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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 an aim to assess the soil fertility status along with geospatial mapping of available nutrients in the soils of Pauni block of Maharashtra, India during the year 2015 to 2018. The 134 composite georeferenced surface soil samples were collected from entire study area and thereafter analyzed with standard methodology. The results revelated 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% samples were found medium (280-560 kg ha^{-1}), whereas, both phosphorus and potassium contents were found high in major area. Sulphur content was also low in 61.9% 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% 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). Defienct soil nutrient should be replenished by adding fertilizers and manures for enhancing soil fertility and crop productivity.

INTRODUCTION

Globally, the agricultural lands are facing the 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). Million hectares of land is 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). The crop productivity is limited by nutrient deficiencies and it can only be judged by evaluating the fertility status of the soils. Use of macronutrient has increased excessively in past few years but the deficiency of micronutrients increased drastically and it is found that it affects the growth, metabolism and reproduction in plants, animal and humans (Jegadeeswari *et al.*, 2018). Soil properties differs across the specified regions which results differences in crop production. Therefore, it is essential to counter the deficiency and deterioration of soil while applying the required balanced fertilizers in agriculture land (Gyawali *et al.*, 2016). The soil test based nutrient application is the important to counter the declining soil fertility by filling up the gap between nutrient requirement of the crop and nutrient reserve available in the soil (Srivastava *et al.*, 2014; Srivastava and Singh, 2005; Srivastava and Singh, 2009; Kashiwar *et al.*, 2018). In current scenario the modern technologies like Remote Sensing, GIS and GPS are providing the vital information about the soils with easy visualization which can be used for future policies by policy makers, scientists, planners and farmers also (Kashiwar *et al.*,2020; Santhi *et al.*,2018). Current technologies are efficient in time, cost effective and applicability. 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 Pauni block of Maharashtra, India

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Pauni block of Maharashtra state in India during 2015 to 2018, which is located between 21.001811 to 20.639904 Latitude and 79.502582 to 79.784010 Longitude having 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 annual rainfall from southwest monsoon during June to October and annual minimum and maximum temperature lies between 5ºC to 48ºC. The Wainganga (Pranhita) river which is a principle tributary of Godavari river is covering the 37 km stretch in the block along with a National water reservoir named Indirasagar Dam (Gosikhurd Project) having a total capacity of 930,000 acre-ft.

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 2015 to 2018. The geocoordinates data (Latitude and Longitude) were collected using Garmin GPSMAP 78S Marine GPS Navigator. The collected soil samples were air dried and sieved for the determination of physico-chemical properties. The pH was estimated using glass electrode pH (Jackson, 1973), electrical conductivity by EC meter (Jackson, 1973), organic carbon was estimated using wet oxidation method given by Walkley and Black (1934). The available nitrogen content was estimated by alkaline $KMnO_4$ method by Subbiah and Asija (1956). Bray and Kurtz (1945) and Olsen (1954) method was used to estimate available phosphorus content. Neutral normal ammonium acetate method by Hanway and Heidel (1952) was used to estimate available potassium and calcium chloride method (Hanway and Heidel, 1952) was used for the estimation of sulphur content. The 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 low, medium and high category. The formula given by Ramamoorthy and Bajaj (1969) was used to calculate and it is given as follow

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

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 entire study area were prepared using *ordinary kriging* interpolation method 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).

RESULTS AND DISCUSSION

Physico-chemical properties

The soil pH of Pauni block was neutral to alkaline in nature, which was 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

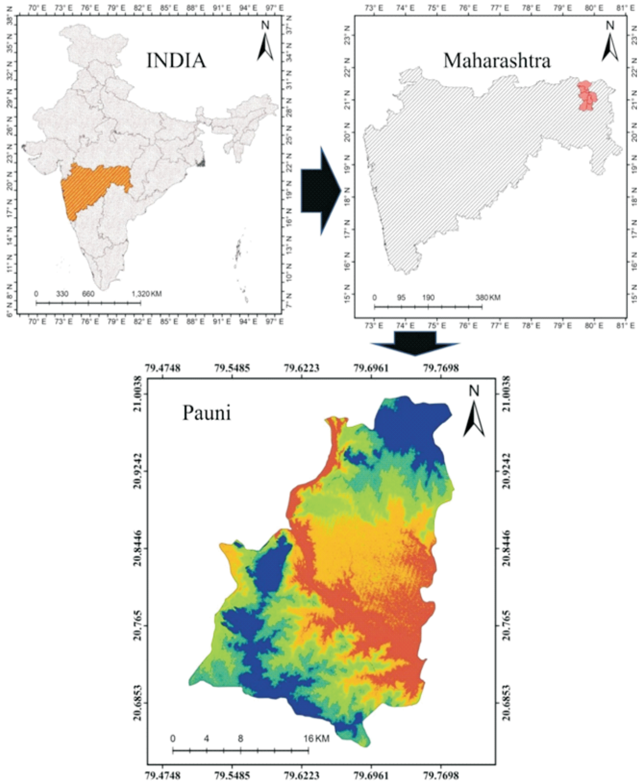

Figure 1. Location map of Pauni block in Maharashtra

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 was 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% which was ranged from 0.29% to 0.79%. Among the total samples analzed, 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 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 application of organic matter to soil after harvesting the crop. 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.

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 medium category (Table 1). The lowest (211.9 kg ha^{-1}) and highest (542.7 kg ha^{-1}) available nitrogen was recorded in the

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

Parameter/Nutrient	Range	Mean	SD	CV	Per cent sample category Acidic/ Non-saline /Low/ Deficient	Neutral /Slightly Saline/ Medium /Moderate	Alkaline /Saline/ High /Sufficient	NIV	Fertility Rating
pH	6.8-7.8	7.3	0.2	0.02	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	0.7	-	-
Available N (kg ha^{-1})	211.9-542.7	353.7	73.1	0.2	15.7	84.3	0	1.8	Marginal
Available P (kg ha^{-1})	15.9-70.6	41.4	13.7	0.3	0	21.6	78.4	2.8	Very High
Available K (kg ha^{-1})	109.4-739.6	461.1	151.1	0.3	1.5	7.5	91	2.9	Very High
Available S (kg ha^{-1})	4.4-109.5	16	18.8	1.2	61.9	19.4	18.7	1.6	Low
Available Zn (mg kg^{-1})	0.2-19.0	1.2	2.4	2	64.9	21.6	13.4	1.5	Low
Available Fe (mg kg^{-1})	0.3-19.7	5.1	3.5	0.7	59	40.3	0.7	1.4	Low
Available Cu (mg kg^{-1})	0.5-3.8	1.1	0.4	0.4	0	14.2	85.8	2.9	Very High
Available Mn (mg kg^{-1})	1.5-15.5	7.3	2.8	0.4	3	15.7	81.3	2.8	Very High
Available B (mg kg^{-1})	0.1-2.0	0.8	0.5	0.6	100	0	0	1	Very Low

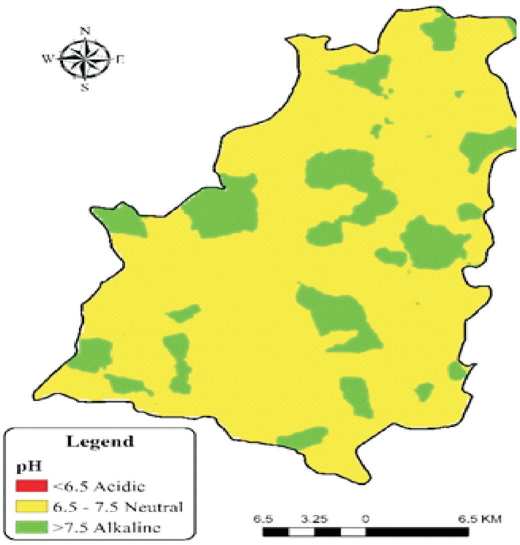

Figure 2: Thematic map of soil pH

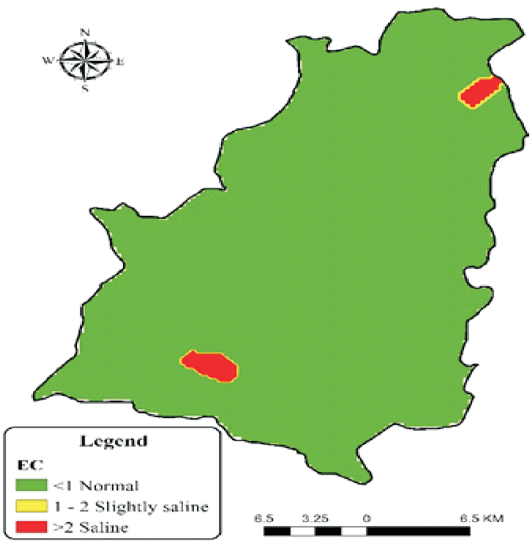

Figure 3. Thematic map of soil EC

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. The similar results were also recorded by 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 medium category which counts 21.6 % of total samples whereas, 105 samples were in high category which counts 78.4% of 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 to very high category. The GIS based thematic map representing the available phosphorus content is presented in Fig. 6. Dongarwar *et al.* (2015); 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 the range of 109.4 to 739.6 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 uppermost potassium was recorded in Lohara village (739.6). The results were further classified by NIV and it was in 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 farmers to address the sugar content of the cane. Initial the soil is rich in potassium content due to parent material and the excessive application has shown the effects on results. The similar findings were also observed by Dongarwar *et al.* (2015);

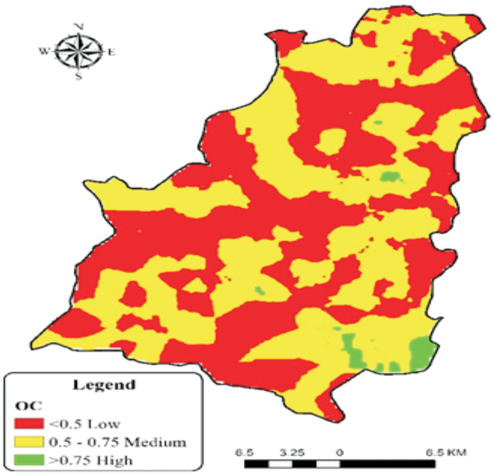

Figure 4: Thematic map of soil OC

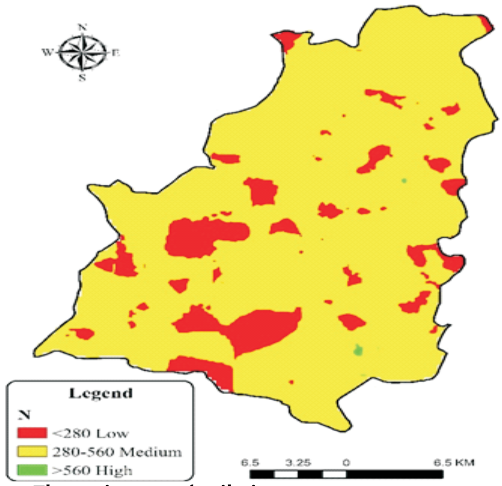

Figure 5: Thematic map of soil nitrogen

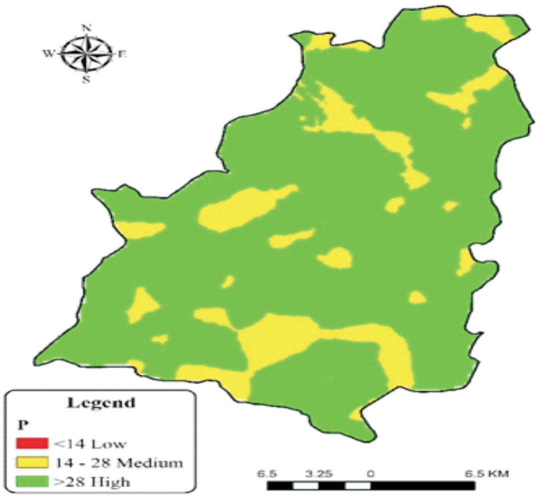

Figure 6: Thematic map of soil phosphorus

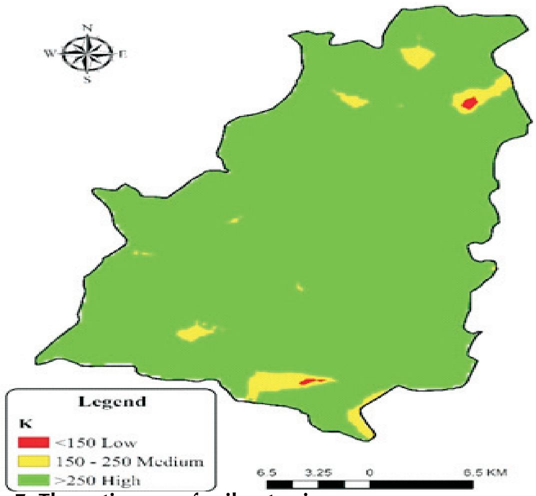

Figure 7: Thematic map of soil potassium

Dongarwar *et al.* (2018); Kashiwar *et al.* (2019a); Kashiwar *et al.* (2019b) and Kashiwar *et al.* (2020) in this region. The results regarding available sulphur content has shown that out of total samples anayzed 61.9%, 19.4% and 18.7% were grouped as low, medium and high respectively (Table 1). 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 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, excessive use of fertilizers. The amount of sulphur removed by crop is not replenished again by means of organic matter or fertilizers (Singh *et al.,* 2015).

Available micronutrient status

The average value of available zinc was 1.2 mg kg^{-1} with range of 0.2 to 19.0 mg kg^{-1}. Around 61.9% of the total analysed soil samples were low in zinc content whereas, 21.6% and 13.4% were in medium and high category (Table 1). The least content of zinc (0.2 mg kg^{-1}) was identified in Singora village and upmost availability (19.0 mg kg^{-1}) was noted in Nandikheda village. According to NIV classification, it is classified in 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 by famers rather than adequate application of micronutrients and may be this is the major cause for low zinc content. The results are in close conformity with 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) has 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 was 0.3 to 19.7 mg kg^{-1} and 5.1 mg kg^{-1} respectively. Among the total samples, 79 samples were in low category, 54 were medium and only 1 sample found high in iron content (Table 1). The Sindpuri village identified with lowest iron content (0.3 mg kg^{-1}) and soils of Belgata village have the highest content of iron (19.7 mg kg^{-1}). 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 is in close conformity with Kashiwar *et al.* (2018), Kashiwar *et al.* (2019b) and Jyothi and

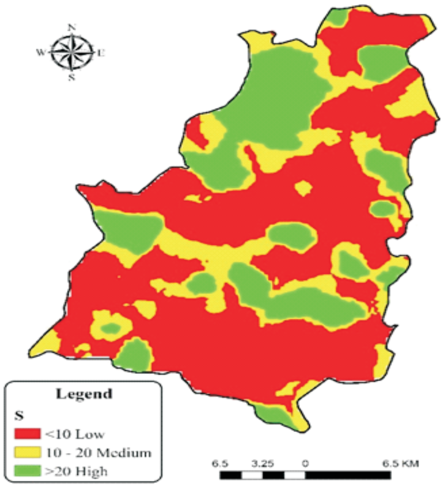

Figure 8: Thematic map of soil sulphur

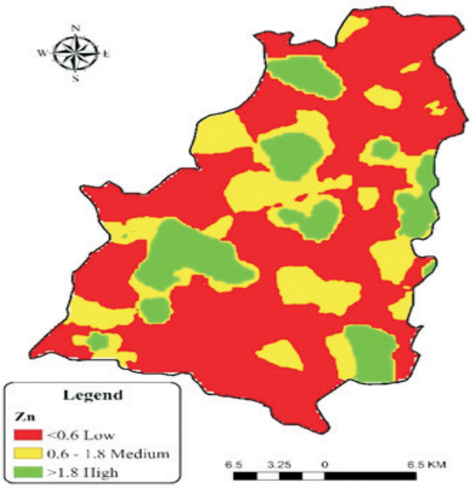

Figure 9: Thematic map of soil zinc

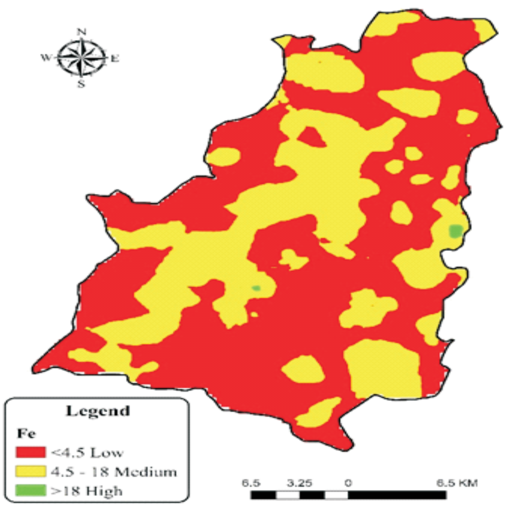

Figure 10. Thematic map of soil iron

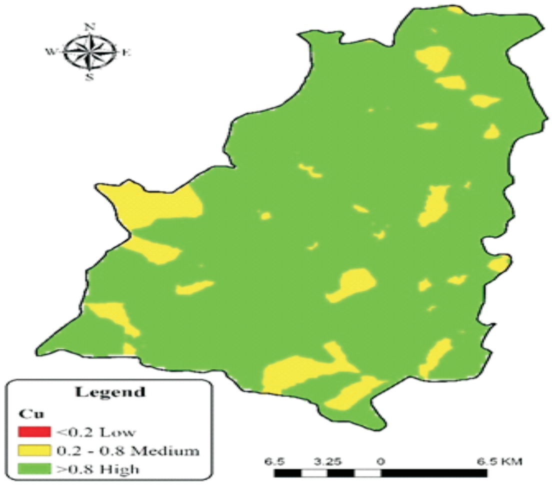

Figure 11: Thematic map of soil copper

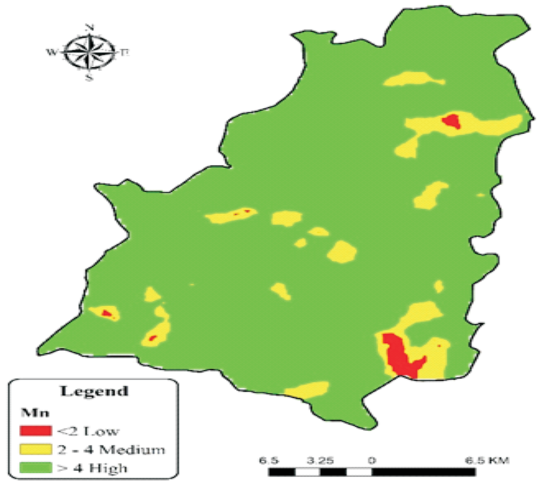

Figure 12. Thematic map of soil manganese

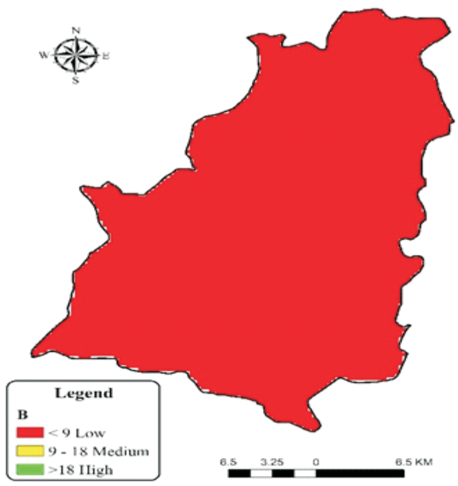

Figure 13. Thematic map of soil boron

Hebsur (2016). Around 85.8% soil samples shown the high content of copper whereas, 14.2% shown the 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 to very high (2.9) availability. The range and mean of manganese content of Pauni block was 1.5 to 15.5 mg kg^{-1} and 7.3 mg kg^{-1}. The soil samples of Pauni block has shown high content of manganese in 115 samples, 21 samples showed medium content and only 4 samples were identified with least availability (Table 1). According to NIV classification, it has been classified to very high (2.8) category. Rahana (Ahnapurna) village was recorded with lowest (1.5 mg kg^{-1}) manganese availability and Gaidongari village has 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 found extremely deficient in boron content (Table 1). The NIV classified the boron content to very low category (1.0). The GIS based thematic map representing the available boron content is presented in Fig. 13.

CONCLUSION

The soils of a major part of 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.

REFERENCES

Arunkumar, V., Patil, S. G. and Paramasivan, M. 2016. Mapping of Available Nutrient Status of Thirunavalur Village , Villupuram district , Tamil Nadu using Geographic Information System. *Madras Agric. J.* **103:** 219–222.

Bray, R. and Kurtz, L. T. 1945. Determination of Total, Organic, and Available Forms of Phosphorus in Soils. *Soil Sci.* **59(1):** 39–46.

De Datta, S. K. and Buresh, R. J. 1989. Integrated Nitrogen Management in Irrigated Rice. In B. A. Stewart (Ed.), *Adv. Soil Sci.* **10:** 143-169.

Dongarwar, U. R., Khedikar, G. R., Kashiwar, S. R. and Dongarwar, L. 2015. Effect of different Organic Sources Available with Farmers on Paddy (*Oryza sativa*) in Bhandara District of Maharashtra Effect of different Organic Sources Available with Farmers on Paddy (*Oryza sativa*) in Bhandara District of Maharashtra. *J. Agric. Eng. Food Technol.* **2(2):** 142–144.

Dongarwar, U. R., Patke, N., Dongarwar, L. N. and Kashiwar, S. R. 2018. Effect of Row Spacing on Growth, Yield and Economics of Direct Seeded Rice in Eastern Vidharbha Zone of Maharashtra, India. *Int. J. Curr. Microbiol. Appl. Sci.* **7(07):** 2930–2941.

Gyawali, C., Dahiya, D., Devraj, Bhat, M. A. and Bhandari, R. R. 2016 Spatial Distribution of Physico-Chemical Properties and Macronutrients in Rice Growing Soils of And Macronutrients in Rice Growing Soils of Haryana. *The Ecoscan*, **10(1 & 2):** 365-370 (Supplement on Rice).

Hanway, J. J. and Heidel, H. 1952. *Soil analysis methods as used in Iowa state college soil testing laboratory*. Iowa Agriculture.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. p. 498.

Jegadeeswari, D., Muthumanickam, D., Chitdeshwari, T. and Shukla, A. K. 2018. Fertility Mapping of Available Micronutrients Status in the Soils of Dharmapuri District, Tamil Nadu, Using GIS and GPS Techniques. *Madras Agric. J.* **104 (10-12):** 330.

Jyothi, T., and Hebsur, N. 2016. Evaluation of Fertility Status of Selected Bt Cotton Growing Soils of Northern Transition Zone (Zone 8) Of Karnataka. *The Ecoscan.* **10(3 & 4):** 449-455.

Kashiwar, S. R., Kundu, M. C. and Dongarwar, U. R. 2019a. Assessment and mapping of soil nutrient status of Sakoli tehsil of Bhandara district of Maharashtra using GIS techniques. *J. Pharmacogn. Phytochem.* **8(5):** 1900-1905.

Kashiwar, S. R., Kundu, M. C. and Dongarwar, U. R. 2019b. *Delineation and GPS-GIS based mapping of available macro and micronutrients of soils of Lakhani block of Bhandara , Maharashtra. Int. J. Chem. Stud.* **7(5):** 2312-2318.

Kashiwar, S. R., Kundu, M. C. and Dongarwar, U. R. 2020. Soil fertility appraisal of bhandara block of Maharashtra using geospatial techniques. *Int. J. Chem. Stud.* **7(5):** 2312-23188.

Kashiwar, S. R., Nath, T., Kumar, D., Kundu, M. C., Dongarwa, U. R., Rajput, B. S., Pandey, S. K. and Dongarwar, L. N. 2018. Evaluation of Soil Fertility Status of Rajiv Gandhi South Campus (Banaras Hindu University), Mirzapur, Uttar Pradesh by Using GIS. *Int. J. Curr. Microbiol. Appl. Sci.* Special Issue **(7):** 3825–3836.

Kumar, A., Srivastava, L. K., Mishra, V. N. and Banwasi, R. 2017. Major and micro nutrient status of rice-chickpea grown in soilsof Chhattisgarh Plain region of India. *Indian J. Agric. Res.* **51(1):** 1–8.

Lindsay, W. L. and Norvell, W. A. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc. Am. J.* **42(3):** 421–428.

Mishra, A., Pattnaik, T., Das, D. and Das, M. 2014. Soil Fertility Maps Preparation Using GPS and GIS in Dhenkanal District, Odisha, India. *Int. J. Plant Soil Sci.* **3(8):** 986-994.

Mondal, K. 2016. Horizontal soil sulphur status and fertility map of north-eastern region of Haryana, India. *The Ecoscan.* **10(1 & 2):** 165-168.

Olsen, S. R. 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. United States Department Of Agriculture; Washington.

Ramamoorthy, B. and Bajaj, J. C. 1969. Available nitrogen, phosphorus and potassium status of Indian soils. *Fert. News*. **14:**24–26.

Santhi, R., Stalin, P., Arulmozhiselvan, K., Radhika, K., Sivagnanam, S., Sekar, J., Muralidharudu, Y., Dey, P. and Rao, A. S. 2018. Soil fertility appraisal for Villupuram District of Tamil Nadu using GPS and GIS techniques. *J. Indian Soc. Soil Sci.* **66(2):**158.

Singh, S., Dey, P., Singh, S.P., Sharma, P.K., Singh, Y., Latare, A., Singh, C.M., Kumar, D., Kumar, O., Yadav, S.N. and Verma, S. 2015. Emergence of boron and sulphur deficiency in soils of chandauli, mirzapur, sant ravidas nagar and varanasi districts of eastern uttar pradesh. *J. Indian Soc. Soil Sci.* **63(2):**200–208.

Srivastava, A. K. and Singh, S. 2005. Zinc Nutrition, a Global Concern for Sustainable Citrus Production. *J. Sustain. Agric.* **25(3):**5–42.

Srivastava, A. K. and Singh, S. 2009. Citrus Decline: Soil Fertility and Plant Nutrition. *J. Plant Nutr.* **32(2):**197–245.

Srivastava, A. K., Das, S. N., Malhotra, S. K. and Majumdar, K. 2014. SSNM-based rationale of fertilizer use in perennial crops: a review. *Indian J. Agric. Sci.* **84(1):**3–17.

Subbiah, B. V. and Asija, G. L. 1956. A Rapid Procedure for the

Estimation of Available Nitrogen in Soils. *Curr. Sci.* **25(8):**259–260.

Tagore, G., Kulhare, P., Sharma, G. and Suryawanshi, A. 2017. Characterization of Spatial Variability of Soil Fertility Parameters Using Geo-Spatial Techniques. *Int. J. Plant Soil Sci.* **19(1):**1–10.

Walkley, A. and Black, I. A. 1934. An Examination Of The Degtjareff Method For Determining Soil Organic Matter, And A Proposed Modification Of The Chromic Acid Titration Method. *Soil Sci.* **37(1):**29–38.

Wolf, B. 1974. Improvements in the azomethine H method for the determination of boron. *Commun. Soil Sci. Plant Anal.* **5(1):**39–44.

Yurembam, G. S., Chandra, H. and Kumar, V. 2015. Status of available macro and micronutrients in the soils of Someshwar watershed in Almora district of Uttarakhand. *The Ecoscan.* **9 (3 & 4):** 725-730.