Soil & Tillage Research 154 (2015) 136–144

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

# Soil physical quality in contrasting tillage systems in organic and conventional farming

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ARTICLE INFO

*Article history:*
Received 10 March 2015
Received in revised form 26 June 2015
Accepted 29 June 2015
Available online 24 July 2015

*Keywords:*
Reduced tillage
Conventional farming
Organic farming
Soil physical quality
Soil carbon

ABSTRACT

Reduced tillage can improve soil physical quality relative to mouldboard ploughing by lessening soil disturbance, leaving organic matter at the soil surface, and stimulating soil biological activity. In organic farming, continuous ploughing may negate benefits to soil structure and function from increased use of manures and more diverse crop rotations, which are particularly important components of organic farming. The current study examined soil physical quality (i.e., properties and functioning) of a 4-year old reduced tillage system under organic and conventional farming with crop rotations that included root crops. Reduced tillage was compared to conventional mouldboard ploughing (MP) in 2 organic fields at different points of the same crop rotation (Org A and Org B) and 1 conventional field (Conv A). Reduced tillage consisted of non-inversion tillage (NIT) to 18–23 cm depth whereas MP was characterised by annual mouldboard ploughing to 23–25 cm depth. NIT improved soil water retention in Org B but had no effect in Org A. NIT increased soil aggregate stability at 10–20 cm depth compared to MP in all fields, and additionally at 0–10 cm in Conv A. Penetration resistance was higher in NIT in all fields. Furthermore, soil organic matter content was higher in NIT than MP at 0–10 cm depth in all fields and at 10–20 cm in Org B and Conv A. NIT increased carbon stocks in Org B but not in Org A. NIT statistically increased crop yields in spring wheat/faba bean mixture in Org A, and there was no yield penalty from NIT in Org B spring wheat nor Conv A sugar beet. In contrast, field-saturated hydraulic conductivity in all fields in autumn was lower in NIT. Differences in crop (i.e., phase of rotation) and associated organic inputs between Org A and B likely accounted for the differences in effects of tillage system. Overall, the NIT system improved or imposed no penalty on soil physical quality (except field-saturated hydraulic conductivity) and improved or imposed no penalty on crop yields and could therefore be considered as a viable alternative for farmers.



## 1. Introduction

Reduced soil tillage systems aim at improving soil physical quality and at decreasing risk of drought and water logging. Reduced tillage systems also known to increase soil organic matter, improve soil biodiversity, and reduce production costs (El Titi, 2003; Morris et al., 2010; Soane et al., 2012). Conventional mouldboard ploughing systems invert soil during primary tillage operations to control weeds, incorporate organic material (i.e., crop residues and manures), and loosen top soil. Mouldboard ploughing (MP), and tillage in general, increase porosity on the short term but decrease stable soil aggregation over the long term (Bronick and Lal, 2005), and can reduce soil organic matter content, deteriorate soil structure, lower water-holding capacity, and compact subsoil (Lal et al., 2007; Munkholm et al., 2008).

Reduced tillage increases soil stability due to less physical disruption of aggregates (D'Haene et al., 2008), soil carbon may increase from greater protection inside aggregates and less exposure to oxygen (Kay and Vandenbygaart, 2002), and subsoil compaction may be decreased if machinery only drives on the soil surface and not the subsoil as is often done in MP (Chamen et al., 2003). Reduced soil disturbance that promotes soil life may increase soil organic matter content and improve macroporosity and thereby infiltration rates (Martens and Frankenberger, 1992). However, reduced tillage systems have also been shown to increase medium sized water holding pore volumes while decreasing large water conducting pores (Rasmussen, 1999). Soils under reduced tillage systems in northern Europe tend to warm

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http://dx.doi.org/10.1016/j.still.2015.06.018

slowly in spring because of high water contents that reduce trafficability, seedling emergence, and crop yield (Rasmussen, 1999; Soane et al., 2012).

Non-inversion tillage, and reduced tillage more broadly, tend to cause increases in bulk density due to natural reconsolidation (Ahuja et al., 1998) and are therefore at risk of lowering yield (Arvidsson et al., 2014). In a meta-analysis of European studies that investigated the effects of tillage systems (conventional, reduced, and no-tillage) deep reduced tillage (>0.15 m depth) only decreased yields for maize and not for root crops, and in many cases yield losses were compensated by lower production costs (Van den Putte et al., 2010).

Reduced tillage systems such as non-inversion tillage (NIT) are implemented as an alternative to systems with MP as primary tillage in temperate north-western European conditions. NIT may consist of sub-soiling or chiseling at shallower depth and can be used in crop rotations that include root and tuber crops that require intensive soil disturbance during ridge building and are subjected to compaction from heavy harvesting machinery (D'Haene et al., 2008). In addition to tillage system and main crop, the soil physical environment is also affected by farming system, cover crop, and trafficking. Organic and conventional farming systems have been compared in The Netherlands. Organic farming may have higher soil water supply capacity and thus higher potential water-limited crop yields relative to conventional farming (Droogers et al., 1996). Organic farming may also yield higher soil organic matter content and stable aggregation than conventional farming but may cause higher risk of soil compaction (Droogers et al., 1996; Pulleman et al., 2003). There is a particular lack of studies focusing on reduced tillage in organic farming (Gadermaier et al., 2012). Confirmation, therefore, is needed on the effects of NIT on soil physical quality in organic and conventional farming under Dutch soils and crops.

NIT affords an increased window of opportunity for cover crops where ploughing would normally occur in autumn which may bring additional effects to soil physical quality. Cover crops are acknowledged to promote soil and ecosystem functions, in particular cover crops benefit soil carbon and nitrogen, weed suppression, and erosion control (Schipanski et al., 2014). Crops with deep tap roots, radish for example, have been reported to decrease soil compaction since they are able to penetrate and loosen compacted soils (Hamza and Anderson, 2005).

The objective of this study was to compare NIT to the standard MP practice in terms of soil physical functions (i.e., soil water retention and field-saturated hydraulic conductivity), soil structural parameters (i.e., aggregate stability, penetration resistance, and bulk density), soil organic matter, and crop yield. In addition, we aimed to assess the effect of non-inversion tillage on soil organic carbon stocks and depth distribution along the soil profile.

## 2. Materials and methods

### 2.1. Site description

The study was carried out at the PPO Lelystad experimental farm (52 ° 32′N, 5° 34′E) of Applied Plant Research Wageningen UR, The Netherlands. The soil is a calcareous marine clay loam (22% clay, 10% silt, 68% sand), with a pH of 7.9. Average annual temperature is 9.7 °C and average annual precipitation is 825 mm (Royal Netherlands Meteorological Institute, 2013).

### 2.2. Experimental design

The research farm maintains a set of fields under conventional farming and organic farming that contain the tillage experiments (Fig. 1). Two fields under organic farming and one field under conventional farming were used in this study. All fields contained the same tillage systems arranged in randomised complete block designs with 4 blocks. Tillage systems were mouldboard ploughing (MP) and non-inversion tillage (NIT). Organic field A (Org A) and Organic field B (Org B) are separated by approximately 200 m (Fig. 1). Fields became certified organic in 2004 (certification number: 006211). Org A, Org B, and Conventional field A (Conv A) from Crittenden et al. (2014) are used here.

After the last ploughing of all plots in autumn 2007 the experimental tillage systems were established in autumn 2008 in both conventional and organic fields. Soil was subsoiled to 30 cm depth to break up the existing plough pan at the start of the experiment. All farm operations, except harvest and ploughing, are performed using controlled-traffic farming permanent tracks

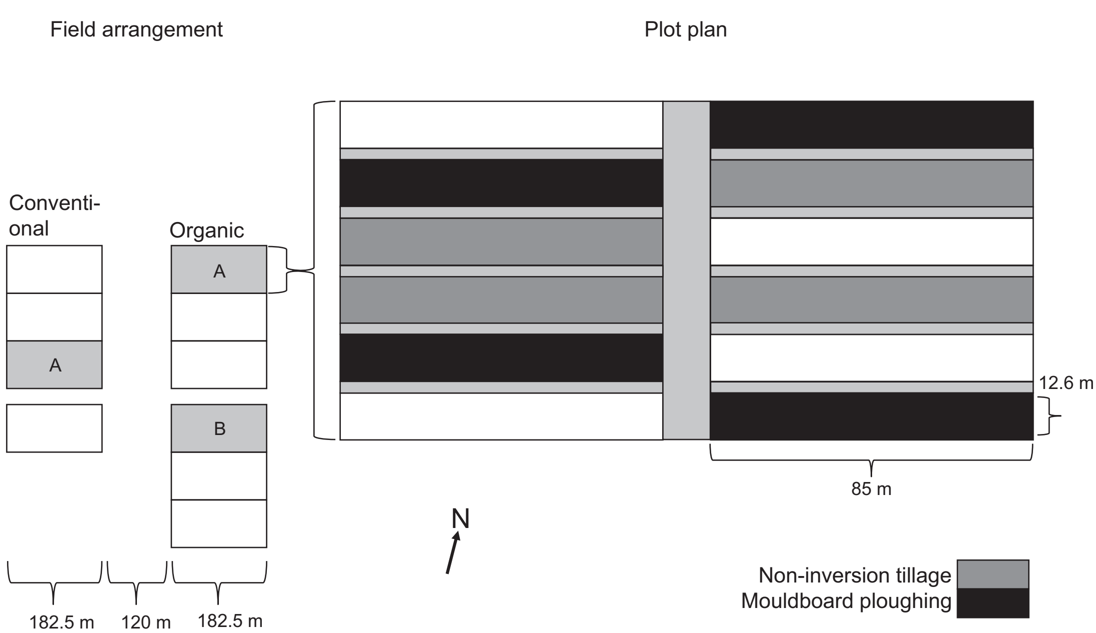


**Fig. 1.** Arrangement of experimental fields and plots.