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Spatial variability of organic carbon of a tea estate in Jorhat district of upper Assam

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Abstract

The organic carbon of the soils were normally distributed in 0-30 cm and 30-60 cm soil depths. It maintained a range which is of low variability and maintained the same in both the surface and sub-surface soil layers. The number of soil samples required for obtaining a mean value of 95 per cent probability level with an error of 5 per cent around the true mean needed a sample size of 47 for the topsoil and 52 for the sub-surface layer. The observations showed slight variability at point boundary and are spatially related upto lag 9 and beyond randomness exists.

Additional keywords : Geostatistics, spatial distribution

Introduction

Soil properties vary both in the lateral and/or vertical direction and can be expressed in terms of the differences in particular or properties. Most of the studies on soil properties are however, confined to the classical statistics based on the central limit theorem where the basic assumption is that the observations on a property are randomly distributed. But, in reality this is not so because the calculated variances does not take into account the effect of space (distance of separation). As such classical statistics can not take into account *viz.*, the spatial distribution of data. Neighbouring samples may not be independent of each other and as a result samples drawn closer tend to be more similar than those taken apart and the samples differ for most of the observations.

The above mentioned deficiencies of classical satistics led to develop the theory of regionalized variables (Matheron 1963, 1965, 1971; Krige 1966). The geostatistical techniques are based on this theory. The theory treats every observation in relation to its neighbour. Variability with respect to the distance of measurement can also be described with the help of this theory.

Materials and methods

Experimental site : Assam is situated between 24°08' to 28°09' N and 89°42' to 95°16' E. Teok tea estate is located at about 30 kms east of Jorhat in Upper Brahmaputra Valley Zone of Assam. The estate has 21 sections with a gross area of 125.3 ha approximately. The area is mainly flat with a little elevation. A small rivulet is at the southern boundary of the estate, which serves as the main outlet for drainage the estate. In recent years this outlet has been blocked by human interference and as a result the water moves out of the estate at a very slow rate to join the main river.

In the present study, random sampling is followed as the area under the present investigation is not uniform in all the aspects including cropping history of the crops grown. Soil samples were collected at random which were later transferred to grid co-ordinates. Out of all the sections only sixteen sections were selected for soil sampling, half of which were from waterlogged sections and the other half from non waterlogged sections. The number of samples collected were from two soil depths *viz.* 0-30 cm and 30-60 cm from 10 locations in each section. The basic soil properties were determined by the standard laboratory procedures (Jackson 1973).

Statistical method

The data collected on different soil parameters were suitably treated with different satistical methods in order to determine their spatial distribution and their effect on productivity potential of the tea estate.

Fractile diagram : In order to assess the distribution of observations, fractile diagrams are constructed (Biggar and Nielsen 1976; Hajrasuliha *et al.* 1980; Malik *et al.* 1984; Saddiq *et al.* 1985; Davidoff *et al.,* 1986). The basis for making such a plot is the cumulative probability function P(x) for a normal distribution, where values of P(x) were approximated (Biggar and Nielsen 1976) as under :

$$P(x) = (i - 0.5)/n$$

by arranging the observations of random variable 'x', in increasing order of magnitude (i = 1, 2, 3... n). By using these values of P(x), corresponding values of probability unit (U), were obtained from the statistical tables. A fractile diagram of U *versus* 'x' yields a straight line, if the population is normally distributed.

Determining sample number : For determining the number of samples necessary to estimate the mean value of a property with a specified allowable error and degree of confidence, the equation given by Cline, (1944) is used. *i.e.* $N = [(t.\sigma)/d]^2$

where, N is the number of samples required; s is the estimate of standard deviation; t is the Students t with indefinite degrees of reedom at the desired level and d is the allowable level of error.

Semivariance analysis : The semivariance at a given lag, 'h' is estimated by the average of the squared difference between all observations separated by the lag :

$$G(h) = [1/2N(h)]\, d[Z(xi) - Z(xi+h)]2 \text{ for } i=1 \text{ to } N$$

where, N(h) is the number of pairs of observations. The semivariogram is displayed as a plot of G(h) *versus* lag, h.

Results and discussion

The soils are low in organic carbon content for plantation crops like tea, where addition of organic matter in the form of litter from the annual pruning cycle or added organic matter is a common practice. The mean values of organic carbon content at surface soil was 0.57 per cent with a range of 0.31 to 0.81 per cent. Again in sub-surface soil the range was 0.41 to 0.96 per cent with a mean value of 0.57 per cent. This indicated that organic carbon content at both the soil layers were nearly equal and that there is no migration of organic carbon to the sub-surface soil from the surface. The values of all other statistical parameters like standard deviation, variance and coefficient of variation were all the same for both the depths (Table 1), indicating very good homogeneity of variability at both the depths. This is also an indication that deposition of organic carbon at surface has not been adequately maintained and if this continues for a longer period of time, this may be a cause of concern leading to adverse effect on crop yield. This can be attributed to the fact that usually in a tea estate there is addition of organic matter to the surface soil layer from the annual prunning cycle, thereby increasing the organic carbon content of the surface soil layer, but this is not the case here (Table 1). The coefficient of variation values for organic carbon reported by Beckett and Webster (1971) and Indorante and Jansen (1981) are higher than the observed coefficient of variation values. This indicates that the soils under study maintain a homogeneity so far as the organic carbon for both depths are concerned. This can be attributed to the long duration of tea crop and to less soil disturbance within short periods of time.

Table 1. Statistical parameters of variability of organic carbon in soils

Parameter	0-30 cm	30-60 cm
Range (%)	0.31-0.81	0.41-0.96
Mean	0.57	0.57
Standard deviation (σ)	0.10	0.11
Coefficient of variation (%)	17.54	17.54
Median	0.54	0.54
Mode	0.56	0.56
Variance (σ^2)	0.01	0.01
Nugget variance (Co)	0.364	0.9634

As far as organic carbon is concerned the sample size ranged from 47 to 4 at the highest and lowest levels of precision, respectively. The corresponding values for the sub-soil ranged from 52 to 4 only (Table 2). Various workers reported that the number of samples for organic carbon varies from 25 (Babalola 1978) to 18 (Webster and Cuanalo 1975). Thus the current sample size as found to be adequate to draw conclusion.

Table 2. Number of samples required for 90 and 95% probability levels to obtain sample mean within +5, +10 and +15% of the true mean

Depth	95% probability level			90% probability level		
	5%	10%	15%	5%	10%	15%
0-30	47	12	5	33	8	4
30-60	52	13	6	37	9	4

The plot of the fractile diagram of organic carbon (Fig. 1) for both the depths gave a straight line which indicated a normal distribution of the data. This is authenticated by the highly significant 'r' values. The mean, median and mode (Table 1) at both the depths were almost at par indictive of a normal distribution. Similar observations were reported earlier by Dahiya *et al.* (1984a), Kalita (1988) and Patgiri and Baruah (1993). However, lognormal distribution of organic carbon was reported by Sondheim and Standish (1983), Jiyan and Webster (1984) and Ameyan (1986).

The semivariogram models of organic carbon for the two depths were

$$G(h) = 9.36 \times 10^{-3} + 1.96 \times 10^{-3} h$$

for the surface soil and for the sub-surface soil the model could be described as :

$$G(h) = 9.63 \times 10^{-3} + 1.978 \times 10^{-3} h$$

The nugget variances are 9.36×10^{-3} and 9.63×10^{-3}, which were 34.4 per cent and 33.3 per cent of the population variance for the surface and sub-surface soil layers, respectively, indicating that the observations have slight variability at point boundary (Table 1). The observations are spatially related upto lag 9 only and beyond that randomness exists. The 'r' values being highly significant at 0.99 for both the depths indicated a strong fit of the semivariogram models (Fig. 2). Trangmar *et al.* (1985) reported a range of 7m for organic carbon; while Dahiya *et al.* (1984b) reported a range of more spatial dependence of organic carbon for a lag beyond 100 m, with no definite range. However, a tendency of the semivariogram to become bounded with increasing depth of measurement has been reported by Patgiri and Baruah (1993).

Conclusion and practical utility : From the study we can come to a conclusion that the organic carbon content of the soils in both the soil depths were almost at par, as seen from their mean values of 0.57% in both the soil layers. This is further confirmed by the similar values of mode and median of 0.56% and 0.54% respectively.

The practical utility of this study can be briefly summarized as follows :

i) predicting the spatial variability of the observations can be done accurately and determined upto which lag they are spatially related.

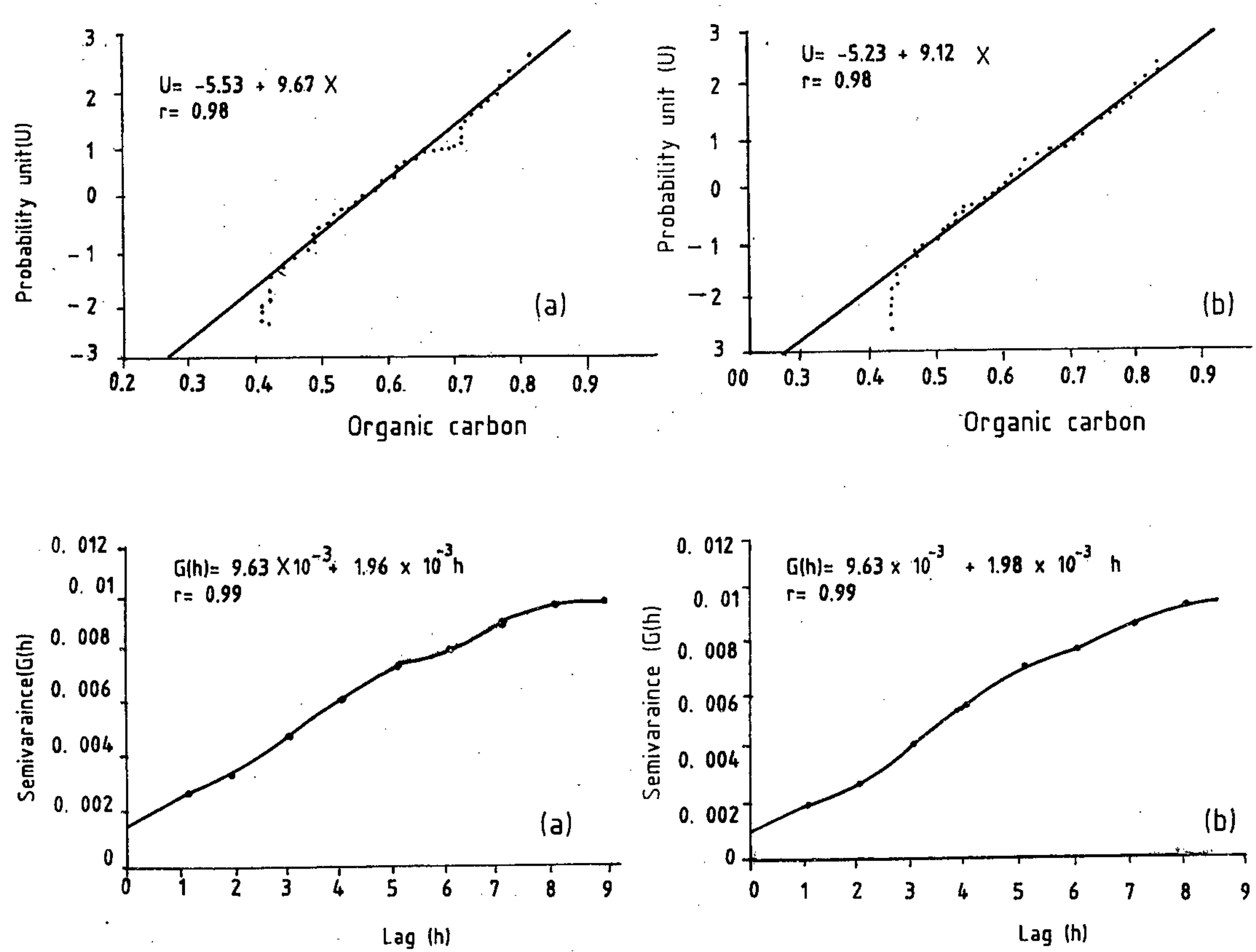

Fig. 2. Semivariogram of organic carbon at a) 0-30 cm depth, b) 30-60 cm depth.

ii) the number of samples required for precise estimate of the variable can be determined, thereby minimizing the size of the sample collection and whether the actually collected sample size will give precise estimate of the analysis or not.

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