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Geostatistical Study of Surface Soil Properties Under an Oil Palm Plantation. II. Kriging

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Abstract

Kriging is a technique for optimal estimation of values of continuous random spatial variables without bias at unsampled locations, using structural properties of the semi-variogram and an initial set of data values. Selected soil properties were evaluated from samples collected on a 10m x 10m grid from a 100m x 100m plot under oil palm. Soil properties from unsampled points between the grids were estimated by punctual Kriging, using data obtained from sampling and the properties of their semi-variograms. The estimated values for cone index (CI) were found to be statistically close to the true values as determined from data collected later from points between the grids. Isarithmic maps of the kriged estimates for the soil properties are presented along with those of the raw data.

Introduction

The variability of soil properties has long been recognised by soil scientists. To take care of this, fields are usually divided into classes and each class treated as being different from its neighbours. The classical statistical procedures assume that variations are randomly distributed within each class. The mean is therefore used for estimation of properties at unsampled locations within each class. Statistics of dispersion (e.g. coefficient of variation, standard deviation, standard error, confidence limits) are used to indicate the precision of the mean as an estimator. Soil properties have however been found not to change abruptly but rather to vary continuously in space (Webster, 1985). Thus, the classical model is inadequate for interpolation of spatially dependent soil variation and takes no account of spatial correlation and relative locations of samples.

Methods such as trend analysis, moving averages and spline interpolation, all of which incorporate some degree of sample location, have been used. These methods are usually unsatisfactory. Many of them give biased estimates that are not optimal, many do not provide estimates of the interpolation error, and those that do, do not try to minimize the error (Burgess and Webster, 1980). A relatively new system that has been found to be more appropriate is the kriging technique. This method has all the desirable attributes for interpolation (Trangmar et al, 1985). It provides interpolated values that are local, unbiased and have minimum variances which itself can be estimated.

This work is aimed at evaluating the precision of kriging technique in the interpolation of selected soil physical properties.

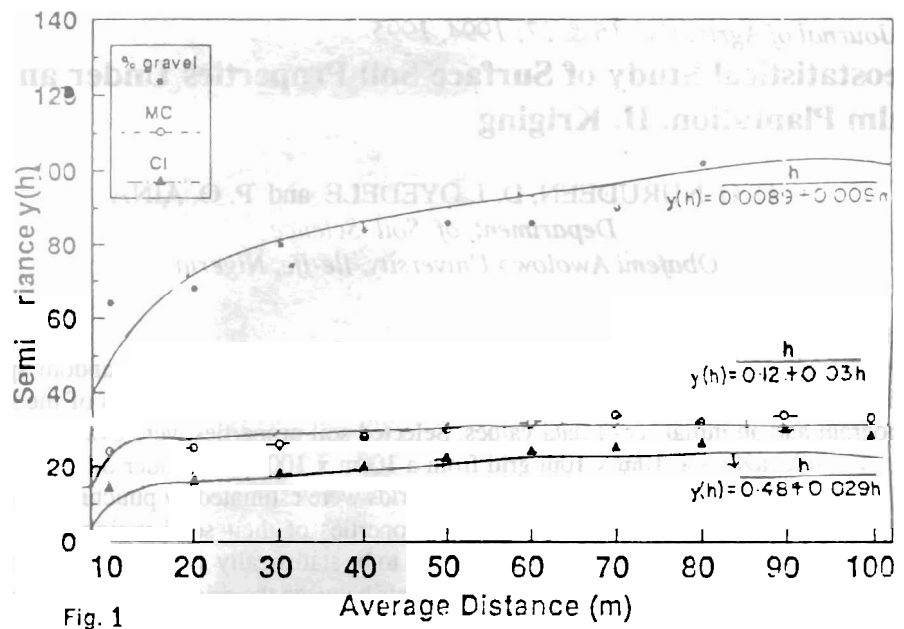


Fig. 1

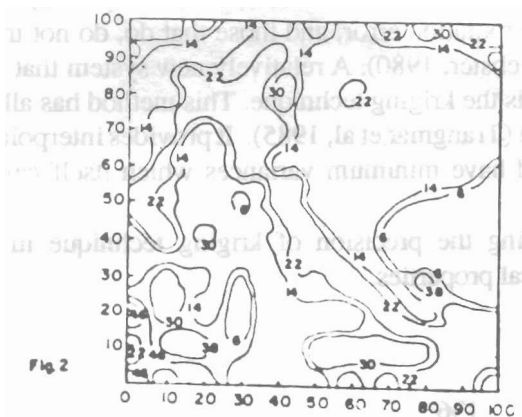
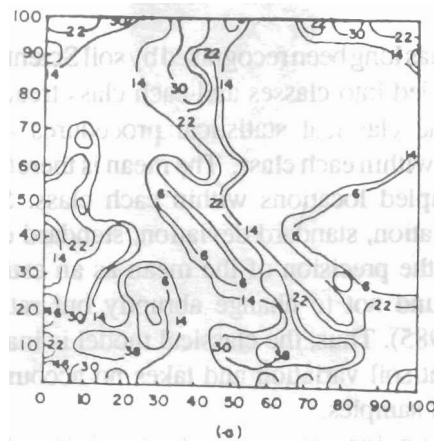


Fig. 2

Fig. 1: Pooled variogram of % gravel, Cone index and Moisture content.
 Fig. 2: Isarithmic map of % gravel for (a) kriged estimates and (b) samples.

Theory

Kriging is a technique for optimal estimation of values of continuous random spatial variables without bias at unsampled locations. This method which is embodied, in regionalized variable theory (Matheron, 1971), makes use of the parameters of the semi-variogram and an initial set of data values. The estimates are linear sums of weighted observations within a given neighbourhood:

(i)

where $z(X_0)$ is the estimate of z at X_0 , w_i is the weight associated with the i^{th} observation and n is the number of observations within the neighbourhood, usually no less than sixteen. In simple kriging the weights sum up to 1 thereby assuring lack of bias.

i. e.

(ii)

The estimation variance of $z(X_0)$ for a point is

(iii)

Error is minimized when



where $Y(Z_i, X_j)$ denotes the semi-variance between the i^{th} and j^{th} sampling points. $Y(X_i, X_0)$ represents the semi-variance between the i^{th} point and the point to be kriged. λ is a Lagrangian multiplier.

Materials and methods

Soil samples were collected at grid points as described by Oyedele et al (1991). Interpolation was done by kriging, at locations midway between the grid points for the three soil properties; % gravel, % moisture content (% M.C.) and cone index % (C.I.) (Fig. 1). To allow for a check on the accuracy of values interpolated by kriging, penetrometer measurements (for cone index) were taken at points midway between the grid points. These (raw) values were then compared with the interpolated values, using the chi-square test.

Isarithmic (contour) maps of the raw data on one hand, and those containing the interpolated values on the other, were plotted for the soil properties and compared.

Results and discussion

Thirty-six points midway between the sampling points were interpolated by punctual kriging for each of the soil properties determined. A search radius of 30 meters was selected for use in the interpolation since this falls within the average range of influence of the soil properties (38 metres) (Fig. 1). The interpolated values along

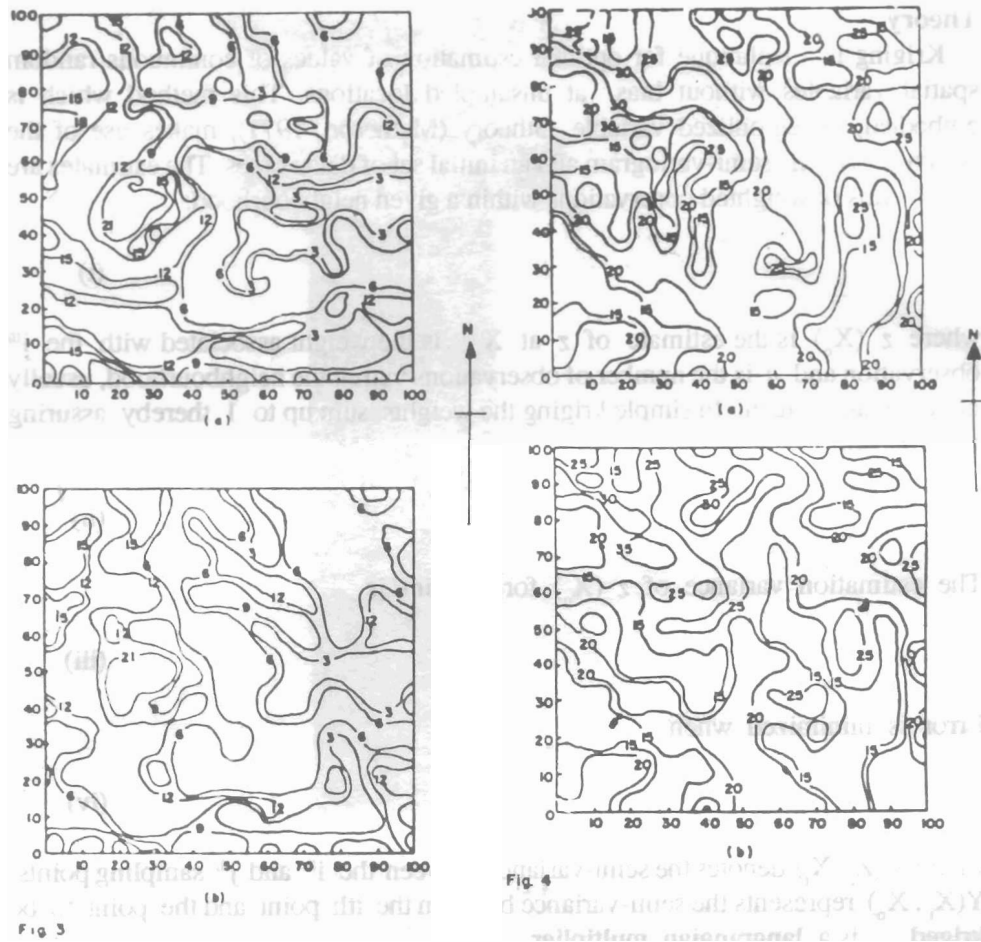


Fig. 3: Isarithmic map of Cone index for (a) kriged estimates and (b) samples.

Fig. 4: Isarithmic map of moisture content for (a) kriged estimates and (b) samples.

with their variance of estimation are presented in Table 1. This shows the high degree of precision of kriging as a method of interpolation. The interpolated values of cone index as compared with the raw values using the chi-square were statistically the same ($\alpha = 0.05$). The estimation variances of the soil properties were 12.5, 25.3 and 95.0 respectively for cone index, moisture content and gravel content compared to the respective values of 25.6, 30.4 and 125.9 for the original sample. This further highlights the high precision of kriging method of interpolation. This is in spite of the strong geometric anisotropy exhibited by the soil properties.

Table 1: KRIGED ESTIMATES OF CONE INDEX AND ASSOCIATED PARAMETERS COMPARED WITH OBSERVED VALUES

Sample No.	Observed values	Kriged Est.	Std. Error of Est.	No. of Neighb.
1	14.42	14.92	3.32	32
2	14.40	11.82	3.32	32
3	6.51	5.85	3.32	32
4	4.80	4.93	3.32	32
5	3.75	6.39	3.32	32
6	9.60	6.23	3.32	32
7	17.11	14.49	3.32	32
8	7.36	7.32	3.32	32
9	8.00	4.59	3.32	32
10	8.45	5.42	3.32	32
11	21.44	20.78	3.32	32
12	6.72	8.77	3.32	32
13	5.44	8.37	3.32	32
14	15.25	18.45	3.32	32
15	9.28	5.02	3.32	32
16	13.12	10.17	3.32	32
17	8.43	8.35	3.32	32
18	6.06	8.10	3.32	32
19	8.64	9.73	3.32	32
20	10.35	9.64	3.32	32

$X^2_c = 15.01$ $X^2_r = 31.53$

The isarithmic maps of the raw values only, and those containing the 36 interpolated points are presented in Figs. 2, 3 and 4 respectively for % gravel, C.I. and M.C. The map shows the % gravel and C.I. to vary maximally in the N.W. - S.E. direction while the direction of maximum variation for M.C. was in the N.E. - S.W. The N.W. - S.E. direction coincides with the direction of maximum slope on the field. The selective removal of fine soil separates along this direction by erosional process may be the cause of the high variation of % gravel along this direction. The subsequent soil compaction as a result of erosion and the increased gravel content of topsoil may be responsible for the cause of the high-variability of the C.I. along this direction. The

addition interpolated points helped in smoothening the boundaries. The extent of smoothening is minimal at the border which has few interpolated points and zero at sampling points but optimal in the middle which contains the interpolated values. Thus by increasing the number of points interpolated, improvements can be made on the accuracy of locating the boundaries of various classes of soil properties.

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