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Spatial Variability of Soil Chemical Properties in Patna, Vaishali and Saran Districts Adjoining the Ganga River, Bihar, India

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ABSTRACT

The spatial variability in soil nutrients was recorded during 2019-2020 at Patna, Vaishali and Saran districts of Bihar, India which are adjoined to Ganga river. The soil samples were collected from pin pointed locations using GPS device to obtain the exact local coordinates of each sampling site and subsequently the protocol for sampling procedure was followed. Then, soil properties, viz., pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen (N), phosphorus (P), potassium (K) and available iron (Fe) content were analysed in the laboratory. Descriptive statistics were applied to explain the normality status of soil properties The data of skewness and kurtosis for soil pH at 0–15 cm soil depth were negative (-0.72) and (-0.55). Standard deviation of available nitrogen, phosphorus and available iron was found equal to 1/3 of mean indicating the non-normality of the distribution of parameter of data. In sub-surface soil, the value of kurtosis was recorded negative values with pH, OC, available N whereas, positive data recorded with EC, available P, K and Fe respectively. The correlation coefficients indicated that organic carbon was positively correlated with available N, P and K and available iron had negative correlation. The negative correlation was also noticed with available iron with pH, EC, SOC, available nitrogen, phosphorus and potassium at 0-15 cm soil depth. Spatial distribution maps of soil properties were developed for these districts using kriging interpolation techniques in a GIS environment. The generated maps of soil fertility parameter could be helpful to the farmers and policy makers.

KEYWORDS: Available nutrients, geocoordinates, soil properties, spatial distribution

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1. INTRODUCTION

The soil nutrients play a significant role in maintaining soil quality and also act as an indicator of the fertility of soil. The spatial variability of soil nutrients occurred with variation in land use patterns that revealed through the relationship between land use patterns and soil nutrients (Hegde et al., 2021, Alam and Salahin, 2013; Kavianpoor et al., 2012). Soil properties may vary in different spatial areas as a result of combined effect of biological, physical, and chemical processes over time (Santra et al., 2008) and the use of land as well as management practices which greatly impact soil properties (Spurgeon et al., 2013) and productivity. The significant changes in total SOC content might be due to different land management practices with different cropping systems (Conant et al., 2003). The utilization of soil under different cropping pattern and its management affects the soil quality in understanding how soils respond to agricultural practices over time. The supply of adequate plant nutrient by farming community of the study area holds the key for improving food grain production and sustaining soil health. It is very important to know the fertility status of the soils for better crop production (Hegde et al., 2021; Mahendra Kumar et al., 2015). In India various researchers have assessed the soil fertility status in order to optimise the fertiliser use, management practices, cropping system and ultimately optimize the yield of agriculture land (Prabhavathi et al. 2013; Hegde et al., 2021). Soil testing is an important tool which provides information regarding nutrient status and its availability in soils which helps in the fertilizer recommendations for maximising crop yields (Singh et al., 2014; Pujari et al., 2016; Mahendra Kumar et al., 2015). After assessment of soil, the variability in soil fertility can be depicted through maps, highlighting the nutrient needs, based on fertility status of soils to realise good crop yields. The techniques of using Geographical information system (GIS) software can be employed to generate stability in the use of fertilisers for optimum crop production Kashiwar et al., 2021). Obviously, a soil fertility map generates an idea for a particular area that can prove highly beneficial in guiding the farmers, manufacturers and planners in ascertaining the requirement of various fertilizer doses in a season/year and making projections for increased requirement based on cropping pattern and intensity. In India, generally the composite soil samples are collected without collecting the geocoordinates of that specific location and it results in non-significant in site specific nutrient management at farm condition (Hegde et al., 2021). The use of GPS devices can improve the quality and future applicability of that data for various purposes. Study of soil fertility status and mapping of pH, electrical conductivity, organic carbon, nitrogen, phosphorus, potassium, sulphur, zinc, iron, copper and manganese using GIS interface were reported from several localities (Arunkumar et al., 2016; Kumar et al., 2017; Santhi et al., 2018). Thus, the geostatistical tools are getting much more effective in soil health management. As the prices of fertilizers are increasing and with the use of these techniques, the cost of cultivation can be reduced in a drastic way (Cherry et al., 2012; Raza et al., 2017).

The farmers of Patna, Vaishali and Saran districts adjoining the Ganga River, Bihar are not much aware about the soil testing and are not using fertilizers according to the soil test-based recommendations. Keeping all these in view, the evaluation of soil chemical characteristics, generation of spatial information's regarding fertility status and its depictions through maps in these districts could assist policy makers and farmers for fertilizer allocation in these districts and fertilizer application in agri-horticultal field.

2. MATERIALS AND METHODS

2.1. Location of study

The climate of Patna, Vaishali and Saran districts, Bihar, India that prevails is sub-tropical and monsoon rain received is about 990 mm. with maximum precipitation accounting to nearly 90% of the total rainfall is received from June to September month. The study sites refer to three districts adjoining Gangetic basin *i.e.* Vaishali and Saran lying on the Northern bank of the Ganga river, and Patna located on the southern bank with their coordinates lying between 25°13' to 25°45' N latitude and 84°43' to 85°44' E longitude. The district Saran is located between 25°36' N-26°13' N latitude and 84°24' E-85°15' E longitudes and Vaishali district is spread over 2,036 sq. Km located between 25°41'-25°68' N latitudes and 85°13'-85°22' E longitudes. The area is covered with alluvial soils with lot of transported alluvium materials were showed neutral to alkaline in reaction and belongs to order Inceptisols under soil taxonomy.

2.2 Soil sampling and analysis

For the present study, the soil samples were analysed to evaluate the soil fertility status of the study area in which, soil samples were collected (2019-2020) from pin pointed locations using GPS device to obtain the exact local coordinates of each sample site and subsequently the protocol for sampling procedure was followed. These soil samples were received from sites to be investigated in the selected districts of Gangatic plains *i.e.*, Patna, Saran and Vaishali using GPS techniques which lay within latitudes 25°33' N to 25°42' N and longitudes 84°52' E to 85°23' E. Further, the soil samples collected separately from two depth *viz* 0-15 cm and 15-30 cm at each sampling site. These soils were processed and used for analysis of various chemical parameters. The samples were air dried and sieved through a 2-mm sieve for the final analysis of soil nutrient elements.

The soil pH was determined with the help of a glass electrode pH meter (Model-Systronics-36) keeping up the soil-water suspension ratio 1: 2.5 as recommended by (Jackson, 1962).

The EC (electrical conductivity) of the soil was measured with soil-to-water ratio of 1:2.5 with the help of an EC meter (HANNA-HI2300) (Anonymous). Similarly, available nitrogen of the soils was determined by alkaline potassium permagnate method using Kjeldahl flask method (Bremner and Mulvaney, 1983). Available phosphorus was extracted from the soil with the help of 0.5 M $NaHCO_3$ (Olsen's method) at pH 8.5 and the molybdophosphoric blue colour method was employed for determination (Murphy & Riley, 1962) using spectrophotometer (Elico SL-177). The available potassium was extracted from the soil with 1 N NH_4OAc at pH 7.0 (Jackson, 1973) and analyzed by a flame analyzer (Elico CL-378) at 589 nm for determination. Organic carbon content of samples were determined by Walkley and Black's wet oxidation method as outlined by Jackson, 1962.

Iron content in soil was determined (Lindsay and Narvel, 1978) using Perkin-Elmer Atomic Absorption Spectrophotometer. The analysed data obtained on soil chemical parameters were used to know the level of nutrient content for recommendation of fertilizers.

The location coordinates of soil samples were obtained through GPS device and the geocoordinates imported to base map in ArcGIS software. The world geodetic system 1984 (WGS 84) reference coordinate systems were used for locating and georeferencing the sampling location in GIS software. The variability in soil chemical parameters were depicted by different colour notations.

2.3. Statistical analysis

Descriptive statistics, including the mean, minimum, maximum, medium, mode and standard deviation, skewness, kurtosis and correlation coefficient were calculated using SPSS 20.0 (Duffera et al., 2007). The ArcGIS 10.4.1 software was used to generate the soil thematic maps using the geostatistical interpolation technique named *kriging interpolation technique* as it considers both the distance and the degree of variation between known data points when estimating values in unknown areas (Paramasivam and Venkatramanan, 2019).

3. RESULTS AND DISCUSSION

3.1. Distribution of Soil pH, EC and organic carbon in the study area

The data obtained revealed that the soil pH of the study area ranged from 7.3-8.5 and 7.4-8.8 with average value of 8.03 and 8.11 at 0-15 and 15-30 cm soil depth respectively which is presented in Table 1. Most of the soil samples were found to be slightly alkaline in soil reaction, however, few samples were neutral in nature. The lowest pH 7.3 and 7.4 were recorded in soils of Kitta Chauhattar village lying on longitude 25°39'50.4" N and latitude 84°52'46.2" E, while, highest pH 8.5 and 8.8 was recorded in surface and sub-surface soils at Pataliputra Colony of coordinates 25° 37' 36.7" N and 85° 06' 36.5" E. The distribution of soil pH accounted about 33% of total samples falls below 8.0 in surface soil, whereas, 38% sample contains less than pH 8.0. The higher pH may be due to accumulation of exchangeable sodium and calcium carbonate in the soil (Kashiwar et al., 2021). The variability in soil pH are represented in figure 1, 2 and 3.

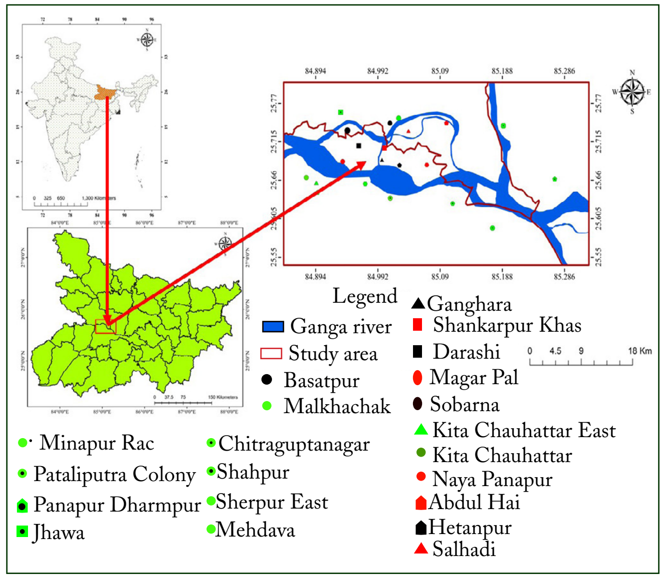

Figure 1: Map of the study area along with sampling sites

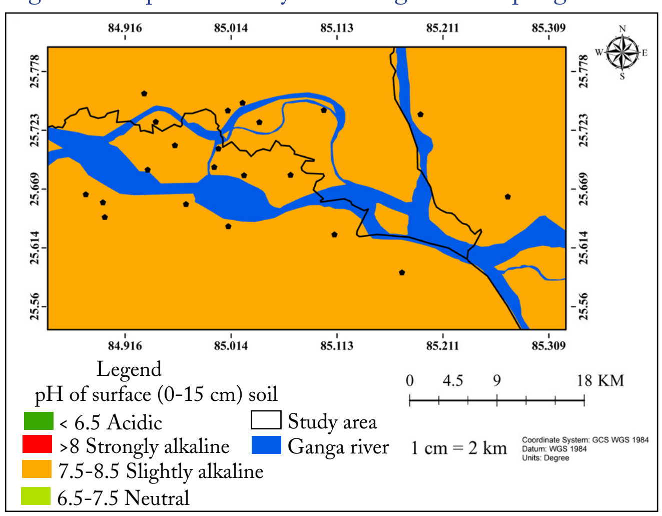

Figure 2: Distribution of soil pH at 0-15 cm

Electrical conductivity of soils of the study area ranged from 0.11 to 0.63 dS m^{-1} and 0.13–0.9 dS m^{-1} with average value of 0.36 and 0.39 dS m^{-1} at surface (0–15 cm) and sub-surface (15–30 cm) soil depth. Almost all the soil samples were found to be non-saline in nature and are not problems in these areas. The lowest EC content in surface soil (0.11 dS m^{-1}) was recorded from two locating in Patna district, namely Kita Chauhattar East located at latitude 25°39'23.8" N and longitude 84°53'43.2" E and Mehdava located at latitude 25°38'34.5" N and longitude 84°53'49.6" E which

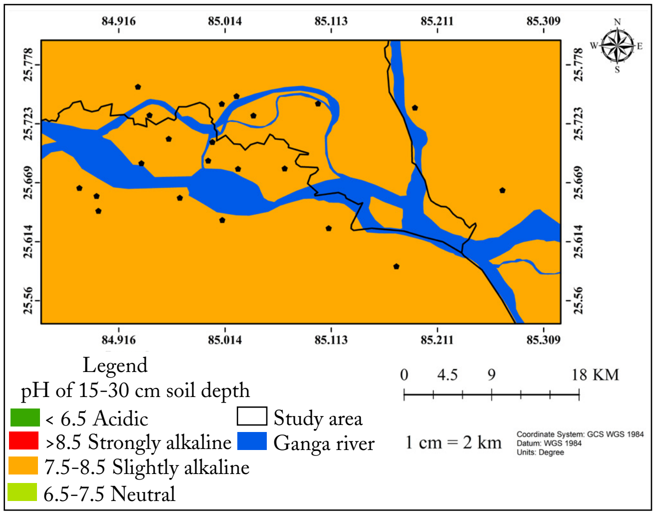

Figure 3: Distribution of soil pH at 15-30

sub-surface soil, at Malkhachak, Saran with geocoordinates of 25°44'50.4" N and 85°01'27.3" E recorded which is depicted in table 1 and the distribution of EC is denoted by different colour notation shown in figure 4 and 5.

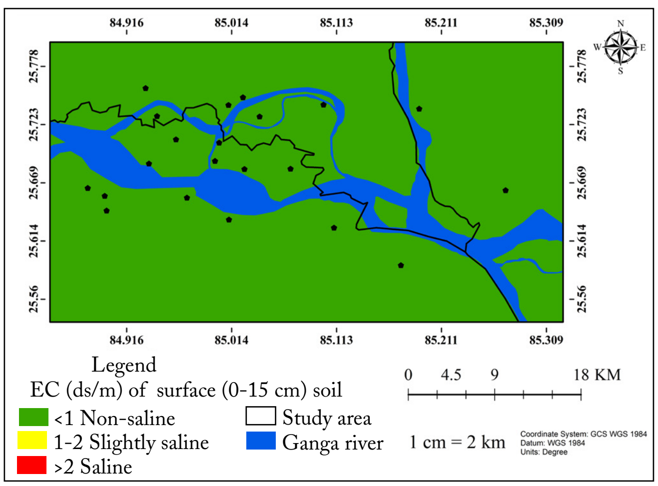

Figure 4: Distribution of soil EC at 0-15 cm

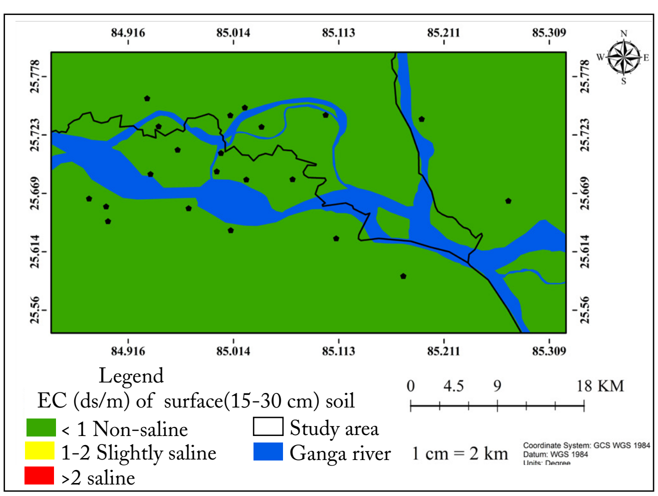

Figure 5: Distribution of soil EC at 15-30 cm

The data on soil organic carbon (SOC) content ranged from 0.35 % to 1.08 % and 0.31 to 0.73 % of 0–15 & 15–30 cm soil depth respectively. The average organic carbon was found to be 0.63% and 0.50% at 0–15 and 15–30 cm soil depth respectively. In surface soil, about 28.6% of the analysed samples were found low content (<0.5 %) and 43 % samples were under medium (0.5–0.75%) range of organic carbon content, whereas in sub surface soil 67% of the samples were found to be low organic carbon content, and the remaining samples were found to be in medium range of organic carbon content. The data (Table 1) revealed comparatively higher organic matter in surface soil as compared to sub-surface soil at all locations. Higher amount of OC in the surface soil layers might be attributed to the addition of plant litters, FYM, incorporation of stubble left after harvesting of crops (Rajeswar et al., 2009; Meena et al., 2006) (Figure 6 and 7).

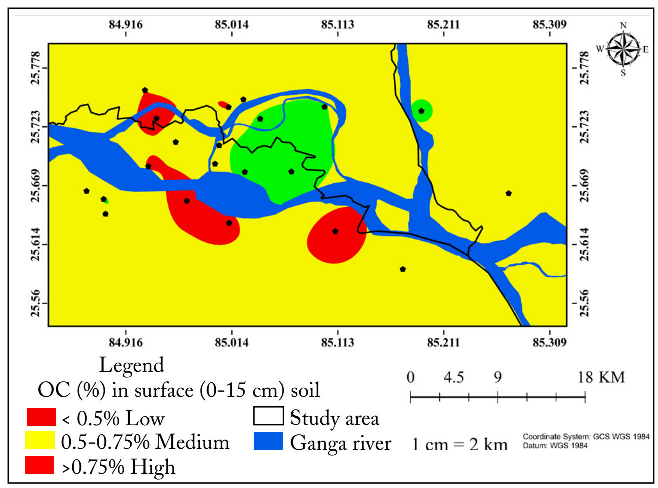

Figure 6: Distribution of soil OC at 0-15 cm

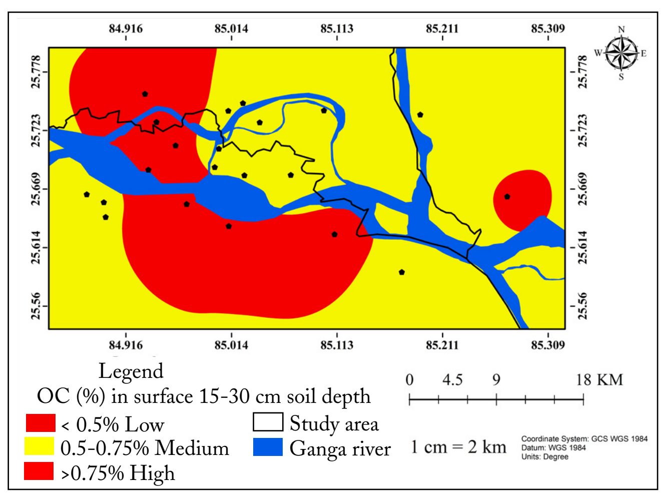

Figure 7: Distribution of soil OC at 15-30 cm

3.2. Distribution of available N, P K and Fe content in the study area

The available nitrogen content in soils of the study area

Table 1: Status of chemical properties of soils at two depths (0–15 cm and 15–30 cm) of the study area

Sl. No.	Sampling Locations	pH		EC (dS m^{-1})		OC (%)		Avail. N (kg ha^{-1})		Avail. P (kg ha^{-1})		Avail. K (kg ha^{-1})		Avail. Fe (mg kg^{-1})	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2
1.	Sobarna	8.3	8.4	0.5	0.47	0.47	0.43	120.5	96.5	15.6	15.0	90.0	56.0	6.58	6.22
2.	Magar Pal	8.2	8.3	0.56	0.48	0.49	0.46	115	120.5	12.4	11.0	72.0	33.8	6.12	5.89
3.	Darashikoh-pur Jazira	8.3	8.4	0.23	0.21	0.54	0.46	132.5	62.0	17.5	17.0	112.5	74.3	5.89	6.56
4.	Shankarpur Khas	8.1	8.3	0.49	0.32	0.68	0.73	163	125.0	24.0	24.0	218.3	216	7.49	7.14
5.	Ganghara	8.1	8.3	0.23	0.21	0.62	0.49	165.6	135.6	21.5	16.5	112.5	74.3	7.79	7.26
6.	Salhadi	8.3	8.2	0.53	0.33	0.79	0.68	166.5	150.0	17.8	15.5	212.5	76.5	7.66	7.50
7.	Hetanpur	8.4	8.4	0.46	0.17	0.89	0.49	185.7	120.0	12.4	12.8	83.8	72.0	6.98	7.62
8.	Abdul Hai	8.4	8.3	0.4	0.35	0.76	0.68	190.6	145.0	15.6	13.2	175.5	137.3	5.43	5.66
9.	Malkhachak	8.3	8.4	0.14	0.13	0.62	0.45	161.5	115.5	15.4	14.2	139.6	140	8.38	8.12
10.	Naya Panapur	8.0	7.8	0.44	0.18	1.08	0.65	225.0	137.8	43.3	21.9	77.0	32.9	8.42	8.52
11.	Kita Chau-hattar	7.3	7.4	0.19	0.16	0.5	0.45	62.0	55.62	12.7	11.5	41.9	40.0	17.93	15.86
12.	Kita Chau-hattar East	8.1	7.6	0.11	0.85	0.76	0.7	126.5	98.6	18.1	16.6	28.1	24.3	9.6	9.06
13.	Mehdava	7.5	7.8	0.11	0.9	0.73	0.44	177.6	108.8	18.2	17.0	38.9	32.2	8.6	8.13
14.	Sherpur East	7.7	7.8	0.36	0.31	0.41	0.32	67.6	55.08	11.8	12.0	32.2	40.5	6.65	6.89
15.	Shahpur	7.6	7.8	0.45	0.23	0.44	0.39	62.0	50.2	11.0	12.0	37.0	18.9	6.6	6.42
16.	Jhawa	7.8	7.9	0.53	0.43	0.5	0.4	87.6	65.0	13.8	14.0	76.9	25.2	9.86	9.12
17.	Basatpur	7.5	7.7	0.63	0.55	0.49	0.43	105.8	67.0	13.5	14.5	153.0	85.5	8.22	8.05
18.	Panapur Dharmpur	8.1	8.3	0.11	0.9	0.68	0.44	150.0	102.0	17.6	14.3	43.2	40.5	5.44	5.06
19.	Minapur Rae	7.9	8.0	0.47	0.37	0.78	0.66	155.0	82.5	16.4	16.5	200.3	171.0	6.73	5.76
20.	Pataliputra Colony	8.5	8.8	0.37	0.35	0.35	0.31	62.0	37.2	13.4	9.5	36.5	24.3	7.88	7.04
21.	Chitragup-tanagar	8.3	8.5	0.39	0.30	0.66	0.62	125.79	125.0	18.7	16.5	79.4	42.1	11.9	9.66
	Average	8.03	8.11	0.366	0.39	0.63	0.50	133.70	97.85	17.17	15.02	98.14	69.40	8.10	7.7
	Maximum	8.5	8.8	0.63	0.9	1.08	0.73	225.0	150	43.3	24	218.3	216	17.93	15.86
	Minimum	7.3	7.4	0.11	0.13	0.35	0.31	62.0	37.2	11.0	9.5	28.1	18.9	5.43	5.06

1: 0-15 cm; 2: 15-30 cm

ranged from 62–225 kg ha^{-1} and 37.2–150 kg ha^{-1} with average value of 133.7 and 97.85 kg ha^{-1} at surface (0–15 cm) and sub-surface (15–30 cm) soil depth respectively as presented in Table 1. These data are also presented in Figure 8 and 9. Nearly all samples had low available nitrogen content (<250 kg ha^{-1}). The available nitrogen is comparatively higher in surface soil than the subsurface soil, at all the soil sampling locations, which may be because of higher content of OC in the upper (0–15 cm) soil layer (Meena et al., 2006). Similarly, available phosphorus of soils of the study area ranged from 11.0–43.3 kg ha^{-1} and 9.5–24.0 kg ha^{-1} with average value of 17.17 and 15.02 kg ha^{-1} at surface and subsurface soil depth (table 1). About 85% of the surface soil samples and 81% of the subsurface soil samples fell under medium range for available phosphorus content i.e. 12.5–24.4 kg ha^{-1}. The lowest available

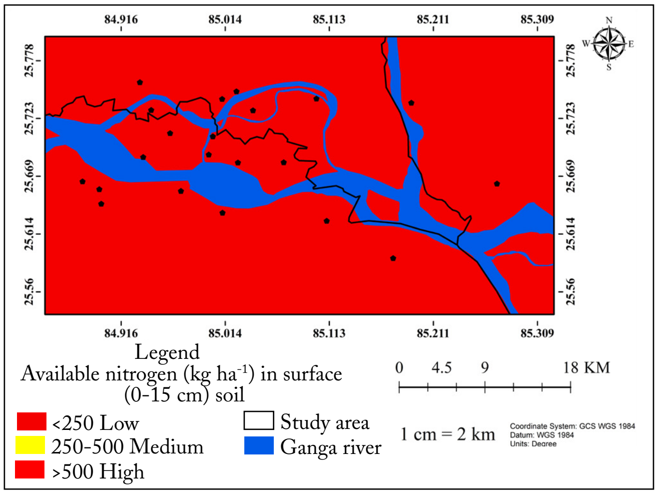

Figure 8: Distribution of soil avail. N at 0-15 cm

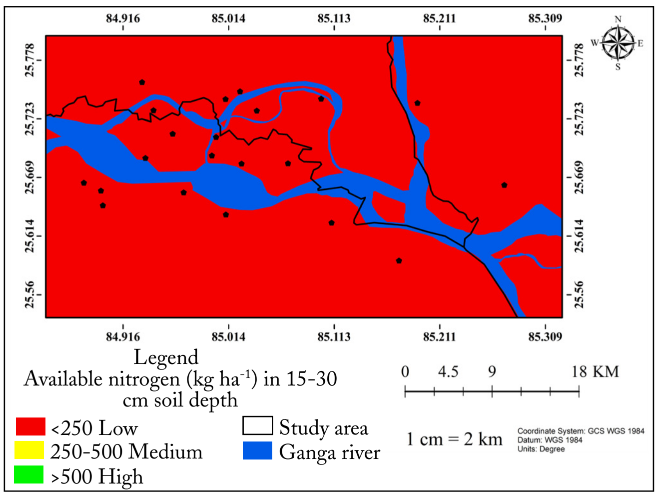

Figure 9: Distribution of soil avail. N at 15-30 cm

phosphorus content of 11.0 and 9.5 kg ha^{-1} were recorded in soils of Shahpur and Pataliputra Colony respectively (both belonging to Patna), while the highest available phosphorus (43.3 kg ha^{-1}) was recorded in soils of NayaPanapur located at latitude 25°40'55.4" N and longitude 85°04'10.1" E. The variation in phosphorus content may be due to improper use of phosphatic fertilizers for compensating nitrogen through DAP and not urea by the farmers of the locally depicted in figure 10 and 11.

Available potassium in the surface soil ranged from 28.1–218.3 kg ha^{-1} with mean concentration of 98.14 kg ha^{-1}, while for subsurface soil it ranged from 18.9–216 kg ha^{-1} with mean concentration of 69.4 kg ha^{-1}. Most of the studied soils were found to be low in available potassium (<113 kg ha^{-1}). About 71.4 % of the surface soil samples and 81 % of the subsurface soil samples had low available potassium content. The variability in available potassium indicated in figure 12 and 13. The available iron content in surface and subsurface soil ranged from 5.43–17.93 mg kg^{-1} and 5.06–15.86 mg kg^{-1}, with a mean value of 8.1 and

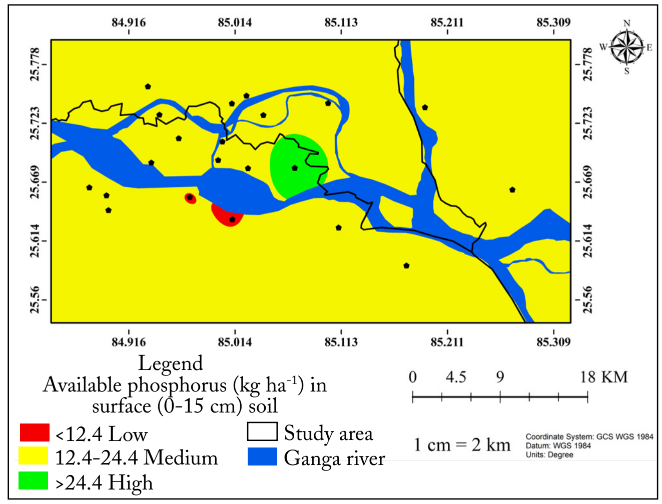

Figure 10: Distribution of soil avail. P at 0-15 cm

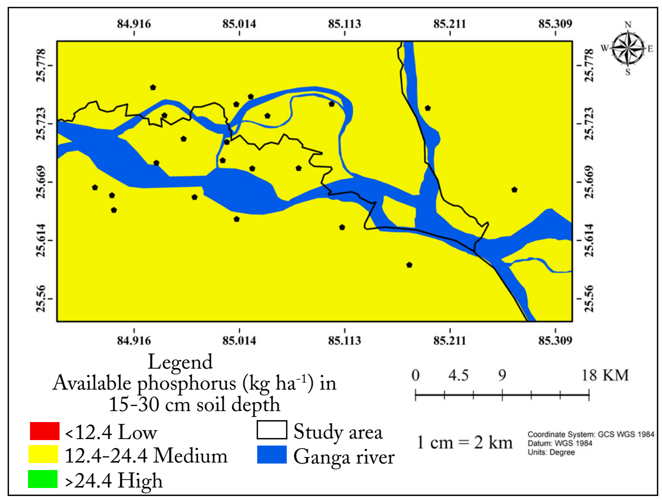

Figure 11: Distribution of soil avail. P at 15-30 cm

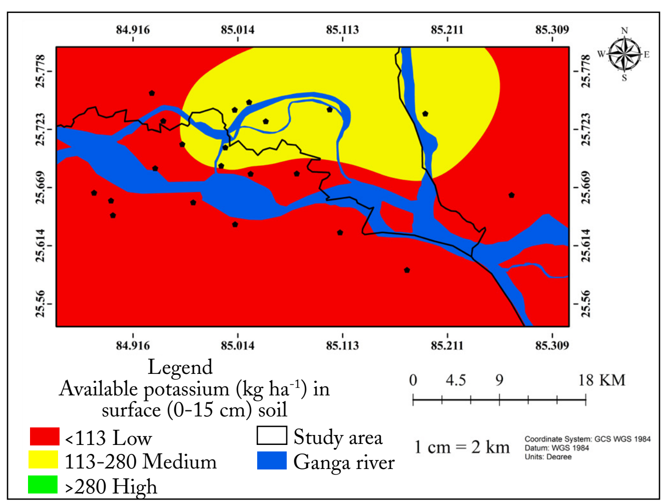

Figure 12: Distribution of soil avail. K at 0-15 cm

7.6 mg kg^{-1} respectively, which has been depicted in table 1 and figure 14 and 15. The analysis revealed that all the soil samples of either depth had medium available iron content

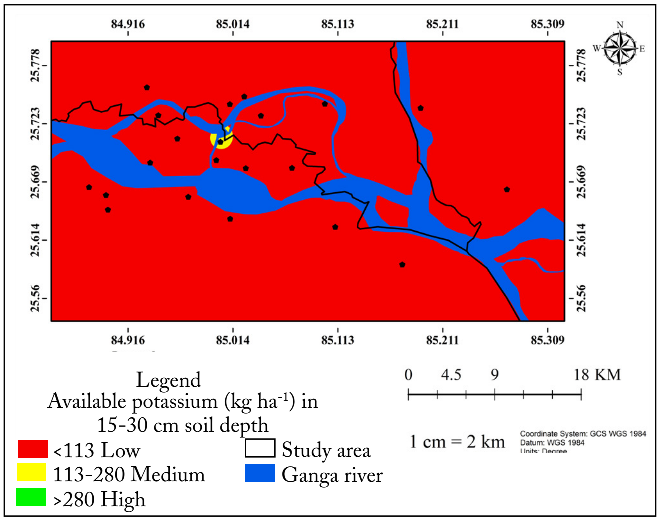

Figure 13: Distribution of soil avail. K at 15-30 cm

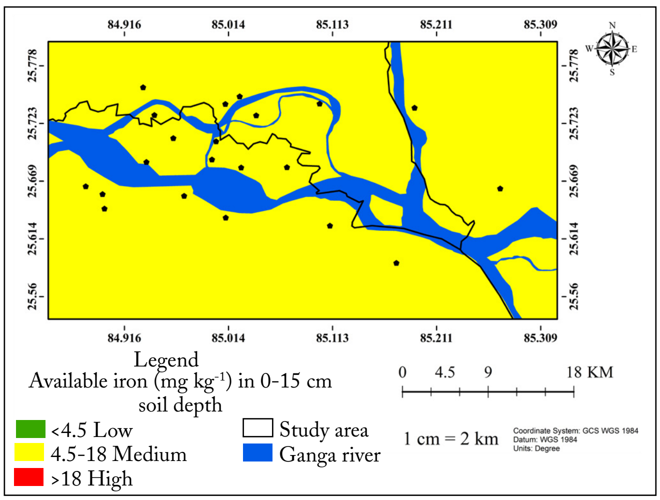

Figure14: Distribution of soil avail. iron at 0-15 cm

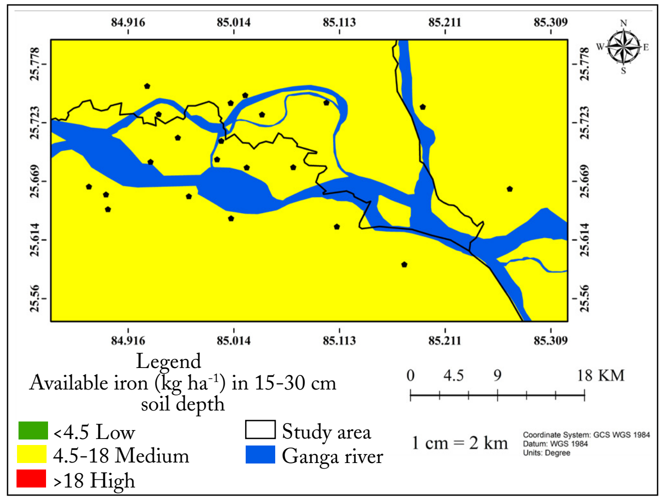

Figure 15: Distribution of soil avail. iron at 15-30 cm

(4.5–18 mg kg^{-1}) with 5.43 and 5.06 mg kg^{-1}. Available iron content recorded decreased with depth, this might be due to accumulation of humic materials in the surface layers, which may chelate the iron to surface layer.

3.3. Descriptive analysis and correlation among selected soil properties

The descriptive statistics of soil parameters at surface (0–15 cm) sub-surface (15–30 cm) is depicted in the Table 2. The mean value of pH (8.03 and 8.11) was lower than the median value (8.1 and 8.3) and mode value (8.3) was higher than the medium value in surface and sub-surface soil. Standard deviation of soil pH was 0.34 and 0.35. The data of Skewness and Kurtosis was reported negative (-0.72) and (-0.55) is presented in Table 2. The median data of available nitrogen, phosphorus, potassium and iron was found to be less than mean value, whereas the median

Table 2: Descriptive statistics (n=21) of soil chemical properties at the depth of 0-15 cm and 15-30 cm

	Min.		Max.		Mean (μ)		Median		Mode		SD (σ)		Skewness		Kurtosis	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
pH	7.3	7.4	8.5	8.8	8.03	8.11	8.1	8.3	8.3	8.3	0.34	0.35	-0.72	-0.247	-0.55	-0.641
EC	0.11	0.13	0.63	o.90	0.37	0.39	0.40	0.33	0.11	0.21	0.16	0.23	-0.38	1.27	-1.15	0.184
OC	0.35	0.31	1.08	0.73	0.63	0.50	0.62	0.46	0.49	0.43	0.17	0.123	0.64	0.406	0.42	-1.129
Avail. N	62.0	37.2	225.0	150.0	133.7	97.85	132.5	102.0	62.0	125.0	46.49	34.64	-0.12	-0.22	-0.73	-1.276
Avail. P	11.0	9.5	43.3	24.0	17.17	15.02	15.6	14.5	15.60	16.5	6.83	3.41	3.01	1.007	11.15	1.627
Avail. K	28.1	18.9	218.3	216.0	98.14	69.40	79.4	42.1	112.5	74.3	62.35	53.75	0.75	1.504	-0.64	1.677
Avail. Fe	5.43	5.06	17.93	15.86	8.10	7.69	7.66	7.26	N/A	N/A	2.74	2.24	2.54	2.51	8.09	8.74

1: 0-15 cm; 2: 15-30 cm

value of other parameters *viz.* pH and EC recorded higher than mean value. Standard deviation of available nitrogen, phosphorus and available iron was found equal to 1/3 of mean indicating the non-normality of the distribution of parameter of data as mentioned in Table 2. In case of sub-surface soil, the value of kurtosis was recorded negative values with pH, OC, available N whereas, positive data recorded with EC, available P, K and Fe respectively. This finding is in conformity with the observations made by Behra et al. (2017) and Kingsley et al. (2019).

The correlation coefficient between soils parameters were analysed and are presented in Table 3. It is observed that soil organic carbon content was positively and significantly correlated with available N, P and K content. The negative and siginificant correlation was also noticed with available iron content and soil pH at 0–15 cm soil depth as depicted in Table 3.

Table 3: Correlation matrix based on pearson's correlation coefficients soil chemical properties

	pH		EC		OC		Avail. N		Avail. P		Avail. K		Avail. Fe	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
pH	1.000	1.000												
EC	0.063	-0.203	1.000	1.000										
OC	0.206	-0.036	-0.076	0.003	1.000	1.000								
Avail. N	0.373	0.259	-0.084	-0.002	0.882**	0.684**	1.000	1.000						
Avail. P	0.104	-0.069	-0.039	0.033	0.686**	0.666**	0.478*	0.478*	1.000	1.000				
Avail. K	0.263	0.235	0.424	-0.257	0.301	0.520*	0.331	0.331	0.146	0.451*	1.000	1.00		
Avail. Fe	-0.457*	-0.518*	-0.225	-0.212	-0.073	-0.006	-0.185	-0.185	-0.006	-0.046	-0.253	-0.239	1.00	1.00

4. CONCLUSION

Soils were slightly alkaline in nature in the soil of Gangatic plains. As the soil samples were taken from surface as well as subsurface zone and it shows the clear decline in organic carbon as the depth has increased andthese results also shown the effect on available nitrogen content and rest of soil nutrients like phosphorus, potassium and iron also. To improve the soil nutrient status, it is very important to use organic manures in agricultural land for upmost benefits. As these spatial mapping techniques are extremely useful in future planning and policy makers can also use it to adopt the better techniques to improve the crop production and maintain the soil health for future prospective.

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