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BOOK OF ABSTRACTS

Block C

C4 Innovation and methods for data acquisition

Contents

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C4 Innovation and methods for data acquisition

Session Description

Conveners: Emmanuelle Vaudour, Luboš Borůvka

The session will focus on proximal and remote sensing of soils with special attention to soil spectroscopy and to soil organic carbon as the target soil characteristic. Presentations will be considered dealing with: 1) methods of data collection (lab/field proximal/UAV/ airborne/ satellite; tools/instruments/platforms; standard procedures and/or protocols; spectral/spatial/temporal resolution; spatial extent etc.); 2) data processing (pre-treatment, model development and calibration, machine learning methods, downsaling/upscaling; building and exploitation of soil spectral libraries including transfer options between lab, field and remote data); 3) elimination of the effect of disturbing factors (soil moisture, texture, vegetation and plant residues, atmospheric conditions); 4) accuracy assessment and uncertainty (validation methods and approaches, criteria, ground truth determination, comparison of methods and models).

Influence of soil texture on the possibilities to estimate soil organic carbon using Sentinel-2 data

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Remote sensing using satellite data is frequently put forward as a possible tool for estimating and monitoring soil properties such as soil organic carbon (SOC). SOC affects soil spectra in the visible and near-infrared region due to specific vibrations in chemical bonds in organic molecules. This has been successfully used for modelling SOC content under laboratory conditions often using high spectral resolution data. Encouraging performances have also been obtained using multispectral Sentinel-2 satellite data. However, results are variable. Several factors affect the satellite data, including other soil properties. Clay minerals influence the spectra in similar spectral regions as SOC, with the risk of masking important information. This is especially problematic in multispectral data (low spectral resolution). Soil texture also affects the visibility of SOC, with lower visibility of SOC in clay soils, and both SOC and soil texture influence the water holding capacity and soil moisture, affecting soil colour.

To study the effect of variation in soil texture, especially clay content, on the performance of modelling SOC content using Sentinel-2 data, a joint study was conducted within the STEROPES project, including 34 sites in 10 European countries. The countries covered various pedoclimatic conditions and cropping systems across Europe and included Türkiye, Spain, Italy, Switzerland, France, Czech Republic, Poland, Lithuania, Denmark, and Sweden. The sites were individual or neighbouring fields ranging from a few hectares to more than 500 ha at two sites, with a median size of 20 ha.

A pixelwise temporal mosaicking described by Castaldi et al. (2023) was used for the satellite data. Best condition bare soil Sentinel-2 images from the time series 2019-2022 were selected using cloud filters in Google Earth Engine and a combination of Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio 2 (NBR2). Two approaches for calculating the pixel values from the retrieved images were included, the median value and the 90th percentile. The reasoning behind the 90th percentile was to use as dry soil conditions (bright images) as possible without including extreme values. Local models for SOC and clay content were developed for each site using Partial least squares regression and random forest. SOC was modelled using satellite data with or without adding information on soil texture and soil sampling location (geographic coordinates).

Results showed large variations in SOC modelling performance between the 34 sites, from very poor performing models to models with Lin's concordance correlation coefficient (ccc) of 0.8-0.9. However, at 50 % of the sites, SOC models using satellite data resulted in ccc < 0.5. Models predicting clay content also resulted in similar variable performances, although, clay content was easier to predict at a majority of the sites. There were no general explanations apparent for the SOC results related to possible clay interference. However, good models for both soil properties were generally achieved when they followed similar or reverse spatial patterns.

References:

Castaldi, F., Koparan, M.H., Wetterlind, J., Žydelis, R., Vinci, I., Savaş, A.Ö., Kıvrak, C., Tunçay, T., Volungevičius, J., Obber, S., Ragazzi, F., Malo, D., Vaudour, E. 2023. Assessing the capability of Sentinel-2 time-series to estimate soil organic carbon and clay content at local scale in croplands, ISPRS Journal of Photogrammetry and Remote Sensing, 199, 40-60, https://doi.org/10.1016/j.isprsjprs.2023.03.016

Keywords: remote sensing; SOC; clay content; soil moisture; time series

Semi-automatic supervised bare soil pixels retrieval: impact of different classification approaches on soil organic carbon prediction

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Green and dry vegetation can cover agricultural soils and hence interrupt the acquisition of surface reflectance by remote earth observation sensors. Several spectral indices have been introduced to detect and discriminate bare soil from different types of vegetation. Spectral unmixing has also been under special consideration to estimate the fractional abundance of each soil surface cover class at the sub-pixel level. This study aims to compare the performance of the index-based and unmixing-based classification approaches as well as their integration on discrimination of the bare soil pixels on Sentinel-2 (S2) and Landsat 8-OLI (L08-OLI) single-date scenes from dry and green vegetation within four local agricultural sites in the Czech Republic. A reference soil cover RGB image representing the percentages of the three cover classes in each band (R: bare soil, G: green vegetation, and B: dry vegetation) was created using an airborne hyperspectral imagery along with the same date ground truth photos taken at the sampling points. A reference bare/non-bare soil binary map was also produced after classification of the reference image pixels to bare and non-bare, with an 80% of bare soil fraction threshold. The bare soil fraction images obtained by applying different classification approaches on different satellite data were compared with the reference image at 400 points evenly distributed all over the area. Accordingly, the best bare soil fractions estimations were obtained when using the integrated approach (R^2 0.81 and RMSE 0.02 for L08-OLI and R^2 0.87 and RMSE 0.01 for S2).

Furthermore, bare/non-bare soil binary maps produced by the integrated approach were more accurate than the others (overall accuracy 76% and 85% for L08-OLI and S2, respectively). In addition, random forest (RF) models were developed to predict SOC using sample-pixels retrieved as bare soil by each of the classification approaches. Models performed best on outputs of the integrated approach with average RMSE of 0.17 and 0.14 for L08-OLI and S2, respectively. The highest average prediction errors were yielded by the index-based approach (RMSE 0.24 and 0.20 for L08-OLI and S2, respectively). Considering all approaches, results obtained on S2 data were more accurate than those delivered on L08-OLI. In brief, classification of soil cover using the integrated approach led to a more accurate extraction of bare soil and higher performance of SOC prediction models on both types of satellite data.

Keywords: soil cover classification; spectral indices; linear spectral unmixing; soil organic carbon; airborne and satellite data

Effects of Vegetative Covers on Soil Properties in Semi-Arid Areas: Insights from the SANCHOSTHIRST Project

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Integration of remote sensing data with ground-based measurements approaches can enhance our understanding of the relationships between soil management, soil health, and landscape-scale processes. In our study on the impact of vegetative covers on soils, we sampled 15 pairs of plots of woody crops, vineyards, and olive groves in semi-arid areas of Spain. These areas typically suffer soil degradation and erosion under tillage management, but vegetative covers offer a solution. Yet, their adoption remains low in semi-arid regions. We present data from the ongoing SANCHOSTHIRST project. We compared soil conditions between covered and tilled plots, noting variations in soil types, terrain, and management practices. This diversity provides insights across different contexts that ultimately will help to assess the potential for remote sensing to monitor these changes over time. Parameters analyzed include physical, chemical, and biological soil characteristics. Cover crop (CC) age ranges from two to over twenty years, impacting soil conservation indicators such as porosity, water content, organic carbon, humification, and enzymatic activity.

The results obtained are variable, just as the types of soil and management practices are. Overall, it has been found that CC significantly increase carbon content, potentially doubling it in cases where the covers have been in place for more than ten years. This data is important because in these crops, the organic carbon content is usually less than 1%. This increase refers to fresh organic matter (SOM), but its humification is also being analyzed to assess the carbon sequestration capacity of these management practices. As expected, fresh SOM increases in management with CC, and in some cases, humification also increases, but not in others. Not all analyses have been completed yet, so conclusions cannot be drawn completely. Regarding soil structure, total porosity also tends to increase in soils with CC, even in subsurface layers, but this only occurs in crops managed with CC for the medium term. Variation in total available water has been observed in some crops with CC compared to tilled crops, which must be analyzed based on soil textures, whose values are still to be fully determined.

Several enzymes pivotal in assessing nutrient cycling, SOM decomposition, and overall soil fertility are analyzed. Phosphatase enzymes, facilitating the conversion of organic phosphorus compounds into inorganic phosphates, have not exhibited significant differences across management in the samples analyzed thus far, which comprise only one third of the total. Similar findings have emerged concerning Arylsulfatase, involved in the mineralization of sulfur-containing organic matter. Beta-glucosidase, which catalyzes the breakdown of beta-glucosidic bonds in carbohydrates, plays a crucial role in carbon cycling and nutrient availability have to date shown heightened activity in the topsoil layers (0-10 cm) of CC owing to elevated SOM content and oxygen levels. Dehydrogenase enzymes, serving as indicators of microbial activity, exhibit notable variances across management practices. Likewise, Urease enzymes, key for nitrogen cycling in soils by catalyzing the hydrolysis of urea into ammonia and carbon dioxide, generally demonstrate significantly higher activity in soils with CC.

Keywords: woody crops; carbon sequestration, enzymatic activities, soil health

In-situ measurement of surface soil reflectance with SoilPRO® apparatus

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The general aim of the ProbeField project is to develop a novel protocol for robust in field monitoring of carbon stocks and soil fertility based on proximal sensors and existing soil spectral libraries. This study introduces an innovative approach for the accurate assessment and harmonization of undisturbed soil surface spectra under field conditions, achieving laboratory-grade precision, while minimizing systematic discrepancies. The SoilPRO® assembly was employed for its efficacy in precisely measuring seven different soil samples under similar field and laboratory conditions in six different laboratories. While some discrepancies were noted in and between field and laboratory measurements, aligning the laboratory measurements with a reference sample, Lucky Bay (LB) internal soil standard (ISS), significantly reduced variations across different laboratory settings. A similar approach was employed to align field spectra through the use of a field ISS (FISS), which could be practically applied in the field and adjusted to the laboratory reference LB before utilization. Correcting to the FISS facilitated the alignment of field reflectance among the six laboratories and closely matched with laboratory ISS measurements adjusted to the LB standard. This alignment of field reflectance with ISS-corrected laboratory measurements represents a ground-breaking achievement in field soil spectroscopy, which suffers from instabilities. It not only ensures preservation of the soil surface condition in the field, but also enables objective comparisons with all soil spectral library (SSL) measurements and robust harmonization of field spectral data from different sources. This study marks the first use of a controlled method for soil-surface spectroscopy measurements, opening a path for the construction of in-situ SSLs. This development is a significant stride forward in obtaining more accurate and standardized soil analyses.

Keywords: soil field spectroscopy; standard and protocol; harmonization; internal soil standards; SoilPRO®

Adjustments of the Rock-Eval® thermal analysis for SOC and SIC quantification: application on calcareous soils and soil fractions

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Standard methods to quantify both soil organic and inorganic carbon (SOC & SIC) in calcareous soils requires pretreatments (carbonate or organic matter removal), at least two aliquots, and calculations. This procedure can lead to i) analytical bias due to pretreatment, ii) measurement deviation stemming from the heterogeneity of the bulk and pretreated aliquots, and iii) cumulative errors associated with the calculation. Thus, thermal analyses may be useful tools for quantifying SOC and SIC content on a single non-pretreated aliquot. Originally developed in the 1970s by IFPEN for studying oil-bearing rocks, the Rock-Eval (RE) analysis has been increasingly used to quantify and characterize SOC. Previous work has also used the RE to estimate both SOC and SIC contents from the TOC and MINC standard parameters respectively, calculated from the carbonaceous effluents emitted during the ramped pyrolysis of the aliquot and the ramped oxidation of the residue. In literature, statistical corrections of the TOC and MINC parameters have been proposed to improve SOC and SIC content estimations using the RE analysis, but no adjustment of the RE standard analysis cycle has been investigated.

This study aims at adjusting the RE standard cycle to quantify SOC and SIC without using statistical corrections and exploring the impact of these adjustments on the indices used to characterize SOC (*e.g.*, Hydrogen index, Oxygen index, I-index, R-index). A panel of calcareous soil samples and soil fractions with a wide range of SOC and SIC contents was analyzed by both standard and adjusted RE cycles. Results from the soil samples were also compared to SOC and SIC quantifications by an Elemental Analyzer (EA) after carbonate and organic matter removal, respectively.

First, the total carbon content measured by RE systematically underestimated the total carbon content assessed by EA for samples with high SIC contents. The CO_2 signal obtained for crucibles containing more than 4 mg of SIC dropped suddenly at the end of the oxidation, suggesting a stop of the SIC thermal breakdown. To address this issue, the final oxidation isotherm was extended to complete the SIC thermal breakdown.

Secondly, the pyrolysis thermograms showed that, after 550°C, a part of thermoresistant SOC and a part of SIC, decomposed simultaneously. To avoid the mixing of fluxes and the need for statistical corrections, the pyrolysis was stopped at a lower temperature to decompose SIC exclusively during the oxidation, where the separation of SOC and SIC was clearer.

The new analysis cycle (extended oxidation and low temperature pyrolysis) improved the estimation of C contents compared to EA without any statistical corrections. The SOC indices are little affected by the cycle adjustments and are correlated to those obtained with the standard cycle. This new cycle of RE analysis provides more accurate estimations of SOC and SIC contents and characterizes SOC with a single analysis. Such an analysis is particularly relevant to explore SOC and SIC in soil fractions as it requires small sample amounts of a single aliquot and no sample pre-treatment.

Keywords: C data acquisition; SOC characterisation; lab methodology

Advancements in non-invasive soil salinity monitoring: integrating electromagnetic induction, inversion, and remote sensing techniques

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Keywords: Soil Salinity; Electromagnetic Induction; NDVI; Inversion; Monitoring

Soil salinization poses a significant threat to agricultural productivity worldwide, leading to soil degradation, hindered plant growth, and even desertification. Addressing this issue is crucial due to its adverse social, economic, and environmental impacts. As agricultural practices intensify and global warming progresses, it becomes critical to adapt management strategies to mitigate and manage soil salinity effectively. To achieve this, there is an increasing need for efficient field-assessment methods capable of mapping and monitoring soil salinity dynamics.

Traditional methods have often limitations in addressing the soil salinity dynamics at a field scale, due to a small scale of investigation. Hence, our study aims to evaluate the effectiveness of non-invasive, cost-effective Electromagnetic Induction (EMI) sensors and emerging inversion techniques in monitoring soil salinity across various irrigated agricultural lands in several Mediterranean countries. Additionally, we assessed the possibility of using Sentinel-2 NDVI imagery in combination with EMI to further study the impact of salinity on crop development during the crop season.

Our methodology involves several key steps: conducting repeated (time-lapse) EMI surveys to measure soil apparent electrical conductivity (ECa), inverting ECa data to evaluate spatiotemporal soil electrical conductivity (σ) distribution, calibrating σ with proxies for soil salinity (ECe), converting σ distribution into salinity cross sections using calibration equations, and comparing NDVI imagery with σ distribution. We also assessed the prediction ability of in-situ established calibrations across different spatial and temporal scales.

Our findings reveal that the EMI can predict soil salinity with reasonable accuracy in most study sites. However, efficacy of our methodology depends on the soil salinity levels and spatial variability of other soil properties, such as soil texture and moisture content (θ), which influence the EMI signal. While accurate predictions of soil salinity were achieved in regions with higher salinity levels and less variability in soil texture, challenges arose in predicting soil salinity dynamics over large areas due to the variability of dynamic parameters like θ, soil temperature, and groundwater salinity. In one case study where the NDVI was assessed for the growing season, the observed spatial distribution of EC exhibited a steadily increasing inverse correlation with NDVI throughout the growing season. This finding confirms the potential of EMI tomography in conjunction with NDVI imagery for providing a detailed spatial assessment of soil salinity impacts on crop development throughout the growing season.

Predicting soil salinity dynamics over large areas from time-lapse EMI data proved more challenging due to the substantial variability of dynamic parameters, including θ, soil temperature, and groundwater salinity, all of which significantly impact the EMI signal and complicate the inference of soil salinity changes. This challenge was particularly pronounced in assessing soil salinity in topsoil in most of our study sites.

Mapping compost and digestate spreadings from Sentinel-2 and Sentinel-1 on a farm scale

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According to few recent studies, exogenous organic matters (EOM) can be detectable on either emerging vegetation or bare soil using optical and radar remote sensing techniques. Nevertheless, these image processing approaches considered one single EOM, one season and/or year only and were limited to one surface condition prior to spreading. So far no method addressed the simultaneously tracking of both liquid and solid EOM applications using satellite imagery, for several years and surface conditions. Relying on Support Vector Machine (SVM) classifier, this study aimed to track applications of both composted manure and liquid digestate over three periods and years in agricultural fields on a farm scale with distinct surface conditions (grassland, winter crop, bare soil) in Nouzilly, France. Various combinations of covariates from Sentinel-2 and Sentinel-1 data served to train SVM in a bootstrapping approach in order to assess the uncertainty of map results. Classification performance was higher for pre- and post-application image pairs compared to post-application images alone and slightly improved when adding Sentinel-1 data. While the areal percentage of the highest uncertainty class covered less of 10% of the mapped area regardless of the year, the best models showed accuracies higher than 93% in 2020 and 2021. In 2019, the overall accuracy did not reach more than 79%, probably due to rainfall events and considerable time lags between the image pairs. This study underscores not only the potential of Sentinel-2 and 1 for monitoring EOM applications, but also the requirement of better understanding the spectral behaviour of the EOM spreadings, in line with a thorough characterization of the sequence of crop technical management.

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Keywords: compost; digestates; spreadings; Sentinel; machine learning; SVM

The impact of different fertilization on total organic carbon content and the spectroscopic properties of soil organic matter after fifty five years of rye and maize monocultures

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The research was related to the issue of carbon sequestration, and aimed to determine the impact of long-term diversified cultivation on the content of soil organic matter and the properties of its most persistent fraction. They were carried out on plots of the long-term field experiment established in 1967 in the Norekiskes1 area of the Experimental Station of the Vytautas Magnus University, Agricultural University in Kaunas, Lithuania. The experiment was established on loam Cambisol and included plots on fallow and two cultivation variants: rye monoculture and corn monoculture. Three fertilization variants were used for each crop: no fertilization as a control (CON), NPK fertilization (NPK) and NPK fertilization with manure and legumes (NPK+MAN+LEG).

Soil samples were collected from A horizon and analysed for total organic carbon (TOC), fractional composition of humic substances, and spectroscopic properties of isolated humin fraction (HUM). HUM was obtained after discarding humic and fulvic acids, and digesting the mineral residue in an HF-HCl mixture. The obtained HUM was purified by dialysis, and then freeze-dried. To analyse HUM spectroscopic properties absorption spectra in the UV-Vis range and fluorescence spectra (synchronously scanned SSF and three-dimensional EEM matrix spectra) were recorded.

Compared to fallow, both the cultivation of rye and maize monoculture exhibited the increase in TOC content, which was especially evident in the case of maize fertilized with manure accompanied by the application of legume. However, in relation to CON, application of manure with legume resulted in a statistically significant increase in the TOC content only in the case of maize monoculture. No clear statistical dependencies were found in the fractional composition of SOM, but there was a significantly lower % share of HUM in fallow soils. The application of manure and legume in both crops caused a

reduction in the share of HUM in humic substances, however, this management did not result in a decrease in HUM total amount, when expressed in g kg^{-1}.

The UV-Vis properties of HUM isolated from NPK+MAN+LEG objects indicated the lower polymerization degree of this fraction, compared to CON. This is related to the presence of chemically young aromatic structures originated from lignin introduced with organic components applied. The fluorescence spectra of this HUM indicated its enrichment in protein- and/or phenol-like fluorophores.

The results confirmed the beneficial effect of long-term organic fertilization on carbon dioxide sequestration, especially compared to fallow. However, it is strongly depended on cultivated plant type. The most beneficial changes were found in maize monoculture as a result of fertilization with manure and legume application. UV-Vis and fluorescent properties indicate that this kind of management contributes to the formation of a HUM fraction with less complex structure, enriched in the protein- and/or phenol-like fragments.

The research was financed by the EJP SOIL program (NCBR project EJPSOIL/I/78/SOMPACS/2022, and the Ministry of Agriculture of the Republic of Lithuania project TM-22-1).

Keywords: long-term field experiment; carbon sequestration; SOM spectroscopic properties; humin; fluorescent properties, UV-Vis.

Unveiling soil properties from FTIR spectra

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In general, various physicochemical properties of soils can be predicted from spectra of different types (FTIR, vis-NIR, X-ray fluorescence). The EJP Soil ProbeField project (*A novel protocol for robust in-field monitoring of carbon stock and soil fertility based on proximal sensors and existing soil spectral libraries*) proposes innovative techniques for determining SOC stocks and other relevant properties to the health of EU soils. This study aims to predict soil properties using partial least squares regression (PLS) models and identify significant spectral bands for predicting soil physicochemical properties. To achieve this, 28 soil samples from Andalusia were analyzed using infrared spectroscopy (FTIR) (400–4000 cm^{-1}), and various soil properties (calcium carbonate, sand, silt, clay, available P, and available K contents) were determined using conventional laboratory techniques. The applied protocol includes: i) optimizing prediction models for each property using partial least squares regression (PLS) applied to FTIR spectra, ii) testing methods to extract spectral features showing bands with greater importance in prediction, and iii) identifying mineral components acting as surrogate descriptors. Good predictions were obtained for the considered parameters, with cross-validation functions with R^2 and RMSE values of 0.904 and 4.147 for silt content, 0.878 and 4.778 for clay content, 0.813 and 9.451 for sand content, 0.874 and 5.819 for available P, and 0.803 and 139 for available K. The best prediction was for calcium carbonate content, which showed an R^2 = 0.984 and RMSE = 2.789, being notable the fact that, in this case, the highest values of VIP (variable of importance in the prediction) corresponded to the small bands at 2500 and 2900 cm^{-1}, which were the most useful for quantification, higher than that of the most intense carbonate bands (at 1425, 875 and 718 cm^{-1}), which overlap to a greater extent with that of other minerals. Mean centering and multiplicative scatter correction (MSC) were the most satisfactory spectral pretreatments. Spectral patterns of different soil components (carbonates, hydrated oxides and silicates, quartz, kaolinite, and smectite clay minerals) were shown to be influential according to the model for each parameter. Finally, and to illustrate to what extent the different spectral bands were important in the prediction of each soil property, the strategy of constructing subtracted scaled semispectra (SSS) was used, ie., calculating two spectra, one of which shows the bands that predominate in the samples with high values (above the average) of the property, and the other one, the bands that predominate in the samples with low values. As the profile of these SSSs largely resembles that of the FTIR spectra of wellknown soil minerals, the mineralogical composition associated with the values of different soil properties was tentatively proposed. Although the number of samples in this study is small, it has allowed for pilot exploratory studies on data management strategies that enable the extraction of maximum possible information from spectroscopic patterns in the case of larger databases.

Keywords: MIR spectroscopy, partial least squares regression, PLS, proximal sensors

Temporal S2/S1 mosaics combined with environmental covariates for regional SOC mapping: lessons from la Beauce (France) and the Veskra-Skaraborg (Sweden)

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Satellite-based soil organic carbon content (SOC) mapping over wide regions is generally hampered by the low soil sampling density and the discrepancy of soil sampling collection dates. Some unfavorable topsoil conditions, such as high moisture, roughness, the presence of crop residues, the limited amplitude of SOC values and the limited area of bare soil when a single image is used, are also among the influencing factors. For two contrasted wide agricultural areas in boreal and temperate zones, Veskra-Skaraborg (Sweden) and la Beauce (France), this study compares approaches relying on Sentinel-2 (S2) temporal mosaics of bare soil (S2Bsoil) over ≥5 years jointly with Sentinel 1, SOC measurements data and other environmental covariates derived from digital elevation models and/or lithology maps and/or airborne gamma-ray data.

Prediction models relied on quartile random forest, with 10 fold cross-validation, according to several datasets: i) “Sentinel-2”, the Sentinel-2 bands of a given S2Bsoil; ii) “terrain”, the terrain covariates (Digital Elevation Model and its derivatives, plus oblique geographic coordinates); iii), “Sentinel-2” plus “terrain”; iv) “all”, i.e. “Sentinel-2”, “terrain” and a selection of relevant Sentinel-2 spectral indices.

Lessons from la Beauce (Urbina-Salazar et al., 2023) deal with (i) the dates and periods that are preferable to construct temporal mosaics of bare soils while accounting for soil moisture and soil management; (ii) which set of covariates is more relevant to explain the SOC variability. The models using all the covariates had the best model performance. Airborne gamma-ray thorium, slope and S2 bands (e.g., bands 6, 7, 8, 8a) and indices (e.g., calcareous sedimentary rocks, "calcl") from the "late winter–spring" time series were the most important covariates in this model. Our results also indicated the important role of neighboring topographic distances and oblique geographic coordinates between remote sensing data and parent material. These data contributed not only to optimizing SOC mapping performance but also provided information related to long-range gradients of SOC spatial variability, which makes sense from a pedological point of view.

Lessons from the Veskra-Skaraborg deal with the impact of percentile thresholding for temporal mosaicking of bare soils in relationship with soil moisture and cloud frequency. Performance decreased from R90 to R25. Models were highly predictive over both Plain (RPIQ≤1.3) or Till, yet with a slight improvement for Till (best RPIQ 1.4). Results confirm the differences in performances according to soilscape and agricultural system, and the complex interactions due to soil moisture in satellite-based soil property mapping.

For both study áreas, spectral models alone were not well performing, but covariates such as morphometric layers slightly improved the prediction from temporal mosaics of bare soils.

Reference:

Castaldi, F., Koparan, M.H., Wetterlind, J., Žydelis, R., Vinci, I., Savaş, A.Ö., Kıvrak, C., Tunçay, T., Volungevičius, J., Obber, S., Ragazzi, F., Malo, D., Vaudour, E. 2023. Assessing the capability of Sentinel-2 time-series to estimate soil organic carbon and clay content at local scale in croplands, ISPRS Journal of Photogrammetry and Remote Sensing, 199, 40-60, https://doi.org/10.1016/j.isprsjprs.2023.03.016

Urbina-Salazar, D., Vaudour, E., Richer-de-Forges, A.C., Chen, S., Martelet, G., Baghdadi, N., Arrouays, D., 2023. Sentinel-2 and Sentinel-1 Bare Soil Temporal Mosaics of 6-year Periods for Soil Organic Carbon Content Mapping in Central France. Remote Sensing 15, 2410. https://doi.org/10.3390/rs15092410

Keywords: bare soil temporal mosaicking, quartile random forest, Sentinel-2, soil organic carbon

Mapping soil organic carbon content by combining time series of Sentinel-2 and Sentinel-1 with vis-NIR laboratory spectra – Application to study site in Brittany (France)

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Mapping Soil organic carbon (SOC) is essential for continuous monitoring of its spatial and temporal dynamics. In this study, we developed a method using time series of Sentinel-2 (S2) data combined with Sentinel-1 (S1) and vis-NIR laboratory spectra to map SOC content of agricultural soils. The study site, located in Brittany (northwest France), is an agricultural area of 1.5 km². Soil samples were collected from agricultural fields within this site, their SOC content measured and their spectra recorded under laboratory conditions. The SOC content ranged from 15.2 to 49.4 $g.kg^{-1}$. Deep neural network algorithms were implemented after dividing the data set built up from the time series of S2 and S1 images into calibration (70%) and validation (30%) sets. Three random draws of the validation sets were performed to assess model robustness. Four approaches were tested: (1) models developed using S2 bands as a single input, (2) applying multiple factor analysis (MFA) to select 12 of 40 indices calculated from S2 data and adding them to the S2 bands, (3) adding soil moisture derived from the time series of S1 (SM1), and (4) gradually adding five indices calculated from laboratory spectra, in descending order of their correlation with SOC. Model performance was compared based on validation results, and semi-variograms for observed and predicted SOC were then used to analyze the maps generated. Results showed that only models using approach 4 were validated (RPIQ = 1.78±0.19 - 3.07±0.6). The addition of SM1 improved model robustness since predictive performance remained stable over the 3 random draws of the validation sets. In approach 4, laboratory indices showed significant correlations with SOC content. Thus, we were able to validate our models once we added the two indices with the highest correlation. Semivariograms of the predicted values showed lower sill-to-nugget ratios but similar shapes to the observed values. Finally, the developed method allowed us to map 70% of the area of the study site.

Keywords: Soil organic carbon content, Sentinel-2, time series, Deep Neural Network,