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Loss of soil organic matter upon ploughing under a loess soil after several years of conservation tillage

Heinz-Josef Koch *, Nicol Stockfisch

Institut für Zuckerrübenforschung, Holtenser Landstr. 77, 37079 Göttingen, Germany

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Abstract

Restricting tillage to shallow-mixing operations as conducted in many conservation tillage systems occasionally causes problems such as compaction of the formerly ploughed layer or severe weed and slug infestation. To overcome these constraints, one moulboard ploughing operation is carried out and, subsequently, cultivation is shifted back to non-inverting shallow-mixing tillage. This study investigated the effect of one single ploughing action conducted after several years of conservation tillage on the amount of organic matter in the soil profile. It was hypothesized that soil organic carbon (SOC) and soil nitrogen (SN) stocks decrease very rapidly during the first few months after ploughing.

The study was carried out in temperate climate on three adjacent fields with loess-derived soil (Stagnic Luvisol) located in southern Lower Saxony, Germany. The crop rotation included sugar beet (*Beta vulgaris* L.), winter wheat (*Triticum aestivum* L.), winter barley (*Hordeum vulgare* L.), and white mustard (*Sinapis alba* L.) as a catch crop. Conservation tillage started in 1992 on all fields and consisted of 30 cm deep non-inverting tillage combined with shallow-mixing (10 cm deep) operations. Mouldboard ploughing (30 cm deep) was conducted once in each field in August 1998–2000 prior to sowing of mustard. Thereafter, shallow conservation tillage (10 cm) was established. Soil samples were taken once before and at three dates (1–6 months, 7–9 months, 1.5–2.5 years) after ploughing and masses of SOC and SN were determined.

After 7–9 years of conservation tillage, SOC and SN were concentrated in the top 10 cm layer of the soil. One ploughing operation resulted in a substantial loss of organic matter. At 0–30 cm soil depth, losses of 0.26 kg m^{-2} SOC and 0.046 kg m^{-2} SN occurred within 1–6 months after ploughing, accounting for 4 and 7% of the total initial masses, respectively. At the soil layer of 0–45 cm, these early losses were much lower (2% and 5% of the initial masses of SOC and SN per unit of soil area, respectively), caused by an increase of masses in the 30–45 cm depth. Further losses of SOC and SN from the 0–30 cm layer were small, while from the lower layer a second pronounced loss of organic matter occurred. After 1.5–2.5 years after ploughing, losses from the 0–45 cm depth accounted for 6% and 10% of the initial total mass of SOC and SN, respectively.

In temperate climate, one ploughing operation after several years of conservation tillage obviously causes a partial loss of organic matter within a few weeks after ploughing.

Keywords: Conservation tillage; Mouldboard ploughing; Soil organic matter; Soil organic carbon; Soil nitrogen; Organic matter decomposition

* Corresponding author. Tel.: +49 551 5056250; fax: +49 551 5056299.
E-mail address: koch@ifz-goettingen.de (H.-J. Koch).

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1. Introduction

Conservation tillage omitting annual deep ploughing is accepted to reduce water erosion (Andraski et al., 1985), to improve soil quality (Franzluebbers, 2002), to sequester carbon in soils and, thus, to alleviate global climate change (Lal et al., 1999; ECCP, 2003). In the past decade, application of conservation tillage practices has considerably increased in several regions of Germany (Schmidt et al., 2002; Reich and Wurlitzer, 2004). About 25% of the national sugar beet crop was grown with conservation tillage in 2002 (Merkes et al., 2003). Although the environmental benefits are obvious, for the farmers cost reductions are the primary driving force to apply conservation tillage practices, predominantly consisting of non-inverting shallow-mixing tillage operations (Wegener, 2001; Tebruegge and Boehrnsen, 2003). The potential for reduction of machinery costs is especially high if these techniques are implemented for all crops grown on a farm during at least several consecutive years (Becker, 1997). Long-term conservation tillage may, however, decrease yields due to soil compaction in the lower layers of the previously ploughed horizon (Meyer et al., 1996; Ahl et al., 1998) or due to increased weed and slug infestation (El Titi, 2003a, 2003b; Turley et al., 2003), mostly caused by management decisions inappropriate for the local conditions.

In order to alleviate such problems, farmers tend to plough soils under once after several years of non-inverting tillage. Thereafter, tillage is shifted back again to non-inverting shallow-mixing operations.

While numerous literature exists on carbon sequestration through the use of no-till and other conservation tillage practices (Rasmussen and Collins, 1991; Lal et al., 1999; ECCP, 2003), studies on changes in soil organic matter after mouldboard ploughing of previously unploughed soil are scarce (Pierce et al., 1994; Larney et al., 1997; Stockfisch et al., 1999). In a loess-derived soil SOC and SN masses tended to be higher after 20 years of shallow cultivation compared to continuous 25 cm deep mouldboard ploughing (Stockfisch et al., 1999). This enrichment was lost within the first 5 months after ploughing once in autumn.

The objective of the study presented was to investigate the time course of SOC and SN changes at different soil depths due to ploughing under a multi-year non-ploughed soil. It was hypothesized that SOC and SN is completely redistributed in the ploughed layer and, additionally, SOC and SN stocks decrease very rapidly during the first few months after the ploughing operation.

2. Materials and methods

2.1. Site description

In autumn of 1992, a long-term field experiment was established in temperate climate (Fig. 1) near Goettingen (Lower Saxony, Germany, 51°30′N, 9°56′E) to study the effects of three different tillage

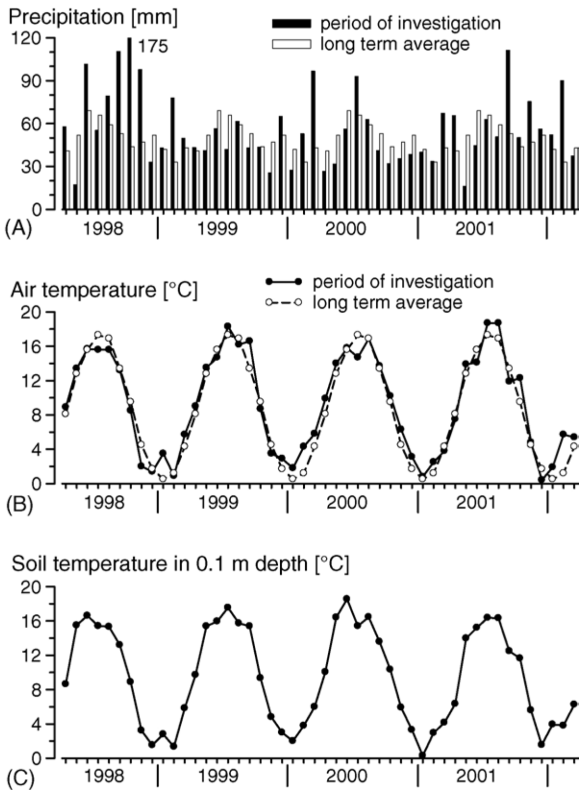

Fig. 1. Monthly precipitation (A), mean monthly air temperature 2 m above ground (B) and mean monthly soil temperature in 0.1 m depth (C) during the period of investigation as compared to the long-term average (long-term averages only for A and B). The mean annual precipitation at Goet tingen is 601 mm and the mean annual air temperature is 8.8 °C (40-years' average 1952–1991).