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Exploitation of nutrient- and C-rich paleosols by deep rooting plants in Dutch drift- and coversands

Martina Gocke (1), Fabian Kessler (1), Jan van Mourik (2), Boris Jansen (3), and Guido L.B. Wiesenberg (1)

(1) University of Zurich, Department of Geography, Soil Science and Biogeochemistry, Zurich, Switzerland (martina.gocke@geo.uzh.ch), (2) IBED-Paleoecology, University of Amsterdam, Amsterdam, The Netherlands, (3) IBED-Earth Surface Science, University of Amsterdam, Amsterdam, The Netherlands

Plant roots are commonly assumed to be most abundant in topsoil, with strongly decreasing frequencies in underlying soil horizons with incrasing depth and almost absence of roots below the uppermost few dm due to unfavorable environmental conditions in terms of e.g. aeration, nutrient availability or water, that hamper root growth. It still remains unknown, to which extent roots might be able to exploit deeper parts of soils and underlying soil parent material as well as buried paleosols.

The study site is located in SE Netherlands. Undisturbed oak forests developed about 200 years ago on stabilized driftsand, deposited on a plaggic Anthrosol after approximately 700 years of agricultural use. The soil profile, consisting of the recent initial Podzol in driftsand, overlying 1.1 m thick plaggic deposits that were established in a 0.5 m thick residual Podzol in coversand, was excavated in a pit of 2.3 m depth. Living and dead roots were counted throughout the profile on both, the vertical wall and horizontal levels. Additionally, soil or sediment samples free of visible root remains were collected in depth intervals between 0.05 m and 0.15 m from topsoil down to the coversand. A multi-proxy approach, including assessment of bulk elemental composition of soil, sediments and paleosol and molecular structure of organic matter therein, organic carbon contents, bulk density and pH was applied in order to comprehensively describe the varying environmental conditions within the soil profile and in transects from roots to root-free material.

The burried agricultural soil revealed low density and high organic carbon contents compared to the coversand parent material, and especially in its lower part, high phosphorous contents. In contrast, the burried Podzol was characterized by completely different geochemical and physical properties, like increasing pH with depth and high iron and aluminium contents. In the recent initial Podzol, fine roots ($\leq$ 2 mm), deriving from both oak trees and understory vegetation, immediately decreased from 476 m-2 to 24 m-2, whereas medium roots (2–5 mm) from oak trees continuously increased from 8 m-2 at the surface to 188 m-2 within the upper part of the agricultural soil. Both, frequencies of fine and medium roots peaked at 4.448 m-2 and 216 m-2, respectively, in the uppermost part of the burried Podzol, thus considerably exceeding topsoil abundances. Comparison of these results with those obtained at the profile wall demonstrated that fine root abundances might be considerably underestimated by the more traditional approach of profile wall investigation, because fine roots were growing vertically to exploit the nutrient-rich burried paleosols. Unlike fine roots, medium roots and even more, large roots (> 5 mm) were not able to penetrate the hard sesquioxide crusts of the burried Podzol in larger numbers.

Our results show that roots are able to deeply penetrate the soil and underlying soil parent material or paleosols, if the latter provides nutrition benefits. Root distribution strongly depends on physical and chemical properties of the deep subsoil, which should be taken into account when interpreting complex soil profiles covering recent and paleosols.