



Effect of parent material on soil acidity and carbon content in soils under silver fir (*Abies alba* Mill.) stands in Poland



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ABSTRACT

The objective of this research was to investigate the influence of parent materials on soil acidity, particularly pH, fractions of aluminium (Al_{TA}) and hydrogen (H_{TA}), and their effect on soil organic matter accumulation in acid forest soils under silver fir stands. We established 86 investigation plots with soils developed from Triassic sandstones, TS (33 plots), and Quaternary sand derived from weathering of sandstones, QSW (53 plots). Soil samples of the A horizons were analysed for pH measured in water extract (pH_w), the content of carbon (C_t), base cations (BC_{EX}) and total acidity (TA). Additionally, TA was fractionated into H_{TA} and Al_{TA} . We also analysed chemical composition of water extracts. Soils developed from TS were significantly richer in clay and C_t than QSW soil. The mean pH_w of soils developed from TS and QSW was similar. TA was significantly greater in TS soils; however, this difference was only related to the content of Al_{TA} . Conversely, the content of H_{TA} was similar in TS and QSW soils. The content of C_t and TA soil showed a moderate significant positive correlation with clay content ($r = 0.50$ and 0.60 , respectively). The TA correlation was largely attributed to Al_{TA} ($r = 0.60$), while H_{TA} was not correlated with clay content. The positive correlation between clay content and TA suggests that clay fraction increases soil acidity. Higher TA of TS soils was particularly related to the higher Al_{TA} content, while the content of H_{TA} was not related to either parent material or clay content. Small differences in soil pH_w between the investigated parent materials may result from the similar relationship between Al_{TA} and C_t . Al_{TA} and H_{TA} appeared to have a positive similar impact on soil C_t .

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1. Introduction

In temperate forest ecosystems, soil organic matter (SOM) accumulates both at the surface as the organic layer, and within mineral soil (e.g. Schulpe et al., 2008; Deluca and Boisvenue, 2012; Gruba et al., 2015). The SOM accumulated in the organic horizon is relatively easily decomposable and prone to forest management (Olsson et al., 1996; Jandl et al., 2007; Galka et al., 2014). In contrast, SOM accumulated in the mineral soil is protected by various mechanisms (Hassink, 1997). The parent material from which any given soil has developed, has a substantial impact on the ability of that soil to accumulate organic matter (Heckman et al., 2009). In particular, the capacity of soils to store SOM is related to the content of mineral fine fractions (silt and clay), and the content of amorphous aluminium (Al) and iron (Fe) substances (Hassink, 1997; Giardina and Ryan, 2001; Kleber et al., 2005; Mikutta et al., 2005; Chabbi et al., 2009).

Recent findings reveal that soil acidification, caused by trees or acid deposition positively influences the accumulation and stabilization of SOM in forest soils. Mueller et al. (2012), based on previous research

by Hobbie et al. (2007), proposed the concept that tree species lower soil pH, resulting in enhanced mineral weathering and complexation of metals (particularly Al and Fe) to SOM. This process increases soil total acidity (TA) and may positively affect the stability of SOM in soils. In fact, soil acidity, particularly this resulted from acid deposition, is a major soil parameter, which is usually considered in the context of its negative impact on the environment. It is accepted that acidification of soil leads to a decrease in nutrient content (particularly Ca and Mg) and an increase in the activity of potentially toxic aluminium (Al^{3+}) or hydrogen (H^+) in soil solution (Kinraide, 2003; van Schöll et al., 2004). However, Mulder et al. (2001) found that lower pH and enhanced concentration of Al^{3+} in soil solutions increased carbon stores in forest soils under spruce stands.

To date, little is known about the complex subject of soil acidification and variable parent material on soil acidity and SOM accumulation. The majority of the investigations are based on a common garden approach, where parent material remains relatively stable (e.g. Hobbie et al., 2007; Mueller et al., 2012). Therefore, there is no proof that the concept proposed by Mueller et al. (2012) is valid over different types of parent materials. Moreover, Mueller et al. (2012) found that accumulation of C in soil is positively affected by TA in general. Technically, TA comprises hydrogen (H_{TA}) and aluminium (Al_{TA}) ions adsorbed to the soil solid

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phase, particularly to SOM (McBride, 1994; Gruba and Mulder, 2015). Therefore, the potential influence of H_{TA} and Al_{TA} on stabilization of SOM remains unknown. From Hobbie et al. (2007) and Mueller et al. (2012) it can be concluded that Al_{TA} fraction plays the major role in stabilization of SOM, however, results shown recently by Gruba and Mulder (2015) suggest that H_{TA} also has a positively correlated the content of SOM, particularly in very acid soils. Other studies analysing Al_{TA} or H_{TA} are more often related to soil depth and SOM content (Skjyllberg, 1999; Lofts et al., 2001; Drabek et al., 2003), whereas information concerning the relationship between Al_{TA} or H_{TA} and the type of parent material or clay content is minimal. Many European forest soils have developed on acid parent materials, poor in base cations but rich in Al sources (e.g. Lofts et al., 2001; Brożek and Zwydak 2003; Drabek et al., 2003; Gruba and Mulder, 2015; and many others). Also parent materials of the investigated area represent two types of acid sedimentary deposits with variable texture (Gruba et al., 2015), dominated by quartz with minor admixture of kaolinite. Kaolinite is a major potential source of Al_{TA} in the investigated soils.

The objective of this research was to investigate the influence of parent materials on the components of soil total acidity, including pH Al_{TA} and H_{TA} , as well as other related soil properties, and these components effect on the accumulation of SOM in acid forest soils under silver fir (*Abies alba* Mill.) stands. We investigated mineral A horizons of soils derived from two different types of parent material of similar mineral composition but with variable texture (from sands to loams).

2. Materials and methods

2.1. Study site

The study site, located on the Mesozoic shield in the Świętokrzyskie Mountains of central Poland, covers 9.8 km² in the central part of a fir forest managed by the State Forest Administration (Fig. 1). The dominant tree species is silver fir (*A. alba* Mill.) with a minor admixture of European beech (*Fagus sylvatica* L.). There has been no previous disturbance to the soils in the study area because the forest has grown from natural regeneration.

The terrain at the study site was gently inclined to the NW and the elevation varied from 290 to 412 m above sea level. According to the Detailed Geological Map of Poland (1:50,000, sheets 778 and 779, Polish Geological Institute, Krajewski, 1955), the local soils are derived from two types of parent material (Fig. 1): Triassic sandstones (TS) and Quaternary sands (QSW). The QSW are derived from the material washed from weathering of sandstones. Authors who investigated mineral composition of Triassic sandstones from the Świętokrzyskie Mountains consist mostly of different-sized quartz and relatively small admixtures kaolinite and hematite. The soils were classified as Dystric Cambisols, usually developed from TS, and Haplic Luvisols (Abruptic), derived from QSW (WRB, 2006).

2.2. Sampling scheme

Plots were set up on a regular 200 × 200 m grid. Only plots in which silver fir was a dominant species (>60% of the total above ground biomass, with minor admixture of European beech) were chosen for this investigation (76 plots). Additionally, at randomly selected locations in pure fir stands, another 10 plots were set up (Fig. 1). Based on geological map of the investigated area, we split plots into two groups: with soils developed from TS (33 plots) and from QSW (53 plots). Each plot was represented by one sampling point located at the plot's centre. The depth of the surface organic horizons (O) was measured but no soil was taken. Next, the depth from the surface of the mineral topsoil (A or E) horizon was measured and sampled, as an approximate 20 × 20 cm block of soil.

2.3. Laboratory analysis

Living roots were removed prior to soil sieving. Soil samples were air-dried for about 1 week at room temperature, and then sieved with a 2-mm sieve. The particle size composition was determined using laser diffraction (Analysette 22, Fritsch, Idar-Oberstein, Germany). The soil pH in water extracts (pH_w) or in 1 mol dm⁻³ KCl (pH_{KCl}) solutions was measured electrochemically with a combination electrode in a suspension (1:5 mass-to-volume ratio) after 24 h of equilibration (Buurman et al., 1996). The content of exchangeable base cations

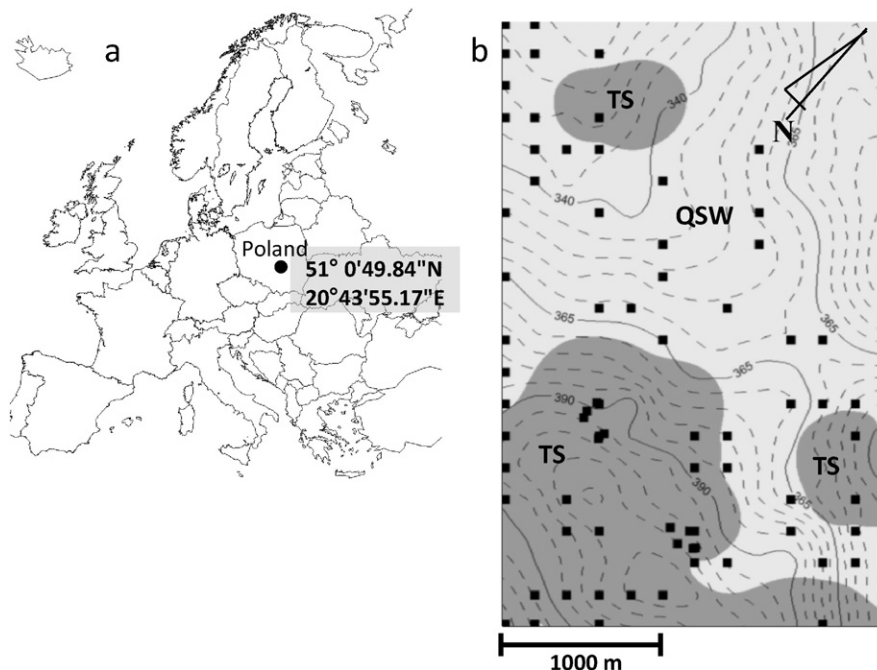


Fig. 1. a) Location of the investigation sites in Europe and Poland, b) the generalized geological map developed based on a detailed geological map of Poland. TS, Triassic sandstones; and QSW, Quaternary sands derived from the material washed from weathering sandstones. Black squares indicate the investigation sites.

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