



# **Assessment and Mapping of Soil Nutrient Status Using GPS and GIS Techniques for Sustainable Agriculture in Barpeta District, Assam, India**

**S. Ramachandran <sup>a\*</sup>, S. Bandyopadhyay <sup>b</sup>, S. K. Reza <sup>b</sup>,  
Shelton Padua <sup>c</sup>, Bachaspati Das <sup>b++</sup>, Dimpi Barpatra <sup>d++</sup>,  
R. K. Jena <sup>e</sup>, P. Ray <sup>f</sup>, K. K. Mourya <sup>d</sup>, Surabhi Hota <sup>g</sup>,  
S. K. Ray <sup>b</sup> and U. Baruah <sup>d</sup>**

<sup>a</sup> ICAR- Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru-560089, Karnataka, India.

<sup>b</sup> ICAR- National Bureau of Soil Survey & Land Use Planning Regional Centre, Kolkata-700091, West Bengal, India.

<sup>c</sup> ICAR- Central Marine Fisheries Research Institute, Kochi, Kerala-682018, India.

<sup>d</sup> ICAR- National Bureau of Soil Survey & Land Use Planning Regional Centre, Jorhat-785004, Assam, India.

<sup>e</sup> ICAR-Indian Institute of Water Management, Bhubaneswar-751 023, Odisha, India.

<sup>f</sup> ICAR-Indian Agricultural Research Institute, New Delhi -110012, India.

<sup>g</sup> ICAR- Directorate of Weed Research, Jabalpur - 482004, (M.P.), Madhya Pradesh, India.

## **Authors' contributions**

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

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<sup>++</sup> Young Professionals;

\*Corresponding author: Email: S.Ramachandran@icar.gov.in;

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## ABSTRACT

In Barpeta District of Assam, agricultural is a major livelihood activity. The region faces annual challenges from floods and erosion, depleting soil nutrients. Additionally, the mono-cropping system of rice further degrades the land. Assessing macro and micro nutrients and mapping the soil nutrient status help develop targeted strategies to replenish nutrient levels, improve farming techniques, and enhance the productivity and resilience of agriculture in Barpeta District. To address these issues and highlight the importance of soil nutrients for sustainable agriculture, soil fertility status maps were prepared using GPS and GIS techniques. For this study, 1,293 georeferenced soil samples were collected at 1 km intervals from 718 villages, covering 11 community development blocks and 9 revenue circles. These samples were analyzed for 9 (pH, OC, N, P, K, Fe, Mn, Zn and Cu) chemical parameters, and the data, along with GPS readings, were used to create soil fertility maps using GIS. The results revealed that a significant portion of the district was acidic (53.0% of TGA), with 13.0% of the area being slightly to moderately alkaline. Organic carbon (OC) levels were recorded as low, medium, and high in 7.6%, 24.1%, and 42.9% of the area, respectively. Nitrogen (N) and phosphorus (P) were found to be medium in most areas, while potassium (K) was largely low. Zinc (Zn) was predominantly deficient (47.2% of TGA), while iron (Fe), manganese (Mn), and copper (Cu) were sufficient. Overall, the major nutrient constraints in Barpeta District are soil acidity, available potassium (K), and zinc (Zn). The assessed soil nutrient status can be a valuable tool for local farmers to plan their crops and for agricultural planners to develop large-scale crop improvement strategies and recommend site-specific nutrient management practices. In the future, GIS and GPS-based nutrient management will help monitor soil nutrient status, maintain soil health, and ensure sustainable agricultural production. Also, it will assist in providing soil test crop response-based nutrient recommendations and applying corresponding micronutrients to enhance soil fertility and crop productivity.

**Keywords:** *GPS; GIS techniques; soil nutrient mapping; soil fertility appraisal and sustainable agricultural.*

## 1. INTRODUCTION

Sustainable agriculture is crucial to meet the increasing food demand of Assam's growing population. High crop productivity, which depends on fertile soil, is essential for food security. Evaluating the soil fertility status is vital for crop production, as it is influenced by essential nutrients like Nitrogen (N), Phosphorus (P), Potassium (K) (Singh and Mishra, 2012), and micronutrients (Bingham, 1982; Chesnin and Yien, 1950). Unfortunately, crop production in Assam remains stagnant due to imbalanced and inadequate fertilizer use, along with low efficiency of other inputs. The response efficiency of chemical fertilizers has declined significantly under intensive agriculture. Periodic characterization of soil fertility and mapping the spatial distribution of available soil nutrient status are essential for location-specific crop management and sustainable agriculture, as well as precision farming. However, such geo-coded

data is lacking for in-depth studies. At the field level, farmers need time-series information to plan crops and procure fertilizers, while at district and state levels, technocrats require time-series data to identify critical areas needing different fertilizers. Barpeta district, known for its jute production, has 85% of its population engaged in agriculture. The district faces severe soil erosion, causing significant nutrient loss and agricultural destruction (Makbul Hussain Khan, 2012). Due to illiteracy, poverty, unemployment, disguised unemployment, high growth rate, and other socio-economic challenges, the people of Barpeta depend heavily on agriculture for their livelihood (Makbul Hussain Khan, 2012). To boost crop productivity, judicious use of macro and micronutrients is necessary. Soil nutrient variation is natural, with some nutrients being sufficient while others are deficient. Soil testing plays a critical role in the effective use of fertilizers and other agricultural inputs (Santhi et al., 2018). Soil test summaries and soil fertility

maps are essential reference materials for scientific soil management (Bowman et al., 1999; Palm et al., 2007). Soil properties vary spatially due to intrinsic factors (parent materials and climate) and extrinsic factors (soil management practices, indigenous fertility status, crop rotation, and standing crop nature) (Cambardella and Karlen, 1999). The spatial variability of soil fertility has been challenging to describe until the advent of technologies like GPS and GIS. Collecting soil samples using GPS is crucial for preparing thematic soil fertility maps (Mishra et al., 2013). GIS is a powerful tool for easy access, retrieval, and manipulation of large volumes of natural resource data (Hussain et al., 2024), aiding farm planning (Mandal and Sharma, 2009 and 2010). Understanding soil fertility status is essential for the judicious application of fertilizers and amendments to achieve higher crop production (Barua and Bora, 1969). Since such work has not been previously conducted in Barpeta district, the current study aims to assess the status of available major and micronutrients using advanced technology to enhance sustainable agricultural production more effectively, timely, and cost-efficiently. Given all these considerations, a project was undertaken by the ICAR-National Bureau of Soil Survey and Land Use Planning, Jorhat, titled "Soil Nutrient Status Mapping of Assam for Site-Specific Nutrient Management Using Geospatial Techniques." The project focused on 13 priority district of Assam in which Barpeta district one with the goal of creating GPS and GIS-based soil fertility maps of the district. By employing these maps to guide fertilizer application in a site-specific manner, new opportunities for managing soil health and achieving optimal fertilizer usage efficiency may arise. These maps could also serve as reference points for future surveys, providing a real-time perspective of the evolving fertility scenario at the block, village, or district level. Therefore, it is important to investigate nutrient status and map their spatial distribution to provide valuable information for agricultural development. Hence, these activities were initiated with the objective of identifying and classifying soil nutrient status in the study area and mapping soil fertility parameters.

## 2. MATERIALS AND METHODS

### 2.1 Geographical Setting

Barpeta district in Assam is located between latitudes 26° 05' 40" N and 26° 39' 30" N and longitudes 90° 39' 0" E and 91° 17' 45" E, covering an area of 2237.2 km<sup>2</sup> (as per ICAR-

NBSS&LUP, ICAR, Govt. of India). Of this area, 569.2 km<sup>2</sup> (25.46% of the total geographical area) is occupied by water bodies and sandbars (Fig. 1).

The district comprises two subdivisions, Barpeta and Bajali, and nine revenue circles: Barpeta, Baghbar, Sarthebari, Barnagar, Kalgachia, Chenga, Bajali, Sarupeta, and Jalah. Barpeta serves as the district headquarters. Situated in Lower Assam, Barpeta is bordered by Baksa District to the north, Nalbari District to the east, Kamrup and Goalpara Districts to the south, and Bongaigaon District to the west.

### 2.2 Collection and Analysis of Soil Samples

The base maps of Barpeta district were created using village boundary maps published by the Assam Survey, Government of Assam, in conjunction with Survey of India Topographical Sheets at a 1:50,000 scale (78 J / 14, 15, and 16; 78 N / 2, 3, 4, and 7). All maps were marked with grid points at 1 km intervals. A total of 1,293 grid samples were collected across the district, excluding grids in water bodies and inaccessible forest areas. Representative soil samples (0-25 cm depth) were gathered from each grid point for analysis. The soil samples were air-dried, sieved, ground, and analyzed for various parameters: pH was measured using a glass electrode in a 1:2.5 soil/water suspension, organic carbon was determined by Walkley and Black (1934), available potassium was extracted with 1 M NH<sub>4</sub>OAc and measured by flame photometer, available nitrogen was determined by Subbiah and Asija (1956), available phosphorus was measured by Bray P-1 (Bray and Kurtz 1945), and cationic micronutrients were assessed by Lindsay and Norvell (1978) using an atomic absorption spectrophotometer (Shimadzu model No. AA-6300). The soils were then classified into different fertility assessment classes as per Takkar's (2009) guidelines.

#### 2.2.1 Per cent sample category

The analytical results for each soil sample were categorized into low, medium, and high categories for organic carbon and macronutrients, and as deficient, moderate, or sufficient based on the critical limits for available micronutrients in Assam. The percentage of samples in each category and nutrient index values (NIV) were computed using the provided formulae.

Per cent sample category = No. of "low (L)" or "medium (M)" or "high (H)" category / Total no. of samples \* 100

## 2.2.2 Nutrient index values and fertility rating

The Nutrient Index Value (NIV) is calculated based on the proportion of soils falling into low, medium, and high available nutrient categories, using the formula:

$$NIV = [(P_H \times 3) + (P_M \times 2) + (P_L \times 1)] / 100$$

Here, NIV represents the nutrient index value;  $P_L$ ,  $P_M$ , and  $P_H$  are the percentages of soil samples falling in the low, medium, and high nutrient status categories, respectively. These categories are given weightages of one, two, and three, respectively (Ramamoorthy and Bajaj, 1969). The index values are then rated into various categories viz., low (<1.67), medium (1.67-2.33) and high (>2.33) for OC and available N, P and K. For available

micronutrients, the ratings are very low (<1.33), low (1.33-1.66), marginal (1.66-2.00), adequate (2.00-2.33), high (2.33-2.66) and very high (>2.66).

## 2.2.3 Statistical Analysis and Generation of thematic soil fertility maps

Descriptive statistics (mean and range) of soil parameters were computed using an Excel data sheet. The point-wise analytical database was imported into the GIS platform (ArcGIS software version 10.3.1) to create soil nutrient maps. Point data were transformed into area features using the Regular Spline method of interpolation (Collins and Bolstad, 1996; Hutchinson, 1995). Based on the available nutrient status, thematic maps were generated in GIS, ranking macro-nutrients as 'low', 'medium', and 'high', and micro-nutrients as 'deficient', 'moderate', and 'sufficient'.

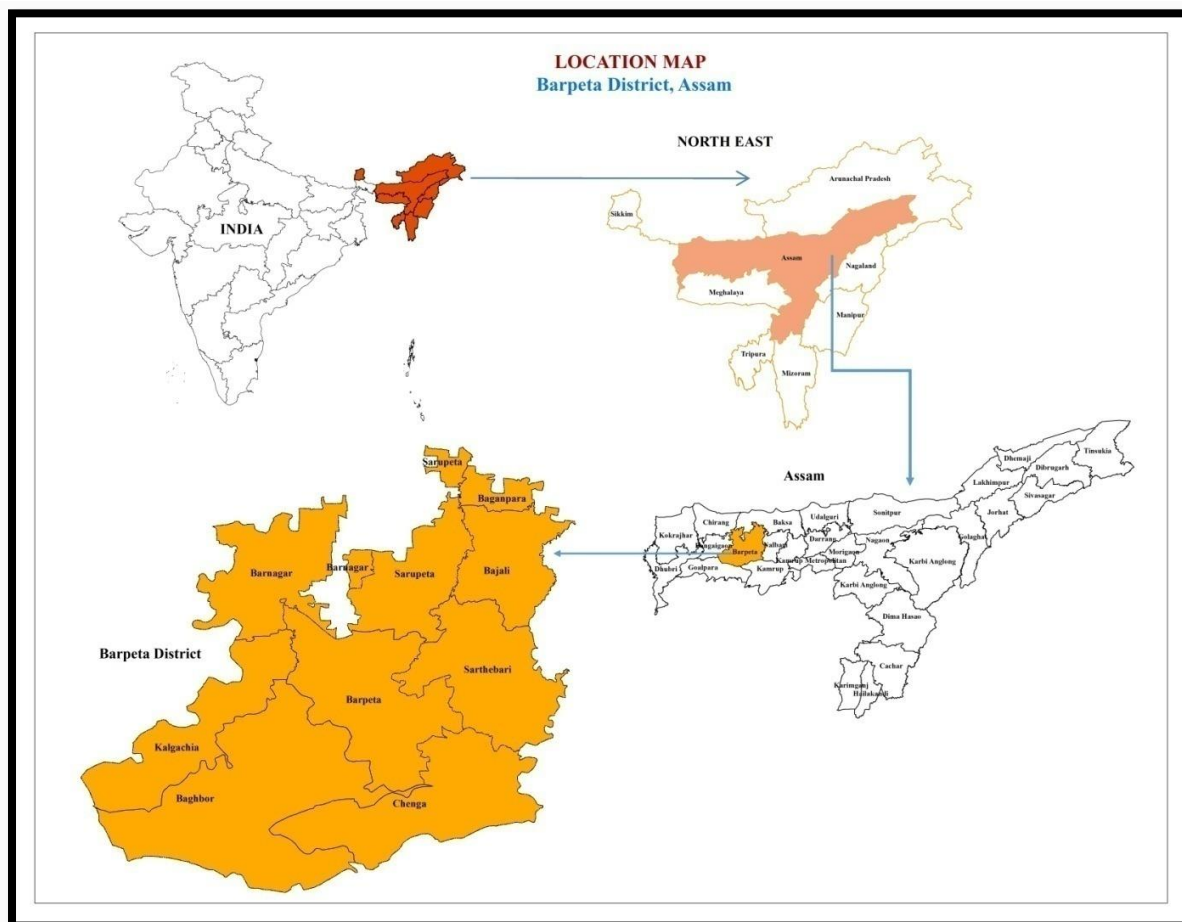


Fig. 1. Location map of Barpeta district, Assam (India)

### 3. RESULTS AND DISCUSSION

#### 3.1 Soil Reaction (pH)

The pH of the surface soil (Table 1) ranged from 3.99 to 8.4, with a mean of 5.91. Approximately 53.0% of the samples were found to be acidic, likely due to the high annual rainfall (2000-2500 mm) in this region, which leads to the loss of basic cations, as reported by Chakravarty et al. (1987) and Sathish et al. (2017), resulting in low base saturation of the soil (Prasenjit Ray et al., 2018). Similar results were also reported in Assam by Barooah et al. (2020) and Bikram Borkotoki et al. (2024). In contrast, 21.5% of the samples exhibited neutral to alkaline pH, which may be attributed to a higher degree of base saturation (Waghmare et al., 2008; Sharma et al., 2008). The extensive area with low pH is also influenced by the long-term use of inorganic fertilizers instead of green manure, farmyard manure, and rice-straw residues, which has contributed to a decrease in soil pH (Tiwarly et al., 2003).

#### 3.2 Organic Carbon

The overall organic carbon (OC) status of the soil (Table 1) ranged from 0.02% to 3.47%, with a mean value of 0.80%. The OC levels were recorded as high, medium, and low in 42.9%, 24.1%, and 7.6% of the area, respectively. About 7.6% of the soil samples were categorized as low OC status, resulting in an overall fertility rating of 'high.' This low OC status is primarily due to high temperatures leading to a higher rate of organic matter decomposition (Kameriya, 1995), and the lack of organic matter additions (Rego et al., 2003; Sathish et al., 2017). This indicates a need for rejuvenation for high crop productivity. The maximum area with high and medium OC can be attributed to the frequent addition of crop residues, higher root mass density, and organic root tissue (Patil and Ananth Narayana, 1990; Behera and Shukla, 2014).

#### 3.3 Available N, P and K

The overall available nitrogen (N) status (Table 1) ranged from 91 to 685 kg ha<sup>-1</sup> with a mean value of 336 kg ha<sup>-1</sup>. The results indicated that 48.2% of the district's soils had a medium availability of nitrogen (280-560 kg ha<sup>-1</sup>). In Lakhimpur, Assam, 65% of the soils fall into the medium category (Bikram Borkotoki et al., 2024). Another 22.7% of the area showed low nitrogen availability (<280 kg ha<sup>-1</sup>), while only 3.7% had high nitrogen availability (>560 kg ha<sup>-1</sup>). The

majority of soil samples (48.2%) had a medium status with an overall fertility rating of 'medium.' This could be attributed to the higher OC content in the surface, which might have aided in the mineralization of soil nitrogen, leading to a build-up of higher available nitrogen (Urkurkar et al., 2010; Sharma et al., 2007). Similar result was also reported by Verma et al., (2007) and Pandiaraj et al., (2017). The Bray-P (Table 1) ranged from 18 to 359 kg ha<sup>-1</sup> with an overall mean value of 55 kg ha<sup>-1</sup>. The sample categories revealed 30.8% under medium status with an overall fertility rating of 'medium,' and 22.3% in the high status category. This high status could be due to the continuous application of single superphosphate (SSP) for crops, which would have built up soil available phosphorus, and the high rate of soil organic matter (SOM) mineralization of organic phosphorus to available phosphorus. It may also be partly due to inheritance from parent materials and the effects of continuous application of phosphate fertilizers over the past 2-3 decades (Singh et al., 2007). The low sample category status, covering 21.5% of the area, may be due to high rainfall and a higher rate of SOM decomposition, which increases the leaching of available phosphorus from surface soils (Urkurkar et al., 2010) and precipitation of phosphorus as iron and aluminium complexes due to soil acidity (Prasenjit Ray et al., 2018). In acid soil the tendency of low soil phosphorus over time reported by Dutta et al., (2008) this result confirmation with finding of Barooah et al., (2020). The available potassium (K) ranged from 40 to 479 kg ha<sup>-1</sup> with a mean of 134 kg ha<sup>-1</sup>. The sample categories under low, medium, and high were 42.9%, 26.5%, and 5.2%, respectively, with an overall medium fertility rating. The 'low' available potassium in these soils may be due to the continuous drain of potassium from the soil reserve over the years with inadequate supply of chemical fertilizers to meet crop needs. Mining of potassium has started appearing in the soils, which is a matter of concern. In Assam, potassium deficiency is observed due to higher amounts of non-exchangeable potassium content in the soil than potassium in solution (Dutta and Zaman, 2013), and a negative balance of potassium has been reported by Basumatary and Talukdar (1999) and Borkakati et al. (2001). Moreover, the application of higher amounts of nitrogenous fertilizers than phosphorus-type and potassium-type fertilizers may result in decreased soil available phosphorus and exchangeable potassium (Singh et al., 2010).

Table 1. Soil fertility status of Barpeta district of Assam

Parameters/Nutrients	Range	Mean	Per cent sample category			NIV	Fertility rating	Per cent area based on soil fertility maps		
			Acidic/ Low/ Deficient	Neutral/ Medium/ Moderate	Alkaline/High/ Sufficient			D	M	S
pH	3.99-8.40	5.91	68	24	8	-	-	53	9	13
OC (%)	0.02-3.47	0.80	15	34	51	2.38	High	8	24	43
Available N (kg ha <sup>-1</sup> )	91-685	336	34	64	2	1.68	Medium	23	48	4
Available P (kg ha <sup>-1</sup> )	18-359	55	27	40	33	2.07	Medium	21	31	22
Available K (kg ha <sup>-1</sup> )	40-479	134	61	38	1	1.4	Low	43	26	5
Available Fe (mg kg <sup>-1</sup> )	0.95-197.67	66.29	0	73	27	2.27	Adequate	4	48	23
Available Mn (mg kg <sup>-1</sup> )	1.12-136.77	21.14	0	75	25	2.25	Adequate	7	48	20
Available Cu (mg kg <sup>-1</sup> )	0.23-17.31	3.31	0	50	50	2.5	High	6	33	35
Available Zn (mg kg <sup>-1</sup> )	0.04-0.85	0.58	70	24	6	1.36	Low	47	21	7

\*25.46% of TGA is occupied by river and sand bar; Acidic, neutral and alkaline for pH; Low, medium and high for OC and available N, P and K; Deficiency, moderate and sufficient for micronutrients

Table 2. Proposed nutrient plan for Barpeta district

Strategies	Revenue circle/Tehsil	Remedial measures
Soil amendment Acidity	Whole district except Kalgachia and Baghbor revenue circle.	Calcium carbonate @ 4 t ha <sup>-1</sup> or 5 q/ bigha at every alternate year during land preparation Acid tolerant crops viz., rape seed (variety - varuna, sonmukhi), green gram (K851 and Sonmngu); vegetables: potato, sweet potato, chow-chow, yam and dioscoria sp, cauliflower etc. can be grown.
Application of organic manures and bio-fertilizer like <i>Rhizobium</i> culture @ 150g for enhancing organic carbon status.	Whole district	Well decomposed FYM @ 5-10 t ha <sup>-1</sup> during land preparation. organic manures viz., FYM/vermicompost @ 5 t ha <sup>-1</sup> . <i>In-situ</i> crop decomposition etc. for residue incorporation along with <i>Trichoderma viride</i> enhancing the organic (@ 4g kg <sup>-1</sup> ).
Recommendations for NPK	Low N status- Kalagachia and Chenga revenue circle.	<a href="http://www.stcr.gov.in">http://www.stcr.gov.in</a> and <a href="http://www.soilhealth.dac.gov.in">http://www.soilhealth.dac.gov.in</a> . 25% higher than the recommended of K <sub>2</sub> O is recommended as maintenance dose.

Strategies	Revenue circle/Tehsil	Remedial measures
	Low P status - Barpeta, Sarupeta, Balaji, Sarthebari and Chenga Low K status- Barnagar, Balaji, Sarupeta, Jelah and Sarthebari revenue circle.	
Recommendations for micronutrients	Fe- sufficient in whole district	Recommended dose of $\text{FeSO}_4$ can be applied according to crop and varieties (e.g. Sugarcane - $\text{FeSO}_4$ @ 100 kg ha <sup>-1</sup> ).
	Mn- moderate in whole district except Baghbor revenue circle.	Recommended dose of $\text{MnSO}_4$ can be applied according to crop and varieties (e.g. pearl millet - $\text{MnSO}_4$ @ 12.5 kg ha <sup>-1</sup> ).
	Cu - sufficient in whole district except fringe are of Baghbor and Chenga revenue circle.	Recommended dose of $\text{CuSO}_4$ can be applied according to crop and varieties (e.g. rice - $\text{CuSO}_4$ @ 5 kg ha <sup>-1</sup> ).
	Zn - deficient in whole district except Sarthebari revenue circle.	Recommended dose of $\text{ZnSO}_4$ can be applied according to crop and varieties (e.g. rice - $\text{ZnSO}_4$ @ 25 kg ha <sup>-1</sup> ).

### 3.4 Available Micronutrients

Iron is a crucial micronutrient for plants, playing a significant role in various metabolic processes (Rout and Sahoo, 2015). The available Fe status (Table 1 and Fig. 7) ranged from 0.95 to 197.7 mg kg<sup>-1</sup>, with a mean of 66.3 mg kg<sup>-1</sup>. Deficient, moderate, and sufficient Fe statuses were observed in 4.2%, 47.7%, and 22.6% of the samples, respectively, with a mean fertility rating of adequate based on the nutrient index value (NIV). Fe solubility increases with a reduction in soil pH (Shukla et al., 2015), which aligns closely with the findings of Brady and Weil (2002). Soils in Barpeta with higher organic matter content may contribute to increased Fe levels, consistent with Khalifa et al. (1996) and Goldberg et al. (2002).

Manganese is another essential micronutrient involved in various plant metabolic processes, including photosynthesis and acting as an enzyme antioxidant-cofactor (Millaleo et al., 2010). The available Mn status ranged from 1.12 to 136.77 mg kg<sup>-1</sup>, with a mean value of 21.14 mg kg<sup>-1</sup>. About 75% of the samples had moderate Mn levels, with an overall fertility rating of "adequate." This may be due to the decomposition of organic matter releasing micronutrients and lowering the soil pH around plant roots, thus increasing the solubility of cationic micronutrients (Sharma and Chaudhary, 2007).

Copper is an essential micronutrient for plant growth and development, though it can be toxic in high amounts (Yruela, 2005). The available Cu status ranged from 0.23 to 17.31 mg kg<sup>-1</sup>, with a mean of 3.31 mg kg<sup>-1</sup>. About 50% of the samples showed sufficient Cu levels, with an overall fertility rating of "high." This may be due to the high organic carbon content and acidic pH of the soils, which favor Cu solubility (Prasenjit Ray et al., 2018).

Zinc deficiency is a significant micronutrient constraint for food production globally, and its application has shown positive responses in almost all crops (Welch, 2002). The available Zn status (Table 1 and Fig. 10) ranged from 0.04 to 0.85 mg kg<sup>-1</sup>, with a mean of 0.58 mg kg<sup>-1</sup>. About 70% of the soil samples were deficient in available Zn, with an overall rating of "low," consistent with findings by Bhuyan et al. (2014) in Lakhimpur district and Reza et al., (2021) in Nalbari district of Assam. Zn deficiency in Barpeta may be due to the coarse soil texture

and intensified agricultural systems leading to imbalanced micronutrient use (Shukla et al., 2014). The total Zn content in soils largely depends on the parent rock materials (Kabata-Pendias and Pendias, 1992), and Zn deficiency is often more common in sandy soils than in clayey soils due to higher Zn adsorption in clay soils, controlled by cation exchange capacity (CEC) and pH (Ellis and Knezek, 1972). The lowest Zn levels were recorded in the soils of the recent alluvial high flood plain (Ray and Banik, 2016).

### 3.5 Thematic Soil Fertility Maps

The percentage area based on soil fertility maps for all nine chemical parameters is depicted in Figs. 2 to 10.

### 3.6 Soil pH and Organic Carbon

Regarding soil pH, the soils are primarily acidic, with 53% of the total geographical area falling under this category. Neutral and alkaline soils follow. As for organic carbon (OC) status, it is predominantly high, covering 43% of the total geographical area, followed by a medium status accounting for 24%.

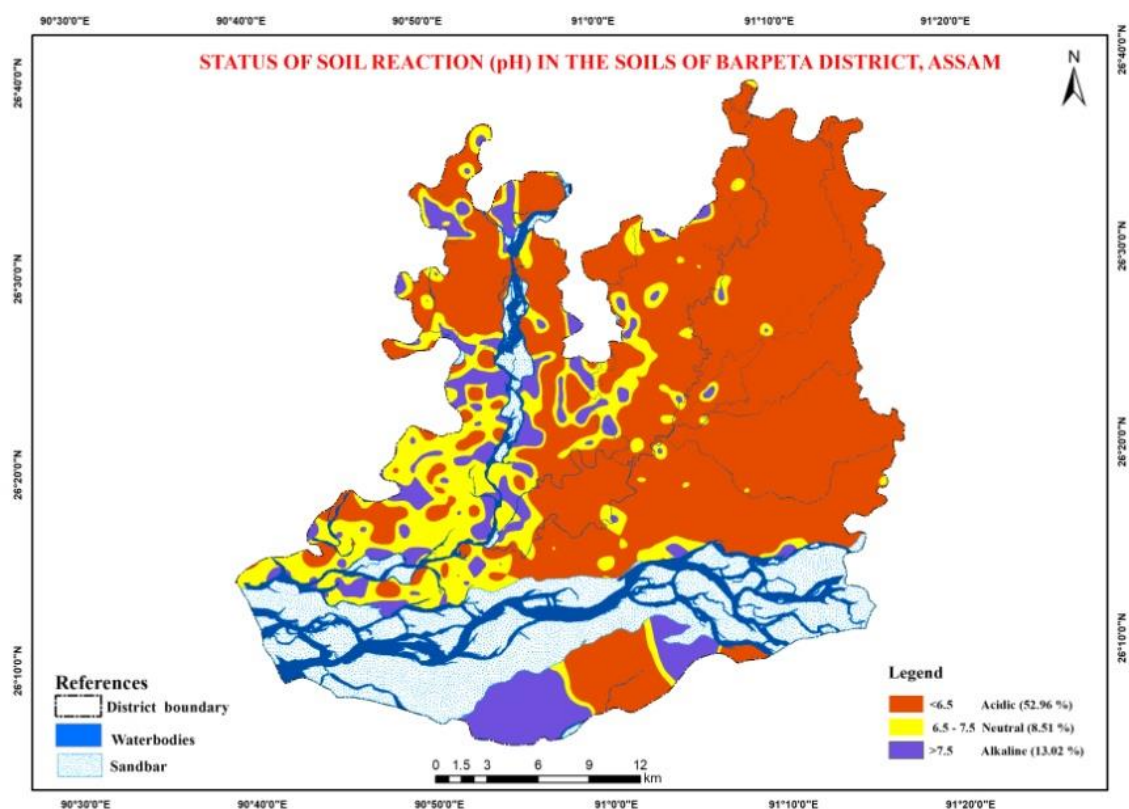
### 3.7 Available Nutrients

About 48% of the area falls under the medium category for available nitrogen (N). For available phosphorus (P), approximately 31% of the area is medium, 22% is high, and 21% is low. Around 43% of the area is low in available potassium (K), 26% is medium, and only 5% is high. Regarding micronutrients, iron (Fe) status is moderate in 48% of the area, sufficient in 23%, and deficient in 5%. Manganese (Mn) is predominantly moderate in 48% of the area, sufficient in 20%, and deficient in 7%. Copper (Cu) is sufficient in 42% of the area, with 35% and 33% of the area under sufficient and moderate status, respectively. Zinc (Zn) is predominantly deficient in 47% of the area, moderate in 21%, and sufficient in only 7% of the total geographical area (TGA).

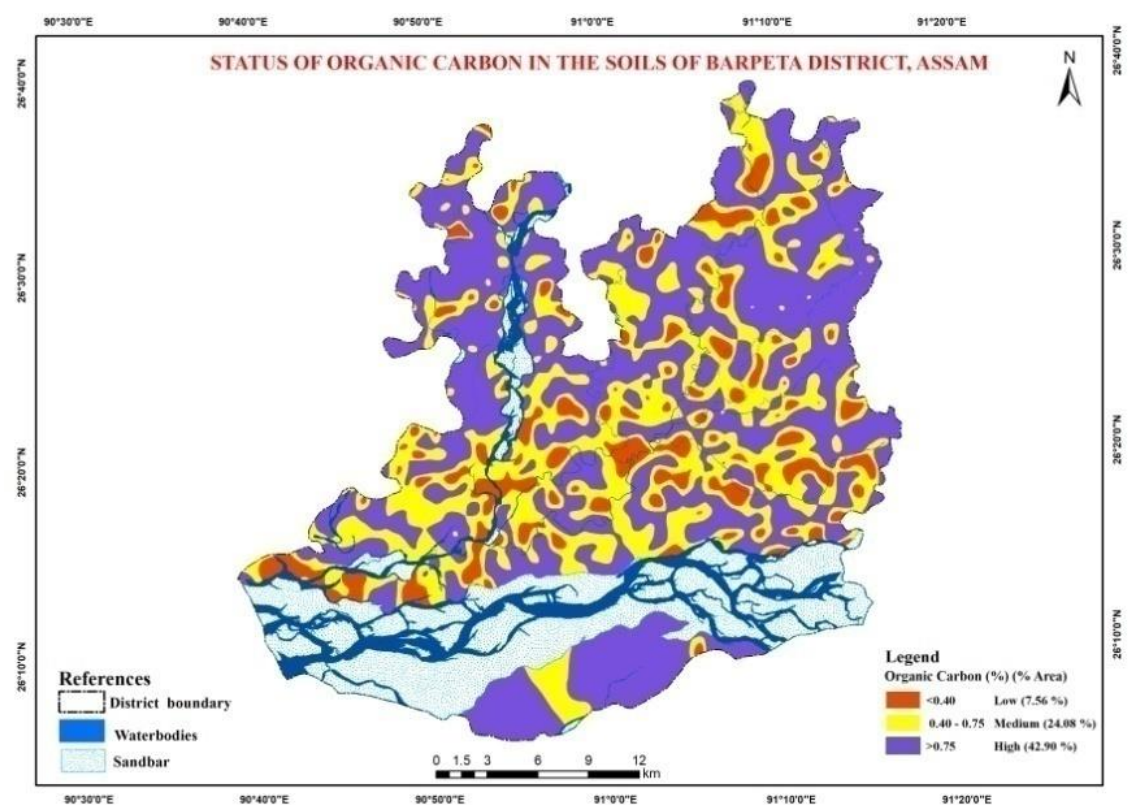
### 3.8 Proposed Nutrient Plan for Barpeta District

Based on the soil fertility appraisal of the district, a nutrient plan for various revenue circles/tehsils has been prepared and is presented in Table 2 for implementation.





**Fig. 2. Status of Soil reaction (pH) in the soils of Barpeta district, Assam (India)**



**Fig. 3. Status of Organic carbon in the soils of Barpeta District, Assam (India)**

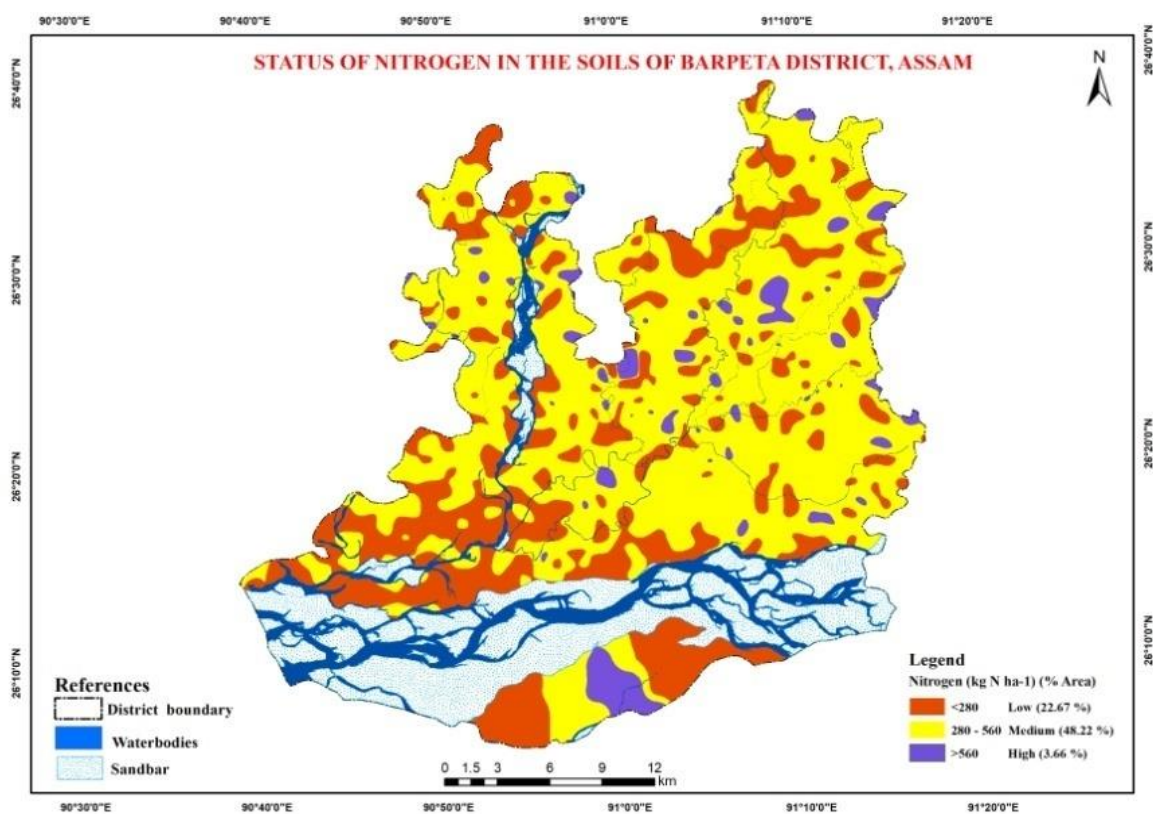


Fig. 4. Status of Available nitrogen in the soils of Barpeta District , Assam (India)

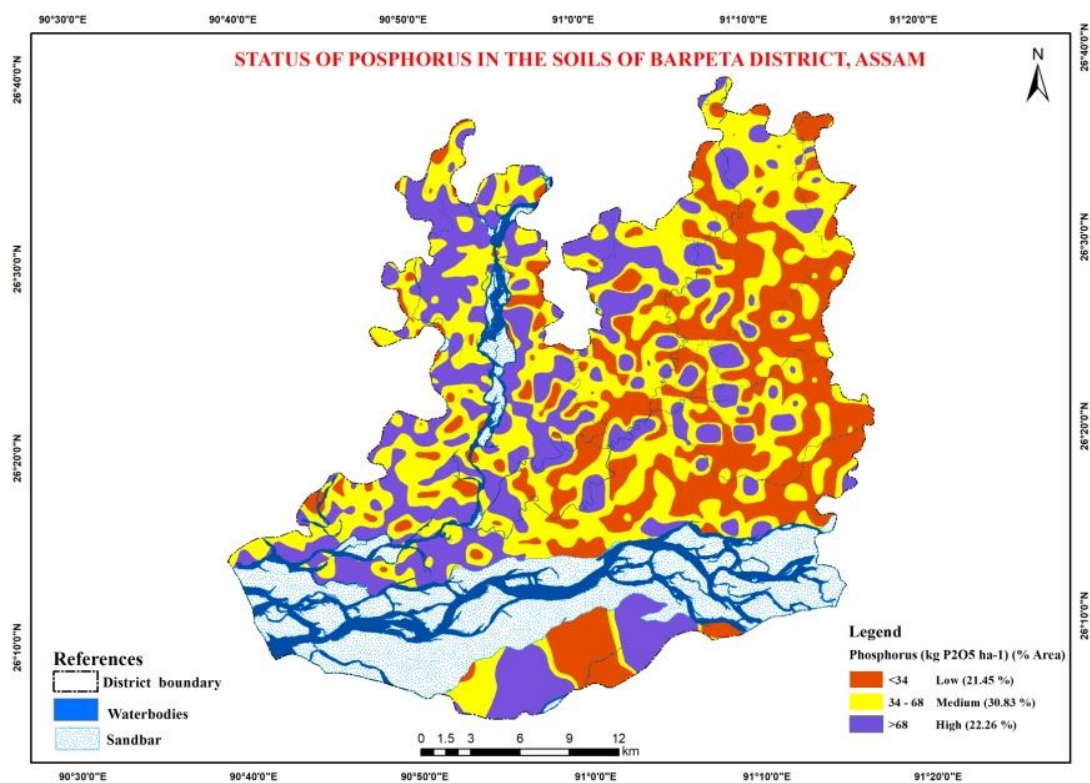


Fig. 5. Status of Available phosphorus in the soils of Barpeta District, Assam (India)

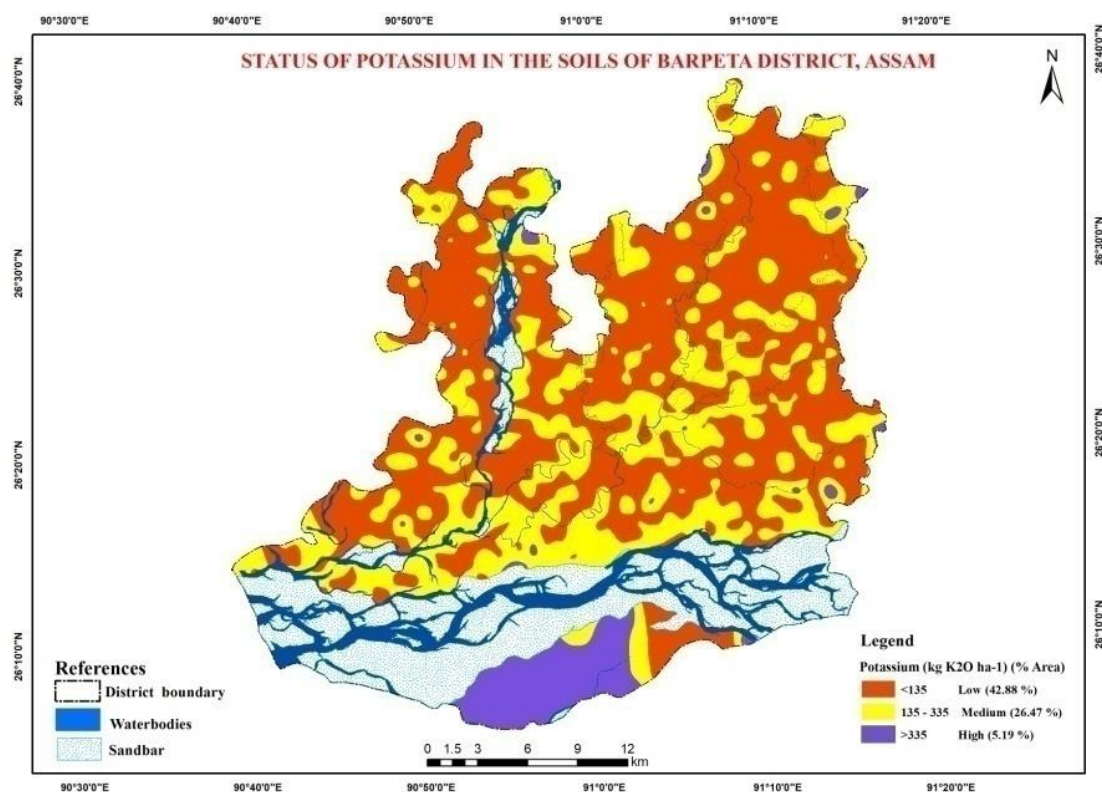


Fig. 6. Status of Available potassium in the soils of Barpeta District, Assam (India)

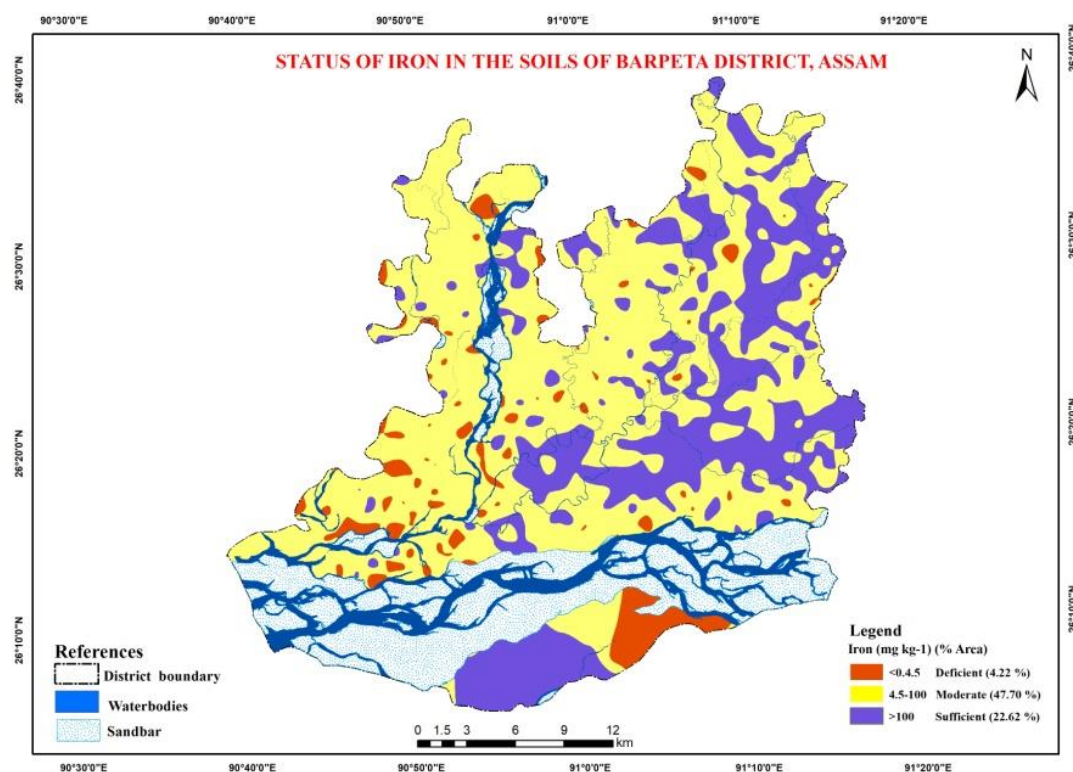


Fig. 7. Status of Available iron in the soils of Barpeta District, Assam (India)



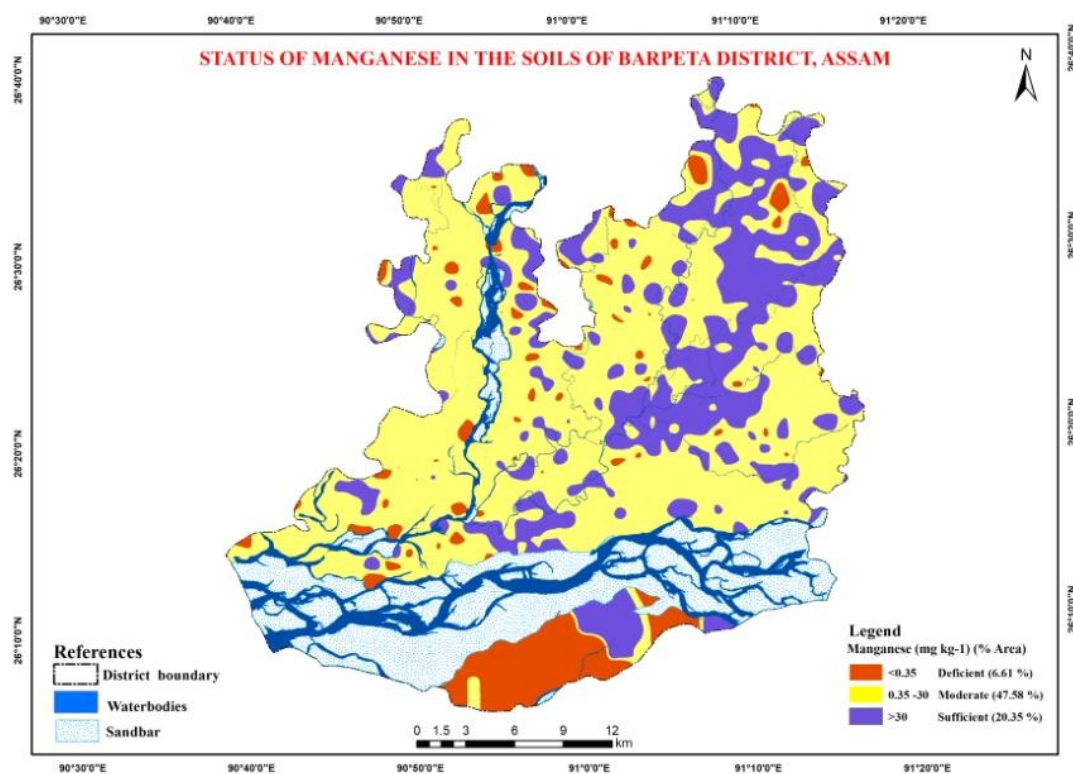


Fig. 8. Status of Available manganese in the soils of Barpeta District, Assam (India)

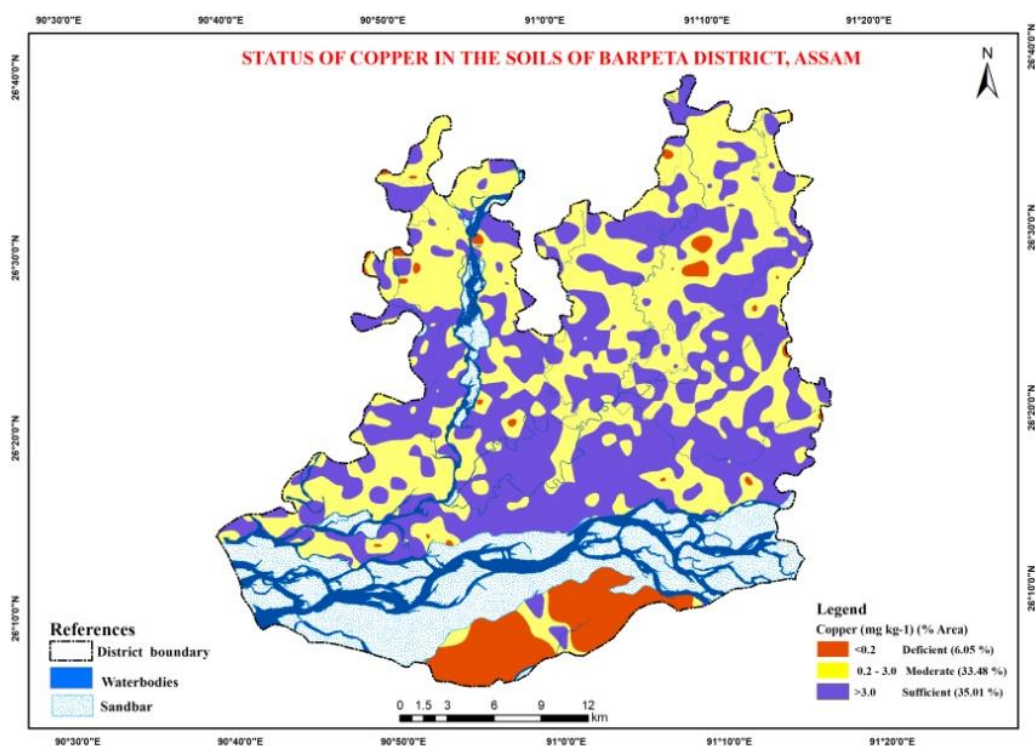


Fig. 9. Status of Available copper in the soils of Barpeta District, Assam (India)

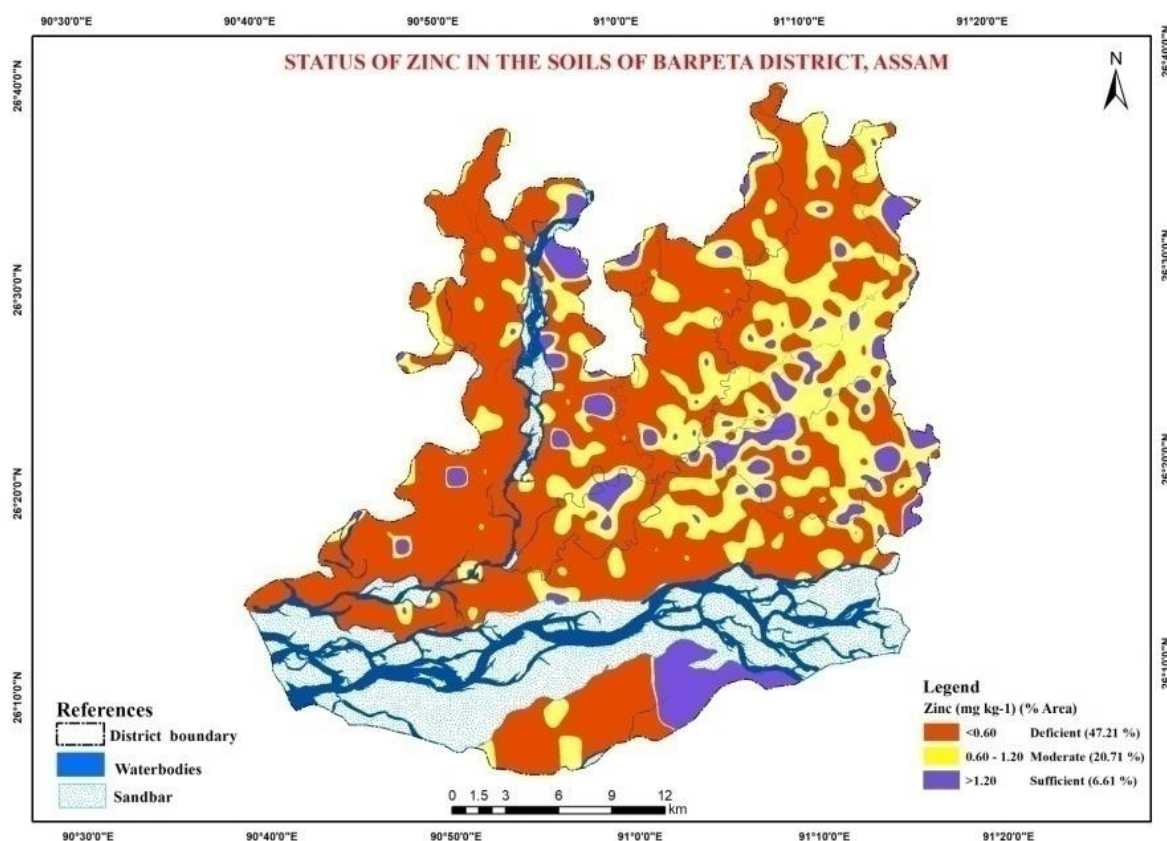


Fig. 10. Status of Available zinc in the soils of Barpeta District, Assam (India)

#### 4. CONCLUSION

The study concludes that the soils in Barpeta District are generally acidic, with a high range of organic carbon. Available nitrogen is found in the medium category, while phosphorus and potassium are in the low category. The availability of micronutrients, such as iron and manganese, is in the moderate range, while copper is sufficient, and zinc is deficient. Therefore, the major nutrient constraints in Barpeta District are available potassium and zinc. To address these deficiencies and enhance crop productivity, it is important to introduce a soil test crop response-based integrated system for various crops and cropping systems. This approach will enhance soil fertility and support sustainable crop production in the area. The information developed from this study can help revisit and monitor soil fertility changes over time. The findings are crucial for guiding nutrient management strategies, improving crop productivity, and promoting sustainable agriculture in Barpeta District.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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