Spatial Analysis of some soil physicochemical properties in mountainous massif of Sicó, Portugal [1]

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Abstract: The mountainous massif of Sicó, with a maximum altitude of 553 meters, is an extensive area of 50.000 ha composed of calcareous Jurassic formations. In these calcareous soils there are some physicochemical properties that are very important to analyze, because of their relevance in the protection of that region. This is a preliminary study where four of those characteristics were measured: soil pH, soil organic matter, plant available phosphorus and soil exchangeable calcium. Classical geostatistical methods are used to analyze separately the spatial variability of the variables under study and to model the dependence structure of the data.

Keywords: soil physicochemical properties, spatial analysis, prediction

1 Introduction

Calcareous soils with high pH present chemical restrictions to support plant growth. These soils have a high capacity to bind phosphorus. On the other hand, hillside soils are subjected to important erosion processes, if not protected by vegetation. The establishment of pastures in these soils can be an important step towards soil protection and to support traditional livestock activity, representing an important element for humanization of the landscapes in less developed regions. Soil organic matter plays an important role in soil quality, productivity and soil resilience to erosion. The variables considered in this study were soil pH, soil organic matter, plant available phosphorus and soil exchangeable calcium. The aim of this study is to

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analyze the spatial variability of those soil properties. First an exploratory analysis of the data is made in order to address the spatial variability of those physicochemical properties in the calcareous soils of the massif of Sicó, central Portugal. Using then classical geostatistical methods, Cressie (1993), Goovaerts (1997) and Diggle *et.al.* (1998), the spatial dependency level of those soil attributes is analyzed and their krigged maps are generated. This is the beginning of a more ambitious study that will involve more data collected over different periods. As the region under study is a protected area, to compare the distribution of soil physicochemical properties through several years is another challenge.

2 Materials and Methods

The data underlying this work were collected in that region in October, 1988 at 60 locations where four variables were measured: soil pH, soil organic matter, plant available phosphorus and soil exchangeable calcium.

First an exploratory analysis of the data was performed within the R environment (R Development Core Team, 2006), where many packages are available for the analysis of spatial data. Table 1 shows the summary statistics for the variables under study.

Samples soil properties	Mean	Median	Min	Max	Skewness	Kurtosis
pH	8.185	8.200	8.090	8.500	1.7489	6.7177
P2O5 (mg/ kg)	17.317	17.500	9.000	25.000	-0.3007	-0.6736
Org.Mat.(%)	1.721	1.760	0.950	2.190	-0.4405	-0.4989
Ca (cm(+) /kg)	11.183	11.280	7.990	15.090	0.1865	-0.4217

Table 1: Summary statistics

It can be seen that phosphorus and soil organic matter are skewed; phosphorus presents very high values for skewness and kurtosis coefficients estimates. Soil organic matter reveals a high concentration of high values, see histograms Figure 1.

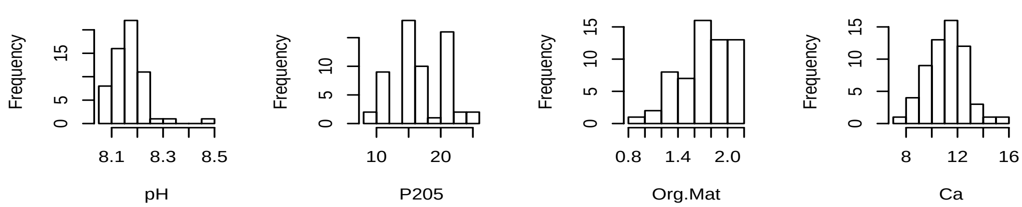

Figure 1: Histograms of the four variables under study

Thus the data were log-transformed to perform the subsequent geostatistical analyses. Sample values of these variables did not show high variability, the highest value was for phosphorus, $CV = 23.1\%$. In accordance with its high skewness, pH showed the presence of outliers, see boxplots Figure 2.

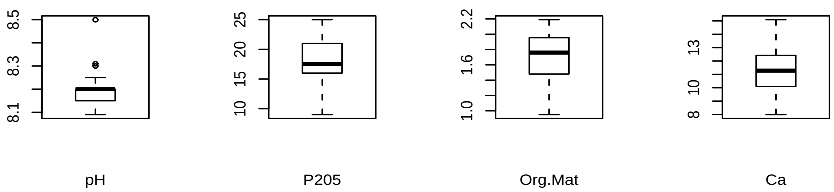

Figure 2: Boxplot of the four variables under study

These first steps in the descriptive analysis led us to construct the experimental semivariograms for lognormal values of pH and soil organic matter. Figure 3 displays the experimental and the theoretical semivariograms and Table 2 gives the parameters of the models fitted to empirical semivariograms.

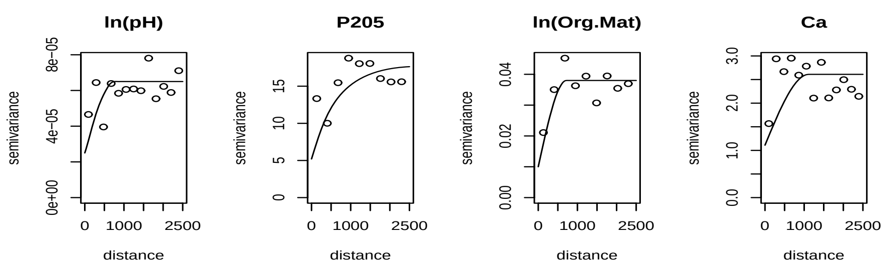

Figure 3: Experimental and theoretical semivariograms for the soil variables

Sample Property	Semivariogram fitted	Nugget	Sill	Range
ln(pH)	Spherical	2.5×10^{-5}	4×10^{-5}	760
P2O5 (mg/ kg)	Exponential	5.2	12.7	650
ln(Org.Mat.(%))	Spherical	0.01	0.028	720
Ca (cm(+) /kg)	Spherical	1.11	1.5	1120

Table 2: Parameters of the fitted models

These first analysis were done using `geoR`, Diggle and Ribeiro (2007) and `gstat`, Pebesma (2011).

3 Concluding remarks

This is a preliminary study using observed values of soil pH, soil organic matter, plant available phosphorus and soil exchangeable calcium, in order to exploit the variability and to look for models for the spatial dependence. Each variable was studied separately and some difficulties were found in fitting models to sampled values. Some more work is needed and is in progress, trying to study the joint behaviour of the variables.

Another challenge topic is to compare distributions of the variables over the years, in order to understand the evolution of the soil in that region, regarding these properties.

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