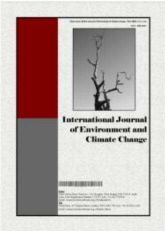

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Block Wise Spatial Distribution and Mapping of Cationic Micronutrients in Soils of Jhargram District of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. Author SD designed the study, performed the statistical analysis, drew all maps, wrote the protocol and wrote the first draft of the manuscript. Authors AGB, NC and BP conducted soil sample collection and managed the laboratory analysis. Author DG managed the literature searches and helped in map preparation. Author GCH checked and improved the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This investigation is aimed to conduct a delineation study to know the spatial distribution of available cationic micronutrients (Zn, Cu, Fe and Mn) in red and lateritic soils of Jhargram district of West Bengal and their relationship with soil chemical properties.
Study Design: Spatial distribution.
Place and Duration of Study: Geo-referenced 253 surface soil (0-15 cm depth) samples were collected from eight blocks (Gopiballavpur- 1, Gopiballavpur- 2, Nayagram, Jhargram, Sankrail, Jambani, Binpur- 2 and Binpur- 1) of Jhargram district of West Bengal, India during 2017- 2018.

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Methodology: Grid based detailed block wise soil sampling has been carried out in long term crop growing fields of Jhargram district of West Bengal.The collected soil samples were analyzed and their cationic micronutrient status were depicted through nutrient index and fertility maps. Geographical information system (GIS) is an important tool to identify the risk areas. In our study Arc Info GIS has been used to prepare the spatial distribution maps of available cationic micronutrients and soil chemical properties (pH and organic carbon) of different blocks of this district.

Results: The pH, organic carbon content, available Zinc, Copper, Iron and Manganese content in soils were in the range of 3.68-7.6, 0.15-2.01 (%), 0.56-5.52, 2.4-11.76, 31.6-208.4 and 6.32-99.74 mg kg^{-1}, respectively, with the mean value of 4.97,0.64 (%),2.21, 5.75, 114.68 and 41.87 mg kg^{-1} respectively. The lowest zinc content has been recorded from the soils of Gopiballavpur- 2 block.

Conclusion: The calculated NIV and spatial distribution maps clearly indicated that there is no deficiency of Iron, Manganese and Copper in this region. Zinc status did not resemble with other cationic micronutrient status which was mostly low to medium with some patches of deficiencies. Soil pH has significant positive relation with Iron. Copper has significant positive relation with soil organic carbon.

Keywords: Cationic micronutrients; mapping; red and lateritic soil; Jhargram; NIV.

1. INTRODUCTION

Soil is one of the most important environmental components and is considered as the main source for providing essential plant nutrients, water reserves and a medium for plant growth. Any change in soil quality, e.g., loss of essential nutrients, decrease in soil organic matter content, increase in soil erosion, loss of soil structure etc. can lead to degradation of agro-ecosystem [1]. Since soil is highly heterogeneous in nature and distribution of soil properties and cationic micronutrients (Zn, Fe, Cu, and Mn) varies spatially, blanket application of these nutrients leads to their imbalanced addition. Intensive agriculture with inadequate and imbalanced use of chemical fertilizers, non-ecofriendly tillage practices coupled with little or no use of organic manure caused severe fertility deterioration of agricultural soils resulting in stagnating or even declining of crop productivity and soil health [2]. In such a scenario, site specific nutrient management can be effective in order to achieve sustainable crop production.

With the advent of Green revolution, intensive cultivation with high yielding varieties and high analysis fertilizers triggered the crop productivity for decades. Macronutrient specifically nitrogen (N), phosphorus (P) and potassium (K) had played a crucial role in achieving food sufficiency in the world's 2nd most populous country, India. Micronutrients bioavailability in crops is generally low due to heavy use of NPK fertilizers in rice-wheat dominated cropping system with little or no addition of micronutrients which depletes the soil reserve of native micronutrients [3,4]. As a result, in the post green revolution period, micronutrient deficiency not only limits crop productivity but also create a profound influence on human nutrition. According to Welch and Graham [5], approximately one–half of the world's population in the developing countries is affected due to the high consumption of micronutrient deficient cereals. Therefore, information on status of micronutrients for different soil types, districts and region as well as for the country is highly essential to determine the nature and extent of their deficiencies/toxicities and to formulate strategies for their correction for enhancing crop production. Soil testing is a promising way to provide such information regarding availability of soil nutrients but it is inaccurate and cannot be used for site specific recommendations and subsequent monitoring until the composite soil samples for soil testing are collected with geographic reference. In the developing countries like India, major constrains like lack of infrastructural facilities and prevalence of small holding systems of farming impede the wide-scale adoption of soil testing.

Geographical Information System (GIS)-based soil fertility mapping has appeared as a promising alternative in this context guiding the farmers to decide the amount of micronutrient fertilizers for optimum/economic returns in areas having deficiency of one or more nutrients than those having sufficient nutrients. For this, many sampling strategies including stratified random sampling and grid sampling were used in earlier studies [6, 7]. For example, to assess the spatial variability at the field level Cambardella and Karlen [8] suggested a 100 m grid interval but to develop a variable fertilizer rate for locations within a field the grid interval was 15 m. However, different grid intervals (1, 1.5 and 2 km) were used in earlier studies for small scale mapping [9, 10]. Thus, the grid interval depends on the scale of mapping and variability of the parameter. Interpolation is a technique of estimating a variable at an unsampled location from observed values at the neighbourhood [7]. Among the various methods of interpolation, kriging provides best unbiased linear estimates and information about estimation errors. The advantage of this method is the minimum local error variance [11,12]. Using this kriging interpolation Seyedmohammadi et al. [13] predicted soil nutrients, and cation exchange capacity for Guilance Province of Iran for optimising nutrient management. Similarly, Tamburi et al. [14] mapped the spatial variability of micronutrients in the Vertisols of Kalaburgi, Karanataka. Sharma et al. [15] prepared the soil fertility maps of Kelapur block of Yavatmal district, Karnataka using this technique. Block wise soil fertility status of Jhabua district of Madhya Pradesh was also reported by Rajendiran et al. [16] with the help of fertility maps.

Keeping in view the above said context, the present study was carried out with an objective to assess the spatial distribution of available cationic micronutrients (Zn, Cu, Fe and Mn) in surface soil and their relationship with soil chemical properties (pH, soil organic carbon content).In this occasion, a study on GPS based soil testing was done to evaluate the cationic micronutrient status in red and lateritic soils of eight blocks of Jhargram district of West Bengal, India.

2. MATERIALS AND METHODS

2.1 Site Description

Jhargram is a district situated at red and lateritic belt with an average altitude of 81 m above from mean sea level under humid and tropical region of West Bengal state of India. This district is located between 21º52' N and 22º48' N latitudes and between 86º34' E and 87º20' E longitudes and covers an area of 3,037.64 km^2 out of which 2,68,249 ha is agricultural land. It consists of eight blocks, viz.Nayagram, Jhargram, Sankrail, Jambani, Binpur- 2 and Binpur- 1. For this study soil samples were collected from this district covering all eight blocks (Fig. 1).

2.2 Soil Sample Collection, Processing and Storage

Soil samples were collected from 0-15 cm layer of the experimental field after harvesting of rice crop. Grid based soil sampling was carried out at 5 x 5 km grid using hand held GPS (Garmin GPS 12). Total 253 soil samples were collected from the whole district of Jhargram respectively. Composite samples were air dried, ground with wooden mortar and passed through 2 mm sieve and was stored in a refrigerator after packing in polyethylene packets for further analysis.

2.3 Soil Analysis

Soil samples were analysed for pH in soil suspension [17], oxidizable organic carbon [18]. Available cationic micronutrients viz., Zn, Cu, Fe and Mn were extracted with DTPA (diethylenetriaminepenta acetic acid) solution following standard protocol as described by Lindsay and Norvell [19] and analysed through Atomic Absorption Spectrophotometer (Perkin Elmer PinAAcle™ 900F, USA).

2.4 Preparation of Thematic Maps

The GIS based maps were prepared with the help of ArcGIS 10.1, Microsoft Office 2007 software by using the Satellite Data of Landsat TM (Path-138, 139; Row-44; Year-1990). The sample points have been used to locate on the district map of the district chosen for study. These points have been interpolated following Inverse Distance Weighted (IDW) method for cationic micronutrients (Zn, Cu, Fe and Mn) through ArcGIS software. After that, the district map has been extracted from the India Map as shape file which has been used to extract the interpolated cationic micronutrients maps. The thematic maps unfold the distribution pattern of soil available cationic micronutrients of whole Jhargram district. Soil available cationic micronutrients are categorized into four classes (Table 1). On the basis of the categorization of soil available cationic micronutrients proposed by Staben et al. [20] and Hornek et al. [21] the above classes are categorised namely deficient, low, medium and high for our convenience to unveil the detailed distribution of cationic micronutrients in soil.

2.5 Statistical Analysis

Statistical analysis was performed by DOS-based SPSS version 24.0. Simple correlation coefficients were also developed to evaluate relationships between available cationic micronutrients and influencing soil chemical properties using the same statistical package.

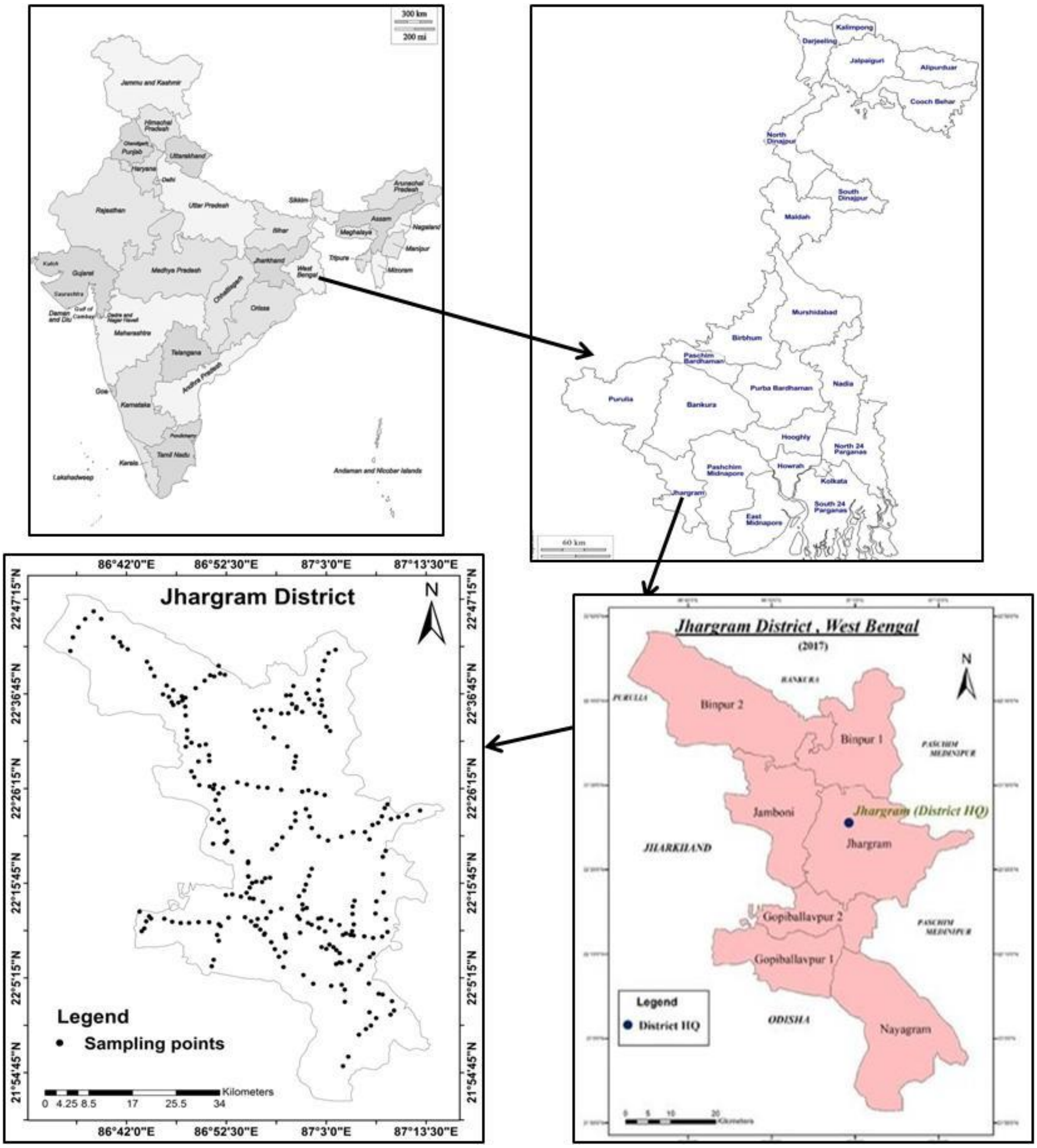

Fig. 1. Study area with sampling points.

Table 1. Categorization of cationic micronutrients for their classification

Cationic micronutrients	Deficient	Low	Medium	High
DTPA-extractable Zn (mg kg^{-1})	<0.6	0.6-1.2	1.2-2.4	>2.4
DTPA-extractable Cu (mg kg^{-1})	<0.2	0.2-0.4	0.4-1.2	>1.2
DTPA-extractable Fe (mg kg^{-1})	<4.5	4.5-9.0	9.0-27.0	>27.0
DTPA-extractable Mn (mg kg^{-1})	<2.0	2.0-4.0	4.0-16.0	>16.0

3. RESULTS AND DISCUSSION

3.1 Soil pH

The results indicated that pH of the soil in the Jhargram district ranged from 3.68 to 7.6 with an average value of 4.97.From the mean value of individual block it is revealed that the lowest soil pH was recorded in the Jamboni block whereas the highest soil pH was found in the Binpur-2 block of this district (Table 2). The spatial distribution of soil pH of this district is depicted in Fig 2. Both Table 2 and Fig 2 indicated that the soils of majority of the blocks (Gopiballavpur- 1, Gopiballavpur- 2, Jhargram, Sankrail, Jambani) are moderately acidic in nature. Such decrease in soil pH might be attributed to exhaustion of basic cations or higher microbial oxidation that creates organic acids causing lower soil pH [22]. Application of liming material is recommended in these soils. Slightly acidic (pH 5.5-6.5) soils are found in parts of Nayagram and Binpur-2 blocks. Very small patches of neutral soils (pH 6.5-7.5) are also found in the extreme parts of these two blocks. The reason behind this increase in pH of surface soil of agricultural land might be soil submergence during the rice-growing period and use of the urea form of fertilizer. Similar findings on soil pH of Jhargram districts were reported by previous authors [23, 24].

3.2 Soil Organic Carbon

The soils of this district were found to have low to high organic carbon content (0.15%-2.01%) with a mean value of 0.64%. Based on the mean value calculated for individual block of this district, the lowest soil organic carbon content was reported in Nayagram block whereas the highest soil organic carbon content was found in Gopiballavpur- 1 block (Table 2). The spatial distribution of soil organic carbon content of this district is depicted in Fig 2. Both Table 2 and Fig 2 indicated that the majority of soils of this district contain medium soil organic carbon (0.5-0.75%). High soil organic carbon content (>0.75%) were reported in some pockets of north-west, west and central part of this district. This may be attributed to drainage of high amount of decomposed organic matter from forest floor of this region. Carbon stocks in the soil are affected by the accumulation and decay of organic matter in forest areas [24]. Patches of low soil organic carbon content (<0.5%) were found in parts of Binpur-2, Binpur-1, Jhargram, Jamboni, Gopiballavpur-1 and Nayagram block. The reason behind this may be addition of very little amount of organic matter in these soils and prevailing warm and hot climate causing faster decomposition of organic matter. Similar findings were corroborated by earlier authors [23].

3.3 Available Zinc (Zn)

The available Zn content in soils of Jhargram district varied from 0.56-5.52 mg kg^{-1} with the mean value of 2.21 mg kg^{-1} (Table 3). Overall, 0.43% and 7.77% of total samples of this district fall under deficient and low category of Zn respectively. Percentages of samples falling in medium and high category of Zn are 56.59% and 35.20% respectively (Table 4). The calculated Nutrient Index Value (NIV) for soil available Zn of this district is 2.28. According to the NIV class proposed by M.R. Motsara [25], this district falls under medium category in this context (Table 3). The spatial distribution of soil available Zn content of this district is depicted in Fig 3. From Table 3 and Fig 3 it is clearly indicated the available Zn content varied widely in soils of this district. Soil deficient in available Zn content (<0.6 mg kg^{-1}) is found mainly in Binpur-2 block. Soil or foliar application of Zn may be recommended in this region**.** Distinct patches of low Zn content in soil are found in Binpur- 2, Jhargram, Gopiballavpur-2, Gopiballavpur-1, Sankrail and Jamboni block. Majority of the soil of this district falls under medium category of Zn content. High Zn content in soil is recorded mostly in north-western, north-eastern and south-western part of this district. The results corroborate with the findings of Das et al. [26] in Jhargram district. Previous studies also revealed that in West Bengal, on an average about 30% of cultivated soils are deficient in Zn [27]. Chattarjee and Khan [28] also reported that DTPA extractable Zn in Alfisols of West Bengal varied from 1.8 to 77.3 mg kg^{-1} soils. Shukla et al. [29] reported that available Zn content ranged from 0.01-3.27 mg kg^{-1} in soils of the Indo-Gangetic-Plains (IGP) of India. The result of the present study also corroborated with Mandal et al. [30] who reported that DTPA extractable Zn was in the range of 0.36 to 5.0 mg kg^{-1} in Oxisols and Entisols of Assam and it constituted 3.17 per cent of the total Zn. The available Zn content in soils of Jhargram district showed negative correlation with soil pH and positive correlation with organic carbon content (Table 5). The reason behind this may be the higher availability of Zn at lower pH in soil. Soils high in organic matter promote biological and chemical reactions that result in the dissolution of relatively unavailable Zn in soil [31].

3.4 Available Copper (Cu)

The available Cu content in soils of Jhargram district varied from 2.4-11.76 mg kg^{-1} with the mean value of 5.75 mg kg^{-1}. The calculated NIV is high (3.00) (Table 3). There is no need of Cu application for crop production in this district. The spatial distribution of soil available Zn content of this district is depicted in Fig 3.No patches of deficiencies are found in the soils of this district. Similar findings are reported by Shukla et al. [29] in a study conducted at the IGP of India. The results are also corroborated with the findings of Sah et al. [32], who reported that available Cu ranged from 0.9 to 6.9 mg kg^{-1} in the soils of 24-Parganas (S) in West Bengal. Saha [33] also reported that the available Cu content in soils of the district Jalpaiguri and Nadia was also reported to be high with a mean value of 8.9 and 3.65 mg kg^{-1}, respectively. The DTPA extractable Cu content was in the range of 3.20 to 4.46 mg kg^{-1} in lateritic soil of Maharashtra as reported by Borkar et al. [34]. The available Cu content in soil of Jhargram district showed a significant and positive correlation (r= 0.168, *P*= .01) with soil organic carbon content. Similar findings were also reported by Tur et al. [35] and Aich et al. [36]. This is may be due to formation of soluble chelates of Cu by the organic matter which increases Cu availability in soil.

Table 2. Soil chemical properties of different blocks of Jhargram district of West Bengal in 2017 and 2018

Name of the Blocks	No. of samples	pH		Organic Carbon (%)	
		Range	Mean ± SD*	Range	Mean ± SD
Gopiballavpur- 1	32	3.82-6.86	4.75 ± 0.65	0.21-1.83	0.78 ± 0.39
Gopiballavpur- 2	29	3.85-6.01	4.99 ± 0.62	0.3-2.01	0.74 ± 0.42
Nayagram	35	3.94-6.39	4.84 ± 0.56	0.18-0.96	0.53 ± 0.20
Jhargram	33	3.85-6.38	5.00 ± 0.55	0.33-1.17	0.65 ± 0.22
Sankrail	30	4.09-6.81	4.94 ± 0.48	0.15-1.05	0.55 ± 0.23
Jambani	30	3.68-5.52	4.66 ± 0.57	0.18-1.17	0.55 ± 0.22
Binpur- 2	32	4.19-6.8	5.34 ± 0.5	0.21-1.2	0.73 ± 0.23
Binpur- 1	32	4.62-7.6	5.22 ± 0.54	0.15-1.5	0.58 ± 0.28
Overall	253	3.68-7.6	4.97 ± 0.59	0.15-2.01	0.64 ± 0.29

**SD- Standard Deviation*

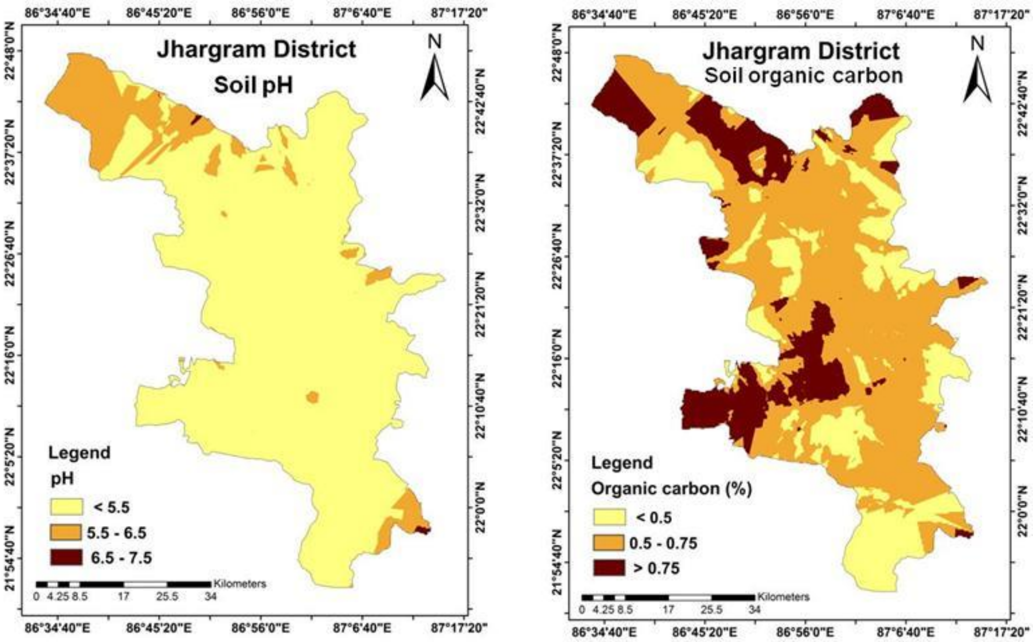

Fig. 2. Maps showing distribution of soil pH and organic carbon (%) in soils of Jhargram district of West Bengal state of India

Table 3. Block wise soil fertility status of cationic micronutrients of Jhargram district of West Bengal in 2017 and 2018

Name of the Blocks	DTPA extractable micronutrients							
	Zn (mg kg^{-1})		**Cu (mg kg^{-1})**		**Fe (mg kg^{-1})**		**Mn (mg kg^{-1})**	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Gopiballavpur- 1	1.08-4.07	2.10± 0.64	3.5-9.31	6.26 ± 1.29	36.02-184.88	121.76 ± 43.66	15.6-73.78	41.41 ±14.14
Gopiballavpur- 2	1.04-4.59	2.61 ± 0.92	3.78-10.08	6.51±1.33	52.06-202.6	127.61± 34.03	6.32-77.14	47.52 ±17.93
Nayagram	1.23-5.52	2.62±1.0	2.4-9.5	5.53±1.67	65.44-203.0	116.27± 40.15	14.08-99.74	43.31± 20.79
Jhargram	0.96-3.88	2.01± 0.68	2.4-6.6	4.89± 0.91	42.28-208.4	122.63± 45.99	11.29-64.9	33.18± 14.45
Sankrail	0.87-3.16	1.94± 0.67	2.7-8.82	5.75 ± 1.64	73.96-200.6	116.27± 36.61	17.82-77.18	45.75± 17.40
Jambani	0.88-5.41	2.08± 0.99	3.49-8.1	5.51± 1.19	87.48-198.26	143.2 ± 35.66	9.89-72.58	33.05± 18.84
Binpur- 2	0.56-3.66	1.79 ± 0.79	3.09-11.76	6.31 ± 2.11	36.12-175.54	90.81± 29.20	29.56-94.2	49.67± 14.56
Binpur- 1	1.18-4.17	2.40± 0.77	2.86-8.3	5.31± 1.59	31.6-107.32	81.56± 15.90	17.00-53.14	41.44± 11.67
Overall	0.56-5.52	2.21± 0.86	2.4-11.76	5.75± 1.58	31.6-208.4	114.68± 40.36	6.32-99.74	41.87± 17.21
Nutrient Index	2.28		3.00		3.00		2.95	
Nutrient Index class*	Medium		High		High		High	

** NIV: Low:<1.5, Medium: 1.5-2.5, High:>2.5*

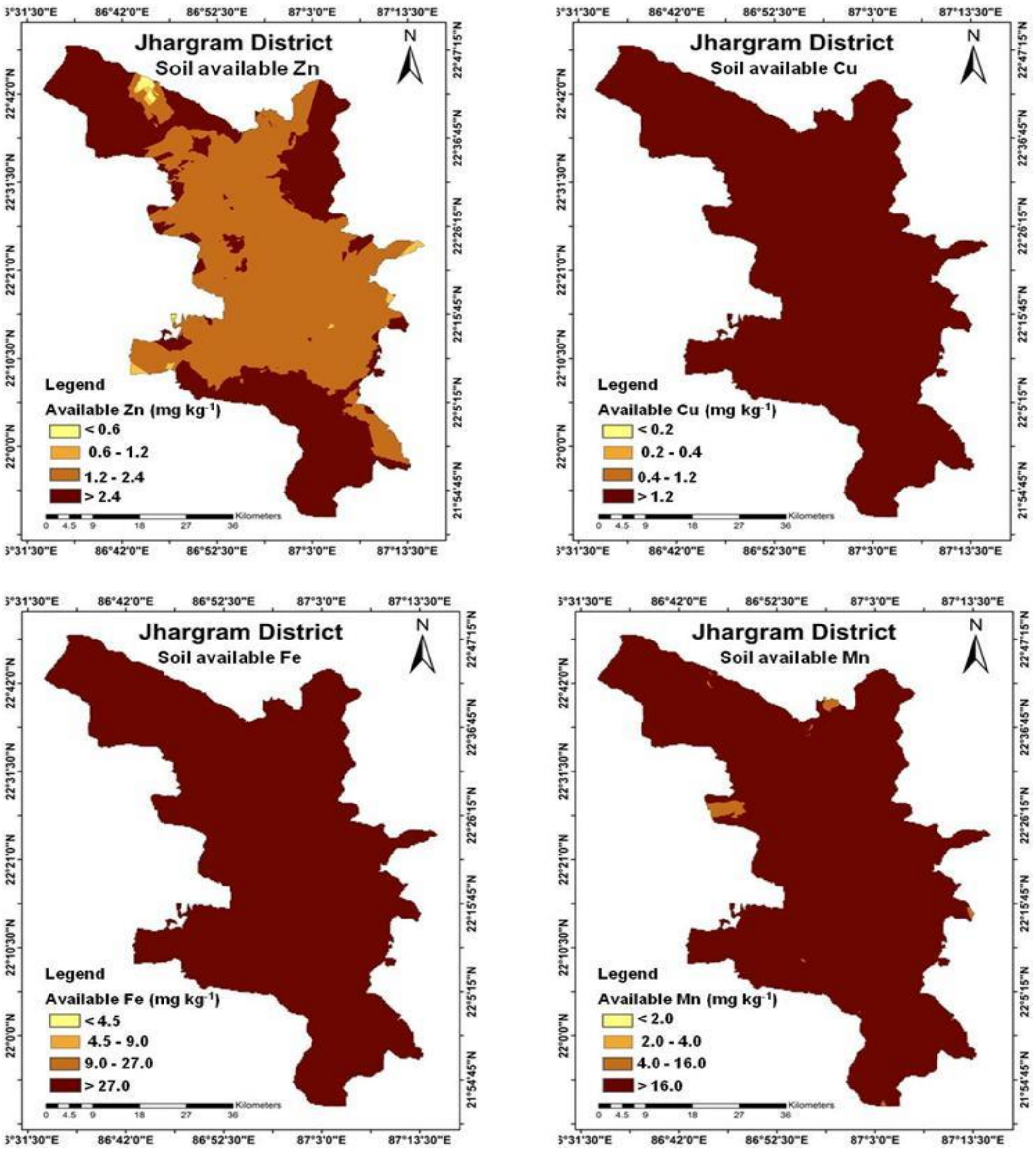

Fig. 3. Maps showing cationic micronutrient fertility status in soils of Jhargram district of West Bengal state of India

Table 4. Percent sample category of available cationic micronutrients in soil of Jhargram district

Name of the Blocks	DTPA extractable micronutrients							
	Zn				Cu	Fe	Mn	
	Deficient	Low	Medium	High	High	High	Medium	High
Gopiballavpur- 1	0.00	6.25	65.63	28.13	100	100	3.13	96.88
Gopiballavpur- 2	0.00	3.13	46.88	50.00	100	100	6.90	93.10
Nayagram	0.00	0.00	51.43	48.57	100	100	2.86	97.14
Jhargram	0.00	9.09	66.67	24.24	100	100	9.09	90.91
Sankrail	0.00	10.00	60.00	30.00	100	100	0.00	100.00
Jambani	0.00	13.33	56.67	30.00	100	100	20.00	80.00
Binpur- 2	3.45	17.24	58.62	20.69	100	100	0.00	100.00
Binpur- 1	0.00	3.13	46.88	50.00	100	100	0.00	100.00
Mean	0.43	7.77	56.59	35.20	100	100	5.25	94.75

Table 5. Correlations between soil properties and soil available cationic micronutrients

Parameters	pH	OC	DTPA-Zn	DTPA-Cu	DTPA-Fe	DTPA-Mn
pH	1					
OC	0.027	1				
DTPA-Zn	-0.029	0.033	1			
DTPA-Cu	0.011	0.168**	0.229**	1		
DTPA-Fe	-0.421**	0.094	-0.083	0.123*	1	
DTPA-Mn	0.124*	0.086	0.090	0.425**	-0.079	1

*P = .05; **P = .01

3.5 Available Iron (Fe)

The available Fe content in soils of Jhargram district varied from 31.6-208.4 mg kg^{-1} with the mean value of 114.68 mg kg^{-1} (Table 3). Taking into consideration the critical value of DTPA extractable Fe i.e. 4.50 mg kg^{-1} (Table 1), it can be concluded that the red and lateritic soils of this district contain sufficiently higher amount of available Fe. The thematic map made explicit distribution of Fe in soils of this district (Fig. 3) where no patches of deficiencies are found. The deficiency of Fe is rare in rice soils and the DTPA extractable Fe in rice soils is generally much greater than the level considered to be adequate was reported by Doberman and Fairhurst [37]. Similar findings were reported by Pati et al. [38] and Mandal et al. [1]. Gupta [39] reported that the soils of many states of India have sufficient available Fe and it was highest in the soils of Karnataka followed by Himachal Pradesh. The available Fe content in soil of Jhargram district showed a significant and negative correlation (r= -0.421, *P*= .01) with soil pH and positive correlation with organic carbon content. The reason behind this may be the higher solubility of Fe at lower pH in soil. Similar types of correlations were reported by Thangasamy et al. [40] and Meena et al. [41].

3.6 Available Manganese (Mn)

The available Mn content in soils of Jhargram district varied from 6.32-99.74 mg kg^{-1} with the mean value of41.87 mg kg^{-1} (Table 3). Overall, 5.25% of total samples fall under medium category whereas, 94.75% of total samples fall under high category (Table 4). The calculated NIV is also high with a value of 2.95. Thematic map unveil the meticulous distribution of Mn in the soils of this district (Fig. 3) where no patches of deficiencies are found. Patches of medium Mn content (4.0-16.0 mg kg^{-1}) in soil are found in Jambani, Jhargram, Nayagram, Gopiballavpur-1 and Gopiballavpur-2 block. Majority of the soil of this district is high in available Mn content (>16.0 mg kg^{-1}).The higher Mn status in the surface soils may be attributed to the lower oxidation, acidic nature of the soils and also due to the release of chelated Mn from the organic compounds. Similar findings were reported by earlier researchers [42, 43, 44, 45].

4. CONCLUSION

From the above study it may be concluded that long-term crop growing red and lateritic soils of Jhargram district of West Bengal are sufficient in plant available Fe, Mn and Cu content. Available cationic micronutrient status in soils of this district showed that0.43% and 7.77% of total samples of this district fall under deficient and low category of Zn respectively whereas 56.59% and 35.20% of total soil samples fall in medium and high category of Zn respectively with overall a medium NIV value of 2.28. Among the eight blocks, Binpur-2 is deficient in available Zn content in soil. No patches of Cu and Fe deficiency are found in the soils of this district. A high NIV (2.95) is reported for available Mn content in the soils of this district where 94.75% of total soil samples fall in high category and remaining 5.25% fall in medium category of Mn. This study, therefore, would provide valuable information for future researchers and field extension workers working in such areas for recommending micronutrient application for improving production and also maintaining their availability particularly in deficient soils through external sources. It would be directly beneficial for the farmer to practice site specific nutrient management as well as use of chemical fertilizers judiciously. The thematic maps will help the researchers to get familiarize with the geographic area covered on the map. Another advantage of GPS-GIS technique is future monitoring of soil nutrient status of different locations/villages from where the soil samples were collected. This study can also be widely acceptable to the areas under this major soil group (red and laterite soil) with similar parent materials and agro-climatic condition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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