A method for mapping the spatial variability of soil physical quality

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Abstract

The objective of this work was to propose a method for mapping the spatial variability of soil physical quality. Basically, the method consisted of mapping the spatial variability of Easily Available Water (E.A.W.), Air Filled Porosity (P.A.) and soil Penetration Resistance (R.P.), using geostatistics, and a standard vector classifier, to scale the physical attributes and classify the Soil Physical Quality (S.P.Q.). The studied site was an area of 6.24 ha pertaining to an Integrated Agroecological Production System (IAPS), located at Seropédica, Rio de Janeiro/BR. A regular georreferenced grid was used to assess and determine the physical attributes E.A.W., P.A. and R.P., respectively, at 0.10, 0.20 and 0.30 m soil depth. The classes of S.P.Q. used were: Restrictive (E.A.W.<3.9 mm, and/or P.A.<10%, and/or R.P.>2mPa), Suitable (E.A.W. = 3.9-5.5 mm, and P.A. = 10-20%, and R.P.=1-2 MPa) and Optimum (E.A.W. > 5.5 mm, and P.A.>30%, and R.P.< 1MPa). All physical attributes presented spatial dependence with fitted spherical (E.A.W. and P.A.) or exponential (R.P.) semivariograms models. Most part of the area was classified as restrictive, at all depth for the sake of low E.A.W., followed by suitable and Optimum, respectively. The method must be tested in different environmental conditions.

Key Words

Management zones, precision agriculture, geostatístics, multivariate analysis, euclidian distance.

Introduction

The knowledge of the spatial variability of soil physical quality of an area is frequently necessary to improve the management of agriculture production systems. Recently, the Least Limiting Water Range (LLWR) has been proposed and used as an index of soil physical quality for crop growth (Silva *et al.* 1994), since it integrates the effects of soil aeration, resistance to penetration, and soil water retention on crop growth into a single attribute. Despite the advantage of using this index, the process of its measurement in a specific site is too expensive and time consuming, especially in projects aiming to map the spatial variability of soil physical quality in precision agriculture. Considering this limitations, the objective of this work was to propose a more cost-effective method for mapping the spatial variability of soil physical quality.

Material and methods

The study site is 6.24 ha hectares and is located between 43º40'00" and 43º 41'10" W, and 22º44'30" and 22º45'30" S, in Seropédica municipality, Rio de Janeiro. The area is composed by glebes, 5.05 ha managed in a mixed farming system, and pasture, 2.89 ha, it was implanted in 1997 and farmed exclusively to the grass Transvala (Digitaria decumbens Stent cv Transvala). In order to apply geostatistics to investigate the spatial variability of soil physical attributes, the sampling strategy included the definition of a regular square grid with 20 meter spacing. As recommended by Trangmar *et al.* (1985), since spacing between sampling points might affect data modeling, additional soil samples were collected in reduced spacing (1, 5 and 10 meters), according to topography and soil classes. A grid with 169 points were performed, where altitude and coordinates (UTM system) were measured using a GPS with differential correction (DGPS- Trimble-GeoExplorer 3 model), with submeter accuracy. In 122 georreferenced points, undisturbed soil samples were collected at depths 0.0–0.10, 0.10–0.20 and 0.20-0.30m, for the determination of water retention at 10 kPa (Field Capacity) and 80 kPa (limit of tensiometer reading) and soil bulk density - ρ_b (EMBRAPA 1997). Thereafter, the soil samples were grinded and air-dried for determination of soil particle density (ρ_s) and soil particle size distribution (Pipette method) (EMBRAPA 1997). Easily Available Water (EAW) and Air-Filled Porosity (PA) were calculated by the expressions, E.A.W. = (θ_{10kPa}- θ_{80kPa}) and P.A. = ($\theta_{total\ porosity}$ - θ_{10kPa}), respectively. Penetration resistance (PR) was determined in 169 grid points, at 0.0-0.10, 0.10-0.20 and 0.20-0.30m soil depth, using a penetrometer of impact developed by Stolf (1991). Geostat (Vieira *et al.* 1981) software was used both to determine measures of spatial continuity (experimental semivariograms) and for experimental data modeling, by fitting data to an analytical model to be further used in the estimation and simulation stages. The selection of the most suitable analytical model was done by cross-validation (jack knifing). The kriged estimation of EAW, PA and PR, in each soil depth, were used to classify the Soil Physical Quality (SPQ) as: 1- Restrictive (E.A.W.<3.9 mm, and/or P.A.<10%, and/or R.P.>2mPa), 2- Suitable (E.A.W. = 3.9-5.5 mm, and P.A. = 10-20%, and R.P.=1-2 MPa) and, 3- Optimum (E.A.W. > 5.5 mm, and P.A.>30%, and R.P.< 1MPa). The integration of each soil attribute (EAW, PA and PR) on classes of SPQ was performed on Matlab software, using the Euclidian distance of each point in relation to a standard vector (Restrictive, Suitable and Optimum).

Results and discussion

Figure 1 shows the semivariograms of E.A.W., P.A. and P.R., at 0.10, 0.20 and 0.30m soil Depth. All the attributes present spatial dependence and the Spherical model was best fitted to the attributes E.A.W. and P.A. at all depth, and P.R., at 0.10m depth. The Exponential model was best fitted to P.R. at 0.20 and 0.30 m soil depth. Considering the spatial dependence index proposed by Cambardella *et al*. (1994), all the attributes presented strong spatial dependence ($C_0/C_o+C_1< 25\%$) at all depth, with exception of P.R and E.A.W. at 0.10m soil depth. It was observed that the nugget effect, for all the attributes, decreased as the soil depth increase. This behavior is probably associated to the pedogenetic process commonly occurring in the soil of the study site. Up to 0.30 m soil depth, the clay content increase forming an argilic horizon and reduces the erratic component of the semivariance.

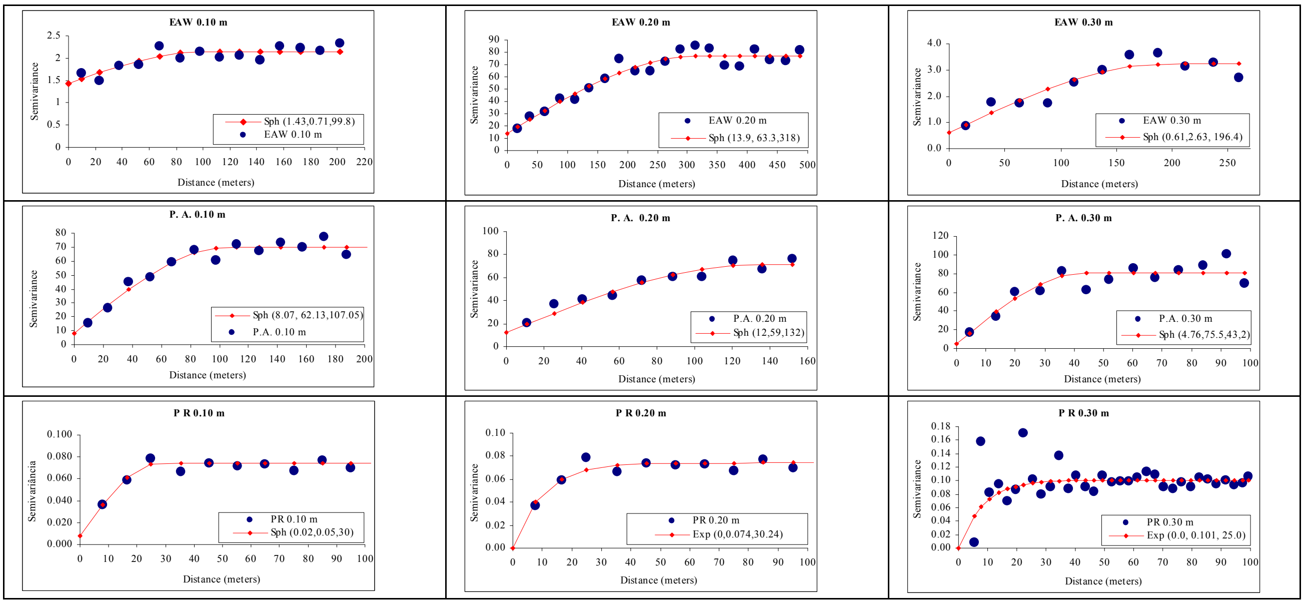

Figure 1. Semivariograms of E.A.W., P.A. and P.R. at 0.10, 0.20 and 0.30 m soil depth.

Figure 2 shows the spatial variability maps of S.P.Q. at 0.10, 0.20 and 0.30 m soil depth. At all depth, the restrictive class represented the most part of the area and increase according to the soil depth (56, 64 and 68%, respectively). The higher percentage of restrictive class was caused by the low values of E.A.W. of the study site, mainly at the 0.10 m soil depth. On the other hand, as the soil depth increase, the P.R. increase and reduced the occurrence of optimum class (30, 15 and 13%, respectively).

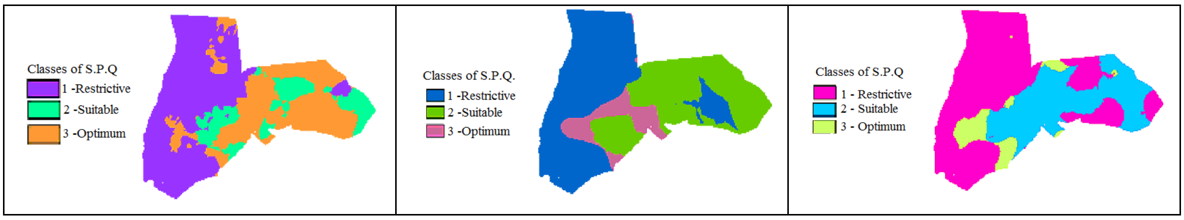

Figure 2. Spatial variability maps of Soil Physical Quality at 0.10 , 0.20 and 0.30 m soil depth.

Conclusions

The most part of the study site presented a restrictive S.P.Q. due to the low values of EAW. The proposed method was efficient to classify the soil physical quality of the study site, and must be tested in different environmental conditions.

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