EGU22-1618, updated on 11 Aug 2022
https://doi.org/10.5194/egusphere-egu22-1618
EGU General Assembly 2022

Improving SOC predictions from Sentinel-2 soil composites by assessing surface conditions and uncertainties

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SOC prediction from remote sensing is often hindered by disturbing factors at the soil surface, such as photosynthetic active and non-photosynthetic active vegetation, variation in soil moisture or surface roughness. With the increasing amount of freely available satellite data, recent studies have focused on stabilizing the soil reflectance by building reflectance composites using time series of images. Even if SOC predictions from composite images are promising, it is still not well established if the resulting composite spectra mirror the reflectance fingerprint of the optimal conditions to predict topsoil properties (i.e. a smooth, dry and bare soil).

We have collected 303 photos of soil surfaces in the Belgium loam belt where five main classes of surface conditions were distinguished: smooth seeded soils, soil crusts, vegetation, moist soils and soils covered by crop residues. Reflectance spectra were then extracted from the Sentinel-2 images coinciding with the date of the photos. The Normalized Burn Ratio (NBR2) was calculated to characterize the soil surface, and a threshold of NBR2 < 0.05 was found to be able to separate wet soils and soils covered by crop residues from dry bare soils. Additionally, we found that normalizing the spectra (i.e. dividing the reflectance of each band by the mean reflectance of all spectral bands) allows for cancelling the albedo shift between soil crusts and smooth soils in seed-bed conditions. We then built the exposed soil composite from Sentinel-2 imagery (covering the spring periods of 2016-2021), and used the reflectance information to predict SOC content by means of a Partial Least Square Regression Model (PLSR) with 10-fold cross-validation. The uncertainty of the models (expressed as $q_{0.05}+q_{0.95}/q_{0.50}$) was assessed via bootstrapping, where each model was repeated 100 times with a slightly different calibration dataset. The cross validation of the model gave satisfactory results ($R^2 = 0.49 \pm 0.10$, RMSE = 3.4 ± 0.6 g C kg^{-1} and RPD = 1.4 ± 0.2). The resulting SOC prediction maps show that (1) the uncertainty of prediction decreases when the number of scenes per pixel increases, and reaches a minimum when more than six scenes per pixel are used (median uncertainty of all pixels is 28% of predicted SOC value) and (2) the uncertainty of prediction diminishes if SOC predictions are aggregated per field (median uncertainty of fields is 22% of predicted value). The results of a validation against an independent data set showed a median difference of 0.5 g C kg^{-1} ± 2.8 g C kg^{-1} SOC between the

measured and predicted SOC contents at field scale. Overall, this compositing method shows both realistic SOC patterns at the field scale and regional patterns corresponding to the ones reported in the literature.