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GIS-based spatial mapping of soil nutrient status of Pauni block of Maharashtra, India

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ABSTRACT

A study was conducted with the aim to assess the soil fertility status along with geospatial mapping of available nutrients in the soils of the Pauni block of Maharashtra, India during the year 2019-20. The 134 composite georeferenced surface soil samples were collected from the entire study area and thereafter analyzed with standard methodology. The results revealed that, 101 (75.4%) samples were neutral in soil reaction, and organic carbon was found low in 66 (49.3%) and medium in 67 (50%) soil samples. In terms of nitrogen, 84.3% of samples were found medium (280-560 kg ha^{-1}), whereas both phosphorus and potassium contents were found high in the major area. Sulphur content was also low in 61.9% of soil samples. The micronutrients like zinc, iron, and boron were deficient in 61.9% (87 samples), 59% (79 samples), and 100% of soil samples respectively. Only copper and manganese contents were found high in 85.8% and 81.3% of soil samples, respectively. The available N, K, P, S, Zn, Fe, Cu, Mn, and B contents were categorized as marginal, very high, very high, low, low, low, very high, very high, and very low, respectively using nutrient index values (NIV). Deficient soil nutrients should be replenished by adding fertilizers and manures to enhance soil fertility and crop productivity.

Keywords: GIS, Soil fertility mapping, Pauni block, Maharashtra, Kriging

INTRODUCTION

Globally, agricultural lands are facing tremendous pressure to achieve higher production from each unit of cultivable land to feed the excessively growing population of the world (Arunkumar *et al.,* 2016; Kashiwar *et al.,* 2020; Kumar *et al.,* 2017). A million hectares of land are being deteriorated worldwide due to high input-intensive cultivation and farmers are neglecting it as well but soil health is directly related to nutrient availability and production potential (Yurembam *et al.,* 2015; Arunkumar *et al.,* 2016; Kashiwar *et al.,* 2019a; Kashiwar *et al.,* 2019b; Kashiwar *et al.,* 2020; Singh *et al.,* 2015; Tagore *et al.,* 2017). Nutrient deficiencies limit crop productivity, and it can only be judged by evaluating the fertility status of the soils. The use of macronutrients has increased excessively in the past few years but the deficiency of micronutrients increased drastically and it is found that it affects the growth, metabolism, and reproduction in plants, animals, and humans (Jegadeeswari *et al.,* 2018). Soil properties differ across the specified regions which results in show differences in crop production. Therefore, it is essential to counter the deficiency and deterioration of soil while applying the required balanced fertilizers on agricultural land (Gyawali *et al.,* 2016). The soil test-based nutrient application is important to counter the declining soil fertility by filling up the gap between the nutrient requirement of the crop and the nutrient reserve available in the soil (Srivastava *et al.,* 2014; Srivastava and Singh, 2005; Srivastava and Singh, 2009; Kashiwar *et al.,* 2018). It is necessary to gather a large number of representative soil samples from the study area in order to increase its acceptability and accuracy (Kashiwar *et al.,* 2022). This is a laborious task for researchers because, as the number of soil samples increases, accuracy also improves and vice versa (Lai *et al.,* 2021; Hengl *et al.,* 2015). In the current scenario, modern technologies like Remote Sensing, GIS, and GPS are providing vital information about the soils with easy visualization, which can be used for future policies by policymakers, scientists, planners, and farmers (Kashiwar *et al.,* 2020; Santhi *et al.,* 2018). Current technologies are efficient in time, cost-effective, and applicable. Considering the views cited above, an attempt was made to assess the soil fertility status along with geospatial mapping of available nutrients in the soils of the Pauni block of Maharashtra, India.

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MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Pauni block of Maharashtra state in India during 2019-20, which is located between 21.10 to 20.66 Latitude and 79.51 to 79.78 Longitude having a gross area of 662 km^2, including 653.62 km^2 rural area and 8.53 km^2 urban area (Fig. 1). The study area receives average 1200 mm of rainfall from southwest monsoon during June to October and annual minimum and maximum temperature lie between 5°C to 48°C. The Wainganga (Pranhita) River which is a principal tributary of the Godavari River, covers the 37 km stretch in the block along with a National water reservoir named Indira Sagar Dam (Gosikhurd Project), having a total capacity of 930,000 acre-ft.

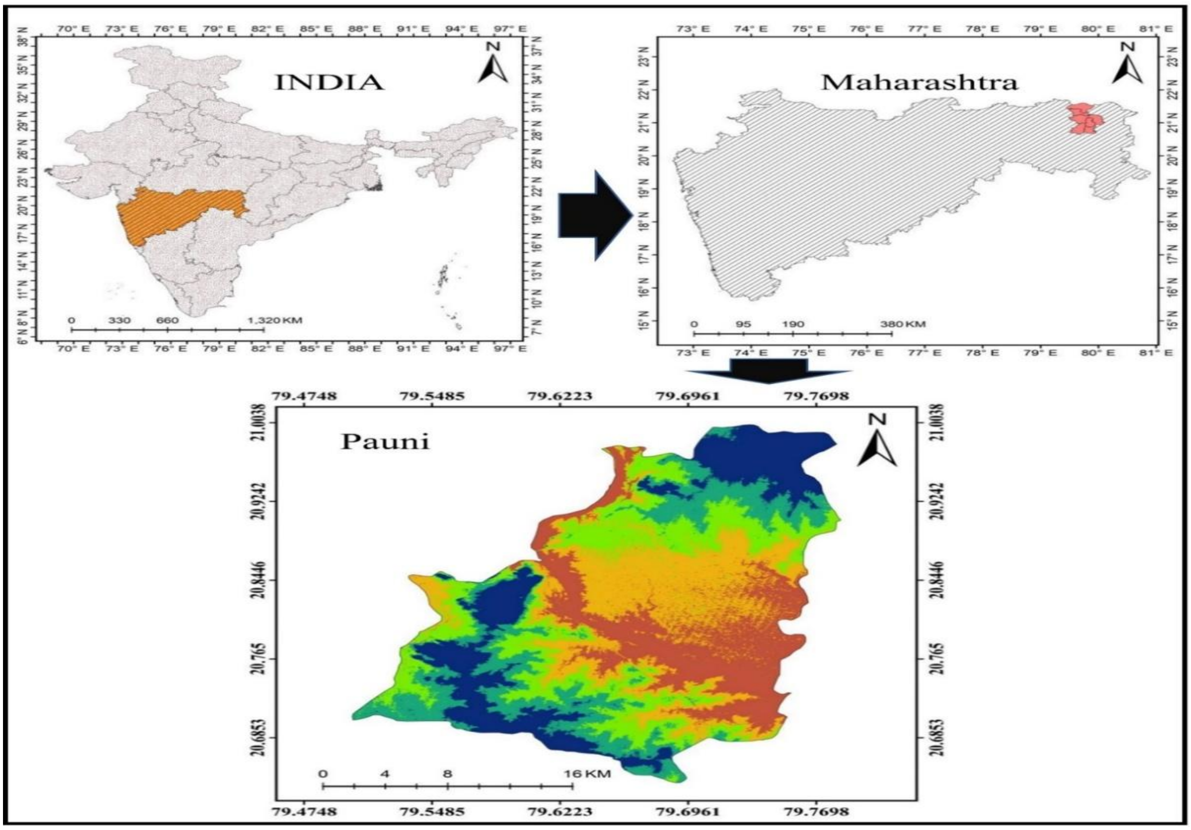

Figure 1. Location map of Pauni block in Maharashtra

Soil Sampling and Analysis

One hundred thirty-four composite surface (0-15 cm) soil samples were collected from 134 villages of the study area with their GPS geocoordinates during 2019-20. The geocoordinates data (Latitude and Longitude) were collected using Garmin GPSMAP 78S Marine GPS Navigator. The collected soil samples were air-dried and sieved to prepare for the determination of physico-chemical properties. The pH was estimated using glass electrode pH (Jackson, 1973), electrical conductivity by EC meter (Jackson, 1973), and organic carbon was estimated using the wet oxidation method given by Walkley and Black (1934). The available nitrogen content was estimated by the alkaline $KMnO_4$ method by Subbiah and Asija (1956). Bray and Kurtz (1945) and Olsen (1954) method was used to estimate available phosphorus content. The neutral normal ammonium acetate method by Hanway and Heidel (1952) was used to estimate available potassium and the calcium chloride method (Hanway and Heidel, 1952) was used for the estimation of sulphur content. The cationic micronutrient (zinc, iron, copper, and manganese) were estimated by DTPA solution (Lindsay and Norvell, 1978). The Azomethine-H method given by Wolf (1974) was used to determine soil available boron.

Nutrient index and rating

The nutrient index values were calculated from the proportion of soil samples in the low, medium, and high categories. The formula given by Ramamoorthy and Bajaj (1969) was used to calculate and it is given as follows:

$$NIV = \frac{[(P_H * 3) + (P_M * 2) + (P_L * 1)]}{100}$$

Where,

NIV= Nutrient Index Value (NIV)
P_H = Percent of soil samples under high category
P_M= Percent of soil samples under medium category
P_L= Percent of soil samples under low category

The soil samples were categorized according to NIV as <1.33, 1.33-1.66, 1.66-2.00, 2.00-2.33, 2.33-2.66 and > 2.66 into very low, low, marginal, adequate, high, very high respectively (Ramamoorthy and Bajaj 1969; Santhi *et al.,* 2018).

Generation of thematic soil fertility maps

The results acquired from laboratory analysis were tabulated in Microsoft Excel and converted to comma-separated values (.CSV) file format which was further imported to ArcGIS 10.4 software. Twelve thematic maps representing physico-chemical properties of the soils of the entire study area were prepared using *ordinary kriging* method interpolation in ArcGIS toolbox as described by Mishra *et al.* (2014); Mondal (2016); Kashiwar *et al.* (2019a); Kashiwar *et al.* (2019b); Kashiwar *et al.* (2020); Singh *et al.* (2015); Tagore *et al.* (2017); Srivastava and Singh (2005); Srivastava and Singh (2009).

Statistical analysis

The descriptive statistical analysis (range, mean, standard deviation, and coefficient of variation) of all the studied soil properties was calculated using SPSS 20.0 version and tabulated in MS-Excel-2013.

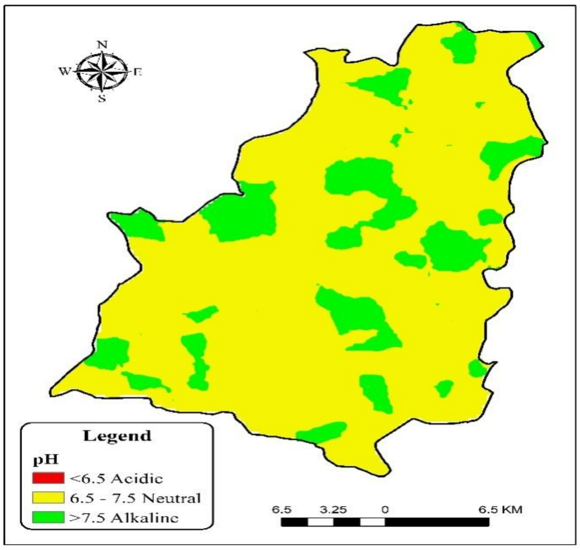

Figure 2. Thematic map of soil pH

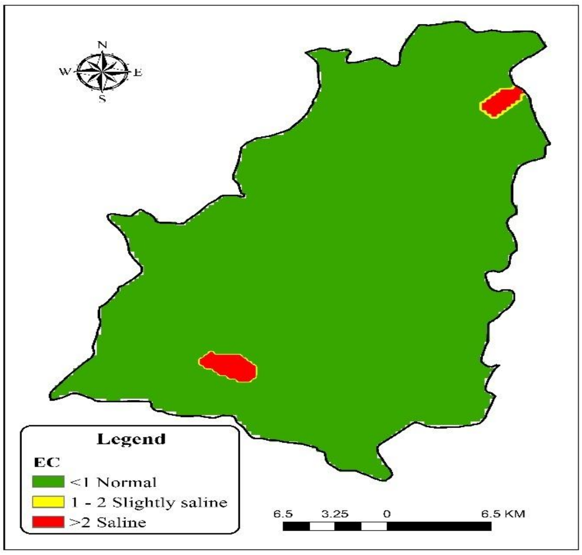

Figure 3. Thematic map of soil EC

RESULTS AND DISCUSSION

Physico-chemical properties

The soil pH of the Pauni block was neutral to alkaline in nature, which ranged between 6.8-7.8 with a mean of 7.3. From 134 (100%) soil samples 75.4% were neutral whereas, 24.6 were alkaline in nature (Table 1). The GIS-based thematic map representing the soil pH is presented in Fig. 2. The electrical conductivity (dS m^{-1}) was recorded with a mean of 0.3 dS m^{-1} which ranged between 0.1 dS m^{-1} to 2.5 dS m^{-1}. Among the 134 (100%) soil samples, 98.6% were normal whereas, 0.7% were non-saline and 0.7% were saline in conductance (Table 1). The GIS-based thematic map representing the soil EC is presented in Fig. 3. The soils of Waigaon village (2.5 dS m^{-1}) were recorded with saline in conductance. The mean organic carbon content was 0.51%, ranging from 0.29% to 0.79%. Among the total samples analyzed, 66 soil samples (49.3%), 67 soil samples (50%), and 1 soil sample (0.7%) were found low, medium, and high in organic carbon content respectively in the soils of the Pauni block of Maharashtra (Table 1). The highest organic carbon was recorded in Savarla village only which was 0.78%. The GIS-based thematic map representing the soil organic carbon is presented in Fig. 4. The low content of organic carbon in the soils may be due to ignorance in applying organic matter to the soil after harvesting the crop. Tagung *et al.* (2022); Singh *et al.* (2022); Hegde *et al.* (2021); Dongarwar *et al. (*2015); Dongarwar *et al. (*2018); Kashiwar *et al. (*2019a); Kashiwar *et al. (*2019b); Kashiwar *et al. (*2020); Santhi *et al. (*2018); Tagore *et al. (*2017); Jyothi and Hebsur *(*2016) and Kumar *et al. (*2017) have found the similar results.

Table 1: Macro-Micro nutrient status in soils of Pauni block of Maharashtra

Parameter/Nutrient	Range	Mean	SD	CV	Per cent sample category			NIV	Fertility Rating
					Acidic/Non-saline/Low/ Deficient	Neutral/Slightly Saline/Medium /Moderate	Alkaline/ Saline/High /Sufficient		
pH	6.8-7.8	7.3	0.2	0.02	0.0	75.4	24.6	-	-
EC (dS m^{-1})	0.1-2.5	0.3	0.2	0.7	98.6	0.7	0.7	-	-
OC (%)	0.3-0.8	0.51	0.1	0.2	49.3	50.0	0.7	-	-
Avail. N (kg ha^{-1})	211.9-542.7	353.7	73.1	0.2	15.7	84.3	0.0	1.8	Marginal
Available P (kg ha^{-1})	15.9-70.6	41.4	13.7	0.3	0.0	21.6	78.4	2.8	Very High
Avail. K (kg ha^{-1})	109.4-739.6	461.1	151.1	0.3	1.5	7.5	91.0	2.9	Very High
Avail. S (kg ha^{-1})	4.4-109.5	16.0	18.8	1.2	61.9	19.4	18.7	1.6	Low
Avail. Zn (mg kg^{-1})	0.2-19.0	1.2	2.4	2.0	64.9	21.6	13.4	1.5	Low
Avail. Fe (mg kg^{-1})	0.3-19.7	5.1	3.5	0.7	59.0	40.3	0.7	1.4	Low
Avail. Cu (mg kg^{-1})	0.5-3.8	1.1	0.4	0.4	0.0	14.2	85.8	2.9	Very High
Avail. Mn (mg kg^{-1})	1.5-15.5	7.3	2.8	0.4	3.0	15.7	81.3	2.8	Very High
Avail. B (mg kg^{-1})	0.1-2.0	0.8	0.5	0.6	100.0	0.0	0.0	1.0	Very Low

Available Nitrogen, Phosphorus, Potassium and Sulphur content

The range of available nitrogen content was 211.9 to 542.7 kg ha^{-1} with a mean of 353.7 kg ha^{-1}. Among the 134 soil samples, 21 (15.7%) were low and 113 samples (84.3%) were in the medium category (Table 1). The lowest (211.9 kg ha^{-1}) and highest (542.7 kg ha^{-1}) available nitrogen was recorded in the soils of Umari village and Savarla village respectively. The nutrient index value (NIV) of nitrogen was 1.8 which is further classified as marginal in availability. The GIS-based thematic map representing the available nitrogen content is presented in Fig. 5. Similar results were also recorded by Tagung *et al.* (2022); Singh *et al.* (2022); Hegde *et al.* (2021); Jyothi and Hebsur *(*2016); Dongarwar *et al. (*2015); Dongarwar *et al. (*2018); Kashiwar *et al. (*2019a); Kashiwar *et al. (*2019b) and Kashiwar *et al. (*2020) in this region and this might be due to low content of soil organic carbon as well as the losses caused due to leaching, volatilization, microbial fixation, denitrification and runoff, etc. (De Datta and Buresh, 1989; Kumar *et al.,* 2017). In phosphorus content, 29 soil samples were in the medium category which counts 21.6 % of total samples whereas, 105 samples were in the high category which counts 78.4% of the total 134 soil samples. The range of available phosphorus was 15.9 to 70.6 kg ha^{-1} with a mean of 41.40 kg ha^{-1} (Table 1). The lowest (15.9 kg ha^{-1}) and highest (70.6 kg ha^{-1}) value of available phosphorus was recorded in Sindpuri village and Ambadi village respectively. According to NIV (2.8), it was further classified as very high category. The GIS-based thematic map representing the available phosphorus content is presented in Fig. 6. Dongarwar *et al. (*2015); Tagung *et al.* (2022); Singh *et al.* (2022); Hegde *et al.* (2021); Dongarwar *et al. (*2018); Kashiwar *et al. (*2019a); Kashiwar *et al. (*2019b) and Kashiwar *et al. (*2020); Santhi *et al. (*2018); Tagore *et al. (*2017) and Kumar *et al. (*2017) have found the similar results. The mean available potassium content of 134 soil samples was 461.1 kg ha^{-1} with a range of 109.4 to 739.6

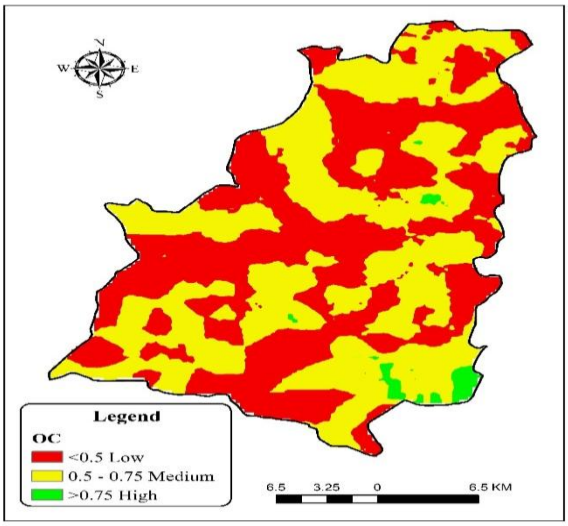

Figure 4. Thematic map of soil OC

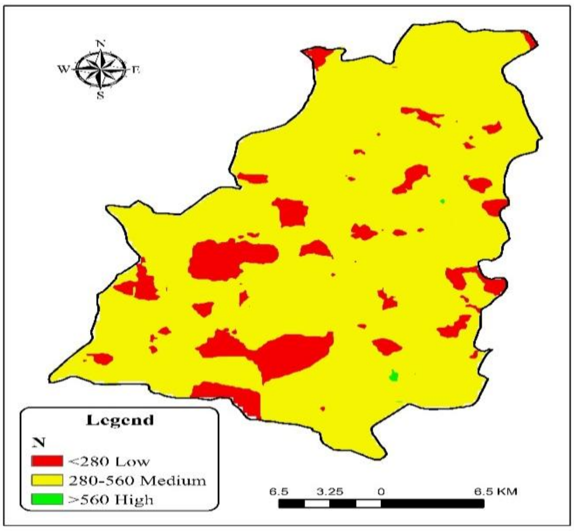

Figure 5. Thematic map of soil nitrogen

kg ha^{-1}. Among the total soil samples analyzed numbers of samples categorized as low, medium, and high in available potassium content were 2 (1.5%), 10 (7.5%), and 122 (91%) respectively (Table 1). The least content of potassium was recorded in Katurli village (109.4) and the uppermost potassium was recorded in Lohara village (739.6). The results were further classified by NIV and it was in the very high category (2.9). The GIS-based thematic map representing the available potassium content is presented in Fig. 7. The rice and sugarcane crops are grown in the study area and the potassium is excessively being used by farmers to address the sugar content of the cane. Initially, the soil is rich in potassium content due to parent material and the excessive application has shown the effects on results. Similar findings were also observed by Dongarwar *et al. (*2015); Dongarwar *et al. (*2018); Tagung *et al.* (2022); Singh *et al.* (2022); Hegde *et al.* (2021); Kashiwar *et al. (*2019a); Kashiwar *et al. (*2019b) and Kashiwar *et al. (*2020) in this region. The results regarding available sulphur content have shown that out of the total samples analyzed 61.9%, 19.4%, and 18.7% were grouped as low, medium, and high respectively (Table 1).

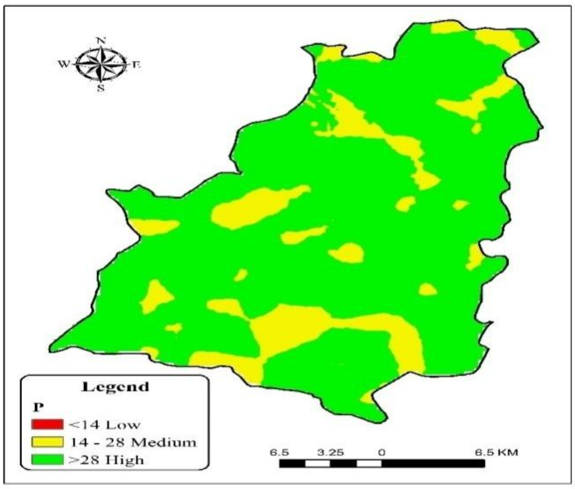

Figure 6. Thematic map of soil phosphorus

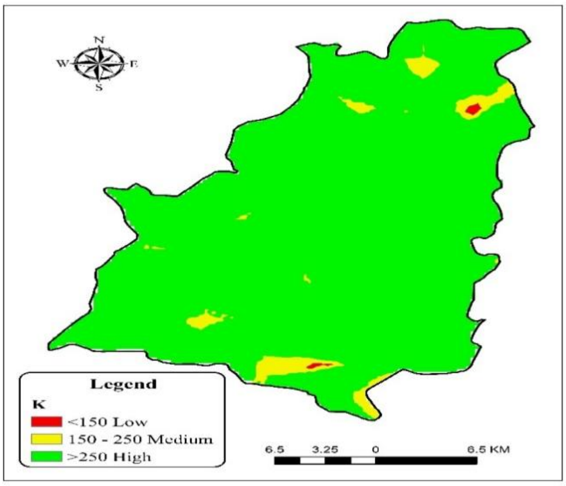

Figure 7. Thematic map of soil potassium

Its average value was 16.0 kg ha^{-1} which was under the range of 4.4 to 109.5 kg ha^{-1}. The lowest sulphur content 4.4 kg ha^{-1} was recorded in Thana Navegaon village whereas, Bhuyar village was recorded with the highest content of sulphur (109.5 kg ha^{-1}). The GIS-based thematic map representing the available sulphur content is presented in Fig. 8. Further these results were categorized according to NIV and it classified the sulphur content as low (1.6). 61.9% of soil samples were deficient in sulphur content might be due to intensive cropping, and excessive use of fertilizers. The amount of sulphur removed by the crop is not replenished again by means of organic matter or fertilizers (Singh *et al.,* 2015; Tagung *et al.,* 2022; Singh *et al.,* 2022; Hegde *et al.* 2021).

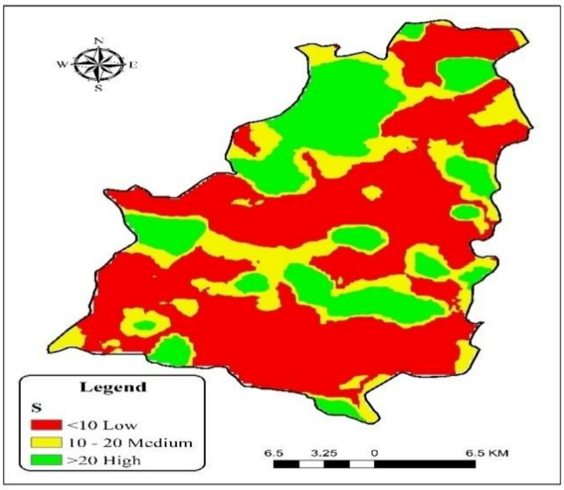

Figure 8. Thematic map of soil sulphur

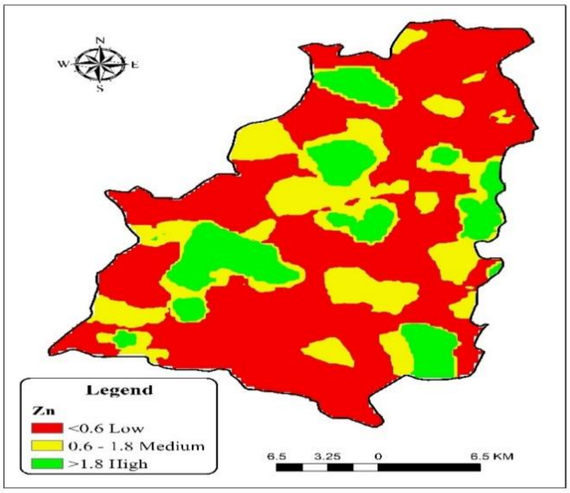

Figure 9. Thematic map of soil zinc

Available micronutrient status

The average value of available zinc was 1.2 mg kg^{-1} with a range of 0.2 to 19.0 mg kg^{-1}. Around 61.9% of the total analyzed soil samples were low in zinc content whereas, 21.6% and 13.4% were in the medium and high categories (Table 1). The least content of zinc (0.2 mg kg^{-1}) was identified in Singora village and the upmost availability (19.0 mg kg^{-1}) was noted in Nandikheda village. According to NIV classification, it is classified in the low (1.5) category. The GIS-based thematic map representing the available zinc content is presented in Fig. 9. The application of major nutrients is always focused on by farmers rather than the adequate application of micronutrients and this may be a major cause for low zinc content. The results are in close conformity with Singh *et al.* (2022); Hegde *et al.* (2021); Jegadeeswari *et al.* (2018); Kashiwar *et al.* (2019a), Kashiwar *et al.* (2020); Jyothi and Hebsur (2016) and Santhi *et al.* (2018). Santhi *et al.,* (2018) have stated that zinc deficiency may be also due to poor management, parent material, and climatic conditions. The range and mean value of available iron content were 0.3 to 19.7 mg kg^{-1} and 5.1 mg kg^{-1} respectively. Among the total samples, 79 samples were in the low category, 54 were medium and only 1 sample was found high iron content (Table 1). The Sindpuri village was identified with the lowest iron content (0.3 mg kg^{-1}) and the soils of Belgata village have the highest content of iron (19.7 mg kg^{-1}).

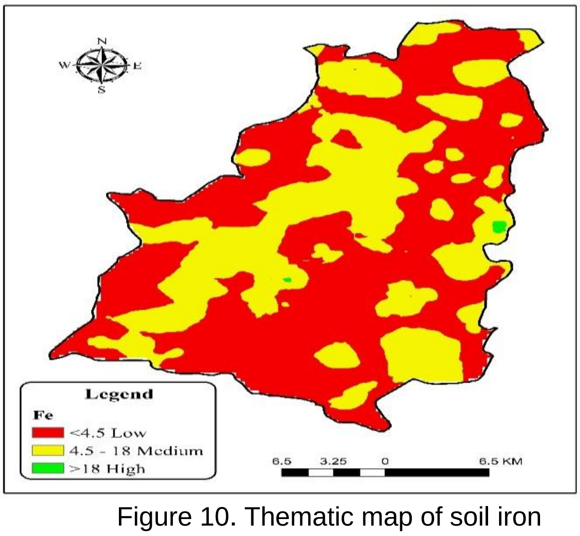

Figure 10. Thematic map of soil iron

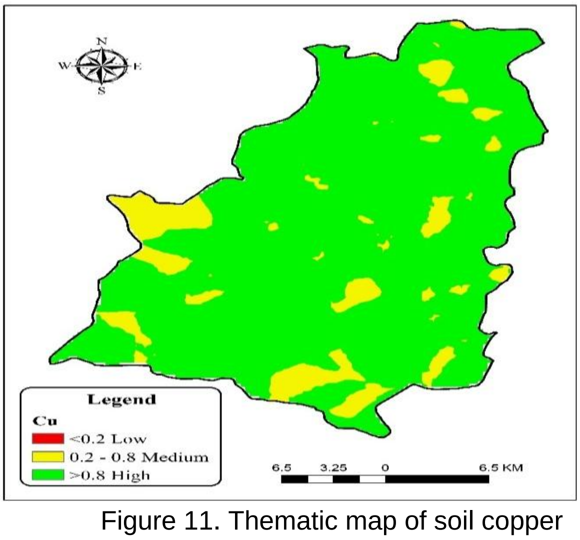

Figure 11. Thematic map of soil copper

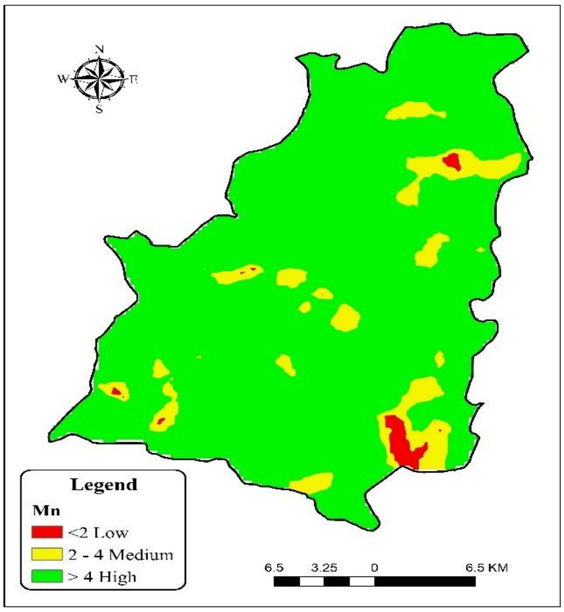

Figure 12. Thematic map of soil manganese

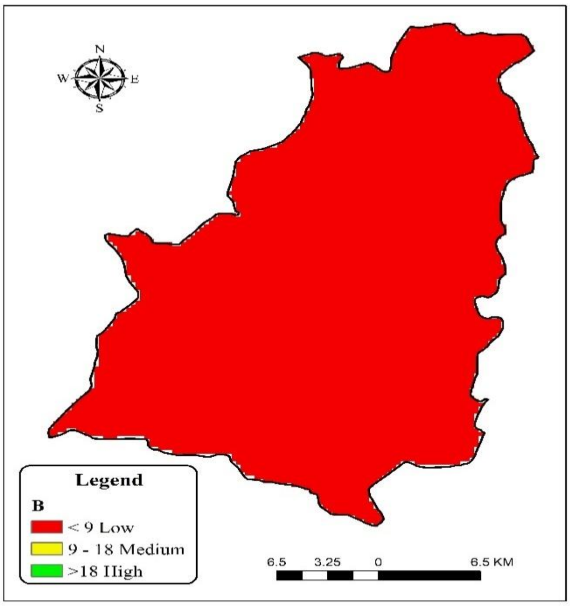

Figure 13. Thematic map of soil boron

The NIV classified the iron content as low in availability (1.4). The GIS-based thematic map representing the available iron content is presented in Fig. 10. The results are in close conformity with Singh *et al.* (2022); Kashiwar *et al.* (2018), Kashiwar *et al.* (2019b), and Jyothi and Hebsur (2016). Around 85.8% of soil samples showed a high content of copper whereas, 14.2% showed medium availability (Table 1). The mean copper content was 1.1 mg kg^{-1} with a range of 0.5 to 3.8 mg kg^{-1}. The least (0.5 mg kg^{-1}) and highest (3.8 mg kg^{-1}) copper content was recorded in Ranala and Belgata villages respectively. The GIS-based thematic map representing the available copper content is presented in Fig. 11. According to NIV, it has been categorized as very high (2.9) availability. The range and mean of manganese content of the Pauni block was 1.5 to 15.5 mg kg^{-1} and 7.3 mg kg^{-1}. The soil samples of the Pauni block have shown high content of manganese in 115 samples, 21 samples showed medium content and only 4 samples were identified with the least availability (Table 1). According to the NIV classification, it has been classified as a very high (2.8) category. Rahana (Ahnapurna) village was recorded with the lowest (1.5 mg kg^{-1}) manganese availability and Gaidongari village has the highest (15.5 mg kg^{-1}) availability. The GIS-based thematic map representing the available manganese content is presented in Fig. 12. The mean hot water-soluble boron content was 0.8 mg kg^{-1} which was under the range of 0.1 to 2.0 mg kg^{-1}. The entire Pauni block has been found extremely deficient in boron content (Table 1). The NIV classified the boron content in the very low category (1.0). The GIS-based thematic map representing the available boron content is presented in Fig. 13.

CONCLUSION

The soils of the major part of the Pauni block of Maharashtra, India are neutral in reaction, non-saline (normal), low to medium in organic carbon and marginal in available nitrogen, and very high in both available phosphorus and potassium content. The contents of available sulphur, zinc, iron, and boron were low, whereas, copper and manganese were successively available. Deficient soil nutrients should be replenished through a proper nutrient recommendation schedule for enhancing soil fertility and crop productivity. For making soils more fertile in future prospect it is necessary to use organic manures which are readily available with farmers along with paddy straws rather than burning it. In future this research can be continued as crop specific land suitability as this study is proving vital data related to soil nutrients of entire pauni block.

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