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Modeling soils physical-hydric attributes through algorithms for quantitative pedology in Guapi-Macacu watershed, RJ

SANTOS, Priscilla A.[1]; PINHEIRO, Helena S. K.[2]; JÚNIOR, Waldir C.[3]; PEREIRA, Nilson R.[3]; BHERING, Silvio B.[3]; SILVA, Igor L.[4]
[1]UFRRJ Master in Geoscience - Petrology and Geotectonics Department, priscillaas@ufrrj.br; [2]UFRRJ Soil Department Professor, koenow@ufrrj.br; [3]Embrapa Solos CNPS Researchers, {waldir.carvalho@embrapa.br, nilson.pereira@embrapa.br, silvio.bhering@embrapa.br};[4]UFRRJ Specialization in Applied Statistics – Mathematics Department, igorleite-ils@hotmail.com.

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Abstract
The research goal is to analyze soil's properties and associate them with the behavior and vertical variability of soil basic infiltration speed (bir) and saturated hydraulic conductivity (ksat) in soils from Guapi-Macacu watershed using the Algorithm for Quantitative Pedology (AQP) package, in order to support predictive vertical modeling of soil attributes. To achieve the goals, 36 soil profiles were subjected to statistical analysis and then applied the AQP depth functions: standardization, slicing and aggregation methods. Thus, having the harmonized data set, the results were quantitatively and qualitatively evaluated, which pointed to high soil granulometric and physicochemical properties variability, maintaining a moderate to strong correlation with the physical-hydric attributes. It is concluded that the high soil properties variability can affect the vertical modeling in terms of prediction, as it tends to reduce the assertive degree in the training/validation of the models.
Keywords: AQP; Geoprocessing; Hydropedology; Digital Soil Mapping; Predictive Modeling.

Introduction

Knowledge about soil physical-hydric attributes, such as is important to understand the water dynamics in watersheds (GARCÍA-SINOVAS et al., 2001). The water content stored and available affects the environmental functions of soils, the biodiversity and sustainability of this natural resource (FAO, 2017). Thus, the present work aims to understand soil`s physical-hydric attributes vertical variability, specifically the soil basic infiltration ratio speed (bir) and saturated hydraulic conductivity (ksat) from soils in Guapi-Macacu`s watershed and its relationship with other soils properties, such as particle size composition (sand, silt and clay), soil and particle density and porosity to apply pedotransfer functions (PTFs).

Methodology

The studied area is composed by Guapi-Macacu whatershed (Figure 1), located in the Guanabara Bay Hydrographic Region (RH-V), in metropolitan region of Rio de Janeiro. Its domain is delimited by the political-administrative limits of the Itaboraí, Guapimirim and Cachoeiras de Macacu municipalities; and also by Guapiaçu town, reaching dimensions of 1250.78 km^2 of water catchment area and 199.2 km in perimeter extension (Projeto Macacu, 2010).

The soil profiles, as well as their physical-chemical analysis, come from the pedological survey carried out in 2011 by Embrapa Solos company in partnership with the Research and Development Support Foundation - FAPED (CHAGAS et al., 2011). Data from 36 hydropedological sampling profiles were obtained by conducting a hydropedological survey with Guelph Permeameter.

The variables measured (bir and ksat) in two different layers (0-20 cm and 0-40 cm) were subjected to an exploratory statistical analysis. Then, soil depth functions were applied in final database, through the spline method implemented in a routine developed in RStudio v. 1.3.959 environment with R v.4.0.1 (R CORE TEAM, 2020), using Algorithms for Quantitative Pedology (AQP) package (BEAUDETTE et al., 2013). The soil profiles were sliced at a 1 cm interval (slice-wise method), and the data set was aggregated according to six predefined intervals of 20 cm in depth (slab-wise method). The results obtained through the AQP modeling were characterized in profile collections and analyzed according to each soil property. The methodology is shown at Figure 2.

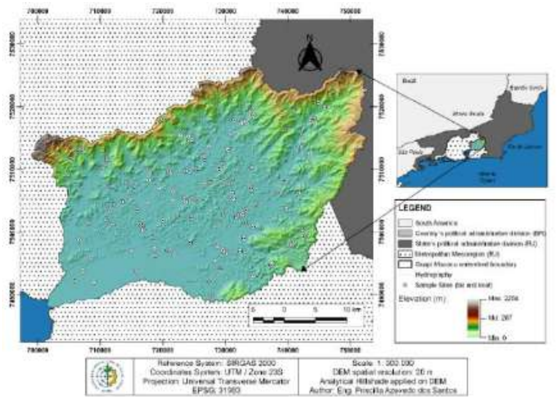

Figure 1. Study area: Guapi-Macacu whatershed, Rio de Janeiro, Brazil.

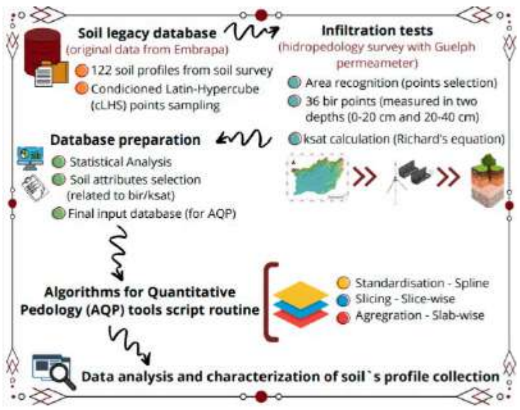

Figure 2. Proposed methodology flowchar.

Results and discussion

The soil profiles collection presented characteristics such as: a total of 36 soil profiles, ranging from 0.30-1.15 cm in depth. The largest fraction of clay (400 to 700 $g.kg^{-1}$) (Figure 3) is found in the subsurface B horizon and increases with depth; the fraction of clay dispersed in water (350 to 450 $g.kg^{-1}$) (Figure 4) behaves inversely, being greater in the A horizon and decreasing in depth.

Sand (Figure 5) is well distributed along the profiles in the surface and sub-surface layers, ranging from 400-800 $g.kg^{-1}$. Soils with different particle sizes presented distinct behaviors in terms of easy water movement and particle translocation, greater in clay and silt, less in san, due to weight and size. Thus, indicating that bir and ksat is greater in superficial and subsurface horizons where the thin sand particle size portion (Figure 6) quantity is greater compared to coarse sand (Figure 7), and soil porosity (Figure 8) also increases in these saturated layers.

The ksat measured mainly increased in the limit between surface and subsurface layers (~20-40 cm), where clay (Figure 3) and silt (Figure 9) fraction decreases due to the fine sand proportion increase, affecting water flow in pores. Rain saturated soils shown a decrease in ksat value influencing measurements (low values in superficial layers and null values in subsurface portion).

Soil density (Figure 10) generally increases with soil depth of the Basin. Organic soils have low soil density values around 0-0.6 g.cm^{-3}. Mineral soils (presence of horizon AB, BA and C) density decreased, while other soils density increased in depth. The behavior is quite different for particle density (Figure 11), which affects aggregation and water flow, associated with particle size (soil granulometry). The particle density values are higher than soil density, reaching a maximum of 2.65 g.cm^{-3}.

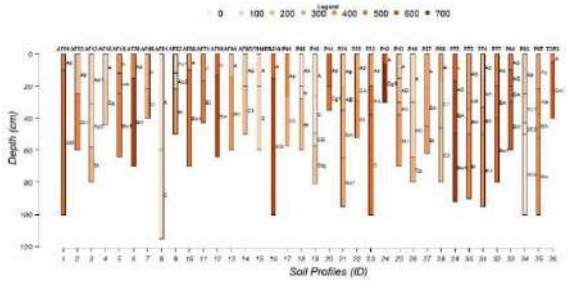

Figure 3. Clay attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

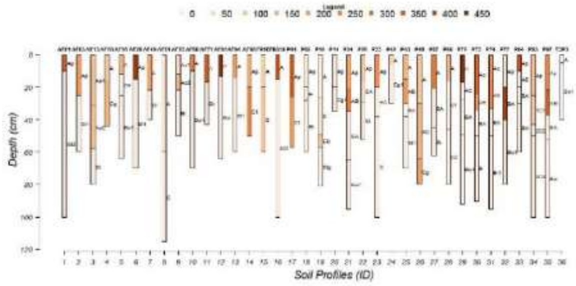

Figure 4. Dispersed clay attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

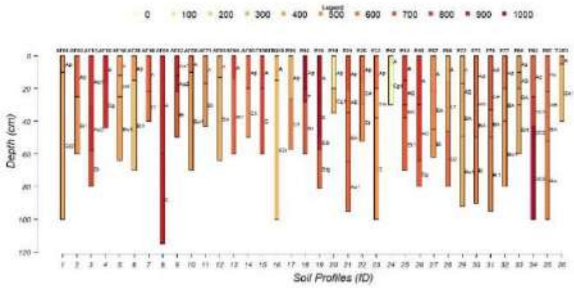

Figure 5. Sand attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

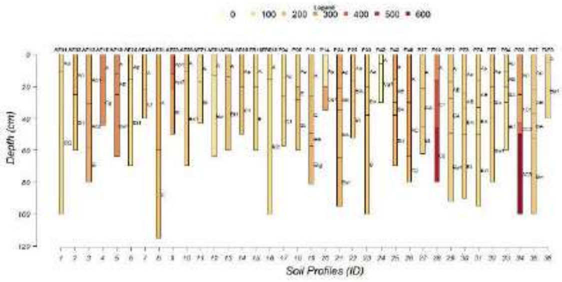

Figure 6. Thin sand attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

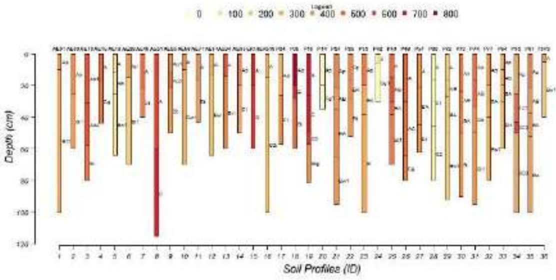

Figure 7. Coarse sand attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

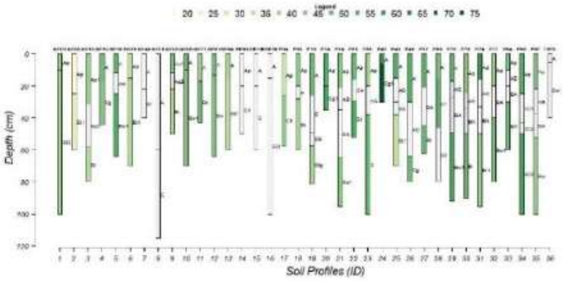

Figure 8. Porosity attribute variability in Guapi-Macacu soils profile collection, in percentage (%).

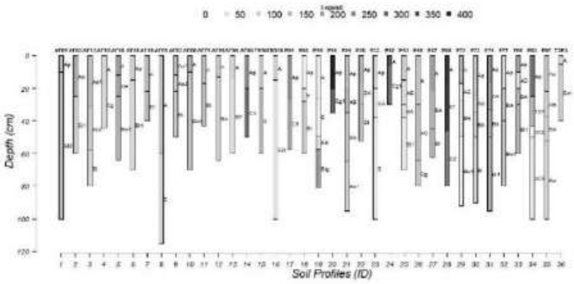

Figure 9. Silt attribute variability in Guapi-Macacu soils profile collection, in g.kg^{-1}.

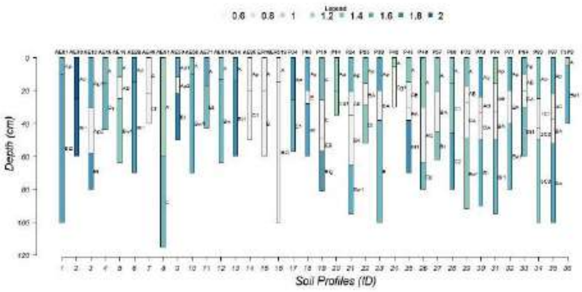

Figure 10. Soil density attribute variability in Guapi-Macacu soils profile collection, in g.cm^{-3}.

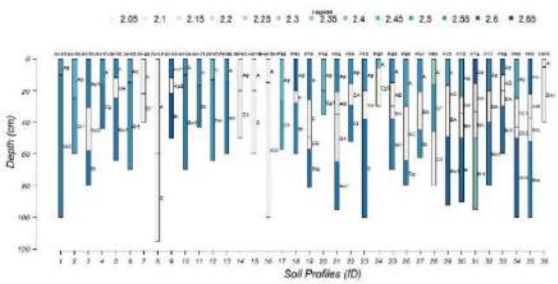

Figure 11. Particle density attribute variability in Guapi-Macacu soils profile collection, in g.cm^{-3}.

Conclusions

The AQP use contributed to the texture variability analysis and soil physical-hydric attributes in depth, allowing the correlation between soil characteristics and its textural classification properties. Thus, this tool acts as a support for analysts in decision making at choosing input variables in predictive models' development (digital soil mapping), enabling the input data harmonization. Associated with machine learning methods and models, the AQP is a potential tool for preliminary studies in hydropedology, such as the implementation of pedotransfer functions, being recommended its use in research aimed at maintenance and conservation of soil water functions as directed by FAO (2017) (storage, availability and human supply, among others).

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