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(4052 - 1212) On-farm technique to assess the nitrogen status of winter crops from optical sensors

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Agriculture precision (AP) technologies allow increasing the efficiency of nitrogen (N) application. However, it is necessary to optimize those using AP techniques that allow evaluating N spatial status in a fast, accurate and robust way. The objective was to propose and test a field technique to determine the spatial status of N in wheat/barley, combining on-farm strip-trials and optical sensors. The technique includes: *(i)* to delimitate zones within field using an algorithm coupling spatial principal components and Fuzzy K-means (sPC-FKM); (*ii*) to design a strip-trial of increasing dose of N; and (*iii*) to determine sampling points in each strip, using Latin Conditioned Hypercube (cLHS). Three agricultural field located in the southeast of Buenos Aires Province, Argentina (Lat: -38,529; Lon -60,419) were used. Zone within field were delimitated based on elevation, terrain and vegetation indices, using sPC-FKM. A strip-trial was designed including a wide range of soil series. The treatments were: control (0 N), doses commonly used by farmer and double dose used by farmer. A total of 10 sampling points were determined per strip using cHLS. At each point, NDVI using GreenSeeker®, chlorophyll content with SPAD 502® and biomass per m^2 at tillering, stem elongation, heading and ripening stages were measured. Also, grain yield and quality parameters were determined. Yield indices such as agronomic efficiency (AEN), grain yield response index (GYRY) and N recovery efficiency (R_{EN}) were calculated. Sensor indices such as INSEY (in-season estimated yield) and grain N uptake were also calculated. Two zones were delimitated in all fields. The results suggest that the on-farm technique proposed was able to capture the spatial variability of AEN, GYRI and R_{EN}, per zone and field. The ranges of differences for AEN, GYRI and R_{EN} were 12.06 kg grain kg N^{-1}, 76.12 % and 11.02 kg grain kg N^{-1}, respectively. INSEY, calculated from the sum of NDVI at tillering and stem elongation, showed a high correlation with yield (R^2=0.72), as have been reported in other studies. INSEY, calculated from SPAD, showed a low correlation with yield (R^2=0.2). Grain N uptake showed a high correlation (R^2=0.72) with SPAD measured at heading. These results demonstrated that the technique was efficient to evaluate the spatial variability of N status at regional scale, in a fast, accurate and robust manner.

Keywords: nitrogen spatial status; Argentina; strip-trial; sensor
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(7818 - 613) Potential of synergy of multiple sensor data layers to predict soil properties

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Site-specific management of crops is essential to ensure maximum crop production profitability with minimum negative environmental impact. Today, systematic (grid) soil sampling is the most common practice to obtain the data needed to produce variable rate prescription maps. However, the cost and the labor needed to obtain this high-density soil sampling limit the ability to accurately represent spatial and, in some cases, temporal variability of soil properties across a field. Thus, it is expected that emerging proximal soil sensing technologies could help to reduce significantly the cost of data acquisition while increasing the accuracy of thematic soil maps. The objective of this work was to evaluate the synergy of multiple sensor data layers to predict maps for several important soil attributes (e.g., texture, organic matter content and chemical soil properties). The work was performed in Brazil on a 100-ha agricultural field used for sugarcane production. Within a couple of days, 423 soil samples were collected and subdivided randomly into a calibration (70% - 296) and a validation (30% - 127 samples) set of soil samples. All the samples were simultaneously sent to a commercial soil-testing laboratory for wet chemical and physical analysis. Gamma-ray spectroscopy and apparent soil electrical conductivity measurements were collected *in situ*. Field topography was measured using a real-time kinematic (RTK) global navigation satellite system (GNSS) receiver. To represent bare soil imagery, a Landsat 8 satellite image obtained within five months of soil sampling with minimum crop coverage was used. Each data layer provides unique information pertaining to soil characteristics. Based on these data, predictive variables were calculated and used to compose a series of prediction models to estimate both physical and chemical soil properties. As a result, it was determined that successful models were obtained to predict percent clay and sand, organic matter content, cation exchange capacity and copper using all data layers together, mostly achieved by bare soil imagery, field topography and apparent soil electrical conductivity. Unfortunately, a relatively poor connection was found between the gamma-ray count with the most soil properties. Such capability was not found for chemical soil properties typically used to prescribe mineral fertilization rates such as phosphorus or potassium.

Keywords: Soil sensing, library, remote sensing, soil mapping, environment, big data
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(5752 - 1182) Predicting soil clay content from NIR, gamma-ray and XRF curves

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Near-infrared spectral reflectance curves, and gamma ray and x-ray fluorescence (XRF) energy curves contain data that can be exploited as covariates in multivariate models for soil property prediction. This is the typical approach in the case of NIR reflectance curves. However, for gamma ray and XRF energy curves, the usual approach is to use the derived information they provide, that is, K, eU and eU contents, and multiple element contents, respectively. These element contents are derived from algorithms that are pre-calibrated in the factory using data from the energy curves, whose shapes and peaks relate to specific or multiple elements. In this study, data from NIR, gamma ray and XRF curves, and three multivariate methods (partial least squares regression - PLS, random forest – RF, and support vector machine - SVM) were used to predict soil clay content at 0-10-cm depth. Training and validation data included 103 and 25 samples, respectively. Gamma ray and XRF data were taken *in situ* at the soil surface, using portable sensors, whereas NIR reflectance curves (800-2500 nm) were measured from air-dried fine earth samples in the laboratory. Clay contents were measured by the densimeter method. In the case of XRF, curves from the three x-ray beams were used separately to derive distinct prediction models. Clay contents minimum, maximum, mean, median, and standard deviation were 40, 360, 180, 170, and 90 g kg^{-1}, respectively. Training R^2 and root mean squared errors (RMSE) for NIR, gamma ray and XRF (x-ray beams 1 through 3) models were (R^2/RMSE): 0.91/26, 0.86/33, 1.00/4, 0.85/34 and 0.90/28 (PLS); 0.95/22, 0.96/21, 0.98/17, 0.98/17 and 0.96/20 (RF); and 0.90/28, 0.99/9, 1.00/0, 1.00/0 and 1.00/0 (SVM), respectively. Validation RMSE were: 49, 109, 45, 35 and 44 (PLS); 43, 61, 54, 52 and 46 (RF); and 50, 63, 45, 30 and 52 (SVM), respectively. In validation, the XRF curves derived the best clay content predictions from PLS and SVM models, and the NIR curves were superior in RF. Compared to NIR, the XRF sensor is field-portable, and thus, it is preferred for faster and cheaper clay content prediction. The same applies for the gamma ray sensor if the magnitude of the errors are acceptable for the desired use. Overall, the results support NIR, gamma ray and XRF curves as potential covariates for soil clay content prediction, though there is room for improvement, for example, by testing other prediction methods or pre-processing the curves.

Keywords: Proximal soil sensing; Geophysics; Multivariate modeling; Near-infrared diffuse reflectance; X-ray fluorescence
Financial support: Embrapa; CNPq

(4145 - 2672) Prediction of Soil Organic Carbon using Neural Network with Vis–NIR spectra in highlands of Itatiaia National Park, Rio de Janeiro

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Visible and near-infrared reflectance (Vis–NIR) techniques are alternative methods to conventional chemical laboratory soil analyses for many soil attributes, including soil organic carbon. Besides, Vis–NIR techniques are fast, environment friendly, and non-destructive of samples. In this study soil organic carbon (SOC) was predicted applying Vis–NIR, and the spectrums on 305 soil samples by using a FieldSpec 4® spectrometer (350–2500 nm). The study area is located at the western region of Rio de Janeiro State, in the highlands of Itatiaia National Park (INP) that has its highest point at 2.791,6 m. Conditioned Latin hypercube sampling (cLHS) method was used to design the collection of samples from 90 soil profiles. The INP plateau has a relatively expressive area of organic soils, located in the valleys formed among the rocky outcrops. Organic carbon was also measured in all samples in the laboratory by using the dry combustion method. Prediction was performed with Neural Network using the R package neuralnet. The RMSE for normalized 0-1 values was of 0.067 and the R^2 0.90. The technique shows potential for large application, and it is especially important in areas of limited access such as the INP. Considering the SOC is an important indicator of soil quality and degradation, it is also relevant for the management plan of the INP, since the good correlation with Vis–NIR techniques allows for future monitoring by using remote sensing tools.

Keywords: Keywords: Soil properties; organic soils; chemometrics; remote sensing.
Financial support: CAPES, TEMPUS PUBLIC FOUNDATION, FAPERJ.

(1469 - 2887) Qualitative evaluation of soil organic matter using Vis-NIR diffuse reflectance spectroscopy in an agroecological production system in Seropédica, Rio de Janeiro (Brazil)

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Soil organic matter (SOM) is a key component to understand and monitor soil quality and processes, providing information on agronomic and ecological use and management of agroecological production systems. Visible and near infrared reflectance (Vis-NIR) has presented potential as a non-invasive and non-destructive method to characterize soils and their chemical, physical and mineralogical attributes. The aim of this study was to compare SOM contents and associated Vis-NIR spectral curves among areas with different agroecological production systems/treatments.The experiment was carried out in 2014 at the *Sistema Integrado de Produção Agroecológica* (Integrated System of Agroecological Production), in Seropédica city, Rio de Janeiro state, Brazil. The area has Planosols and was divided in two sub-areas: Sub-area 1 (3578 m²) – for organic vegetables production with (3051 m²) and without shading screens (527 m²), and Sub-area 2 (4676 m²) – for biomass production (straw) with 3982 m² of elephant grass cv. Cameroon (*Pennisetum purpureum*) and 694 m² of shrub legumes (*Gliricidia sepium*). A total of 246 soil samples were collected at a depth of 20 cm on a 0.5 by 0.5 m regular grid. After air-drying, they were sieved (2 mm) and analysed for SOM via wet oxidation. Then, Vis-NIR reflectance spectral curves (350-2500 nm) were obtained in the laboratory and interpreted qualitatively in relation to the SOM contents and chemical groups. The screen-covered area (36 samples) showed the highest SOM contents (1,55% of SOM and 25% of reflectance on average) whereas the shrub legumes area (27 samples) showed the lowest SOM contents (0,86% of SOM and 30% of reflectance on average). The sun-exposed organic vegetables area (120 samples), and elephant grass area (63 samples) showed similar Vis-NIR curves and intermediate SOM contents of about 1,43% of SOM and 28% of reflectance on average. The spectral curves of soils from the four areas/treatments showed absorption peaks at the same wavelengths, related to water and C-H, O-H, C-O, N-H and S-H groups. On the other hand, higher SOM contents produced lower Vis-NIR reflectance (albedo), enabling to rapidly (qualitatively) screen and monitor SOM contents among the different agroecolgical production system/treatments.

Keywords: Organic farming; Tropical soils
Financial support: CNPq; UFRRJ; Embrapa Solos; Embrapa Agrobiologia.

(7630 - 1940) Soil analysis through portable fluorescence X-ray (pXRF) spectrometer: predicting sum of bases (SB) and cation exchange capacity (CEC) in tropical soils.

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Traditional methods to evaluate important soil chemical properties such as cation exchange capacity (CEC) and pH require laborious chemical analysis that are often expensive and time consuming. As an alternative to these methods, some studies have recently introduced the use of portable X-ray fluorescence (pXRF) spectrometry as a means to infer soil properties. However, such analyses are still scarce in tropical soils and, thus, need to be evaluated. This work further studies this possibility by utilizing data obtained via pXRF to predict the sum of bases (SB) and the CEC of Brazilian soils. 594 samples of soil A horizon were collected in 6 Brazilian states and subjected to laboratory analyses of SB and CEC. The samples were also analyzed by a Bruker® pXRF S1 Titan, in triplicate for 60 seconds using Trace mode. Ordinary least square (OLS) and random forest (RF) methods were used to create SB and CEC predictive models with 70% of the total data. The models were further validated by calculating the root mean square error (RMSE), mean error (ME) and R^2 using the remaining 30% of the data. Results by the RF method were evaluated through the mean of squared residuals (MSR) and the percentage of explained variance obtained from the generated models. The models achieved through OLS to predict SB and CEC, respectively, are given by: $SB = 2.5411 + 38.2560CaO + 14.0360Cl - 13.8962K_2O + 7.6625Mn + 7{,}0441Rb$ ($R^2 = 0.45$); and $CEC = 8.838 - 4.9681Al_2O_3 + 38.0318CaO - 9.1297K_2O + 13.1336Ni + 36.2903Y + 4.1521Zn - 14.2889Zr$ ($R^2 = 0.31$). Random forest resulting mean of squared residuals (MSE) and explained variance were 8.52 and 52.83% for SB and 22.52 and 29.36% for CEC. Random forest models performed better in validation tests when compared to OLS, providing overall higher R^2 (0.8 vs. 0.63 and 0.59 vs. 0.54, for SB and CEC models, respectively), as well as lower RMSE (1.95 vs. 2.6 and 3.13 vs. 3.78) and ME (1.32 vs. 1.92 and 2.41 vs. 3.04). pXRF spectrometry can ease the efforts to gather important information about tropical soils and the models generated show it is conceivable to apply and further improve this idea for these