# Soil heterogeneity in karst soils in Yucatan, Mexico: a geostatistical approach of soil parameters

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## Abstract

*The aim of this study was to identify the soil properties better enabling zoning. Geostatistical analyses were performed. The accuracy of the interpolations was estimated. The parameters with the best model values were: organic carbon, bulk density, rockiness, real density, stoniness, silt, and sand. Probabilistic maps of soil depth allowed identifying the areas with Nudilithic, Lithic and Leptosols. This technique was used to identify the areas of greatest difficulty for cultivation.*

**Keywords**: *indicator kriging, ordinary kriging, soil properties*

## 1. Introduction

Understanding spatial distribution and the accurate mapping of soil properties are important (Lamsal*et al*., 2009) in order to achieve control of fertilization and nutritional management.

In karst environments, soils have a high spatial heterogeneity (SH) of soil properties (Bautista *et al*., 2003, 2004, 2005). SH needs to be taken into account when selecting plots for conducting agricultural experiments. The aim of our study was to analyze the SH of soils in order to identify soil properties better enabling zoning.

## 2. Materials and methods

The study was conducted in Merida Yucatan, Mexico. The plot had 54 quadrants of 25 $m^2$ each. The soil properties were described, including such as, stoniness, rockiness and depth. Samples were analyzed in the laboratory for silt, sand, clay, real density, bulk density, organic carbon and field capacity.

A georeferenced database of soil properties was constructed. Geostatistical analyses were performed using ordinary kriging and, for depth soil, indicator kriging interpolations (Goovaerts, 1999, 2011).

The accuracy of the estimates was achieved through the use of correlation coefficient (r) from the cross validation $r^2$, mean error (ME), root mean squared error (RMSE), and normalized root mean squared error (NRMSE) between measured and estimated soil parameter values,where: r will be >0.75; ME, RMSE and NRMSE will be near to 0 (Delgado *et al*., 2010).

## 3. Results

The models with the highest values of $r^2$ >0.95) semivariogram models were organic carbon, bulk density, rockiness, real density and stoniness (Figure 1).

Considering the association (*r*) between estimated and observed values, the parameters with high accuracy (from 0.75 to 0.8), were sand and real density, whereas, those with good accuracy (from 0.66 to 0.74. were organic carbon, bulk density, and stoniness.

Considering the ME values of the interpolations the parameters without bias were bulk density,real density and organic carbon. The parameters with low RMSE were bulk density, real density, and stoniness. Considering the NRMSE values the Stoniness had a residual variance of 0. The parameters with the largest accuracy of estimates considering at least three of these statistical indices were real density, bulk density, organic carbon and stoniness, whereas clay had the lowest accuracy.

### 3.1 Maps with ordinary Kriging

The graphic representations show the southeast portion of the parcel higher percentage of stoniness (>68%), organic carbon (>17%) (Figure 1). Also, higher percentages of organic carbon and rockiness (>51%) were found to be in the central part of the study area.

The parameters of real density and bulk density (Figure 1) had the highest values in the western portion of the parcel, and are similarity to the sites with highest depth (>40 cm); sites having the lower percentages of rockiness, stoniness, organic carbon and field capacity.

The graphic representation for real density, bulk density, and depth show the higher percentage values are distribute to the east, mainly at the southwest portion. Also in the eastern portion, the sites have higher percentage of rockiness, we found lower percentages for depth, real density and bulk density (Figures 1, 2).

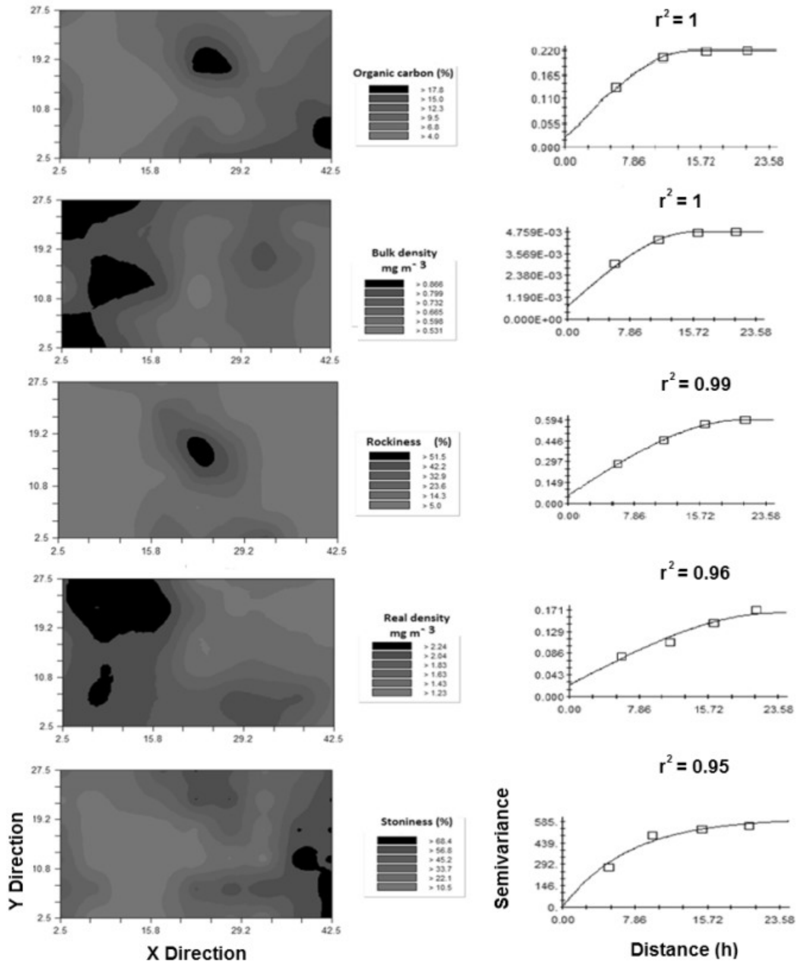


Figure 1.Diagrams of soil properties models with their semivariograms

### 3.2 Probabilistic maps

The probability in the parcel of finding soils with depths between 0 and 5 cm, or NdLP, is greater in the central-southern and the western parts of the parcel; soils with a depth of 0 to 10 cm (NdLP and LiLP) is higher in the central, northern, southern, extreme west, northeast and southeast portions; andsoils with a depth of 0 to 25 cm (NdLP, LiLP) is greater throughout most of the parcel, except in the northeastern, central-western, and northwestern extremes (Figure 2). This means that these sites present soil depths greater to 25 cm.

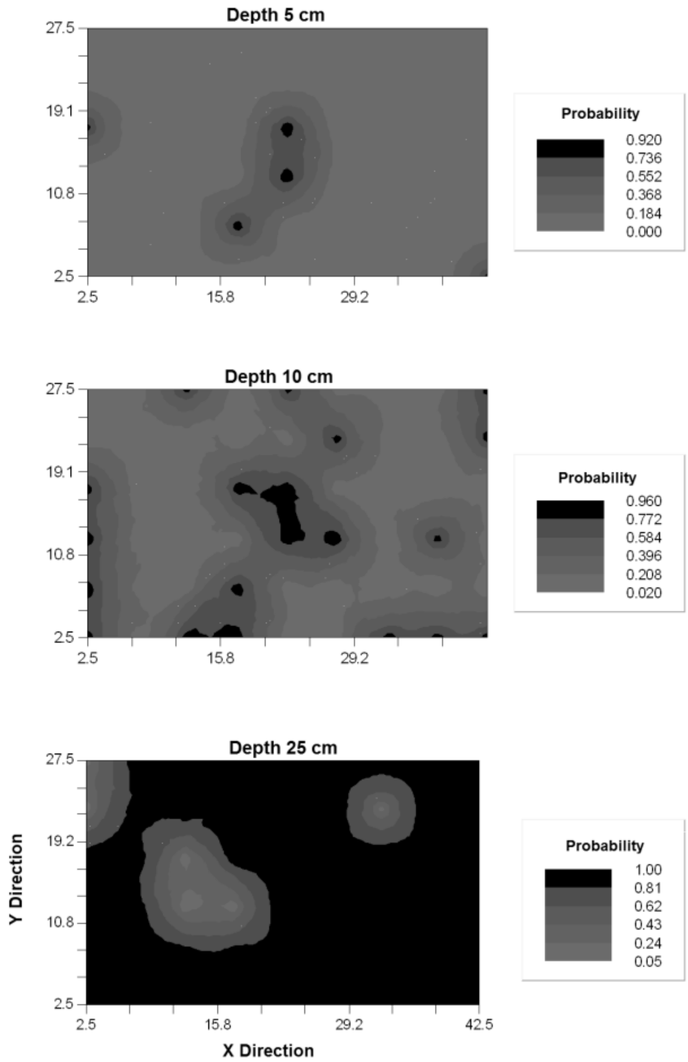


**Figure 2.** Diagrams the probability of soil depth for three different cutoff values

It is possible to identify Leptosols and Cambisols. The Leptosols had several qualifiers, as Nudilithic, Lithic, and Skeletic, and probably also Rendzic and Humic.

The geostatistical analysis allowed to demonstrate the high heterogeneity of soils in karst areas of the state of Yucatan, Mexico.

Traditionally the Maya farmers are aware of the high soil heterogeneity in karst areas, so much so that their Maya Soil Classification includes depth, rockiness, stoniness and soil color (Bautista et al., 2010). However, their agronomic tests are qualitative. On the other hand, agronomists wishing to conduct quantitative agricultural experimentation are limited by the high heterogeneity of soils. In this direction, the identification of the distribution patterns of the most important properties of soils for agricultural experimentation is crucial to improve experimental designs with crops of local interest. These soil properties are: the depth (at three levels, less than 5 cm or Nudilithic Leptosols, between 5 and 10 cm or Lithic Leptosolsand 10 to 25 cm or other Leptosols); rockiness, stoniness (SkeleticLeptosols), organic carbon, and retention moisture at field capacity.

For agricultural technicians who ignore either the Maya Soil Classification or the International Classification of Soils, it is recommended that they use the fourclasses of agricultural suitability of land: I)Depth 25-43 cm; II) Depth 10-25 cm; III) Depth 5-10 cm; and IV) Depth 0-5 cm (Bautista and Zinck., 2010).

## 4. Conclusions

The indicator kriging technique was of great importance for identifying the areas the greatest difficulties for cultivation, such as Nudilithic Leptosols, and Lithic Leptosols. Other Leptosols are the best soils for agriculture

Real density, bulk density, organic carbon, and stoniness are soil properties producing higher accuracy maps using ordinary kriging. These soil properties allow a better understanding of the differences between the "other Leptosols" ie soil depths between 10 and 25 cm.

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