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Long Term Effects of Nitrogen Fertilization on Soil Organic Matter: Applications of the DSSAT Model

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Introduction

The conversion from natural to agricultural ecosystems and unsustainable land management and agricultural practices have often lowered the soil organic matter (SOM) content (Doran, 2002). An increase of SOM is required almost everywhere (Triberti et. al 2008), since it plays a key role to maintain sustainable cropping systems. It prevents soil degradation by limiting soil cracking and erosion, reduces pollution risks by adsorbing toxic substances, improves soil structure, plant nutrients availability and soil microbial biodiversity. Part of SOM which has been lost can be re-sequestered through adoption of recommended soil and crop management practices. DSSAT 4.02 (Jones et al., 2003) has been recently integrated with the CENTURY SOM module (Gijsman et al., 2002) and the module for tillage effects on soil processes, to simulate the long term dynamics of SOM.
The objective of this study was to analyze the long term impact of tillage and fertility management on soil organic matter fractions in a durum wheat-corn rotation in a hilly rainfed area using field experiments and model simulations. In this paper we report the results of the effect of the nitrogen fertilization on SOM.

Methodology

This study is based on a long term field experiment established at the farm of the Faculty of Agriculture of the Polytechnic University of Marche, in Agugliano (100 m a.s.l., 700 mm mean annual rainfall), in a hilly area (slope: 10-15%) with a silt-clay soil type. The experiment has been designed to compare the effects on SOM of three different soil tillage practices (no till vs 25 cm deep scarification and 40 cm deep plowing) and three levels of nitrogen fertilization (0-90-180 kg ha^{-1} N) using a split-plot randomised block design with two replicates (2 for each crop). Results reported in this paper refer to fertilization treatments under conventional tillage (ploughing). The sub-plot size was 500 m^2. Wheat and corn were alternatively sown on two adjacent groups of 6 sub-plots (3N x 2rep), so that both crops were sown every year.
The long term effect of nitrogen fertilization on SOM was simulated by DSSAT. Observed daily meteorological data (Tmax, Tmin, precipitation) from 1998 to 2006 and daily radiation estimated by Radest 3.00 (Donatelli et al., 2003) were used as meteorological inputs. Soil texture, bulk density, organic carbon, cation exchange capacity, pH, total nitrogen were measured from sixteen different soil profiles within the experimental field, while wilting point, field capacity, saturation hydraulic conductivity were estimated by pedo-transfer functions (Saxton and Rawls, 2006). Grain yield and main yield components were measured in the field for both crops. According to local farm surveys, a 50-year time interval and a durum wheat-corn rotation regularly ploughed and fertilized with 140 kg ha^{-1} of N were considered to initialize soil organic matter fractions starting from default values of model (tab. 1).

Results

Simulation outputs were consistent with field data collected from the long term trial. The long term (i.e. 12 years) dynamics of three different soil organic pools was analysed in relation to contrasting nitrogen fertilization rates (0-90-180 Kg ha^{-1}) and a conventional tillage technique. DSSAT simulations were carried out for the same time interval of the field trial (1994-2007) and results are reported as total soil organic carbon (SOC) in the upper 30 cm of soil (figure 1).

Table 1 – Soil organic matter fractions obtained after initialization, default values in brackets.

Soil texture	Depth	SOM1	SOM2	SOM3
Silty clay	0-30 cm	0.03 *(0.03)*	0.63 *(0.38)*	0.34 *(0.59)*
	>30 cm	0.01 *(0.01)*	0.09 *(0.22)*	0.90 *(0.77)*
clay	0-30 cm	0.02 *(0.02)*	0.63 *(0.34)*	0.35 *(0.64)*
	>30 cm	0.01 *(0.01)*	0.09 *(0.17)*	0.90 *(0.82)*

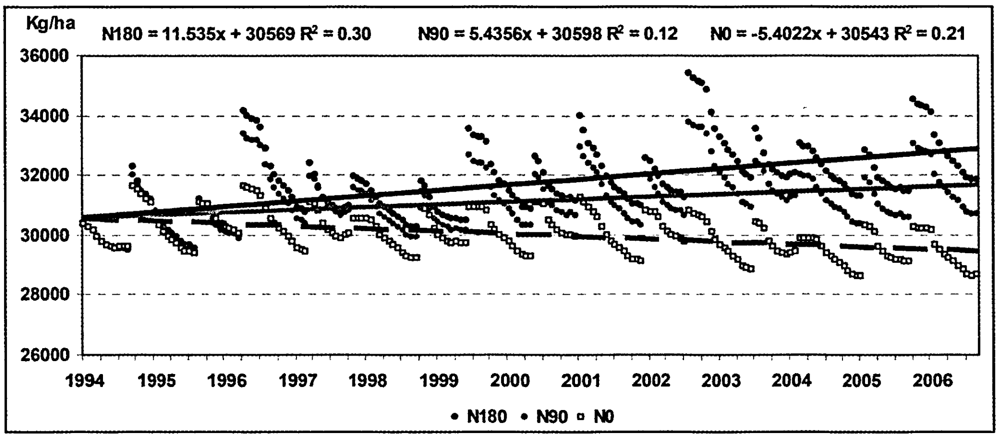

Figure 1 – Soil Organic Carbon content simulated in relation to three nitrogen fertilization levels

SOC showed a slight negative trend in the unfertilized treatment (-0.08 t ha^{-1} year^{-1}), while a slight positive trend was observed with 90 kg ha^{-1} of N (0.08 t ha^{-1} year^{-1}). The highest fertilization level (180 kg ha^{-1} of N) resulted in increased SOC sink rate (0.17 t ha^{-1} year^{-1}), mainly as a consequence of the increased SOM2, the intermediate soil organic matter pool.
However, N180 treatment leached 37.9 kg [N] ha^{-1} year^{-1}; significantly more than 23.0 and 13.6 kg ha^{-1} year^{-1} leached by N90 and N0 treatments respectively.

Conclusions

The model estimated a positive trend of SOC under N180 fertilization scheme, but, at the same time, this resulted in higher N leaching. However, leaching was mostly attributed to the long bare soil period between wheat harvest and corn seeding under conventional tillage, in a period in which soil water surplus is very likely to occur. The long term effects on SOM dynamics of different tillage techniques on soil organic carbon dynamics is being considered for further simulations with DSSAT.

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