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Impact of acquisition date on the prediction performance of topsoil organic carbon from single date or multidate Sentinel-2 images

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The spatial assessment of soil organic carbon (SOC) is a major environmental challenge, notably for evaluating soil carbon stocks. The current remote sensing methods are inoperative in the presence of vegetation, as vegetation cover disturbs the soil reflectance signal. As a consequence, the soil areal fraction that is available for the mapping of topsoil property from remote sensing imagery varies with acquisition date. More, soil surface condition changes across the available bare soil area, particularly in terms of soil moisture and roughness according to tillage operations.
Over the Versailles Plain near Paris, France, a single Sentinel-2 image has demonstrated encouraging capability to estimate topsoil SOC for temperate soils with annual crop systems (Vaudour et al., 2019). Considering the same study area and a Sentinel-2 time series, this study aimed : i) to analyse the impact of acquisition date and related soil surface conditions on the prediction performance of topsoil SOC content; ii) to assess the potential added value of aggregating several Sentinel-2 images into a multidate mosaic for predicting SOC content.
A Sentinel-2 time-series was gathered, composed of the dates corresponding to a maximum coverage of bare soil, from 1 March to 30 April in 2016 and 2017 and 1 November to 31 December in 2016. Cross-validated partial least squares regression (PLSR) models were constructed between soil reflectance image spectra and SOC content. Soil samples were comprised between 49 to 151 for a NDVI threshold of 0.27. In addition to single date, four variants of composite image were tested for prediction performance, constructed each on the following criteria: i) least NDVI value amongst several available acquisition dates ; ii) least soil moisture content amongst several available dates ; iii) least normalized difference water index (NDWI) amongst several available dates ; iv) best single prediction performance by decreasing order amongst dates.
R^2, RMSE, RPD values varied according to date and ranged from 0.002 to 0.57, 5.57 to 3.14 g C.Kg-1, 1.01 to 1.53, respectively, for single date. The main factors influencing these differences were the composition of the dataset, cloud cover, soil moisture and soil roughness. The best performing dates of April 2017 had the lowest soil moisture content and the lowest roughness, in conjunction with perfect sky conditions. Under the 0.27-threshold, NDVI values did not influence prediction performance.
The best results were yielded from the composite image constructed on the criteria of best performance of 3 dates, that relied on 167 samples : R^2, RMSE, RPD of 0.5, 3.34 g C.Kg-1, 1.41. It was closely followed by the 3 date-mosaic constructed on the criteria of least NDWI (R^2, RMSE, RPD of 0.4, 3.64 g C.Kg-1, 1.38) which is easier to apply and validate. This consolidates the previous results yielded from single date and offers wider perspectives for the further use of Sentinel-2 multidate mosaics for digital soil mapping.

Reference
Vaudour, E., Gomez, C., Fouad, Y., Lagacherie, P., 2019. Sentinel-2 image capacities to predict common topsoil properties of temperate and Mediterranean agroecosystems. Remote Sensing of Environment, accepted.

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