International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Assessment of Geostatistical Models for the Major Soil Nutrients for Tumkur District of Karnataka, India

Leena H.U, Premasudha B.G, P. K. Basavaraja, H. Mohamed Saqeebulla,G.V. Gangamrutha

Abstract*: Digitization of agriculture has tremendously increased in the adoption of various advanced techniques in the Indian agricultural sector. One of the core agriculture objectives is preserving soil fertility. To achieve this efficient soil fertility management alongside an effective spatial distribution of soil nutrient properties is required. The main objective of this study is to evaluate and propose the best interpolation technique on estimating the soil nutrients status to provide site-specific fertilizer recommendations through the Soil Test Crop Response target yield approach. In this study, we have focused on three major soil nutrients viz., nitrogen (N), phosphorus (P_2O5) and potassium (K_2O) for evaluation. The benchmarking study has considered four most successive interpolation techniques like Ordinary Kriging (OK), Radial Basis Function (RBF), Inverse Distance Weighted (IDW), and Global Polynomial Function (GPI). The evaluation and analytical results proved Ordinary Kriging is better by securing the highest accuracy against other interpolation techniques concerning RMSE and ME for interpreting the soil nutrients N, P_2O5, and K_2O. The interpreted values are also cross-validated with actual soil test samples with an accuracy of more than 85% for each nutrient. Nevertheless, these results are dependent on the number of actual soil test samples and the accuracy of the designed network with overall accuracy between the interpreted and the actual data.

Keywords : Soil nutrients, Ordinary Kriging, Radial Basis Function, Inverse Distance Weighted, Global Polynomial Function

Manuscript published on November 30, 2019.
* Correspondence Author

Leena H.U.*, Full-time Research Scholar, Department of Master of Computer Application, Siddaganga Institute of Technology, Tumakuru, India and affiliated to Visvesvaraya Technological University, Belagavi, Karnataka, India. Email: leenahu@sit.ac.in

Premasudha B.G., Professor (bgpremasudha@sit.ac.in) Department of MCA, Siddganga Institute of Technology, Tumakuru, Karnataka, Email: bgpremasudha@sit.ac.in

P.K. Basavarja, Professor & Scheme Head, **H. Mohamed Saqeebulla**, Senior Research Fellow and **G.V. Gangamrutha**, Research Associate AICRP on STCR, Department of Soil Science & Agricultural Chemistry, UAS, GKVK, Bengaluru 560065, India. Email: pujarikbraj@gmail.com

H. Mohamed Saqeebulla,working as Research Fellow in AICRP on STCR, Dept. of Soil Science & Agril. Chemistry UAS, GKVK, Bangalore - 560 065, India.

G. V. Gangamrutha, working as Senior Research Fellow in the scheme AICRP on STCR, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, G.K.V.K., Bengaluru, Karnataka.

I. INTRODUCTION

The extensive use of GIS applications in the agricultural sector is increasing enormously. Indian precision farming is stepping towards the use of internet of things (IoT) and machine learning embedded with GIS applications. As the soil properties vary spatially and temporally from small fields to large fields affecting both intrinsic and extrinsic of farming practices, crop management, soil fertility management, etc. [1]. Evaluating the soil properties effectively before crop cultivation is highly required and the application of a proper dose of fertilizers throughout the cropping period is most essential for targeting high yield [2]. The significance of spatial distribution of soil nutrients and adopting the latest interpolation techniques to provide optimum site-specific nutrient requirements is very important. Currently, In India sever-al measures have been taken to collect the soil samples from farming land and obtaining the soil test values from Soil Test Laboratories (STL) is an on-going process. However, most of the farmers are still practicing the blind application of fertilizers and are lethargic to get their soil nutrients test-ed. To overcome the current situation, using the interpolation techniques the soil nutrients can be interpreted for unsampled areas for each geo-coordinate. Based on the interpreted values, the fertilizer recommendations using Soil Test Crop Response (STCR) equations for specific yield tar-gets for each crop can be provided to the farmers through GIS based cloud solution services at their fingertips to increase their productivity without going for the actual soil test analysis.

The fundamental of geostatistics is to analyze the geospatial autocorrelation of the variables and determine the range of spatial dependence that is calculated by performing experimental semivariograms [3]. In most of the studies, determining the performance of various interpolation methods depend upon spatial data structure, selection of semi-variogram models, number of nearest neighboring points and search radius. Researches have evolved the significance and put efforts for spatial modeling of soil proper-ties by adopting various geostatistical methods [4]. Over the decades, the commonly used conventional interpolation techniques are Ordinary Kriging (OK) and Inverse Distance Weighted (IDW) in various agricultural activities [5]-[7].

In many research studies [8]-[10], authors adopted OK and cokriging, geometric method-IDW, global and local polynomial, and statistical methods such as the linear regression model (LR) in predicting the soil properties.

Another study by Wang [6] proved OK and IDW techniques gave comparative root mean square error (RMSE) values while evaluating the soil properties. Then again, most investigations supported OK over IDW when contemplating soil nutrient parameters [11], [13], [5].

The kriging technique is ideal and superior to any supplementary [12] for determining the spatial variability on soil properties; this was proved in some of the research studies [13]. The study adopted many other techniques like IDW, Radial Basis Function (RBF) and OK to scrutinize the spatial circulation of organic content and pH value of soil for various constraints. However, kriging resulted better over all other techniques studied.

The implementation of IDW technique resulted in good results on various soil parameters excluding N. However, Reza[13] reported the results obtained are better analyzed with OK but not by IDW technique.

Yasrebi [3] evaluated and com-pared some soil chemical parameters by OK and IDW methods and reported spatial variability for different soil parameters (except N) may be better understood by OK than by IDW method.

The past studies have proposed many qualitative types of research on the comparison, prediction and performance of interpolation techniques in climatology [11],[3] and environmental studies [10],[14]. Few studies specific to soil science are found in the area of erosion of soil [9],[10], comparison of soil fertility for pH values [8],[15] macronutrients [10],[12] and organic matter [4],[14].

Based on the previous studies and analysis of spatial modeling of soil nutrients, the best-chosen interpolation techniques that are less prone to errors were identified. The fundamental objectives of this study were: (1) To examine reasonable landscape spatial modeling for soil nutrients, (2) Interpret the soil nutrients by exploiting OK, IDW, RBF and GPI. (3) Analyze the accuracy level of referenced techniques against the cross validation methods such as root mean squared error (RMSE) and mean error (ME) and to adopt the best method. (4) Compare and analyze the accuracy level with interpreted data and actual soil test values.

II. MATERIALS AND METHODS

The soil sampling and soil analysis was carried out by the team of AICRP on STCR, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru to investigate the spatial variability of available macro soil nutrients in extremely developed soils by collecting soil samples through randomly choosing revenue number of 223 villages out of 2708 villages of Tumkur [1] of Karnataka covering 8 to 10% of aggregate number of villages by collecting farmer details along with geo-referenced data for each soil sample. The study area is carried out in Tumkur District 1059.7 (about 000 ha) of Karnataka state.

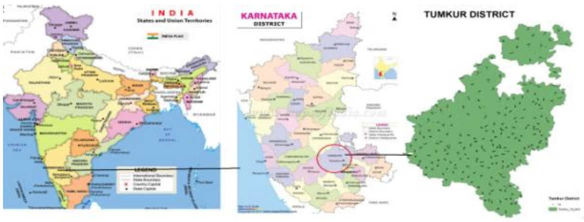


Fig. 1.Geographical location of the study area

A. Normalization of Soil Sampled Data

A total of 1332 soil samples were collected randomly covering whole of Tumkur district and these soil samples were analyzed for various soil parameters at UAS, GKVK, Bengaluru. The soil test results for both major and micronutrients along with farmer details, fertilizer usage, land details, and geo-referenced (latitude, longitude) values were provided in excel format. These data were pre-processed using ArcGIS 10.2 software for each major nutrients viz., N, P_2O5, and K_2O and spatial variability maps were generated. Using geostatistical analyst wizard in ArcGIS software, the data distribution were reviewed graphically using semi-variogram, cross-validation, and covariance plots.

For this research study, the 1332 soil samples were randomly selected as input for the interpolation for each of the soil nutrients and for evaluation of the interpolated results, around 20 soil samples were collected from each taluq of Tumkur district for validation and accuracy measurement.

The preliminary step before exploiting geostatistical techniques, the presence of spatial structure among the soil nutrient data by analysis variogram was studied. Skewness coefficient was worked out to understand the state of spatial distribution and analyzing the normality of data. As per previous studies, many researchers considered if the skewness coefficient is lower than 0.5 formerly normality of data is usage of skewness coefficient. As conversion of data is not required, but if this coefficient ranges from 0.5 to 1, and more than 1, then data normalizing using square root and algorithm must be adopted, respectively [18]

B. Ordinary Kriging (OK)

OK is a geostatistical method to statistically correlate a function of distance measurement utilizing the semivariogram analysis. A semivariogram can be calculated using the below equation(1):

$$s(n) = \frac{1}{2N(n)} \sum_{i=1}^{N(n)} [Z(x_i) - Z(x_i + n)]^2 \qquad (1)$$

where s(n) denotes the experimental semivariance value at a distance n for all pairs, N denotes the number of sample pairs of observations within the distance n, $Z(X_i)$ symbolize the sample variables at point i and $Z(X_i+n)$ is the sample variables of two points separated from X_i, by a discrete distance interval n,X_i is the geo-referenced point where $Z(X_i)$ values are measured[19].

The basic parameters like nugget, sill and range are used to calculate the semivariogram models. The variance distance denoted by nugget is 0, the variables spatially reliant each other with distance that is known as range.

Though, variance at point does not impact the neighboring range/distance point. The best fit model was shortlisted [2] based on many changing parameters looking up the smallest nugget with the best fit. The model-like spherical, circular, power, exponential and Gaussian included the semivariogram model with best fit soil property.

C. Inverse Distance Weighting (IDW)

IDW interpolation is a technique to determine the multivariate interpolation for known sample points. This technique interprets the unknown values with specifying search distance and nearest points based on the power values. IDW can be defined as mentioned in equation(2) and (3):

$$D(x) = \sum_{i=1}^{n} G_i H_i \Big/ \sum_{i=1}^{n} G_i \tag{2}$$

$$G_i = d_i^{-u} \tag{3}$$

From the equation, the interpolated point is predicted by value at D(x), and known point value is identified by parameter H_i. Further interpolation and know points count and total is represented by parameter n, keeping the prediction in mind i and d_i to measure the distance prediction point and actual distance. As the distance increases, the weight also decreases and we calculate these values by using parameter u as weighting power, the total weight is identified by G_i parameter and is allocated to point i. The power parameter value is the key factor in upsetting the accuracy of IDW. The most standard and practiced IDW technique is analyzed with the assessed comparison with parameter ranging from 1 to 4 [6], [11].

D. Radial Basis Function (RBF)

RBF geostatistical method is used for multi-dimensionally scattered sample data to analyze each measured sample value through surface data [12]. The radial basis functions are classified into various types such as thin-plate spline, completely regularized spline, multiquadric function, spline with tension and inverse multiquadric function. Only two functions gave least errors for the soil nutrients N, P_2O_5 and K_2O and we considered a completely regularized spline method in our study. Every function depicts diverse contour and effects in different interpolation surfaces. Comparably both IDW and RBF are known as exact interpolators, but IDW predicted values cannot measure the value below the minimum measured or above the maximum measured value. Conversely, the RBFs can predict values below the minimum and above the maximum measured values [2].

E. Global Polynomial Interpolation (GPI)

GPI, commonly referred to as trend surface analysis, is an interpolation method that addresses potential relationships between variables and the spatial locations of sample points [20]. This method could prove to be valuable for modeling significant variations of the mean value in a spatially continuous dataset [21]. Trend surface analysis relies on a polynomial function to produce a smooth surface model relative to the known values of the sample points. The 17 polynomial equation utilized during calculations is a two-dimensional polynomial equation of the first, second, or higher degree [2]. GPI is defined by a mathematical polynomial function that fits a smooth surface to input sample points. GPI surface varies gradually and captures coarse-scale pattern in the data and also fits a polynomial to the whole surface.

F. Evaluation of Interpolation Techniques

The evaluation of four interpolation techniques is performed using the statistical criteria namely RMSE and ME. The interpolation techniques comparison [11] was validated by applying cross-evaluation mode as it is considered to be the standard practice. This technique was highly implemented to educate the model with the used model [8] for validation, the technique considers the sample points that separated by two sets of data. Further, this technique was consumed for evaluation and comparison of various interpolation techniques for better accuracy. Two key methods *viz.*, Root Mean Square Error (RMSE) and Mean Error (ME) are integrated while performing the comparison of interpolation techniques to accomplish best results. The RMSE failed to offer a point of direction to authentic data [13], we considered ME as prime measuring source. Additionally, the lowest values in the computation displayed errors with both ME and RMSE. The below equation (4) and (5) narrates,

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \tag{4}$$

$$ME = \sum \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n} \tag{5}$$

Where n is the number of samples, P_i is the predicted value of missing point soil nutrient status (N, P_2O_5, K_2O), P is the actual point tested soil nutrients (N, P_2O_5, K_2O) and O_i is the geographic coordinates at location i.

By utilizing the geostatistical analysis tool available in ArcGIS 10.2, all four interpolation techniques were performed.

III. RESULTS AND DISCUSSION

A. Ordinary Kriging (OK)

The soil nutrients are highly considered for expressing the spatial structure and the best shortlisted interpolation model was adopted for standard soil major nutrients N, P_2O_5, and K_2O to perform OK technique. The natively available models like power, circular, gaussian, exponential and spherical were adopted to calculate the small and large nuggets but investigated semivariogram found to be the best fit for computing the lag distance kriging on each soil N, P_2O_5 and K_2O nutrient with a circular distance of 500 meters. The two formulae methods RMSE and ME performed better on each soil nutrient for small values with the least errors. Table 1 explains the semivariogram and shortlisted parameters.

Table-I: Soil nutrients and associated semivariogram parameters

Variable	Semi-variogram models	Nugget	Sill	Range	RMSE	Mean Error
N	Circular	1913.60	1540.07	0.23	50.62	0.04
P_2O_5	Circular	159.79	153.94	0.01	16.81	0.12

K_2O	Exponential	10548.65	7221.64	0.00	139.61	-1.08

The spatial distribution maps for the major nutrients (N, P_2O_5, K_2O) according to OK are shown in Fig 2.

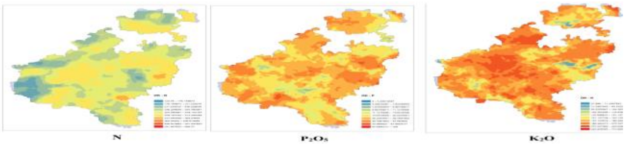
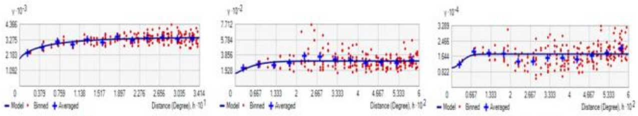


Fig. 2.Spatial distribution maps of soil N, P_2O_5 and K_2O nutrients using OK interpolation technique

Various types of semivariogram functions such as circular, exponential, spherical and gaussian can be used to model the semivariogram. In the present study, we have used a circular model for N and P_2O_5 and an exponential model for K_2O nutrient as it showed the least error when compared with other semivariograms. Fig 3 displays the semivariogram of the soil N, P_2O_5, and K_2O nutrients.



N **P_2O_5** **K_2O**

Fig. 3.Semivariogram N, P_2O_5 and K_2O nutrients using OK method

B. Inverse Distance Weighted (IDW)

The IDW method was evaluated using the power model ranging from 1 to 4. We have selected the power 2, 3, and 4 powers exponential for the soil nutrients and limiting distance to 50m. The various trial and errors were performed with a distance of 50 m, 100m and 500m, 50 m and 50 m gave the nearest accuracy. Table 2 details the power's values and accuracy of selected soil nutrients for cross-validation methods. However, power value with 2 was selected for the study with the least errors.

Table-II: Cross-validation of IDW interpolation method based on various power values

Power values	N		P_2O_5		K_2O	
	MRE	*RMSE*	*MRE*	*RMSE*	*MRE*	*RMSE*
2	-1.02	53.78	0.39	17.52	-0.18	145.84
3	-1.32	56.16	0.53	18.29	0.39	151.38
4	-1.51	57.83	0.63	18.87	0.67	155.73

Spatial distribution of IDW maps are shown in below Fig 4.

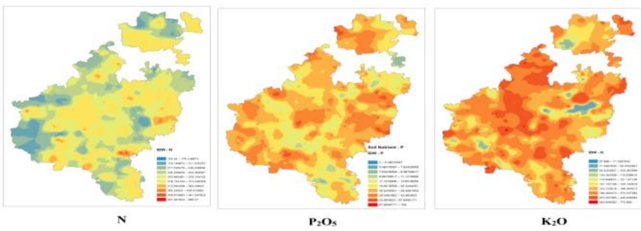
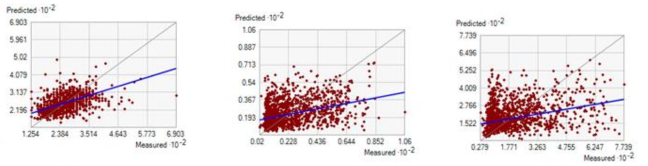


Fig. 4.Spatial distribution maps of soil nutrients N, P_2O_5 and K_2O using IDW interpolation technique



N **P_2O_5** **K_2O**

Fig. 5.Semivariogram of N, P_2O_5 and K_2O nutrients using IDW interpolation technique

From the calculation excluding the parameter N, P_2O_5 and K_2O nutrients generated very low errors with IDW, where the calculation by ME and RMSE was in power of 2 in the comparison with other nutrients. However the rise in power from 2 to 3 benefited results, which can be seen in Fig 5, displays the soil property interpolation using the IDW technique on soil N, P_2O_5 and K_2O nutrients with lowermost RMSE.

C. Radial Basis Function

Radial basis function using regularized and tension Splines gave similar results in the prediction of soil nutrients (N, P_2O_5 and K_2O) as RMSE observed in case of regularized and spline with tension was 50.98 and 50.99 respectively. According to RMSE values that are shown in Table 3, completely regularized spline produced more accurate maps when compared with all other functions for the soil N, P_2O_5 and K_2O nutrients with RMSE values of 50.99, 16.81 and 139.98 respectively.

Table-III: Cross-validation of RBF interpolation method based on various functions

Radial Basis Functions	N		P_2O_5		K_2O	
	ME	*RMSE*	*ME*	*RMSE*	*ME*	*RMSE*
Thin-plate spline	6.58	339.35	-0.13	48.14	0.28	423.89
Spline with tension	-0.43	50.98	-0.04	16.83	-1.55	139.98
Completely regularized spline	-0.43	50.99	-0.03	16.81	-1.50	139.98
Multiquadric function	-0.67	56.34	0.42	18.42	0.20	154.18
Inverse Multiquadric function	-0.60	51.68	-0.10	16.89	-3.23	143.59

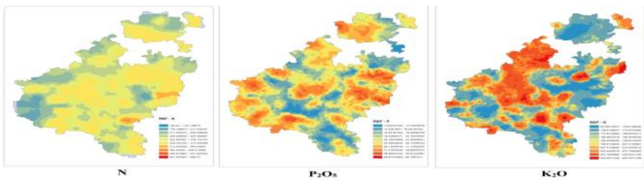
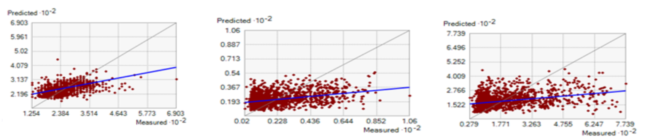


Fig. 6. Spatial distribution maps of soil N, P_2O_5 and K_2O nutrients using RBF interpolation technique



N **P_2O_5** **K_2O**

Fig. 7.Semivariogram of N, P_2O_5 and K_2O nutrients using RBF interpolation technique

Retrieval Number: D9606118419/2019©BEIESP
DOI:10.35940/ijrte.D9606.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

D. Global Polynomial Interpolation (GPI)

Global polynomial interpolation fits single polynomial while local polynomial interpolation fits many polynomials, each within specified overlapping neighborhoods [22]. Therefore, the use of many polynomials within overlapping neighborhood might be the reason for lower mean error and root mean square error values in the global polynomial interpolation method.

Global polynomial interpolation indicated higher mean error and root mean square error as compared to the other three interpolation methods in Table 4.

Table-IV: Cross-validation of GPI interpolation method based on the order of polynomial values

Order of Polynomial	N		P_2O_5		K_2O	
	ME	*RMSE*	*ME*	*RMSE*	*ME*	*RMSE*
1	0.00	56.72	-0.00	18.14	0.00	146.78
3	-0.00	56.16	-0.00	17.91	-0.04	146.29

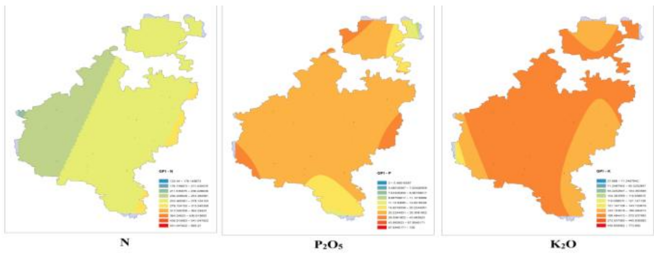
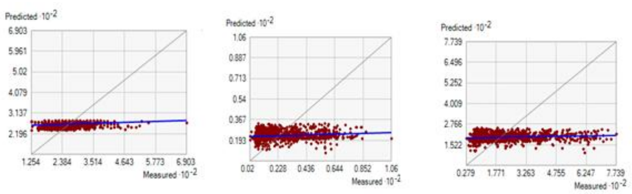


Fig. 8.Spatial distribution maps of soil N, P_2O_5 and K_2O nutrients using GPI interpolation technique



N P₂O₅ K₂O

Fig. 9.Semivariogram of N, P_2O_5 and K_2O nutrients using GPI interpolation technique

Table-V: Comparison of performance of the four interpolation methods based on RMSE and ME

Interpolation Methods	N		P_2O_5		K_2O	
	RMSE	*ME*	*RMSE*	*ME*	*RMSE*	*ME*
OK	50.62	0.04	16.81	0.12	139.61	-1.08
IDW	53.78	-1.02	17.52	0.39	145.84	-0.18
RBF	50.99	-0.43	16.81	-0.03	139.98	-1.50
GPI	56.16	-0.00	17.91	-0.00	146.29	-0.04

The cross-validations were performed for all the four interpolation methods to evaluate the accuracy and to choose the best method based on the least error for the soil nutrients as shown in Table 5. The OK technique resulted in better with ME and RMSE for achieving lower most errors standing next to RBF and GPI.

E. Cross-validation of interpolated values with actual soil test results

The soil samples were collected randomly for each taluk of Tumkur district by the team of Soil Scientist, AICRP on STCR, Dept. of Soil Science and Agril. Chemistry UAS, GKVK, Bangalore after post interpolation. These values were cross-validated with interpolated values for N, P_2O_5, and K_2O nutrients as shown in Table 6. The results showed good accuracy over actual and interpolated values (OK) with 97.84% for N, 85.38% for P_2O_5 and 90.47 for K_2O. The results depicted that overall accuracy of more than 85% of interpreted nutrient values can be used to provide site-specific fertilizer recommendations for individual farmers.

Table-VI: Comparison of actual soil nutrient values with OK interpolated values for randomly selected values for each taluk of Tumkur district

Soil Nutrients	N ($kg\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)	K_2O ($kg\ ha^{-1}$)
Average: Actual soil test value	251.09	22.66	199.62
Average: Interpolated value	256.51	25.97	220.62
%Variation	2.15	14.61	9.52
%Accuracy	97.84	85.38	90.47

IV. CONCLUSION

This study was conducted to provide site-specific fertilizer recommendations based on the interpolated soil nutrients status using the STCR approach. These values were cross-validated through soil analysis by Soil Scientist, AICRP on STCR, Dept. of Soil Science and Agril. Chemistry UAS, GKVK, Bangalore. These results showed a good accuracy of more than 85% for each nutrient. In this study, four important interpolation methods were used to predict the major soil nutrients (N, P_2O_5, and K_2O). The results of the present study clearly showed the Ordinary Kriging (OK) technique is suitable for larger distribution of area with random samples. Though, the soil nutrient status predicted with 97.84% for N, 85.38% for P_2O_5 and 90.47 for K_2O of accuracy, these nutrients can be well utilized for providing site-specific fertilizer nutrient recommendations for individual farmers for achieving the desired yield. Further, the proposed technology benefits the farmers by eradicating the legacy system in availing the soil health report by reaching soil test laboratories every year. The prime benefit of the proposed technology is that it can determine the impact on estimations by adoption of features like sampling size, design and data. This technology suggests the selection of right interpolation method which is necessary to ensure complete consumption of spatial information by samples. The proposed technology demonstrated and strongly suggests OK interpolation is better in assessing the soil nutrients in comparison with other interpolation techniques.

ACKNOWLEDGMENT

The authors extend special thanks for the financial support received by the Department of Agriculture and Co-operation, Government of India, New Delhi during 2018-19. It was also financially supported by the New Age Incubation Network (NAIN) ICT Skill Development
Society, Department of IT, BT and S & T, Govt. of Karnataka.

REFERENCES

1. Basavaraja P. K., Mohamed Saqeebulla H., Dey P, Nethradhani Raj C. R., "Geo- Reference based soil fertility status in Tumkur district of Karnataka, India", *Environment & Ecology*, 2016, vol. 34(4B), pp. 2120-2128.
2. Zandi S., Ghobakhlou A. and Sallis P., "Evaluation of Spatial Interpolation Techniques for Mapping Soil pH", *19th International Congress on Modeling and Simulation, Perth, Australia*, 2011, pp. 1153-1159.
3. Yasrebi J, Saffari M, Fathi H, Karimian N, Moazallahi M and Gazni R, "Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some soil chemical parameters", *Res. J. Biol. Sci*., 2009, vol. 4, pp.93–102.
4. Behera S.K, Shukla A.K, "Spatial distribution of surface soil acidity, electrical Conductivity, soil organic carbon content and exchangeable Potassium, calcium and magnesium in some cropped acid Soils of India", *Land Degrad. Dev*, 2015, vol. 26, pp.71–79.
5. Poshtmasari H. K, Sarvestani Z. T and Kamkar B, "Comparison of interpolation methods for estimating pH and EC in agricultural fields of Golestan province (north of Iran)", *International Journal of Agriculture and Crop Sciences*, 2012, vol. 4(4), pp.157-167.
6. Yao X, Fu B, Lu Y, Sun F, Wang S., "Comparison of Four Spatial Interpolation Methods for Estimating Soil Moisture in a Complex Terrain Catchment", *PLoS ONE, vol*.8(1), doi:10.1371/journal.pone.0054660.
7. Y, Shi Z, Wu C.F, Li H.X and Li F, "Improved prediction and reduction of sampling density for soil salinity by different geostatistical methods", *Agricultural Sciences in China*, vol. 6, pp. 832-841.
8. Kravchenko A. N. and Bullock D. G., "A Comparative study of interpolation method for mapping soil P and K contents", *In: Proceedings of 4th International Conference on Precision Agriculture*, 11-15 Jun 1999, St. Paul, Minnesota, USA, pp. 267-279.
9. Angulo-Martinez M, Lopez-Vicente M, Vicente-Serrano S.M. and Begueria S., "Mapping rainfall erosivity at a regional scale: a comparison of interpolation methods in the Ebro Basin (NE Spain)", *Hydrol. Earth Syst. Sci*., vol. 13, pp.1907-1920.
10. Jin Li, Andrew D. Heap, "A review of comparative studies of spatial interpolation methods in environmental sciences: Performance and impact factors", *Ecological Informatics*, 2010, vol. 6, pp. 228-241.
11. Robinson TP and Metternicht G., "Testing the Performance of Spatial Interpolation Techniques for Mapping Soil Properties", *Computers and Electronics in Agricultur*e, vol. 2006, vol.50, pp.97-108.
12. Christos G. Karydas, Ioannis Z. Gitas, Eirini Koutsogiannaki, Nikolaos Lydakis-Simantiris and Georgios N. Silleos, "Evaluation of spatial interpolation techniques for mapping agricultural topsoil properties in Crete", *EARSeL eProceedings*, 2009, vol. 8(1), pp.26-39.
13. Jafar Yasrebi , Mahboub Saffari , Hamed Fathi , Najafali Karimian , Masome Moazallahi and Reza Gazni, "Evaluation and Comparison of Ordinary Kriging and Inverse Distance Weighting Methods for Prediction of Spatial Variability of Some Soil Chemical Parameters", *Research Journal of biological Sciences*, 2009, vol 4, pp.93-102.
14. Bhunia G. S, Shit P. K and Maiti R., "Comparison of GIS-based Interpolation Methods for Spatial Distribution of Soil Organic Carbon (SOC)", *Journal of the Saudi Society of Agricultural Sciences*, 2016, vol.17(2), pp.114-126.
15. Sourov Chatterjee, Priyabrata Santra, Kaushik Majumdar, Debjani Ghosh, Indranil Das and Sanyal S. K., "Geostatistical approach for management of soil nutrients with special emphasis on different forms of potassium considering their spatial variation in intensive cropping system of West Bengal, India", *Environ Monit Assess*, 2015, pp. 187:183.
16. Christos G. Karydas, Ioannis Z. Gitas, Eirini Koutsogiannaki, Nikolaos Lydakis-Simantiris and Georgios N. Silleos, "Evaluation of spatial interpolation techniques for mapping agricultural topsoil properties in Crete", *EARSeL eProceedings*, 2009, vol. 8(1), pp.26-39.
17. Behera S.K, Shukla A.K., "Spatial distribution of surface soil acidity, electrical Conductivity, soil organic carbon content and exchangeable Potassium, calcium and magnesium in some cropped acid Soils of India", *Land Degrad. Dev*, 2015, vol. 26, pp.71–79.
18. Xie Y, Chen T, Lei M, Yang J, Guo Q, Song B and Zhou X., "Spatial Distribution of Soil Heavy Metal Pollution Estimated by Different Interpolation Methods: Accuracy and Uncertainty Analysis", *Chemosphere*, 2011, vol. 82, pp.468-476.
19. Isaaks E.H. and Srivastava R.M., "An Introduction to Applied Geostatistics", *Oxford University Press, New York* 413, 1989.
20. Burrough P.A. and McDonnell R.A., "Principles of Geographical Information Systems", *Oxford University Press 333*, 1998.
21. Bailey T. C. and Gatrell A. C., "Interactive Spatial Data Analysis", *Longman Scientific & Technical, Essex 413*, 1995.
22. ESRI, *ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Relands*, 2011.

AUTHORS PROFILE

Leena H.U. is currently working as Full-time research scholar in the Department of Master of Computer Applications, Siddaganga Institute of Technology, B.H. Road, Tumakuru- 572103, Karnataka, India. She has 11+ years of experience in IT industry and moved to research. Her research interest is in the area of spatial analytics and cloud computing. A grant of Rs. 3 lakh received for the research project from ICT Skill Development Society, Department of IT, BT and S & T, Govt. of Karnataka, New Age Incubation Network (NAIN) during 2016.

Premasudha B.G. is working as a professor in the Department of Master of Computer Applications, Siddaganga Institute of Technology, B.H. Road, Tumakuru- 572103, Karnataka, India. She has 30 years of teaching experience in the area of computer science. She has published several National and international journal and conference papers. She presented a paper at Map Middle East 2007 at Dubai, for which she has received AICTE travel grants to attend the conference. She has received VGST and several funded projects from various funding agencies. She has guided three PhDs and also three PhD scholars are pursuing their research under VTU. She had delivered technical talk in various organizations and chaired the technical sessions in several conferences. Her areas of interests are spatial analysis, Location Based Services, Mobile and cloud Computing, MANET, VANET and Sensor Networks, data analytics and deep learning.

P.K. Basavaraja is working as Professor and Scheme Head, AICRP on STCR, Dept. of Soil Science & Agril. Chemistry UAS, GKVK, Bangalore - 560 065, India. He is specialized in Soil fertility, Micronutrients, Salt affected soils, Organic residue management, Watershed management, Soil test crop response studies (STCR).He published more than 200 scientific publications including 55 peer reviewed national and international papers. He attended forty eight national and International conferences and presented papers. He successfully operated more than 13 projects worth 3.35 crores including two RKVY projects. He guided Netherland, Dubai, Singapore and presented research papers in international conferences. He has been awarded with five national/ state level awards for his contribution towards soil science research 3 Ph.D.(Agri) and 12 M.Sc. (Agri) students. Through his research he has developed nine technologies and included in the package of practice for the benefit of farming community of different agro climatic zones of Karnataka state, India. Officially he visited Crete, Greece, Wageningen, Amsterdam, Netherland, Dubai, Singapore and presented research papers in international conferences. He has been awarded with five national/ state level awards for his contribution towards soil science research.

Mohamed Saqeebulla, H. is working as Research Fellow in AICRP on STCR, Dept. of Soil Science & Agril. Chemistry UAS, GKVK, Bangalore - 560 065, India. Having 5 years of experience in research. He has published more than 10+ peer reviewed publication in journals and articles. He undergone special training in Geospatial techniques in agriculture and other management trainings. Has secured Best Presentation/Paper Awards, Junior and Young Scientist award in the area of Soil and plant nutrition and also got MANF Award (UGC) for doctoral research.

G. V. Gangamrutha is working as Senior Research Fellow in the scheme AICRP on STCR, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, G.K.V.K., Bengaluru, Karnataka. She has specialization in the field of soil organic carbon. She has worked under the thematic area of soil organic carbon and its fraction in Long Term Fertilizer Experimental studies in her doctoral degree. She has published about 10+ research articles in reputed National journals, extended summaries in national symposia, conferences and three research bulletins and she has six year of experience in research.