EGU22-3873
https://doi.org/10.5194/egusphere-egu22-3873
EGU General Assembly 2022

Prediction of soil organic carbon content using multitemporal Sentinel-2 imagery data and NWP-derived soil moisture over Greek croplands

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The intensive use of soil and the non-adoption of optimal management practices leads to the loss of soil organic carbon (SOC) from soil. SOC accumulates in the atmosphere in the form of CO_2, thus affecting the global temperature. Numerous studies have been carried out in the monitoring of SOC in exposed croplands at global and regional scales, demonstrating the potential of remote sensing to estimate SOC amongst the disturbance effects encountered on the Earth Observation monitoring that affect the prediction of soil properties, soil moisture ranks within the most important. The current study is driven by the need to eliminate the influence of ambient factors and evaluate the efficiency of multitemporal analysis by leveraging numerical simulations of soil moisture data as an auxiliary variable along with Sentinel-2's reflectance values. Multi-year high-resolution coupled atmospheric-soil numerical simulations were utilized from BEYOND/NOA's operational implementation of Weather Research and Forecasting Model (WRF-ARW) on a 2-km grid spacing configuration over Greece. Spectral data were extracted using Sentinel 2 multitemporal imagery (February to December 2020) at the sampling points of the European topsoil dataset provided by the Land Use / Coverage Framework Survey (LUCAS) 2009 and 2015 in Greek croplands with the support of Google Earth Engine, totaling 643 sampling points. After that, bare soil masking was performed, using as a limiting factor the values between 0 and 0.25 to NDVI, NBR2 < 0.08 and the difference between B3 and B2, resulting in 180 sampling points which had exposed bare soil at any given time in the aforementioned period. The SOC prediction was performed using Sentinel 2 multitemporal bands together with soil moisture. Datasets were randomly separated in calibration (75%) and validation samples (25%). Cubist regression algorithm was applied to train predictive models in three separate modeling modes: multitemporal Sentinel-2 bands averages ($S2_{mean}$), multitemporal Sentinel-2 bands ($S2_{multitemporal}$) and multitemporal Sentinel-2 bands and soil moisture (S2+M). Model performance to the multitemporal modes (S2 and S2+M) was measured by averaging the predicted values for each sampling point. Mode S2+M achieved the best accuracy among the modes, reaching an R^2 of 0.68, RMSE of 9.19 and RPIQ of 1.21 , while the $S2_{multitemporal}$ mode had a R^2 of 0.62, RMSE of 9.91 and

RPIQ of 1.12 and the $S2_{mean}$ with R^2 of 0.31, RMSE of 12.58 and RPIQ of 0.87. The modes with multitemporal data proved to be more powerful for SOC prediction than the mode with average spectral values, due to the large amount of spectral information for each sample. The use of NWP-derived soil moisture as an auxiliary variable improved the performance of SOC estimation, due to the direct influence of soil moisture on SOC rates. Therefore, this study indicates that multitemporal Sentinel-2 imagery and NWP-derived soil moisture information can improve the accuracy of SOC prediction. Further investigation is currently focused upon including additional soil-climate variables as well as test different combinations of thresholds in bare soil masking towards a better performance in the prediction of this soil property.