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Soil Fertility Maps Preparation Using GPS and GIS in Dhenkanal District, Odisha, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author AM designed the study and wrote the protocol, author TP managed analyses of the study, author DD wrote the first draft of the manuscript, experimental process, performed the statistical analysis, and identified the suitable crops and author MD managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Soil fertility maps of Dhenkanal district, Odisha were prepared by using Global Positioning System (GPS) and Geographical Information System (GIS) to make awareness among the farmers regarding use of balanced fertilization according to soil test based recommendation and integrated nutrient management for higher and sustainable crop production. Soils of different villages for each block were collected by GPS instrument. These soil samples were processed and analysed in laboratory using standard methods. The soil characteristics data were entered in attributed table and linked with the GIS software to develop a relational database. The analogue soil fertility maps on 1:25000 scale were geo-referenced and digitized by using ArcGIS software. Thematic layers were developed for block boundaries to prepare the base map. Superimposing polygons (Spatial coverage) of block units and the base map, soil fertility maps were prepared. These maps were integrated in GIS to generate a composite database of GPS based soil of Dhenkanal district. These maps were divided into 8 mapping units (8blocks of Dhenkanal district). Based on the generated soil fertility maps, the status of organic carbon, available N, available P, available K, available S and micronutrients like Boron was assessed and suitable crops such as rice, fingermillet, pulses, vegetables and fruit crops have been identified.

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Keywords: Dhenkanal district; GIS; GPS and soil fertility maps.

1. INTRODUCTION

Soil, land and water are essential resources for the sustained quality of human life and the foundation of agricultural development [1]. 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 [2,3].

The state of Odisha is located in the east coast of India and it stretches from $17^0$47'N to $22^0$33'N latitude and $81^0$30'E to $87^0$30' E longitude [4]. Geographical area of the state is 155.57 lakh ha, out of which 62 lakh ha (39.2%) are arable. Out of arable land, 26.95 lakh ha is high land, 19.55 lakh ha is medium land and 16 lakh ha is lowland. Odisha state stands as 10^{th} largest in geographical area and 11^{th} populous state accounting 5% area, 4% population and 11% water resources of the Country [5]. Odisha is bestowed with rich natural resources and the state has a tropical monsoon climate characterized by high humidity, medium to high rainfall and short to medium winters. The average annual rainfall is 1497 mm. Even though the quantum of rainfall received is very high, it is erratic and its distribution is very odd. The mean summer and winter temperatures are 30.3^0C and 21.3^0 C, respectively [4]. Agriculture is the most important sector in the pie of state economy of Odisha. Land and soil play the most vital role in agriculture production which contribute 28% of the Net State domestic production and 64% of the work force [5]. Hence, proper soil and land use planning and management using modern tools is essential for ensuring food security in this state.

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 [6,7]. GIS is a potential tool used for easy access, retrieval and manipulation of voluminous data of natural resources which is difficult to handle manually. It facilitates manipulation of spatial and attributes data useful for handling multiple data of diverse origin [8]. Several databases are available at global and national level which can be analysed and properly utilized for planning management of soil resources. The FAO Soil Map of the World [9] is an important source of soil information used world-wide. While GLASOD, SOTER, WISE, ISIS, SSURGO, STATSGO, NATSGO, CanSIS, NSDB, AAFC and ASRIS are databases prepared at global level and used for natural resource management [10,11,12,13,14,15].

Collection of soil samples by using GPS is very important for preparing thematic soil fertility maps [16]. This instrument helps to know latitude and longitude of that particular place. It has got great significance in agriculture for future monitoring of soil nutrient status of different locations/villages. It also helps to know elevation, road map, nearest city/town(s) and speed of movement.

2. STUDY AREA

Dhenkanal District occupies a Central position in the Geo-Political map of Odisha. It lies between 85°58' E to 86°20'E longitude and between 20°29' N to 21°11' N latitude. It has 8 nos. of blocks consisting of 1215 nos. of villages covering a total area of 4452 Sq Km. It shares common boundary with Keonjhar in the North, Jajpur in the East, Cuttack in the South and Angul in the West. The climatic condition of the district is generally hot with high humidity during April and May and cold during December and January. The onset of monsoon is generally observed during the month of June. The main crops like Paddy, Green gram, Horse gram, Potato and Sesamum are grown in this district.

2. MATERIALS AND METHODS

Dhenkanal district of Odisha was selected for carrying out the study to prepare GPS and GIS based thematic soil fertility maps. Latitude (Lat) and Longitude (Long) were recorded by GPS instrument from soil sampling places. Six composite GPS based soil samples have been collected from selected villages of each block. The soils were collected from 5-6 spots for one composite soil sample and by quartering process the soil quantity was reduced upto 1 kg. Total 594 numbers of GPS based soil samples from 8 blocks/tahasils namely; Kankadahad (54), Bhuban (60), Kamakhyanagar (66), Parjang(60), Odapada (78), Hindol (96), Dhenkanal Sadar (84) and Gandia (96) were collected. Soil samples were brought to the laboratory and air dried under shade avoiding contamination with foreign materials and then crushed with a wooden pestle. The sample is then screened through a 2mm sieve and the pebbles, stones and roots were rejected. About 0.5 to 1kg of air dried crushed soil sample was put in the plastic sample bottle, lebelled and stacked on the open sample racks for analysis. The analysis of soil samples have been done by using standard methods i.e. pH (1:2.5), EC (1:2.5), organic carbon (Walkley and Black method), available nitrogen (Alkaline Permanganate method), available phosphorus (Bray's No.-1), available potassium (Ammonium acetate method), available boron (Hot water extraction method) and available sulphur (0.15%$CaCl_2$ method). Base map of the Dhenkanal district was digitized and geo-referenced. Polygons were superimposed on the geo-referred map. Latitude, longitude and analysis data were entered into attributed table and linked to Arc GIS software for making thematic soil fertility maps.

3. RESULTS AND DISCUSSION

The soil reaction, electrical conductivity and organic carbon content in soils of Dhenkanal district are presented in Table 1. The soil reaction of all the blocks ranged from very acidic to saline (4.33 – 7.83). The highest pH was found in Odapada block (7.83) followed by in Hindol block (7.72) which varied between 4.52-7.83 and 4.68-7.72, respectively with corresponding mean value of 5.66 and 5.85. On the other hand, the lowest pH was observed in Kamakhyanagar block which range from 4.33 – 6.33 with mean value of 5.26 (Fig. 1). All the blocks of Dhenkanal district are acidic in mean soil reaction value. Similar finding was also recorded by [4]. The data revealed that highest mean electrical conductivity was observed in Odapada block (0.182 dS m^{-1}) followed by Dhenkanal Sadar (0.117 dS m^{-1}) and lowest in Kamakhyanagar block (0.080 dS m^{-1}). The organic carbon content varied between 0.336-1.464% in Kankadahad, 0.118-1.929% in Parjang, 0.084-1.785% in Odapada and 0.326-1.255% in Gandia blocks with respective mean value of 0.837, 0.751, 0.822 and 0.756% indicating high range in mean organic carbon content; Whereas, 0.118-1.197% in Bhuban, 0.063 – 2.19% in Kamakhyanagar, 0.201 – 1.812% in Hindol and 0.233-1.634% in Dhenkanal Sadar with respective mean value of 0.685, 0.724, 0.707 and 0.640% indicating medium range (Fig. 2). The data revealed that both highest (2.19%) and lowest (0.063%) organic carbon content was observed in Kamakhyanagar block. The high organic carbon content in different blocks is due to the dense forest area with undulating topography present in this district. Similar finding was also reported by [17].

Table 1. Range and Mean of pH, EC and Organic Carbon of Dhenkanal

Sl. no.	Block name/No. of samples collected	pH		EC (dS m^{-1})		OC (%)	
		Range	Mean	Range	Mean	Range	Mean
1	Kankadahad (54)	4.48-5.80	4.88	0.036-0.231	0.082	0.336-1.464	0.837
2	Bhuban (60)	4.61-7.21	5.24	0.027-0.235	0.088	0.118-1.197	0.685
3	Kamakhynagar (66)	4.33-6.33	5.26	0.024-0.236	0.080	0.063-2.19	0.724
4	Parjang (60)	4.63-7.42	5.38	0.032-0.248	0.098	0.118-1.929	0.751
5	Odapada (78)	4.52-7.83	5.66	0.048-0.592	0.182	0.084-1.785	0.822
6	Hindol (96)	4.68-7.72	5.85	0.028-0.465	0.094	0.201-1.812	0.707
7	Dhenkanal Sadar (84)	4.59-6.81	5.25	0.016-0.402	0.117	0.233-1.634	0.640
8	Gandia (96)	4.41-6.56	5.14	0.032-0.159	0.090	0.326-1.255	0.756

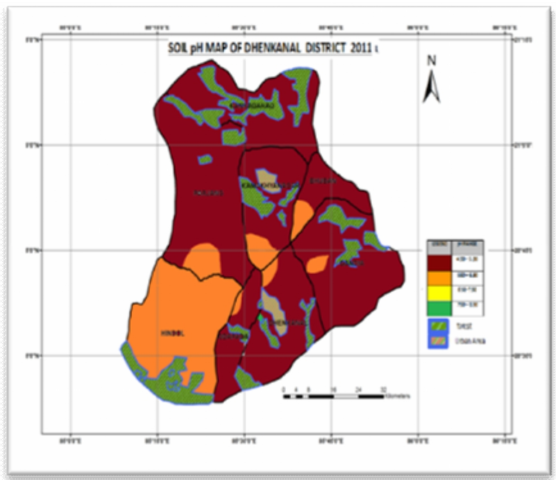

Fig. 1. GPS and GIS based Soil pH map

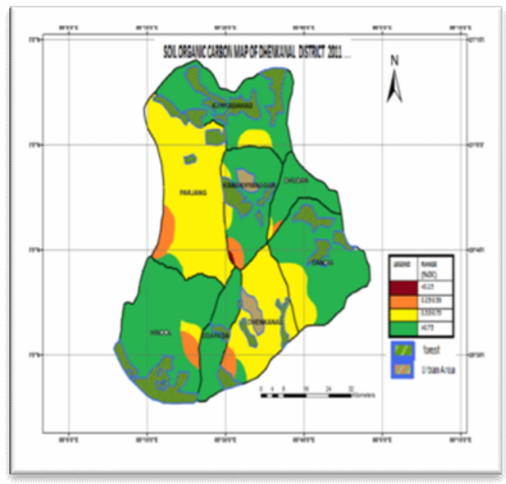

Fig. 2. GPS and GIS based Soil organic carbon content map

Table 2 presents the primary nutrients status namely available nitrogen, available phosphorus and available potassium which are required in large quantity for crop production. Kankadahad, Bhuban, Parjang, Odapada, Hindol, Dhenkanal Sadar, Kamakhyanagar and Gandia blocks were low in available nitrogen content. The highest (396.25 kg ha^{-1}) available nitrogen content was found in Kankadahad block and lowest (71.25 kg ha^{-1}) in Hindol block (Fig.3). All the blocks of Dhenkanal district were low in mean available nitrogen content. Similar result was also found by [17]. The lowest (0.245 kg ha^{-1}) available phosphorus (P) content was found in Kankadahad, Kamakhyanagar, Parjang, Odapada and Hindol blocks and the highest P (50.71 kg ha^{-1}) was found in Gandia block (Fig.4). Similar finding was also reported by [17]. The mean available phosphorus content was low in all the blocks. The available potassium content of Odapada and Parjang blocks were high where as Gandia, Dhenakanal Sadar, Hindol, Kamakhyanagar and Kankadahad blocks were medium and Bhuban block was low in mean available potassium content. The data revealed that the highest available potassium content was observed in Odapada (1004.64 kg ha^{-1}) and lowest (26.80 kg ha^{-1}) in Dhenkanal Sadar block (Fig.5). Similar finding was also reported by [18].

Table 2. Range and mean of primary nutrients of Dhenkanal 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	Kankadahad (54)	81.25-396.25	186.00	0.245-14.2	6.51	66.08-293.44	146.45
2	Bhuban (60)	113.75-281.25	167.54	0.735-28.66	7.38	29.12-300.16	104.84
3	Kamakhynagar (66)	105.00-247.50	163.48	0.245-20.09	4.42	49.28-434.56	187.60
4	Parjang (60)	87.50-336.75	157.86	0.245-17.88	7.00	70.56-840.0	318.56
5	Odapada (78)	107.50-342.50	177.58	0.245-39.69	8.32	73.92-1004.64	383.82
6	Hindol (96)	71.25-252.50	162.92	0.245-26.95	6.39	44.8-440.16	203.53
7	Dhenkanal Sadar (84)	105.00-365.00	170.47	0.49-28.17	5.35	26.80-831.04	216.94
8	Gandia (96)	97.50-242.50	166.18	0.49-50.71	9.09	66.8-538.72	248.51

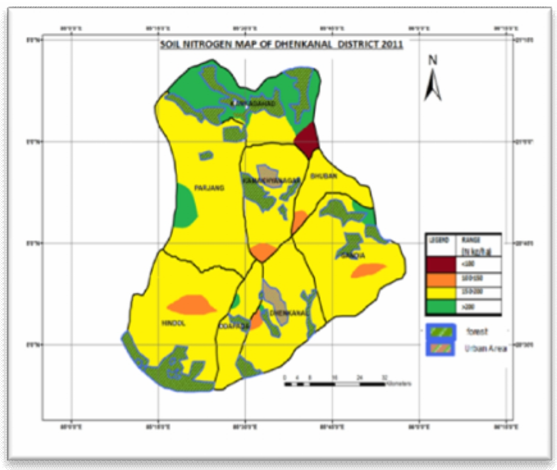

Fig. 3. GPS and GIS based Soil available nitrogen content map

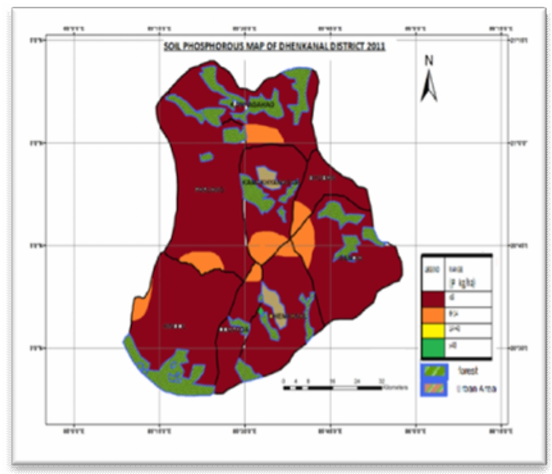

Fig. 4. GPS and GIS based Soil available phosphorus content map

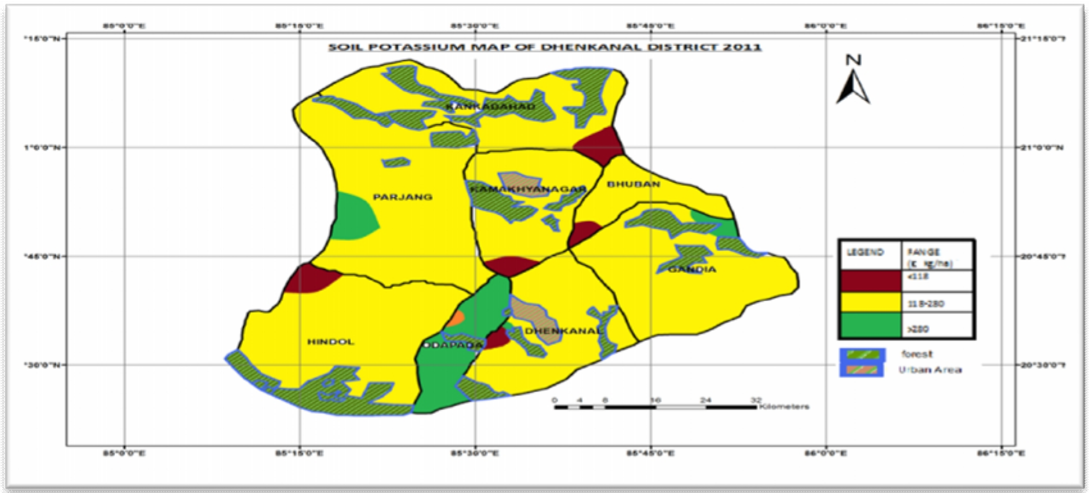

Fig. 5. GPS and GIS based Soil available potassium content map of Dhenkanal district

The status of available sulphur and hot water soluble boron content are presented in Table 3. Mean available sulphur content of all the blocks remained below critical limit (<10 mg kg^{-1}). Highest available sulphur content (83.65 mg kg^{-1}) was observed in Hindol block and lowest (0.70 mg kg^{-1}) in Gandia block(Fig.6). Similar finding was also observed by [19]. The mean value of hot water soluble boron content in Kankadahad, Bhuban and Hindol blocks remained above the critical limits (>0.5 mg kg^{-1}) whereas rest of the blocks remain below critical limit . Hot water soluble boron content was highest(1.47 mg kg^{-1}) in Kankadahad and lowest (0.13 mg kg^{-1}) was observed in both Hindol and Gandia blocks (Fig. 7). Similar finding was also reported by [17].

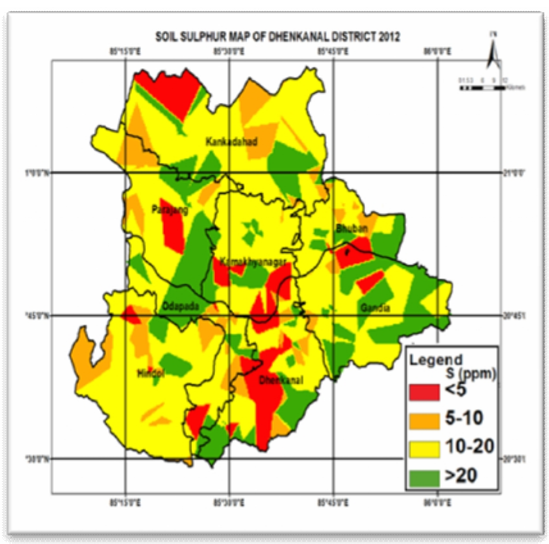

Fig. 6. GPS and GIS based Soil available sulphur content map

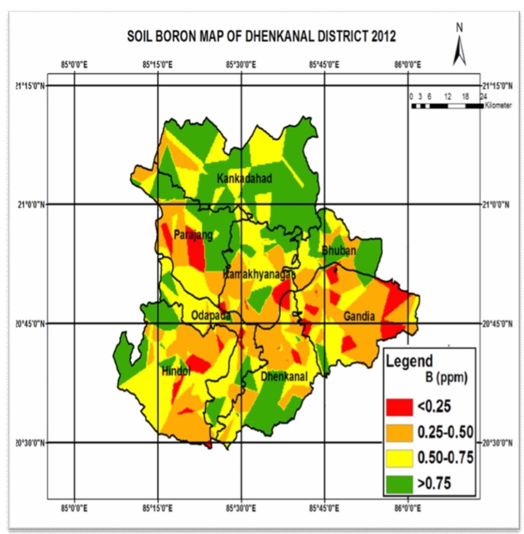

Fig. 7. GPS and GIS based Soil hot water soluble boron content map

Table 3. Availble sulphur and hot water soluble boron content of Dhenkanal

Sl. no.	Block name/No. of samples collected	Sulphur (mg kg^{-1})		Boron (mg kg^{-1})	
		Range	Mean	Range	Mean
1	Kankadahad (54)	4.55-39.90	16.33	0.41-1.47	0.884
2	Bhuban (60)	5.25-28.00	12.38	0.27-0.92	0.556
3	Kamakhynagar (66)	2.45-42.35	14.46	0.23-0.82	0.440
4	Parjang (60)	2.30-69.65	17.80	0.14-0.69	0.378
5	Odapada (78)	3.85-51.10	15.70	0.18-0.87	0.460
6	Hindol (96)	2.45-83.65	14.40	0.13-1.33	0.597
7	Dhenkanal Sadar (84)	2.80-32.20	12.96	0.18-0.64	0.375
8	Gandia (96)	0.70-34.30	16.35	0.13-0.92	0.454

The organic carbon content of the soils ranged from medium to high and the soils of all blocks were acidic in soil reaction which indicate the need for reclamation with lime application for reclamation. Available nitrogen and available phosphorus content were low. Available potassium content ranged from low to high. On the other hand, available sulphur was found to be medium. Hot water soluble boron content remained below the critical limits except in Kankadahad, Bhuban and Hindol blocks. Groundnut and pulses could be grown successfully in the acidic soils and application of mixture of water soluble and insoluable phosphatic fertilizers increased the crop yield. Soil application of boron enhanced legume yield and potato and other vegetables can grow well without liming. Crops like rice, finger millet, miner millets and sesamum are found to grow well with proper fertilizer application. The soil is also found suitable for cultivation of fruit trees like mango, jack fruit, banana, guava, and sapota.

4. CONCLUSION

It can be concluded from the above study that GPS and GIS based soil fertility maps help farmers, scientists, planners and students in providing online soil test based fertilizer recommendation for intensive and sustainable crop production. It's also found useful in site specific nutrient management and for thorough monitoring of the soil health for present and future agriculture. The soils of all blocks were acidic in soil reaction and hence there is a need to apply lime for reclamation. Application of 1 to 2 t ha^{-1} of papermill sludge is recommended to correct soil acidity and groundnut and pulses could be grown successfully in these acidic soils. Available nitrogen and available phosphorus content were low and available potassium content varied low to high and application of mixture of water soluble and insoluable phosphatic fertilizers would increase the crop yield. The available sulphur was found to be medium and hence application of phosphogypsum at 200 kg/ha is recommended to enhance the crop productivity. Hot water soluble boron content remained below the critical limits except in Kankadahad, Bhuban and Hindol blocks and hence soil application of boron is suggested to enhance legume yield. The other recommendations based on this study include cultivation of crops like rice, finger millet, miner millets and sesamum, potato and other vegetables and fruit trees like mango, jack fruit, banana, guava, and sapota with proper fertilizer application

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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