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Uncertainties in estimating the soil carbon sequestration service

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Carbon storage is as a key function of soils, and several studies underpinned its capacity as a critical ecosystem service to contribute mitigating climate changes. Scientists have focused on estimating soil organic carbon stock (SOCs, in kg C/ha), associated with the services regulation of carbon sequestration. SOCs relies on estimates of SOC concentration (SOCc, in g/kg), bulk density (BD) and coarse fragment content (CRF) of the target soil depth. SOCc is usually measured with precision in elemental analysers; however, BD and CRF are often missing. In the available databases, CRF is frequently estimated visually or even ignored (being the greatest uncertainty in SOCs estimates). The general absence of these parameters leads to unrealistic predictions with systematic errors propagation in the calculation of the SOCs. Therefore, the accuracy of its prediction will depend on the availability and quality of the data as well as the calculation approaches. The aim of this study was to evaluate the accuracy of SOCs and SOCc predictions on different available soil mapping products and analyse their uncertainty.

A Mediterranean area was selected in southern Iberia Peninsula (The Region of Murcia) being particularly vulnerable to global environmental change and land degradation. We evaluate six available soil carbon products including global, European, national and local SOC estimates. We compare descriptive statistics and exploratory data analysis tool (such as boxplot and Tukey test at 95% confidence interval) for SOCs and SOCc, respectively. An external local database (255 soil profiles) was used to perform independent validation, using the R^2 and RMSE as information criteria. For this validation, the SOCs was calculated in each horizon of the local database using SOCc, BD and CRF data. The gaps in BD were estimated throughout pedo-transfer function locally adapted. We convert each soil profile of this database to a 0-30 cm standard depth. This standardization was carried out using the equal-area spline. Subsequently, we generated a local map of SOCs and SOCc, and their associated uncertainties, based on tree-based machine learning. To generate the map the point values of SOCc and SOCs were spatially predicted using soil environmental covariates.

The results showed a high diversity of estimates among stock maps ranging from 73,364 GgC to 27,763 GgC, and the Tukey test depicted significant differences among all cases, not being the case for SOCc estimation. The external validation revealed a poorer fit in the carbon stock (R^2= 0.03 and RMSE= 22.82) than the carbon concentration, with the best-fit values of R^2= 0.53 and RMSE=14.74.

Furthermore, all the SOCs products showed overestimated values ranging from 44% to 164% over the estimates of generated maps.

Despite the global interest of a detailed and quantitative information of carbon stock, the poor quality of their parameters can leads to inaccuracy and overestimation prediction. It is due to a high propagation of parameter uncertainty, hence it is essential the uncertainty assessment in SOCS modelling to evaluate the soil carbon sequestration services.