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Spatial Distribution of Soil Nutrient Status of Biswanath District, Assam, North East India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice-based cropping system is a key for food security in Assam. However, the productivity of such systems has declined continuously due to deterioration in soil fertility owing mainly to faulty agricultural practices. The study was carried out to study the nutrient status of soils of the Biswanath district of Assam in the year 2021. A total of 200 no of geo-reference surface (up to 30 cm) soil samples were collected. The coefficient of variation (CV) was used for the interpretation of the variability of the indicators. Available phosphorous, available potassium DTPA-iron, DTPA-manganese, DTPA-zinc, and DTPA-copper were identified to be the most variable soil indicators (CV > 35%). Electrical conductivity, organic carbon, available nitrogen, and cation exchange

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capacity, were found as the moderately variable parameters (CV 15–35%). The least variation (CV < 15) was found pH. The mean pH, electrical conductivity and organic carbon were 5.23, 0.54 ds/m, and 0.81 percent respectively. The cation exchange capacity of the soil varied from 4.40 to 11.60 cmol(p+)/kg with the mean value of 6.74cmol(p+) /kg. The available nitrogen, available potassium and available phosphorus were 380.01kg /ha, 169.00 kg/ha and 38.01 kg/ha. The district's respective DTPA-Fe, DTPA-Cu, DTPA-Mn, and DTPA-Zn levels were found to be 83.34 mg/kg, 2.59 mg/kg, 22.25 mg/kg, and 0.79 mg/kg. The spatial distribution of each parameter was presented on the GIS platform for easy availability through IDW method of interpolation.

Keywords: Geo-reference; Cation exchange capacity; DTPA – Diethylene triamine pentaacetic acid; GIS-Geographical Information system; IDW- Inverse distance weighted interpolation.

1. INTRODUCTION

Soil fertility is one of the main factors impacting crop output. The availability of macro- and micronutrients is one of the significant elements that influence soil fertility and crop productivity. It is a natural occurrence that the number of nutrients in the soil varies, with some being sufficient while others being insufficient. Assessment of a region's soil fertility level is crucial for ensuring sustained agricultural output. One of the most significant issues affecting agricultural productivity has been identified as the reduction in soil fertility caused by uneven fertilizer application. A thorough understanding of soil fertility is essential for detecting crop husbandry challenges and facilitating agro-technology transfer programs. These goals require continued productivity. “To identify the type and severity of their deficiencies/toxicities and to develop strategies for their correction in order to increase crop production, information on the status of fertility for different regions, is absolutely crucial. Therefore, research on the status of macro- and micronutrients and their interactions with soil characteristics is necessary to understand the inherent capacity of the soil. Assam's Upper Brahmaputra Valley Zones' soils showed deficiencies in nitrogen, phosphorus, potassium, zinc, and boron, with ranges of 6.0-16.0%, 11.0-15.0 %, 14.0-17.0 %, 23-34 %, and 17-49%, respectively, according to an analysis of their soil fertility condition” [1]. However, there is a lack of data on the soil properties in the Biswanath District of Assam. Therefore, the present investigation is aimed at computing the district's soil fertility and putting these properties in a GIS environment for ease of future access.

2. MATERIALS AND METHODS

2.1 Study Area

The Biswanath district lies in between Latitudes 26°35' to 27°00' and Longitudes 92°50' to 93°50 with an area of 1,415 square kilometers. The district is bordered on the north by Arunachal Pradesh, on the south by the Brahmaputra, on the east by Lakhimpur district, and on the west by Sonitpur district. The District is situated between Arunachal Pradesh's Himalayan mountains and the mighty Brahmaputra River. The area is part of Assam's hot, humid alluvial plain and in the North Bank Plain agroclimatic zone. In the district, rice crop was cultivated (June–October/ November) and subsequent crops; i.e. potato, rapeseed, and black gram were grown as Rabi crops (November–February).

2.2 Collection of Soil Samples and Analysis

200 geo-referenced surface soil samples (0–30 cm) were collected with the assistance of the Global Positioning System (GPS), for chemical analysis in the year 2021 (Fig. 1). The soil samples were crushed and sieved through a 2 mm sieve after being air-dried. Basic soil parameters (pH, EC, CEC and OC) and macronutrients (N, P, K, Ca, Mg ,Na and S) were examined in the processed soil samples using established techniques [2,3] and neutral normal ammonium acetate, respectively). According to Lindsay and Norvell [4], DTPA solution (0.005MDTPA+0.01 MCaCl 2 + 0.1M triethanolamine, pH 7.3) was used to extract the available Fe, Mn, Cu, and Zn from soil samples. An atomic absorption spectrophotometer was used for the determination of the micronutrients in the extract. The GIS software ArcGIS v.10.3 (ESRI Co, Redlands, USA) was used for the spatial distribution of soil chemical properties. The spatial distribution of each result is presented on the GIS platform for easy availability through the Inverse distance weighted (IDW) method of interpolation.

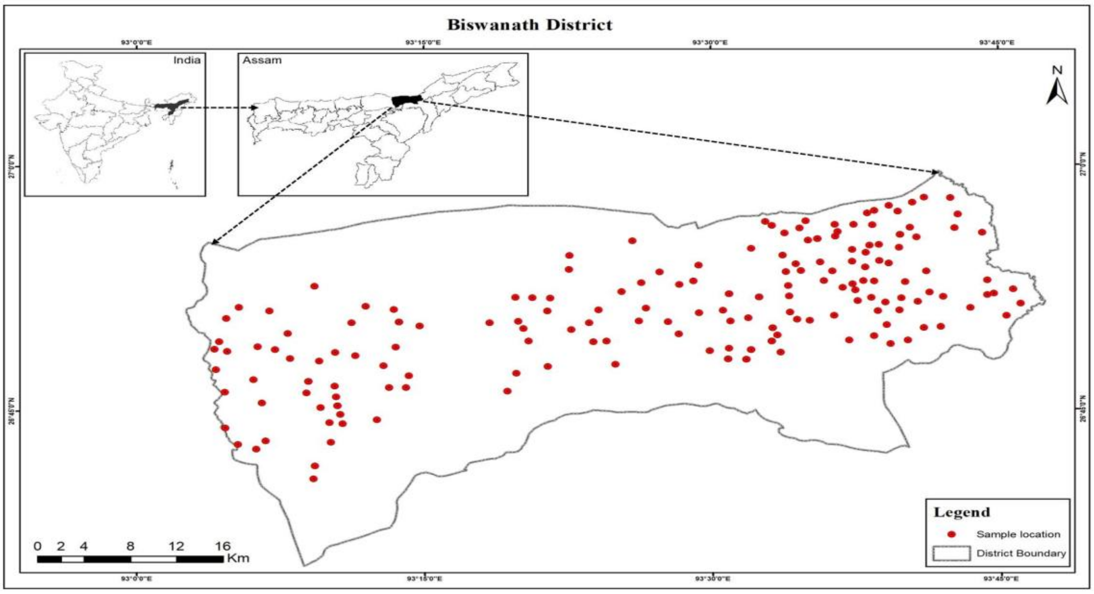

Fig. 1. Location map of study area (Biswanath district, Assam)

3. RESULTS AND DISCUSSION

"The health and productivity of any soil depend on the concentration of soil fertility parameters like organic carbon, nitrogen, phosphorous, and potassium and their effect on the physical, chemical, and biological properties of soil" [5]. "For sustainable agricultural production, maintenance of soil fertility and soil health is crucial [6] as it is related to chemical reactions in soil, availability of essential nutrients, their depletion, and replenishment in soil".

"The pH was recorded from 4.10 to 6.80 with a mean value of 5.23 (Table 1), indicating soils varied from strongly acidic to slightly acidic in nature, which was earlier reported by several workers" [7,8]. "The annual rainfall and relative humidity which has been consistently washing down base elements from the soils, leading to the development of acidic soil. Bhuyan et al. [9] and Basumatary et al. [10] also reported the acidic condition in the soils of Assam". The soils of North-Eastern India were found to be acidic to neutral with low cation exchange capacity [11]. Increased acidity in Assam soil is basically due to high rainfall leading to depletion as well as deposition of some nutrients in soils [12]. The least variation (CV < 15) was found in pH. Fig. 2 provides the spatial distribution of pH in the district.

Table 1. Descriptive statistical parameters of soil properties

Soil properties	Minimum	Maximum	Mean	S.D.	C.V. (%)
pH	4.10	6.80	5.23	0.62	4.10
Electrical conductivity (ds/m)	0.25	0.79	0.54	0.13	24.07
Organic carbon (%)	0.21	1.20	0.81	0.21	26.24
Available N (kg/ha)	200.74	566.78	380.01	90.29	23.76
Available P (Kg/ha)	7.02	56.94	26.86	12.75	47.49
Available K (kg/ha)	49.10	398.36	169.39	89.09	52.59
Available S (mg/kg)	5.35	28.92	15.42	6.04	39.20
Cation exchange capacity (cmol(p+) /kg)	4.40	11.60	6.74	1.95	29.03
Exchangeable Ca^{2+}(cmol(p+) /kg)	0.75	3.23	1.36	0.53	38.77
Exchangeable Mg^{2+}(cmol(p+) /kg)	0.42	1.98	0.90	0.36	40.38
Exchangeable Na^{2+}(cmol(p+) /kg)	0.11	0.34	0.19	0.05	27.54
DTPA-Fe (mg/ kg)	33.64	168.33	83.34	32.56	39.08
DTPA-Cu (mg/ kg)	0.33	5.92	2.59	1.61	62.20
DTPA-Mn (mg/ kg)	3.28	68.68	22.25	12.17	54.70
DTPA-Zn (mg/ kg)	0.22	1.55	0.79	0.31	39.65

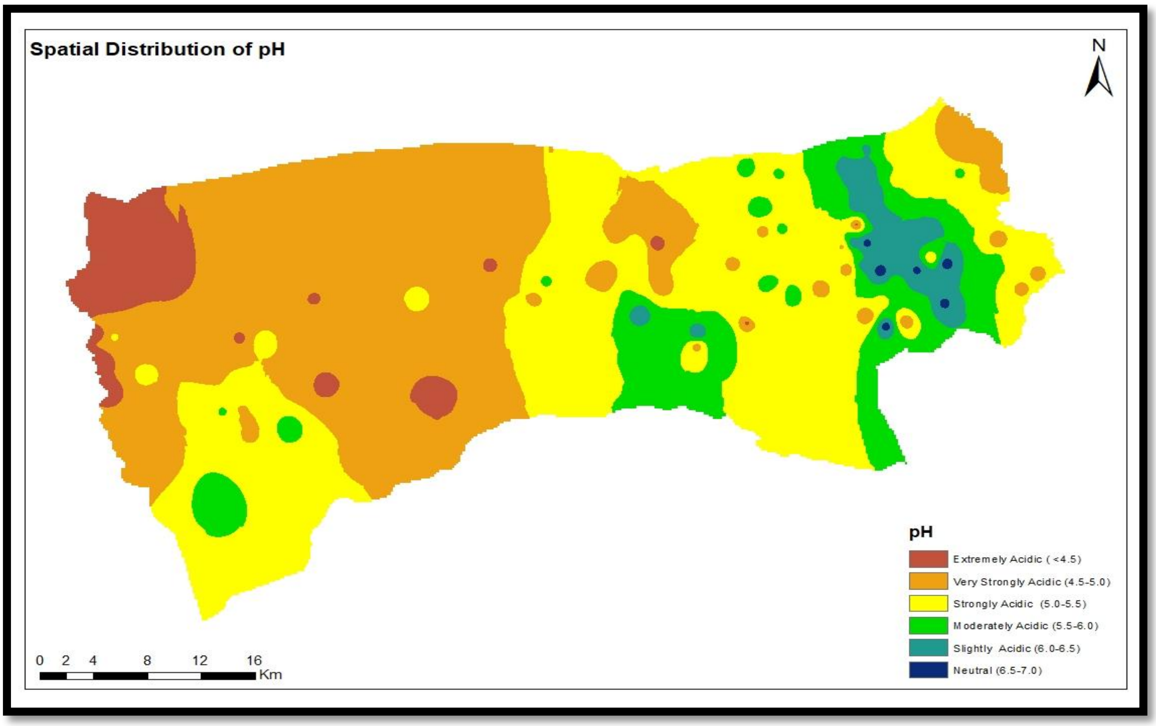

Fig. 2. Spatial distribution of pH in the soils of Biswanath district (Assam)

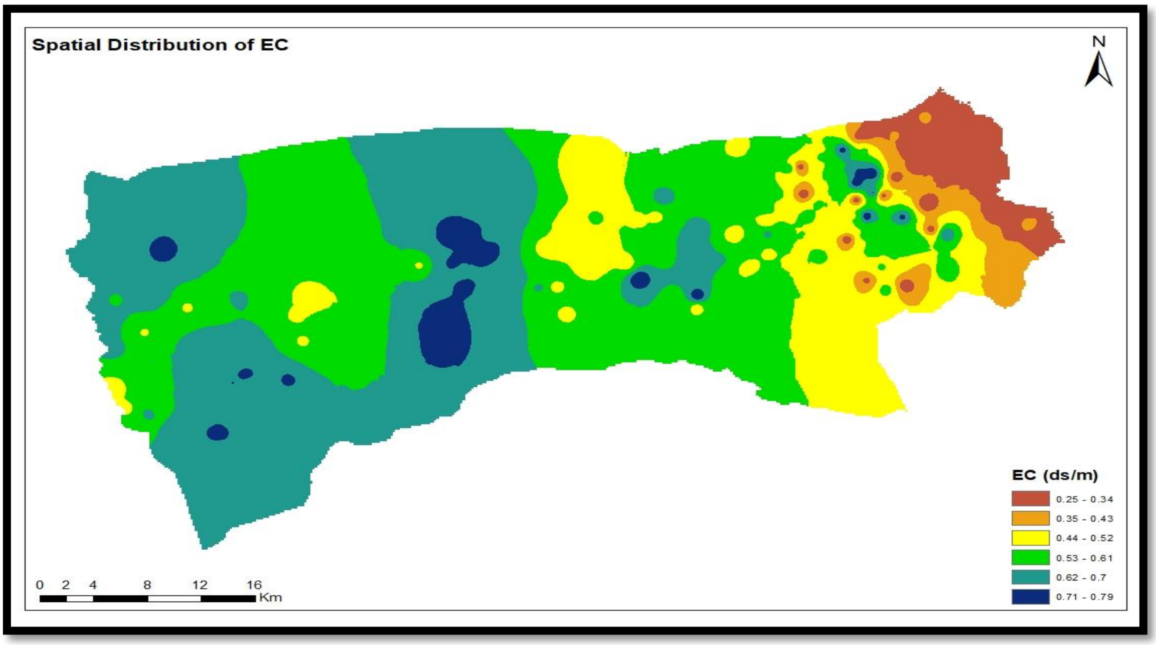

Fig. 3. Spatial distribution of electrical conductivity (ds/m)in the soils of Biswanath district (Assam)

Based on the limits are given by Muhr et al. [13], the electrical conductivity of the study area was found in the normal range (< 1.0 ds/m). The electrical conductivity ranged from 0.25 to 0.79 ds/m with a mean value of 0.54 ds/m (Table 1). "The electrical conductivity can be an important soil fertility index for site-specific management as it is highly correlated with crop yield" [14]. "The low electrical conductivity of the study area might be due to inherent factors like soil minerals, climate, soil texture, and leaching of soluble salts due to excessive rainfall" [15-17]. The CV was found to be 24.07 percent. Fig. 3 provides the spatial distribution of electrical conductivity in the district.

The organic carbon content of the soil ranged from 0.21 to 1.20 percent with an overall mean of 0.81 percent (Table 1). The CV was recorded as 26.24 percent. "Good vegetative growth as well as the addition of organic matter into the soil may increase the organic carbon content in the soil" [18]. "Availability of organic matter like vegetative growth and litter and their slow decomposition may lead to the high level of organic matter which enriches the nutrient and water retention capacity of soil and create a favorable physical, chemical, and biological environment" [19]. Fig. 4 indicated the spatial distribution of organic carbon in the district.

The cation exchange capacity of the soil varied from 4.40 to 11.60 cmol(p+)/kg with a mean value of 6.74cmol(p+) /kg (Table 1), reflecting the dominance of low-activity clay (Kaolinite) in these soils. The CV value was noted as 29.03 percent. Fig. 5 describes the spatial distribution cation exchange capacity of the district.

The available nitrogen status in the soil ranged from 200.74 to 566.78 kg/ha having a mean value of 380.01kg /ha (Table 1). The CV was found to be 23.76 percent. A similar result was also reported by Pandiaraj et al. [20]. "Recommended organic manure and nitrogen fertilizer application in crops may build a medium range of available soil nitrogen. Soil management and application of farm yard manure and fertilizer to the previous crop may be related to variations in soil N content. Soil nitrogen dynamics regulation is mostly controlled by various agronomic practices [21] and anthropogenic activity may also alter nitrogen cycling". Fig. 6 describes the spatial distribution of nitrogen in the district.

The available phosphorus content in soil ranged from 7.02 to 56.94 kg/ha with a mean of 38.01 kg/ha (Table 1). The CV was recorded as 47.49 percent. Dutta et al. [22] reported that "in acid soils, there is a tendency for low soil phosphorus over time". "The integrative effects of phosphorus transformation, availability, and utilization caused by soil, rhizosphere, and plant processes influence the availability of phosphorous in the soil-plant system" [23]. Fig. 7 describes the spatial distribution of phosphorous in the district.

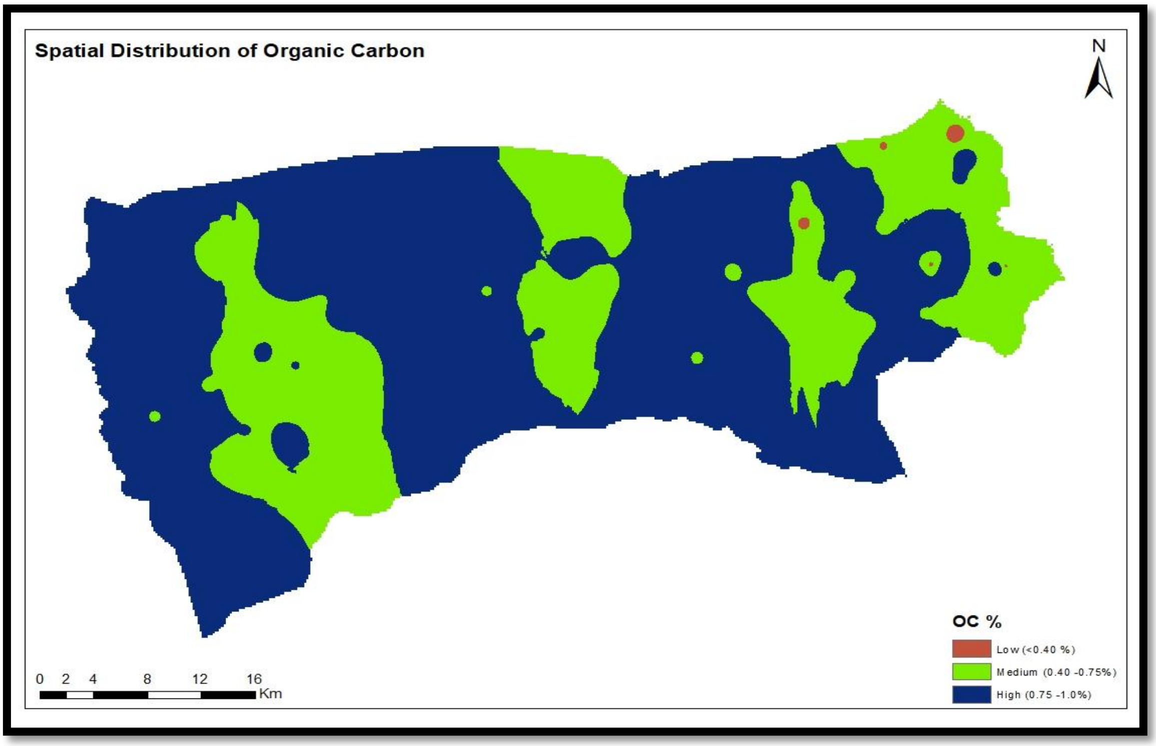

Fig. 4. Spatial distribution of organic carbon percent in the soils of Biswanath district, (Assam)

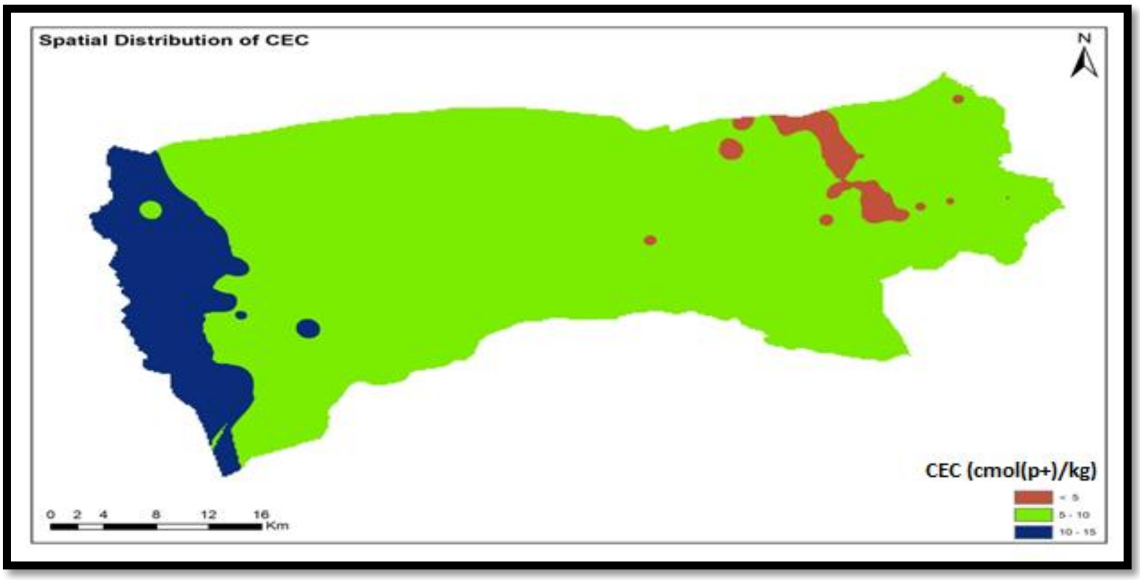

Fig. 5. Spatial distribution of cation exchange capacity (cmol(p+)/kg) in the soils of Biswanath district (Assam)

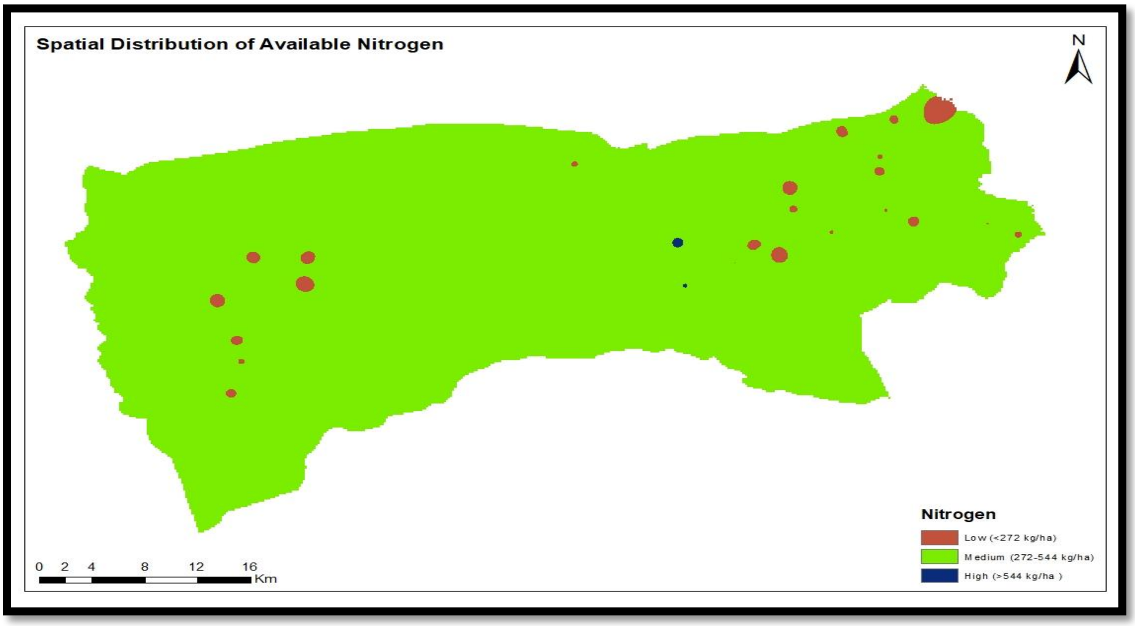

Fig. 6. Spatial distribution of available nitrogen (kg/ha) in the soils of Biswanath district (Assam)

The available potassium in the soil varied from 49.10 to 398.36 kg/ha with a mean value of 169.00 kg/ha (Table 1). The CV was found to be 52.59 percent. “Low levels of potassium [24] and medium range of potassium [25] in Assam soil were reported earlier. The medium and low available potassium content of soil also depends on the Kaolinite type of clay mineralogy” [26]. Fig. 8 describes the spatial distribution of potassium in the district.

The available sulphur varied from 5.35 to 28.92 mg/kg having a mean value of 15.42 mg/kg (Table 1). “Lack of sulphur fertilization and removal of sulphur by crops may lead to low and medium amount of sulphur in soil” [27]. “Intensive cropping without sulphur fertilization may have lead to sulphur depletion in soil” [28]. Fig. 9 indicates the spatial distribution of sulphur in the district.

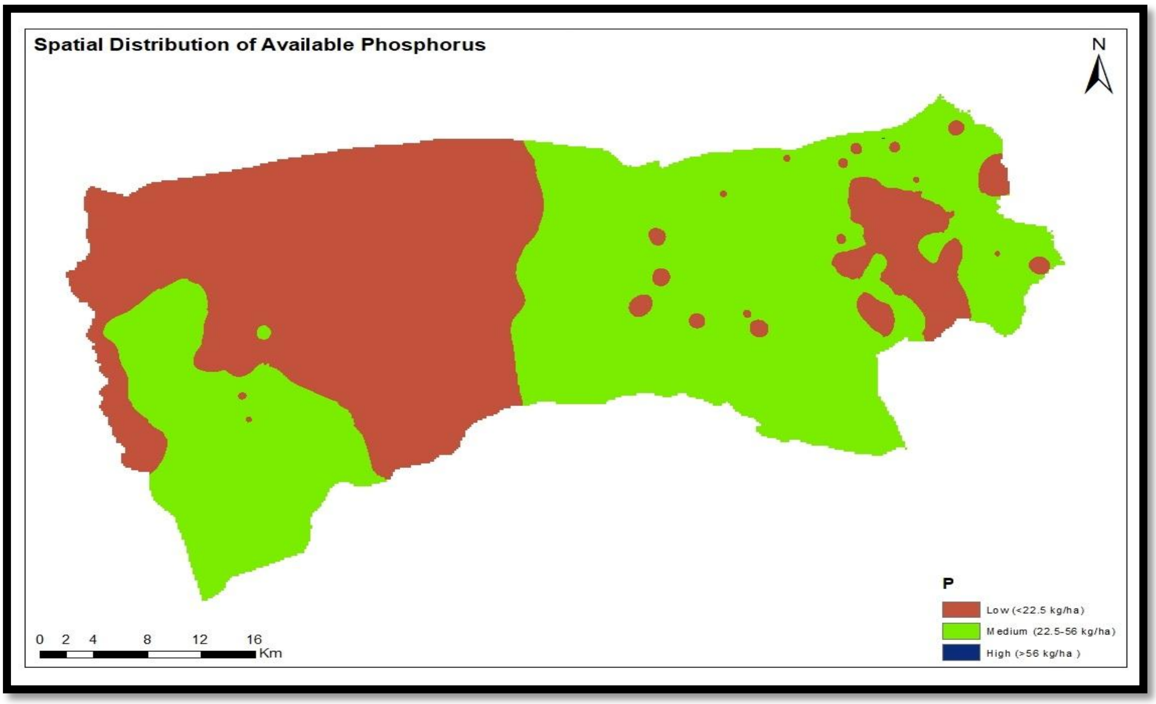

Fig. 7. Spatial distribution of available phosphorus (kg/ha) in the soils of Biswanath district (Assam)

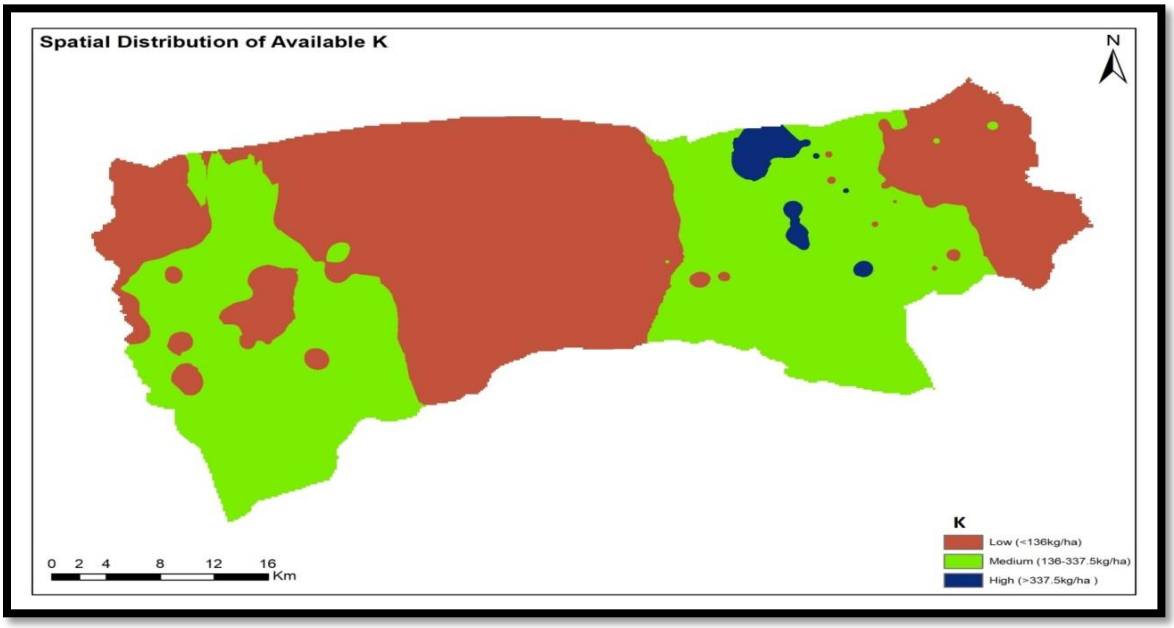

Fig. 8. Spatial distribution of available potassium (kg/ha) in the soils of Biswanath district, (Assam)

The exchangeable calcium and magnesium under study showed the range between 0.75to 3.23 cmol(p+)/kg and 0.42 to 1.98c mol(p+)/kg with the mean value of 1.36 cmol(p+)/kg and 0.90 cmol(p+)/kg (Table 1). The Figs. 10 and 11 indicated the spatial distribution of calcium and magnesium. The exchangeable sodium under study showed the range between 0.11to 0.34 cmol(p+)/kg with the mean value of 0.19 cmol(p+)/kg (Table 1). The Fig. 12 describes the spatial distribution of sodium in the district.

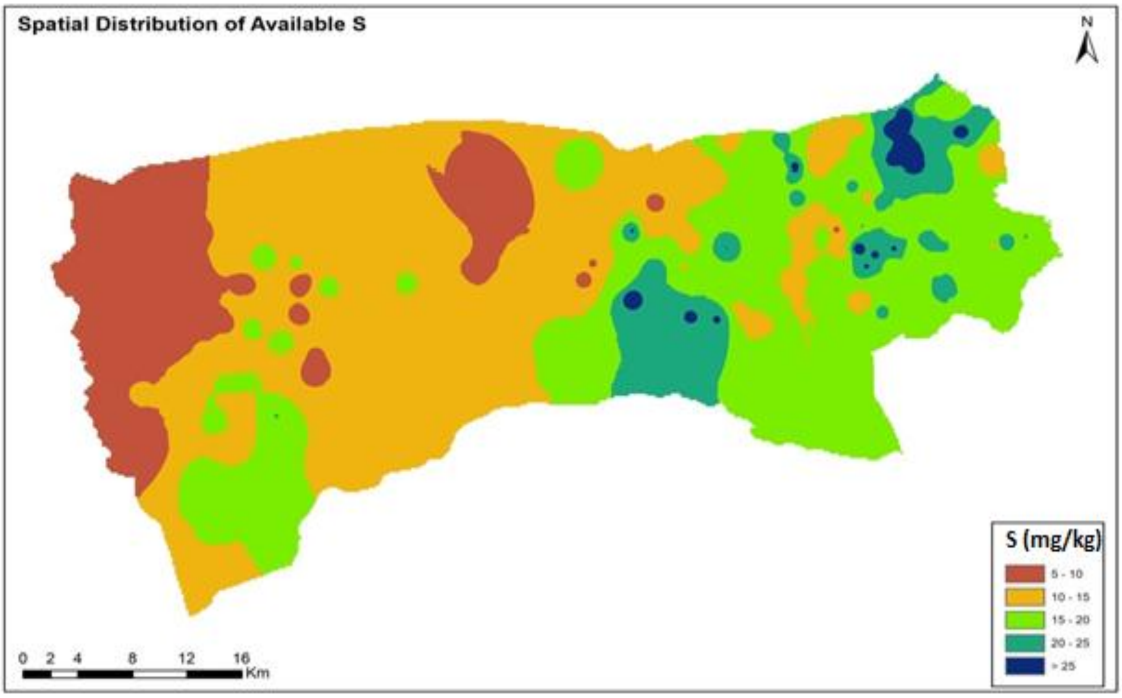

Fig. 9. Spatial distribution of available sulphur (mg/kg) in the soils of Biswanath district (Assam)

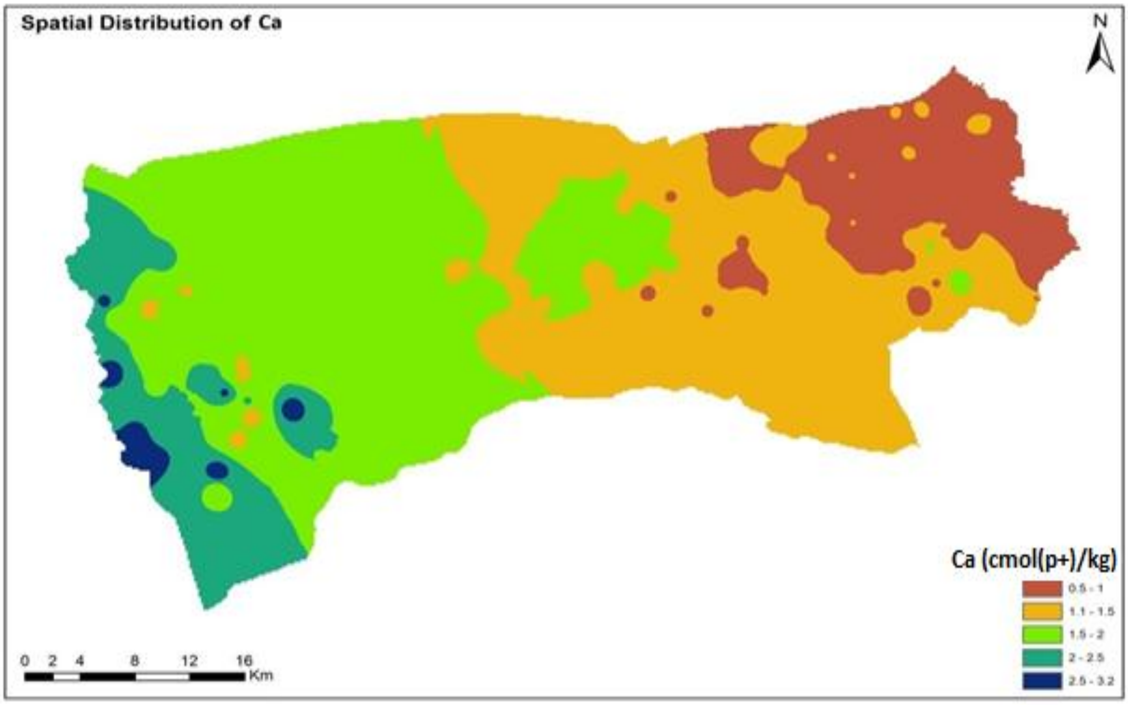

Fig. 10. Spatial distribution of exchangeable calcium (cmol(p+)/kg) in the soils of Biswanath district (Assam)

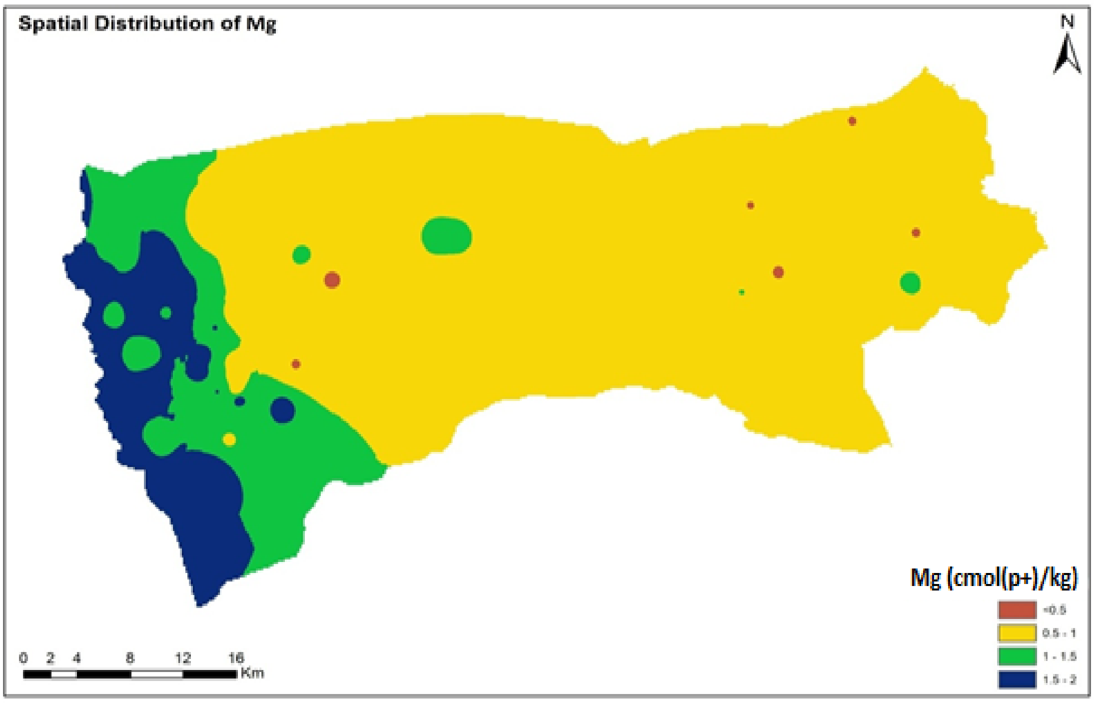

Fig. 11. Spatial distribution of exchangeable magnesium (cmol(p+)/kg) in the soils of Biswanath district (Assam)

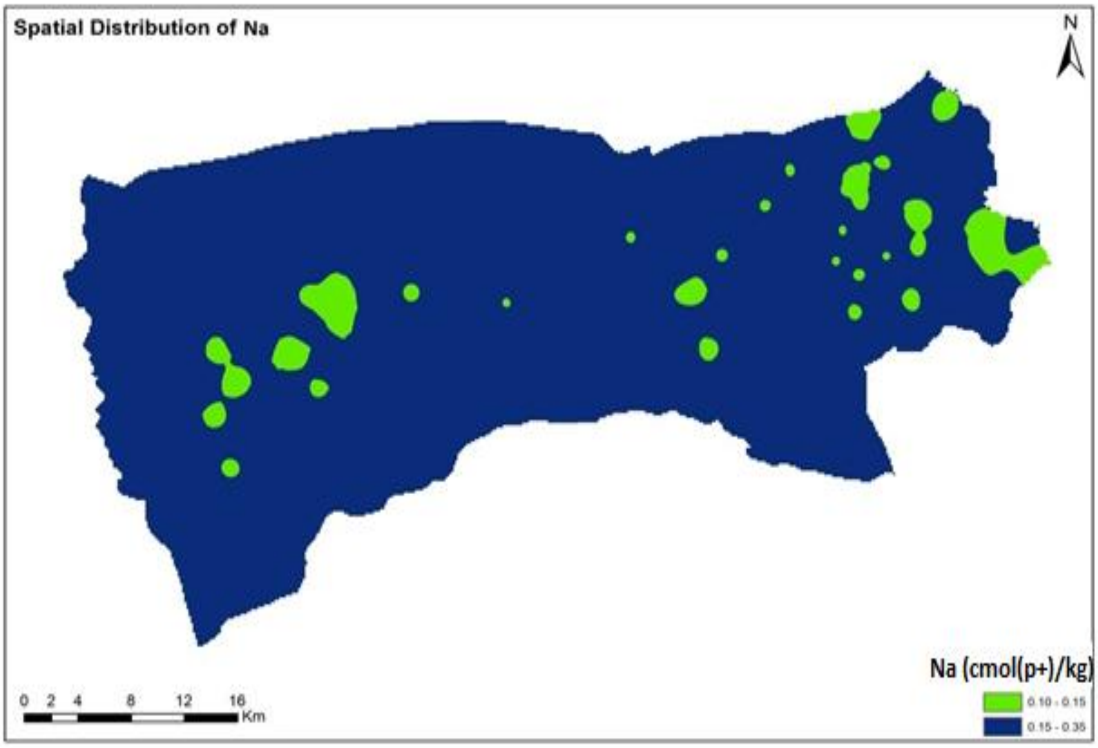

Fig. 12. Spatial distribution of exchangeable sodium (cmol(p+)/kg) in the soils of Biswanath district (Assam)

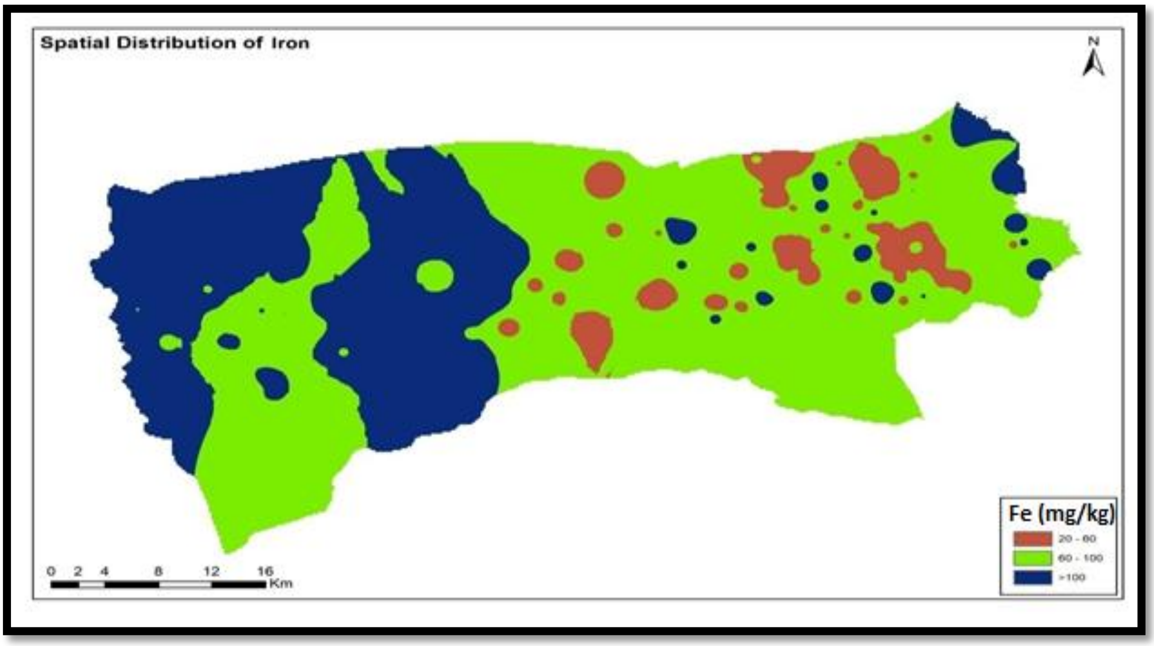

Fig. 13. Spatial distribution of DTPA-Fe (mg/kg) in the soils of Biswanath district (Assam)

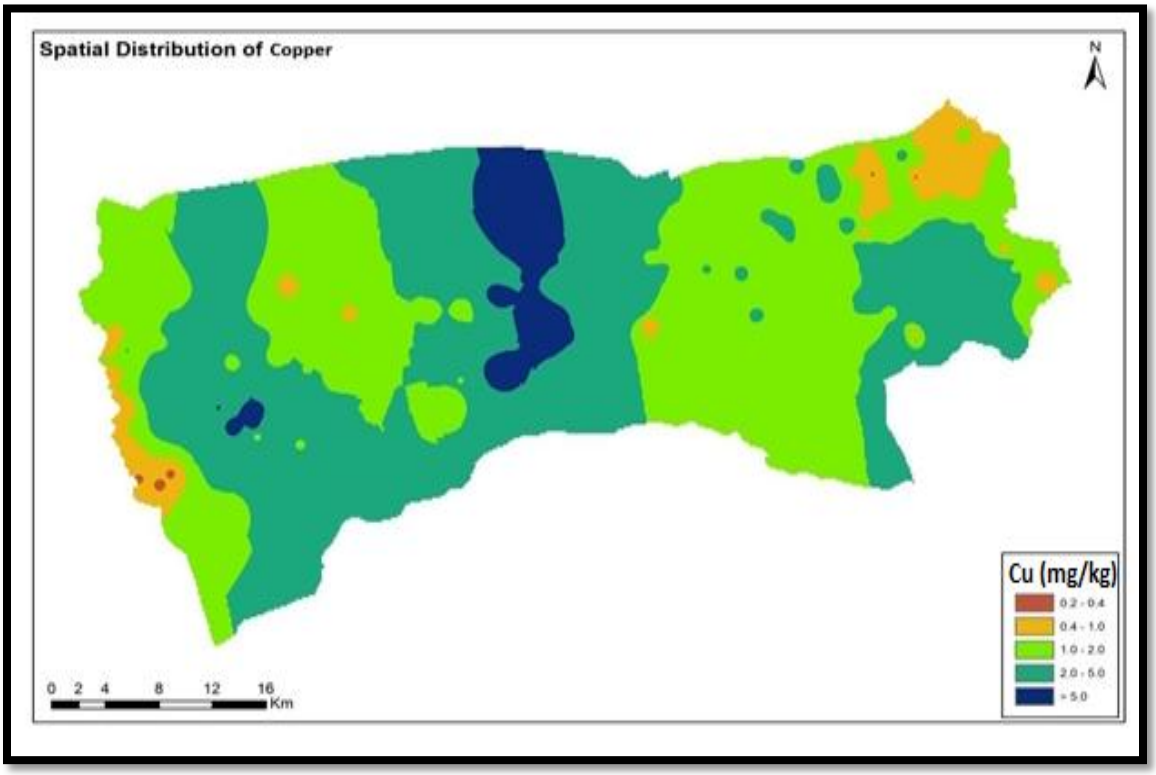

Fig. 14. Spatial distribution of DTPA-Cu (mg/kg) in the soils of Biswanath district (Assam)

The DTPA-Fe content of the district ranged from 33.64 to 168.33 mg/kg with mean value of 83.34 mg/kg (Table 1). The CV was recorded as 39.08 per cent. "The higher concentration of iron may be due to the higher organic carbon content because it acts as chelating agent. Iron reacts with certain organic molecules to form organo metallic complexes as chelates and the soluble chelates can increase the availability of the micronutrient and protect it from precipitation reactions. These chelates may also be synthesized by plant roots and released to the surrounding soil or may be present in soil humus. The increase in iron content with increase in soil organic carbon also reported by various workers" [29,10]. The Fig. 13 describes the spatial distribution of iron in the district.

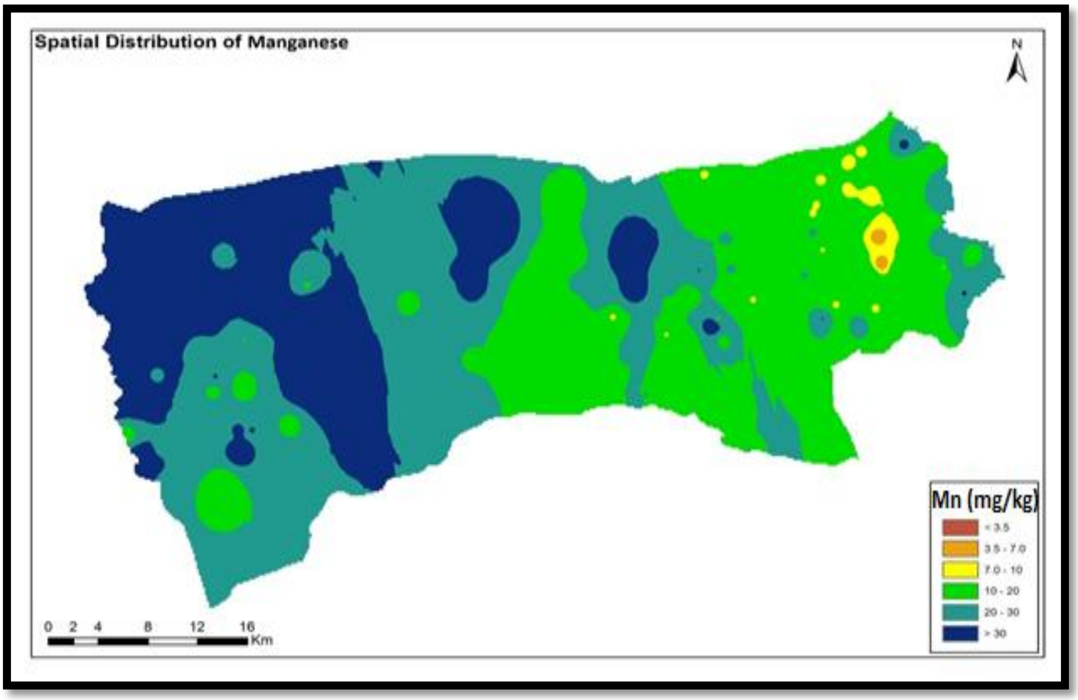

Fig. 15. Spatial distribution of DTPA-Mn (mg/kg) in the soils of Biswanath district (Assam)

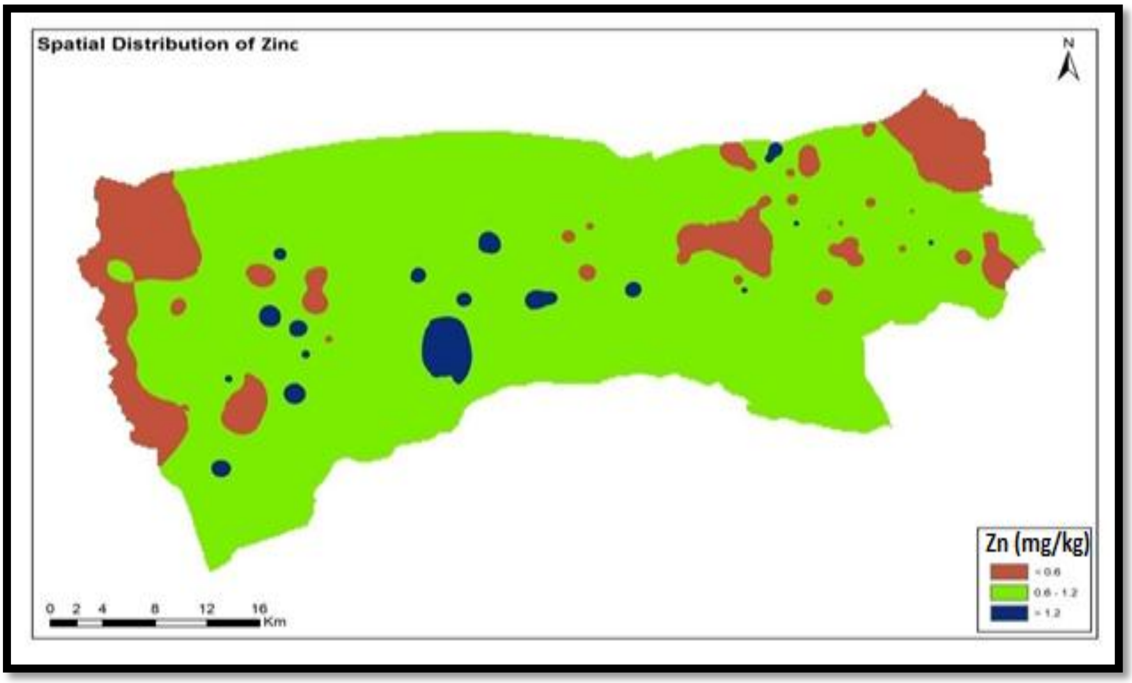

Fig. 16. Spatial distribution of DTPA-Zn (mg/kg) in the soils of Biswanath district (Assam)

The DTPA-Cu content of the District ranged from 0.33 to 5.92 mg/kg with mean value of 2.59 mg/kg (Table 1). The CV value was found to be 62.20 per cent. The variability of copper is due to variation of pH of the soil. The Fig. 14 indicates the spatial distribution of copper in the district.

The DTPA-Mn content of the District ranged from 3.28 to 68.68 mg/kg with mean value of 22.25 mg/kg (Table 1). The CV was recorded as 54.70 per cent. This increase may also be due to the fact that decrease in soil pH increased the solubility of manganese with increase in organic matter and the exchange capacity of the soil leading to more retention of manganese. Similar, results were reported by Bhuyan et al. [9] and Basumatary et al. [1]. The Fig. 15 indicates the spatial distribution of manganese in the district.

The DTPA- Zn content of the district ranged from 0.22 to 1.55 mg/kg with mean value of 0.79 mg/kg (Table 1).The CV was found to be 39.65 per cent. The distribution of zinc in any soil might be altered markedly by soil pH [30]. The Fig. 16 describes the spatial distribution of zinc in the district.

4. CONCLUSION

Maintaining and improving soil fertility are central to mitigating the adverse impacts of changing agricultural production, therefore soil fertility evaluation techniques are developed to track soil health over time. Soil fertility assessment can provide the scientific information required for informed management decisions. This framework also provides a roadmap and standardized approach to accessing soil health status by integrating soil attributes that closely relate to production capacity and sustenance of ecologically important regulatory roles. This information can be useful in developing management practices for cultivated soils of the district.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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