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ASSESSMENT OF SPATIAL VARIABILITY OF SOIL PROPERTIES AS INFLUENCED BY PARENT MATERIALS IN THE LOWER GANGETIC PLAINS OF INDIA

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Abstract

Properties of soils in the eastern part of India were characterized and related to landscape position and parent material texture. Level uplands, dissected side slopes and recent flood plains dominate the topography in this region. The present study was conducted in a part of semi-arid tropical Deccan plateau region, India, to assess the spatial variability of soil pH, organic carbon (OC), soil available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S). A total of 1508 composite samples (0-15 cm) were collected by adopting 325 × 325 m grid interval (one sample for 10 ha area) and they were analysed for soil fertility parameters. Coefficient of variation (CV) indicated that OC, N, P, K and S were high in heterogeneity (CV > 35%). Moreover, pH, P, K and S were non-normally distributed and log transformation produced normalised dataset. The semi variogram parameters (nugget to sill ratio, range and slope) indicated that the spatial distribution of soil properties was inconsistent. The spatial variability of parameters was mapped by ordinary kriging using exponential (pH and OC) and spherical (N, P, K and S) models selected based on root mean square error (RMSE) and r2 values. Multi-nutrient deficiencies were observed in most parts of the study area and N was acutely deficient. Farm level nutrient availability status was derived from spatial variability maps and critical nutrient deficiency zones were identified. Nutrient management recommendations based on soil test results were delivered to farmers

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for adopting need based variable rate of fertilizer application. The generated maps can serve as an effective tool for farm managers and policy makers in site specific nutrient management

Key Words: *Texture, Pedon, Deccan plateau; Spatial variability; Soil fertility*

Introduction

The Lower Gangetic Plains of the Indian sub-continent form one of the most extensive fluviordeltaic plains of the world. They conceal the Bengal Sedimentary Basin. Unsustainable intensification accompanied by imbalanced soil nutrient management is one of the major causes of declining productivity and land degradation in the region (Singh et al., 2015). Though a balanced soil nutrient management includes appropriate mix of organics, and addition of macro- as well as micro- nutrients through chemical fertilizers, very often the mined nutrients are not optimally replenished. Such distortions in the soil nutrient management are highly probable in intensively cultivated regions such as IGP (Singh et al., 2015) primarily due to high cropping intensity, low or non-availability of organics and over-dependence on chemical fertilizers leading to deficiency of several micro- nutrients. Recent Indian studies report extensive deficiency of micronutrients in farms due to regular withdrawal of these nutrients through crop uptake (Shukla et al., 2014; Shukla et al., 2015).

In general, the rate of fertilizer application is low under rainfed conditions due to uncertain water availability. The deficiencies of major nutrients are considered important but minimum research effort was made to identify the spatial extent of their deficiencies in SAT soils of India (Sahrawat et al., 2013; Sahrawat, 2016). On-farm soil fertility testing across different states in Indian SAT areas during 2001–2012 showed widespread deficiencies of sulphur (46–96%), phosphorus (21–74%) and nitrogen (11–76%) (Sahrawat et al., 2010). Therefore, diagnosis of nutrient related limitations and their management assumes a greater significance to sustain or improve the crop productivity. Assessment of spatial variability of available soil nutrients is a viable option to identify and delineate critical nutrient deficiency zones. This will enable farm managers to strategize site specific nutrient management (SSNM) based on soil and crop requirements.

Results and Discussion

Descriptive statistics and distribution of soil fertility parameters

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The descriptive statistics of the soil fertility parameters are presented in (Table 1). The variability was interpreted using the coefficient of variation (CV). The criteria proposed by Wilding (1985) was used to classify the parameters into most (CV >35%), moderate (CV 15-35%) and least (CV <15%) variable classes. Accordingly, OC, N, P, K and S were the most variable and pH was moderately variable. In general, pH and OC are considered to be stable soil parameters (Bouma and Finke, 1993). However, the moderate (pH) to high variability (OC) observed in this study could be attributed to pedogenic processes influenced by the micro-topographical variations (Vasu et al., 2016). The CV value observed in the present study is similar to the results of Fu et al. (2010), who recorded CV for P (68%) and K (60%) in a dairy farm in south-eastern Ireland but the values are higher than the observations recorded by Bogunovic et al. (2014) for P (22%) and K (34%). The normality of the distribution was interpreted from the results of Q-Q plots. Organic carbon and N were normally distributed whereas pH, P, K and S were non-normally distributed. 172 The data of pH, P, K and S were log transformed which reduced the skewness and normalised their distribution.

Properties	Min	Max	Mean	Std. Dev	CV	skewness	Skewness[1]	Normality test
pH	5.5	103	6.84	1.18	17.3	2.885	-0.003	Y=6.8438+*x[a]
OC	0.11	1.61	0.79	0.34	42.6	0.128	-	Y=0.79+0.3339*x
N	32.5	497.7	182.5	88.0	48.2	0.528	-	Y=183.1593+86.13*x
P	4.2	88.9	34.8	20.4	59.0	1.802	0.105	Y=38.4967+21.809*x[a]
K	36.9	3210.0	291.6	236.0	70.0	12.418	0.889	Y=234.88+149.0702*x[a]
S	0.17	224.0	28.5	27.6	92.7	7.191	0.498	Y=20.1206+16.703*x[a]

[a] distribution not normal., [1]after log transformation

The distribution of OC and N were lined up with the straight lines and the skewness (right for OC; left for N) was caused by few outliers. The distribution of pH followed a pattern. The high degree of variation in the slope of K and S indicates strong skewness. This was caused by the extreme soil test K values of 4 samples (1401, 1453, 1576, 3210 kg ha^{-1}178) which could be considered as outliers. Similar to the findings of the present study, Sahrawat (2016) also reported high available K values as high as 3750 kg ha-1 180 in SAT soils and this could be attributed to the presence of almost un weathered biotites in both silt and clay fractions

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which release fairly high amount of K (Pal et al., 1993; Pal et al., 2014). Similarly, test values of sulphur for 16 samples ranged from 106 mg kg-1 to 224 mg kg^{-1}183 . These extreme soil test values may not always be an outlier but a form of natural or management induced variation. However, the presence of the outliers in the dataset might change the structure of semi variograms and its properties. Outliers can cause distortion that violates geostatistical theory (Barnett and Lewis, 2017) and make variogram erratic (Armstrong and Boufassa, 2017). The nutrients K and S showed high heterogeneity in contrast to other properties. Hence, the outlier values were replaced by maximum values for K and S to avoid the negative influence of outliers on semi variograms. After removing the outlier, the CV changed from 71.0 to 58.7, and from 92.9 to 66.4 for K and S, respectively. The skewness was also reduced post outlier removal.

Ordinary kriging was used to assess the spatial variability of parameters. The best fit model was selected based on lowest RMSE value ana r^2.

Parameters	Spherical		Circular		Exponential		Gaussian	
	RMSE	r^2	RMSE	r^2	RMSE	r^2	RMSE	r^2
log pH	1.0101	0.34	1.0114	0.34	0.9930	0.45	1.0238	0.33
OC	0.3103	0.57	0.3104	0.51	0.3098	0.59	0.3106	0.46
log N	0.1556	0.41	0.1850	0.38	0.1904	0.39	0.2008	0.29
log P	0.0899	0.59	0.1004	0.47	0.1112	0.55	0.0991	0.51
log K	0.4420	0.48	0.5231	0.36	0.4960	0.35	0.5200	0.43
log S	0.2789	0.40	0.2991	0.34	0.3101	0.31	0.2980	0.33

Then the nutrient management recommendations were issued to farmers in the form of soil test report cards prepared in local language based on soil test results of soil fertility parameters. The nutrient database generated can be used for village level developmental planning and monitoring of soil fertility for sustaining the crop productivity.

Conclusion:

Given the increasing cost of input management in agriculture, precise nutrient management is the need of the hour to increase farm nutrient use efficiency *viz-á-viz* sustaining the agricultural productivity in rainfed farming systems. In the 345-present study, pH, P, K and S did not follow normal distribution and log transformation effectively shifted the data to

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normality with low skewness values. The observed outliers were collective but inconsistent to the rest of the dataset. Hence, it could be attributed to farm management practices such as fertilizer addition and intensive cultivation. Moreover, the study also revealed that while outliers are reality, dropping them from the spatial variability analysis is one of the limitations of geo statistics. Most of the soil fertility parameters (OC, N, K and S) are low in concentration except P and their deficiency is attributed to semi-arid climate, poor recycling and low level of management. The study also helped to identify and delineate critical nutrient deficiency zones. The generated maps can serve as an effective tool in site specific nutrient management. This is a prerequisite in rainfed farming systems in order to optimise the cost of cultivation as well as to address nutrient deficiency.