ABSTRACT

Soil texture is a vital variable that reflects a number of soil properties such as Bulk Density, Particle Density, Infiltration Rate, Hydraulic conductivity, Water holding capacity, nutrient storage and availability as well as transport and binding and stability of soil aggregates. For better tuber development in cassava soil texture plays vital role. The main objective of this study is to produce kriged maps (Ordinary kriging map and semivariogram) to interpolate the soil texture for Tapioca growing soils of Paramthy block, Namakkal District at unsampled locations. In this study, nearly 54 surface samples were collected covering 19,149 ha of agriculture land with dominant cultivation of Tapioca. This study helps spatial interpolation of unsampled location of soil texture i.e. sand, silt and clay content which rules the soil physical, chemical and hydrological properties. The average
standard error for sand and clay are 0.2 and 0.19 respectively. The results such as provided maps and their associated variance can be used as data source for the development and implementation of further land management and soil water conservation plans in the study area.

Keywords: Soil texture; cassava; geostatistical analysis; kriging; spatial interpolation.

1. INTRODUCTION

Geostatistical estimation is mainly for the prediction and in particularly uncertainty assessment of the soil texture fractions i.e. sand, silt and clay proportions in an unsampled locations. Kriging is a useful tool to predict and interpolate data between measured location [1]. Nowadays, number of soil physical and chemical process models and pedotransfer functions are increasing for various purposes such as modelling the water movement and ion transformation in soil [2]. A vital parameter used in soil process models and pedotransfer functions in soil textural fraction (sand, silt and clay %) should be quantified on the point scale. Tanji [3] has shown that among the different soil physico-chemical properties measured, soil textural variation is a primary soil factor influences the yield of any crop. Reynolds [4] stated that variation in soil texture may influence soil moisture content directly and also soil aggregation had direct influence with clay content of soil [5]. In many cases, scattered sampling is exhibited, in that case spatial interpolation is required for getting detailed knowledge about particular picture. Their result showed that predictive soil mapping technique, such as linear regression equation with ordinary and simple kriging could be used to produce thematic map of soil particles. Geostatistics, a powerful pedometric tool for spatial characterisation of soil properties and estimation with incorporating the spatial community behaviour of soil data into the estimation process has been progressively employed in soil science [6].

The best unbiased and most popular geostatistical analysis method is kriging with simple and ordinary type of interpolation. Ordinary kriging had its wider application in soil science field [7]. Kriging shows higher precision when compared with conventional classification method of soil properties mapping [8]. A special feature of kriging is to produce an estimation variance corresponding to each estimates, which can provide a measure of confidence on the surface of model [9]. Semivariogram/ co variance modelling shows best interpolation by means of variances especially in soil texture [10,11].

In this study, we selected kriging with Ordinary type for sand and simple type for clay content interpolation based on minimal error percent on basis of 254 surface soil samples collected over Tapioca growing tract of Paramathy block, Namakkal. The application of ordinary kriging in soil studies dates back to 1980's [7]. During last two decades, it has been widely applied in large scale soil reclamation, soil pollution studies and soil classification surveys. Our main objectives are analyse and describe the spatial variable pattern of soil sand and clay content of surface soil and to display the variability pattern of sand and clay through the predicted map and its associated variances. These findings give an idea about soil textural property of primary concern.

2. MATERIALS AND METHODS

The study location Paramathy Velur block covered 19,149 ha and it is situated in Namakkal district of TN, India. It falls within 11°11.21 N longitude and 78°00.44 E approximately. The mean annual rainfall distribution of Paramathy block is 637 mm with average elevation of 170m. The moisture regime in the study location is ustic and soil temperature regime is iso-hyperthermic. Average temperature in study location ranges from 27-33°C. The study location is underlined with quartz, feldspar, gneiss and charnockite rocks.

The agricultural lands are dominated by two major soils viz., Sandy clay loamy and silty clay soil. Both rainfed and irrigated Tapioca was cultivated in the study location, the crops cultivated in the study location are Oilseeds, Sugarcane, Vegetables, Forage crops and meager amount of cereals and pulses.

2.1 Soil Survey and Data preparation

Samples were collected from 54 points at depth of 0-30 cm randomly on the grid drawn in Arc GIS 10.2.2, whereas the status of soil texture for the remaining locations were interpolated with
2.2 Geostatistical Analysis

Geostatistical studies consists of variography and kriging steps (Mohammedi, 2002). In the variography stage the spatial structure of each soil particles were characterized by experimental semi variogram \( \gamma(h) \) using the following equation:

\[
\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (Z(x_i)+h) - Z (x_i))^2
\]

Where \( N(h) = \) no.of pairs separated by distance interval \( h \) between observations \( Z(x_i) \) and \( (x_i+h) \).

A preliminary variogram surface analysis was performed to check whether there existed any zonal affect or trend in either direction. The omni directional experimental variogram for each property were then constructed. Theoretical models were fitted to these. The best fit model for both analysed properties was a spherical model using the equation:

\[
\gamma(h) = C_0 + C_1 \{ 1.5 \left( \frac{h}{a} \right)^3 - 0.5 \left( \frac{h}{a} \right)^3 \} \quad h \leq a
\]

\[
\gamma(h) = C_0 + C_1 \quad h \leq a
\]

Here, \( a \) is the range, \( C_0 \) the nugget semivariance, and \( C_0 + C_1 \) the sill or the total semivariance.

In order to see the relative contribution of nugget to total variance, we calculated the relative nugget effect (RNE) according to:

\[
\text{RNE} = \left[ \frac{C_0}{C_0+C_1} \right] \times 100
\]

The variogram parameters extracted for each fitted model were used to interpolate the value at unsampled location by means of Ordinary kriging. The ordinary kriging is an exact interpolation technique which assumes the local stationary of the mean. Ordinary kriging uses a linear combination of observations within a predefined neighbourhood around \( x_0 \) (Goovaerts, 1997). The Ordinary kriging estimator \( Z'(x_0) \) with the associated variance \( \sigma^2 \) can be represented as

\[
Z' \text{ok} (x_0) = \sum_{a=1}^{n} \lambda_a Z (x_a)
\]

\[
\sigma^2 \text{ok} (x_0) = \sum_{a=1}^{n} \left( \lambda_a \gamma(x_a-x_0) \right) + \psi
\]

Here, \( \lambda_a \) is the weight assigned to \( n \) observations, \( Z (x_a) \) and \( \psi \) is the Lagrange multiplier.

3. RESULTS AND DISCUSSION

Table 1 shows that the results of the main statistical descriptors of the data set analysed. Fig. 2 reports the respective frequency histogram (i.e. sand and clay). The average sand content of the study area is 40% whereas average clay content is 32% and its associated standard deviation is 18 and 14 respectively. Skewness coefficient demonstrate that both clay and sand are symmetrically distributed showing positive skewness for both clay (0.63) and sand (0.28), meanwhile the kurtosis coefficient of clay and sand area 2.3 and 2.1 respectively.

3.1 Mapping Soil Properties

Kriging is employed to estimate the values of sand and clay content at unsampled locations. The continuous maps with their associated uncertainties for each property over the study area have been displayed in Fig.3. Fig. 3 suggest that the entire study area is characterized by a moderate to high level of sand content with only few small areas which are rich in clay. Although the spatial variability of sand and clay content appears in patchier way as also suggested by the natural behaviour of our best fitted model, the distribution of higher sand content area seems to be more suited for crop cultivation since it is a tuber crop. Moreover, clay is also found to be well distributed throughout the area but is always with its relatively lower contents. The areas with higher sand are always associated with low clay contents. We assume that the areas associated with lower clay contents might be due to effect of soil erosion or leaching.
3.2 Variogram Construction and Analysis

Fig. 4 depicts the experimental variogram of sand and clay content, together with the fitted spherical models. Both sand and clay displayed a well-defined spatial structure with their characteristics sill and range indicated by Frogbrook et al. [12] such variogram suggested that the properties vary in a patchy way resulting in areas with small values and other areas with larger values. The range of spatial correlation of the variogram provides average extent of these patches. The average standard error for sand and clay are 0.2 and 0.19 respectively.

Fig. 1. Location of study area

Fig. 2a. Histogram of soil clay content

Fig. 2b. Histogram of soil sand content
Fig. 3a. Distribution of sand content

Fig. 3b. Distribution of clay content
Fig. 4a. Experimental semivariogram of sand

Fig. 4b. Experimental semivariogram of clay

Table 1. Descriptive statistics of sand and clay content

| S.No. | Property | Number | Min. | Max. | Mean | Std.dev. | Skewness | Kurtosis |
|-------|----------|--------|------|------|------|----------|----------|----------|
| 1     | Sand     | 254    | 14.48| 72.7 | 40.4 | 18.05    | 0.28     | 2.10     |
| 2     | Clay     | 254    | 13.6 | 60.02| 31.8 | 14.02    | 0.63     | 2.35     |

4. CONCLUSIONS

Our study clearly reveals the application and utility of Geostatistics especially kriging with ordinary and simple type to study and analyse the spatial behaviour of soil texture contents. The predicted map will help the decision makers, agricultural scientists for large scale planning and soil management by keeping the spatial heterogeneity of soil texture in mind. Every crop has its own economic part which may be below ground part or above ground part, both needs better soil for good yield, specifically the crop had their economic part below the ground majorly depends soil texture. The final report of this study will also give an idea about crop selection for farmers in Paramathy block of Namakkal District of Tamil Nadu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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