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AVAILABLE MICRONUTRIENTS STATUS IN RELATION TO SOIL PROPERTIES IN NEW ALLUVIAL ZONE OF WEST BENGAL INDIA

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ABSTRACT

This study was conducted to investigate the relationship between available micronutrients in soil and soil properties in the newly formed alluvial zone of West Bengal. The research covered three districts Murshidabad, Nadia, and Hooghly focusing on rice-based cropping systems. A total of 96 surface soil samples (0–15 cm depth) were collected using geo-referenced points. The soil pH ranged from 4.1 to 8.01, with most soils (about 96%) being neutral to strongly acidic. Electrical conductivity (EC) values were low (0.21 to 0.61 dSm^{-1}), indicating no major salt problems. Organic carbon levels ranged from 0.18% to 1.23%, showing mostly low to medium fertility. Micronutrient concentrations differed among samples: zinc (Zn) ranged from 0.054 to 13.16 mg kg^{-1}, copper (Cu) from 0.413 to 15.3 mg kg^{-1}, iron (Fe) from 33.44 to 352.80 mg kg^{-1}, manganese (Mn) from 5.04 to 207.5 mg kg^{-1} and boron (B) from 0.077 to 1.77 mg kg^{-1}. The results showed that these soils generally contain sufficient levels of Cu, Fe, and Mn, but Zn and B are usually low to moderate. Correlation analysis demonstrated that higher soil pH typically reduces the availability of micronutrients like Zn, Cu, Fe, and Mn. On the other hand, higher organic carbon concentrations correlated with increased availability of nutrients like boron.
Keywords **:** Micronutrients, soil properties, correlation, Spatial Variability Map.

Introduction

Alluvial soil, which makes up more than 46% of India's total land area, is one of the most fertile soil types in the world (Siddiqui *et al*., 2017). However, the increased agricultural activity and the widespread use of high-yield crop varieties have caused the soil to lose important micronutrients. Indian soils, according to Singh (2008), lack zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), and boron (B) to the extent of about 49%, 12%, 5%, 3%, and 33%, respectively. More recent estimates put the figure at, on average, 36.5%, 12.8%, 7.1%, 4.2%, and 23.2% of soils being Zn, Fe, Mn, Cu, and B-deficient, respectively (Shukla *et al*., 2019). Due to the extensive lack of micronutrients, it severely impacts agricultural output and presents significant health risks to both humans and animals via the food chain (Saha *et al*., 2019).

Micronutrients are essential for the metabolic processes, growth, and development of plants, serving functions as vital as those of macronutrients. For efficient plant performance, such micronutrients should be available in sufficient and bioavailable amounts above certain critical limits. Moreover, one micronutrient deficiency cannot be compensated by the addition of other nutrients. Therefore, information about the vertical distribution of cationic micronutrients in soils is required in deciding inherent supply capacity of soils as well as potential mobility of such micronutrients in the soil profile (Pati and Mukhopadhyay, 2011).

A comprehensive understanding of the chemical behaviour of micronutrients in soils requires insights into the various soil fractions that regulate their distribution between active soil components and the soil solution (Viets, 1962). Several studies have revealed that micronutrient availability is significantly and positively correlated with soil parameters such as silt content, clay content, organic carbon, and cation exchange capacity (CEC), while it is negatively correlated with sand content, calcium carbonate, and soil pH (Kumar and Babel, 2011).

In the current scenario, inefficient or indiscriminate use of fertilizers not only diminishes crop yields but also poses long-term threats to soil health and environmental sustainability. Hence, it is essential to have a good understanding of the physicochemical properties and fertility status of soils to achieve sustainable productivity and make the best use of nutrients. The present study was thus conducted to assess the distribution and status of essential micronutrients in soils; to evaluate the physical and chemical properties of soils that influence micronutrient availability and to examine the interactions between micronutrients and secondary nutrients in soil systems.

Materials and Method

Study area

The surface soil samples (0-15 cm) were collected from rice-based cropping systems of different villages of Murshidabad, Nadia and Hooghly districts of New Alluvial Zone of West Bengal. Description of the soil collection sites are given in Table 1. The collected soil samples were air dried, grinded and sieved using 2 mm nylon sieve.

Soil analysis

Soil pH was measured in 1:2.5 soil:water suspension using glass electrode pH meter (Jackson (1973). Electrical conductivity was measured in 1:2.5 soil:water supernatant solution with the help of conductivity bridge (Jackson, 1973). The oxidizable organic carbon was determined using the Chromic Acid wet oxidation method, as described in the Walkley and Black method (1934). Available cationic micronutrients (Fe, Mn, Zn and Cu) were extracted with DTPA buffer at 1:2 soil to extractant ratio (Lindsay and Norvell, 1978) and AAS estimation. Available boron measured by Hot-$CaCl_2$ extraction described by Parker and Gardner (1981).

Table 1: Location of soil sampling sites of Murshidabad, Nadia and Hooghly District.

Murshidabad District					
Location	Latitude (°N)	Longitude (°E)	Location	Latitude (°N)	Longitude (°E)
Samsherganj	24.636101	87.926949	Sagardighi	24.268893	88.15311
Samsherganj	24.654926	87.939736	Lalgola	24.441528	88.213982
Samsherganj	24.644058	87.963606	Lalgola	24.428223	88.262731
Farakka	24.724803	87.917454	Lalgola	24.411348	88.278121
Farakka	24.805092	87.890042	Lalgola	24.386662	88.291861
Farakka	24.765234	87.896511	Suti I	24.546911	88.051455
Farakka	24.784564	87.965526	Suti I	24.524913	88.025953
Raghunathganj-I	24.459986	88.05057	Suti I	24.524569	87.979483
Raghunathganj-I	24.487771	88.035354	Suti I	24.489511	87.991341
Raghunathganj-I	24.433579	88.017811	Suti II	24.622503	88.003604
Raghunathganj-I	24.435802	88.104409	Suti II	24.603763	88.046984
Raghunathganj-II	24.483908	88.079318	Suti II	24.583631	88.003243
Raghunathganj-II	24.468707	88.094183	Suti II	24.574678	87.921935
Raghunathganj-II	24.457527	88.118006	Jiaganj	24.19829	88.229694
Raghunathganj-II	24.492843	88.123687	Jiaganj	24.206274	88.310744
Sagardighi	24.265337	88.07252	Jiaganj	24.227681	88.374855
Sagardighi	24.279619	88.096942	Jiaganj	24.181796	88.414499
Sagardighi	24.232828	88.153282			
Nadia District					
Location	Latitude (°N)	Longitude(°E)	Location	Latitude (°N)	Longitude (°E)
Dogachhiya	23.548431	88.476872	Gobindapur	23.371512	88.617154
Patpukur	23.573182	88.486328	Hazrapota	23.783455	88.282332
Durgapur	23.358698	88.48838	Kadamtala	23.416475	88.482792
Kulgacchi	23.416626	88.563224	Bara Chandghar	23.781159	88.335714
Bamandanga	23.624449	88.364087	Chhotonalda	23.798174	88.364929
Bikrampur	23.643759	88.34794	Chakbehari	23.734922	88.508753
Dhopahat	23.691176	88.474145	Radhanagar	23.809461	88.454081

Chakundi	23.634719	88.246494	Palsunda	23.755981	88.376233
Ashachia	23.679966	88.240281	Baruipara	23.756044	88.405389
Jalalkhali	23.350284	88.512257	Barnia Bazar	23.729236	88.435035
Joyrampur	23.697247	88.210141	Panighata	23.720135	88.29392
Belpukur	23.479473	88.416023	Surendranathpur	23.715551	88.412622
Kanua	23.668767	88.165488	Chapra	23.517088	88.544419
Ballabhpara	23.655445	88.139345			
Hooghly District					
Location	Latitude(°N)	Longitude (°E)	Location	Latitude(°N)	Longitude(°E)
Bajua	22.950237	87.728507	Harat	22.884723	88.189642
Katali	22.892212	87.681522	Rameshwarbati	22.964586	88.131323
Amdoba	22.82616	87.734357	jagannathbati	22.708759	88.221737
Rangamati	22.866878	87.645229	Haripur	22.701933	88.169634
Dashghara	22.969848	88.022453	Kamdebpur	22.710489	88.094586
Arambag	22.884193	87.795423	Gandarpukur	22.838525	88.247923
Mothadanga	22.853994	87.851078	Bainchipota	88.247923	88.275139
Chunait	22.774789	87.860319	Choutara	22.836013	88.099242
Khanakul	22.710697	87.845141	Basudebpur	22.849916	88.107364
Parul	22.811702	87.941046	Rosna	23.030914	88.269505
Banseye	22.923893	88.278515	Pratiharpur	22.848662	88.042386
Bhanderhati	22.919595	88.094298	Duttapur	22.833581	88.017923
Paschim Narayanpur	22.90467	88.003505	Piyasara	22.819498	88.025788
Daspara	22.85292	87.96938	Champarui	23.032897	88.352106
Jangipara	22.732926	88.055854	Dadpur	23.046719	88.430175
Nilapur	22.778641	88.123975	Dwarpara	23.098104	88.418991
Nandakuthi	22.865655	88.072369	Balagarh	23.115546	88.461693

Results and Discussion

Results showed that the pH ranges between 4.1-7.5, 5.4-8.01, 4.67-7.42, 4.1-8.01, with mean values of 5.9, 7.15, 5.73, 6.19 and SD values of 0.94, 0.61, 0.64, 0.97 in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts), respectively (Table 3). The results indicated that out of 96 soil samples, about 54 soil samples showed a pH between 4.0 and 6.5. There are 35 soil samples with a pH between 6.5 and 7.5, and the remaining 7 samples have a pH above 7.5. Thus, the soil of the New Alluvial Zone is near neutral to strongly acidic in nature. Based on the ratings of pH value as suggested by Muhr *et al.*, (1965). Sagardighi village showed the lowest pH value of 4.1, while the highest pH of 8.01 was obtained from Nimtala village. Low soil pH values may result from the influence of parent material, specifically granite and sandstone as well as leaching of basic cations in soils by intense rainfall during the monsoon season Mini *et al.* (2007). According to Athokpam *et al.* (2013), acidity in soil may be caused by heavy rainfall that leaches bases from the surface soil. They also stated that the decay of organic wastes and the use of nitrogenous fertilizers accelerated the acidity of the soil.

Table 2: Rating Chart of Micronutrients in soil required for Plant growth

Nutrient level	Zn(mgkg^{-1})	Cu(mgkg^{-1})	Fe(mgkg^{-1})	Mn(mgkg^{-1})	Reference
Deficient	0.6<	<0.2	<4.5	<2.5	Lindsay and Norvell (1978)
Marginal	0.6-1.2	0.2-0.4	4.5-9.0	2.5-3.5	
Sufficient	1.2-2.4	0.4-0.8	9.0-18.0	3.5-7.0	
High	>2.4	0.8-1.6	18.0-27.0	>7.0	
Very high	-	1.6-3.2	>27.0		

Result indicated EC range varies between 0.21-0.61, 0.29-0.61, 0.23-0.49, 0.21-0.61 dSm^{-1} with the mean 0.371, 0.493, 0.325, 0.389 dSm^{-1} and SD values of 0.113, 0.078, 0.061 dSm^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts), respectively. Among all the soil samples, the lowest EC was obtained from Sarardighi, and the highest EC was obtained from Nimtala, as well as from Farakka village. No significant soluble salt was found in the soils in the study region.

Result showed that oxidizable organic carbon content (%) ranges between 0.43-0.93, 0.3-1.11, 0.18-

1.23, 0.18-1.23%, with mean values of 0.656, 0.738, 0.769, 0.72% and SD values of 0.116, 0.186, 0.276, 0.21% in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). Among all the soil samples, low OC was found in Rathtala village, and the highest OC was found at Fiderroad village.

In general, out of 96 soil samples, 7 samples were categorized as low, 7 samples were high, and the remaining 82 samples were medium OC on the basis of critical limits suggested by Muhr *et al.* (1965). The low organic carbon content of the soils is due to inadequate agricultural management practices, often caused by farmers burning agricultural leftovers, as well as the rapid breakdown and mineralisation of organic matter (Lawal *et al*., 2012). Under extremely high temperatures, organic matter decomposes, creating conditions that are highly oxidizing Kumar *et al*., (2017)

Results also showed that DTPA-Extractable Zn content range varies between 0.18-1.836, 0.612-1.582, 0.054-13.16, 0.054-13.16 mg kg^{-1} with their mean values of 0.801, 0.913, 2.342, 1.38 mg kg^{-1} and SD values of 0.376, 0.239, 2.692, 1.67 mg kg^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). The Zn availability in surface soil of the New Alluvial Zone was lowest in Mohanpat village and highest in Kabla village. Among all soil samples from the new alluvial zone, 14 samples (6.86%) are deficient, primarily from the Murshidabad district. Meanwhile, 46.87% are marginal, and the remaining 46.27% have sufficient available Zinc content. according to the rating chart given by Lindsay and Norvell (1978). The low status of zinc might be due to continuous farming and inadequate fertiliser management, which are likely to cause deficiencies Ibrahim *et al.*, 2011). The higher level of zinc may be due to the higher OC. On the other hand, since high temperatures tend to increase the solubility and mobility of zinc in the soil by promoting its release from adsorption sites, they may also contribute to this phenomenon. Conversely, because zinc is a divalent cation, a one-unit increase in soil pH dramatically reduces its solubility and mobility by a factor of 100. Krishnamurthy and Srinivasamurthy (2005).

Table 3: Variation of soil properties in studied soils

District	Soil Properties	pH	EC	OC	Zn	Cu	Fe	Mn	B
		-	dSm^{-1}	(%)	$mgkg^{-1}$				
Murshidabad	Min	4.1	0.21	0.43	0.18	0.413	50.445	10.58	0.079
	Max	7.5	0.61	0.93	1.836	5.485	242.03	117.4	1.687
	Range	4.1-7.5	0.21-0.61	0.43-0.93	0.18-1.836	0.413-5.485	50.445-242.03	10.58-117.4	0.079-1.687
	Mean	5.9	0.371	0.656	0.801	3.261	124.323	41.081	0.696
	SD	0.94	0.113	0.116	0.376	1.262	42.015	27.373	0.436
Nadia	Min	5.4	0.29	0.3	0.612	5.76	33.44	7.6	0.077
	Max	8.01	0.61	1.11	1.582	12.6	263.46	34	0.93
	Range	5.4-8.01	0.29-0.61	0.3-1.11	0.612-1.582	5.76-12.6	33.44-263.46	7.6-34	0.077-0.93
	Mean	7.15	0.493	0.738	0.913	8.23	105.812	18.711	0.466
	SD	0.61	0.078	0.186	0.239	1.575	54.25	5.615	0.215
Hooghly	Min	4.67	0.23	0.18	0.054	3.64	54.6	5.04	0.094
	Max	7.42	0.49	1.23	13.16	15.3	352.8	207.5	1.779
	Range	4.67-7.42	0.23-0.49	0.18-1.23	0.054-13.16	3.64-15.3	54.6-352.8	5.04-207.5	0.094-1.779
	Mean	5.73	0.325	0.769	2.342	7.918	219.184	45.674	0.65
	SD	0.64	0.061	0.276	2.692	2.785	78.729	39.87	0.307
Overall	Min	4.1	0.21	0.18	0.054	0.413	33.44	5.04	0.077
(irrespective of districts)	Max	8.01	0.61	1.23	13.16	15.3	352.8	207.5	1.779
	Range	4.1-8.01	0.21-0.61	0.18-1.23	0.054-13.16	0.413-15.3	33.44-352.8	5.04-207.5	0.077-1.779
	Mean	6.19	0.389	0.72	1.38	6.31	152.71	36.42	0.61
	SD	0.97	0.111	0.21	1.76	3.06	78.06	30.93	0.35

Result showed that DTPA-Extractable Cu content ranges between 0.413-5.485, 5.76-12.6, 3.64-15.3, 0.413-15.3 mg kg^{-1} with their mean values of 3.261, 8.230, 7.918, 6.31 mg kg^{-1} and SD values of 1.262, 1.575, 2.785, 3.06 mg kg^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). Among all the soil samples, the lowest available Cu was observed in Samsherganj village, and the maximum was observed in Balagarh village. The available copper content in the

New Alluvial Zone is mainly high, with an optimal mean value. according to the rating chart given by Lindsay and Norvell (1978). The chelating action and increased biological activity may be the cause of the greater copper content; similar findings were found by Jibhakate *et al.* (2009) and Shinde *et al.* (2016).

Result showed that DTPA-Extractable Fe content ranges between 50.445-242.03, 33.44-263.46, 54.6-352.8, 33.44-352.8 mg kg^{-1} with their mean values of 124.323, 105.812, 219.184, 152.71 mg kg^{-1} and SD value 42.015, 54.250, 78.729,78.06 mg kg^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). Among the three districts, available Fe was observed to be the lowest in Bamandanga and the highest in Rameshwarbati village. According to the rating chart given by Lindsay and Norvell (1978), the available Fe contents of all the soils are high; it may be the presence of iron-bearing minerals like feldspar, magnetite, hematite, and limonite, which together make up the majority of the trap rock in these soils (Kumar *et al.*, 2013).

The DTPA-Extractable Mn content range varies between 10.58-117.4, 7.6-34, 5.04-207.5, 5.04-207.5 mg kg^{-1} with their mean values of 41.081, 18.711, 45.674, 36.42 mg kg^{-1} and SD value 27.373, 5.615, 39.870, 30.93 mg kg^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). Among all the samples, the available Mn status is lowest in Chilampur village and highest in Duttapur village. According to the rating chart provided by Lindsay and Norvell (1978), the results indicated that the manganese content in all the soils is higher, which may also be attributed to the presence of parent materials that contain Mn. Comparable results were also recorded by Mandal *et al.*, (2019), Nandi *et al.*, (2024)

Hot-$CaCl_2$ extracted Boron content ranges between 0.079-1.687, 0.077-0.93, 0.094-1.779, 0.077-1.779 mg kg^{-1} with their mean values of 0.696, 0.466, 0.650, 0.61 mg kg^{-1} and SD value 0.436, 0.215, 0.307, 0.35 mg kg^{-1} in soils of Murshidabad, Nadia, Hooghly, and overall (irrespective of all districts) respectively (Table 3). Among all the samples, the boron content extracted by Hot-$CaCl_2$ is lowest in the soils of Ballabhpara village and highest in the soils of Choutara village. Considering the soil test rating for available B (<0.5 ppm as low, 0.5 to 0.75 ppm as medium and >0.75 ppm as high), out of all soil samples collected from the New Alluvial Zone, 35 samples (36.45%) are deficit, 32 samples are (33.33%) are sufficient and remaining 29 samples (30.22%) are high in Hot-$CaCl_2$ extractant Boron. The lower boron content is mainly due to intense cropping and limited use of organic manures (Sukhla *et al.*, 2021)

Correlation coefficient (r) between different physicochemical properties of soils in the New Alluvial Zone of West Bengal:

The OC was significantly positively correlated with pH (r=0.21**) (Table 4) and similar result was found by Sharma *et al.* (2003) and Kumar and Babel (2011).

The electrical conductivity of the soil was strongly and significantly positively associated with the soil pH (r=0.79*) as shown in Table 4. Mandal and Ghosh (2020) also came to a similar conclusion in the study of rice growing soil of Birbhum district, West Bengal (r= 0.486**).

The DTPA-Extractable Zn was significantly positively correlated with Iron (r=0.30*) and Manganese (r=0.48*). A similar result was reported by Mandal and Ghosh (2020) in the soil for rice cultivation of Birbhum district, West Bengal (r= 0.653**, r= 0.256** iron and manganese respectively).

Table 4: Correlation coefficient (r) between different physicochemical properties of soils in new alluvial zone of West Bengal

	pH	OC	EC	Zn	Cu	Fe	Mn	B
PH	1.00							
OC	0.21**	1.00						
EC	0.79*	0.09	1.00					
Zn	-0.12	0.17	-0.19	1.00				
Cu	-0.19*	0.32*	0.10	0.09	1.00			
Fe	-0.43*	0.07	-0.44*	0.30*	0.16	1.00		
Mn	-0.22**	0.03	-0.26**	0.48*	-0.09	0.15	1.00	
B	-0.19	0.14	-0.10	0.02	-0.08	0.20	0.11	1.00

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

The DTPA-extractable Cu also showed a significant positive correlation with organic carbon (r = 0.32). The availability of copper (Cu) is increased with the content of organic matter in the soil. The reason is that copper makes a neat combination with organic matter to form soluble complexes. Since the complexation ultimately prevents copper from becoming "fixed" or inaccessible in the soil, it therefore increases copper's solubility and consequently, plant accessibility. A similar result was found by Mandal and Ghosh (2020) in rice growing soil of Birbhum district, West Bengal (r=0.546*), Ray and Banik (2016) also obtained the same result (r= 0.47**) in some soils of West Bengal.

The DTPA-Extractable Cu had a significant negative correlation with pH (r=-0.19*). In other words, as the soil pH value goes up, the availability of Cu goes down. The reason for this is the precipitation of Cu2+ as a relatively insoluble hydroxide $Cu(OH)_2$. According to Somasundaram *et al*., (2009); Vasuki (2010), the inverse relationship between DTPA extractable micronutrients and soil pH is confirmed in their study. DTPA-Extractable Cu showed a significant negative correlation with pH (r=-0.54**) in soil of Malwa plateau in Rajasthan, which was documented by Sahoo *et al*. (1995).

The DTPA-Extractable Fe has a significant negative correlation with pH (r = -0.43*). Iron availability decreased with increasing pH. At higher pH, the readily Available form of iron, Fe^{2+}, oxidises into Fe^{3+}, and this Fe^{3+} ion precipitates as insoluble $Fe(OH)_3$, which is not easily available to plants. DTPA-Fe depicts a negative and significant relationship with pH (r = -0.367**) (Tundup and Akbar, 2014). Kumar *et al*., (2017) observed that soil pH was significantly and negatively correlated with available Fe (r= -0.50**). DTPA-Extractable Fe reveals a significant negative correlation with EC (r=-0.44*). Chandrakar *et al*., (2013) have reported the same result (r=-0.067*) for *Inceptisols* of Akaltara block of Janjgir district, Chhattisgarh. Ghode *et al*., (2020) also recorded similar results (r= -0.72*) for the soils of Nanded district of Maharashtra.

DTPA-extractable Mn showed a significant negative correlation with pH (r = -0.22**). It may be due to the formation of a less soluble compound, Mn(OH)2, at higher pH. Chandrakar *et al*. (2013) reported a negative and significant correlation between available Mn and soil pH (r = -0.122**). DTPA-extractable Mn showed a significant negative correlation with EC (r = -0.26**). Ray and Banik (2016) reported the same result (r=-0.80**) in the soils of different districts (Uttar Dinajpur, Dakshin Dinajpur, Malda and Murshidabad) of West Bengal. Kondvilkar *et al*. (2017) also found a similar outcome (r=-150*) in the soils of Sakri Tehsil of Dhule District, Maharashtra.

Multiple regression equations relating micronutrients with soil pH, EC, OC

Regression analysis of zinc with respect to pH, organic carbon, and EC showed an R^2 value of 0.0738, which indicates that there is 7.38 % variation in zinc with respect to pH, OC, and EC. The zinc content decreases with an increase in EC of soil, and zinc content increases with the increasing organic carbon content and pH up to a certain level.

Regression analysis of copper with respect to pH, organic carbon, and electrical conductivity showed an R^2 value of 0.1204, which indicates that there is 12.04% variation in copper with respect to pH, OC, and EC. The copper content decreases with an increase in EC of soil and copper content increases with the increasing organic carbon content and pH

Regression analysis of iron with respect to pH, organic carbon, and electrical conductivity showed that the R^2 value of 0.2297 which indicates that there is a 22.97 % variation in iron with respect to pH, OC, and EC. The iron content decreases with increasing EC and pH of the soil, and it increases with increasing organic carbon content.

Regression analysis of manganese with respect to pH, organic carbon, and electrical conductivity showed that the R^2 value of 0.0704 which indicates that there is a 7.04 % variation in manganese with respect to pH, OC, and EC. The manganese content decreases with increasing EC and pH of the soil, and it increases with increasing organic carbon content.

Regression analysis of Hot-CaCl2 extractable Boron with respect to pH, organic carbon, and electrical conductivity showed an R^2 value of 0.0832 which indicates that that there is an 8.32 % variation in iron with respect to pH, OC, and EC. Boron content decreases with an increase in the PH of the soil, and boron content increases with the increasing organic carbon content and EC.

Table 5: Multiple regression equations relating micronutrients with soil pH, EC, OC

Step-down regression equations:	$R^2 \times 100$
DTPA-Zn:	
$Y=1.46+0.01X_1-3.47X_2+1.61X_3$	7.38
DTPA-Cu:	
$Y=0.46+0.55X_1-1.74X_2+4.29X_3$	12.04
DTPA-Fe:	
$Y=319.09-23.92X_1-149.52X_2+55.66X_3$	22.97
DTPA-Mn:	
$Y=65.34-2.04X_1-59.33X_2+9.55X_3$	7.04
Hot $CaCl_2$ extractable B:	
$Y=0.99-0.14X_1+0.63X_2+0.34X_3$	8.32

Where, X1= pH; X2= EC; X3= Organic Carbon

Spatial Variability Map (Ordinary Kriging)

The spatial distribution/variability maps of pH, EC, Zn, Cu, Fe, Mn and B of three districts are prepared and presented in Figs. 1-7, which are ordinary kriging (spherical model) maps created using ArcGIS.

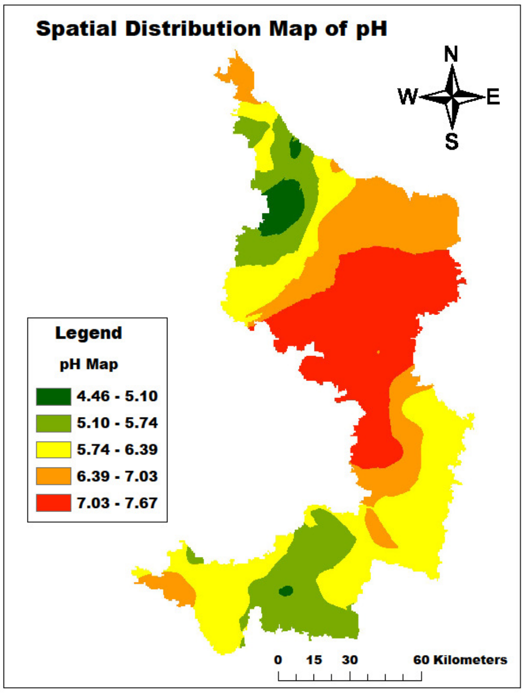

Fig. 1 : Spatial Variability Map of soil pH

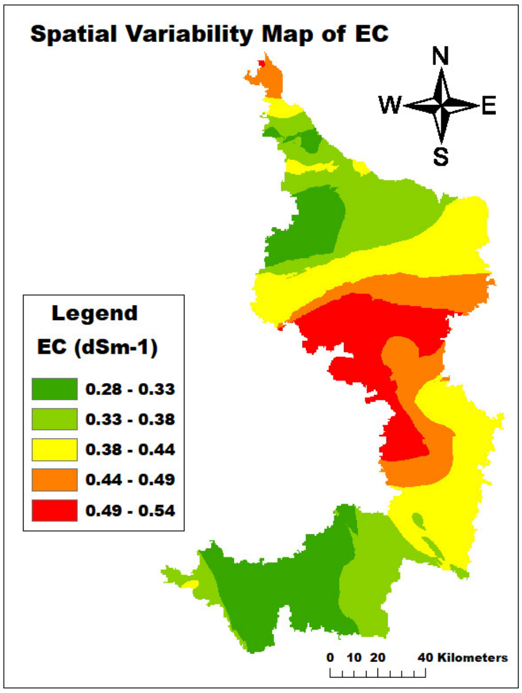

Fig. 2 : Spatial Variability Map of soil EC

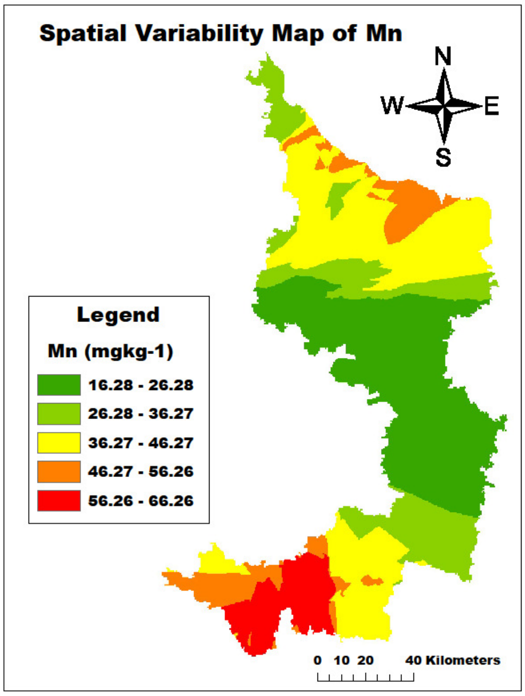

Fig. 3 : Spatial Variability Map of Available Mn

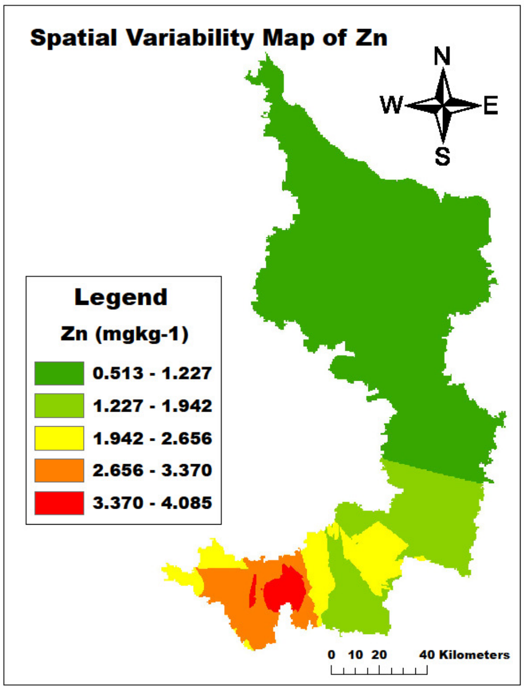

Fig. 4 : Spatial Variability Map of Available Zn

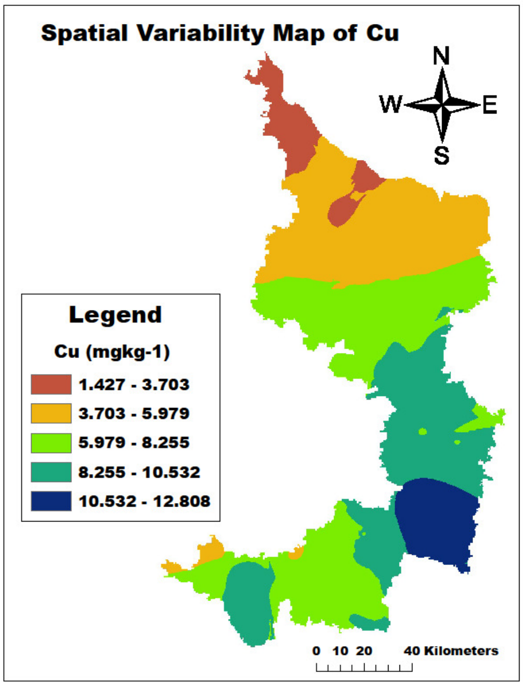

Fig. 5 : Spatial Variability Map of Available Cu

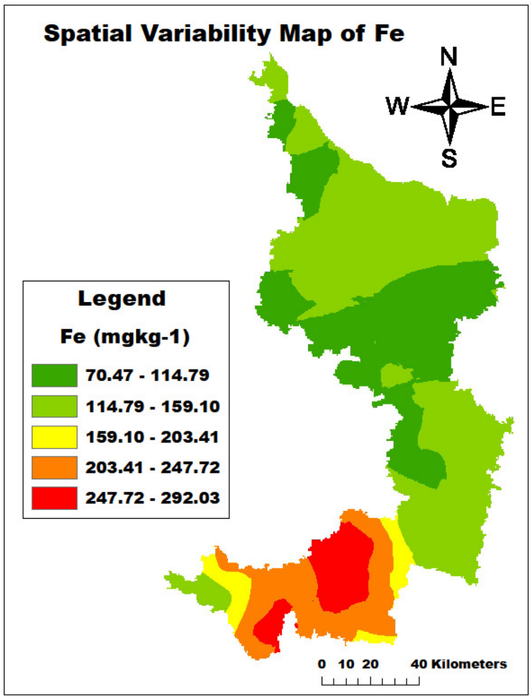

Fig. 6 : Spatial Variability Map of Available Fe

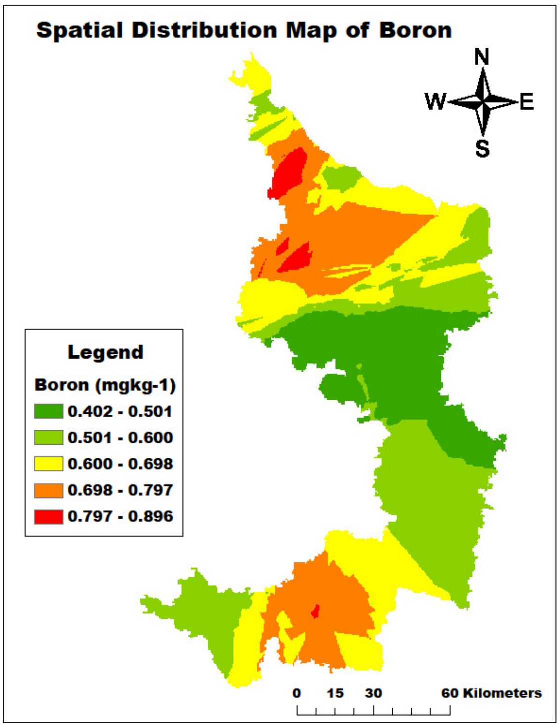

Fig. 7 : Spatial variability map of available B

Conclusion

In the new alluvial soils of West Bengal, available zinc content in soil ranges from 0.054 to 13.16 mg kg^{-1}, copper from 0.413 to 15.3 mg kg^{-1}, iron from 33.44 to 352.80 mg kg^{-1}, manganese from 5.04 to 207.5 mg kg^{-1}, and boron from 0.077 to 1.77 mg kg^{-1}. Soils are well-supplied with Cu, Fe, and Mn, but exhibit low to medium levels of Zn and B. An increase in pH is correlated with a decrease in cationic micronutrients, while organic carbon increases the micronutrient content. Zn and B are critical for soil fertility, emphasizing the need for integrated nutrient management.

References

Athokpam, H., Wani, S. H., Kamei, D., Athokpam, H. S., Nongmaithem, J., Kumar, D., Singh, Y. K., Naorem, B. S., Devi, T. R., & Devi, L. (2013). Soil macro-and micro-nutrient status of Senapati district, Manipur (India). *African Journal of Agricultural Research*, *8*(39): 4932-4936.

Chandrakar, K., Srivastava, L. K., & Devdas, D. (2013). Estimation of available micronutrients on the basis of correlation between physico-chemical properties of pH, EC, OC and available Fe, Mn, Cu and Zn in Inceptisol of Akaltara block of Janjgir district of Chhattisgarh. *An Asian Journal of Soil Science*, **8**: 416-418.

Ibrahim, A. K., Usman, A., Abubakar, B., and Aminu, U. H., (2011). Extractable micronutrients status in relation to other soil properties in Billiri Local Government Area. *Journal of Soil Science and Environmental Management*., **3**(10): 282-285.

Jackson, M.L., (1973). Method of soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi.

Jibhakate, S. B., Raut, M. M., Bhende, S. N., & Kharche, V. K. (2009). Micronutrient status of soils of Katol Tahasil in Nagpur district and their relationship with some soil properties. *Journal of Soils and Crops*, **19**(1): 143–146.

Kondvilkar, N., Thakare, R., & Annapurna, M. V. V. I. (2017). Level of significance of various chemical properties of soils in sakri tehsil of dhule district (MS). *International Journal of Chemical Studies.*, **5**(5): 1960-1967.

Krishnamurthy, R., Srinivasamurthy C.A. (2001). Distribution of some available micronutrients in black and red soils of Karnataka. *The Mysore Journal of Agricultural Sciences.*,**39**(1): 57-63.

Kumar, M. B., Subbarayappa, C. T., & Ramamurthy, V. (2017). Distribution of available (DTPA-extractable) zinc and iron and their relationship with some soil properties in rice soils of Chamarajanagar district, Karnataka, India. *International Journal of Current Microbiology and Applied Sciences*, **6**(5): 1423-1428.

Kumar, M. V., Lakshmi, G. V., & Madhuvani, P. (2013). Appraisal of soil fertility status in salt-affected soils of Ongole division, Prakasam district, Andhra Pradesh. *Journal of the Indian Society of Soil Science*, **61**(4): 333-340.

Lawal, B. A., Odofin, A. J., Adeboye, M. K. A., & Ezenwa, M. I. S. (2012). Evaluation of selected Fadama soils in Katcha local Government Area of Niger State for arable cropping. *Nigerian Journal of Soil Science*, **22**(2): 104–111.

Lindsay, W. L., and Norvell, W. A., (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America*. **42**: 421-428.

Mandal, S., & Ghosh, G. K. (2020). Distribution of DTPA-extractable micronutrients and their relationship with some soil properties in rice growing soils of Birbhum district, West Bengal, India. *International Agricultural, Biological & Life Science Conference*, **237**: 570- 593.

Mandal, S., Mondal, S., Mukherjee, A., Mukhopadhyay, S., & Ghosh, G. K. (2019). Vertical distribution of DTPA-extractable micronutrients and its correlation with soil properties in selected soil profiles of Birbhum district of West Bengal. *Science and Culture*, **85**(7-8): 281- 290.

Mini, V., Patil, P. L., & Dasog, G. S. (2007). Land evaluation of a pilot site in coastal agro-ecosystem of north Karnataka. *Journal of the Indian Society of Soil science.*, **55**(3):317-323.

Muhr, G. R., Datta, N. P., Shankarasubramoney, H., Laley, V. K., & Donahue, K. L. (1965). Soil testing in India. USAID. *New Delhi*, *120*.

Nandi, N., Ghosh, G. K., & Kundu, M. C. (2024). Availability of Cationic Micronutrients in Soils of Bankura District of West Bengal, India. *International Journal of Environment and Climate Change*, **14**(2):915-922.

Parker, D. R., & Gardner, E. H. (1981). The determination of hot‐water‐soluble boron in some acid Oregon soils using a modified azomethine‐H procedure. *Communications in Soil Science and Plant Analysis.*, **12**(12):1311-1322.

Pati, R. and Mukhopadhyay, D. (2011). Distribution of cationic micronutrients in some acid soils of West Bengal. *Journal of the Indian Society of Soil Science*. **59**(2): 125-133.

Ray, S. K., & Banik, G. C. (2016). Available micronutrient status in relation to soil properties in some villages under four agro-climatic features of West Bengal. *Journal of the Indian Society of Soil Science*, **64**(2): 169-75.

Saha, S., Saha, B., Seth, T., Dasgupta, S., Ray, M., Pal, B., ... & Hazra, G. (2019). Micronutrients availability in soil–plant system in response to long-term integrated nutrient management under rice–wheat cropping system. *Journal of Soil Science and Plant Nutrition*, **19**: 712-724.

Sahoo, A. K., Chattopadhyay, T., Singh, R. S., & Shyampura, R. L. (1995). Available micronutrient status in the soils of Malwa Plateau (Rajasthan). *Journal of the Indian Society of Soil Science*. **43**(4): 698-700.

Sharma, R. Á., Singh, M., & Sharma, J. Á. (2003). Correlation studies on micronutrients vis-à-vis soil properties in some soils of Nagaur district in semi-arid region of Rajasthan. *Journal of the Indian Society of Soil Science*, **51**(4): 522-527.

Shinde, H. B., Patil, T. D., & Thakare, R. (2016). Soil fertility status of agriculture college farm, Nandurbar (Maharashtra). *Journal of Chemical, Biological and Physical Science*, **6**(4): 1362-1369.

Shukla, A. K., Behera, S. K., & Singh, G. (2021). Micronutrient fertilizers in Indian agriculture–product profile, availability, forecast and agronomic effectiveness. *Indian Journal of Fertilisers*, **17**: 348-360.

Shukla, A. K., Behera, S. K., Satyanarayana, T., & Majumdar, K. (2019). Importance of micronutrients in Indian agriculture. *Better Crops South Asia*, **11**(1): 6-10.

Shukla, A. K., Behera, S. K., Satyanarayana, T., & Majumdar, K. (2019). Importance of micronutrients in Indian agriculture. *Better Crops South Asia*, **11**(1): 6-10.

Siddiqui, S. A., & Fatima, N. (2017). Indian soils: identification and classification. *Earth Science India*, **10**(iii): 1-14.

Singh, M. V. (2008). Micronutrient deficiencies in crops and soils in India. In *Micronutrient deficiencies in global crop production* (pp. 93-125). Dordrecht: Springer Netherlands.

Somasundaram, J., Singh, R. K., Parandiyal, A. K., & Prasad, S. N. (2009). Micronutrient status of soils under different land use systems in Chambal ravines. *Journal of the Indian Society of Soil Science*, **57**(3): 307-312.

Tundup, P., Akbar, A. (2014). Distribution of micronutrient cations (Zn, Cu, Mn, Fe) and their relationship with soil properties of saffron growing soils of district Kishtwar in Jammu and Kashmir. An Asian Journal of Soil Science, **9**(1): 59–62.

Vasuki, N. (2010). Micronutrient management for enhancing crop production-future strategy and requirement. *Journal of the Indian Society of Soil Science*, **58**(1): 32-36.

Viets, F.G. (1962). Chemistry and availability of micronutrients in soils. *Journal of Agricultural and Food Chemistry*. **10**: 174-178

Walkley, A. and Black, I.A., (1934). An experimentation of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science., **37**: 29–38.