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Geo-referenced appraisal of spatial variability of soil properties in Jharsuguda district of Odisha, India

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Abstract

Precise nutrient management is one of the most essential and vital aspects of modern agricultural practices. To make this happen, we must know about the spatial variability of soil fertility. A detailed geo-referenced investigation was conducted to study the plant's available nutrient status and prepare soil fertility maps, which would act as an important tool for soil as well as nutrient management for higher and more sustainable crop production. The soils of different Villages in each block of Jharsuguda district were collected using GPS instruments and analyzed for chemical properties and maps were prepared subsequently. The results revealed that the soils under investigation were acidic in reaction (pH 5.29 to 5.58) and low to medium in organic carbon status (0.47 to 0.85 %). The mean available nitrogen content varied from 214.09 to 381. 95 kg ha^{-1}, available P content from 15.32 to 25.62 kg ha^{-1} and potassium status from 314.45 to 378.42 kg ha^{-1}. Thus, on a mean basis, the soils of the Jharsuguda district of Odisha were medium in available N and P and high in K status. On the contrary, the mean available sulfur content was found deficient (5.00 to 17.14 kg ha^{-1}). Hot water-soluble boron content was below the critical limit (0.27 to 0.44 mg kg^{-1}) in most of the soils of Jharsuguda district.

Keywords: Soil fertility maps, Jharsuguda district, nutrient management

Introduction

Soil, land and water are the vital resources for the sustained quality of human life and serve as the cornerstone of agricultural growth. (Das *et al*. 2009) [3]. Efficient management of soil and water resources is a major challenge for the scientists, planners, administrators and farmers to ensure food, water and environmental security for the present and future generations (Kanwar 2000) [2]. Soil fertility plays an important role in sustaining crop productivity in an area, particularly in situations where the input of nutrients application differs and the information on the nutritional status can go a long way to develop economically viable alternatives for the management of deficient nutrients in the soil. The modern geospatial technologies such as Remote Sensing (RS), Geographical Information System (GIS), Global Positioning System (GPS) and Information Technology (IT) offer immense potential for soil and water resources development and management (Das 2004) [4]. Geographical Information System (GIS) is a potential tool used for easy access, retrieval and manipulation of voluminous data of natural resources often difficult to handle manually. It facilitates the manipulation of spatial and attributes data useful for handling multiple data of diverse origin (Mandal and Sharma 2010) [15]. Several databases are available at global and national levels that showed for planning management of soil resources. The FAO Soil Map of the World (FAO 1996) [5] is an important source of soil information used worldwide. Collection of soil samples by using Global Positioning System (GPS) is very important for preparing the GPS and GIS-based thematic soil fertility maps (Mishra *et al*. 2016) [6]. Composite soil samples are collected by GPS instrument to know the latitude and longitude of that particular location. It has got great significance in agriculture for future monitoring of the soil nutrient status of different locations/villages. Detail systematic study to assess the soil fertility status of the Jharsuguda district of Odisha has not been done earlier. Therefore, an attempt was made to study the soil fertility status in detail of Jharsuguda district with GPS and GIS tools and to prepare the soil fertility maps for easy understanding of the soil fertility status.

Materials and Methods

Experimental site

Jharsuguda district is situated in the northwestern part of Odisha and is bounded between the 21° 34' North and 22°02' North latitudes and also between 83°25' East and 84°23' East longitudes. It shares its boundary with Sundargarh district in the north, Sambalpur in the east, Bargarh in the south and Chhatisgarh state in the west. Extending over a geographical area of 2081.86 sq. km, it occupies 1.41 % of the area of the state. It receives 1652 mm of average annual rainfall. The district has only one sub-division (Jharsuguda) and five blocks (Jharsuguda, Kirmira, Kolabira, Laikera and Lakhanpur). It is one of the most important industrial districts of the state with a wealth of natural resources (mines and water). The most important rivers flowing through this district are Mahanadi and Ib, the water of which has been most helpful in setting up a number of industries in this district. The Mahanadi reservoir formed by Hirakud Dam is adjacent to Jharsuguda and Lakhanpur block. Jharsuguda district falls under two agroecological zones i.e. (i) West Central Table Land Zone and (ii) North Western Plateau. Laikera block falls under North Western Plateau while the rest of the blocks come under West Central Table Zone.

Soil Sampling and analysis

A total of 528 numbers of GPS-based composite surface (0–15 cm) soil samples were collected from eighty-eight representative villages of all five blocks, namely Jharsuguda (114), Kirmira (96), Kolabira (102), Laikera (90), and Lakhanpur (126) by taking six composite GPS-based soil samples from selected villages of each block. The soil samples were analyzed for pH (1:2), EC (1:2), organic carbon (Walkley and Black method), available nitrogen (alkaline permanganate method), available phosphorus (Bray's No.-1), available potassium (neutral normal ammonium acetate method), available boron (hot water extraction) and available (0.15% $CaCl_2$) sulphur (Jackson, 1973) [7]. Base maps of the Jharsuguda district were digitized and geo-referenced. Polygons were superimposed on the geo-referenced map. Then latitude, longitude and soil characteristics such as soil reaction, organic carbon, available nitrogen, available phosphorus, available potassium, available sulphur and hot water extractable boron content were linked to Arc GIS 10.7.1 software for making thematic soil fertility maps.

Results and Discussion

The average pH of all the blocks of Jharsuguda district is moderately acidic to neutral which ranged from 5.29 to 5.58 (Table 1 and Fig: 1). The pH of Jharsuguda block soils varied between 4.4 and 6.6 (strongly acidic to slightly acidic) with a mean value of 5.35. Similarly, the blocks namely Kirmira, Kolabira, Laikera, and Lakhanpur soils had pH between 4.3 and 6.4, 4.5 and 6.7, 4.5 and 6.6 and 4.4 and 6.7 respectively with their respective mean values of 5.35, 5.43, 5.29, 5.58, and 5.46 (Fig.1). The data revealed that pH of Jharsuguda, Kolabira, Laikera and Lakhanpur block were strongly acidic to slightly acidic whereas, Kirmira block soil ranged from strongly acidic to moderately acidic. Most of the soils of the district suffer from different levels of acidity, which appears to be a major crop production constraint in the area. Similar findings were reported by Mishra *et al.* (2016) [6].

The electrical conductivity of Jharsuguda, Kirmira, Kolabira, Laikera, and Lakhanpur blocks ranged from 0.01-0.50, 0.08-0.28, 0.08-0.28, 0.08-0.24, and 0.08- 0.28, dSm-1, respectively. The highest mean electrical conductivity was diagnosed in Jharsuguda, Kirmira, Kolabira, and Lakhanpur block (0.13 dSm-1) followed by Laikera block (0.12 dSm-1). The data revealed that the electrical conductivity of the soils of the entire district was varied from 0.01 - 0.50 dSm-1with a mean of 0.128 dSm^{-1}. The electrical conductivity of the entire district was found to be less than 1dS m-1(Table 1 and Fig.2). Hence, all the soils under the study area were found safe for all types of crops with respect to the soluble salt content.

The low electrical conductivity of soil could be attributed to the higher leaching induced by heavy rainfall in the absence of an adequate quantity of soil organic matter or decomposition of organic matter at high temperatures. Similar findings were reported by Mohapatra *et al.* (2020) [8].

The overall organic carbon status of the district was found to be in a range of 0.09 to 1.87% with an average value of 0.64%. Within the district, the soils of Jharsuguda block displayed the highest mean organic carbon content of 0.85 %, followed by Kirmira (0.65%), Kolabira (0.64%), Laikera (0.58 %) and Lakhanpur block (0.47 %). With respect to block-wise appraisal, except Lakhanpur, which was categorized under low, all the remaining blocks of the district were assessed as medium category of organic carbon status. The addition of organic matter, either artificially or naturally and its subsequent decomposition could be the cause of the presence of medium amount of organic carbon. Sufficient amount of organic carbon not only encourages the soil microbial activity but also serves to supply various nutrient elements in plant-available forms into the soil solution. Hence, enriching the soils with organic carbon by addition of organic matter to the soil will help in optimizing crop productivity and sustaining soil health. Similar results were also reported by Sethy *et al.* (2019) [9].

Table 1: Range and mean values of pH, EC and organic carbon in the soils of Jharsuguda district

Sl. No.	Block name/No. of samples collected	pH		EC (dSm^{-1})		OC (%)	
		Range	Mean	Range	Mean	Range	Mean
1	Jharsuguda (114)	4.4 - 6.6	5.35	0.01 - 0.5	0.13	0.17 - 1.81	0.85
2	Kirmira (96)	4.3 - 6.4	5.43	0.08 - 0.28	0.13	0.17 - 1.76	0.65
3	Kolabira (102)	4.5 - 6.7	5.29	0.08 - 0.28	0.12	0.09 - 1.76	0.65
4	Laikera (90)	4.5 - 6.6	5.58	0.08 - 0.24	0.13	0.12 - 1.87	0.58
5	Lakhanpur (126)	4.4 - 6.7	5.46	0.08 - 0.28	0.13	0.16 - 1.07	0.47
	Mean	4.3 - 6.7	5.42	0.01 - 0.50	0.128	0.09 - 1.87	0.64

Figures in parenthesis indicate number of soil samples

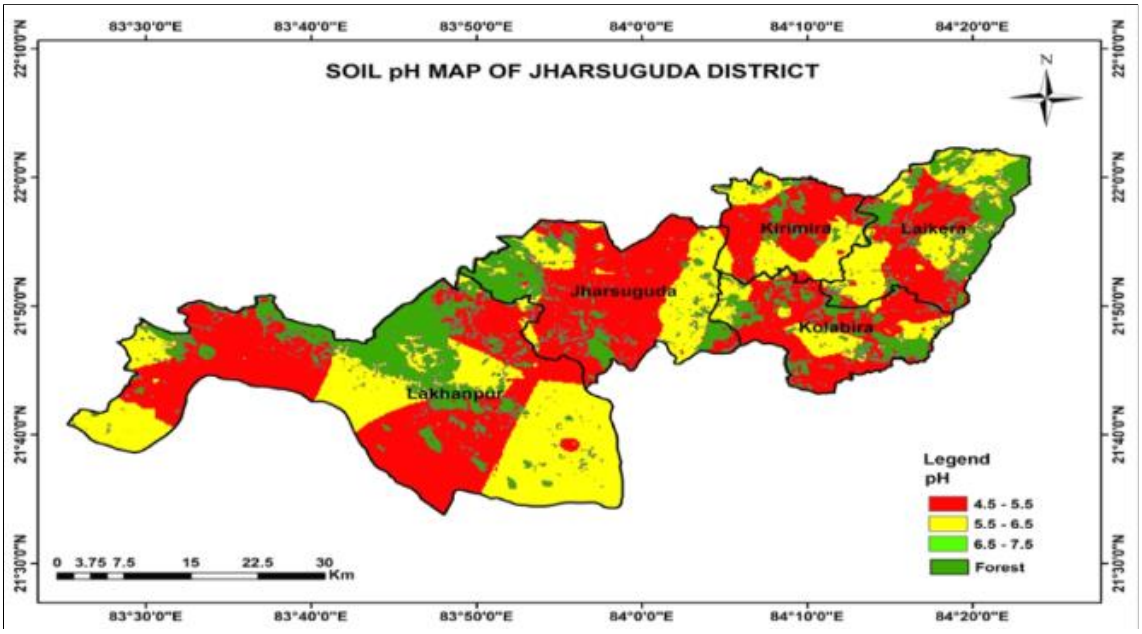

Fig 1: GPS and GIS based Soil pH map of Jharsuguda district

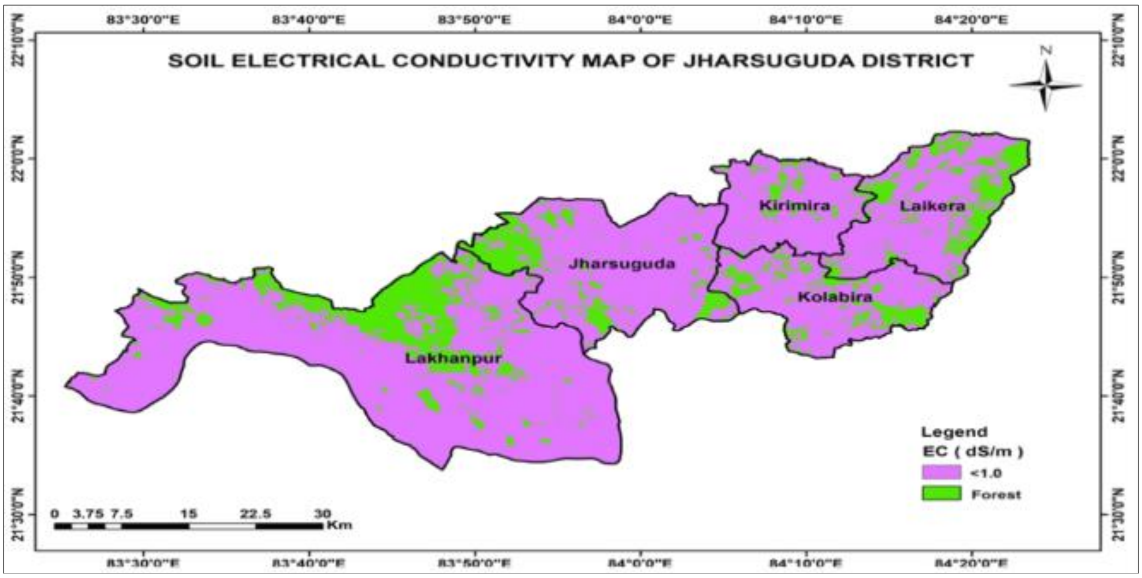

Fig 2: GPS and GIS based Soil Electrical conductivity map of Jharsuguda district

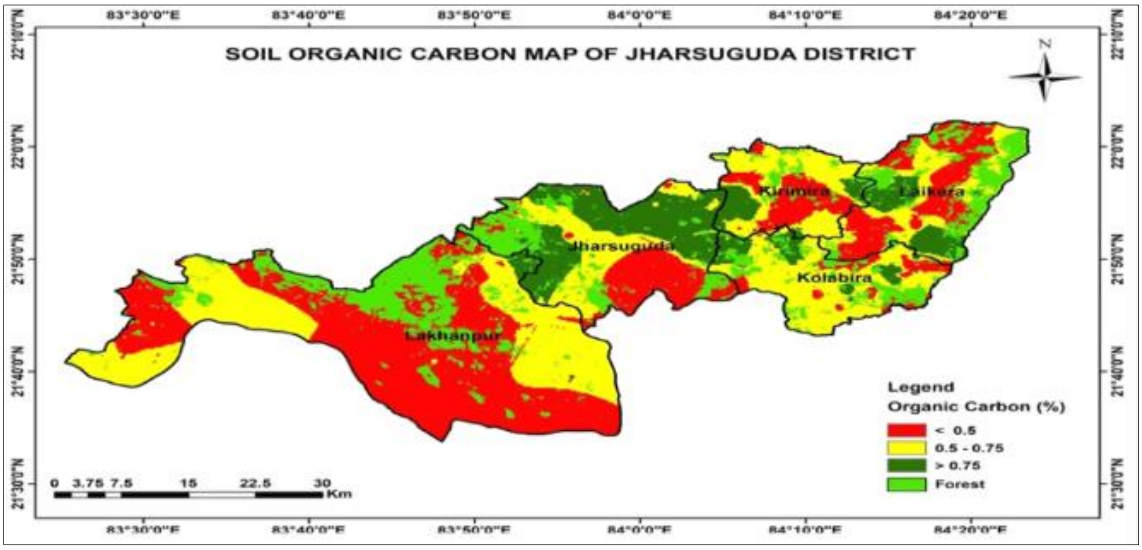

Fig 3: GPS and GIS based soil organic carbon content map of Jharsuguda district

Table 2: Range and mean values of available N, P and K in the soils of Jharsuguda district

Sl. No.	Block name/No. of Samples collected	Av. N (kg ha^{-1})		Av. P (kg ha^{-1})		Av. K (kg ha^{-1})	
		Range	Mean	Range	Mean	Range	Mean
1	Jharsuguda (114)	75.6 - 865.3	381.95	0.35 - 50.71	15.32	120 -770	315.96
2	Kirmira (96)	79.8 - 797.3	278.14	0.75 - 69.32	25.63	120.-790	351.04
3	Kolabira (102)	40.2 - 693.7	280.91	2.21 - 71.82	25.71	100 -920	378.42
4	Laikera (90)	61.3 - 865.3	265.88	0.74 - 69.54	17.14	100 -820	314.45
5	Lakhanpur (126)	72.6 - 481.5	213.93	0.49 - 76.27	20.84	90 - 890	376.96
	Mean	40.2 -865.3	283.71	0.35 - 76.27	20.92	90 - 920	347.37

Figures in parenthesis indicate number of soil samples

The available nitrogen status of the Jharsuguda district, as presented in (Table 2 and Fig: 4) varied between 40.2 and 865.3 kg ha^{-1} with an average of 283.71 kg ha^{-1}. In the district, 53% of the soil samples showed low content of available N, whereas 35% showed a medium category of available N content. The lowest available nitrogen content was observed in the Lakhanpur block which ranged from 72.6 to 481.5 kg ha^{-1} with a mean value of 213.93 kg ha^{-1} and the highest in Jharsuguda block ranged from 78.8 to 360.0 kg ha^{-1} with an average of 168.1 kg ha^{-1}. The highest mean available nitrogen (381.95 kg ha^{-1}) was recorded in Jharsuguda block. Similar results were also reported by Kashiwar *et al.* (2019) [10]. Most of the soils in the district (Table 2) were found to have low available phosphorus content, which ranged from 0.35 to 76.27 kg ha^{-1} with an average of 20.92 kg ha^{-1}. About 47% of the area in the district was categorized under low level, followed by 39% under medium and 14% under high levels of available P. The available phosphorus content of all five blocks ranged from low (14 kg ha^{-1}) to medium (14kg ha^{-1}). However, the mean values of the available phosphorus content of all the blocks as well as of the entire district were diagnosed as medium category. The highest available phosphorus was found in Lakhanpur block (76.27 kg ha^{-1}) and lowest in Jharsuguda blocks (0.35 kg ha^{-1}). A similar result was reported by Swain *et al.* (2019) [11].

The available potassium content in the soils of the district ranged from low to high (90 to 920 kg ha^{-1}) with an average value of 347.37 kg ha^{-1}(Fig.6). The lowest mean available potassium content was found in Laikera block (314.45 kg ha^{-1}) which was in high range and highest in Kolabira block soils which were also reported as high (378.42 kg ha^{-1}) range.

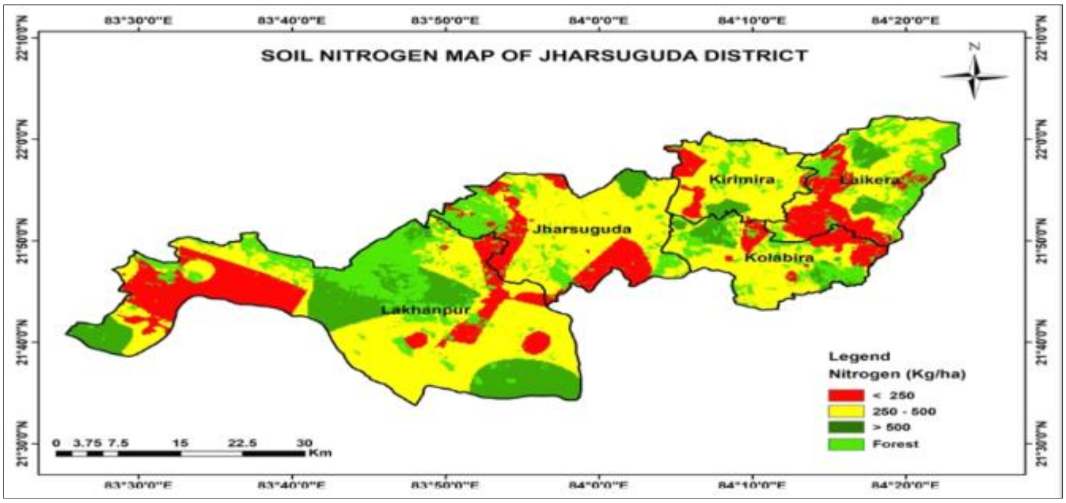

Fig 4: GPS and GIS based available nitrogen map of Jharsuguda district

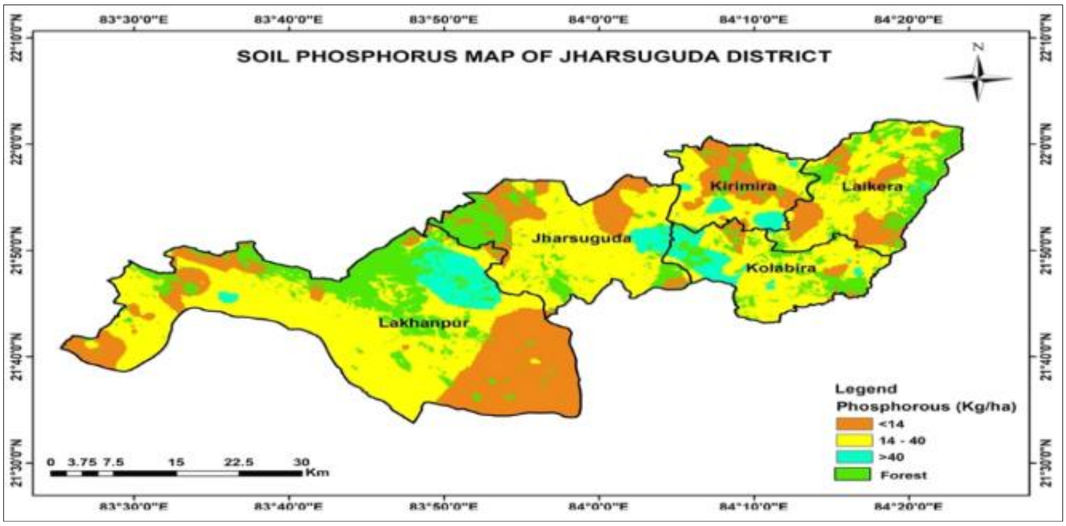

Fig 5: GPS and GIS based available phosphorus map of Jharsuguda district

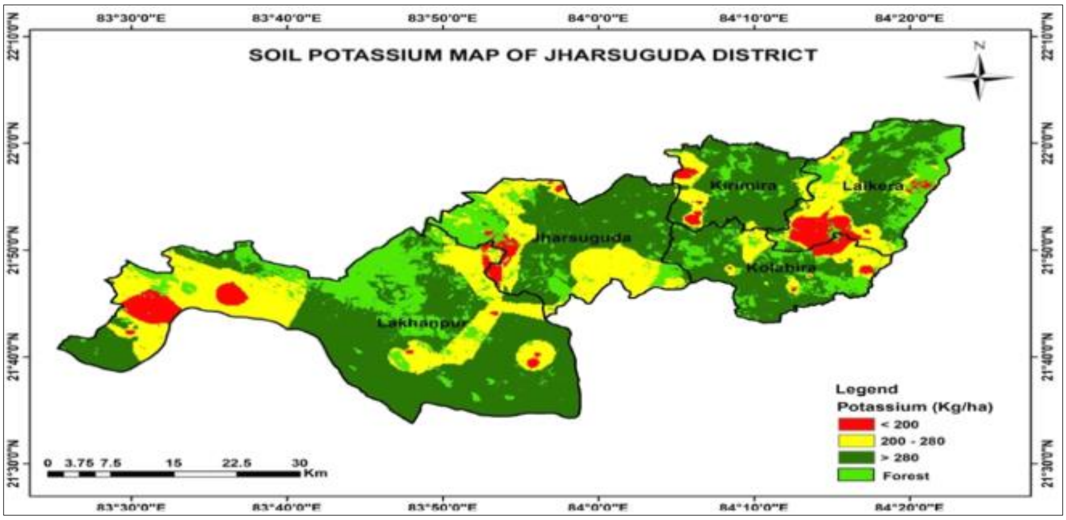

Fig 6: GPS and GIS-based available potassium map of Jharsuguda district

Table 3: Available sulphur and hot water-soluble boron content in the soils of Jharsuguda district

Sl. No.	Block name/No. of	Sulphur (mg kg^{-1})		Boron (mg kg^{-1})	
	Samples collected	Range	Mean	Range	Mean
1	Jharsuguda (114)	0.35 - 39.90	5.53	0.14 - 0.95	0.27
2	Kirmira (96)	0.14 - 37.12	6.67	0.13 - 0.88	0.40
3	Kolabira (102)	0.35 - 23.55	5.00	0.13 - 1.06	0.36
4	Laikera (90)	0.62 - 55.17	17.14	0.13 - 0.97	0.44
5	Lakhanpur (126)	0.34 - 113.50	15.12	0.14 - 1.06	0.42
	Mean	0.14 - 113.50	9.89	0.13 - 1.06	0.38

Figures in parenthesis indicate number of soil samples

High available K content might be attributed to the predominance of K-rich micaceous and feldspars minerals in parent material, (Ravikumar 2004) [12]. Similar results were reported by Sethy *et al.* (2019) [9] for Deogarh district of Odisha.

The available S content of the district (Table 3 and Fig. 7) was found to vary between 0.14 to 113.5 mg kg-1 with an average value of 9.89 kg ha^{-1}. The lowest available sulphur content was observed in Kirmira block (0.14 mg kg^{-1}) and the highest in Lakhanpur block (113.5 mg kg^{-1}). Considering the critical limit (10 mg kg$^{-1)}$ the mean available sulphur content of Jharsuguda, Kirmira and Kolabira blocks were diagnosed as sulphur deficient with average values of 5.53, 6.67 and 5.00 mg kg^{-1} respectively whereas the Laikera and Lakhanpur blocks reported adequate available sulphur content with mean values 17.14 and 15.12 mg kg^{-1}respectively. Similar findings were reported by Digal *et al.*, (2018) [13]. The lack of sulphur addition and continuous application of S-free fertilizers, which induce crops to remove S, maybe the cause of the low level of available sulphur in three blocks of the district Srikanth *et al.* (2010) [14]. Further, in soils with little organic matter (less than 2%) and in environments with a lot of rainfall, the low sulphur status is more likely to result in sulphur deficiency.

Hot water extractable boron content of the district (Table 3 and Fig. 8) varied between 0.13 and 1.06 mg kg^{-1} with an average value of 0.38 mg kg^{-1}. Considering the critical limit of 0.5 mg kg^{-1}, about 72 % of soil samples were found as boron deficient, which was identified as one of the most limiting nutrients in the district. The mean values of hot water soluble boron content in all the blocks were found below the critical limit (0.5 mg kg^{-1}). The highest (1.06 mg kg^{-1}) and hot water soluble boron content was observed in soils of Kolabira together with Lakhanpur blocks, whereas the lowest (0.13 mg kg^{-1}) was noticed jointly in Kirmira, Kolabira and Laikera blocks of the district.

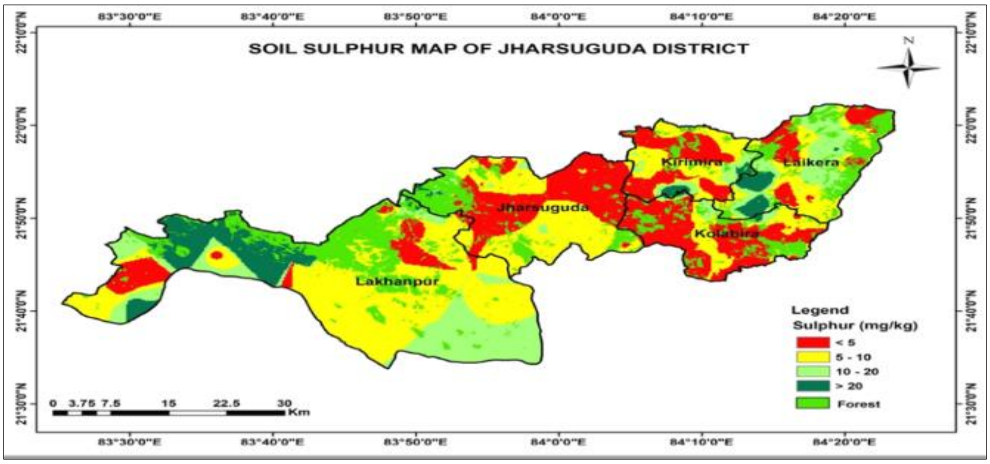

Fig 7: GPS and GIS based available sulphur map of Jharsuguda district

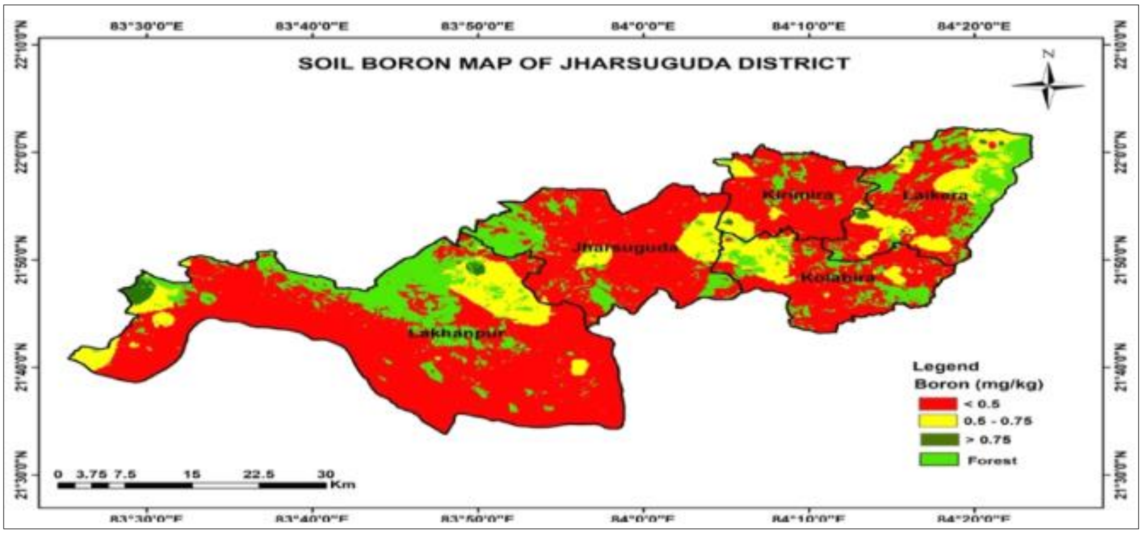

Fig 8: GPS and GIS-based hot water-soluble boron map of Jharsuguda district

Conclusion

The present study revealed that 99% of the soils of Jharsuguda district are suffering from different levels of soil acidity, which appeared as a major crop productivity constraint of the district. In addition to having numerous negative effects on the biological, chemical, and physical properties of the soil, soil acidity also significantly reduces the availability of many nutrients to plants. Suitable low-cost liming materials must be applied to soils based on lime requirements. The electrical conductivity of the entire district was found to be less than 1dSm-1 and thus considered to be safe in respect of soluble salt content. The level of organic carbon in the soils of the district was detected to be ranged from 0.09 to 1.87 % with a mean value of 0.64 %. Among all the blocks of the district, more than 76% of the area fell under the category of medium-range organic carbon. In the district, 53% of the soil samples showed low content of available N, whereas 35% showed a medium range. Hence, the application of nitrogenous fertilizers along with organic manures and soil ameliorant (lime) is of great importance to deal with soil acidity and low N availability. A huge swathe of the district also suffers from available phosphorus deficiency. Hence, the application of soil test-based phosphatic fertilizers along with organic manures and soil ameliorant (lime) is of great importance to increase P availability to crops. Since the available K status was mostly medium to high in range, the application of only recommended doses of fertilizers in most parts of the district (having a medium range of available K) will be sufficient to support optimum crop production. Even recommended doses of fertilizers can be reduced to 25%, where available K status is high. Since, most of the K fertilizers are imported and costly, a reduced application of K fertilizers will reduce the cost of cultivation. An integrated application of soil test-based fertilizer doses, along with sufficient organic matter and suitable ameliorants can optimise crop productivity along with sustaining soil health.

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