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Soil Carbon Stocks, Carbon Dioxide Sequestration and Tillage Techniques

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C sequestration via agricultural soils can be accounted for, under Article 3.4 of the Kyoto Protocol, provided that specific measures are implemented. Sound cropland management can play a positive role in mitigating GHGs emissions from other sources, and carbon dioxide in particular, through a decrease of soil organic carbon (SOC) losses, an increase of organic material inputs or combining these two options. Literature data estimate about 1,500 Gg SOC to 1 m depth (Eswaran et al., 2000), in comparison with 4,000 Gg C of fossil fuels, indicating SOC as the largest sink of C after fossil fuels. Vegetation (600 Gg) and atmosphere (760 Gg) store considerably less C than soils.
Carbon sequestration can occur through a reduction in soil disturbance, since more carbon is lost as CO_2 from tilled soils in comparison with reduced or sod-seeding systems: no tillage systems may absorb on average 0.7-1.4 t CO_2 ha^{-1} yr^{-1} (INRA 2002, ECCP 2003).
This paper compares the effects of conventional tillage and sod-seeding on SOC, in a two-years rotation long term field experiment (durum wheat-sunflower 1994-01; durum wheat-corn 2002-06).

Methodology

A long term field experiment was established in 1994 at the farm "P. Rosati" of the Politechnic University of Marche, in Agugliano (43° 32' 17"N, 13° 22'03"E, 88 m a.s.l.), a hilly area (slope 12%) with a silty-clay soil classified as a Calcaric Gleyic Cambisol (FAO, 2006). We report in this paper results on the effects of SOC of two tillage techniques (C: conventional, i.e. ploughing at 40 cm depth and double harrowing, vs. S: sod-seeding) and two nitrogen fertilization rates (0 vs. 90 kg N ha^{-1}), according to a 2x2 factorial experimental design. SOC was determined in 2006 after 12 years of continuous ploughing vs. sod-seeding on 16 soil profiles, with four replications for each set of plots, i.e. CN90, CN0, SN90, SN0. The amount of SOC was determined according to Batjes (1996), considering the bulk density, the proportion of SOC, and the thickness of the layers for individual soil profiles at three depth intervals: 0-30, 30-50 and 50-100 cm; the equivalent CO_2 was derived from SOC. The availability of previous SOC determinations on four of the sixteen profiles allowed comparing SN90 and CN90 plots (depth 0-30 cm) after a period of ten years (1996-2006).

Results

Differences of carbon stocks among treatments in 2006 in the 0-100 cm soil layer were not statistically significant (table 1). This can be attributed to the relatively high coefficient of variation (19%). Differences between tillage techniques in the topsoil (0-30 cm) were significant ($P<0.05$) but not so between fertilizations. In fact, in this layer, S treatments stored +5.3 t ha^{-1} SOC more (+19%) than C treatments (i.e. +19.4 t ha^{-1} CO_2). Considering the 0-100 cm layer, 69% of the SOC was stored in the 0-50 cm layer and 44% in the 0-30 cm layer. Results indicate that, in the analysed context, tillage effects on SOC after 12 years were limited to top layers, while deeper layers were not affected. These results are in agreement with Blanco-Canqui et Lal (2008), which found in some cases SOC may be higher in plowed that in no-tilled soils.

Table 1. SOC stocks and CO_2 sequestration (t ha^{-1}) as affected by 12 years of contrasting tillage and fertiliser treatments. See text for abbreviations (means ± standard error; CV = coefficient of variation)

Layer:	0-30 cm		30-50 cm		50-100 cm		0-100 cm	
Treatment	SOC	CO_2	SOC	CO_2	SOC	CO_2	SOC	CO_2
SN90	34.3±1.7a	126±6	16.8±1.0	62±4	23.6±3.2	87±13	74.7±5.3	274±19
SN0	33.1±1.7a	121±6	18.1±1.0	66±4	20.9±3.2	77±13	72.1±5.3	264±19
CN90	28.6±1.7b	105±6	19.0±1.0	70±4	25.5±3.2	94±13	73.1±5.3	268±19
CN0	28.1±1.7b	103±6	16.2±1.0	59±4	18.8±3.2	69±13	63.1±5.3	231±19
CV	16%		17%		26%		21%	

When comparing 1996 and 2006 data (Table 2), results showed a tendentially increase of soil carbon stocks and CO_2 sequestration in the no tilled plots (SN90), and a decrease in the conventional system (CN90), with differences of the same order of magnitude, i.e. ± 0.3 and ± 1.1 t ha^{-1} yr^{-1} of SOC stocks and CO_2 sequestration respectively, the treatment x year interaction being nearly significant.

Table 2. Differences in SOC and CO_2 sequestration (t ha^{-1}) measured in the 1996-2006 interval.

Layer	0-30 cm (t ha^{-1})		0-30 cm (t ha^{-1} yr^{-1})	
Treatment	SOC	CO_2	SOC	CO_2
SN90	3.1	11	0.3	1.1
CN90	-3.0	-11	-0.3	-1.1

Conclusions

The long term field experiment provided some evidences that no till can effectively contribute to increase soil C-sink of the rainfed cereal cropping systems of central Italy. However, 12 years were just sufficient to evidence some trends and further efforts may be necessary to achieve clearer figures.

No tillage techniques are not so widespread in Italy. Recent available data from the European Conservation Agriculture Federation report 560,000 ha under conservation agriculture and only 80,000 ha under no-tillage, i.e. less than 10% of the arable land, while in central Europe figures are 30% for United Kingdom, 20% for Germany, 17 % for France.

Considering that in 2005 arable crop area in Italy was 7 million ha, assuming that our findings are applicable to such area, we could estimate a potential additional SOC stock of 2.1 million tons per year in the top soil, and a CO_2 sequestration of 7.7 million tons per year in case no-till systems are extensively used.

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