J Krishi Vigyan 2018, 7 (Special Issue) : 78-83 DOI : 10.5958/2349-4433.2018.00163.0

GIS-Based Interpolation Methods for Estimating Spatial Distribution of Nitrogen Content in the Soil

Neelam Chouksey *, Girish Chand Mishra and Rajesh Chouksey *****

RMD college of Agriculture & Research Station Ambikapur (Chhattisgarh)

ABSTRACT

The spatial statistical method has been found favorable among agricultural scientists who seek to map yield estimates or soil properties of an area from a small number of samples of known location scattered throughout the area. Spatial statistics is concerned with the analysis of spatially referenced data and the study of associated spatial statistical models and processes. The agricultural benefits of accurate interpolation of spatial distribution patterns of nitrogen content (N) are well recognized. For the study different interpolation techniques in a geographical information system (GIS) were analyzed and compared for estimating the spatial variation of N at four different blocks of Raipur. Number of sample was selected by Stratified random samples with PPS (probability proportional to sample) sampling method. Different interpolation methods such as inverse distance weighting (IDW), ordinary kriging (OK) and lognormal kriging were used to generate spatial distribution of N. The cross validation is applied to evaluate the accuracy of interpolation methods through coefficient of determination (R^2) and root mean square error (RMSE). After comparison it has been observed that inverse distance weighting (IDW) did not perform well due to its higher values of RMSE in comparison to ordinary kriging and lognormal kriging Interpolation techniques. The values of R^2 show the strength of relationship among the nitrogen content at different locations. Results showed that after transforming the data for skewed distribution gave the précised result; it means that lognormal kriging provides best result as compared to ordinary kriging interpolation technique.

Key Words: GIS, Spatial interpolation, Nitrogen content, Ordinary Kriging, lognormal kriging.

INTRODUCTION

Indian Institute of Soil Science has developed GIS based soil fertility maps of 19 states using data of different soil testing laboratories in the country. The assessment revealed that about 59, 49 and 9 per cent soils was low in available nitrogen, phosphorus and potassium respectively. This shows that India has the highest nitrogen deficiency than other nutrients. Nitrogen is universally deficient in Indian soils with 99 per cent of soils responding to N application.

From 1950-51, fertilizer N use grew from a measly amount of about 0.45 kg/ha to nearly 87 kg/ha in 2014-15 (Chander, 2016). The exact knowledge of recommended dose as per requirement are necessary, if we know the right dose of nitrogen for the soil then we can reduce the soil and environment contamination by over fertilization. In the study, different spatial interpolation methods were use for estimating nitrogen content in the soil for unknown points by the help of known point. In previous studies, many researchers have used spatial interpolation to check the accuracy of different spatial interpolation methods for spatially predicting soil properties. Wu *et al* (2006) compared ordinary kriging and lognormal kriging and found

Corresponding Author's Email : neelamtyagi999@gmail.com

Assistant Proffesor (Agricultural Statistics), RMD college of Agriculture & Res. Sta. Ambikapur (C.G.)

** Professor (Agricultural Statistics), Institute of Agricultural Science, Banaras Hindu University, Varanasi (U.P.)

***Scientist (Soil Science), Krshi Vigyan Kendra, Surguja (C.G.)

that kriging estimates were improved after data transformation (lognormal kriging). Shukla *et al* (2015) also compared various interpolation techniques for estimating micronutrient content in the soil.

MATERIALS AND METHODS

Study area

Raipur District is situated in the fertile plains of Chhattisgarh Region. This District is situated between 22o 33' N to 21o14'N Latitude and 82o 6' to 81o38'E Longtitude. The spatial study was confined to Arang, Abhanpur, Tilda and Dharsiva blocks in Raipur district. A stratified random sampling under proportional allocation has been used for estimating the sample size for each strata and substrata. Deterministic (create surfaces from measured points i.e. inverse distance weighted) and geostatistical (utilize the statistical properties of the measured points ordinary kriging (OK), and lognormal kriging) interpolation techniques were used to generate the spatial distribution of nitrogen content.

Ordinary kriging

Ordinary kriging gives both a prediction and a standard error of prediction at unsampled locations The aim of kriging is to estimate the value of a random variable Z at one or more unsampled points or over large blocks from more or less spread data say $z(x_1),..., z(x_N)$ at $x_1,..., x_N$ locations. The data may be distributed in one, two or three dimensions, though applications in the agricultural sciences are usually two-dimensional. Finally, the data value for each point can be estimated by inputting the weights into the formula (Krige,1950).

$$\hat{z}(x_0) = \sum_{i=1}^{n} \lambda_i z(x_i)$$

Where, n is the number of sample points used to interpolate the data value for point x_0 and λ_i is Lagrange multiplier (which ensures that the λ_i values add up to 1.0). This equation can be solved by substituting the estimated values of γ from the variogram model. The validity of the variogram model may also be tested for consistency by comparing the actual values for a data point with the estimated value. This process, known as cross validation,

Lognormal kriging

When a data set is constraint to positive values and regionalized, and specially when positively skewed, a logarithmic transformation is usually expected to symmetrize it.

$$\text{if } Y(\mathbf{x})=\log Z(\mathbf{x}) \sim N(\mu,\sigma^2),$$

where $Z(\mathbf{x})$ is observed at $\mathbf{x}_1,..., \mathbf{x}_n$ locations to obtain a sample $z_1,..., z_n$, then the optimal estimator Z^* of $Z_0=Z(\mathbf{x}_0)$ is

$$Z^* = E\,[Z_0 \mid y_1,..., y_n] = \exp\,(\,Y^* + \tfrac{1}{2}\,\sigma_{ok}^{\,2}\,),$$

where $y1,..., yn$ is the logarithmic transformed sample, Y^* the usual *ordinary kriging* estimator of $Y_0=Y(\mathbf{x}_0)$ = given this sample, and σ_{ok}^2 is the associated *ordinary* kriging variance

Inverse Distance Weighting (IDW) Method

This method comes under Weighting Moving Average Methods. This family of techniques estimate the data value for each point by calculating a distance weighted average of the points within the search radius. These techniques are local, exact and deterministic. The general formula is:

$$\hat{z}(x_0) = \sum_{i=1}^{n} \lambda_i . z(x_i)$$

Where $z(x_i)$ are the data values for the n points $(x_1 \ldots x_n)$ within the search radius, and λ_i are weights to be applied to the data values for each point.

Cross-Validation

Cross-validation technique was adopted for evaluating and comparing the performance of different interpolation methods. the root mean square error (RMSE) for error measurement and coefficient of determination (R^2 value) were estimated to evaluate the accuracy of interpolation methods. Expressions of the measures are

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (\hat{y}_i - \bar{y}_i)^2}{n}}$$

$$R^2 = \frac{\sum(y-\hat{y})^2}{\sum(y-\bar{y})^2}$$

RESULTS AND DISCUSSION

The ordinary kriging (OK), lognormal kriging & inverse distance weighting technique (IDW) were applied for estimating nitrogen content in the soil for different blocks of Raipur. After comparing all techniques, lognormal kriging was found best with lower RMS as compared to the ordinary kriging (OK) and inverse distance weighting (IDW) for all blocks of Raipur district. In the other word, stochastic methods i.e. ordinary kriging and lognormal kriging were good as compared to deterministic interpolation technique i.e. inverse distance weighted method.

The exponential, spherical, Gaussian and linear

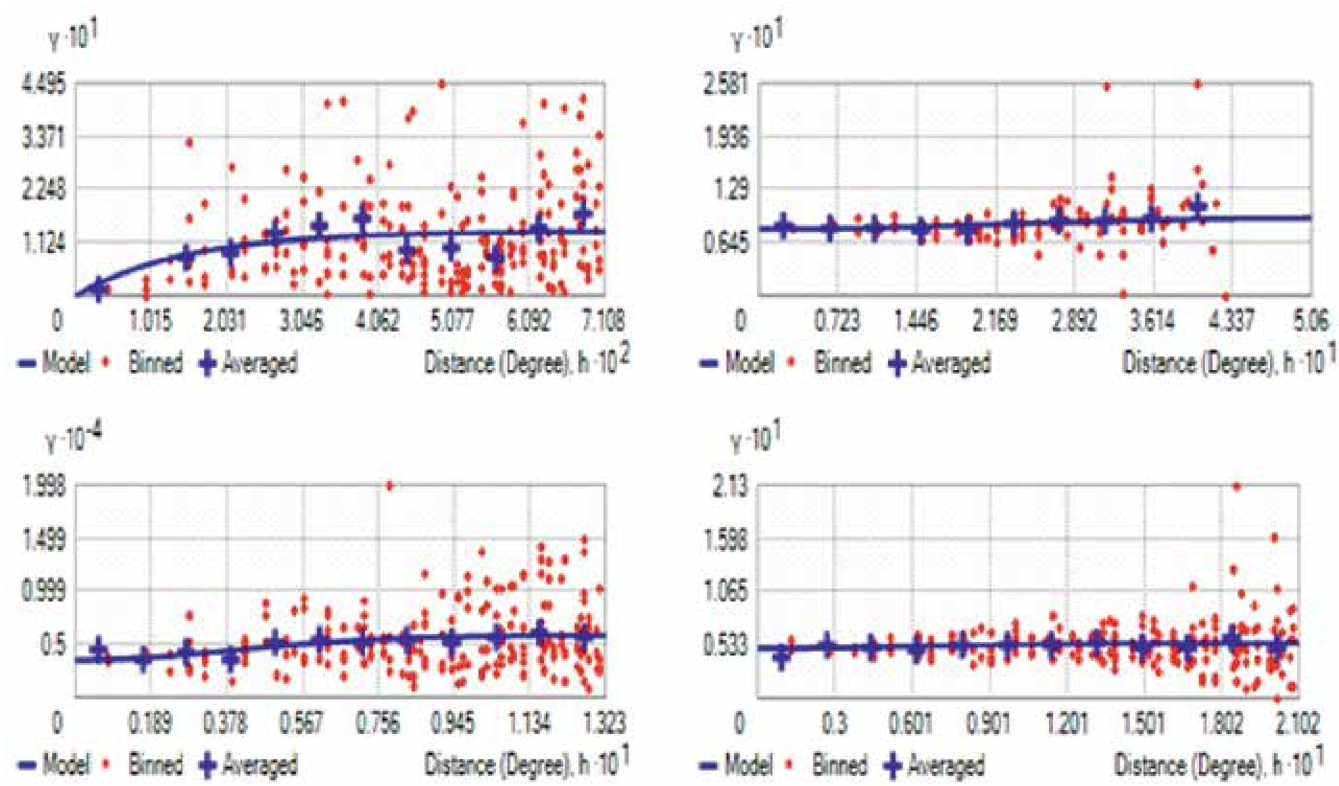

Figure 1: variograms of best fitting models for all the blocks Tilda, Arang, Abhanpur and Dharsiwa respectively.

models were fitted to the experimental variogram and the model with the lowest residual mean sum of squares error (RMSE) was chosen as minimum. Table 1, 2 and 3 summarizes the RMSE for each fitted model for all blocks. The best fitting models variogram for all the blocks are presented in Figure 1.

Table 1 shows that gaussian variogram model was found the best model in comparison to the other model (spherical, circular, exponential and Gaussian) for Dharsiwa in the all the blocks for ordinary kriging and model has been chosen as a best model on basis of lowest RMSE (50.76) value. Table 2 shows that gaussian variogram model was found the best model in comparison to the other model (spherical, circular, exponential and Gaussian) for Dharsiwa in the all blocks for lognormal kriging. After comparison it has been observed that inverse distance weighting (IDW) was not perform well due to its higher values of RMSE in comparison to ordinary kriging and lognormal kriging Interpolation techniques (from

Table 1. performance of Ordinary Kriging Interpolation on different models for nitrogen content in the soil.

Abhanpur block	Spherical	Circular	Exponential	Gaussian	Linear
RMSE	67.40	67.26	68.31	67.41	66.63
R square	0.82	0.83	0.81	0.81	0.85
Tilda Block					
RMSE	81.22	85.51	82.87	85.99	82.82
R square	0.85	0.86	0.89	0.87	0.84
Arang block					
RMSE	75.02	75.77	76.55	76.12	76.53
R square	0.87	0.86	86.48	86.53	85.35
Dharsiwa block					
RMSE	52.12	52.84	51.83	50.76	51.86
R square	0.92	0.90	0.89	0.914	0.90

Table 2. Performance of lognormal kriging interpolation on different models for nitrogen content in the soil.

Abhanpur block	Spherical	Circular	Exponential	Gaussian	Linear
RMSE	67.25	67.31	67.98	67.25	65.62
R square	0.82	0.72	0.82	0.81	0.86
Tilda Block					
RMSE	82.76	83.08	80.11	83.05	82.60
R square	0.84	0.85	0.91	0.85	0.84
Arang block					
RMSE	69.36	70.00	69.46	68.21	69.31
R square	0.87	0.86	87.71	87.92	85.66
Dharsiwa block					
RMSE	50.69	51.68	51.77	49.48	51.58
R square	0.83	0.83	0.84	0.84	0.82

Table 3. performance of inverse distance weighting (IDW) technique for nitrogen content in the soil.

	Abhanpur block	Tilda Block	Arang block	Dharsiwa block
RMSE	68.17	84.63	80.21	54.27
R square	0.74	0.83	81.76	0.80

table 1,2 & 3). The values of R^2 show the strength of relationship among the nitrogen content at different locations. Result was also concluded that after transforming the data for skewed distribution gave the précised result; it means that lognormal kriging provides best result as compared to ordinary kriging interpolation technique. Estimates of nitrogen content on the basis of best fitted interpolation method (Lognormal kriging) at different locations

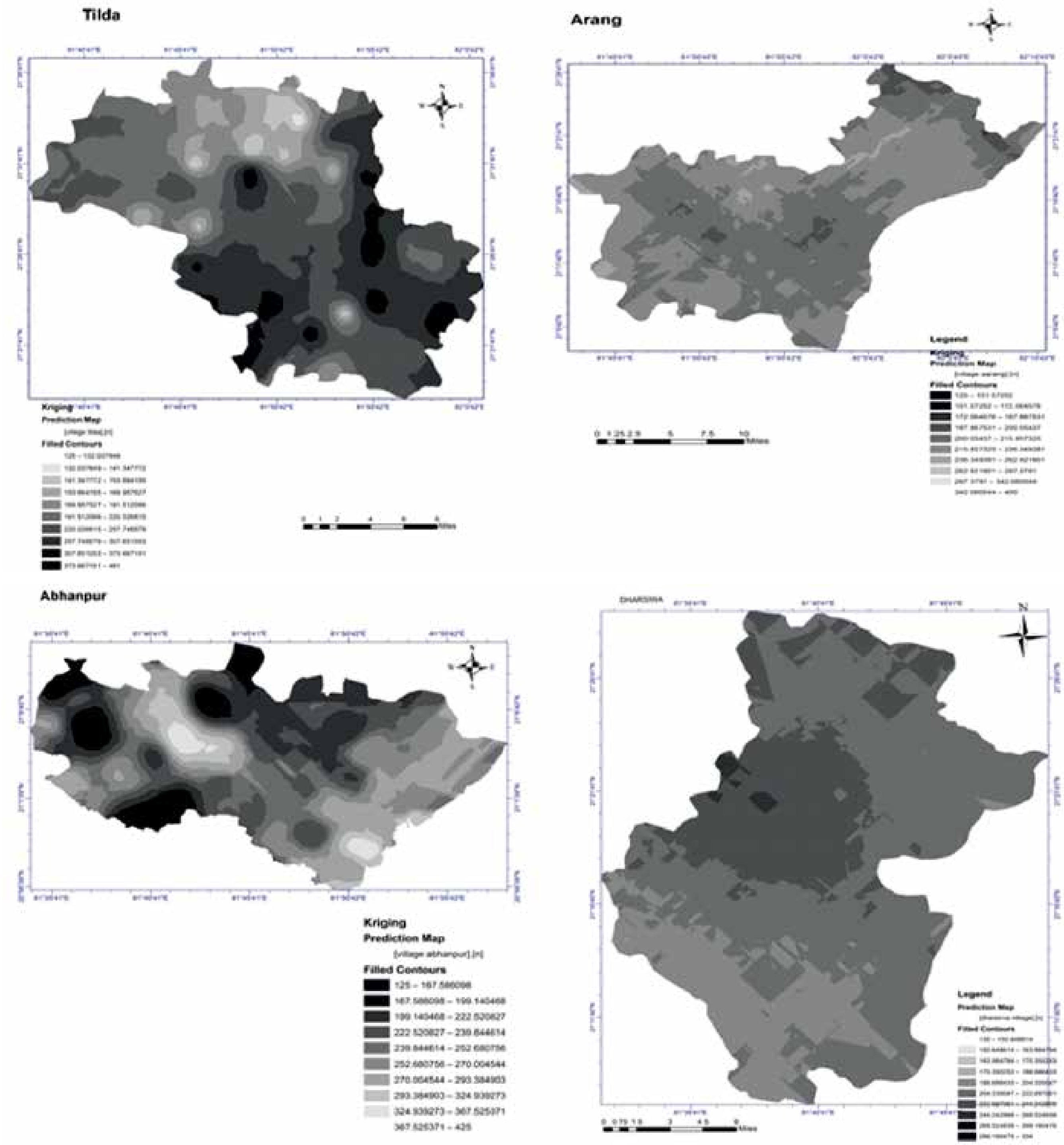

Figure 2: represents the spatial distribution of nitrogen content in the soil

have been represented by the spatial distribution maps (Figure 2).

CONCLUSION

The clear understanding of nitrogen content distribution is the key issue for agricultural and environment management. Due to relative profusion of a variety of methods, many algorithms are presently applied, and research continues, aiming at the definition of the "best" method for delineation of spatial distribution of nitrogen content. The methods are evaluated using accuracy and error estimates of interpolation techniques. The accuracy is assessed by coefficient of determination (R^2), and errors are represented by the root mean square error (RMSE). The study shows that lognormal kriging interpolation method was superior to ordinary kriging and Deterministic methods (IDW). The performance of the Gaussian variogram model was the best with lognormal kriging and OK interpolation techniques. Finally, the results guide to the finding the prediction of nitrogen content at different location which can significantly contribute to proper application of agricultural and ecological modeling.

REFERENCES

Almasi A , Jalalian A and Toomanian N (2014). OK and IDW methods for prediction the spatial variability of a horizon depth and OM in soils of Shahrekord, Iran. *J Environ and Earth Sci* **4**(15):69-176.

Chabala L M, Mulolwa V and Lungu O (2017). Application of Ordinary Kriging in Mapping Soil Organic Carbon in Zambia *Soil Science Society of China*, **27**(2): 338–343.

Chang Y H, Liu X J, Li K H, Lv J L and Song W (2013). Numerical modeling atmospheric nitrogen deposition: evolution process and models' screening. *Arid Land Geography* **36**:383–392.

Jianshu L V, Yang L, Zhang Z and Dai J (2013). Factorial kriging and stepwise regression approach to identify environmental factors influencing spatial multi-scale variability of heavy metals in soils, *J Hazardous Materials* **261**: 387– 397.

Reza, S K, Sarkar D, Daruah U and Das T H (2010). Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some chemical parameters of Dhalai district, Tripura. *Agropedology*. **20**(1):38-48.

Chander S (2016). Nitrogen in Indian agriculture, *Indian J Fert* 12-13.

Shukla G, Mishra G C and Singh S K (2015). Kriging approach for estimating deficient micronutrients in the soil: A Case Study. *Int J Agri, Environ and Biotech* **8**(2):136-139.

Shukla G, Mishra G C and Singh S K (2016). Estimation of micronutrients in the soil. *The Bioscan* **11**(1): 305-308.

Wu J, Norvell W A and Welch R M (2006). Kriging on highly skewed data for DTPA-extractable soil Zn with auxiliary information for pH and organic carbon. *Geoderma* **134**: 187– 199.

Received on 17/11/2018 *Accepted on 20/12/2018*