SPATIAL VARIABILITY OF SATURED SOIL HYDRAULIC CONDUCTIVITY IN THE REGION OF ARAGUAIA RIVER - BRAZIL

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ABSTRACT: This study evaluates the spatial variability of saturated hydraulic conductivity in the soil in an area of 51,850 ha at the headwaters of the Araguaia River MT/GO. This area is highly vulnerable because it is a location of recharging through natural water infiltration of the Guarani Aquifer System and an area of intense increases in agriculture since its adoption by growers in the last 30 years. Soil samples were collected at 383 points, geographically located by GPS. The samples were collected from depths of 0 - 20 cm and 60 - 80 cm. Exploratory statistics and box-plot were used in the descriptive analysis and semivariogram were constructed to determine the spatial model. The exploratory analysis showed that the mean hydraulic conductivity in the superficial layer was less than at the level of 60-80 cm; however, the greatest variability evaluated with a coefficient of variation also was from this layer. Data tended towards a normal distribution. These results can be explained by the greater soil compaction in the superficial layer. The semivariogram models, adjusted for the two layers, were exponential and demonstrated moderate and strong dependence, with ranges of 5000 and 3000 utm respectively. It was concluded that soil use is influencing the spatial distribution model of the hydraulic conductivity in the region.
KEYWORDS: semivariogram, hydraulic conductivity, spatial dependence, soils

INTRODUCTION: The soils located in the region of the headwaters of the Araguaia River are considerably fragile and have been receiving intense agricultural use which compromises the quality of the soil and provokes ecologic disequilibrium in the region as argued by GOMES et al, 2006.
Hydraulic conductivity is an attribute that is influenced significantly by soil use and management. For CAMARGO & ALLEONI (1997), soil management alters quality of the soil, which modifies the availability and flow of water.
Spatial variability is a characteristic of the majority of the natural phenomena which could include the parameters related to the movement of water in the soil (QUEIROZ, 1999).
Classic statistics and geostatistics are two powerful tools that interact with each other in the analysis of the hydro-physical data of soil, demonstrating the magnitude of spatial variation and the structure of spatial variability, which could help in the understanding and definition of the management strategies of the soil for irrigation, drainage and soil conservation (EGUCHI et al, 2003).
According to CORREA (1986), there are still few studies in Brazil that measure the spatial variability in one unit of soil and among taxonomic units with the principal parameters of the soil.
The objective of this work was to characterize the spatial dependency of the hydraulic conductivity of the saturated soil from the headwaters' region of the Araguia River, using semivariogram models.

METHODOLOGY: The area studied was located in the headwaters' region of the Araguaia River between the states of Mato Grosso and Goias. 383 sampling points of saturated hydraulic conductivity were evaluated at each depth within an area of 51,580 ha. The sampling points were distributed throughout the entire area and demarcated with GPS.
The evaluations were made at depths of 0-20 cm and 60-80cm with the goal of discovering if a difference occurred in water flow at the different depths.
The soil analyzed was uniform throughout the profile and could be classified as sandy textured however a relatively high variation was noted in the experimental area because of the size of the area and the occurrence of diverse classes of soil.
In the exploratory data analysis procedure, statistics were calculated at the two sample depths. The box-plot graphs were used with the objective of identifying the occurrence of outliers. Interquartile criteria were used to identify outliers.
The geostatistical analysis was done with semivariograms and theoretical models were adjusted to the experimental semivariances.
The degree of spatial dependence was also analyzed using the relation between the nugget effect and the sill, conforming to the proposal of Cambardella et al. (1994). Kriging was conducted so that the attribute could be mapped at the two depths. Each geostatistical analysis was done with the GS Plus program (Gamma Design Software, 2004) and using the procedures described in Vieira (2000).

RESULTS AND DISCUSSION: In Table 1, the results are presented from the exploratory analysis of the hydraulic conductivity data of the saturated soil at the two depths evaluated.

Tabel 1. Exploratory analysis of saturated soil hydraulic conductivity (Ks) at depths of 0-20 cm and 60-80 cm.

Statistics	Ks	
	0 -20 cm	60 -80 cm
Mean	54.290	176.898
Median	52.160	174.590
Mode	69.540	245.410
Standard deviation	16.881	85.990
CV	31.095	48.610
Kurtosis	-0.777	0.361
Skewness	0.265	0.639
Minimum	22.080	34.120
Maximum	101.080	515.200

It was verified that the capacity of the soil to conduct water in the superficial layer was inferior to the layer at 60-80 cm. This fact can be associated with possible soil compaction from improper soil use.
The relatively close average and median values at each depth, together with the skewness and kurtosis close to zero, allows us to infer that the attribute presented an approximately symmetric distribution tending to normal for the two depths analyzed. The CV data and the minimum and maximum reveal relatively high variability, a fact which was also observed by EGUCHI et al (2003) and Gomes et al (2007).
The box-plot in Figure 1 reveals that the hydraulic conductivity attribute of the saturated soil didn't present outliers or extreme values for the depth of 0-20 cm. At the 60-80 cm level, two outliers occurred that were above 445mm/h.

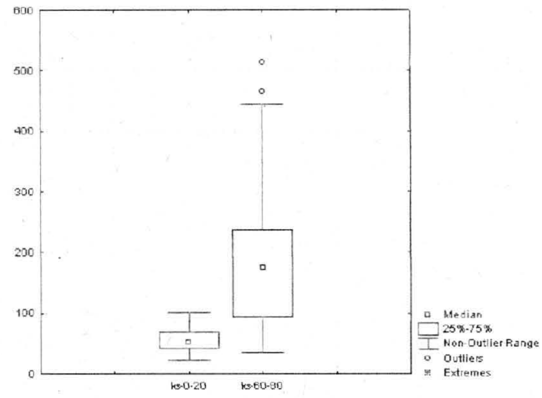

Figure 1. Box plot of saturated soil hydraulic conductivity (Ks) at depths of 0-20 cm and 60-80 cm.

The experimental semivariograms and the adjusted models are presented in Figure 2, The semivariogram model adjusted to the experimental semivariances of hydraulic conductivity were exponential with ranges of spatial dependence of 5000 utm and 3000 utm, respectively for 0-20 cm and 60-80 cm. Authors like EGUCHI et al (2003) and Gomes et al (2007) also adjusted semivariogram models to the data of hydraulic conductivity; however, these authors completed their experiments in smaller areas. These results show that this attribute had spatial autocorrelation independent of the scale analyzed.

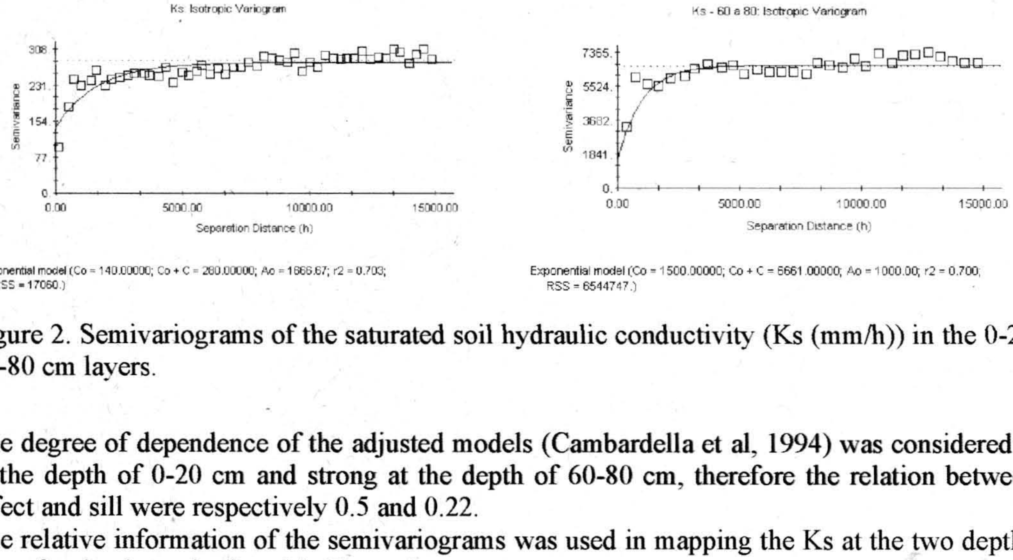

Figure 2. Semivariograms of the saturated soil hydraulic conductivity (Ks (mm/h)) in the 0-20 cm and 60-80 cm layers.

The degree of dependence of the adjusted models (Cambardella et al, 1994) was considered moderate at the depth of 0-20 cm and strong at the depth of 60-80 cm, therefore the relation between nugget effect and sill were respectively 0.5 and 0.22.
The relative information of the semivariograms was used in mapping the Ks at the two depths and the maps for depth can be found in Figure 3.
The strong difference between the values of conductivity in the two layers is shown in the maps. It can be seen that the maximum class of the superficial layer is found in the minimum class of the sub-superficial layer which indicates that antropic processes could be contributing to the degradation of the soil. It is expected that the conductivity will be similar throughout the profile because the granularity of this soil didn't present significant differences between the layers.
It is noted that although the smallest classes of saturated hydraulic conductivity occur in the lower part of the maps, this suggests that this area should receive special attention from erosion control programs and soil and water conservation programs.

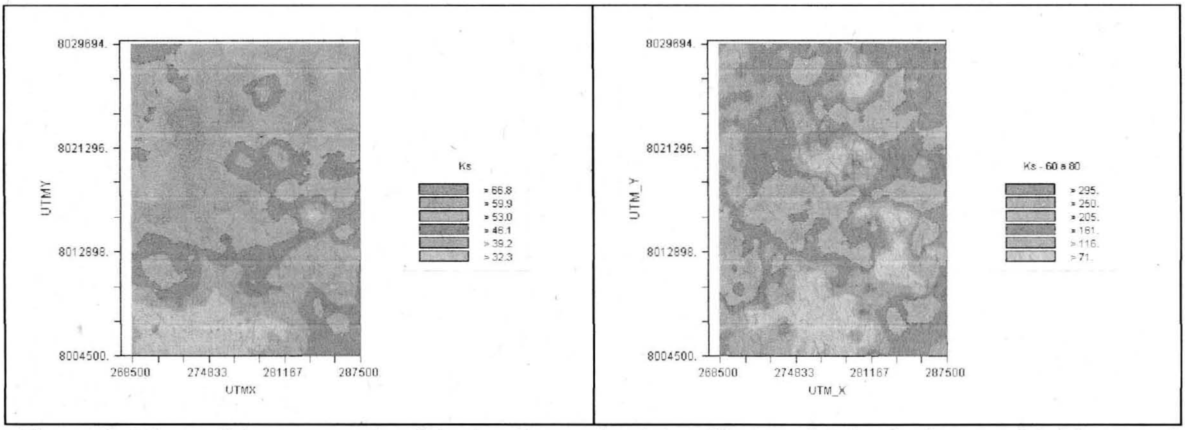

Figure 3. Maps of the saturated soil hydraulic conductivity (Ks (mm/h)) in the layers of 0-20 cm and 60-80 cm.

CONCLUSION: The hydraulic conductivity of saturated soil presents autocorrelation in space; agricultural planning for soils should consider the spatial variability models, especially in areas where aquifers are recharged; the use and management of soil influence the model of spatial dependence.

REFERENCES:

CAMARGO, O.T. & ALLEONI, L.R.F. **Compactação do solo e o desenvolvimento das plantas**. Piracicaba, 1997. 132p.

CAMBARDELA, C.A.; MOORMAN, T.B.; NOVAK, J.M.; PARKIN, T.B.; KERLEN, D.L.; TURCO, R.F. & KONOPKA, A.E. Field scale variability of soil properties in Central Iowa soils. **Soil Sci. Soc. Am. J.**, 47:1501-1511, 1994.

CORRÊA, J. B. D. **Variabilidade espacial de características e propriedades físicas de latossolo roxo do Município de Lavras - MG**. 1986. 83 f. Dissertação (Mestrado em Solos e Nutrição de Plantas) – Escola Superior de Agricultura de Lavras, Lavras, 1986.

EGUCHI, E.S.; SILVA, E.L. & OLIVEIRA, M.S. Variabilidade espacial da condutividade hidráulica do solo saturado e da taxa de infiltração básica determinadas "in situ". **Ci. Agrotecnol.**, Edição especial:1607-1613, 2003.

GOMES , M.A.F.; FILIZOLA, H.F.; SPADOTTO, C.A.; PEREIRA, A.S. **Caracterização das áreas de afloramento do Aqüífero Guarani no Brasil: base para uma proposta de gestão sustentável**. Jaguariúna: Embrapa Meio Ambiente, 2006. 20p.

GOMES, N. M.; SILVA, A. M.; MELLO, C. R.; FARIA, M. A; OLIVEIRA, P. M. Métodos de ajuste de semivariogramas aplicados ao estudo da variabilidade espacial de atributos físicos-hídricos do solo.**R. Brás. de Ci. Solo.** 31: 435-443, 2007.

GAMMA DESIGN SOFTWARE. **GS+: Geostatistics for the Environmental Sciences**. Plainwell: Gamma Design Software, 2004.

QUEIROZ, J.E.; CRUCIANI, D.E. & LIBARDI, P.L. Variabilidade espacial da porosidade drenável de um solo de várzea, no município de Piracicaba, Estado de São Paulo. **R. Bras. Eng. Agríc. Amb**. 3:135-139, 1999.

VIEIRA, S.R. **Geoestatística em estudo de variabilidade espacial do solo**. In: NOVAIS, R.F.; ALVAREZ V., V.H. & SCHAEFER, C.E.GR., eds. Tópicos em ciência do solo. Viçosa, MG, Sociedade Brasileira de Ciência do Solo, 2000. p.1-55.