Geophysical data to modeling soil properties in tropical hillslope areas

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Thematic Session: Legacy data: How turn it useful?

Abstract

Aero geophysical data is becoming an important source of environmental covariate in digital mapping. Airborne gamma-ray spectrometry is more common in digital soil mapping, because of the penetration potential of approximately 30-40 cm. However, the airborne magnetic method can be tested to add and improve the prediction of soil properties. Therefore, the objective of this work was to implement a preliminary study to model the spatial distribution of soil properties using pedological legacy data, aero geophysical data, and terrain covariates to discuss their importance to the digital soil mapping in Bom Jardim county, Rio de Janeiro, Brazil.

Introduction

Considering the applicability of the airborne gamma-ray spectrometry to represent different sources of parental material, its use for digital soil mapping has increasing. The penetration potential of approximately 30-40 cm and the correlation with weathering and pedogenesis processes (Wilford et al., 1997) where discussed by Reinhardt et al. (2019), Bonfatti et al. (2020) and Loiseau et al. (2020). The airborne magnetic method, on the other hand, despite being less frequent, showed potential for soil studies as McCafferty et al. (2009), Siemon et al. (2020) and Iza et al. (2018). The research goal is to predict soil properties using legacy soil data, terrain covariates derived from the Digital Elevation Model (DEM) and aero geophysical data (AGD) through Random Forest model, to evaluate the potential of these covariates in digital soil mapping.

Methodology

The soil dataset gathers 208 superficial soil samples collected in Bom Jardim county, between 2009 and 2011 (Figure 1), and from those samples some of the soil properties were addressed this study: Bases saturation (VV), Soil density (DEN), Clay and Sand contents. The procedures used to collect, describe and analyze the soil samples are detailed by Calderano Filho (2012). The DEM was obtained by interpolation of vectorial data from the official cartographic database of Rio de Janeiro state, at 1:25,000 scale, with a 20m of spatial resolution. From the DEM, 17 terrain covariates were derived in the SAGA-GIS open-source software.

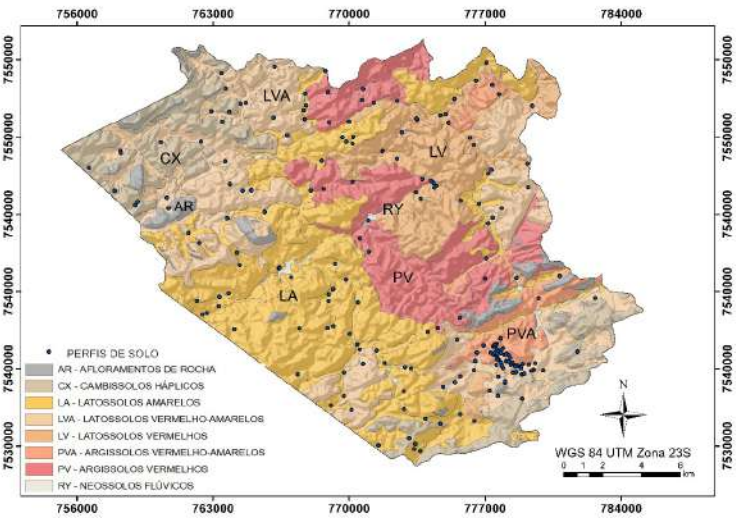

Figure 1: Location of soil profiles, Bom Jardim - RJ, modified from Calderano Filho, B. (2012).

The AGD was obtained from CPRM (2012), and the interpolation was performed using the methods minimum curvature for gamma-ray data (Briggs, 1974) and bidirectional for magnetic data (Geosoft, 2010), totaling 19 covariates with a resolution of 100 m, as suggested by Vasconcellos et al. (1994). After processing, all the products were resampled in the RStudio software to 20 m resolution to adapt them to the terrain covariates resolution. After processing the covariates, Spearman's correlation was applied with a critical value of 95% to exclude covariates that are not correlated with dependent variables. The Random Forest (Breiman, 2001) model was applied with the parameters: ntree=350 and mtry= 10, to modeling soil properties in RStudio software. The accuracy was evaluated through the coefficients R^2 and RMSE obtained by the cross-validation method.

Results and discussion

Four airborne magnetic covariates were excluded from Spearman's correlation, including Total magnetic anomaly, Tilt angle and your absolute value (Miller e Singh, 1994), and Horizontal tilt angle (Cooper e Cowan, 2006). After that, the model RF was applied. Table 1 demonstrates the cross-validation R^2 and RMSE values.

Tabela 1: R^2 and RMSE for each dependent variable.

	DEN	Sand	Clay	VV
R^2	0.37	0.18	0.15	0.19
RMSE	0.46 g/cm3	45.63 g/kg	87.62 g/kg	19.07 %

Carvalho Junior et al. (2014), from the same database, considering 0-5 cm soil depth and the method ordinary kriging, obtained R^2 values 0.19 and 0.17 to predict soil clay and sand contents, respectively. The study considering 18 environmental covariates derived from DEM and satellite imagery. Comparing with the R^2 values of this study for clay and sand, the AGD seems to be important to improve the prediction performance. Figure 2 shows the top five variables that most contributed to regression model performance.

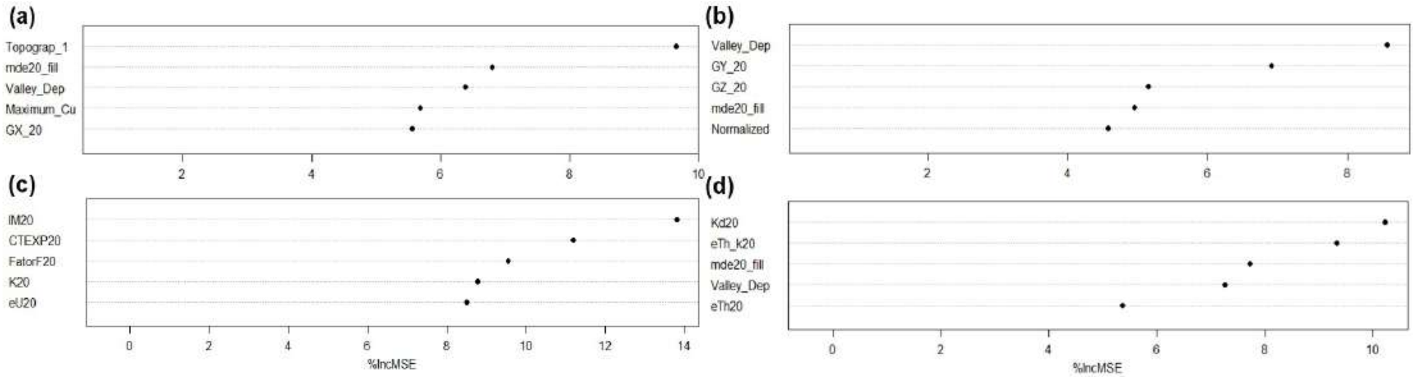

Figure 2: Top 5 most important variables for RF model performance: (a) Sand, (b) Clay, (c) Soil density (DEN), (d) Bases saturation (VV).

The AGD is present in the top 5 covariates to all properties studied (Figure 2). The magnetic data GX, GY and GZ as we can see in Barbosa et al. (2013) are related to the presence of magnetic bodies, in other words, the reflecting parental material characteristics. The Mafic Index (IM) was calculated by combing magnetic and gamma data and allows the removal of the influence of iron-rich soils (Barbosa et al., 2013) and according to Figure 2, has importance in the prediction of DEN. The importance of gamma-ray data was remarkable to predict DEN and VV. CTEXP is mostly related to the source material (high K, eU and eTh values). High values of eTh can be related to the parental material or clay related with intense weathering process (Wilford et al., 1997). Kd is the value of K (%) without the eTh contribution highlighting these element anomalies (Pires, 1995) and FatorF is calculated by the formula F=K*(eU/eTh), where high values show K (%) enrichment (Ribeiro et al., 2014), that can explain your contribution to the VV prediction.

Conclusions

From the results observed, it was possible to conclude that the aero geophysical data have significant importance. AGD can be used in predictive modeling procedures to map soil properties as support with terrain covariates to understand the origin of soil property's spatial variability.

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