still lack a detailed insight on the impact–response relation to fully grasp how, when and to what extent humans have changed sediment fluxes. It is for instance still uncertain which threshold levels of human impact need to be reached to increase sediment supply from hill slopes to the river system and completely alter the floodplain morphology. To identify such threshold levels and fully understand the role human impact has played to change sediment fluxes, a reconstruction of the vegetation changes and quantitative measures of human impact on the landscape during the Holocene are needed (e.g. Verstraeten et al., 2009a). Moreover such a reconstruction is necessary at a catchment scale to understand whether differences between subcatchments can be attributed to heterogeneity in the timing and nature of the driving forces or to a different response of floodplains to the same driving forces, indicating a (non-)linearity in the process–response relationship.

Data on land cover history can be reconstructed based on archaeological and palynological records. Traditionally, human impact has been reconstructed in pollen diagrams based on specific anthropogenic indicators in the pollen diagrams (e.g. Behre, 1981),

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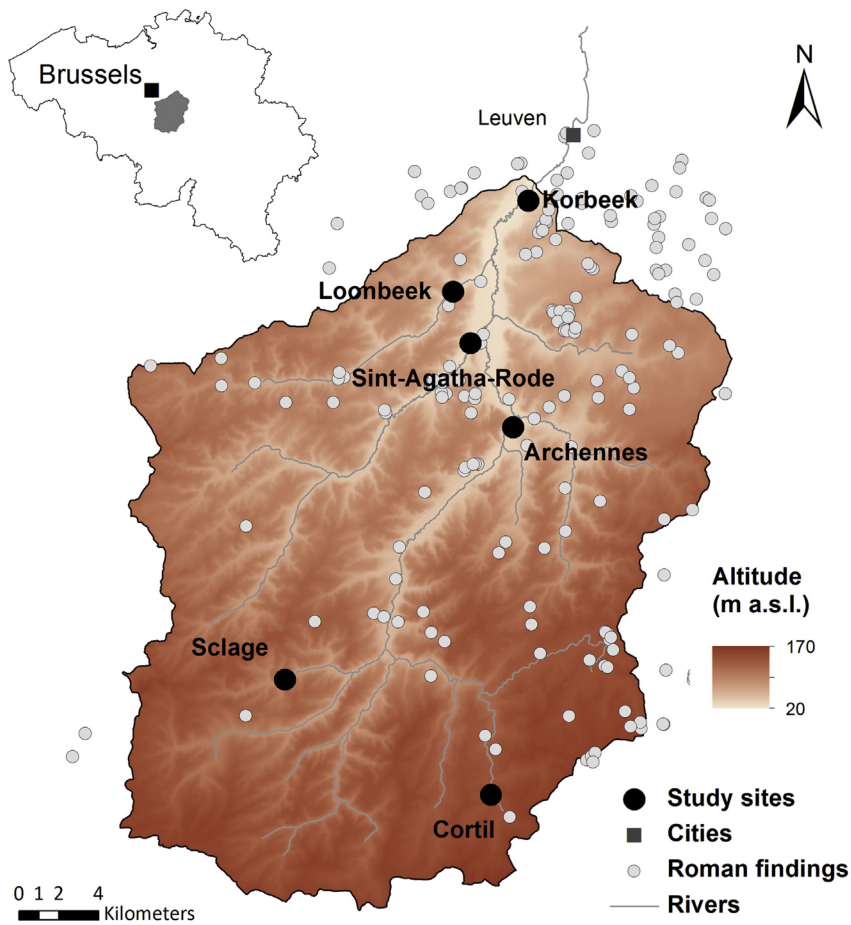

Fig. 1. Location of the study sites in the Dijle catchment and in Belgium, with indications of Roman findings in and near the Dijle catchment (location of the Roman archaeological findings are based on Notebaert (2009)).

or by changes in the vegetation composition (e.g. non-arboreal/arboreal pollen ratio) (e.g. Faegri and Iversen, 1989; Favre et al., 2008). These traditional interpretations of pollen data are mainly qualitative approaches, and detailed determination of causal factors or detailed comparisons of different study sites are difficult. Recently, advances in pollen studies have been made and new approaches are proposed to (semi-) quantify vegetation cover based on pollen data, such as the Multiple Scenario Approach (MSA; Bunting and Middleton, 2009) and the Landscape Reconstruction Algorithm (LRA; Sugita, 2007b, 2007a). Although these models have been validated and successfully applied in several studies (e.g. Hellman et al., 2008; Soepboer et al., 2010), several restrictions are associated with them, limiting their use. For instance, both models rely on good approximations of pollen productivity which are not available for many regions (e.g. Brostrom et al., 1998) and the LRA is only validated for pollen data from large lakes. Alternatively, statistical analysis of pollen data has recently been used to characterize vegetation changes and to extract semi-quantitative data on human impact based on the entire pollen signal (e.g. Birks, 1985; Kerig and Lechterbeck, 2004; Lechterbeck et al., 2009; Bakker et al., 2012; Lopez-Merino et al., 2012). Although these statistical techniques allow a comparison over different study sites (Lechterbeck et al., 2009), these techniques have not yet been used at the scale of an entire catchment. Reconstructing human impact at a catchment scale will help to understand (non-)linearity in the process–response relationship.

In this study we present a reconstruction of vegetation changes in the Dijle catchment, central Belgium, throughout the Holocene based on palynological data of six study sites. We aim to reconstruct and semi-quantify human impact in the catchment based on statistical analyses (cluster analysis and non-metric multidimensional scaling (NMDS)) of the pollen records. NMDS is used to compare vegetation changes through time in different subcatchments of the Dijle catchment.

2. Study area

This study focuses on the Dijle catchment south of Leuven (758 km^2), located in the central Belgium loess belt (Fig. 1). The Dijle catchment is characterized by an undulating plateau in which several rivers are incised. The soils of the catchment are mainly Luvisols, developed in the loess deposits. Previous palynological studies in the Dijle catchment show that the catchment was mainly forested during the first half of the Holocene (Mullenders and Gullentops, 1957; Mullenders et al., 1966; De Smedt, 1973; Broothaerts et al., 2013). The Linearbandkeramik arrived in the Belgian loess belt around 7200 cal a BP, however, no indications of the presence of this culture in the Dijle catchment are present (Vanmontfort, 2007, 2008). The Neolithic Period in the Belgian loess belt lasted from ca 6400 to 3900 cal a BP (CAI, 2014). The oldest known Neolithic settlement in the Dijle catchment ('Ottenburg'), located nearby study site Archennes (Fig. 1), dates from ca 6200 cal a BP (Crombé and Vanmontfort, 2007; Vanmontfort, 2007). The impact of the Neolithic activities in the Belgian loess belt was limited to local-scale deforestation. Neolithic clearances were small and only used for a few decades