Evaluation of Spatial Variability in Sand Content and Moisture Constants of Some Haryana Soils

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Abstract : *Structural analysis of sand content and soil moisture constants (field capacity, wilting point and available water capacity) were stochastically modeled. Four hundred seventy samples were drawn at 10x10 km grid nodes. The coefficient of variation was 15.8, 19.2, 27.0 and 14.4 per cent for sand, field capacity, wilting point and available water capacity, respectively. The semivariograms were well expressed by exponential model, as the semivariances were increasing exponentially for all the separation distance. Block kriged variances were 4.77 to 19.54 and 2.44 to 10.21 times les than that calculated by the classical and point kriging techniques, respectively. Block kriging also reduced the sampling efforts 5 (classical) and 2.5 (point kriging) times to get the same precision ($\pm$ 10 % error) at 99 percent confidence level for mapping the parameters. Hence, to characterize the Haryana soils for their sand content and three moisture constants, only 8 soil samples should be collected instead of 470 samples.* (**Key words:** *Available water capacity, field capacity, kriging, sand content, spatial variability and wilting point).*

Spatial variability is an inherent and dynamic feature of soils. It may be both vertical within a pedon, and horizontal across the landscape. Cultivation, through homogenization has a major influence on variability by increasing the similarity between plough layers of various soils. It is therefore imperative to evaluate soil resource and its response to management practices. Response of several inputs is being generally tested with the help of Fisherian statistical approaches. However, these approaches do not account for spatial dependence of soil properties. This is the reason spatial models are being developed wherein structural variation can be accounted for to arrive at spatially independent or truely random error models (Besag & Kampton 1986; Martin 1986; Williams 1986). Similarly, knowledge of spatial variability has been exploited in the past for precise mapping of soil resources (Webster 1985).

For such purposes, kriging is an interpolation technique of spatially dependent variation with a known error. It is an unbiased estimate with a minimum and known variance

(Journel & Huijbregts 1978; Burgess & Webster 1980; and Webster 1985). Recently soil-sampling strategies of local estimatitons at an desired precision by the optimal method of kriging have also been elaborated (McBratney & Webster 1983). This paper reports the spatial distribution of sand content and three soil moisture constants of the state.

MATERIAL AND METHODS

The State of Haryana extends between 27°39' and 30°55'N Lat. and 74°27'8" to 77°36'5" E Long., with total area of 44,222 km^2. Of this, 12,840 km^2 (29.03 %) is arid; 26,880 km^2 (60.78%) is semi-arid and 4,502 km^2 (10.10%) is sub-humid. The soils have light to medium texture and are derived from alluvium. The type of soils with respect to soil moisture regime and great group association is depicted in Figure 1. Grid map at a distance of 10x10 km. was prepared for soil sampling. From each location, five soil samples, each from 0-50 cm (effective root zone), were taken randomly, composited and a sub-sample was retained. In all, 470 samples were collected and analysed for their sand content, moisture retention at 300 kPa (FC) and 1500 kPa (WP). The available water capacity (AWC) was then determined from the difference in moisture content at field capacity (FC) and wilting point (WP).

Statistical Analysis

Preliminary analysis : Using classical statistical methods, mean (m), variance (s^2), standard deviation (s) and coefficient of variationn (CV) were computed. The number of observatitons required to obtain the mean value with a given degree of precision and significance level was calculated (Dahiya *et al.* 1984).

Spatial analysis: It was carried out in the form of semivariance as per the procedure described by Marx and Thompson (1987). This function related the similarity of difference, expressed as semivariance, between values at different places to their separation distance. An average semivariance was defined by :

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

where G(h) is the semivariance; h is the modulus of interval; N is the number of pairs; z(xi + h) and z(xi) are values of soil properties separated by a distance h. Regression equations were fitted to quantify the structural components of variation. Weights were assigned according to the num-

Fig. 1. Study area with respect to soil moisture zone and soil great group association, in different distict of Haryana

ber of pairs on which an estimate was based during fitting the least-squares method. Soil properties were interpolated at 5 km interval both by point and block kriging.

Thus, interpolated value (point krigging) of the regionalised variables, z*, at location xo is

$z^*(xo) = \sum Wiz\ (xi)$ for i = 1 to N (2)

where Wi is the weights attributed to the neighbours subject to the restriction that :

Wi = 1 for i = 1 to N ......(3)

Kriging was done under the conditions of unbiasness and minimum variance in which it is an optimal interpolation technique (Webster 1985). The kirging variance can be estimated by:

$s^2k = \sum Wiz\ (xi, xo) + U$ ..... (4)

where U is the larngrangian multipliar with the minimisation of s^2k.

For interpolation of values by block kriging, a block size of 24x24km was used. It gave the minimum estimation variance. The kriged value, z* for any block V is a weighted average of the observed values xi in the neighbourhood of the block, i.e.

$z^*V = \sum Wiz\ (xi)$ for i = 1 to N ..(5)

The estimation variance, $\bar{s}^2kb$, is given by :

$s^2kb = \sum WiG\ (xi, V) + UV - G\ (V,V)$ for i = 1 to N .....(6) where

G(xi,V) is the average semivariance between the sample points xi in the neighbourhood and those in the block V, G (V,V) is the average semivariance between all points, and UV is the langrangian parameter associated with the minimization.

Soil sampling strategies were carried out within + 10 percent of the true mean by both point and block kriging techniques. The appropriate semivariogram was done by the so-called Jack knifing, or fictitious-point method (Tabos & Salas 1985).

RESULTS AND DISCUSSISON

Preliminary analysis : The values of sand content, moisture content at field capacity and wilting point and available water capacity of soil ranged from 26.40 to 87.80; 10.53 to 31.48; 2.82 to 13.14 and 7.59 to 17.14 per cent, respectively. The magnitude of variation was low in sand content and AWC (CV = 15.80 and 14.40 %), where as FC and WP were found moderately variable with a CV value of 19.20 and 27.00 per cent, respectively (Table 1). It is because the soils have been derived from alluvium which is less variable in itself.

Spatial analysis : In order to study any possible continuity between pairs of observations required for establishing any spatial dependence of variance structure, semivariograms of sand content, FC, WP and AWC were drawn (Figure 2: a,b,c and d, respectively). All semivariograms showed strong spatial dependence, because the semivariance [G(h)] is increasing exponentially with log distance (h) i.e. showing spatial dependence for all the separation distance more than the sampling distance. The semivriograms were well described by exponential model with an r value of 0.993, 0.992, 0.991 and 0.991 for sand, FC, WP and AWC, respectively. The higher unstructured component (nugget variance) observed for all the parameters studied (54.5, 6.33, 1.84 and 1.32 $(\%)^2$ for sand, FC, WP and AWC, respectively) correspond to the variability that occurs within distance shorter than the sampling interval (10 km) and to experimental errors (Table 2). This short range variation was 51 per cent of the sample variance for all the parameters.

In order to get the constant value of the semivariance, samples from a still larger area should have been collected. But for interpolation of a value of given parameter at unsampled location within study area, the presence or absence of a constant semivariance value is immaterial, as only the semivariance of the nearest points is used for interpolation. These results are in confirmity with (Raman *et al.* 1983; Trangmar *et al.* 1987; and Kalita 1988).

With the help of the model of the semivariogram (Figure 2: a,b,c & d) and observed values, additional values of sand content, FC, WP and AWC were generated at the unsampled locations both by point and block kriging. For block kriging, a block size of 24 x 24 km was used as it gave the minimum estimation variance as compared to other block sizes tested.

Validation of Kriging Model : The means and their dispersion statistics of experimental and kriged values are summarised in Table 3. Means of the kriged estimates were at par with the experimental values for all the parameters studied. This was also supported by nonsignificant paired t values (Table 4). The estimation variance of experimental values and point kriged values differed by a fac-

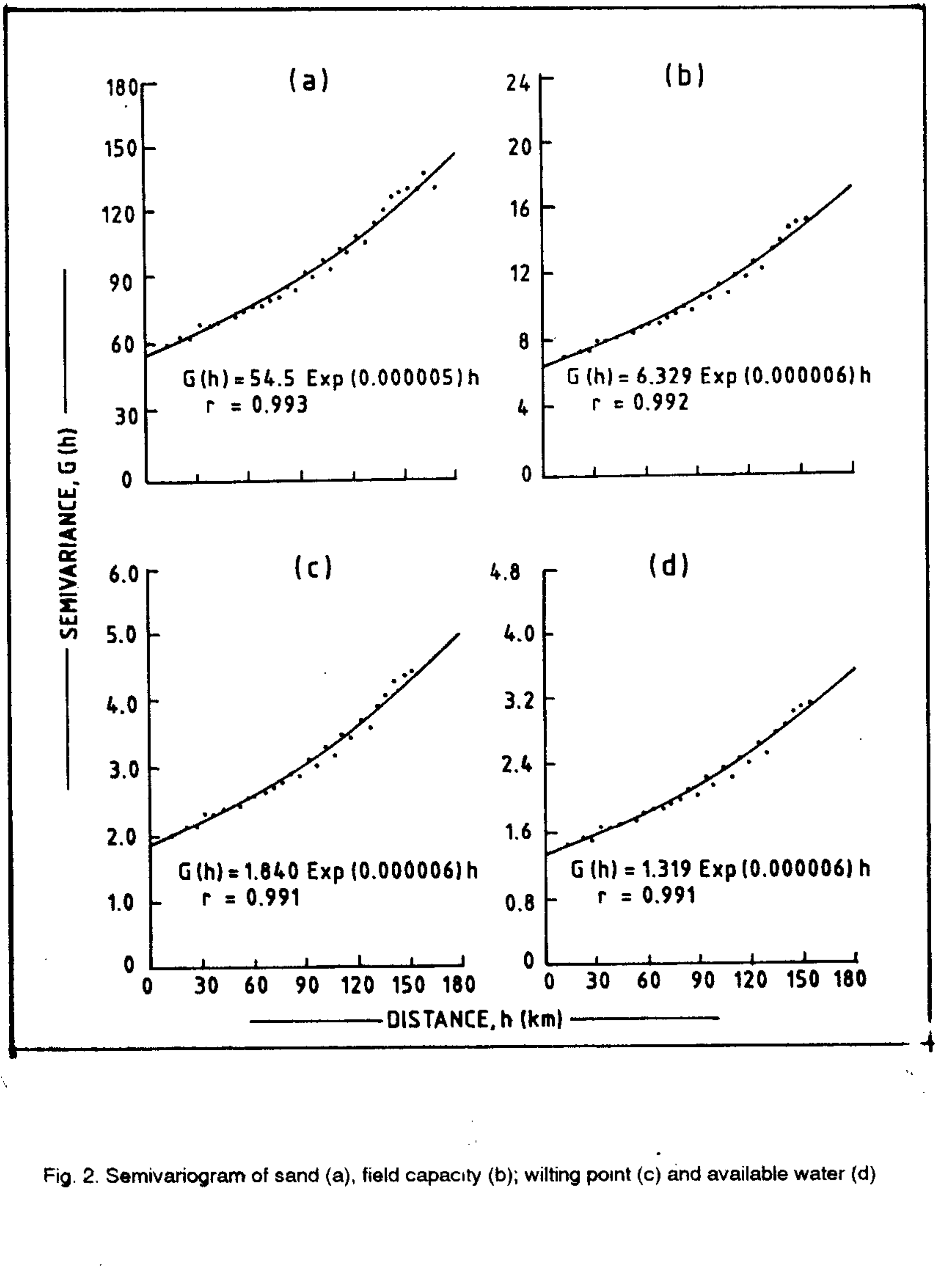

Fig. 2. Semivariogram of sand (a), field capacity (b); wilting point (c) and available water (d)

TABLE 1. Coefficient of variation (%) for sand content and soil moisture constants

Parameter	Lowest value	Highest value	CV(%)
Sand (%)	26.40	87.80	15.8
FC (%)	10.53	31.48	19.2
WP(%)	2.82	13.14	27.0
AWC (%)	7.59	17.14	14.4

FC = Field capacity; WP = Wilting point; AWC = Available water capacity.

TABLE 2. Nugget variance (Co) and its ratio (%) with sample variance (s^2)

Paramter	Co	Co/s^2
Sand	54.50	51.42
FC	6.33	51.41
WP	1.84	51.40
AWC	1.32	51.52

tor equal to 1.58 (sand), 2.46 (FC), 1.96 (WP) and 1.71 (AWC) without showing any substantial precision by the latter over the former method. However, those obtained by classifical and block kriging approaches differed significantly by a factor equal to 16.18, 19.54, 4.77 and 16.00 for sand, FC, WP and AWC, respectively (Table 3). This demonstrates an improvement in estimation precision by kriging methods over the classical method. Therefore, it conclusively suggests that the classical method overestimated the variance to a greater extent, assuming that the kriging variances are closed to the true values. Practically, it means that if a variable is spatially dependent, the estimation of variance by classifical method is not a reliable parameter for the interpretation of the data. Further, the ratio of the point and block kriged variances exhibited 2.44 to 10.21 fold differences for the

TABLE 3. Comparision of statistical aproaches

Statistical technique	Parameter			
	Sand	FC	WP	AWC
Classical				
Mean (m)	65.00	18.27	7.00	11.13
Variance (s^2)	106.00	12.31	3.58	2.56
Standard deviation (s)	10.30	3.51	1.89	1.60
Point kriging				
Mean (mk)	65.05	18.22	6.99	11.11
Variance (s^2k)	66.90	5.00	2.83	1.50
Standard deviation (sk)	8.18	2.24	1.35	1.22
Block kriging				
Mean (mkb)	64.79	18.25	7.10	11.15
Variance (s^2kb)	6.55	0.63	0.75	0.16
Standard deviation (skb)	2.56	0.79	0.87	0.40
Ratio				
s^2/s^2k	1.58	2.46	1.96	1.71
s^2/s^2kb	16.18	19.54	4.77	16.00
s^2k/s^2kb	10.21	7.94	2.44	9.38

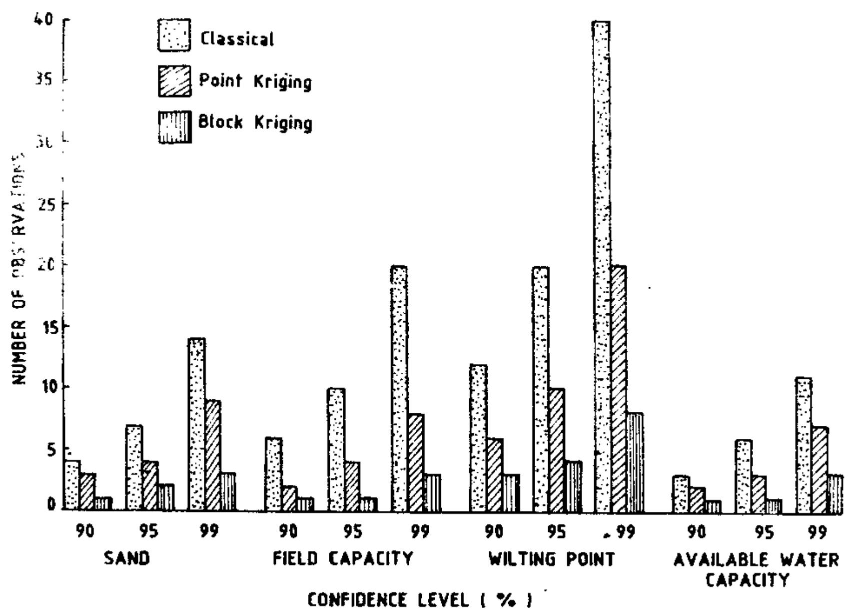

Fig. 3. Number of observations to be recorded within ± (90%) of the true mean at different confidence level

TABLE 4. Parameters for testing the zero mean estimation error(uniasceess) and low variance condition of the kriging estimation.

Parar meter	e^1	s^2e	se	t	% $e^1 + 2se$
Sand	0.122	69.49	8.34	0.310	94.6
FC	0.036	8.19	2.86	0.268	94.4
WP	0.014	2.35	1.53	0.195	95.1
AWC	0.012	1.68	1.23	0.196	95.3

$t = 2.093$; e^1 = mean estimation error; s^2e = variance of errors; se = standard deviation of errors

parameters under consideration (Table 3). Similar improvement in estimation precision has been reported by Trangmar *et al.* (1985), Webster (1985), Dahiya *et al.* (1990) and Kumar *et al.* (1993).

By comparing means, variances and t-values, we validated kriging for all the parameters studied. Validation could also be done from mean estimation error (e^1), variance of errors (s^2e) and standard deviation of errors

(Table 4). These tests were performed on both point and block krigged values, and validation was found to be better for block kriged estimates because of their lower standard errors.

Designing Optimal Sampling Strategy: The most important application of this kind of information is in the designing of efficient sampling scheme. The standard deviation of kriged data was determined, number of observations required to get the precision with + 10 per cent error at different probability levels were calculated and compared with that obtained by classical method (Figure 3). The estimated sample sized was 11 to 40 and 7 to 20 to get the precision at 99 per cent confidence level of classical and point kriging methods, respectively. However, block kriging reduced the sample size 3 to 8 to get the same precision for these parameters. Hence, to characterize the Haryana soils for their sand content, FC, WP and AWC only 8 samples would be sufficient instead of 470 samples. Thus block kriging reduced the sampling effort and cost considerably compared to other methods.

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