Reconstructing past hydrology from drift sand archives: possibilities and limitations

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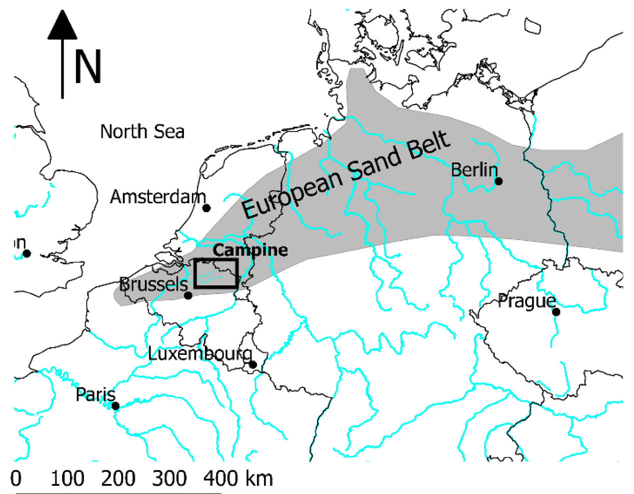
Study area



The Campine region (NE Belgium) is a flat sandy area with very small altitude differences and relief gradients. It is generally underlain by a sandy aquifer with (very) shallow phreatic groundwater tables. Groundwater is discharged into small rivers occupying weakly incised floodplains, and is replenished, on a yearly basis, by recharge from infiltrating precipitation. The region is characterized by a temperate climate and precipitation surplus, especially in winter.

Narrative

At the onset of the Holocene, the existing Late Glacial landscape became stabilized by vegetation allowing **podzol soils** to develop outside the floodplains, especially on higher grounds, and even in wet depressions. In the deepest depressions **peat** would have accumulated and podzol soils would have been hydromorphic and/or weakly expressed. During the course of the Holocene human-induced (and/or climatically enhanced) landscape instability subsequently caused aeolian **deflation** of presumably dry and exposed podzol soils. The redeposited material is known as **drift sand**, which builds up irregular dunes or even would have become trapped in closed depressions. These depressions can be dry, or occupied by a shallow pool of standing water from precipitation or outcropping groundwater. Drift sand may be redeposited on (partially eroded) podzols.

Introduction

Earth surface processes continuously modified sandy soils and landscapes of the temperate region during the Holocene. Shallow water tables in unconfined aquifers that underlie these soil-landscapes would influence these processes and thus the archives that resulted from these processes. There are two main archives: floodplain archives (discharge areas) and non-floodplain archives (recharge areas). Elevated areas adjacent to floodplains (interfluves, sometimes only a few meters altitude difference) are outside the fluvial realm. Yet, various natural and human-induced processes such as soil formation, peat development, aeolian deflation and associated sediment deposition have a significant impact on the soil-landscape. These archives, which are common in drift sand landscapes, basically would produce four different types of hydrological proxy as indicated in the box below. The 5 study sites are all situated within a few km from each other.

Objectives

The objective of this work is to explore the significance of various palaeohydrological proxies in drift sand landscapes in the Campine area, NE Belgium.

- Soil horizon morphology
- Aeolian deflation horizons
- Sediment facies
- Palaeobotanical content

Key

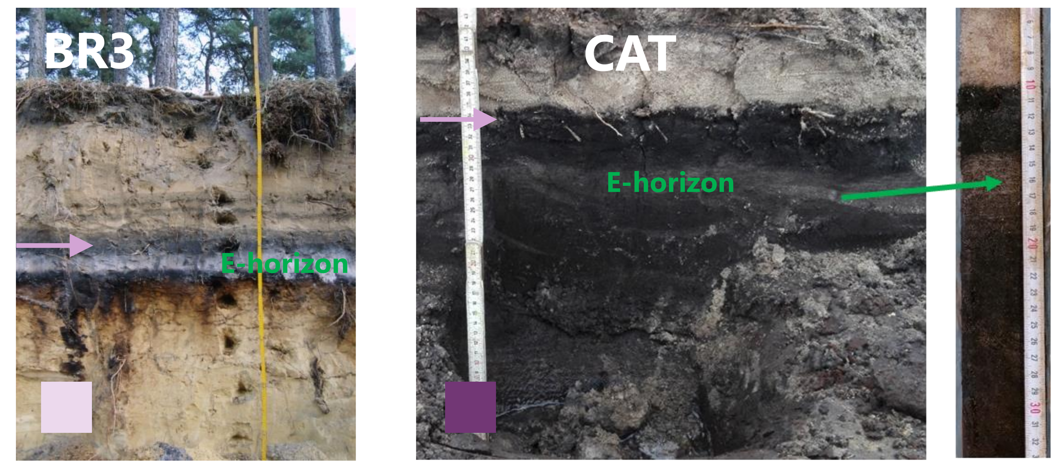
Position of palaeo-surface → ↕

Sites **BR3/CAT/MA/GKD/BP**

Position of average palaeo-groundwater table below palaeo-surface

> 2 m | 1-2 m | 0.5-1 m | < 0.5 m

Soil horizon morphology

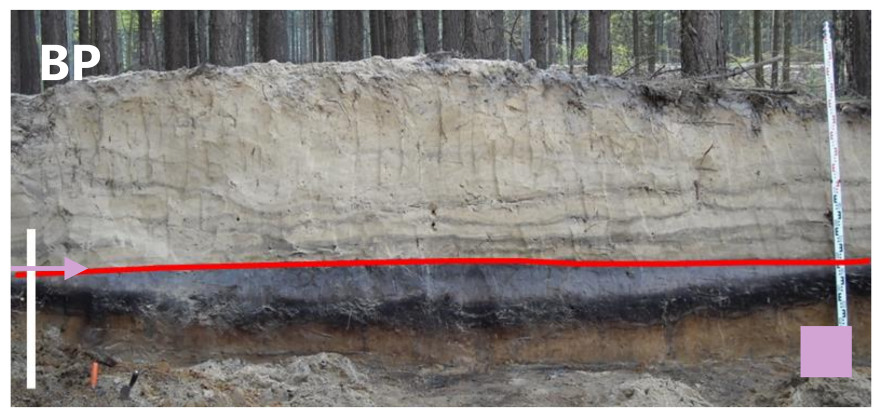


Podzol with well-developed E-horizon on top of a low dune (left, BR3) and one with a very weakly developed E-horizon in a depression (right, CAT).

Both soils are palaeosoils and thus are indicators for the position of the groundwater table in the past. Age control is provided by radiocarbon dating of macroremains from the A-horizon or optically stimulated luminescence (OSL) dating of the overlying drift sand (terminus ante quem).

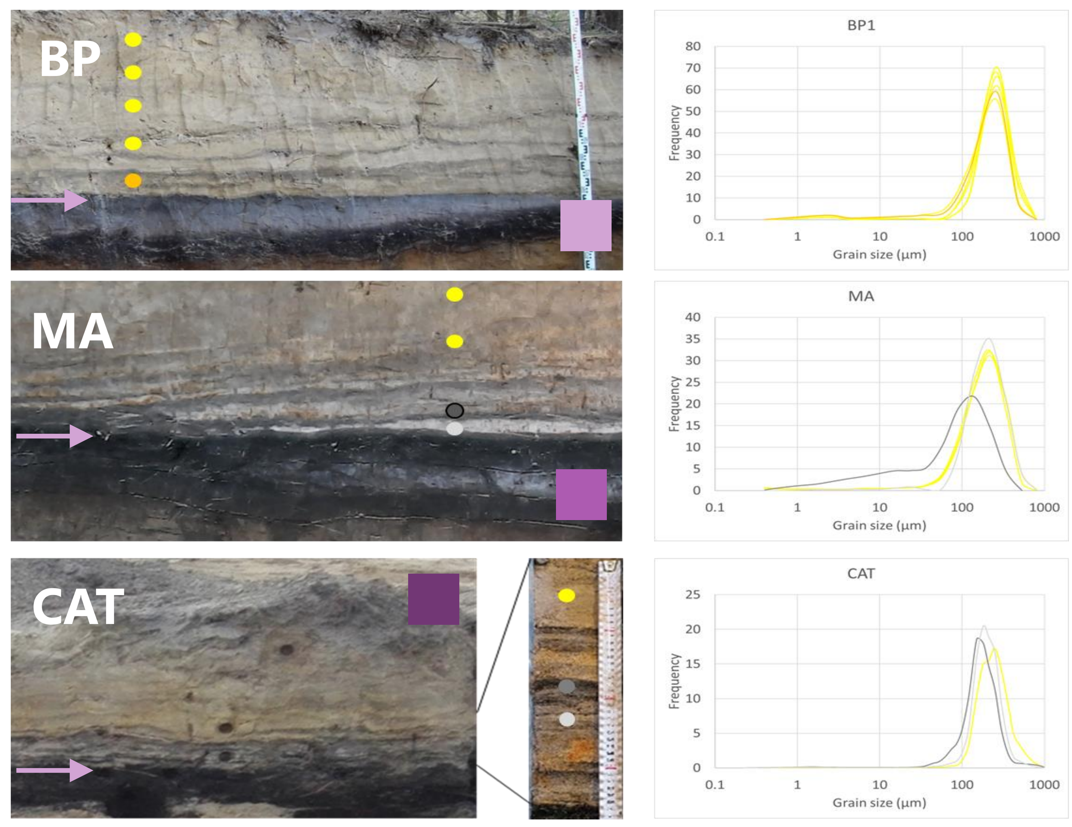
A podzol with a clear E-horizon near the edge of the palaeo-depression and a very weakly developed one in the center of the depression (MA). This hydrosequence is a low-resolution proxy for the groundwater table. Shallow groundwater tables hamper the development of a clear E-horizon (see also upper right panel). The blue line suggests the presence of the average highest palaeo-groundwater table for the time period roughly between 5000 BP and 3500 BP.

Deflation horizons



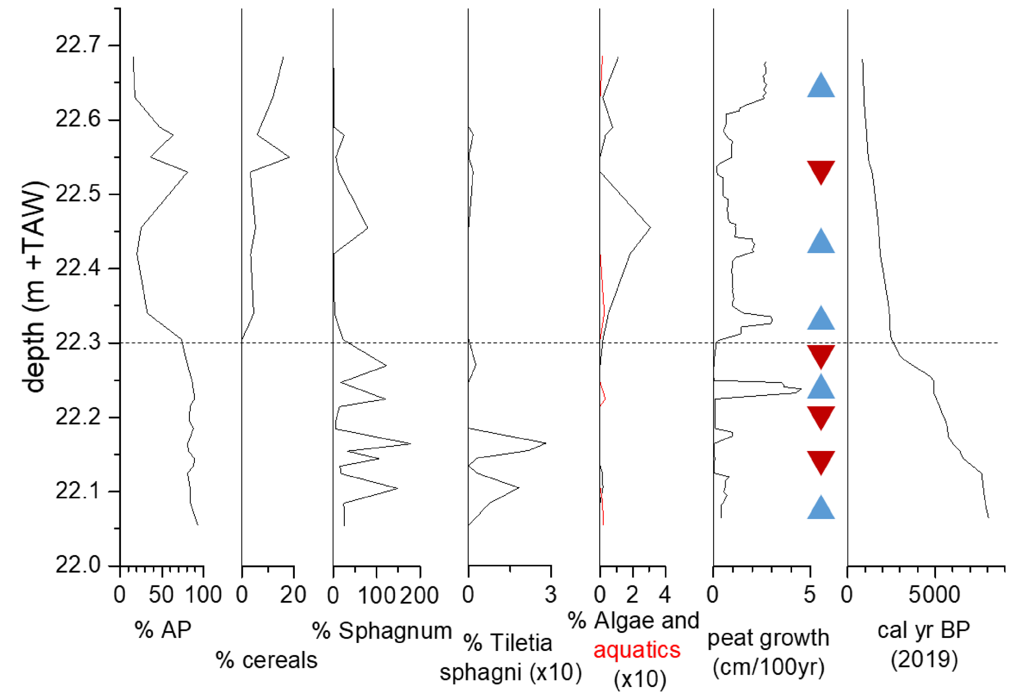
Aeolian deflation can only occur above the water table. These erosion surfaces are low-resolution proxies and provide an upper limit for the average groundwater table only. OSL dating of overlying sediment (ca. 250 BP for he upper panel (GKD) and ca. 450 BP for the lower panel (BP)) povides a terminus ante quem for the deflation surface and the contemporary groundwater table.

Sediment facies



Drift sand blown over a surface in a dry setting shows little grain size variation, even in macroscopically darker layers (upper panel, BP). In contrast, sand deposited in wet environments shows distinct heterolithic bedding, which is thought to be the result of sediment demixing during surficial runoff (heavy precipitation events) and deposition in a sufficiently deep water column (middle panel, MA). Alternating organic-rich dark layers and 'clean' sand layers at cm scale also indicate a wet environment, possibly aeolian deposition in standing water (lower panel, CAT). Age control is provided by OSL dating: ca. 400-450 BP for the upper and lower panel, and ca. 2400 BP for the middle panel. These are potential high-resolution point-in-time proxies.

Palaeobotanical content



Significant amounts of peat may develop in deep depressions, such as the one shown here (MA). The peat covers the time period between ca. 8000 BP and 1000 BP, and is sandwiched between a podzol hydrosequence below and drift sand with wet-deposition features on top. Peat growth can generally be distinguished into peat growth above the water table, and peat growth in partially submerged conditions. Relevant indicators for peat growth above the water table are Sphagnum and Tiletia sphagni, which are dominant in the lower part of the peat column and coincide with smaller peat growth rates (below the horizontal line). From ca. 2700 years BP onwards, the peat growth rate increases and algae, aquatics and aquatic vertebrates significantly increase in number. Millenial and sub-millennial (see blue and red triangles) variations in hydrology (most likely groundwater) can be deduced from this high-resolution archive.

Summary

Although not necessarily time-equivalent, the various proxies show consistency when evaluated at a single location (e.g., hydromorphic podzols overlain by peat and/or reworked or pseudo-lacustrine sediment; dry-deposited sand on top of a deflation surface in a relatively dry podzol). It opens up the possibility to determine first-order palaeo-groundwater tables, with a low temporal resolution. Palaeobotanical research of peat in deep depressions may help increasing the resolution. Given the very fast response of the groundwater table to long-term precipitation events in this area, we suggest that these palaeohydrological archives are actually good indicators to assess long-term first order palaeo-groundwater levels and trends.