Soil Quality Changes in Field Trials Comparing Organic Reduced Tillage to Plough Systems across Europe

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Introduction

Conserving and improving the fertility and quality of the limited soil resource to produce food, feed and fibre has always been the key to organic farmers' management practices. This issue is also addressed in conservation agriculture systems that give up on soil tillage (no-tillage) or reduce tillage intensity, but often build on the extensive use of herbicides and mineral fertilizers. Both systems show advantages for soil quality (Holland, 2004; Mäder et al., 2002) and therefore their combination is promising and may provide better soil quality. Challenges of introducing no- or reduced tillage systems into organic farming are increased weed pressure, retarded mineralization of nutrients that both may lead to reduced crop yield (Peigné et al., 2007). Pioneer farmers have developed solutions and new machinery to be applicable in organic farming systems. Comparisons of reduced tillage to the traditional plough system have started on farms and systematic research started a decade ago. It was the aim of our research activities, accomplished within the frame of the European network TILMAN-ORG (www.tilman-org.net), to evaluate changes in soil carbon stocks and biological soil fertility parameters in soils from European field trials that compared reduced primary soil tillage options with standard procedures (mainly plough). The selected sites represent a geo-climatic gradient from the North-East to the South-West. The hypothesis was that reduced tillage is enhancing the stratification of soil organic matter, soil microbial biomass and activity, and is changing microbial community structure and microbial functions.

Material and methods

Soil samples for carbon stock changes were taken in spring 2012 from replicated field plots of short- (< 2 yrs.), medium- (2-7 yrs.) and long-term (> 7 yrs.) field trials comparing reduced tillage, minimum, or no tillage and plough in Scheyern and Frankenhausen (DE), Thil (FR), Windpassing (AT), Fischbach (LU), Gallecs (ES), and Frick (CH), as well as the use of green manures in Tartu (EE) and San Piero a Grado (IT). Soil strata were sampled according to tillage depths and from the deepest tillage depth down to 50 cm. Ten to 15 soil cores from each replicate field plot were combined to one bulk sample per plot and soil layer. Bulk density was measured in the middle of each sampled soil layer. Soil organic carbon was measured by wet oxidation (Nelson and Sommers, 1996). Soil samples from Scheyern (Start: 1992; chisel plough 15 cm, cultivator and rotary harrow 5 cm; sandy loam) (Reents et al., 2008; Sprenger, 2004), Thil (start 2004; plough 30 cm, shallow plough 18 cm, chisel 15 cm, superficial (5 cm) or no tillage with crimper roller; sandy loam) (Vian et al., 2009) and Frick (start 2002; plough 15 cm, stubble cleaner 5 cm with occasional loosening at 15 cm; clayey loam) (Gadermaier et al., 2012) were studied in more detail: Dissolved organic carbon was analysed by infrared spectrometry. Soil microbial biomass was analysed by chloroform fumigation extraction according to Vance et al. (1987). The soil bacterial and fungal diversity has been determined by amplicon tagging of 16S and ITS rRNA genes to determine microbial genotypes as well as phospholipid fatty acid (PLFA) fingerprints to analyse the microbial phenotype (analyses on-going). Dried samples were used for soil chemical analyses, field moist samples were stored at 4°C for soil microbial biomass and samples for DNA and PLFA analyses were kept frozen at -80°C.

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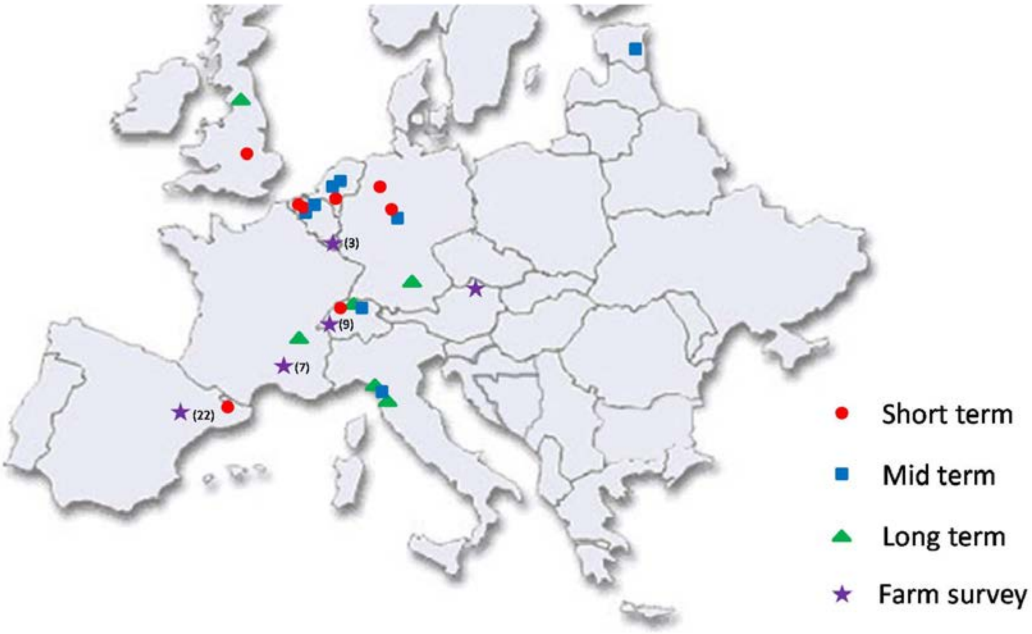

Figure 1. Field trials and farm surveys under investigation in the European network TILMAN-ORG.

Preliminary results from 9 field trials across Europe as shown here will be presented in more detail including hitherto not accomplished soil biological assessments.

Results

Soil organic carbon (SOC) content decreased significantly with soil depth in all soils. Ploughed soils showed a relatively homogenous distribution of SOC within the plough layer but decreased sharply thereunder. The reduction in primary soil tillage intensity and depth caused a relative accumulation in the uppermost soil layer being most important in no tillage soils. In Windpassing (AU) SOC in the uppermost layer was higher in reduced (stubble cleaner) as compared to plough (p=0.05), whereas below this horizon the ploughed soil showed higher SOC values than the reduced tilled one (p=0.05). In the soil beneath the plough layer that has not been tilled at all, SOC ranged between 0.7 and 1.4% across all sites. Compared to this soil layer, where differences between ploughed and unploughed soils at each site were small, SOC in the plough layer was higher by the factor 1.5 to 1.9. In reduced tillage soils this factor ranged between 1.7 and 3.2 for the uppermost layer (0-10 cm) and 1.3 to 2.1 for the layer beneath (10-20 cm). In minimal tillage soils in Scheyern this factor was 2.5 as compared to 1.9 in reduced tillage. Reduced tillage soils over all study sites showed a topsoil (0-10 cm) accumulation of SOC by 15 to 35% as compared to the plough system.

SOC stocks that consider bulk densities in each soil layer showed a decrease with soil depth. Over the 50 cm sampling depth, SOC stocks in reduced tillage soils were not significantly different from those under plough use. In the top ten cm SOC stocks were higher for reduced tillage in Frick and Windpassing and for no tillage in Thil as compared to plough (p=0.05).

Dissolved organic carbon (DOC) decreased with soil depth, except for the site Windpassing, where DOC increased strongly by the factor 5 in the ploughed soil and by the factor 8 in reduced tillage soils. The decrease in DOC was generally stronger in reduced tillage soils than in ploughed soils. In the uppermost soil layer of reduced tillage soils DOC was between 28 and 70% higher than in ploughed soils.

Soil microbial biomass carbon (C_{mic}), as an active soil organic matter pool, also showed a stronger stratification in reduced tillage soils as compared to ploughed soils. Compared to the untilled soil layer below the deepest tillage depth C_{mic} in the topsoil layer of ploughed soils was higher by the factor 2 to 2.9. This factor in reduced tillage soils was 3.4 in Frick and 4.2 to 5.5 (no tillage) in Thil. A repeated analysis with Thil soils in 2013 confirmed these results also for microbial biomass nitrogen. In Scheyern this comparison showed a factor of 2.3 in reduced tillage soils and 3.1 with minimum tillage.

Table 1: Significant soil tillage effects in field trial soils on SOC content (C_{org}) and stocks, dissolved organic carbon (DOC) and microbial biomass carbon (C_{mic})

Site	Tillage	Depth [cm]	C_{org} [%]	C-stock [g m^{-2}]	DOC [µg g^{-1}]	C_{mic} [µg g^{-1}]
Scheyern DE	Chisel 18cm (C) *vs.* Rotary harrow + Cultivator 8cm (R)	0-10	R > C	n.s.	n.s.	n.s.
		10-25	n.s.	n.s.	n.s.	n.s.
		25-50	n.s.	n.s.	n.s.	n.s.
Frick CH	Stubble cleaner 5-7 cm (R) *vs.* plough 15cm (P)	0-10	R > P	R > P	R > P	R > P
		10-20	n.s.	n.s.	n.s.	R > P
		20-50	n.s.	n.s.	n.s.	n.s.
Thil FR	Plough 30cm (P) Plough 18cm (sP) Chisel 15cm (C) No till 5cm (N)	0-10	N > all	N > P	N > P	N > P
		10-20	n.s.	N > P	n.s.	n.s.
		20-30	n.s.	n.s.	n.s.	n.s.
		30-50	n.s.	n.s.	n.s.	n.s.

Soil microbial diversity as assessed by t-RFLP analyses of 16S rRNA genes showed a significant differentiation between soil depths for the field trials in Scheyern, to a lesser extent in Frick and yet not detectable in Thil (analyses are to be confirmed). The different tillage treatments tended to influence microbial diversity patterns in Scheyern, less pronounced in Frick and yet not detectable in Thil. The intensity of change in soil microbial diversity appears to be related to the time of exposure to different tillage systems.

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Conclusions

Reduced soil tillage often leads to accumulation of soil organic matter at the soil surface resp. in the uppermost soil layers, where crop residues are mixed in. This is one of the common features of all the field trials comparing reduced tillage options with the soil inversion by ploughing. The accumulation, however, was only significant when looking at the topsoil layers. When the whole soil profile down to 50 cm depth was examined no difference between reduced tillage and plough tillage was statistically significant. The stratification of soil organic matter and organic matter fractions was more pronounced in reduced or no-tillage soils, however sometimes at the cost of contents in deeper soil layers. Long-term experiments show stronger effects than young experiments, particularly with respect to the microbial community structure.

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