

Chapter 4

Characterization of Spatial Variability of Soil Properties of Malda District in West Bengal, India



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Abstract Understanding soil fertility status is crucial for fertilizer management and sustainable crop production. A study was conducted in the Malda district of West Bengal in 2019 to evaluate the nutrient status of surface soil. A total of 45 composite surface soil samples were collected at a depth of 15 cm, and the actual location of the sampling sites was detected by GPS. The soil fertility parameters such as soil pH, available nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (OC), electrical conductivity (EC), available boron (B), available zinc (Zn), available iron (Fe), available manganese (Mn), available copper (Cu), and available sulfur (S) were analyzed and categorized as low, medium, and high using nutrient index (NI). The spatial distribution of parameters was mapped by inverse distance weighted (IDW) interpolation method. The coefficient of variation (CV) showed that P, K, EC, B, and Cu were highly heterogeneous ($CV > 33\%$). The soil pH reveals that most of the surface soil samples of the study area are neutral and slightly acidic. Available phosphorus, potassium, iron, manganese, and sulfur are more or less satisfactory, whereas widespread deficiencies were observed for nitrogen (54.25%), organic carbon (65.76%), boron (100%), zinc (64.31%), and copper (7.5%) in the study area. More precisely, multinutrient deficiencies were observed in Barind region of the study area that noticeably influenced the productivity of crops.

Keywords Soil fertility · Nutrient index · Sustainable crop production · Malda

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4.1 Introduction

Soil is an important natural resource for the production of crops, plant growth, subsistence of life, and the socioeconomic development of human beings (Mandal et al. 2020). It is dynamic in nature, and its trend is determined by the interaction between chemical, biological, physical, and anthropogenic processes (Salgado-Velázquez et al. 2020). Knowledge of soil characteristics, soil fertility, distribution, and potential is extremely important for the strategic setting of irrigation, agricultural management, and optimum land use planning (Das and Bhattacharya 2015). However, for normal growth and accomplishment of their life cycle, plants require more or less 18 essential elements. Among these, 15 are taken from the soil as mineral form by plants or supplementary as fertilizers. Soil nitrogen (N), phosphorus (P), and potash (K) are the primary macronutrients of the soil and are used in great quantities, which set the fertility status of a soil. Available calcium (Ca), magnesium (Mg), and sulfur (S) are the secondary elements, required in smaller amounts than the primary nutrients, whereas boron (B), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) are micronutrient elements that normally occur in very small amounts in both soils and plants, but their role is equally important as the primary or secondary nutrients (Khadka et al. 2019). A deficiency of one or more of the above nutrients can lead to severe retardation toward growth, yield, and crop quality. Hence, for a better understanding of plant growth and the present soil fertility status and trend, wide-ranging knowledge of soil nutrients is mandatory (Dafonte et al. 2010).

However, the fertility of soil may vary from place to place to a bigger regional scale, probably due to the variation in soil-forming factors, which can be termed as intensive and external factors. Precipitation, crop rotation, soil management practices, slopes, soil characteristics, etc. are such soil-forming intensive and external factors that create varied soil fertility from one region to another (Cambardella and Karlen 1999). This may impact on the crop productivity and agricultural practices of any region in different ways. Soil survey helps to identify such extent of problems and potentials, which in turn help to work out the suitability of land for agricultural and non-agricultural uses (Aandahl 1958; Sehgal 1996). Thus, assessment of soil fertility may be the most elementary decision-making tool to plan effective land use systems (Havlin et al. 2010) to maintain soil dynamics to increase agricultural production and crop management performance (MacCarthy et al. 2013). Moreover, several parts of the district are experiencing the problems of arsenification, overuse of chemical fertilizers, intensive farming with traditional plus modern technology, and waterlogging. Therefore, it is very indispensable to evaluate the spatial variation and distribution of soil fertility properties of the district.

There are various methods available for evaluating the soil quality status and the spatial variability of soil fertility parameters in a region; among these, soil testing is most popular (Panda 2010). But the technique normally follows merged soil samples collectively forming into one mean sample collected from the field of proximal geographic locations. Hence, the results of such soil testing are not appreciated for site-specific recommendations and successive monitoring (Pulakeshi et al. 2012).

Maul's Griddle method, nutrient index, soil quality index, etc. are also being used by some researchers to identify soil fertility status where the specific soil nutrient status has been categorized into three groups, e.g., low, medium, and high (Mitchel 1977). However, for soil and water resources, improvement and management of some modern geospatial technologies, e.g., Global Positioning System (GPS) and Geographic Information System (GIS) have played an important role due to its immense potential (Rao et al. 1997; Das 2004; Majhi 2018). Geospatial techniques are very useful for acquiring the knowledge of distribution, characteristics, and variability of soil fertility for sustainable farming practices in an appropriate and precise manner (Liu et al. 2014; Desavathu et al. 2018). For agricultural productivity, enhancement, and management, it also plays an important role by site-specific management practices. Several researchers have more popularly assessed the soil fertility distribution using *inverse distance* weighted (IDW) *method*. Its simplicity and robustness make it the best interpolation methods (Goovaerts 1997, 2000; Cressie 2015).

4.2 Study Area

The study is conducted in Malda district covering 15 community development blocks from both the subdivisions, Chanchal and Malda Sadar. Malda, the gateway of North Bengal, lies between latitudes of 24°40'20"N to 25°32'08"N and longitudes of 87°45'50"E to 88°28'10"E. The district is surrounded by Murshidabad district in the south; North and South Dinajpur districts in the north; international border of Bangladesh in the east; Santhal Parganas of Jharkhand and Purnia of Bihar in the west; and the river Ganga in the southwestern boundary. The total geographical area of Malda district is 373,300 ha, out of which 283,714 ha (76.00%) is under net sown area. The main crops are grown in the summer monsoon season (June–September) which include rice (*Oryza sativa*), maize (*Zea mays*), jute (*Corchorus* species), sugarcane (*Saccharum officinarum*), and maskalai (*Vigna mungo*). In winter or retreat monsoon season (November–February), wheat (*Triticum aestivum*), gram (*Cicer arietinum*), masoor (*Lens culinaris*), khesari (*Lathyrus sativus*), rapeseeds (*Brassica juncea*), mustard (*Brassica campestris*), and potato (*Solanum tuberosum*) are the major crops of the district. The average annual rainfall of the district is 1485.2 mm for the period of 2000–2015, and the mean annual temperature varies from 27.2 to 30.6 °C (2000–2015). The cropping intensity of the district is very high (196%) and, therefore, dependency on the nutrient status of the soil is seriously concerned.

Based on relief characters, the district can be divided into three physiographic zones *Barind*, *Tal*, and *Diara*. *Barind* tract is rising and falling in nature, covering the district's 34.45% cultivable land. *Tal* is a low-lying region subject to seasonal deluge by the rivers, mostly during the rainy season, covering 32.34% of cultivable land. *Diara* is the result of fluvial actions maximum of the river Ganga, partially by Fulahar, Kalindri, Mahananda, etc. occupying 30.21% of the total cultivable land.

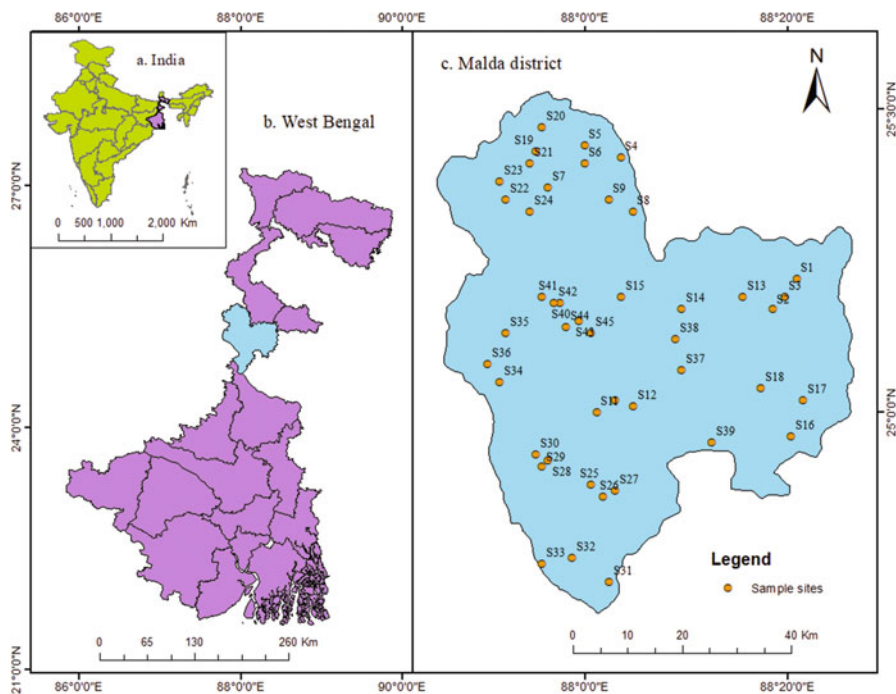


Fig. 4.1 Location map of the study area. (a) India, (b) West Bengal, and (c) Malda district with location of sample sites

Since the study area is located on the western portion of the alluvium-filled cracks in between the Rajmahal Hills on the west and the Garo Hills on the east, the entire area is covered by alluvium soil, which is of two different ages displaying different physical and physiographic characteristics (Sengupta 1969). *Barind* region is dominated by older alluvium, and Tal and Diara are dominated by newer alluvium. The district is divided into three different soil groups, i.e., (1) old alluvium soils (77,700 ha), (2) Vindhyan alluvial soils (17,130 ha), and (3) Ganga alluvial soils (243,540 ha). On the other hand, the district is receiving the major agricultural tracts of char lands of Ganga, i.e., parts of bars and flood plains associated with Mahananda-Tangan, Tangan-Punarbhava, and Fulahar-Ganga interfluves (Fig. 4.1).

4.3 Material and Methods

4.3.1 Collection of Soil Samples

A systematic survey has been conducted over the study area, and composite surface soil samples (0–15 cm depth) were collected from 15 community development

blocks of Malda district. A composite soil sample of 8 to 10 core fixtures was followed and mixed for specific mean sampling. A total of 45 soil samples were incorporated from the various mouzas based on cluster sampling according to the variability of the crop production. Soil samples of high agricultural lands on an observation basis were considered as intake sites. The sample locations were tagged on the base map using a handheld GPS receiver during the autumn and winter since 2017–2019. After collecting, the samples were air-dried under the shade, processed and passed through a 2 mm sieve to get a homogeneous and uni-representative grade of solum, and sent to the laboratory.

4.3.2 Soil Sampling Analysis

The composite soil samples were tested in the District Soil Testing Laboratory, Malda, and Pedological Laboratory, Department of Geography and Applied Geography, NBU. The test results were used after simplification to maintain the association of degree of homogeneity in data character. However, the different soil parameters were tested using the following methods (Table 4.1).

Afterward, descriptive statistical computations on simplified and rounded off datasets were performed to assess the degree of variability for detailed study. The main objective of the study was to characterize the spatial variability of the soil properties in Malda district based on nutrient elements. The *nutrient index* (NI) method has been applied to evaluate soil characteristics. In this method, the individual nutrient status has been categorized into three groups: low, medium, and high. The basic and central theme of this method is constructed better by Parker et al. (1951) and is represented below:

Table 4.1 Soil properties and their measuring methods

Soil parameter	Methods	Reference
Soil pH	pH meter	Eckert and Sims (1995)
Available N	Kjeldahl	Bremner and Mulvaney (1982)
Available P ₂ O ₅	Byer's method	Byers et al. (2005)
Available K ₂ O	Ammonium acetate	Jackson (1967)
Organic carbon	Walkley and Black method	Walkley and Black (1934)
Electrical conductivity	Electrical conductivity meter	Rhoades and Corwin (1981)
Available B	Hot water	Berger and Truog (1939)
Available Zn	DTPA	Lindsay and Norvell (1978)
Available Fe	DTPA	Lindsay and Norvell (1978)
Available Mn	DTPA	Lindsay and Norvell (1978)
Available Cu	DTPA	Lindsay and Norvell (1978)
Available S	Turbidimetric	Verma et al. (1977)

$$NI = \frac{(N_l \times 1) + (N_m \times 2) + (N_h \times 3)}{N_t}$$

where:

NI: Nutrient index

N_l : Number of samples of low nutrient category

N_m : Number of samples of medium nutrient category

N_h : Number of samples of high nutrient category

N_t : Total number of sample

On the other hand, the IDW interpolation method was used to generate the spatial variability maps of the different soil properties. The R 3.5.1 and Arc 10.3 software for Windows have been used for statistical analysis and mapping purposes.

4.4 Results and Discussion

4.4.1 Descriptive Statistics of the Soil Properties

Table 4.2 depicts some statistical analysis parameters of different soil parameters, such as maximum, minimum, mean, range, first quartile, third quartile, mean, median, standard deviation (SD), standard error, variance, coefficient of variation (CV), skewness (C_S), and kurtosis (C_K) of 45 soil samples. According to the criteria recommended by Wilding (1985), there are three variable classes, i.e., most (>35%), moderate (15–35%), and least (<15%) in the district. The analysis of variability reveals the phosphorus, potassium, and electrical conductivity are extremely variable, whereas pH is least variable. The rest of the fertility parameters are moderately variable in the district (Table 4.2). In general, soil pH and organic carbon (OC) are considered as the stable parameters of soil (Bouma and Pinke 1993). Skewness is a measure of the degree of symmetry or asymmetry in any given dataset. As per results, the skewness of the different soil fertility parameters of the study area varied from -0.64 (boron) to 1.16 (electrical conductivity). So, it can be inferred that the data are skewed in nature since the value of the skewness coefficient (Karl Pearson's) is not smaller than zero and the majority of the soil parameters are positively skewed. Additionally, most of the parameter's mean is greater than the median of the datasets, enough provision as skewed. Comparable results are obtained from the kurtosis of the time series data and varied from -1.35 for nitrogen to 1.99 for copper. Since the values are lesser and greater than zero, the kurtosis is not mesokurtic (normal distribution).

Table 4.2 Descriptive statistical analysis of the sample soil properties of Malda district

Statistic	pH	N	P	K	OC	EC	B	Zn	Fe	Mn	Cu	S
Data size	45	45	45	45	45	45	45	45	45	45	45	45
Maximum	8.30	372.40	222	549	0.84	0.79	0.12	0.81	9.30	4.20	0.52	5.10
Minimum	5.20	131.30	16	18	0.25	0.07	0	0.28	5.20	2.30	0.09	2.20
Range	3.10	241.10	206	531	0.59	0.72	0.12	0.53	4.10	1.90	0.43	2.90
First quartile	6.10	231.30	64	188	0.42	0.17	0.07	0.42	6.30	2.60	0.18	3.20
Third quartile	7.60	348.60	125	281	0.55	0.33	0.11	0.61	7.8	3.40	0.28	4.20
Mean	6.88	280.39	92.60	244.58	0.49	0.29	0.08	0.51	7.08	3.10	0.24	3.76
Median	6.90	241.60	80	228	0.46	0.26	0.08	0.52	6.8	3.10	0.23	3.8
Standard deviation	0.93	66.16	45.53	100.06	0.14	0.16	0.03	0.14	1.16	0.57	0.08	0.74
Standard error	0.14	9.86	6.79	14.92	0.02	0.02	0.01	0.02	0.17	0.09	0.01	0.11
Variance	0.85	4279.98	2026.55	9790.02	0.02	0.02	0.01	0.02	1.31	0.32	0.01	0.53
Coefficient of variation (%)	0.13	0.23	0.49	0.41	0.27	0.53	0.31	0.28	0.16	0.18	0.33	0.19
Skewness	-0.15	0.11	0.75	0.95	0.5	1.16	-0.64	0.03	0.6	0.45	0.97	0.11
Kurtosis	-1.21	-1.35	0.20	1.57	-0.03	1.12	0.65	-0.73	-0.75	-0.82	1.99	-0.64

4.4.2 Spatial Distribution of the Soil Properties

The widespread variability of the soil fertility parameters is categorized into different classes to determine and demarcate the regions with their deficiency for their better management. The soil fertility parameters are grouped into different categories with the help of the nutrition index range, representing their amount in soil, and the area of each class.

4.4.2.1 Soil Reaction (pH)

The NI of sample soils for soil pH and their spatial variability are presented in Table 4.3 and Fig. 4.2a. The obtained results reveal the soil pH of the study area is ranged from moderately acidic (5.20) to slightly alkaline (8.30), which slightly differ from the standard limit for majority of the crops. From the agrarian point of view, soil pH ranging between 6.5 and 7.5 is optimum to maintain soil fertility (Daji et al. 1996; Dhale and Prasad 2009). From the areal coverage, it is observed that the majority of the soils in this area are neutral (48.75%) in character, followed by slightly acidic (33.54%), slightly alkaline (17.16%), and moderately acidic (0.55%) (Table 4.3). The neutral soils are mainly found in the middle-western and north-western part of the district covering parts of Gazole, Chanchal I, Chanchal II, Ratua II, Kaliachak II, and English Bazar and a little portion of Old Malda, Habibpur, Manikchak, and Kaliachak I and II blocks (Fig. 4.2a). Due to heavy rainfall in the monsoon season and high temperature in the summer, washing of soil has resulted in deacidification with increasing neutrality. Neutral to slightly acidic, and slightly alkaline, soil in the study area is quite prevalent. However, slightly acidic soil is comparatively higher than the other two types in the study area due to agroforestry and agricultural practices. Kaliachak II and III are having slightly alkaline soil owing to bank erosion and prolonged agri-practices and rainwash effects. However, Vasu et al. (2017) emphasize the nature of parent material, use of fertilizer, and microtopography for spatial variation of pH in an area.

4.4.2.2 Available Nitrogen (N)

From the analysis of available N content in the study area, it is found that there are two classes as low and medium are exist, and they are summarized in Table 4.3 and Fig. 4.2b. The estimated value of the available N content in the district varies from 130 to 370 kg/ha on average. It is also inferred from the results that the available N is low or deficit in the major portion (54.25%) of the study area with values <280 kg/ha, covering vast parts of Bamangola, Gazole, Habibpur, Kaliachak I, and Old Malda and a little part of English Bazar, Manikchak, Ratua I, Harishchandrapur I, and Chanchal I (Fig. 4.2b). The severe scarcity of nitrogen in the study area is observed mainly due to insufficiency of organic carbon content and increased rate of

Table 4.3 Parameter-wise soil nutrient index classes and their salient features

Parameter	Value	Rating	Area (sq km)	Percentage of area
Soil pH (%)	5.2–5.5	Moderately acidic	20.47	0.55
	5.5–6.5	Slightly acidic	1251.98	33.54
	6.5–7.5	Neutral	1819.98	48.75
	7.5–8.30	Slightly alkaline	640.57	17.16
Available nitrogen (kg/ha)	131–280	Low	2025.23	54.25
	280–372	Medium	1707.76	45.75
Available phosphorus (kg/ha)	<45	Low	58.33	1.56
	45–90	Medium	1607.4	43.06
	>90	High	2067.28	55.38
Available potassium (kg/ha)	<500	Low	362.33	9.71
	500–750	Medium	3298.79	88.37
	>750	High	71.89	1.93
Organic carbon (%)	<0.50	Low	2454.76	65.76
	0.50–0.75	Medium	1270.4	34.03
	>0.75	High	7.85	0.21
Electrical conductivity (dS/m)	<0.28	Low	2157.41	57.79
	0.28–0.40	Medium	1328.3	35.58
	>0.40	High	247.29	6.62
Boron (mg/kg)	<0.03	Low	12.96	0.35
	0.03–0.06	Medium	117.85	3.16
	0.06–0.09	High	3236.28	86.69
	>0.09	Very high	365.91	9.8
Zinc (mg/kg)	<0.41	Very low	337.77	9.05
	0.41–0.54	Low	2400.86	64.31
	0.54–0.67	Medium	963.07	25.8
	>0.67	High	31.3	0.84
Iron (mg/kg)	<6.23	Low	437.11	11.71
	6.23–7.25	Medium	1747.76	46.82
	7.25–8.27	High	1410.76	37.79
	>8.27	Very high	137.37	3.68
Manganese (mg/kg)	<2.77	Low	292.91	7.85
	2.77–3.25	Medium	2706.74	72.51
	3.25–3.72	High	673.91	18.05
	>3.72	Very high	59.44	1.59
Copper (mg/kg)	<0.20	Low	280.12	7.5
	0.20–0.30	Medium	3347.65	89.68
	0.30–0.40	High	94.82	2.54
	>0.40	Very high	10.4	0.28
Sulfur (mg/kg)	<2.93	Low	54.23	1.45
	2.93–3.65	Medium	1166.37	31.24
	3.65–4.37	High	2382.36	63.82
	>4.37	Very high	130.04	3.48

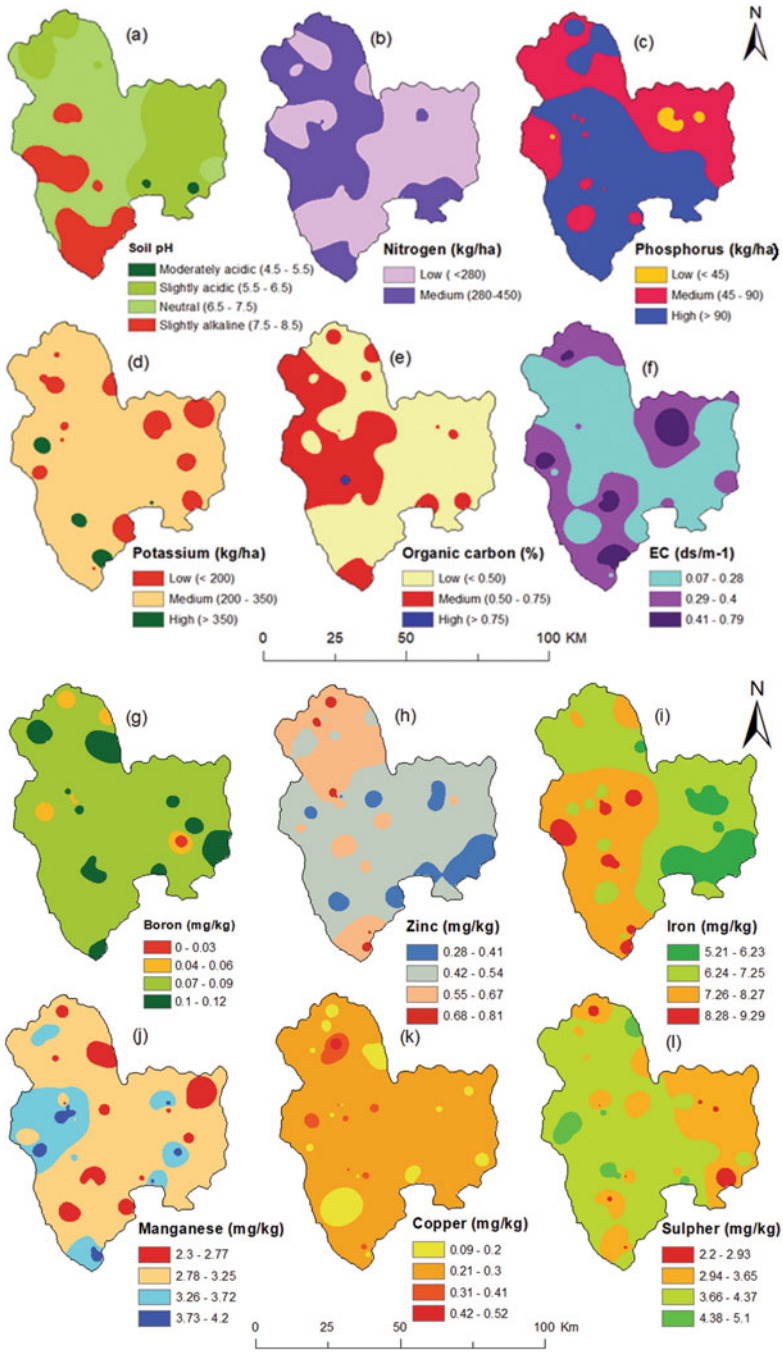


Fig. 4.2 Soil fertility parameters and their spatial distribution in Malda district. (a) Soil pH, (b) nitrogen, (c) phosphorus, (d) potassium, (e) organic carbon, and (f) electrical conductivity, (g) boron, (h) zinc, (i) iron, (j) manganese, (k) copper, and (l) sulfur

mineralization; however, lack of nitrogen fertilizer application to comprehensive nutrient crops especially maize and existence of high sulfur in the soil are considered as the reason of N deficiency (Vasu et al. 2017). On the other hand, medium available N is found in all the areas except the parts mentioned above, whereas low nitrogen content is expected to be more coinvestigated. The areal coverage of medium available N is 45.75%, and surprisingly, there is no portion in this district with a high level of available N (expectedly 400 kg/ha), and thereby yield rate is hampered to produce healthy and nutritious crops.

4.4.2.3 Available Phosphorus (P)

The results of the P availability obtained from NI are presented in Table 4.3 and Fig. 4.2c. The estimated value of the availability of P content in this region varies from 16 to 222 kg/ha (Table 4.2). From the spatial distribution, it is found that 55.38% are covered by high concentration of available P observed at the middle and southern part of the district and 43.06% are covered by a medium concentration especially found at north-eastern, north-western, and western part of the district. The comparatively healthier availability of P is mainly due to dissolution of Ca-P in the soil with deep-rooted crops under neutral soil reaction (Pal et al. 2012). Simultaneously, only 1.56% area of the total district is observed with a low concentration of available P found in the middle part of the Gazole and western part of Bamangola block (Fig. 4.2c).

4.4.2.4 Available Potassium (K)

The NI of available K and its spatial distribution are summarized in Table 4.3 and Fig. 4.2d. The assessed value reveals the available K in the study area ranges from 18 to 549 kg/ha (Table 4.2). It is also experienced from the results that the major soils (88.37%) have a medium available K content, observed at almost every block of the district, except some pockets of Gazole, Bamangola, Habibpur, English Bazar, Manikchak, Chanchal II, and Harishchandrapur II. High potassium availability is found only at 1.93% of the region, scattered over the district. However, a tiny part of Kaliachak I and Kaliachak III, located in the southern part of the district, and Manikchak, located in the western part, is included in this group. Whereas 9.71% area has been observed with low available K, scattered over the district especially in the north-western part including Gazole, Bamangola, and Chanchal II blocks. On the other hand, Habibpur, English Bazar, Harishchandrapur II, and Manikchak blocks are also considered potassium-deficit blocks (Fig. 4.2d). The poor cation exchange capacity may be the one causing factor of the deficiency of K (Srinivasarao et al. 2014).

4.4.2.5 Organic Carbon (OC)

The estimated value of the organic carbon in the district varies from 0.25% to 0.84%, summarized in Table 4.2. The magnitude of the average OC reveals the study area is dominated very low contention is the case of commonality. Organic carbon in the soil of the whole of India is very poor (Venkanna et al. 2014). Most of the area (65.76%) of the district has low organic carbon content, located in the northern, eastern, and southern part of the district covering blocks of Harishchandrapur I, Chanchal I and II, Gazole, Bamangola, Habibpur, Old Malda, English Bazar, and Kaliachak I and III (Fig. 4.2e). Heavy showers are responsible for washing out the surface and subsurface organic compounds creating further deficits.

4.4.2.6 Electrical Conductivity (EC)

The results show that the average value of EC in this region is 0.29 dS/m and ranged from 0.07 to 0.79 dS/m (Table 4.1). It is also found from the estimated results that most soils of the district are with low (57.79%) electrical conductivity, and a very little parts are with high electrical conductivity (6.62%). The low level of electrical conductivity is prevalent in the north-western to the south-eastern part of the district, and high EC has been observed in very little portions of Gazole, Kaliachak II and III, Manikchak, and Harishchandrapur I blocks (Fig. 4.2f). The fluctuation of soil electrical conductivity depends on the amount of soil moisture detained by particles of soils. However, the soils of the study area are free from strong salinity as all the collected sample values of EC are <1. It is so typical that if the EC is high in the substrate flushing, the soil with irrigation water is necessary. Similarly, if it is low, it indicates that some supplementary inputs especially salts and other nutrients are necessary.

4.4.2.7 Available Boron (B)

Boron is another typical and essential trace element of the soil. The concentration of boron in the study area ranges from 0.00 to 0.12 mg/kg, with an average of 0.08 mg/kg. However, the outcome of areal exposure shows a large quantity of the soil (86.69%) of the district has the optimum availability of boron content, experienced at every block of the district. The highest level of boron is concentrated in the north-eastern, north-western, eastern, and some middle part of the study area in a scattered manner, whereas the rest of the part of the district are observed with medium (3.16%) and low (0.35%) available boron. This is a key element for agriculture as soil pH, calcium, soil texture, organic matter, and moisture content are influenced by the availability of boron in soil (Orlov 1992).

4.4.2.8 Available Zinc (Zn)

The NI of available Zn and its spatial distribution are summarized in Table 4.3 and Fig. 4.2h. The assessed value clearly reveals the proportion of the available Zn in this region varies from 0.28 to 0.81 mg/kg. Except for the northern and southern parts of the study area, the entire region is enclosed with the soil of low (57.79%) share of zinc content. Medium concentration (25.80%) has been found in all the areas except the parts mentioned above, where low zinc content is observed. The yield of flowers and fruits is considerably reduced and delayed if Zn deficiency persists.

4.4.2.9 Available Iron (Fe)

The results of the NI of available Fe and its spatial distribution are presented in Table 4.3 and Fig. 4.2i. In the study area, the availability of iron ranges from 5.20 to 9.30 mg/kg (Table 4.2). Nearly half (46.82%) of the study area is enclosed with the medium concentration of iron, observed mainly at the northern and eastern part of the district. On the other hand, approximately one third (37.79%) of the area experienced high concentration of Fe, mainly observed in the west and southwestern part of the district. In contrast, only 3.86% of the area is observed with a very high concentration of iron found in the western part of the study area but in a scattered manner.

4.4.2.10 Available Manganese (Mn)

The existing Mn content in the study area varies from 2.30 to 4.20 mg/kg (Table 4.2); however, the results of NI and its spatial variation are presented in Table 4.3 and Fig. 4.2j. The assessed results show the medium quantity of available Mn is experienced for the majority of the portion (72.5%) of the district covering a vast part of Bamangola, Gazole, Habibpur, Kaliachak I and II, English Bazar, Old Malda, Harishchandrapur I and II, and Chanchal I and II. On the other hand, high available manganese (18.5%) is found in the little part of the western, southern, and eastern portion of the study area. The areal coverage of a very high concentration of Mn (1.59%) is significantly less than others.

4.4.2.11 Available Copper (Cu)

The analysis results of Cu and its spatial distribution in the study area are presented in Tables 4.2 and 4.3 and Fig. 4.2k. The estimated results reveal most of the area (89.68%) of the district is covered with the medium quantity of the copper blend soil. However, very high absorption of copper in the soil occupied merely 0.28% of the region, located only in the very little proportion of the northern part of the study area.

A very low (7.50%) concentration of the nutrient is found in the eastern, south-western, and northern parts of the district in a diffused manner. In the present study, the availability of copper has varied from 0.09 to 0.52 mg/kg with an average of 0.24 mg/kg.

4.4.2.12 Available Sulfur (S)

Sulfur in the study area ranges from 2.20 to 5.10 mg/kg, with an average of 3.76 mg/kg (Table 4.2). More than half (63.82%) of the study area is covered with the soil of good absorption of S except the eastern part of the study area. On the other hand, the medium quantity of sulfur is associated with 31.24% of the whole study area (Fig. 4.21). The rest of the area is covered with the soil of a very high percentage of sulfur content. Surprisingly, there is hardly any evidence of existing soil with a low and very low concentration of sulfur in this district. The possible reason behind poor availability of S content in the study area is low organic matter and acidic soil pH (Hareesh et al. 2014).

4.5 Conclusion

This study explored the characterization of the soil properties and its spatial variability in Malda the district. The assessment revealed most of the soils (49%) of the district are neutral, followed by slightly acidic (34%). The low status of organic carbon is noticed in 65.76% of the area. The available nitrogen and potassium in the soils are of low to medium category. However, higher content of phosphorus has been observed in 55.38% of soils. A deficiency was observed in boron in the whole study area and zinc in about 75% of areas. The availability of iron, copper, and manganese in soils was observed almost permissible. Precise inspection proves that Tal and Diara regions are comparatively more fertile than the Barind tract. Fertilizer recommendations can be made for maximum crop yields. Improper agriculture practices, intensive farming, monoculture, cropping pattern, and over-irrigation are responsible for the deterioration of soil quality in some portion of the study area. To overcome the adverse effect of the chemical fertilizers in cultivation, efforts should be made to probe ahead for integrated nutrient management (INM). Under this approach, the best available option lies in the complementary use of biofertilizers, organic manures in suitable combinations for chemical fertilizers. “Organic agriculture” system should be inculcated which begins to consider potential environmental and social impacts by eliminating the use of synthetic inputs such as synthetic fertilizers, pesticides, etc. The camps, rallies, and training programs for the farmers should be arranged for increasing awareness regarding the benefits of organic agriculture, biofertilizers, etc. in better crop production and thereby improving soil fertility and nutrient status.

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