Application of CarboSOIL model to predict the effects of climate change on soil organic carbon stocks in agro-silvo-pastoral Mediterranean management systems

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CarboSOIL is an empirical model based on regression techniques and developed to predict soil organic carbon contents (SOC) at standard soil depths of 0-25, 25-50 and 50-75 cm (Muñoz-Rojas et al., 2013). The model was applied to a study area of north-eastern Sardinia (Italy) (40˚46'N, 9˚10'E, mean altitude 285 m a.s.l.), characterized by extensive agro-silvo-pastoral systems which are typical of similar areas of the Mediterranean basin (e.g. the Iberian peninsula). The area has the same soil type (Haplic Endoleptic Cambisols, Dystric according to WRB), while cork oak forest (*Quercus suber* L.) is the potential native vegetation which has been converted to managed land with pastures and vineyards in recent years (Lagomarsino et al., 2011; Francaviglia et al., 2012; Bagella et al, 2013; Francaviglia et al., 2014). Six land uses with different levels of cropping intensification were compared: Tilled vineyards (TV); No-tilled grassed vineyards (GV); Hay crop (HC); Pasture (PA); Cork oak forest (CO) and Semi-natural systems (SN).

The HC land use includes oats, Italian ryegrass and annual clovers or vetch for 5 years and intercropped by spontaneous herbaceous vegetation in the sixth year. The PA land use is 5 years of spontaneous herbaceous vegetation, and one year of intercropping with oats, Italian ryegrass and annual clovers or vetch cultivated as a hay crop. The SN land use (scrublands, Mediterranean maquis and Helichrysum meadows) arise from the natural re-vegetation of former vineyards which have been set-aside probably due to the low grape yields and the high cost of modern tillage equipment.

Both PA and HC are grazed for some months during the year, and include scattered cork-oak trees, which are key components of the "Dehesa"-type landscape (grazing system with Quercus L.) typical of this area of Sardinia and other areas of southern Mediterranean Europe. Dehesas are often converted to more profitable land uses such as vineyards (Francaviglia et al., 2012; Muñoz-Rojas et al., 2012) or olive groves (Lozano-García and Parras-Alcántara, 2013).

The local climate is warm temperate with dry and hot summers, with a mean annual rainfall of 623 mm (range 367–811 mm) and mean annual temperature of 15.0?C (13.8–16.4?C).

Climate change scenarios were generated from the baseline climate with two Global Climate Models: GISS (Goddard Institute of Space Studies, USA), and HadCM3 (Met Office, Hadley Centre, UK), for two of the Intergovernmental Panel on Climate Change (IPCC) emission scenarios (A2 and B2). Three time horizons were chosen for climate change projections: 2020, mean climate change for the period 2010–2039; 2050 for the period 2040–2069; and 2080 for the period 2070–2099, providing respectively a very close, an intermediate, and a fully realized climate change scenario.

The agreement of model predictions with the measured values of soil organic carbon stocks was tested using the correlation coefficient R^2, the root mean square error RMSE and the modelling efficiency EF. For a good model performance, RMSE should have approximately the same order of magnitude of the standard deviation, while EF should be positive and close to 1. With reference to the three soil depths (0-25, 25-50, 50-75 cm), R^2, RMSE and EF are in the range 0.76-0.99, 5.07-8.42, and 0.63-0.98 respectively. CarboSOIL predictions are fully acceptable since the linear regression coefficients are always significant at p<0.001 and R^2 are high, the standard deviation of the measured values is in the range 11.09-19.53, i.e. higher than RMSE, and EF is very close to the optimum value.

CarboSOIL model predicted an overall increase of SOC stocks in the 2020 climate scenarios in all the soil sections, with the higher increases in the 50-75 cm section, and the smaller in the 25-50 cm soil section. A SOC decrease is instead expected in the 2050 and 2080 scenarios in the 25-50 cm soil section, more marked in the vineyards in comparison with the other land uses. Oppositely, SOC increases are still expected in the 0-25 cm section and to a more extent in the 50-75 cm section, particularly evident in the vineyards.

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