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Variability of soil water repellency in sandy forest soils with different stand structure under Scots pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*)

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Abstract

Soil water repellency has important consequences for hydrological and ecological properties of forest soils. It is a dynamic property, varying temporally throughout the course of the year. The objective of this study was to characterize the temporal variation of soil water repellency on sites at the Kahlenberg forest in northeast Germany, with comparable geological substrate, soil type, and climatic conditions, but with different stand ages and tree species in terms of the effects of forest transformation upon soil physical properties. The Kahlenberg forest area under investigation contains stands of Scots pine (*Pinus sylvestris*) and European beech (*Fagus sylvatica*) of different age structures forming a transformation chronosequence from pure Scots pine stands towards pure European beech stands. To measure water repellency, the water drop penetration time (WDPT) and the critical surface tension (CST) tests were carried out using soil samples from four forest plots at soil depths of 0–30 cm, and four sampling periods between autumn/winter 2000 and autumn 2001. Both WDPT and CST revealed a pronounced seasonal variability in repellency from being strongest in summer to weakest in autumn (2001), after a prolonged wet period. In general, plots in pine-only and beech-only stands exhibited relatively low water repellency values compared to those in mixed stands, which had higher proportions of mor-type humus forms and greater thicknesses of forest floor layer compared to the pure stands (as described previously—[Buczko, U., Bens, O., Fischer, H., Hüttl, R.F., 2002. Water repellency in sandy luvisols under different forest transformation stages in northeast Germany. Geoderma 109, 1–18]). The relatively small differences in the degree and persistence of hydrophobicity between the plots are largely overshadowed by the large differences between the sampling periods.

Keywords: Water repellency; Hydrophobicity; Soil hydrology; Soil organic matter; Humus forms; Forest transformation; Luvisols; Seasonal variability

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1. Introduction

Soil water repellency is often observed in forest soils under various climatic conditions. Water repellent (hydrophobic) soils resist wetting by water for seconds, minutes, hours, or even days (e.g., Wallis and Horne, 1992; Doerr et al., 2000). In general, soil water repellency is mostly caused by soil organic matter, for example, as coatings of plant-derived waxes covering the soil particles (e.g., Neinhuis and Barthlott, 1997), by fungal hyphae (e.g., Bond and Harris, 1964; Chan, 1992), or as particles in interstitial pore spaces (e.g., Bisdom et al., 1993). Occurrences of anthropogenically induced soil hydrophobicity, for instance by crude oil spills (Roy and McGill, 1998) or dumped lignite fragments (Gerke et al., 2001), are relatively rare.

Soil water repellency was first described for semiarid and subtropical climatic conditions. More recently, occurrences of water repellency have also been reported from other climatic conditions (e.g., Wallis and Horne, 1992; Doerr et al., 2000; Jaramillo et al., 2000). The focus is still, however, on semiarid and Mediterranean-type climates. Findings of soil water repellency from non-Mediterranean Europe, with distinct seasonal variability of climatic conditions, have been described mainly from the Netherlands, for example, for dune sands and pastures (Dekker and Ritsema, 1994), from Sweden for organic soils under grass cover (Berglund and Persson, 1996) and soils under agricultural land use from Denmark (De Jonge et al., 1999), and Scotland (Hallett and Young, 1999), for golf greens in the United Kingdom (York and Canaway, 2000), and for moraine sandy soil under horticultural land use in Germany (Bachmann, 1996). In few of these studies, however, was seasonal variability of soil water repellency reported.

Investigations of water repellency for forest soils in central Europe were often focused on afforested reclamation sites (Katzur and Haubold-Rosar, 1996; Gerke et al., 2001). However, soil hydrological investigations have indicated that water repellency is also a major concern for natural forest soils of central Europe (e.g., Ehwald et al., 1961; Buczko et al., 2002).

Specific investigations of soil hydrophobicity are important because soil physical and hydrological corollaries of hydrophobic soil properties are manifold: hysteresis of the water retention curve (Ritsema et al., 1998; Bauters et al., 2000), unstable wetting fronts with fingered flow (Hendrickx et al., 1993), reduced infiltration capacity as compared to wettable soils (e.g., Ritsema et al., 1993; Wang et al., 2000), and, consequently, greater surface runoff and erosion (Burch et al., 1989; Benavides-Solorio and MacDonald, 2001). Water repellency depends, among other factors, on water content. Thus, rainstorm events after prolonged dry periods may produce distinctly more surface runoff than after wet periods (Jungerius and Dekker, 1990; Imeson et al., 1992; Doerr et al., 2003).

In many parts of Europe, forest is the dominating form of vegetation under natural conditions (Ellenberg, 1996). In many German forests, during the past 200 years, pine or spruce stands have been established in areas originally dominated by deciduous trees. For several decades, these man-made stands consisting exclusively of single-age coniferous trees have been criticized for ecological and economic reasons. Therefore, it is an important objective to create forests that are genuinely site-specific and richer in species diversity. It is planned to increase the proportion of beech trees versus the proportion of Scots pine in the northeast German lowland. The aim is to change about 800,000 ha of pure Scots pine stands to mixed pine-beech and beech stands by forest transformation over the next 25–30 years (Müller, 2000). This forest transformation measure has impacts on the ecology of forest ecosystems, for example, on soil organic matter dynamics and carbon storage (e.g., Fischer et al., 2002; Rumberger et al., in press). The effects of forest transformation on soil physical properties have so far been only poorly documented (e.g., Buczko et al., 2002; Bens et al., in press).

Soil water repellency is a function of many factors, including the soil water content (e.g., King, 1981; Dekker and Ritsema, 1994), the wetting and drying history of the soil (Doerr and Thomas, 2000), temperature (e.g., Dekker et al., 1998; De Jonge et al., 1999), relative ambient air humidity (Doerr et al., 2002), and the amount and quality of the soil organic matter (e.g., Singer and Ugolini, 1976; Wallis et al., 1990; Dekker and Ritsema, 1994). Because all these factors influencing soil water repellency exhibit spatial and temporal variability, often following the seasons of the year, it has to be expected that the soil water repellency for a specific site exhibits in most