Impacts of Climate Change on SOC Dynamic and Crop Yield of Italian Rainfed Wheat-Maize Cropping Systems Managed with Conventional or Conservation Tillage Practices

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Introduction

There is still uncertainty on the ability of conservation tillage (i.e., reduced- RT and no till - NT) in contributing to the resilience of cropping systems to climate change pressures (Powlson et al 2016). RT or NT can improve soil physical and biological proprieties thus increasing water holding capacity and fertility, stabilizing soil structure and enhancing soil biodiversity and functions. They are also frequently proposed as mitigation practices as they can contribute to increase soil organic carbon (SOC) compared to conventional moldboard ploughing practices (Gonzalez-Sanchez*et al.*, 2012). However, SOC increase occurs mostly in the upper soil layer but not always in the deeper profile (Haddaway *et al.*, 2016) where SOC measurements are less frequently measured. In this study, we used data obtained from long term field experiments(LTE) coupled with three crop simulation models in order to assess the long-term effects of different tillage management practices on crop yield and on changes in SOC stocks in both superficial (0-20cm) and deeper layers (20-50cm) in Mediterranean rainfed cereal cropping systems at current and future climate scenarios.

Methods

Two long-term experiments under rainfed conditions were utilized for this study, located in Agugliano - LTE AN (Ancona, Marche, IT; 43.32°N, 13°22°E) and San Piero a Grado - LTE PI2 (Pisa, Toscana, 43.41°N, 10.23°E) and belonging to the Italian LTE IC-FAR network (www.icfar.it).
The ANLTE (Seddaiu, 2016) is located in a hilly area with a silt-clay soil type and it is characterized by a two-year durum wheat-maize rotation. In this paper we used for the model calibration a subset of treatments of this LTE to analyze the long term effects of different soil tillage practices (NT: no till; CT: 40 cm deep ploughing, both fertilized with 90 kg ha^{-1} N) on SOC dynamics and yield.
The PI2 site (Mazzoncini *et al.*, 2011) is located in a lowland coastal area with a poorly drained alluvial loam soil with cracking-swelling properties. The site was based on a maize continuous crop from 1994 to 1998 followed by a two-year durum wheat-maize rotation until 2005. From 2005 onwards, the LTE was changed in a four-year crop rotation of durum wheat-maize-durum wheat-sunflower. In this paper we used a subset of treatments of the LTE with durum wheat and maize fertilized with 180 and 300 kg ha^{-1} N respectively and no cover crop, to analyze the effects of tillage and N fertilization on SOC dynamics and crop yield.

Experimental and weather data collected and harmonized in the common IC-FAR database (Ginaldi *et al.*, 2016) were used to calibrate CropSyst, DSSAT and EPIC. Climate scenarios were generated by setting up a statistical model, based on Canonical Correlation Analysis, using predictors from ERA40 reanalysis and the seasonal indices of temperature and precipitation from E-OBS gridded data network for the period 1958-2010. Then, the statistical downscaling model was applied to the predictors of CMCC-CM global model to obtain climate scenarios of temperature and precipitation at local scale over the period 1971-2000 (control run) and 2021-2050 (RCP45 and RCP85 emission scenarios). A CO_2 concentration of 460 ppm and 490 ppm were considered for RCP45 and RCP85 scenarios, respectively.

Results and conclusions

The performance of the models in simulating crop yields (t ha^{-1}) of the studied cropping systems was evaluated by calculating the indicators reported in Table 1.

Table 1- Performance indicators of crop yield calibration

Model	LTE	Crop		MAE*	%RRMSE*	EF*	CRM*	CD*
			Min	0.00	0.00	-inf.	-inf.	0.00
			Max	+inf.	+inf.	1.00	+inf.	+inf.
			Best	0.00	0.00	1.00	0.00	1.00
DSSAT	AN	WHT		0.59	23.33	0.54	0.02	1.71
DSSAT	AN	MZE		0.86	32.29	0.66	-0.06	1.59
DSSAT	PI2	WHT		0.85	33.99	0.24	-0.27	0.70
DSSAT	PI2	MZE		0.90	23.82	0.64	-0.03	0.86
EPIC	AN	WHT		0.36	17.84	0.73	0.04	1.72
EPIC	AN	MZE		0.44	36.99	0.86	0.07	1.52
EPIC	PI2	WHT		2.09	109.58	-6.86	-0.68	0.15
EPIC	PI2	MZE		1.40	38.85	0.04	-0.13	0.46
CropSyst	AN	WHT		0.73	28.00	-0.01	-0.01	0.36
CropSyst	AN	MZE		1.02	50.98	0.07	0.07	8.84

*MAE =Mean Absolute Error, *RRMSE%= Percentage Relative Root Mean Square Error, *EF=modeling efficiency, *CRM=Coefficient of Residual Mass, *CD= Coefficient of Determination

Considering the climate scenarios, the most negative impacts for maize were observed in the AN site with a potential yield reduction up to -41.6% assessed with DSSAT under CT in RCP45. On the contrary, wheat yields were more affected by climate change in PI2 with all models with the most negative impact -55.1% assessed by EPIC under the RCP45 scenario.

The simulation models satisfying reproduced the observed changes in SOC at different soil depths in the two sites, despite the large range of measured data. Hence, the SOC models proved to be robust over a long term period and can be effectively used to develop climate change adaptive options and assess the mitigation potential of different tillage treatments.

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