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Soil organic carbon evolution as affected by tillage and cover crops: results of a long-term modelling analysis

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An effective way to quantify the effect of conservation agriculture practices on soil carbon sequestration is modelling, which allows to consider various processes at the same time and to evaluate many what-if scenarios. The process-based crop model ARMOSA simulates crop growth, implementing the WOFOST approach but dividing the canopy into 5 layers for the light interception, calculating water dynamics with the Richards' equation. Carbon and Nitrogen related processes have been implemented following the approach of the SOILN model, but each input of C and N are considered independently, each one with its own decomposition rate and fate. Tillage is simulated as affecting bulk density (BD) and soil organic carbon (SOC) mineralization and humification. Hydrological parameters of the water retention curve are daily calculated based on BD and SOC, which are affected by tillage operations (approach proposed in the WEPP manual, 1995).
We run 36 scenarios: 3 sites in Lombardy plain (= 3, Carpaneta, Milzano, Caviaga), meteorological data (= 2, current, 1987-2017, and future, 2020-2050), 3 soil tillages (CVTA=ploughing at 0.3 m; MT=minimum tillage as harrowing at 0.1 m; NT=sod seeding), a 3-year crop rotation of maize-soybean-winter wheat-maize with and without winter cover crops (CC and NoCC, respectively). Meteorological data are made available by the JRC Joint Research Center, Agri4cast, Gridded Agro-Meteorological Data in Europe (http://agri4cast.jrc.ec.europa.eu/DataPortal/Index.aspx). A repeated measures linear mixed model was applied to the modelling results.
In general, there is a more marked effect of crop cover compared to the effect of the tillage on carbon sequestration ($p>0.001$). The effect of the cover crop was always significant in increasing the SOC and the SOC stock, in all scenarios. The combination that causes a decrease in annual SOC stock is CVTA and NoCC (-0.069 Mg ha-1 y-1). Conversely, MT and NT scenarios with cover crop (CC) resulted in the highest SOC sequestration (0.381 Mg ha-1 y-1). The differences in SOC between NT and MT were not significant.
The mean annual increase in SOC stock in the topsoil (0-0.3 m) were significantly higher in MT (0.328 Mg ha-1 y-1) and NT (0.262 Mg ha-1 y-1) than in CVTA (0.004 Mg ha-1 y-1), with no significant interaction with crop rotation and climate scenario. The future scenario was unexpectedly characterized by a higher increase, which was likely due to the limiting water content in the summer months, which caused a slowing down of the mineralization process.
These results represent a starting point for a regional and national application of the model, using use of legacy databases on land cover (CORINE land cover), soil data and maps (LUCAS and ESDAC-JRC products), and weather data (MARS, Worldclim). These activities are ongoing and planned in the LANDSUPPORT project (H2020-RUR-2017-2/No. 774234).