



The added value of biomarker analysis in palaeopedology; reconstruction of the vegetation during stable periods in a polycyclic driftsand sequence in SE-Netherlands



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ABSTRACT

Polycyclic driftsand sequences are records of alternating unstable periods with aeolian erosion and deposition and stable periods with soil formation. In numerous studies, pollen analysis, radiocarbon dating, and optically stimulated luminescence dating have been applied to collect palyno-ecological information and to establish a robust geochronology for the reconstruction of the profile genesis. A correct reconstruction of the local vegetation during stable periods in the profile evolution cannot be based on pollen spectra alone, because of the impossibility to separate pollen species produced in-situ and at distance. We considered biomarker analysis as a possibility to solve this problem. In a selected sequence with a well-established geochronology, we applied pollen and biomarker analysis on samples of humic Ah horizons of buried (initial) podzols. Based on species matching in soil pollen spectra and biomarker patterns of samples of (buried) humic horizons, it was possible to distinguish pollen species produced in-situ and at distance from the study site, and consequently to determine the plant species composing the vegetation during stable periods with soil formation.

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1. Introduction

The application of *n*-alkanes, and to a lesser extent *n*-alcohols, as biomarkers to reconstruct past vegetation from organic matter preserved in soils or sediments is a growing field of research (e.g. Huguenot et al., 2004; Zech et al., 2009a; Gocke et al., 2010; Andersson and Meyers, 2012; Ortiz et al., 2013). However, in most instances separation has been limited to reconstructing shifts in vegetation groups based on changes in concentration ratios of a limited number of *n*-alkanes and *n*-alcohols. Examples are shifts in the ratio of C31/C29 or C31/C27 *n*-alkanes being interpreted as indicating a transition from forest to non-forest vegetation cover or vice versa, or a dominance of C26 *n*-alcohol interpreted as indicating a dominance of grass vegetation (e.g. Rieley et al., 1991; Tareq et al., 2005; Lei et al., 2010; Zech et al., 2011; Lavrieux et al., 2012). The main reason for this limitation is the fact that for *n*-alkanes and *n*-alcohols, concentration ratios of lipids of different chain-lengths are species-specific, and not the individual lipids themselves (Lavrieux et al., 2012). As a result, the biomarker signal preserved in a soil is a mixed signal of a large

number of lipids of various chain-lengths. To enable interpretation of this preserved mixed signal, we recently developed the VERHIB model (VEgetation Reconstruction with the Help of Inverse Modelling and Biomarkers) (Jansen et al., 2010). The VERHIB model is based on the assumption that the presence of vegetation over time is a multi-variate autoregressive process with a forcing and several constraints (Jansen et al., 2010). It uses a constrained linear regression model as a forward model to describe the way in which a certain vegetation pattern resulted in an accumulation of biomarkers in a suitable archive, such as a soil, over time. An inversion of the forward model is then used to reconstruct past vegetation on the basis of the accumulated biomarker signal encountered in that archive (Jansen et al., 2010). We successfully applied biomarker analysis using the VERHIB model in combination with pollen analysis to reconstruct vegetation shifts in northern Ecuador based on biomarkers and pollen preserved in peat cores as well as soil profiles (Bakker et al., 2008; Jansen et al., 2008, 2010). However, two important limitations of biomarker archives in palaeo-reconstructions are their potential degradation in soils as well as potential disturbance of chronology through the input of root material at depth (e.g. Gocke et al., 2010; Lavrieux et al., 2012). Because of these limitations, the applicability of biomarkers must always be separately tested in different soil types. Upon degradation of *n*-alkane patterns, the characteristic odd-over-even chain length predominance diminishes, as does the ratio between longer chain

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length ($>C_{20}$) plant-derived and shorter chain length ($<C_{20}$) microbial derived *n*-alkanes. Several proxies including Average Chain Length (ACL), Carbon Preference Index (CPI), Odd over Even Pre-dominance (OEP) and Long Chain Alkane Ratio (LAR) have been developed and are used alone or in combination to follow degradation trends in soils (e.g. Zech et al., 2009b; Buggle et al., 2010; Lei et al., 2010). In spite of potential degradation, biomarkers have been successfully applied in vegetation reconstructions from aeolian palaeosol sequences in loess (e.g. Schatz et al., 2011; Zech et al., 2011; Zeng et al., 2011). To our knowledge, biomarkers have yet to be applied in vegetation reconstructions in aeolian palaeosol sequences in sandy deposits. Therefore, we applied biomarker analysis using the VERHIB model as an additional proxy in the key profile Defensiedijk-1 in our study area in SE Netherlands (Fig. 1). The landscape of this area is underlain by aeolian coversand, deposited during the Late-glacial of the Weichselian. During the Holocene, the coversands were vegetated, but several forms of disturbance could be responsible for small or large scale sand drifting (Stichting voor Bodemkartering, 1972; Koster, 2010). Until the Preboreal, aeolian processes reduced soil formation and stimulated sand drifting. From the Preboreal to the Atlantic, soil development dominated under several forest types. The distribution of forest types and soils correlated with the geomorphological units of the coversand landscape, Umbric Podzols developed under mixed oak-birch forest on coversand ridges, Gleyic Podzols developed under oak and alder forests on coversand plains and Histic Podzols and Gleysols developed under wet land vegetations in depressions and on valley bottoms (van Mourik et al., 2012a,b).

The area was used by hunting people during the Late Paleolithic and Mesolithic (Nies, 1999). Analysis of the urn field 'Boshoverheide' indicated that the population increased during the Bronze Age between 1000 and 400 BC to a community of several

hundreds of people, living from forest grazing, shifting cultivation and trade (Bloemers, 1988). Partly, the natural deciduous forests gradually degraded into heathlands and due to soil acidification, the Umbric Podzols transformed into Carbic Podzols with a pronounced albic horizon. Farmers learned to manage the heath as a valuable source area for organic manure, honey production and other applications.

In prehistoric time, small scale sand drifting occurred, caused by natural event as forest fires and storms, later also by shifting cultivation. After the introduction of sedentary agriculture around 1000 BC, farmers were confronted with the properties of chemically poor sandy substrates, requiring application fertilizers for sustainable crop productions. They learned to prepare organic fertilizer in shallow potstables, composed of animal manure and mowed grasses and *Calluna* (Vera, 2011). Until the 10th century, the slightly increasing population managed a stable landscape system, consisting of forests, heathlands, pastures and much arable land (Bloemers, 1988; Vera, 2011).

During the 11th and 12th centuries, clear-cutting of the remaining forests took place, to sell timber to the Flemish cities, and the first large scale extension of sand drifting took place (Vera, 2011). A part of the coversand landscape transferred in a driftsand landscape composed of deflation plains and complexes of inland dunes (van Mourik et al., 2012a,b).

From the middle of the 18th century until 1900, deep potstables came in use and farmers collected heath sods, composed of humus and minerals (Vera, 2011). The impact of sod digging on soils and landforms was the development of plaggic antrosols on arable land and the degradation of the *Calluna* heath, resulting in the second large scale extension of the driftsand landscapes. In such driftsand landscapes, the majority of the podzolic soils in coversand have been truncated by aeolian erosion. Only on scattered sheltered sites

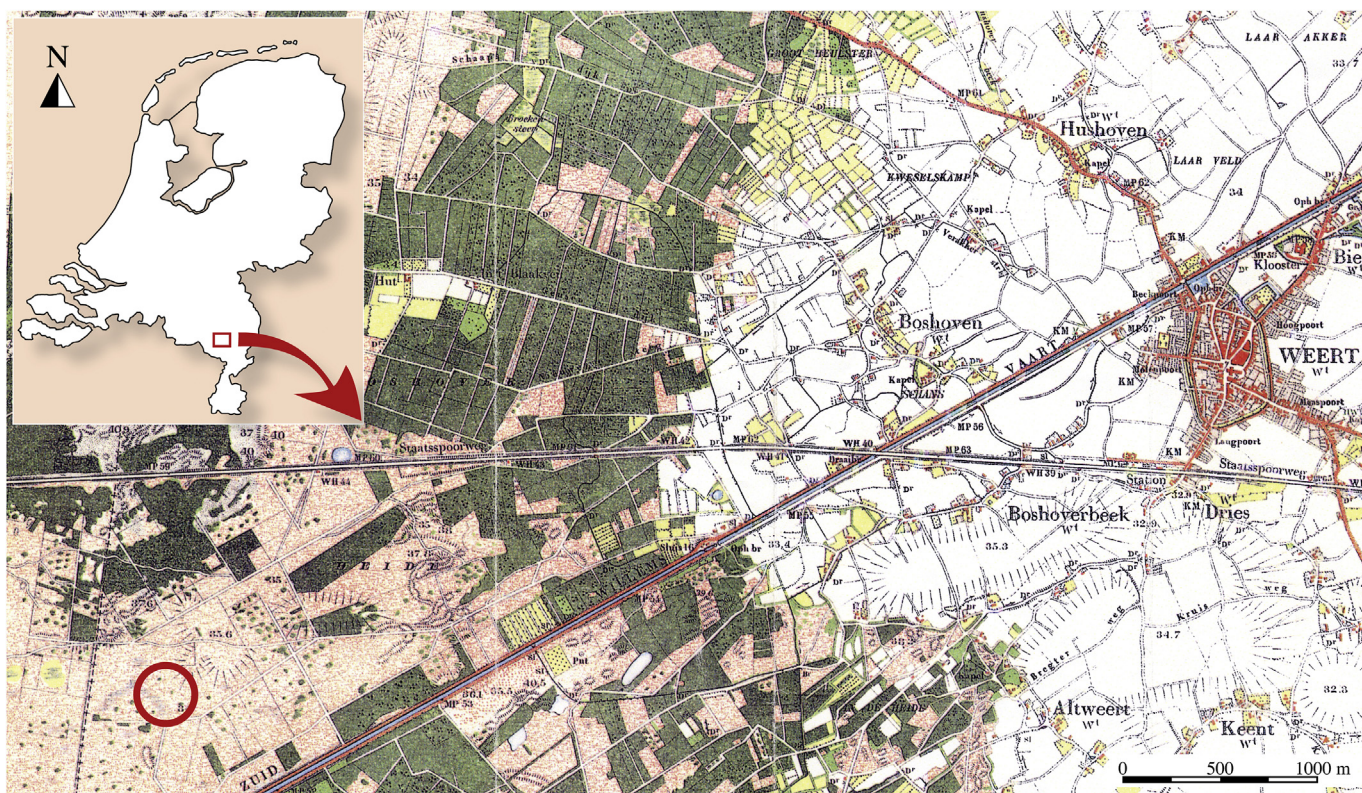


Fig. 1. Location of profile Defensiedijk on a fragment of the historical topographical map (scale 1:25,000, 1900 AD) with the location of profile Defensiedijk. The map shows the area around Weert with arable land (Plaggic Antrosols) and heath (Podzols and Arenosols). Western of Weert, the heath was already partly reforested.

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