International Journal of Plant & Soil Science

33(2): 53-59, 2021; Article no.IJPSS.66483
ISSN: 2320-7035

Kriging: An advanced Geostatistical Tool to Interpolate the Textural Variation Influences the Yield and Productivity of Tapioca (*Manihot esculenta*) in Namakkal District, Tamil Nadu, India

V. Sabareeshwari[1*], P. Christy Nirmala Mary[1], P. P. Mahendran[1], P. Saravana Pandian[1], A. Gurusamy[1] and R. Subhashini[1]

[1]Agriculture College and Research Institute, Madurai-625104, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors PCNM and PPM acting as my Chairpersons who guided me to complete my research work with novel result, where as the remaining authors helped me at all occasion to write a good research paper for the benefit of all stakeholders. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2021/v33i230414
Editor(s):
(1) Dr. Hon H. Ho, State University of New York, USA.
Reviewers:
(1) Konan-Waidhet Arthur Brice, University Jean Lorougnon Guede, Côte d'Ivoire.
(2) Marwah M. Alkhuzaie, University of Al-Qadisiyah, Iraq
Complete Peer review History: http://www.sdiarticle4.com/review-history/66483

Original Research Article

Received 14 January 2021
Accepted 22 March 2021
Published 26 March 2021

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

**Corresponding author: E-mail: sabareeshwaris99@gmail.com;*

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 uncertainity 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 software. In each location geo coordinates were recorded using hand held Global Positioning System (GPS) instrument (Garmin etrex 10 GPS) on cloud free days. Geo-spatial coordinates with analytical data were dropped in Arc GIS 10.2.2 with standard database of GIS environment for better spatial prediction and thematic map preparation by using standard ordinary kriging for sand and simple kriging for clay in order to minimize the error value.

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 γ(h) using the following equation:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} * \{Z(x_\alpha + h) - Z(x_\alpha)\}^2$$

Where N(h)= no.of pairs separated by distance interval h
$\gamma(h)$ = variogram for a distance (lag) h between observations Z (x_α) and (x_α+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 constructred. Theoretical models were fitted to these. The best fit model for both analysed properties was a spherical model using the equation:

$$\gamma(h) = C_0 + C_1\{ 1.5 \left(\frac{h}{a}\right) - 0.5 \left(\frac{h}{a}\right)^3\} \qquad h \le a$$

$$\gamma(h) = C_0 + C_1 \qquad h \le a$$

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

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

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

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 σ^2 ok (x_0) can be represented as

$$Z^* \text{ok}(x_0) = \sum_{\alpha=1}^{n(x_0)} \lambda_\alpha Z(x_\alpha)$$

$$\sigma^2 \text{ok}(x_0) = \sum_{\alpha=1}^{n(x_0)} [\lambda_\alpha \gamma(x_\alpha - x_0)] + \psi$$

Here, λ_α is the weight assigned to n observations, Z (x_α) and ψ 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 uncertainities 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.

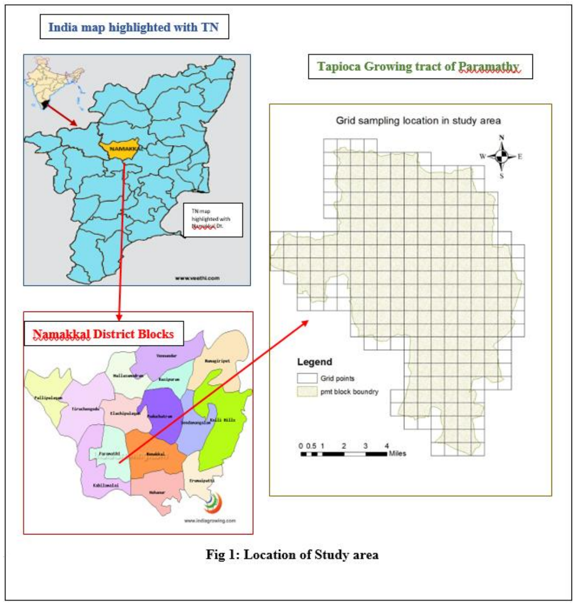

Fig. 1. Location of study area

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.

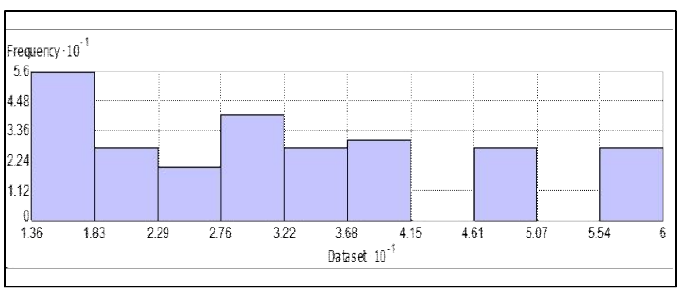

Fig. 2a. Histogram of soil clay content

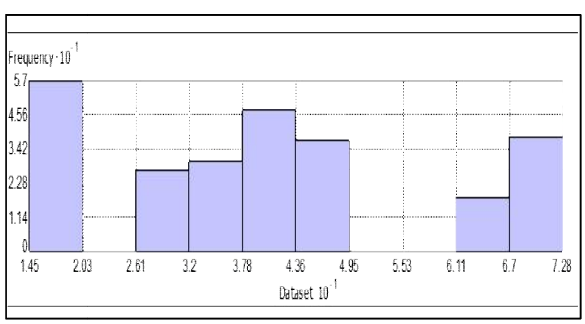

Fig. 2b. Histogram of soil sand content

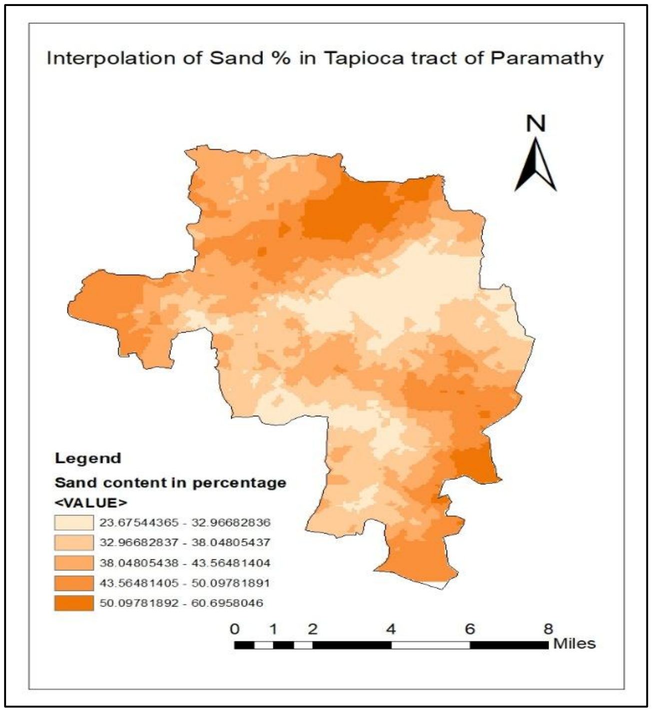

Fig. 3a. Distribution of sand content

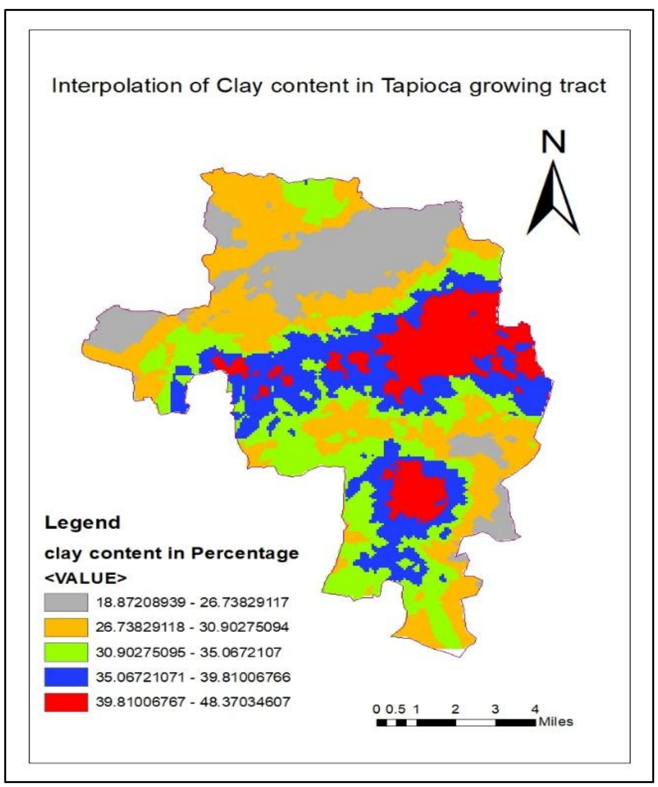

Fig. 3b. Distribution of clay content

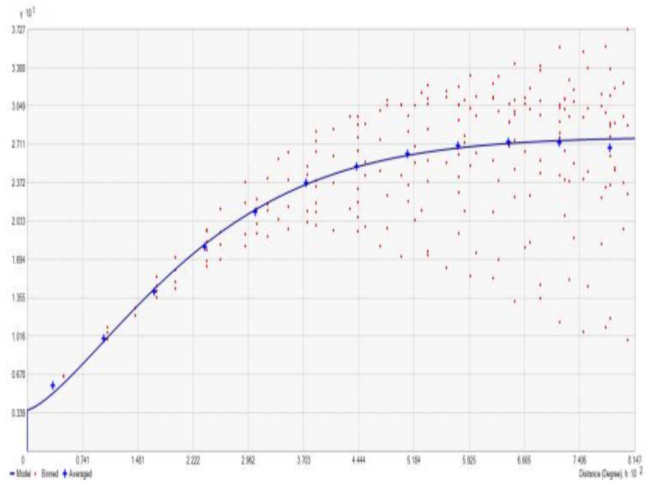

Fig. 4a. Experimental semivariogram of sand

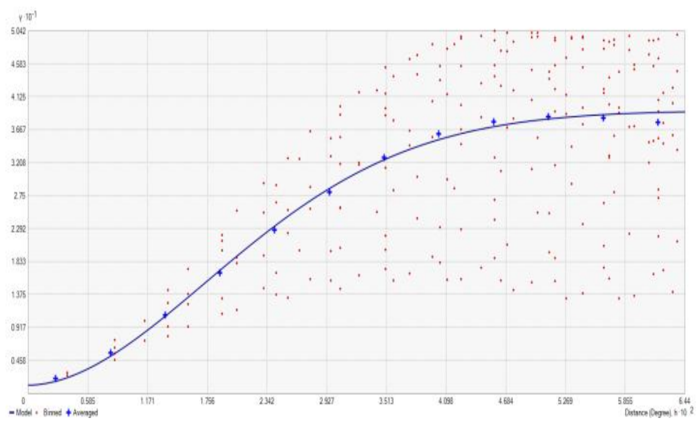

Fig. 4b. Experimental semivariogram of clay

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.

REFERENCES

1. Emadi M, Shahriari AR, Sadegh-Zadeh F, She-Bardan BJ, Dindarlou A. Geostatistics

based spatial distribution of soil moisture and temperature regime classes in Mazadaran province, Northern Iran. Archives of Agronomy and Soil Science. 2015;62(4):502-522.
2. Rawls WJ, Brakensiek DL, Saxton KE. Estimation of soil water properties. Transactions of ASAE. 1982;25:1316–1320.
3. Tanji KK. Agricultural salinity assessment and management. ASCE, New York; 1996.
4. Reynolds SG. The gravimetric method of soil moisture determination, I: A study of equipment and methodological problems. Hydrology. 1970;11:258–273.
5. Luk SH. Effect of soil properties on erosion by wash and splash. Earth Surface Processes. 1979;4(3):241-255.
6. Delbari M. Estimation and stochastic simulation of soil properties for case studies in Lower Austria and Sistan plain, southeast of Iran. PhD. Thesis. University of Natural Resources and Applied Life Sciences, Vienna; 2007.
7. Burgess TM, Webster R. Optimal interpolation and isarithmic mapping of soil properties: The variogram and punctual kriging. Journal of Soil Science 1980;31:315–331.
8. Voltz M, Lagacherie P, Louchart X. 1997. Predicting soil properties over a region using sample information from a mapped reference area. *European Journal of Soil Science* 48: 19–30.
9. Goovaerts P. Geostatistics for natural resources evaluation. Oxford University Press, New York; 1997.
10. Safari Y, Boroujeni IE, Kamali A, Salehi MH, Bodaghabad MB. Mapping of the soil texture using geostatistical method (a case study of the Shahrekord plain, central Iran). Arabian Journal of Geoscience. 2013;6;3331-3339.
11. Reza SK, Baruah U, Singh SK, Das TH. Geostatistical and multivariate analysis of soil heavy metal contamination near coal mining area, Northeastern India. Environmental Earth Science. 2015;73:5425-5433.
12. Frogbrook ZL, Oliver MA, Salahi M, Ellis RH. Exploring the spatial relations between cereal yield and soil chemical properties and the implications for sampling. Soil Use and Management. 2002;18:1-9.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66483