Simulating Changes of Organic Carbon Content in Soil Following Tillage Intensity and Fertilizer N Rate Reduction

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Economic, environmental, and societal benefits are expected from good practices of soil carbon (C) management (Kimble et al., 2007). However, new tools are required for national and local policymakers to accurately estimate the effects of different agricultural management practices on greenhouse gas emissions and removals. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006), which provide methodologies for estimating national inventories of anthropogenic emissions and removals of greenhouse gases, together with the *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), provide internationally agreed methodologies for this purpose, and include the possibility of using simulation models as *higher order* methods for gas inventories in the Agriculture, Forestry and Other Land Use (AFOLU) sector. According to the *IPCC Guidelines*, models should undergo quality-checks, audits, and validations and be thoroughly documented.

Tillage intensity reduction is known to increase the soil organic C sink potential (Paustian et al., 1995; Al-Kaisi and Yin, 2005), whereas the effect on C sink of supplying soil with N fertilizer is less understood (Khan et al., 2007). The main objective of this study was to estimate the change of organic C content in the cultivated soil layer as a function of change in tillage intensity, in interaction with different fertilizer N rates. The Daisy model was used for this purpose, in view of its possible future application at regional scale for the estimation of AFOLU-related greenhouse gas emissions.

Methodology

The simulated system refers to an experiment carried out on a silty clay soil at Agugliano (Ancona, Italy), in the 1994-2006 period. The non-irrigated cropping systems were: durum wheat-sunflower, from 1994 to 2001; durum wheat-maize, from 2002 to 2006. Compared treatments were: tillage (conventional vs. no-till) × N fertilization (fertilized vs. unfertilized), in a split-plot experimental design with 2 replications. Crop residues were always left on the field. Climatic dataset was obtained from multi-year time series measurements at Agugliano (43° 54’ N, 13° 39’ E; altitude 255 m) and Jesi (43° 32’ N, 13° 17’ E; altitude 96 m). The following information was used for the model parameter setting: soil measurements (texture, organic C and Kjeldahl N); crop height at harvest (measurement-based) and maximum rooting depth (from expert-estimate). The other parameters were kept at the value suggested by the model library. The hydrological parameters were estimated by means of pedotransfer functions (Saxton and Rawls, 2006). Starting soil conditions were referred to tilled, well fertilized crops (conventional management). The soil profile was simulated up to 1.60-m depth. The simulations started on 1 Aug 1994 and ended on 31 Dec 2006.

Results

According to the model simulations, when no N fertilizer was supplied, the total organic C stock, that is surface C plus soil C in the top 0.45 m soil layer (corresponding to the mean depth of the Ap horizon, for the soil of the experiment) decreased, both in tilled and in non tilled plots (Table 1). In plots receiving N fertilizer, a net increase of total soil organic C content (surface + soil C) was simulated, higher for the non tilled (+0.90 t C ha^{-1} y^{-1}) than for the tilled plot (+0.15 t C ha^{-1} y^{-1}). According to the model, in the non tilled plots the crop-residue organic matter partly accumulated onto the soil surface as litter, was partly bioincorporated to soil. Carbon bioincorporation was higher, and soil biomass respiration lower in non tilled than in tilled plots.

Table 1. Simulated surface and soil organic C (C_{org}) balance components, in no-till (NT) and conventional tillage (CT) plots. Accumulated values for the 1994-2006 period, top 0.45-m soil layer, Agugliano (AN, Italy).

C balance components	NT unfertilized	NT + N fertilizer	CT unfertilized	CT + N fertilizer
	-----------------Kg C ha^{-1}-----------------			
Surface				
Residual top C	13,939	38,509	13,287	38,589
Bioincorporated from surface	-13,296	-25,578	-9,654	-19,303
Removed from surface by tillage	0	0	-3,633	-19,286
Change in surface C_{org} (final - initial)	**643**	**12,931**	**0**	**0**
Soil				
Bioincorporated to soil	5,310	10,214	3,855	7,708
Dead roots added to soil	3,769	9,611	3,584	9,461
Added to soil by tillage	0	0	3,633	19,286
Soil biomass respiration	-12,877	-21,522	-14,541	-34,552
Change in soil C_{org} (final - initial)	**-3,798**	**-1,697**	**-3,469**	**1,903**
Total change in the C_{org} reserve	**-3,155**	**11,234**	**-3,469**	**1,903**

The observed trends in soil total organic C content following tillage intensity reduction are in agreement with the majority of the experimental results reported by relevant scientific literature. Nitrogen fertilizer seems to positively affect the soil C sink by increasing the amount of crop-residue C that may be incorporated into the soil.

Conclusions

The results of our model simulations confirm the positive role played by the no-till management practice on soil organic C content, already observed in several, literature-reported, field experiments, and suggest a positive effect of N fertilization as well. The available soil samples from the long term field experiment will provide a benchmark for the assessment of the model performances.

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