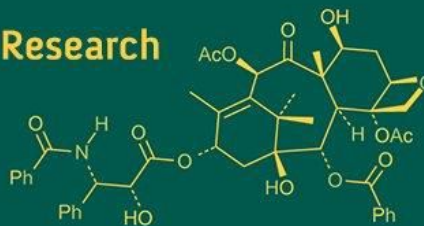


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(1): 1001-1013
www.biochemjournal.com
Received: 08-12-2023
Accepted: 05-01-2024

Yashraj
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Ayam GP
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Mapping spatial variability of soil fertility in Borsi farm of DKSCARS, Bhatapara, Chhattisgarh using GPS and GIS techniques

Yashraj and Ayam GP

DOI: <https://www.doi.org/10.33545/26174693.2024.v8.i1Sm.7353>

Abstract

Present study was conducted to evaluate the fertility status of soils in Borsi farm of Dau Kalyan Singh College of Agriculture and Research Station, Bhatapara, Chhattisgarh. A total of 70 GPS based surface soil samples (0-15 cm) were collected for this purpose with 100 meter grid interval and analysed in the laboratory adopting standard methods with respect to physico-chemical properties and available nutrients and classified their status. The soil reaction (pH) ranged from 6.13 to 7.92 with a mean value 7.33, electrical conductivity of the soil varied from 0.09 to 0.25 dS m⁻¹, with a mean value of 0.15 dS m⁻¹ and organic carbon (OC) of these soils was ranged 0.30-0.82%, with a mean of 0.56%, indicating almost neutral soil reaction with safe limit of electrical conductivity and medium status of soil organic carbon. Among the major nutrients, the available nitrogen (N) ranged 137-206 kg ha⁻¹ with mean 167.07 kg ha⁻¹ and available phosphorus content in the soil ranged 10.30-24.64 kg ha⁻¹ with a mean value of 18.26 kg ha⁻¹ while, available potassium levels varied from 196 to 486 kg ha⁻¹ with an average value of 356.04 kg ha⁻¹. Sulphur content varied between 10.08-30.80 kg ha⁻¹ with an average value 21.52 kg ha⁻¹ indication low to medium category. Most of the soils showed low nitrogen, medium phosphorus and high status of available potassium. In case of available micro-nutrients, iron, manganese, copper and zinc content in the soils varied from 7.17-24.97 mg kg⁻¹, 5.76-23.55 mg kg⁻¹, 0.92-2.73 mg kg⁻¹ and 0.39-1.93 mg kg⁻¹, respectively with mean values 16.22, 14.72, 1.61 and 1.04 mg kg⁻¹, respectively. Most of the samples showed abundance of available Fe, Mn and Cu while sufficient level of available Zn. The soils of the study area had a hot water extractable B concentration ranging 0.11- 0.52 mg kg⁻¹ with average value of 0.24 mg kg⁻¹. Most of the samples (98.50%) were found deficient with respect to available B.

Keywords: GIS, GPS, Physico-chemical properties, available nutrients, soil fertility maps

Introduction

With an ever-growing population, it is necessary to increase food production, which can only be done by making agricultural land more fertile in a sustainable manner. It necessitates the use of integrated soil fertility management techniques that will not only boost crop output but also help to prevent the depletion of vital nutrients and, as a result, result in better soil conditions. Soil exhibits a high degree of spatial variability, even in intensively managed ecosystems. Therefore, it is important to monitor the spatial distribution of soil properties for effective farm field management. The accuracy and quality of soil fertility maps are critical for site-specific soil fertility management practices. These spatial continuous data provide valuable information for making informed decisions and implementing appropriate soil fertility management strategies (Sawyer, 1994; Viscarra-Rossel and McBratney, 1998; Lin *et al.*, 2005) [15, 25, 27]. The application of chemical fertilizers has been identified as a significant factor affecting sustainability. With the increasing population and food demand, farmers are often compelled to use high doses of chemical fertilizers. By adopting soil-test based fertility management practices, farmers can optimize nutrient use efficiency, minimize nutrient losses to the environment, and improve overall soil health. This approach contributes to the long-term sustainability of agricultural production systems by promoting responsible and efficient use of fertilizers (Goovaerts, 1998) [7].

Geo-statistics, when combined with GIS, has proven to be valuable in predicting the spatial distribution of soil properties, this facilitates the estimation and visualization of soil nutrient patterns across larger areas, enabling better decision-making in resource management and

Corresponding Author:
Yashraj
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

agricultural planning (Sahu *et al.*, 2020) [26]. Soil fertility evaluation plays a crucial role in making informed decisions for effective soil fertility management. Geographic Information System (GIS)-based soil fertility mapping has emerged as a promising approach in this regard. It provides a powerful tool for assessing soil fertility at a larger scale and enables the identification of areas with varying nutrient levels. Such maps serve as effective decision support tools for nutrient management, allowing for a more rational approach compared to traditional farmer practices or blanket application of state-recommended fertilization. Additionally, utilizing GIS-based soil fertility maps can reduce the need for extensive plot-by-plot soil testing activities, leading to more efficient and targeted nutrient management strategies. Gathering soil samples by means of GPS is of great consequence for preparing thematic soil fertility maps. It is of great significance in agriculture for as it provides soil nutrient status of different locations for forthcoming supervision (Mishra *et al.*, 2014) [18]. The potential tool of GPS can be effectively used periodically to monitor soil fertility changes.

2 Materials and Methods

2.1 Study area

The selected study was conducted in Borsi farm of Dau Kalyan Singh College of Agriculture and Research Station (DKSCARS), Bhatapara district Balodabazar-Bhatapara in Chhattisgarh state (Figure 1) situated between the latitudes of 21°43'59.17" to 21°44'37.37"N and longitude of 81°59'19.34" to 81°59'47.54" E with an altitude ranging from 260-271 meters above mean sea level (MSL), falls in the Agro Climatic Zone of Chhattisgarh plain has a typically humid and warm climate. Rainfall occurs due to south west monsoon and is mostly concentrated in the months of June to September. The hottest and coolest months are May and December, respectively. The maximum temperature in summer was found as high as 42.6 °C and the minimum temperature in winter was found as low as 10 °C. In the region, dominantly brown to slightly black colour soils, locally called Dorsa soils which fall under the category of Alfisols.

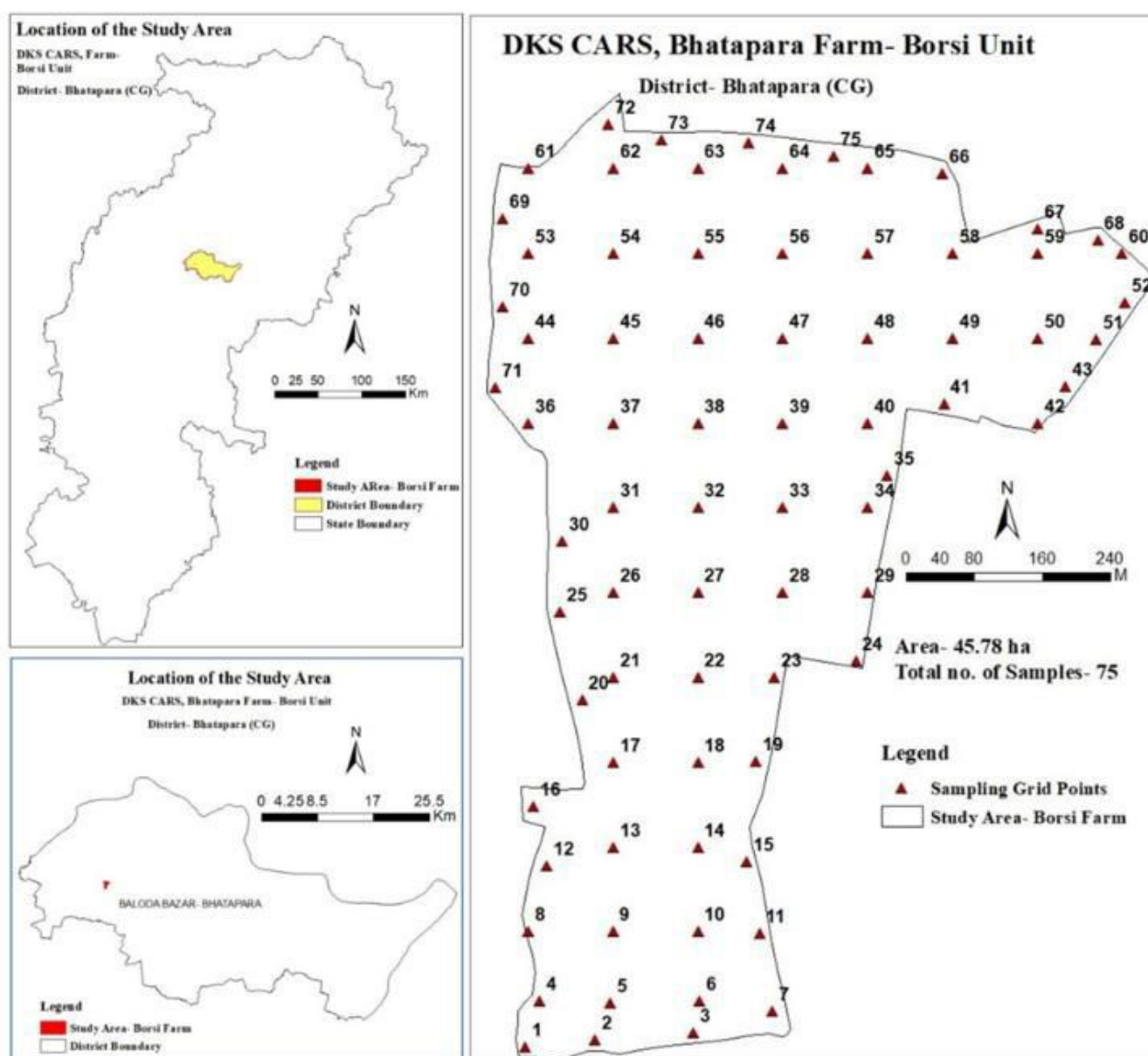


Fig 1: Location of the study area (Borsi farm, DKSCARS, Bhatapara)

2.2 Grid Sampling and laboratory analysis

A total of 70 surface soil samples were collected at grid intervals of 100 meters (Figure 1) with the help of auger at 15 cm depth from the soil surface of the study area. Collected Soil samples were dried with air in a shady place. After drying of soil samples were crushed with a hammer and passed through a 2 mm sieve and kept for analysis in plastic bags with the appropriate labels. Laboratory analysis has been done by adopting the standard methods and procedures. Soil pH was determined by glass electrode pH meter (Piper, 1966) [22], electrical conductivity with solubridge process (Black, 1965) [3], organic carbon by wet digestion method (Walkley and Black, 1934) [32], available nitrogen was estimated by Alkaline potassium permanganate method (Subbiah and Asija, 1965) [30], available phosphorus extracted by Olsens modified method 0.5M NaHCO₃ solution buffer at pH 8.5 (Olsen *et al.*, 1954) [19]. Available potassium was estimated with neutral 1N NH₄OAc using Flame photometer (Jackson, 1967) [10] and available sulphur by CaCl₂ extractable method (Williams and Steinbergs, 1959) [33]. The micronutrients (Fe, Mn, Zn and Cu) were extracted with DTPA extractable method (Lindsay and Norvell, 1978) and analyzed the concentrations with the help of atomic absorption spectrophotometer. Available B was estimated by hot water method as proposed by Berger and Troug (1939) [4]. Based on standard rating values, the analytical results of the soil sample were categorized as low, medium, and high categories for organic carbon and available macro and micronutrients.

2.3 Nutrient indexing and fertility rating

Ramamoorthy and Bajaj (1969) [23] proposed the concept of nutrient index values (NIV) to assess the fertility status of soils based on the usable nutrient content. The NIV is determined by considering the quantity or proportion of soil samples exhibiting low, medium, or high levels of usable nutrients. This approach allows for the classification of soils into different fertility groups using the formula $NIV = \{1 \times PL + 2 \times PM + 3 \times PH\} / \text{Total No. of samples}$. Where, NIV= nutrient index value, PL= percent samples falls under low category, PM= percent samples falls under medium category and PH= percent samples falls under high category. To categorize the actual soil test results into the three fertility grades, the following limits based on the nutrient index values (NIV) were used in this assessment, NIV of less than 1.65, 1.65-2.33 and above 2.33 indicates low, medium and high fertility level, respectively for the given nutrient element.

2.4 Soil fertility mapping: Database on surface soil physico-chemical properties and available nutrients were generated in Microsoft Excel, based on test results. Using these database and GPS location of sample sites, soil fertility maps were prepared by using Arc-GIS 10.4.1 software. Kriging is a geo-statistical interpolation method which deals with both the distance and the degree of variation between known data points when estimating value is unknown area. A kriged estimate is a weighted linear combination of known samples values around the point to be estimated. Soil fertility mapping of the study area was conducted on larger than 1:10000 scale. Among two methods for Kriging viz. Ordinary and Universal, Ordinary Kriging was used. Among various Semivariogram Models, Spherical, Circular, Exponential and Gaussian models were used in this study. Map was extracted by using Extraction tool which comes under Spatial Analyst tool in Arc-GIS software.

3 Results and Discussions

3.1 Soil reaction (pH): Soil reaction (pH) directly affects nutrient availability to crop plants. The pH values ranged from 6.13 to 7.92, with an average of 7.33 ± 0.39 and nutrient index value (NIV) 2.33, indicating overall neutral soil reaction by majority of soil samples (61.43%) as shown in table 1 and spatial distribution presented in figure 2A. Similar findings also reported by Meher *et al.* (2020) [17] and Srivastava *et al.* (2016) [29] in Chhattisgarh plains. These consistent findings suggest a common pattern of soil pH in the respective study areas.

3.2 Electronic conductivity (EC): The electrical conductivity in the study area ranged from 0.09 to 0.25 dS m⁻¹, with a mean value of 0.15 ± 0.03 dS m⁻¹ (Table 1). These values indicated extremely non-saline suggesting that the soils having no adverse effect for the cultivation of any crop in the study area as all of the samples (100%) showed negligible values (Figure 2B). The results are in close agreements with the finding reported by Meher *et al.* (2020) [17] in Chhattisgarh plains and Khairwar *et al.* (2022) [12] in Bastar plateau.

3.3 Soil organic carbon content (OC): Soil organic carbon (OC) content in the Borsi farm ranged from 0.30% to 0.82%, with an average value of $0.56 \pm 0.09\%$. table 1 represents about 75.71% samples had medium status with NIV value 1.81 as spatial distribution depicted in figure 2C helps to illustrate the variation of OC content across the study area. Similar findings were also reported by Triveni *et al.* (2022) and Khairwar *et al.* (2022) [12, 31].

Table 1: Status, distribution and fertility rating for various soil properties

Soil Properties	Class	range	No. of samples	% samples	NIV	Rating
Physico-chemical properties						
Soil Reaction (pH)	Slightly acidic	6.1 - 6.4	2	2.9	2.33	Neutral
	Neutral	6.5 - 7.5	43	61.4		
	Slightly alkaline	7.6 - 7.9	25	35.7	1.0	
Ec (dSm/m)	Good	< 1	70	100.0		Safe
OC (%)	Low	<0.5	15	21.4	1.81	Medium
	Medium	0.5-0.75	53	75.7		
	High	>0.75%	2	2.9		
A. Macro-nutrients						
N (kg/ha)	Low	<280	70	100.0	1.00	Low
P (kg/ha)	Low	<12.5	1	1.4	1.99	Medium
	Medium	12.5-25	69	98.6		

K (kg/ha)	Medium	135-335	27	38.6	2.61	High
	High	>335	43	61.4		
S (kg/ha)	Low	<22.5	40	57.1	1.43	Low
	Medium	22.5-35	30	42.9		
B. Micro-nutrients						
Fe (mg/kg)	Sufficient	4.5-9.0	2	2.9	2.97	High
	High	>9.0	68	97.1		
Mn (mg/kg)	Sufficient	3.5-7.0	3	4.3	2.96	High
	High	>7.0	67	95.7		
Cu (mg/kg)	High	>0.4	70	100.0	3.00	High
Zn (mg/kg)	Deficient	<0.6	1	1.4	2.26	Medium
	Sufficient	0.6-1.2	50	71.4		
	High	> 1.2	19	27.1		
B (mg/kg)	Deficient	<0.5	69	98.5	1.01	Low
	Sufficient	0.5-1.0	1	1.5		

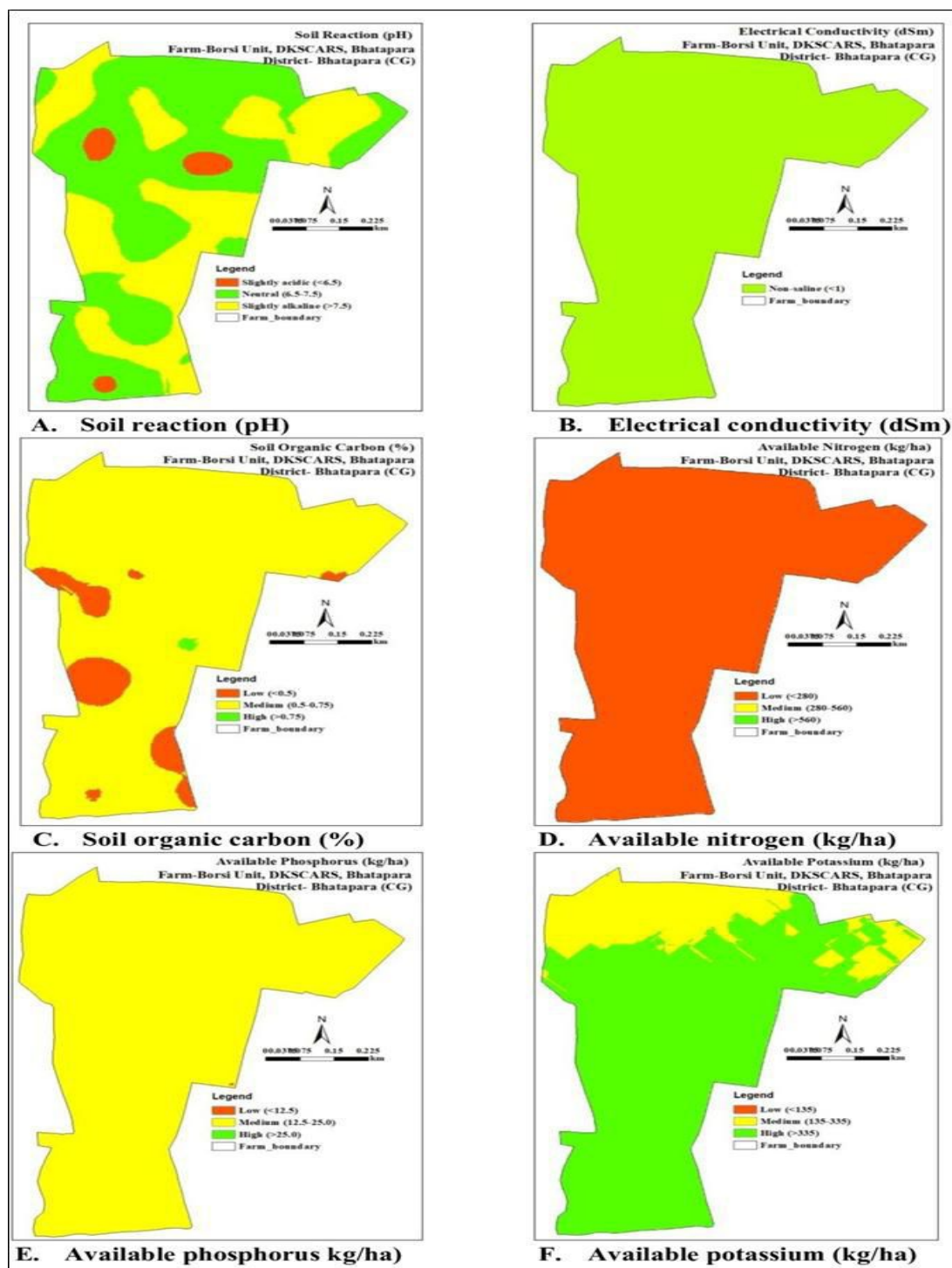


Fig 2: Spatial distribution of physico-chemical properties and major nutrients

3.4 Available nitrogen (N) in soil

The results obtained from the analysis of soil samples in the study area indicated that the available nitrogen (N) content in the soils ranged from 137-206 kg ha⁻¹ with a mean value of 167.07±16.02 kg ha⁻¹ area are shown in table 1. This reflects the level of nitrogen that is readily accessible to plants for their growth and development. Further analysis revealed that all the samples, accounting for 100% of the total, fell within the low category of available nitrogen content as spatial distribution depicted in figure 2D with NIV value 1.0. This indicates that the nitrogen is the most limiting nutrient in soils of the Borsi farm. Identical finding also reported by Iyer and Ayam (2019) ^[8] and Khairwar *et al.* (2022) ^[12] in Bastar district and Banwasi *et al.* (2019) ^[2] in Bemetara district of Chhattisgarh.

3.5 Available phosphorus (P) in soil

In the current study, the available phosphorus content in the soil samples ranged from 10.30 - 24.64 kg ha⁻¹ with a mean 18.26±2.62 kg ha⁻¹ as presented in table 1. The data revealed that about 98.57% of the samples were classified in the medium range with NIV value 1.99 as spatial distribution depicted in figure 2E. This suggests that the majority of the study area has satisfactory levels of phosphorus for plant growth and development. Similar findings were observed by Patel *et al.* (2018) ^[20] and Patil *et al.* (2016) ^[21] in Raigarh district of Chhattisgarh.

3.6 Available potassium (K) in soil

The available K content in the soil samples from the Borsi farm ranged from 196 to 486 kg ha⁻¹ with an average value of 356.04±80.26 kg ha⁻¹, indicating a medium to high level of availability as shown in table 1. The spatial variability of the samples revealed about 38.57% of the samples fell under the medium category, while 61.42% of the samples fell under the high category as depicted in figure 2F. Overall, the study area has adequate levels of available potassium with a NIV value 2.61. This might be attributed to the dominance of potash-rich minerals. These results matched

with findings of Singh *et al.*, (2018) ^[28] and Shrivastava *et al.* (2016) in Chhattisgarh plains and Khairwar *et al.* (2022) ^[12] in Bastar plateau of Chhattisgarh.

3.7 Available sulphur (S) in soil

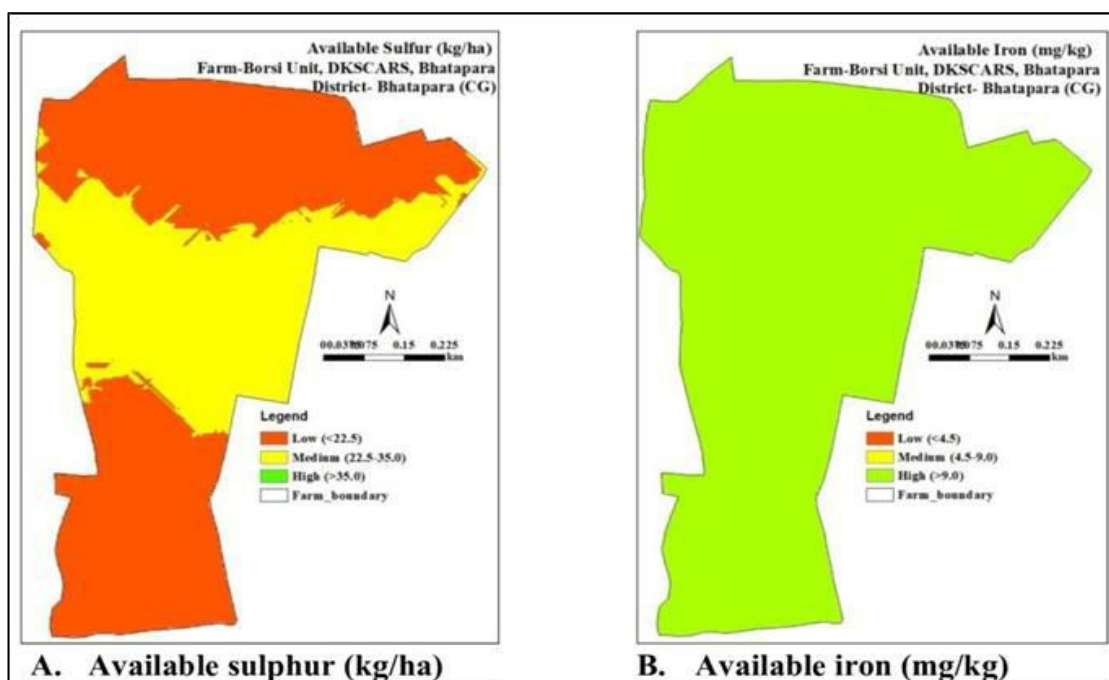
The concentration of available sulphur in the study area ranged from 10.08 to 30.80 kg ha⁻¹ with an average value of 21.52±6.40 kg ha⁻¹ (Table 1). Spatial distribution as depicted in figure 3A represents about 57.14% of the samples fell under the low category while, about 42.86% of the samples were classified under the medium category. Overall, available sulphur content in the soils of the Borsi farm was determined under low fertility category with NIV value 1.43. These findings were in line with Iyer and Ayam (2020) ^[9] in Bastar district and Mehar *et al.* (2020) in the soils Durg district of Chhattisgarh state.

3.8 Available iron (Fe) in soil

The Fe status of the Borsi farm ranged 7.17 - 24.97 mg kg⁻¹ with a mean value of 16.22±1.65 mg kg⁻¹ as summerized in table 1. The spatial variability depicted in figure 3B showed 97.14% of the samples were classified as high in terms of Fe status with INV value 2.97. These results suggest that the majority of the soil samples in the study area have abundance of available iron. Identical results also reported by Devdas and Shrivastava (2021) ^[6] in Gariaband district of Chhattisgarh.

3.9 Available manganese (Mn) in soil

The available Mn content in the soil of the Borsi farm ranged from 5.76 to 23.55 mg kg⁻¹, with a mean value of 14.73±4.41 mg kg⁻¹, as presented in table 1. About 95.71% samples of the study area fell into the high category with NIV value 2.96 as spatial distribution depicted in figure 3C. This indicates the abundance of available manganese in the Borsi farm. The results are in close agreement with the findings reported by Kumar *et al.* (2021) ^[13] and Balkrishna (2017) ^[1] in the soils of Palari, Baloda Bazar district of Chhattisgarh.



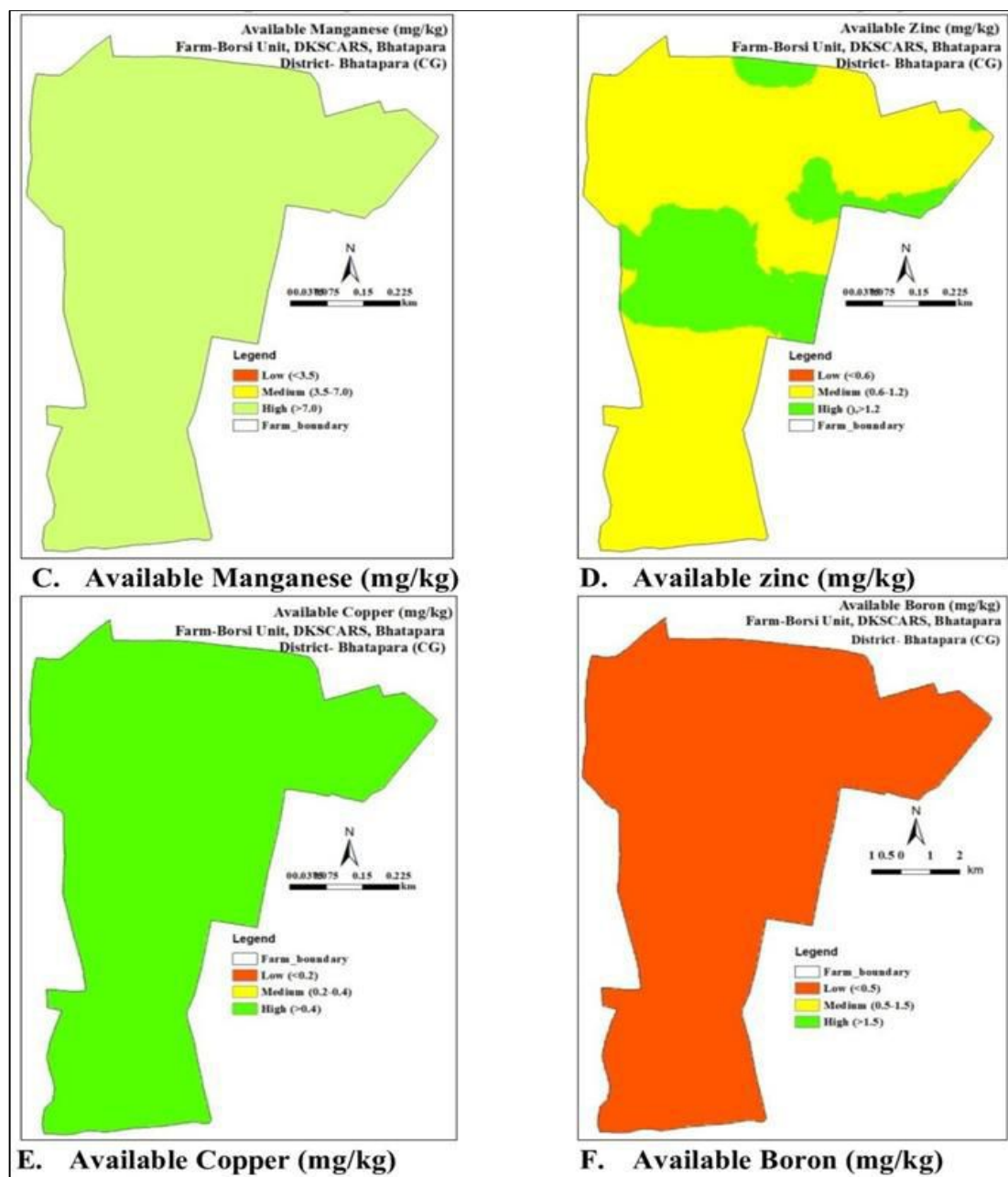


Fig 3: Spatial distributions of secondary and micro nutrients

3.10 Available zinc (Zn) in soil

The results of available zinc (Zn) status in the Borsi farm is presented in table 1 indicated a range of 0.39 to 1.93 mg kg⁻¹ with an average value of 1.04±0.33 mg kg⁻¹. The spatial distribution depicted in figure 3D showed the majority (71.43%, samples) were classified as medium category with the NIV value 2.26, indicating satisfactory levels of available Zn in the Borsi farm. The results are supported by the findings of Meher *et al.* (2020)^[17].

3.11 Available copper (Cu) in Soil

The results of soil accessible Cu concentration in the Borsi farm are shown in table 1 and it ranged from 0.92 to 2.73 mg kg⁻¹ with an average of 1.61±0.37 mg kg⁻¹. All samples analyzed in the study (100%) fell under the high category of available Cu with NIV value 3.0 as spatial distribution depicted in figure 3E. Similar result also reported by Jatav *et al.* (2010)^[11] in Baloda, Janjgir-Chapa district of Chhattisgarh.

3.12 Available boron (B) in soil

The available B status in the Borsi farm is presented in table 1. The concentration of available B in the soil varied from 0.11 to 0.52 mg kg⁻¹ with a mean value of 0.24±0.09 mg kg⁻¹. Based on the standard rating values for B status, it was observed that 98.50% of the samples fell under the low category with the NIV value 1.01 as spatial distribution depicted in figure 3F indicating a deficiency of boron in the Borsi farm. The findings are in agreement with findings reported by those of Mishra *et al.*, (2014) and Rawal *et al.*, (2018)^[18, 24].

Overall, based on the intensive study conducted on Borsi farm, DKSCARS, Bhatapara in Balodabazar-Bhatapara district of Chhattisgarh, the soil was predominantly neutral to slightly alkaline in reaction with extremely non-saline electrical conductivity and medium to slightly low status of soil organic carbon. Soils were deficient in available N, B and low S and the soils were medium in available P and Zn, while, sufficient to high status of available K and micro-nutrientsspecially Fe, Mn and Cu in the soils of Borsi farm.

3.13 Correlation between nutrients and physico-chemical properties of soil: Correlation studies were performed statistically and correlation between physico-chemical properties and available nutrients are summarized in table 2. The pH of the soils of Borsi farm showed significant positive correlation with EC and available nitrogen with 'r' values of 0.25 and 0.33, respectively and significant negative correlation with available Fe and Cu with 'r' values of -0.45, and -0.30, respectively. The EC showed significant negative correlation with available Mn ($r=-0.33$). Organic carbon showed positive and highly significant correlation

with available N ($r=0.86$) Similar result also reported by Kushwaha *et al.*, (2017)^[14] and Iyer *et al.* (2019)^[8]. Among the available nutrients K showed significant positive correlation with Fe ($r=0.25$) and negative with B ($r=0.34$), S correlated positively with Mn ($r=0.29$) and Cu ($r=0.30$), B negatively correlated with Cu ($r=0.29$), Fe showed positive correlation with Mn ($r=0.57$) and Cu ($r=0.70$), Mn positively correlated with Zn ($r=0.37$) and Cu ($r=0.78$), similarly Zn positively correlated with Cu ($r=0.33$).

Table 2: Correlation of various chemical properties of soil

Parameter	pH	EC	OC	N	P	K	S	B	Fe	Mn	Zn	Cu
pH												
EC	0.25*											
OC	0.22	0.06										
N	0.33**	0.07	0.86**									
P	0.15	0.21	0.03	-0.01								
K	0.18	0.12	-0.05	0.06	-0.06							
S	0.02	0.10	0.08	0.05	0.13	0.16						
B	0.10	-0.05	-0.04	0.01	0.05	-0.34**	-0.44**					
Fe	-0.45**	-0.20	0.12	0.12	0.05	0.25*	0.14	-0.24				
Mn	-0.20	-0.33**	0.11	0.06	0.02	-0.13	0.29*	-0.19	0.57*			
Zn	-0.02	-0.18	0.13	0.07	-0.21	-0.06	0.23	-0.07	0.15	0.37*		
Cu	-0.30*	-0.21	0.14	0.12	-0.02	0.09	0.30*	-0.29*	0.70**	0.78**	0.33**	

3.14 Semi-variogram for physico-chemical properties of soil: In order to identify the possible spatial structure of different soil properties and to examine the local characteristics of spatial autocorrelation within the dataset and local outliers, semi-variogram (Fig. 4) and cross validation and QQ plots (Fig. 5 to 7) were calculated and the best models that describe these spatial structures were identified (Table 3). The performance of four models (Circular, Spherical, Exponential and Gaussian) has been compared. According to the cross-validation parameters, among different theoretical models tested, the gaussian model was found to best fit for pH, EC, OC, available Fe and B. The exponential model was found to be best fit for available K, S, Zn and Cu. The spherical model was found to be best fit for available P and Mn, whereas circular model found to be best fit for available N because it had the highest precision and lowest error for estimation (RMSSE) of these nutrients (Zhu *et al.*, 2016)^[34].

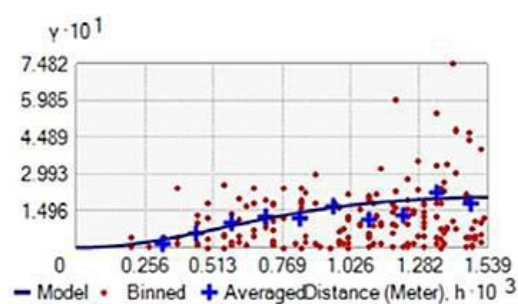
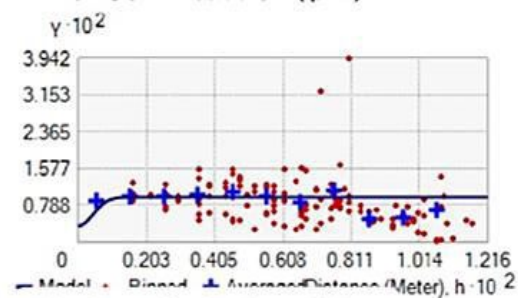
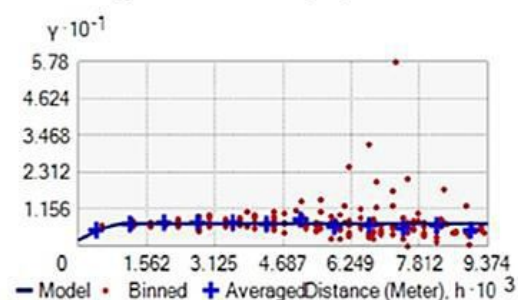
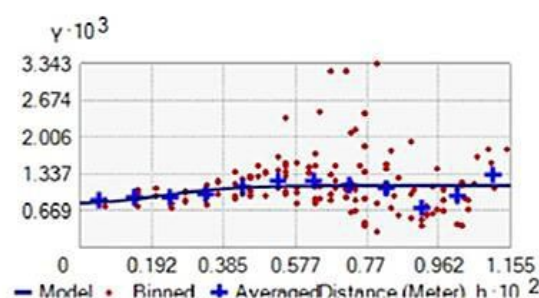
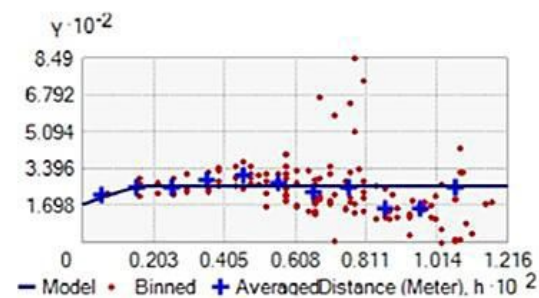
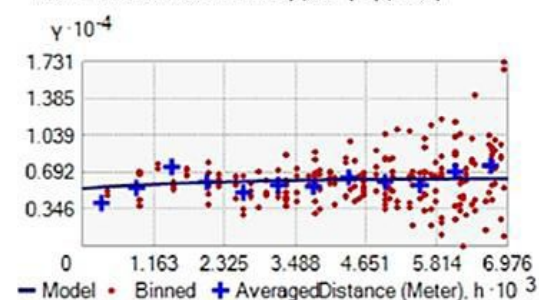
Semivariogram parameters (range, nugget and partial sill) for each soil parameters with the best fitted model are presented in table 4. The range, expressed an average maximum distance over which a soil property of two samples were related. At distances less than the range measured properties of two samples became similar with decreasing distance between the two points. Thus, the range provided an estimate of areas of similarity. Nugget (Co) defines the micro-scale variability and measurement error for the respective soil property, whereas partial sill (C) indicates the amount of variation, which can be defined by spatial correlation structure (Zhu *et al.*, 2016)^[34]. According to the classification of Cambardella *et al.* (1994)^[5] nugget to sill ratio (spatial dependency) is moderate for majority of the soil parameters like EC, available N, K, S and Fe. Strong spatial dependency was reported for available pH, OC, P, Zn and B whereas weak spatial dependency for available Mn.

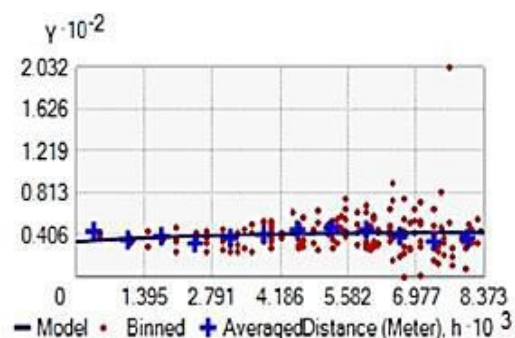
Table 3: Parameters for different theoretical semivariogram models used to fit the experimental semivariogram of soil properties

Soil properties	Semivariogram model	Mean	Root-Mean-Square	Mean Standardized	Root-Mean-Square Standardized	Average Standard Error
pH	Gaussian	-0.0101	0.3978	-0.0199	1.1364	0.3471
EC (dSm)	Gaussian	0.0002	0.0306	0.0053	1.0157	0.0302
OC (%)	Gaussian	-0.0021	0.1097	-0.0213	1.1162	0.0972
Avail. N (kg/ha)	Circular	0.0405	16.5925	0.0011	1.0464	15.8028
Avail. P ₂ O ₅ (kg/ha)	Spherical	-0.0486	2.8028	-0.0119	1.0405	2.6746
Avail. K ₂ O (kg/ha)	Exponential	1.1509	79.2945	0.0145	1.0112	78.5222
Avail. S (kg/ha)	Exponential	-0.0064	6.5271	-0.0009	1.0364	6.2870
Avail Fe (mg/kg)	Gaussian	-0.0327	3.7455	-0.0092	0.9866	3.8067
Avail Mn (mg/kg)	Spherical	0.0514	2.4333	0.0187	0.9433	2.5812
Avail Zn (mg/kg)	Exponential	-0.0023	0.3114	-0.0082	1.0006	0.3107
Avail Cu (mg/kg)	Exponential	0.0034	0.2932	0.0080	0.9689	0.3045
Avail B (mg/kg)	Gaussian	-0.0053	0.1089	-0.0307	1.1455	0.0910

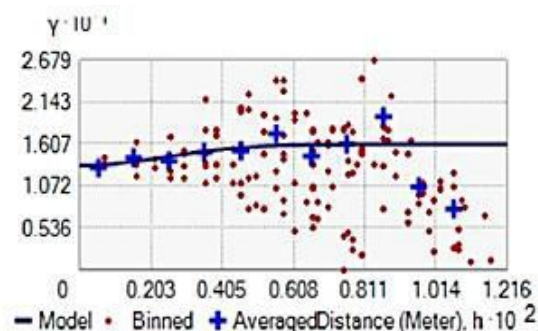
Table 4: Semivariogram parameters (kriging interpolation) of soil properties

Soil properties	Semivariogram model	Range (m)	Nugget (Co)	Partial Sill (C)	Sill (Co+C)	NS Ratio	Spatial dependence
pH	Gaussian	0.001	0.000	0.209	0.210	0.001	Strong
EC (dSm)	Gaussian	0.005	0.0008	0.0003	0.0011	0.723	Moderate
OC (%)	Gaussian	0.001	0.004	0.006	0.010	0.366	Strong
Avail. N (kg/ha)	Circular	0.002	174.52	85.453	259.97	0.671	Moderate
Avail. P2O5 (kg/ha)	Spherical	0.001	1.830	5.173	7.003	0.261	Strong
Avail. K2O (kg/ha)	Exponential	0.007	5392.7	978.6	6371.31	0.846	Moderate
Avail. S (kg/ha)	Exponential	0.008	33.9	9.5	43.340	0.781	Moderate
Avail Fe (mg/kg)	Gaussian	0.006	13.294	2.685	15.979	0.832	Moderate
Avail Mn (mg/kg)	Spherical	0.001	5.648	0.268	5.916	0.955	weak
Avail Zn (mg/kg)	Exponential	0.001	0.032	0.064	0.096	0.333	Strong
Avail Cu (mg/kg)	Exponential	0.004	0.061	0.044	0.106	0.581	Moderate
Avail B (mg/kg)	Gaussian	0.001	0.001	0.009	0.010	0.091	Strong

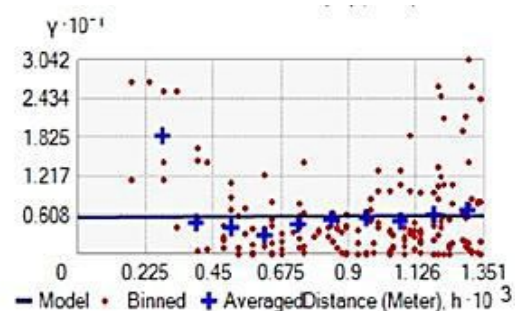
**A. Soil Reaction (pH)****C. Organic Carbon (%)****E. Available Phosphorus (kg/ha)****B. Electrical Conductivity (dSm⁻²)****D. Available Nitrogen (kg/ha)****F. Available Potassium (kg/ha)**



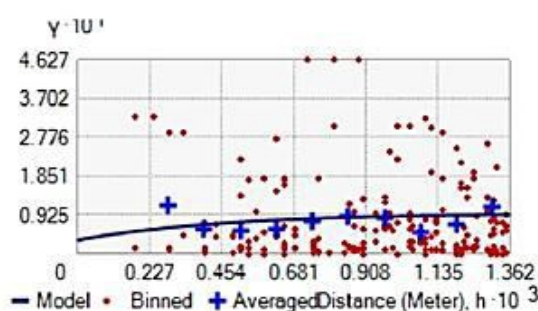
G. Available Sulfur (kg/ha)



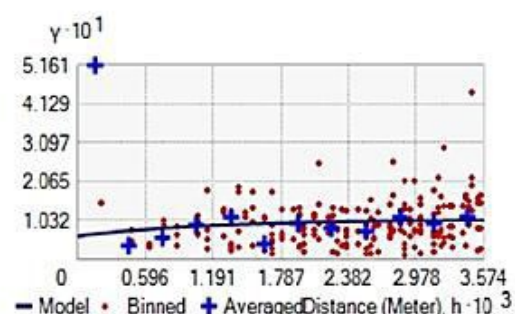
H. Available Iron (ppm)



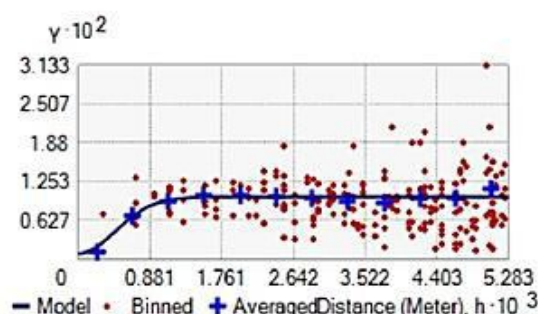
I. Available Manganese (ppm)



J. Available Zinc (ppm)

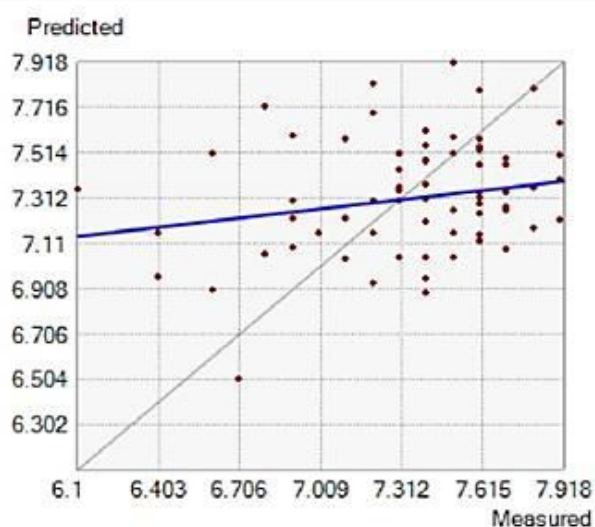


K. Available Copper (ppm)



L. Available Boron (ppm)

Fig 4: Semivariogram for various surface soil parameters



A: Cross Validation and QQ plot for Soil Reaction (pH)

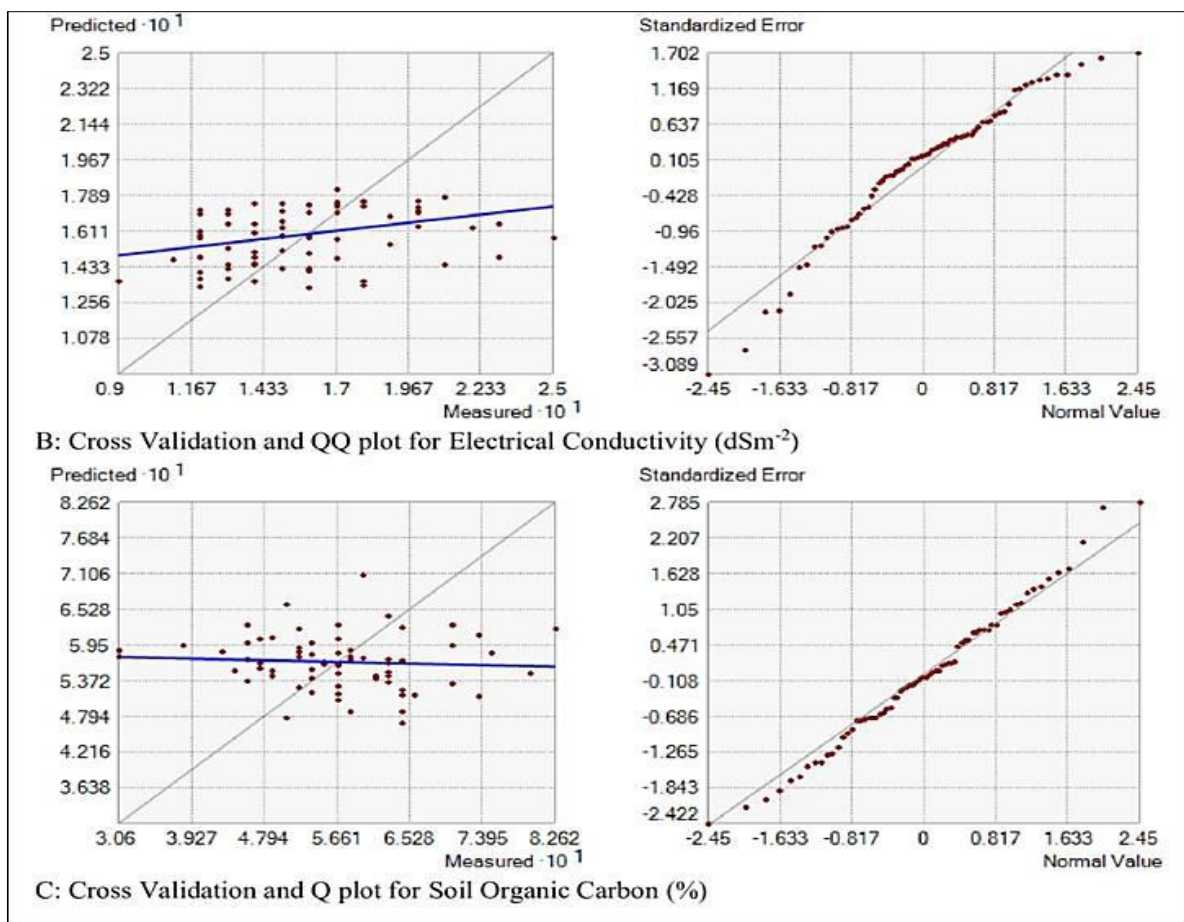
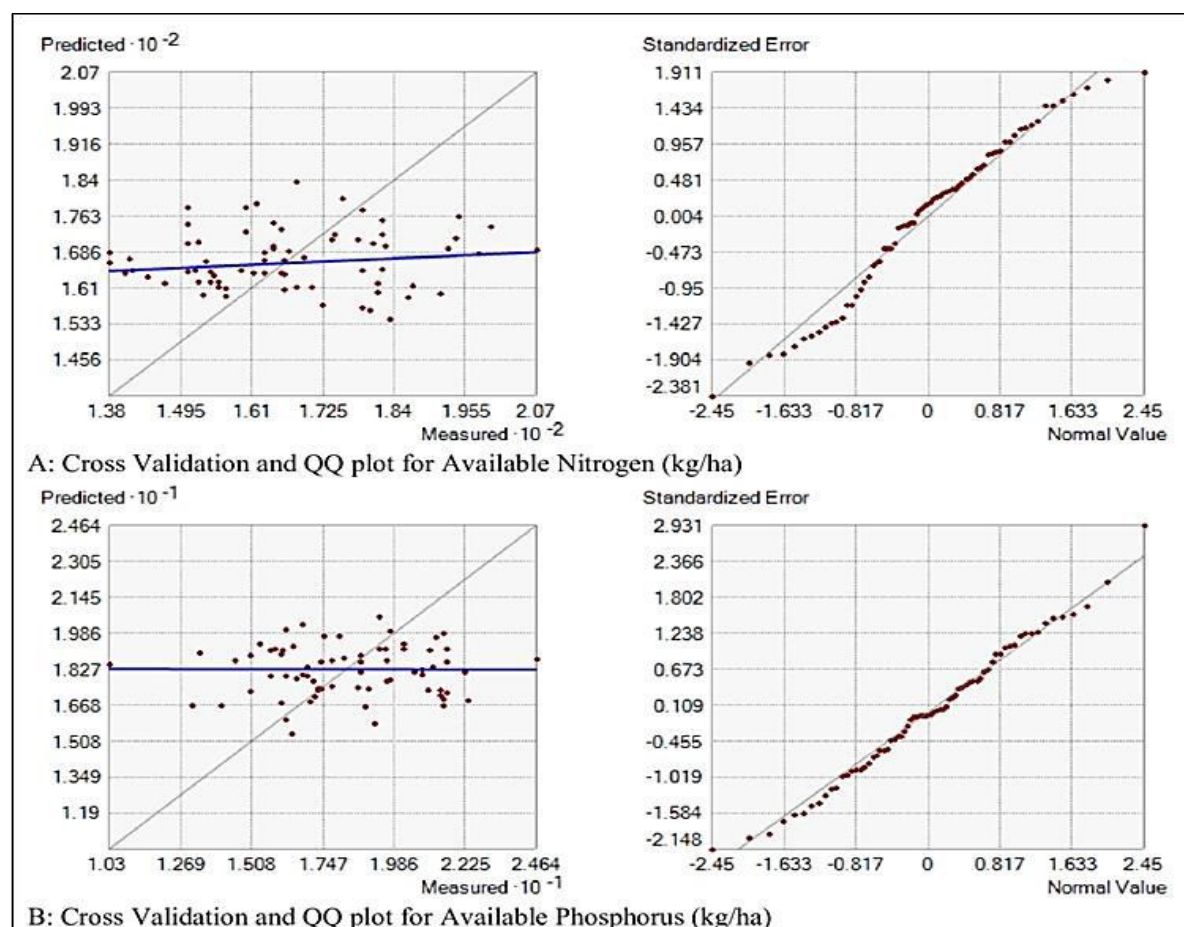


Fig 5: Cross validation and QQ plots for physico-chemical properties of soil



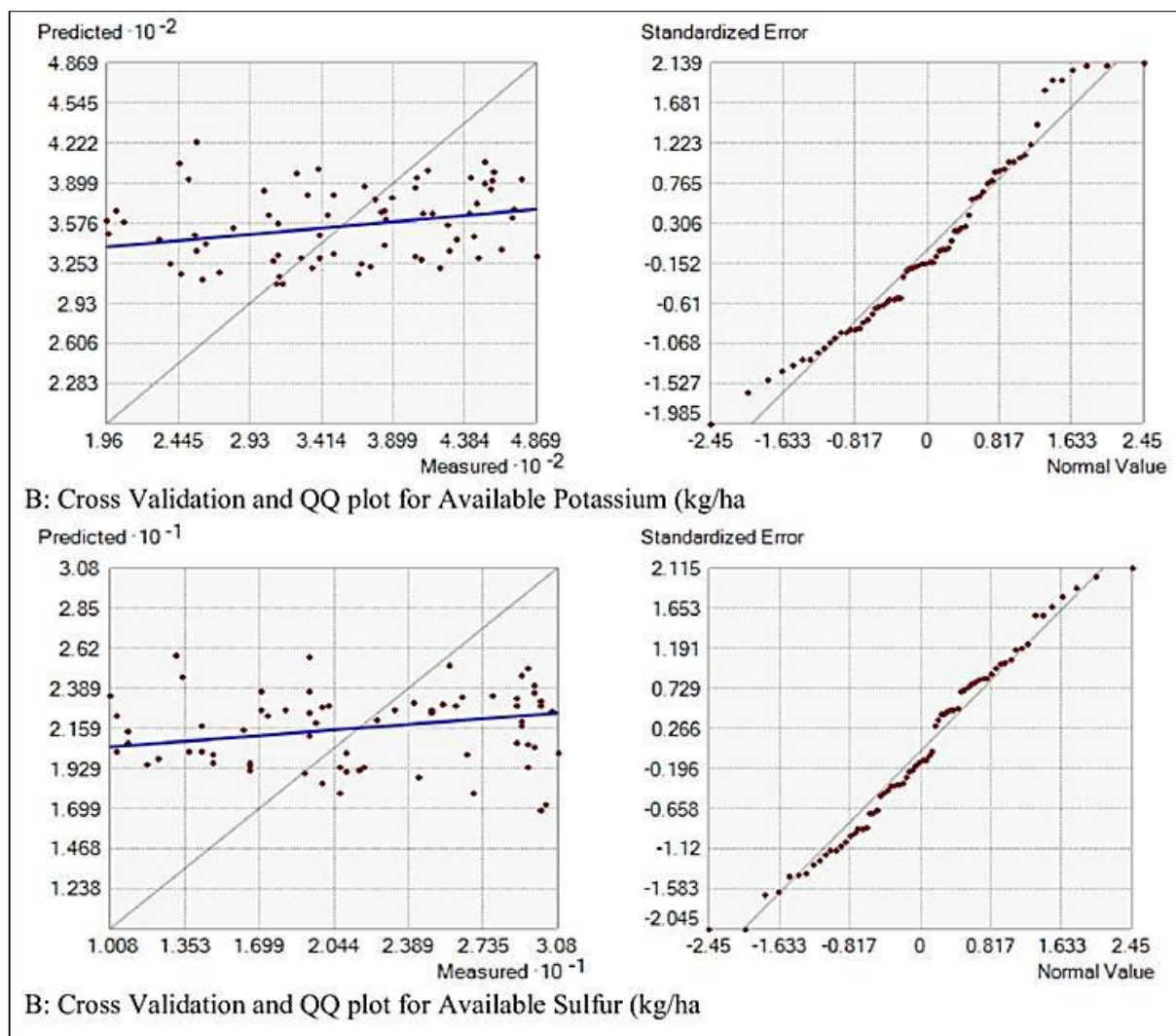
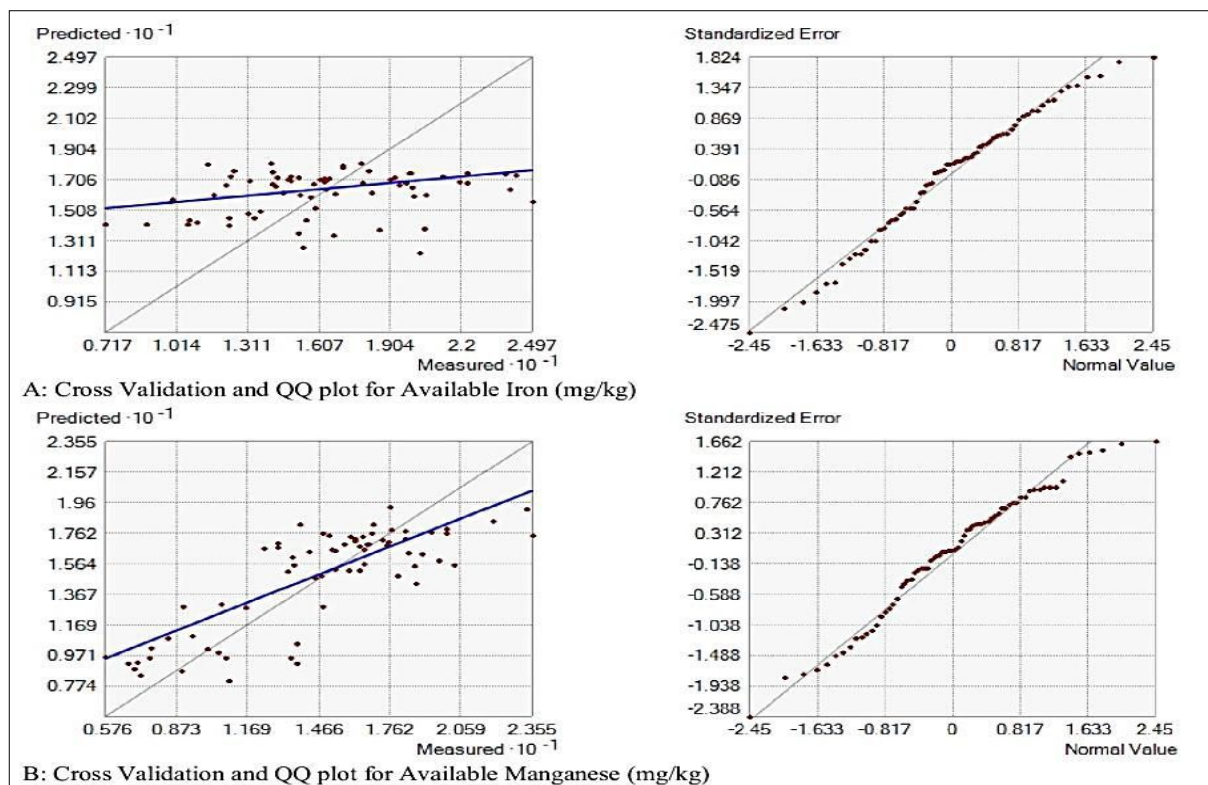


Fig 6: Cross validation and QQ plots for available major nutrients in soil



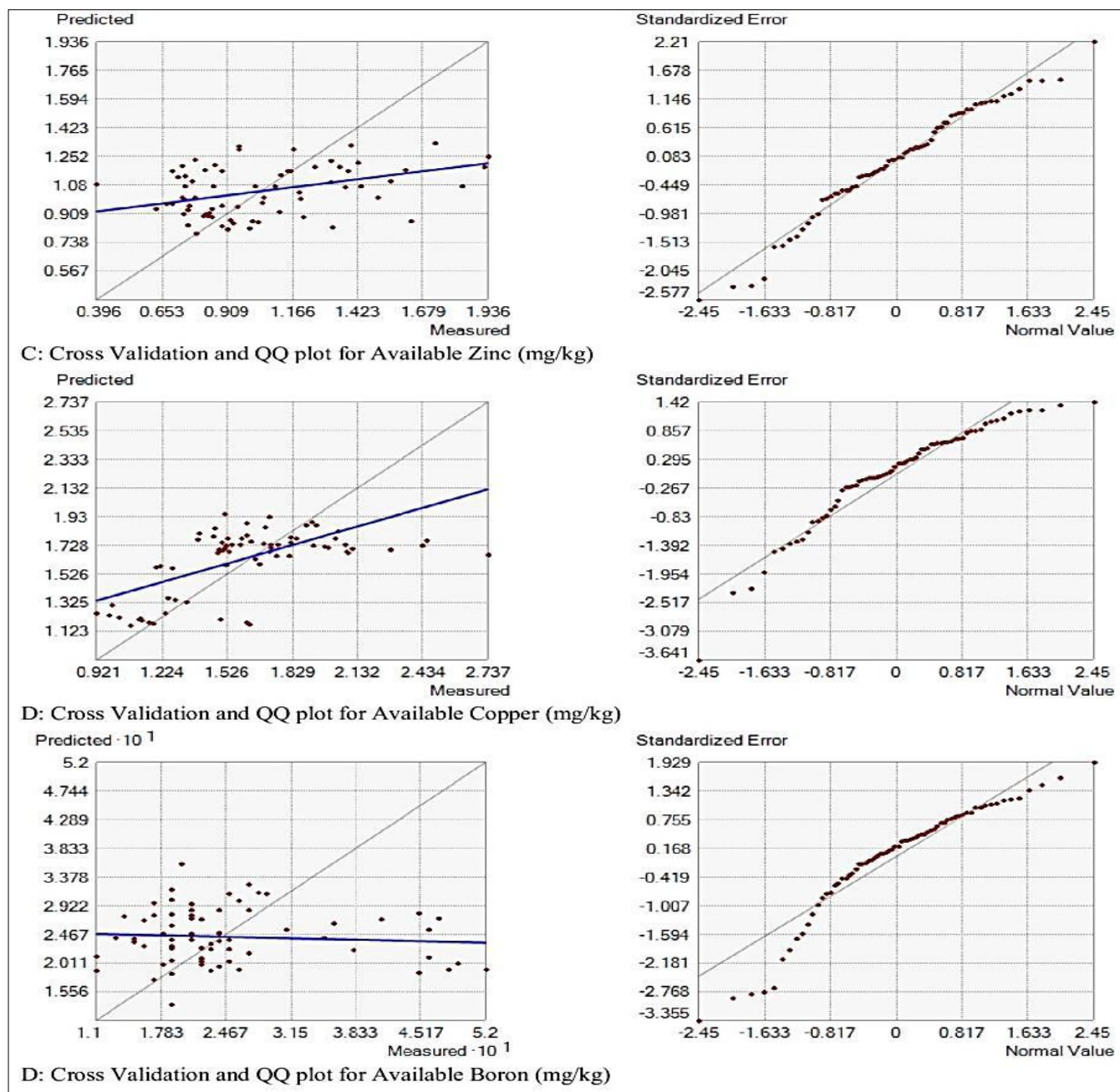


Fig 7: Cross validation and QQ plots for available micro nutrients in soil

3.15 Soil fertility maps

The thematic maps depicting the soil fertility status of borsi farm, DKSCARS, Bhatapara have been generated using point data through kriging. The maps pertaining to all the 12 chemical parameters are depicted in figures 2A-2F to 3A-3F. With regard to soil pH, majority of the area about 61.43% was found to be neutral in reaction. In the case of EC, 100% of the area is under non-saline soil conditions. The overall organic carbon status was medium accounting for 75.71% of the study area. Similarly in case of available N, 100% area of research farm was under low category. Available P, the status was predominantly under medium representing 98.57% of the study area. Available K was predominantly under high level accounting 61.42% area. In case of available sulfur, 57.14% area showed low status. As far as available micronutrients are concerned, Fe status was found to be high in 97.14%, Mn, was high in 95.71%, Cu was found to be under high category in 100% of the study area while, Zn, predominantly under medium category

accounting for 71.43% of the area. Available B was recorded predominantly deficient category in 98.50% area.

4 Conclusion

The soils of the Borsi farm, DKSCARS, Bhatapara in Balodabazar-Bhatapara district of Chhattisgarh state were found to be predominantly neutral in reaction, non-saline and suitable for cultivation of almost all the crops without any major problems. However, available N and B were found to be the most limiting nutrients while, other fertility parameters had medium or no adverse effect on crop production. The results of this study need to be validated with the future research works.

References

1. Balkrishna. Evaluation of soil fertility status in soils of Palari block under Balodabazar district of Chhattisgarh. M.Sc. (Ag.) thesis. Raipur (CG): Indira Gandhi Krishi Vishwavidyalaya; 2017. p. 39-80.

2. Banwasi R, Singh SK, Kumar N, Sahu KK. Assessing the accuracy of geostatistical techniques for mapping soil macronutrients on basaltic landscape of central India. *Int J Chem Stud.* 2020;8(1):1014-1019.
3. Black CA. Methods of soil analysis. Madison (WI): American Society of Agronomy; 1965. p. 131-137.
4. Berger KC, Truog E. Boron determination in soils and plants. *Ind Eng Chem Anal Ed.* 1939;11:540-545.
5. Cambardella CA, Moorman TB, Novak JM, Parkin TB, Karlen DL, Turco RF. Field-scale variability of soil properties in central Iowa soils. *Soil Sci Soc Am J.* 1994;58:1501-1511.
6. Devdas D, Srivastava LK. Soil fertility mapping by geographical information system (GIS) in different blocks of Gariaband district, Chhattisgarh. *J Pharmacogn Phytochem.* 2021;10(2):328-338.
7. Goovaerts P. Geostatistical tools for characterizing the spatial variability of microbiological and physicochemical soil properties. *Biol Fertil Soils.* 1998;27:315-344.
8. Iyer SS, Ayam GP, Thakur DS, Singh KP. Soil fertility status of organic carbon and available nitrogen through soil fertility mapping using GPS and GIS techniques of Dharmaur micro-watershed, Jagdalpur block, Bastar district, Chhattisgarh. *Int J Chem Stud.* 2019;7(4):2139-2142.
9. Iyer SS, Ayam GP. Soil fertility status of available sulphur through soil fertility mapping using GPS and GIS techniques of Dharmaur micro-watershed, Jagdalpur block, Bastar district, Chhattisgarh. *Int J Chem Stud.* 2020;8(3):862-865.
10. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1967. p. 183-192.
11. Jatav GK, Mishra VN. Evaluation of soil fertility status in Inceptisol of Baloda block in Janjgir district of Chhattisgarh. M.Sc. (Ag.) thesis. Raipur (CG): Indira Gandhi Krishi Vishwavidyalaya; 2010. p. 67-78.
12. Khairwar R, Ayam GP, Reddy GPO, Obi GP, Kumar N, Chandrakar T, *et al.* Modeling spatial variability of major soil nutrient status in rice-fallow system of Madpal watershed in Bastar district of Eastern Ghat region using geospatial techniques. *Pharma Innov J.* 2022;11(12):6442-6453.
13. Kumar M, Kar A, Raina P, Singh SK, Moharana PC, Chauhan JS. Assessment and mapping of available soil nutrients using GIS for nutrient management in hot arid regions of north-western India. *J Indian Soc Soil Sci.* 2021;69(2):119-132.
14. Kushwaha S, Sawarkar SD, Thakur R, Khamparia NK, Singh M. Impact of long-term nutrient management on soil nitrogen dynamics under soybean-wheat cropping sequence on a Vertisol. *J Indian Soc Soil Sci.* 2017;65(3):274-282.
15. Lin C, Lu W, Wu Y. Agricultural soils irrigated with acidic mine water: acidity, heavy metals, and crop contamination. *Soil Res.* 2005;43(7):819-826.
16. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci Soc Am J.* 1978;42:421-428.
17. Meher SK, Singh V, Bala J, Samuel S, Motghare R, Tedia K. Assessment of spatial variability of soil fertility status in KVK farm of Pahanda in Durg district, Chhattisgarh using GIS-GPS. *Int J Chem Stud.* 2020;8(2):304-309.
18. Mishra A, Pattnaik T, Das D, Das M. Soil fertility maps preparation using GPS and GIS in Dhenkanal district, Odisha, India. *Int J Plant Soil Sci.* 2014;3(8):986-994.
19. Olsen SR. Estimation of available phosphorus in soils by Olsen's method for slightly acidic, neutral and alkaline soils. 1954; p. 14-15.
20. Patel H, Patel R, Paikara KP, Brajendra, Mishra VN. Assessment of soil fertility in Baramkela block under Raigarh district of Chhattisgarh, India. *Int J Curr Microbiol Appl Sci.* 2018;7:3212-3215.
21. Patil PL, Kuligod VB, Gundlur SS, Katti J, Nagaral LN, Shikdashetti P, *et al.* Soil fertility mapping in Dindur sub-watershed of Karnataka for site-specific nutrient management. *J Indian Soc Soil Sci.* 2016;64(4):381-390.
22. Piper CS. Soil and plant analysis. Bombay: Hans Publishers; 1966.
23. Ramamoorthy B, Bajaj JC. Available nitrogen, phosphorus and potassium status of Indian soils. *Fert News.* 1969;14(8):25-36.
24. Rawal N, Acharya KK, Bam CR, Acharya K. Soil fertility mapping of different VDCs of Sunsari district, Nepal using GIS. *Int J Appl Sci Biotechnol.* 2018;6(2):142-151.
25. Rossel RV, McBratney AB. Soil chemical analytical accuracy and costs: implications for precision agriculture. *Aust J Exp Agric.* 1998;38(7):765-775.
26. Sahu N, Reddy GPO, Kumar N, Nagaraju MSS, Srivastava R, Singh SK. Spatial variability of soil macronutrients on basaltic landscape of central India: a geostatistical approach. *Chem Sci Rev Lett.* 2020;9(33):77-86.
27. Sawyer JE. Concepts of variable rate technology with considerations for fertilizer application. *J Prod Agric.* 1994;7(2):195-201.
28. Singh C, Bajpai RK, Tiwari A, Chandra M, Krishna B. Evaluation of soil fertility status of available major nutrients (N, P, K) and micronutrients (Fe, Mn, Cu, Zn) in Vertisols of Balodabazar block, Chhattisgarh. *J Pharmacogn Phytochem.* 2018;2:10-12.
29. Srivastava LK, Mishra VN, Jatav GK, Banwasi RK, Dubey A, Verma N. GIS-based soil mapping of available macro and micronutrients in Raipur district of Chhattisgarh. *Ann Plant Soil Res.* 2016;18(1):60-65.
30. Subbiah BW, Asija GL. A rapid procedure for the estimation of available nitrogen in soil. *Curr Sci.* 1965;25:259-260.
31. Triveni S, Neelima T, Reddy GK, Sharma S, Jayshree G. Soil fertility mapping of Patancheru area, Sangareddy district, Telangana using GPS-GIS. *J Res.* 2022;49(4).
32. Walkley A, Black AI. Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.* 1934;37:259-260.
33. Williams CH, Steinbergs A. Estimation of available sulphur by CaCl₂ extractable method. 1959; p. 16-17.
34. Zhu H, Zhao Y, Nan F, Duan Y, Bi R. Relative influence of soil chemistry and topography on soil available micronutrients by structural equation modeling. *J Soil Sci Plant Nutr.* 2016;16(4):1038-1051.