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Geoderma 129 (2005) 81–91

GEODERMA

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Accumulation and properties of soil organic carbon at reclaimed sites in the Lusatian lignite mining district afforested with *Pinus* sp.

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Available online 23 February 2005

Abstract

The accumulation of organic carbon mainly derived from litter fall and necromass (Corg recent) has been investigated within the forest floor horizons and the mineral topsoil (0–4 cm and 4–10 cm) at reclaimed forest stands of the Lusatian lignite mining district as well as on an undisturbed forest stand in the general region, planted with *Pinus sylvestris* (L.) or *Pinus nigra* (Arnold). Recently formed organic carbon (Corg recent) was differentiated from organic carbon derived from lignite and lignite derivatives (Corg geogenic), which are inherent in the dumped substrate at post-mining sites, by ^{14}C measurements. Total organic carbon (TOC) was characterized by ^{13}C CPMAS NMR spectroscopy. The storage of TOC, Corg recent, Corg geogenic, and of organic carbon structures was examined. We found that the accumulation of Corg recent increased with stand age at all investigated stands. The results indicate that at the reclaimed stands accumulation of Corg recent takes place in the same order of magnitude when compared to the undisturbed stand. Storage of TOC in the mineral topsoil (0–10 cm) amounted from 2.6 kg m^{-2} to 7.0 kg m^{-2} at the reclaimed stands and to 2.6 kg m^{-2} at the undisturbed stand. At reclaimed stands TOC in the mineral topsoil can be attributed mainly to Corg geogenic. The calculated pools of Corg geogenic effect physico-chemical soil properties. Our results indicate that Corg geogenic in the substrate may compensate in part the lack of soil organic matter derived from soil development as storage for nutrients and water.

Keywords: Soil organic matter; ^{13}C NMR; ^{14}C-AMS; Lignite; Reclamation; Soil development

1. Introduction

During the last 150 years in the Lusatian lignite mining district (Germany), more than 80,000 ha have been turned into dumps by open cast mining. Today, about 30,000 ha of the 80,000 ha still remain to be reclaimed. About 60% of the post-mining landscapes are afforested or will be afforested. *Pinus sylvestris* (L.) stands occupy more than 30% of the post-mining areas. *Pinus nigra* (Arnold) has been planted at sites with more extreme environmental conditions. Most of the overburdened material in the post-mining areas consists of a mixture of Quaternary and carboniferous Tertiary sandy sediments. This substrate is characterized by a lack of pedogenic organic carbon derived by soil development, low pH values, and an insufficient nutrient supply (Waschkies and Hüttl, 1999; Hüttl and

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doi:10.1016/j.geoderma.2004.12.034

Weber, 2001). One of the questions of major interest in forestry recultivation is whether sustainable forest ecosystems can develop at these sites. It is well known from research into undisturbed sites that the formation of soil organic matter (SOM) is of importance to the sustainable development of forest ecosystems. Especially in sandy substrates, SOM serves as important storage component for water, nutrients, and energy.

In the Lusatian lignite mining district, the overburdened materials often contain lignite (Fig. 1). Additionally, alkaline ash derived from lignite combustion processes applied for soil amelioration purposes and airborne immissions of fly ash from power plants and of lignite dust from briquette factories, may be other sources for Corg geogenic in the soil. During ecosystem development, recently formed organic carbon (Corg recent) derived from plant residues in the stand is intermixed with lignite or lignite derivatives containing geogenic carbon (Corg geogenic) in the soil.

In this context, we quantified the formation of Corg recent in the first decades of soil development and differentiated it from the supply of Corg geogenic in stands planted with *P. sylvestris* (L.) or with *P. nigra* (Arnold) at three post-mining sites in the Lusatian mining district as well as at one undisturbed *P. sylvestris* stand in the general region. Pools of total organic carbon (TOC), Corg recent, and Corg geogenic were calculated. The chemical structure of TOC was characterized by ^{13}C CPMAS NMR spectroscopy and the storage of organic carbon structures was assessed and interpreted with regard to its ecological impact.

2. Materials and methods

Soil development investigations were carried out at three post-mining sites as well as at one undisturbed site in the general region, which served as a reference site (Table 1). Soil samples were collected in October and November 2001 at reclaimed post-mining sites and in April 2002 after the ground had thawed at the undisturbed stand. At the investigated soil profiles, horizons were assigned according to the German Soil Classification (AG Boden, 1994). The following organic master horizons were distinguished: L (litter horizon), F (fermentation horizon), H (humification horizon), and M (living moss layer). Samples were taken from the L, F, and H horizons, as well as from the mineral topsoil at depths of 0–4 cm and of 4–10 cm. From each layer, a high amount of single samples was collected and combined afterwards. Before the chemical analyses were carried out, samples were dried for 24 h at 40 °C and intensively homogenized. Samples of the mineral topsoil and of the H horizons were sieved <2 mm.

TOC was measured by IR detection (CNS-Element analysator, LECO). Corg recent was differentiated from Corg geogenic by ^{14}C measurements using the

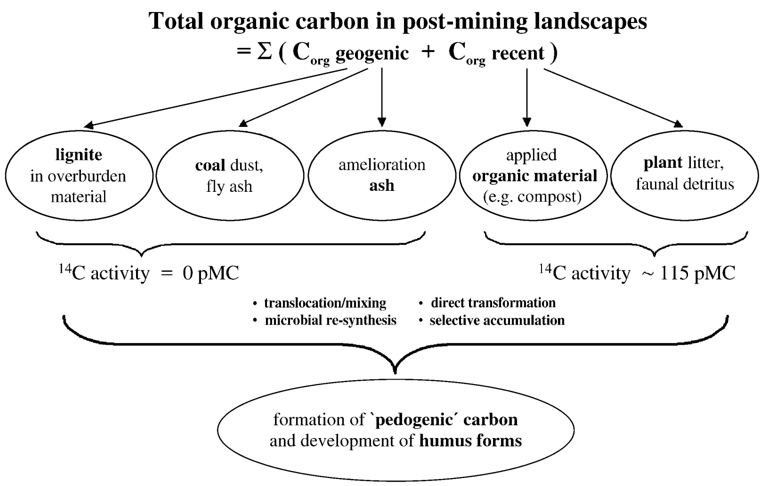

Fig. 1. Organic carbon sources in lignite containing mine sites (after Rumpel et al., 1999, altered, and Hüttl and Bens, 2003).