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Assessment of Soil Fertility Status in Gomati and South Tripura District, Tripura, India

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Authors' contributions

This work was carried out in collaboration among all authors. Authors UT and AK collected the soil samples and recorded field observations. Author NP designed the study, supervised the laboratory analysis, performed data interpretation and prepared the manuscript. Authors GR and SM assisted in data analysis, map preparation and literature compilation. Author UM contributed to field coordination and logistical support. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Geo-referencing of the important physico-chemical and nutrient parameters of Gomati and South Tripura is the prime objective of this study.

Study Design: Random sampling followed by laboratory tests of important properties of soil were derived to conduct a cross-sectional survey of soil fertility.

Place and Duration of Study: This experiment was carried out in Gomati and South Tripura districts of Tripura, India. The entire work was commenced at the College of Agriculture, Tripura during November, 2024 to June 2025.

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Methodology: Using random sampling method, geo-referenced soil samples (0-15 cm depth) were collected followed by dried (air-drying), sieved (2 mm) and inspected with regard to texture, bulk density, water-holding capacity, soil penetration, pH, electrical conductivity, soil organic carbon and available N, P_2O_5, K_2O, Ca+Mg, S and CEC using standard methods of analysis. Correlation analysis and descriptive statistics were carried out. Inverse Distance Weighting (IDW), the special interpolation technique has been used for predicting the values of non-sampled periphery of the sampled locations.
Results: Primarily most soil textured as sandy loam with bulk density ranging within 1.10-1.60 mg m^{-3}; pH was ranged extremely acidic to strongly acidic (4.14-5.70) and Organic carbon ranged from 0.45-2.65%. Available nutrients were diversified: Nitrogen (87.81-225.79 kg ha^{-1}), Phosphate (7.70-43.63 kg ha^{-1}), Potash (60.58-451.89 kg ha^{-1}), Calcium & Magnesium (157.01-753.67 kg ha^{-1}) and Sulphur (0.07-18.92 kg ha^{-1}) but CEC had a mean of 12.29-20.84 cmol kg^{-1}. The correlation coefficient is closely related between SOC and available N (r = 0.574) and between CEC and Ca+Mg (r = 0.999).
Conclusion: Gomati and South Tripura are mostly made up of sands and loam soils that are highly acidic with lower availability of nitrogen, phosphate, calcium, magnesium and sulphur; but possess medium CEC due to moderate to high SOC levels. Sustainable crop production in these districts can be advocated to be done using soil acidity-tolerant legumes, site-specific nutrient management and GIS-based mapping of soil fertility.

Keywords: Acidic soils; geo-referenced sampling; soil physico-chemical properties; IDW; Tripura.

1. INTRODUCTION

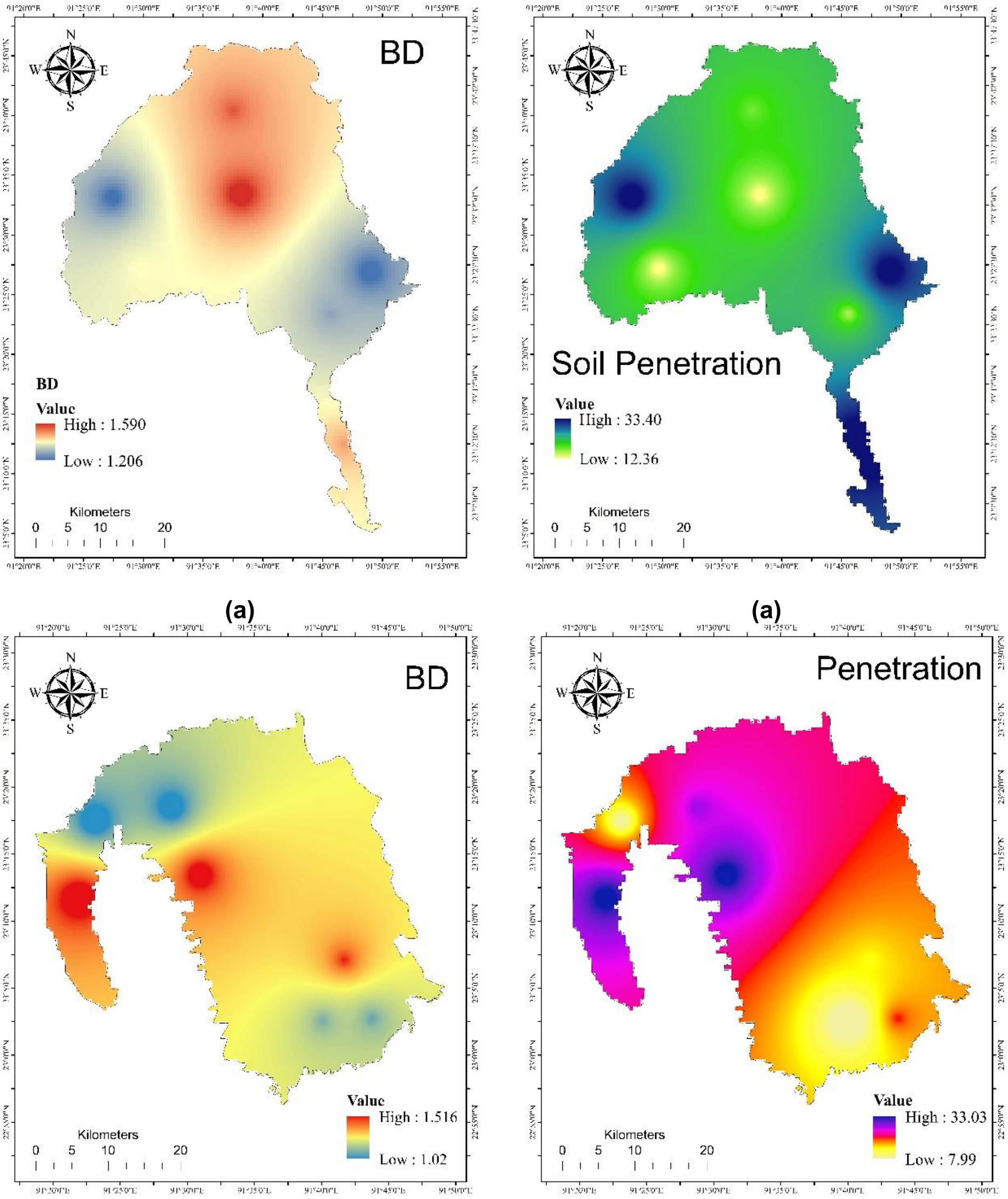
The basic prerequisite to develop a soil information system (SIS) is to have big datasets. The present day information system of any resources requires physical existence in terms of latitude and longitude, exact referencing can only be possible with GIS and the geo-referenced soil information system (GeoSIS) can be projected (Saleh et al., 2023). Tripura is one of the advance states of North East India and the datasets of its soil has been prepared and stored with National Bureau of Soil Survey & land Use Planning during past decade without use of new surveying techniques like Global Positioning System (GPS) and Geographic Information System (GIS).

Soil fertility evaluation is the 'fundamental decision making tool' for efficiently planning a specific land use system. Soil testing offers information about nutrient status-availability, which is a precursor to make fertilizer recommendations for sustainable crop productivity. Soil analysis comprises physical features (texture, bulk density, water holding capacity and so on) as well as chemical properties (pH, SOC, available macronutrients and so on), which are required for long-term soil management (Patil et al., 2016). According to Wilding & Lin (2006), soil contains various amounts of air, water, minerals, organic materials, untold numbers of creatures and other elements that are necessary for life. The availability of nutrients to growing crop plants as well as the total amount of nutrients present, disturbs the overall crop growth and development (Shreekanthet al., 2018). Therefore, systematically regular examination is very important for the sufficiency of major, secondary and micronutrients as well as nutrient deficits. Therefore, the data from soil tests should be most accurate, collected from reliable, authentic sources of information on the availability of plant nutrients and how to modify fertilizer recommendations for different crops. For the purpose of creating thematic soil fertility maps, the old database has been privileged to collect soil samples using GPS (Mishra et al., 2016). Soil fertility is assessed using the physical and chemical parameters: BD, water holding capacity, texture, penetration, slope, pH, Soil Organic Carbon, available nitrogen (N), phosphate (P_2O_5), potash (K_2O), Calcium (Ca), Magnesium (Mg) and Sulphur (S). For the aforementioned fertility indicators, the average weighted data from topsoil samples taken at depths ranging from 0 to 15 cm (Khaki et al., 2017) are considered for preparing fertility mapping of Gomati and South Tripura District and suggesting the best cropping pattern along with management of soil for the yield sustainability of this mild sub-tropical climatic zone.

2. MATERIALS AND METHODS

2.1 Site Description

The present investigation was conducted in the Gomati and South Tripura district, which is situated between latitude 22°75′ to 23°50′ North and longitude 91°20′ to 91°50′ East (Table 1; Fig. 1). The existing crops in the districts are rice, seasonal vegetables in plain-low lying regions along with riverbeds; rubber, tea, cashew nut *etc.* plantation in areas having less than 33% slope and forests in high altitude with >33% slope. The day temperature hovers around 30.8°C while the night temperature is 19.4°C for most of November, often dropping to 12°C during January. Monsoon is expected to occur & extend in June-September with average annual rainfall distribution of 1851 mm in Gomati and 2869 mm in South Tripura. The temperature varies from 38.4°C to 4.3°C.



(b) (b)

Fig. 1. Spatial variability of bulk density and penetration of (a) Gomati and (b) South Tripura

Table 1. Location of soil samples collected from gomati and south Tripura

Sl. No.	District	Range	Beat Name	Latitude	Longitude
S_1	Gumati	Amarpur	Bampur	23.55658	91.63606
S_2	Gumati	Ampi	Dhanlekha	23.67377	91.62537
S_3	Gumati	Karbook	BairagiDokan	23.38958	91.76004
S_4	Gumati	Silachari	Suknachari	23.20871	91.78044
S_5	Gumati	Udaipur	Paratia	23.45346	91.49557
S_6	Gumati	Udaipur	Udaipur	23.55232	91.45794
S_7	Gomati	Silachari	Ghorakappa	23.16618	91.72865
S_8	South	Kakulia	Manirambari	23.22483	91.51569
S_9	South	Bankul	Bankul	23.11821	91.69498
S_{10}	South	Satchand	Manu Bazar	23.04284	91.66868
S_{11}	South	Rajnagar	Anandapur WL	23.19595	91.36649
S_{12}	South	Rangamura	Nidaya WL	23.30189	91.33939
S_{13}	South	Bankul	Rupaichari	23.04575	91.72915
S_{14}	South	Abhoya WL	Maicherra WL	23.30785	91.48072

2.2 Soil Sampling and Analysis

Sampling (0-15 cm depth) was conducted during November, 2024 following recommended methods and stored in a polythene bag. The samples were collected along with the geo-coordinates and recorded from each location by using a global positioning system (GPS) tool. Samples were dried at room temperature and pulverised with a wooden roll on wooden plank followed by sieved at 2 mm. Then, soil samples that had been homogenized were placed in marking-cloth bags for further analysis to determine the physico-chemical properties of the soil. The standard protocols for the analysing parameters are tabulated in Table 2.

2.3 Statistical Analysis

As per the recent study, the modelled techniques were found to be suitable for performing this simple statistical analysis. These analyses included common statistical algorithms *viz.* maximum, minimum, mean, coefficient of variation and correlation. The Coefficient variation was determined by using formula:

C.V. = Standard Deviation Mean × 100

Table 2. Procedure used for physico-chemical analysis of soil

Sl. No.	Properties	Method applied	References
a) Physical Properties			
1	Particle size analysis	International Pipette method	Black (1965)
2	Bulk Density (BD)	Core sampler	Black (1965)
3	Water Holding Capacity (WHC)	Keen Raczkowski Box	Black (1965)
4	Soil penetration (N value)	SPT method	Selvam (2020)
b) Chemical Properties			
1	Soil reaction (pH)	pH meter	Jackson et al. (1973)
2	Electrical Conductivity (dS m^{-1})	EC bridge	Jackson et al. (1973)
3	Organic Carbon (%)	Wet oxidation method	Walkley & Black (1934)
c) Available nutrient			
1	Available N (kg ha^{-1})	Alkaline $KMnO_4$ method	Subbiah &Asija (1956)
2	Available P (kg ha^{-1})	Bray &Kurz Method	Bray &Kurz (1945)
3	Available K (kg ha^{-1})	Ammonium acetate method	Hanway&Heidel (1952)
4	Available Ca+Mg (kg ha^{-1})	EDTA Method	Cheng & Bray (1951)
5	Available S (kg ha^{-1})	Calcium chloride method	Chesnin&Yien (1951)
6	Cation Exchange Capacity (CEC)	Ammonium acetate method	Lewis (1949)

And the correlation coefficient was determined by using the formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where,

r = Correlation coefficient
SP (*xy*) = Sum product of *x*, *y* variables
SS (*x*) = Sum of square of *x* variable
SS (*y*) = Sum of square of *y* variable.

3. RESULTS AND DISCUSSION

3.1 Physical Properties

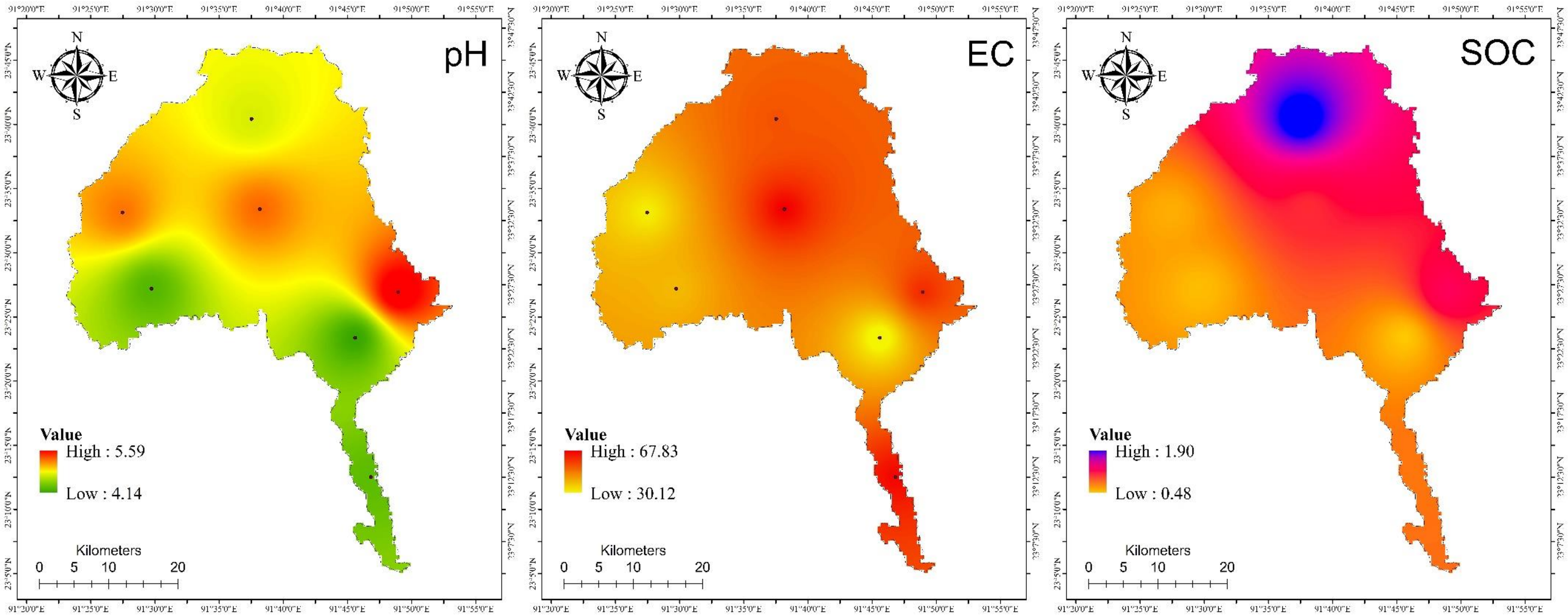
In both Gomati and South Tripura, the sand, silt and clay content of samples ranged from 8-61, 5-63 and 4-47 (Table 3) respectively following no definite trend. The bulk density (BD) ranged from 1.10 to 1.60 mg m^{-3}; whereas water holding capacity was mostly at nearly in the optimum range. The ratio of Sand-Silt-clay reflected most sites were sandy loam type. The CV value of BD, WHC and Sand were in acceptable range and reflected the basic parent soil type of the study area (Gökbulak&Özcan, 2008). Topographical variability affected the formation and range of silt and clay, reflected at a higher range of CV value (Khan et al., 2013). The BD exhibited positive significant correlation ($r = 0.662^{**}$) with sand; whereas silt and clay are negatively correlated ($r = -0.644^{*}$). A similar result was experienced by Wang et al. (2024).

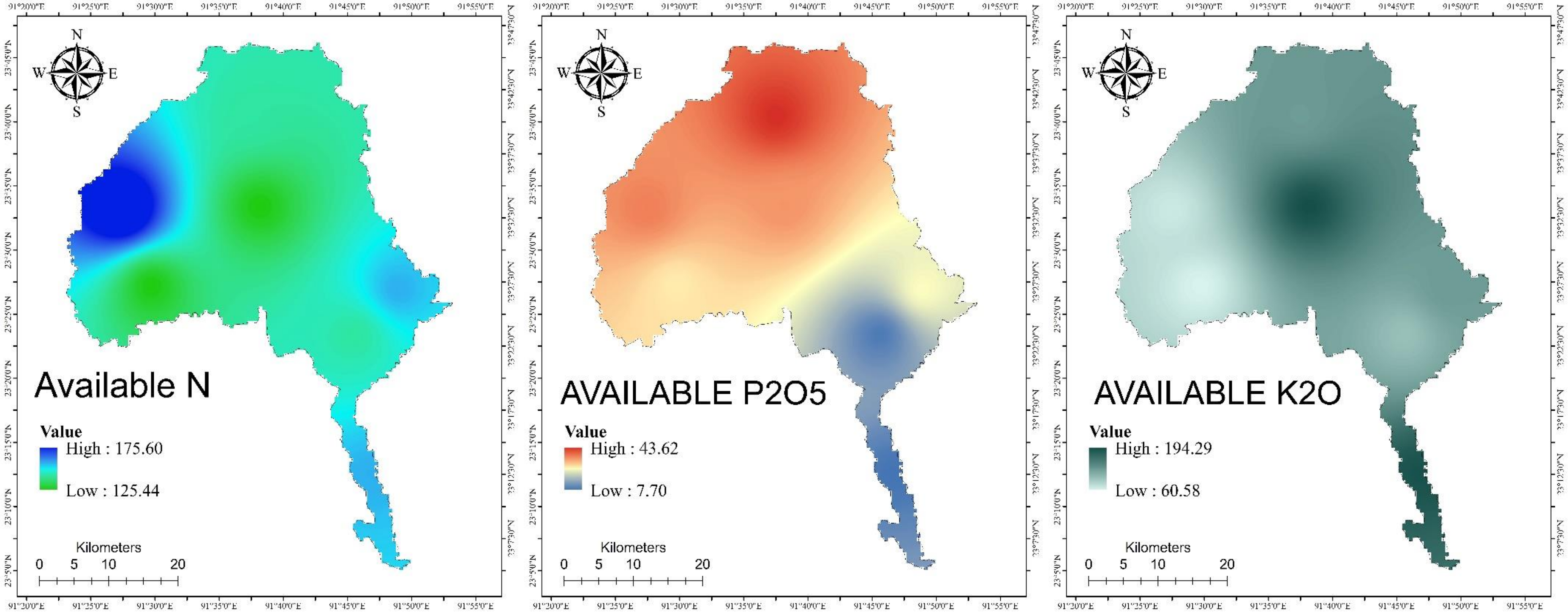
3.2 Chemical Properties

The pH range of sampling area ranges from 4.14 to 5.70 with a mean value of 4.59 (Table 4). The result indicated an extremely acidic pH with a safe limit of electrical conductivity in the entire study area. Intensive rainfall followed by erosion and leaching and or percolation were the reasons for acidity and low EC (Makineciet al., 2015). EC is negatively correlated with available N ($r = -0.690^{**}$) due to the effect of low pH on nutrient dynamics, where high acidity limits the availability of NH_4^+ even when EC is elevated (Kim & Park, 2024). The level of organic carbon from 0.45 to 2.65 existed in the study area, which covered exhaustive farming to virgin or forest or plantation area (Kaushik et al., 2018). Tripura is second highest in rubber production in India and the age of the rubber field might be responsible for the high range of SOC at Manirambari, Dhanlekha, Maicherra WL areas. SOC was lower in young plantations but gradually increased with rubber plantation age as equivalent to that of a natural forest (Nguyen et al., 2020).

3.3 Nutrient Status

The soil in the research region unveiled the range of available nitrogen content, spanning from 37.63 to 225.79 kg ha^{-1}, while mean value is 137.98 kg ha^{-1} (Table 4). Among the sites, the highest level (225.79 kg ha^{-1}) was found at no. S_8Manirambari which also reflected the highest range of 2.65% SOC. Dense rubber cultivation along with synthetic fertilisation, might be the reason for this result as observed by Jinet al. (2024). The universal truth of positive correlation between SOC and available N was re-established in such acidic soil representing the responses of Bharteeyet al. (2023). The wide variations of available P2O5 (7.70 to 43.63 kg ha^{-1}) with mean value of 22.31, resulted in a higher CV (44.34) and a positive correlation with pH.Suknachari (7.70 kg ha^{-1}) reflected the lowest P2O5 with a pH level of 4.30. This established the truth of a negative relation between acidity and available P2O5 (Bharteeyet al., 2017). The status of available potassium ranged from 60.58-451.89 kg ha^{-1}, having a mean value of 173.93 kg ha^{-1}. No. S_8Kakulia has the maximum potassium content, while No. S_5Paratia has the lowest potassium content. 57% of the soil samples had medium, 28% low and 14% had high potassium content. Such a trend in hilly high rainfall subtropical areas had been controlled by SOC and potassium buffering capacity took the lead role on the availability of potash (Gautam et al., 2023; Grandoet al., 2025). The range of available Ca+Mg was 157.01 to 753.67 kg $ha^{-1,}$ having a mean value of 441.47. This range existed in the lower Ca+Mg range, as per the limit proposed in the recent study. Subtropical climate with high rainfall might be the reason for low base saturation as also observed by Grandoet al. (2025). Also the range of available S (0.07 to 18.92 kg ha^{-1}) also existed at a lower range, which might be due to parent soil characteristics along with high rainfall. Paul and Mukhopadhyay (2015) proved that organic S is the most predominant fraction of S and occurs as a major native S reserve. CEC ranges from 12.29 to 20.84 cmol(p+) kg^{-1} where the mean value is 15.66 cmol(p+) kg^{-1}. Only Maicherra WL no. S_{14} reflected lower range and rest areas represented medium range of CEC with CV value of 13.72. CEC was significantly correlated with Ca+Mg ($r = 0.999^{**}$) as re-assessed by Grandoet al. (2025) (Table 5).


pH
Value
High : 5.59
Low : 4.14
Kilometers
0 5 10 20
EC
Value
High : 67.83
Low : 30.12
Kilometers
0 5 10 20
SOC
Value
High : 1.90
Low : 0.48
Kilometers
0 5 10 20
N
S
E
W


Available N
Value
High : 175.60
Low : 125.44
Kilometers
0 5 10 20
AVAILABLE P2O5
Value
High : 43.62
Low : 7.70
Kilometers
0 5 10 20
AVAILABLE K2O
Value
High : 194.29
Low : 60.58
Kilometers
0 5 10 20

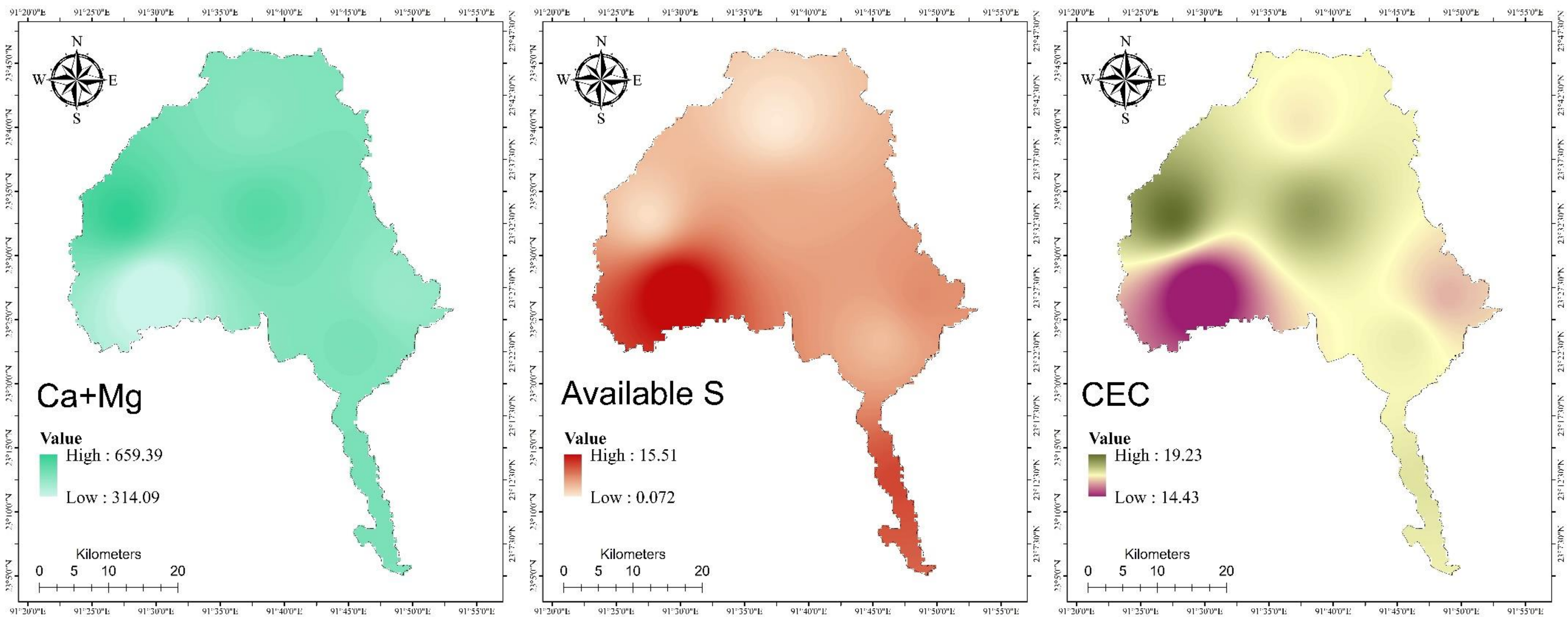
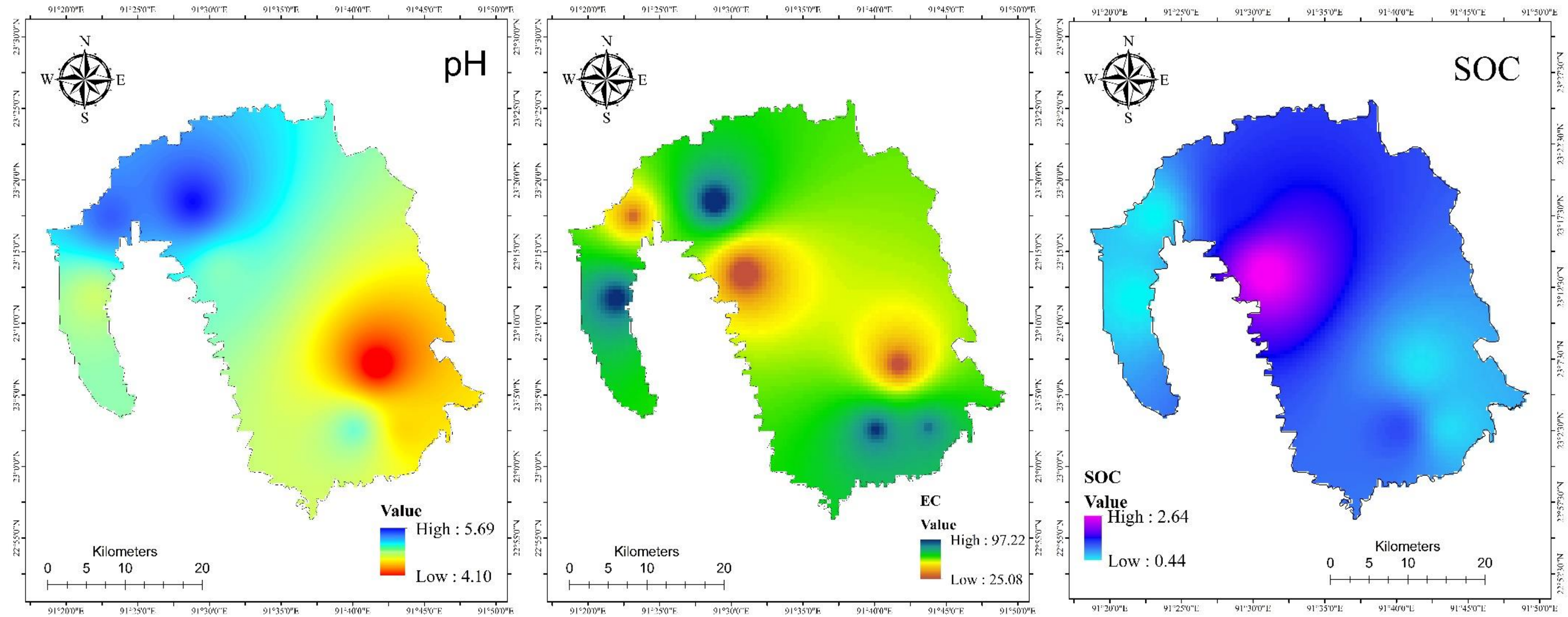
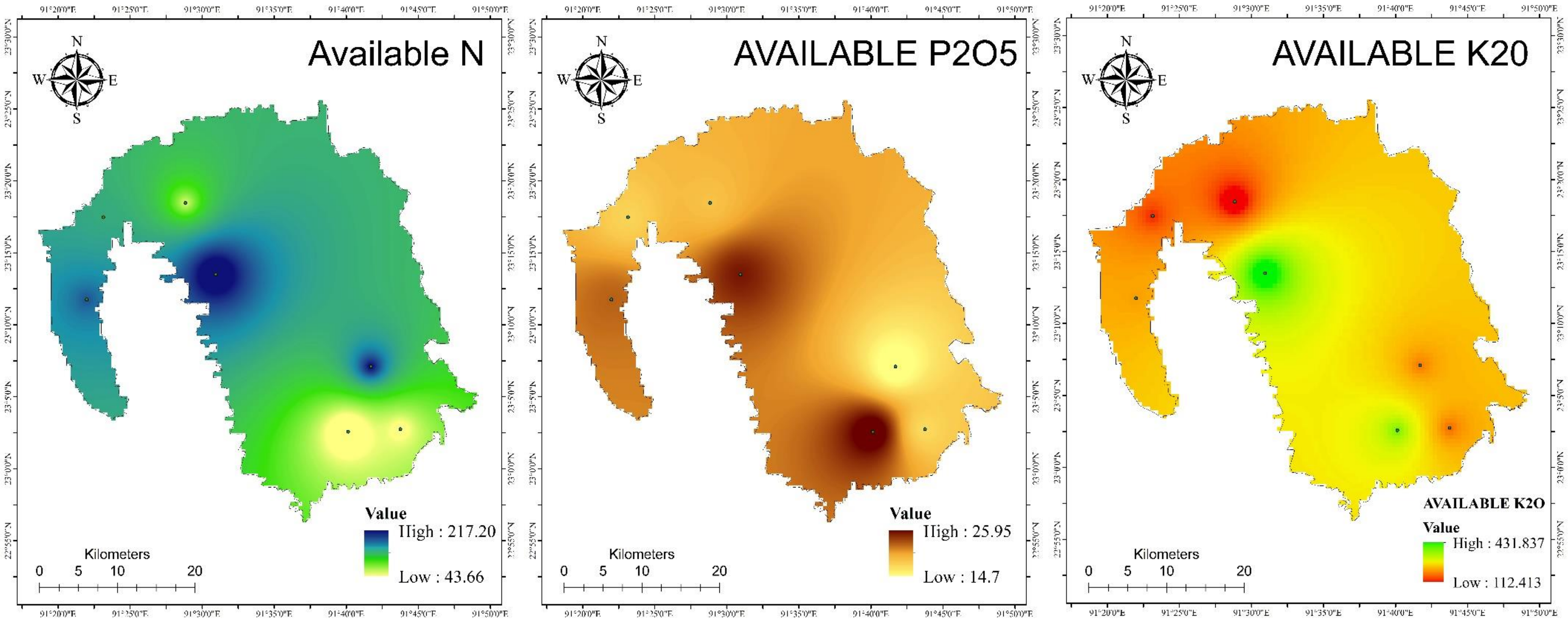


Fig. 2. Spatial variability maps of pH, EC, SOC, available N, P_2O_5, K_2O, Ca+Mg, S & CEC of Gomati District


pH
N
W
E
S
Value
High : 5.69
Low : 4.10
Kilometers
0 5 10 20
EC
Value
High : 97.22
Low : 25.08
SOC
SOC
Value
High : 2.64
Low : 0.44


Available N
N
W
E
S
Value
High : 217.20
Low : 43.66
Kilometers
0 5 10 20
AVAILABLE P2O5
Value
High : 25.95
Low : 14.7
AVAILABLE K20
AVAILABLE K2O
Value
High : 431.837
Low : 112.413

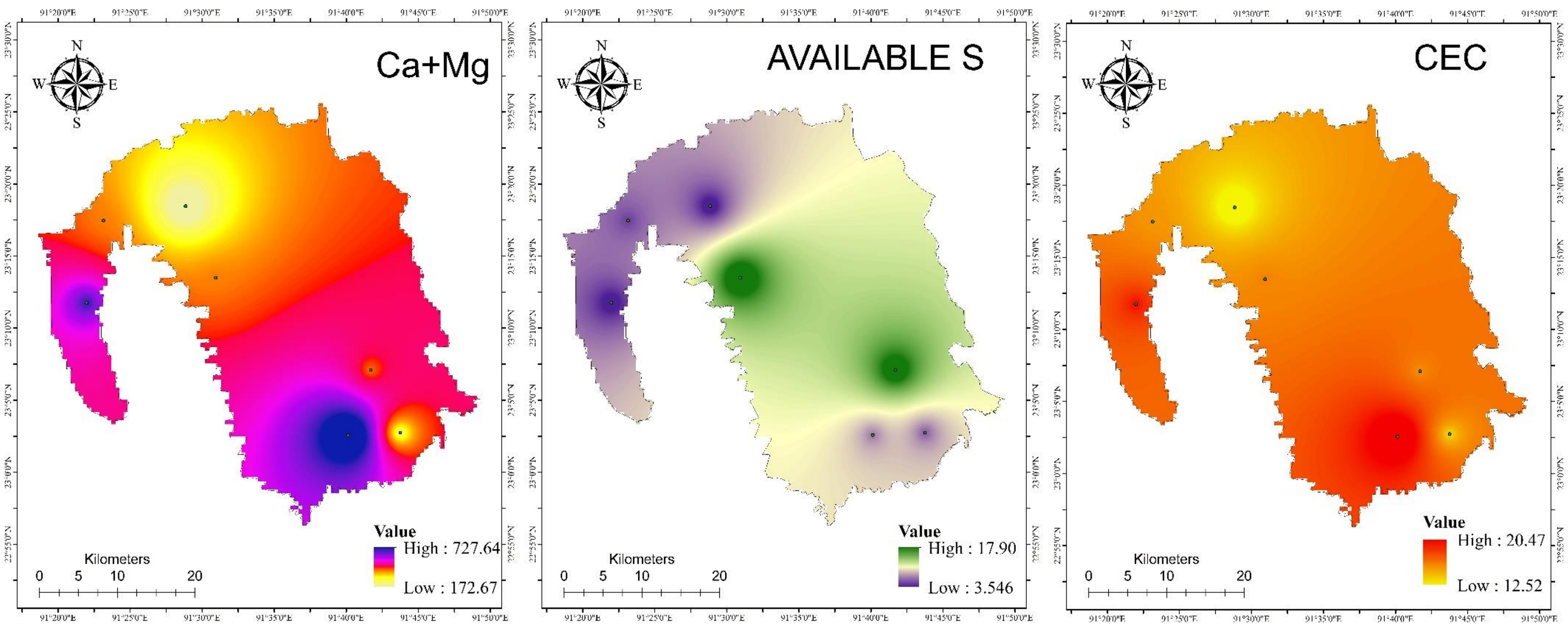


Fig. 3. Spatial variability maps of pH, EC, SOC, available N, P_2O_5, K_2O, Ca+Mg, S & CEC of South Tripura District

Table 3. Physical properties of soils of Gomati and South Tripura

Sl. No.	Beat Name	BD (mg m^{-3})	Water holding capacity (%)	Soil penetration (N value)	Sand (%)	Silt (%)	Clay (%)
S_1	Bampur	1.60	37.00	12	60	5	35
S_2	Dhanlekha	1.50	47.54	17	52	44	4
S_3	BairagiDokan	1.30	76.00	15	54	41	5
S_4	Suknachari	1.45	45.00	34	51	39	10
S_5	Paratia	1.39	65.00	12	47	34	19
S_6	Udaipur	1.21	33.00	32	37	31	32
S_7	Ghorakappa	1.20	76.00	32	56	39	5
S_8	Manirambari	1.51	65.21	34	61	35	4
S_9	Bankul	1.43	76.45	18	49	11	40
S_{10}	Manu Bazar	1.22	67.45	7	42	42	16
S_{11}	Anandapur WL	1.54	71.00	34	48	41	11
S_{12}	Nidaya WL	1.10	73.76	12	8	63	29
S_{13}	Rupaichari	1.21	43.34	23	44	9	47
S_{14}	Maicherra WL	1.11	54.23	27	41	49	10
	SD	*0.16*	*14.99*	*9.54*	*12.61*	*15.54*	*14.21*
	mean	*1.26*	*56.40*	*21.24*	*44.17*	*34.50*	*18.75*
	CV	*12.79*	*26.57*	*44.90*	*28.55*	*45.03*	*75.80*

Table 4. Chemical and nutrient properties of analytical soil samples

Sl. No.	Beat Name	EC (µS cm^{-1})	pH	SOC %	Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})	Avail. (Ca+Mg) (kg ha^{-1})	Avail. S (kg ha^{-1})	CEC (cmol kg^{-1})
S_1	Bampur	67.90	5.20	0.98	125.44	34.66	194.32	596.65	4.17	18.51
S_2	Dhanlekha	55.90	4.70	1.91	137.98	43.63	125.43	502.45	0.07	17.12
S_3	BairagiDokan	29.90	4.14	0.49	137.98	8.62	97.29	533.85	3.21	17.52
S_4	Suknachari	66.70	4.30	0.78	150.53	7.70	191.13	533.85	9.68	17.63
S_5	Paratia	41.50	4.26	0.53	125.44	27.38	60.58	314.03	15.52	14.43
S_6	Udaipur	34.00	5.17	0.59	175.62	36.62	67.50	659.46	1.00	19.23
S_7	Ghorakappa	61.90	5.60	1.17	150.53	25.28	125.43	471.04	5.92	16.68
S_8	Manirambari	20.80	5.06	2.65	225.79	24.24	451.89	376.83	18.92	15.75
S_9	Bankul	28.70	4.10	0.55	188.16	14.72	196.82	376.83	17.30	15.46
S_{10}	Manu Bazar	88.90	5.10	1.25	37.63	25.97	330.33	753.67	6.57	20.84

Sl. No.	Beat Name	EC (μS cm^{-1})	pH	SOC %	Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})	Avail. (Ca+Mg) (kg ha^{-1})	Avail. S (kg ha^{-1})	CEC (cmol kg^{-1})
S_{11}	Anandapur WL	93.40	4.88	0.45	163.07	21.99	217.12	533.85	3.55	17.66
S_{12}	Nidaya WL	38.70	5.54	0.47	137.98	17.72	161.28	376.83	5.42	15.42
S_{13}	Rupaichari	81.70	4.62	0.59	75.26	17.46	188.39	282.63	5.92	14.14
S_{14}	Maicherra WL	100.20	5.70	1.44	87.81	18.70	99.64	157.01	3.12	12.29
	SD	*25.35*	*0.53*	*0.63*	*45.84*	*9.89*	*101.80*	*153.12*	*5.77*	*2.15*
	mean	*55.70*	*4.59*	*0.96*	*137.09*	*22.31*	*173.93*	*441.47*	*7.08*	*15.66*
	CV	*45.51*	*11.45*	*65.15*	*33.44*	*44.34*	*58.53*	*34.68*	*81.52*	*13.72*

Table 5. Correlation between physico-chemical and nutrient properties of Gomati and South Tripura

	Pearson Correlations														
	BD	**WHC**	**N value**	**Sand**	**Silt**	**Clay**	**EC**	**pH**	**SOC**	**N**	**P_2O_5**	**K_2O**	**Ca+Mg**	**S**	**CEC**
BD	1	-0.144	0.093	0.662**	-0.416	-0.133	-0.134	-0.445	0.228	0.454	0.234	0.325	0.241	0.283	0.256
WHC		1	-0.163	-0.103	0.38	-0.324	-0.21	-0.083	-0.079	0.141	-0.438	0.174	-0.148	0.371	-0.137
N value			1	0.26	0.047	-0.283	0.07	0.163	0.206	0.531	-0.129	0.114	-0.132	0.036	-0.125
Sand				1	-0.507	-0.334	-0.009	-0.33	0.407	0.242	0.121	0.24	0.14	0.234	0.152
Silt					1	-0.644*	0.044	0.362	0.138	-0.05	-0.098	-0.091	-0.031	-0.254	-0.036
Clay						1	-0.04	-0.102	-0.513	-0.161	0.000	-0.113	-0.09	0.07	-0.095
EC							1	0.343	-0.055	-0.690**	-0.001	-0.01	-0.012	-0.451	-0.013
pH								1	0.315	-0.159	0.332	0.08	-0.043	-0.38	-0.038
SOC									1	0.192	0.372	0.574*	-0.084	0.194	-0.052
N										1	0.013	0.162	-0.041	0.407	-0.032
P2O5											1	-0.079	0.306	-0.309	0.298
K2O												1	0.165	0.481	0.218
Ca+Mg													1	-0.319	0.999**
S														1	-0.29
CEC															1

***Correlation is significant at the 0.01 level (2-tailed).*
**Correlation is significant at the 0.05 level (2-tailed)*

Among various geostatistical analytical tools, Inverse Distance Weighting (IDW) is most common and this technique is used for creating maps of the physico-chemical properties of Gomati and South Tripura districts, depicted as Fig. 2 and Fig. 3, respectively.

4. CONCLUSION

It can be concluded that Gomati and South Tripura district soil can be classified as sandy loam and clay loam with an extreme to strongly acidic pH. 50% soil samples had high organic carbon, 28% medium, 22% low and 100% low available nitrogen, phosphate, calcium sulphurand magnesium. All the sites reflected medium CEC range due to higher levels of SOC. Intensive plantation as well as rice-fallow cropping pattern in this region, created such a result. Considering soil textural classes, policy makers can introduce acidic soil suitable leguminous crops in rice-fellow cropping pattern. Application of crop specific bio-fertilizer will increase the productivity and make an additional return to the farmers. Soil mapping using GIS may generate an idea about the soil fertility state and it could be very useful for fertilizer management for a specific area simply by applying previously analysed soil data, leading to site-specific smart nutrient management. At plantation sites, at least 2-tier cropping systems like Sal/Segun-black pepper, Sal-pineapple *etc*. can be established to uplift the socio-economic status of the forest dwellers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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