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Improving Soil Organic Carbon stock estimates in agricultural topsoil at a regional scale using a Stochastic Gradient Boosting technique

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Agro-ecosystems have a paramount importance as a source of goods and incomes and have a highly unexpressed potential to mitigate greenhouse gasses (GHG) emission. In agro-ecosystems, Soil Organic Carbon (SOC) is recognized as the most important trait to be managed in order to maintain soil fertility and ecosystems services. Accurate laboratory analysis is indeed the best way to investigate soils. However, it is expensive and time consuming when aiming at gaining information on large areas such as an entire district or region. Remote Sensing (RS) is recently offering increasingly detailed Digital Elevation Models (DEMs) and low-cost multispectral satellite imagery. Moreover accurate worldwide climate records of the last 50 years were recently made freely available. Across Sicily, there is a strong heterogeneity of agro-ecosystems, with a dominance of field crops and orchards. In the present work, we modeled the SOC through a wide range of predictors including both ecosystem and agronomic characteristics of the soils, such as panchromatic bands, a Normalized Differenced Vegetation Index NDVI and landuse based on multispectral remote-sensed data LANDSAT ETM+7, terrain attributes derived by radar satellite data from the Shuttle Radar Topographic Mission (SRTM), as well as soil texture information and climate data record from WORLDCLIM. As dependent variable, a set of 2,891 Walkley-Black SOC and 1,049 bulk density laboratory analyses collected throughout Sicily (Italy) was used for modelling the CS stock and build the map. The Stochastic Gradient Treeboost (SGT) learning algorithm was applied to 75% of the CS stock dataset. The remaining 25% was used to validate the model. In addition, the SGT was compared to a Generalized Linear Mixed Model (GLMM). Both SGT and GLMM models show a high performance. With regards to the full model, both algorithms designated temperature and annual rainfall as fundamental predictors of CS. In addition, SGT highlighted the annual rainfall soil texture, land use and the Band8 among the most important contributors to the model. Conversely, GLMM selected temperature, annual rainfall, slope and LS-factor as primary contributors. Finally, total CS stock was extracted per each agricultural land use within the area of study. The cumulated topsoil CS (0-30cm) within the aforementioned classes accounted for about 59·106 tons, on 1,6 million hectares (about 60% of the island surface). In particular, Non irrigated (rainfed) arable lands, fruit trees and berry plantations, olive groves, and vineyards accounted for 47,4% and 10,2% 13,5%, 9.0 %, of the total CS, respectively, and 48,9%, 9,5%, 13,5%, 9.6% of the total area respectively. The results have implication on both the landscape management when aiming to reduce GHG emission and the computation of the contribute of each land use class to the potential CS and GHG variation. In addition, the model and map resulting from the present work have particular implication when aiming to infer SOC dynamics under climate change or varying ecosystem management scenarios.