SOIL FERTILITY MAPPING USING GEO-SPATIAL TECHNIQUE FOR KHAPRADIH FARM, DKS COLLEGE OF AGRICULTURE AND RESEARCH STATION, BHATAPARA, CHHATTISGARH, INDIA

Abstract

The present study aimed to assess various chemical properties and available macro and micronutrients in the soil. Collection of 101 geo-referenced soil surface samples at 100-meter intervals of the Khapradih Farm of DKS College of Agriculture & Research Station, district Balodabazar-Bhatapara of Chhattisgarh state and examined in the laboratory for pH, electrical conductivity (EC), organic carbon (OC), and available macro-nutrients (N, P, K, S) and micro-nutrients (Fe, Mn, Cu, Zn, B). The results showed that the soil was generally neutral in pH, with a range of 5.7 to 7.6. The electrical conductivity indicated non-saline, varying from 0.11 to 0.26 dSm^{-1}. Available nutrients were categorized as low, medium, or high based on nutrient index values. The study revealed that the soil in the area had low levels of available N and S, medium levels of available P and K, and high levels of available Fe, Mn, and Cu. Zn was found to be in the medium category, while B was low. Significant correlations were observed between various physico-chemical properties and available macro and micro nutrients. Using ArcGIS 10.4.1, thematic maps were created, representing the spatial distribution of soil properties and nutrient status. Based on these findings, fertilizer recommendations were developed for major crops grown in the area, resulting in enhanced crop productivity. The study concludes that GPS and GIS-based tools are valuable for soil fertility mapping, monitoring, and site-specific nutrient management, leading to sustainable and optimal crop yields.

Keywords: Soil fertility maps; Physico-chemical parameters; GIS; GPS.

Introduction

Intensive farming and conventional resource use disturb our ecosystem and threaten soil health, leading to reduced crop production and food insecurity. Effective nutrient management practices can ensure long-term sustainability of our agricultural ecosystem and it's vital for enhancing plant productivity. To address this, understanding the essentiality of nutrients for well growth and development of plants; the Soil-Plant-Atmosphere-Continuum (SPAC) relationship is crucial for maintaining or increasing soil fertility and sustaining agricultural production. Continuous supply of food for growing population to improve the productivity of our soil would be change our ability. Hence, a pressing challenges and difficulties to develop and implement soil, crop, and nutrient management technologies that optimizing plant productivity and soil quality. Describing the spatial variability of soil across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced (Reddy *et al.*, 2018) [14]. The collection of soil samples and the creation of thematic fertility maps are made easier with GPS and GIS technologies, supporting geo-statistical analysis to characterize spatial variability. For long-term monitoring and management, GIS-based soil fertility maps are an invaluable decision-support system. Soil testing and modern approaches like STCR/targeted yield ensure balanced nutrient management and sustainable soil fertility. These methods provide precise fertilizer recommendations, aiming to achieve specific crop yield goals while maintaining soil health.

Materials and Methods

The study area will be the Khapradih Farm of DKS College of Agriculture & Research Station, district Balodabazar-Bhatapara of Chhattisgarh state, located between Latitude- 19°44′ 02.93″ to 21°44′33.56″ N Longitude - 81°57′59.43" to 81°58′44.41″ E Altitude - 268-270 m above the mean sea level. 101 surface soil samples were collected on the basis of grid point which covered almost more than 80% cultivated area of the Khaparadih farm. Collection of soil samples 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. Soil pH was determined by glass electrode pH meter, Piper's method (Piper 1967)[13], electrical conductivity with Solu-bridge process as suggested by (Black, 1965)[2], organic carbon by wet digestion method (Walkley and Black’s, 1934) [17]. Available nitrogen was estimated by alkaline KMnO4 method (Subbiah and Asija, 1956) [11], Available phosphorus extracted by 0.5M $NaHCO_3$ solution buffer at pH 8.5 (Olsen *et al.*,1954) [9] was used for neutral-alkaline soils. Available potassium was estimated through neutral normal ammonium acetate by flame-photometer. (Jackson, 1967) [5]. Available Sulphur (S) by method of Williams and Steinbergs (1959) [18].

The micronutrients (Zn, Cu, Fe and Mn) were extracted with DTPA solution (Lindsay and Norvell, 1978) [7] and analyzed the concentrations with the help of atomic absorption spectrophotometer. Berger and Troug (1939) [3] identified a hot water method for determination of available B in soil. 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

Nutrient index and fertility rating

Ramamoorthy and Bajaj (1969)[15] established nutrient index values (NIV) based on the distribution of soil samples categorized as having low, medium, or high nutrient status. These values were used to classify soils into different fertility groups. NIV = 1 × PL + 2 × PM + 3 × PH 100; Where, NIV = nutrient index value PL= % samples fall under low category. PM= % samples fall under medium category. PH= % samples fall under high category.

In this assessment, an NIV of less than 1.33 indicates a low fertility level, an NIV between 1.33 and 2.33 indicates a medium fertility level, and an NIV greater than 2.33 indicates a high fertility level for each nutrient.

Soil Fertility Map

Soil fertility maps were prepared using the kriging method in ArcGIS software, assisted by GPS readings and measured physicochemical parameters (pH, EC, and OC) and available soil macronutrients and micronutrients to depict spatial variability of the study area.

Kriging is a geostatistical interpolation method that considers both the distance and the degree of variation between known data points to estimate values in unknown areas. Soil fertility mapping of the study area was conducted on a scale larger than 1:10,000 using ordinary kriging for soil parameter mapping. Various semivariogram models—spherical, circular, exponential, and Gaussian—were compared to identify the best fit for different soil fertility parameters. Maps were extracted using the extraction tool under the spatial analyst tool in ArcGIS.

RESULTS AND DISCUSSION

Soil reaction (pH)

A study on the soil reaction (pH) of the study area revealed that the soils were slightly acidic to slightly alkaline and the pH varied from 5.74 to 7.64 with a mean value of 7.07 ± 0.44. Indicated that the overall soil pH of the study area is rated under neutral category. Percentage distribution of soil samples (Table 1). The spatial distribution and status of pH at

Khapradih Farm is represent in Fig. 1. Similar findings were reported by Singh *et al.,* (2018) [12].

Soil electrical conductivity (dSm^{-1})

The electrical conductivity of the soil ranged from 0.11 to 0.26 dSm^{-1} with a mean value of 0.17 ± 0.03 dSm^{-1}. Overall soil samples were recorded under the normal range (<1.0 dSm^{-1}) of EC which are non-saline in study area, percentage distribution of soil samples (Table 3). Spatial distribution of EC content at Khapradih Farm is represent in Fig.1. Similar findings were reported by Meher *et al.,* (2020) [8]

Soil Organic Carbon (%)

The OC content of soil sample ranged from 0.41 to 0.74% with mean value of (0.59 ± 0.07) %. Overall, OC content of study area also fertility rating under medium category with NIV 1.92 and percentage distribution of soil samples (Table 3). Spatial distribution of soil OC content at Khapradih Farm is shown in Fig. 1. Similar findings were reported by Bal Krishna, (2018) [6].

The available macro-nutrients status

Available nitrogen (N)

The available nitrogen content in the soil samples varied from 169.7 to 256.8 kg ha^{-1} with an average value of 227.9 ±18.61 kg ha^{-1}. Overall soil sample of study area available N content is low also, fertility rating under low category with NIV 1.0 and percentage distribution (Table 2). Spatial distribution of available N content of Khapradih Farm is represented in Fig.1. Similar findings were reported by Awanish Kumar (2017) [1].

Available phosphorus (P)

The available phosphorus of soil samples ranged from 11.2 – 22.06 kg ha^{-1} with a mean value of 16.74 ± 2.54 kg ha^{-1}. Overall soil sample of study area available P content, fertility rating under medium category based on NIV 2.0 and percentage distribution of soil samples (Table 2). Spatial distribution of available P content of Khapradih Farm is represented in Fig. 1. Similar findings were reported by Patel *al.,* (2018) [10].

Available potassium (K)

The available potassium of soil samples varied from 259.6 to 399.3 kg ha^{-1} with an average value of 352.3 ± 36.5 kg ha^{-1}. Overall soil samples of study area for available K content under high category based on NIV 2.74 and percentage distribution of soil samples (Table 3). Spatial distribution of available K content of Khapradih Farm is represented in Fig. 1. Similar findings were reported by Singh *et al.,* (2018) [12].

Available Sulfur (S)

The available sulfur of soil samples ranged from 11.3 to 35.1 kg ha^{-1} with an average value of 22.09 ± 6.05 kg ha^{-1}. Overall soil samples of study area available S content, fertility rating under low category based on NIV 1.48 and percentage distribution of soil samples (Table 3). Spatial distribution of available S content of Khapradih Farm is represented in Fig. 2. Similar findings were reported by Iyer *et al*., (2020) [4].

The available micro-nutrients status

Available iron (Fe) status in soil

The available Fe of soil samples ranged from 6.9 to 16.4 mg kg^{-1} with an average value of 11.52 ± 1.90 mg ha^{-1}. Overall available Fe content of study area is high also fertility rating under high category based on NIV 2.91 and percentage distribution of soil samples (Table 3). Spatial distribution of available Fe content of Khapradih Farm is represented in Fig. 2. Similar findings were reported by Singh *et al*., (2018) [12].

Available Manganese (Mn) status in soil

The available Mn of soil samples ranged from 8.14 to 32.4 mg kg^{-1} with a mean value of 19.14 ± 6.4 mg ha^{-1}. All the soil samples of study area available Mn content is high also, fertility rating under high category based on NIV 3.0 and percentage distribution of soil samples (Table 9). Spatial distribution of available Mn content of Khapradih Farm is represented in Fig. 2. Similar findings were reported by Bal Krishna *et al.*, (2018) [6].

Available Copper (Cu)

The available Cu of soil samples varied from 0.42 to 2.66 mg kg^{-1} with an average value of 1.25 ± 0.6 mg ha^{-1}. All the soil samples of study area available Cu content is high also, fertility rating under high category based on NIV 3.0 and Percentage distribution of soil samples (Table 10). Spatial distribution of soil Cu content of Khapradih Farm is represented in Fig. 2. Similar findings were reported by Singh *et al*., (2018) [12].

Available Zinc (Zn)

The available Zn of soil samples ranged from 0.33 to 1.69 mg kg^{-1} with a mean value of 0.86 ± 0.33 mg ha^{-1}. Accordingly, it was found that 26 %, 52 %, 22 % samples were recorded under deficient, sufficient and high range for available Zn, respectively. Overall soil samples of study area available Zn content, fertility rating under medium category based on NIV 1.96 and Percentage distribution of soil samples (Table 1). Spatial distribution of soil Zn content of Khapradih Farm is shown in Fig. 2. Similar findings were reported by Mehar *et al*., (2020) [8].

Available boron (B)

The available B of soil samples ranged from 0.13 to 0.28 mg kg^{-1} with an average value of 0.19 ± 0.03 mg ha^{-1}. All the samples were found to be low rating in available B content with NIV 1.0 and percentage distribution of soil samples (Table 1). Spatial distribution of soil B content of Khapradih Farm is shown in Fig. 2. Similar findings were recorded by Rawal *et al.*, (2018) [16].

Table 1 Distribution of soil samples under different pH and EC rating

Soil pH			
Classes	Range	No. of Samples	Samples (%)
Slightly acidic	< 6.5	12	12
Neutral	6.5 – 7.5	86	85
Slightly alkaline	7.5 – 8.5	3	3
Soil EC dSm^{-1}			
Classes	Range (dSm^{-1})	No. of Samples	Samples (%)
Good (No any harmful effect on crop)	< 1	101	100

Table 2 Distribution of soil samples under different macro-nutrient status rating

Content	Classes	Range (%)	No. of Samples	Samples (%)	NIV	Fertility Rating
OC	Low	< 0.5	8	8	1.92	Medium
	Medium	0.5 – 0.75	93	92		
N	Low	< 280	101	100	1	Low
P	Low	< 12.5	3	23.80	2	Medium
	Medium	12.5 – 25	97	72.22		
K	Medium	135 – 335	26	26	2.74	High
	High	> 335	75	74		
S	Low	< 22.5	53	52	1.48	Medium
	Medium	22.5 – 35	48	48		

Table 3 Distribution of soil samples under different micro-nutrient status rating

	Classes	Range	No. of Samples	Samples (%)	NIV	Fertility Rating
Fe	Sufficient	4.5 – 9.0	9	9	2.91	High
Mn	High	7.0	101	100	3	High
Cu	High	> 0.4	124	98.41	3	High
Zn	Deficient	< 0.6	26	26	1.96	Deficient
	Sufficient	0.6 – 1.2	53	52		
	High	> 1.2	22	22		
B	Deficient	< 0.5	101	100	1	Low

Correlation of the soil properties with soil available nutrients

From the table it was found that the pH was negatively correlated with the Mn, Cu, Zn, B and positively correlated with the EC, OC, N, P, K and S. The electrical conductivity was positively correlated with P, K, S and negatively correlated with the OC, N, Fe, Mn, Zn, B. Organic carbon was positively correlated with the N, K, S, Fe, Mn, Cu, Zn, B and negatively correlated to P, and Zn.

Nitrogen was positively correlated with the K, S, Fe, Mn, Zn while P, Cu, B negatively correlated with the N. Phosphorus was negatively correlated with Fe, Mn, Zn and positively with K, S, Cu, B. Potassium was positively correlated with the S and negatively correlated with the Fe, Mn, Cu and B. Sulphur negatively correlated with Fe, Mn, Cu, Zn, B. Iron positively correlated with Mn, Cu, Zn, and B. Mn positively Zn and B and negatively correlated with Cu. Cu is negative correlated with the Zn and positive with B. Zn is positive correlated with B. The low value of correlation study may be attributed to less number of samples and it may not be possible to draw a definite conclusion.

Table 4: Results of correlation analysis

	pH	**EC**	**OC**	**N**	**P**	**K**	**S**	**Fe**	**Mn**	**Cu**	**Zn**	**B**
pH												
EC	**0.25***											
OC	**0.12**	**-0.05**										
N	**0.004**	**-0.01**	**0.32****									
P	**0.11**	**0.25***	**-0.07**	**-0.13**								
K	**0.09**	**0.07**	**0.10**	**0.16**	**0.06**							
S	**0.18**	**0.15**	**0.07**	**0.04**	**0.24***	**0.14**						
Fe	**-0.31****	**-0.22***	**0.15**	**0.10**	**-0.07**	**-0.08**	**-0.21***					
Mn	**-0.11**	**-0.02**	**0.04**	**0.12**	**-0.02**	**-0.02**	**-0.12**	**0.16**				
Cu	**-0.05**	**-0.05**	**0.07**	**-0.19**	**0.16**	**-0.07**	**-0.09**	**0.03**	**-0.01**			
Zn	**-0.17**	**-0.19**	**-0.03**	**0.07**	**-0.26***	**-0.19**	**-0.34****	**0.34****	**0.10**	**-0.01**		
B	**-0.06**	**-0.10**	**0.02**	**-0.06**	**0.01**	**-0.16**	**-0.04**	**0.01**	**0.004**	**0.14**	**0.19**	

Conclusion

The research farm's soil was mostly neutral, non-saline, and had medium organic carbon content. Nutrient index values indicated low fertility for N, S, and B; medium for P, K, and Zn; and high for Fe, Mn, and Cu. The primary nutrient constraints were N, S, and B. Soil fertility maps, created using the Kriging interpolation technique, highlighted spatial variability and supported site-specific nutrient management. The exponential model best fit pH, EC, N, P, Mn, and Zn; the circular model for K and Fe; the spherical model for Cu; and the Gaussian model for S and B. Strong spatial dependency was found for most soil parameters, with moderate for Cu and B, and weak for Zn. Cross-validation showed that using semivariogram parameters for spatial prediction is more accurate than assuming the mean for unsampled locations. These results can be used to make fertilizer recommendations and best management practices with the help of soil fertility maps and sustain soil productivity.

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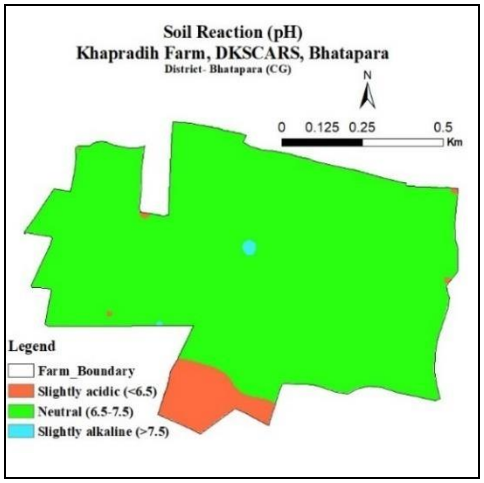
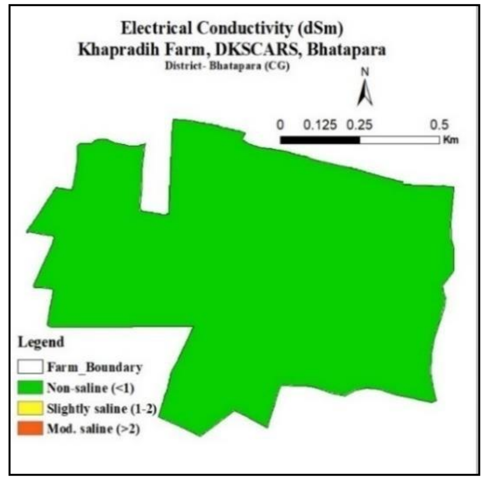
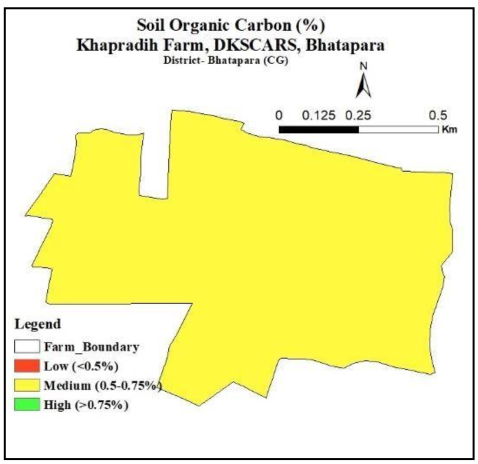


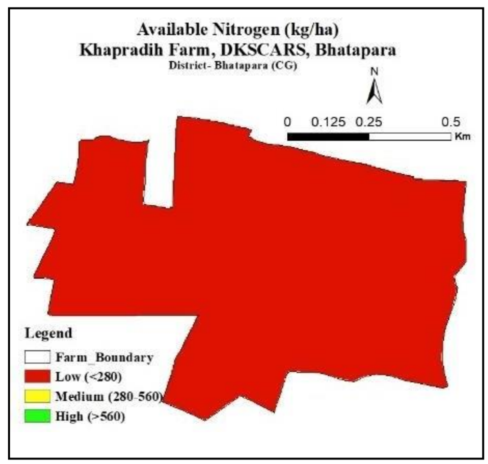
Soil Reaction (pH)



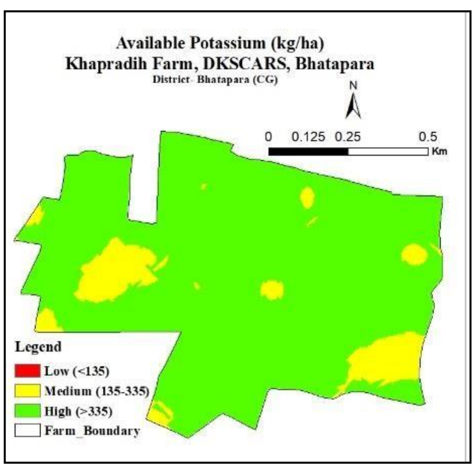
Electrical Conductivity



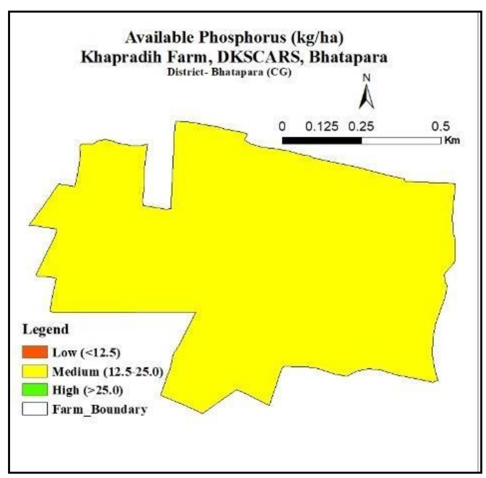
Available Nitrogen



Available Phosphorus

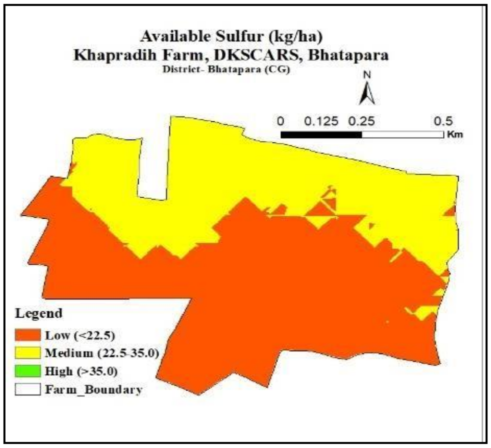


Available Potassium

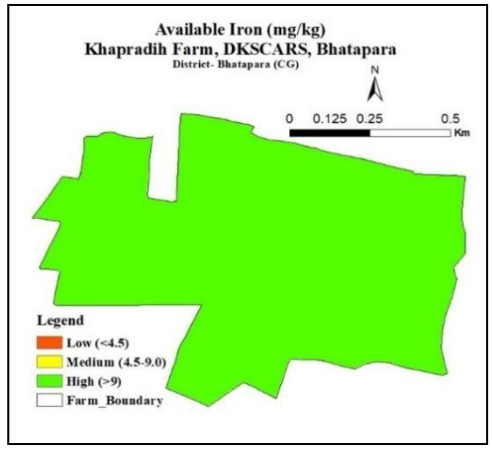


Available Potassium

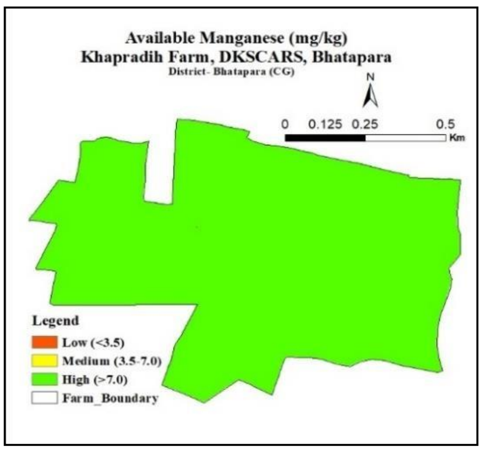
Fig.1 Spatial distribution of Available nutrient in soils of Khapradih farm, DKS College of Agriculture and Research Station, Balodabazar-Bhatapara district (C.G.).



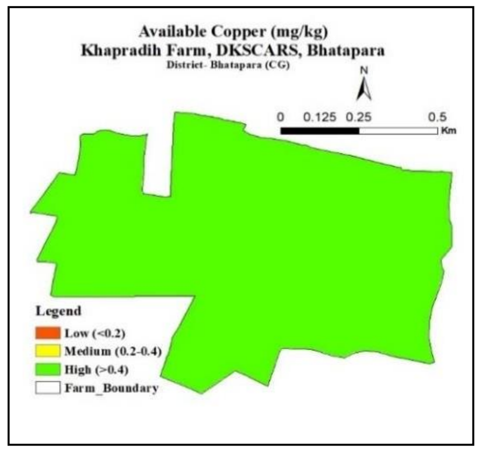
Available Sulfur



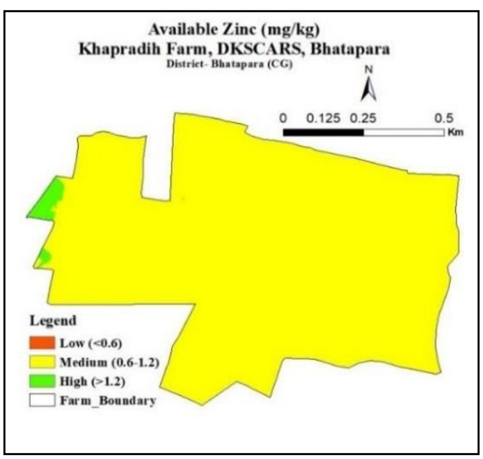
Available Iron



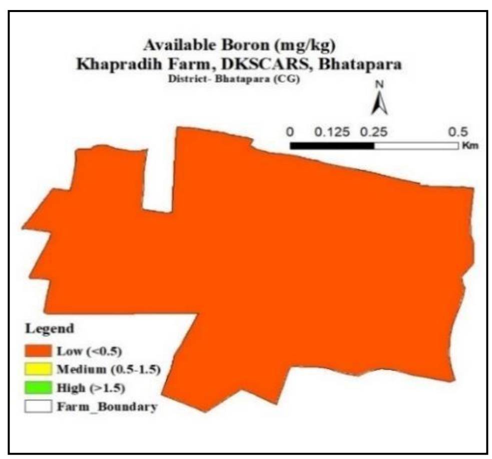
Available Manganese



Available Copper



Available Zinc



Available Boro

Fig.2 Spatial distribution of Available nutrient in soils of Khapradih farm, DKS College of Agriculture and Research Station, Balodabazar-Bhatapara district (C.G.).

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