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Soil Resource Mapping and its Nutrient Status in Two Blocks of Koraput District, Odisha using GIS Technology

Kakoli Banerjee[1#], Rakesh Paul[1] & B. B. Dash[2]
[1]Department of Biodiversity and Conservation of Natural Resources Central University of Orissa, Landiguda, Koraput
[2]Regional Research and Technology Transfer Station (Coastal Zone) Orissa University of Agriculture and Technology, Bhubaneshwar, Odisha 751003

Abstract- **− In India about 25 Mha and in Odisha 0.75 Mha of land covering 11 districts are affected with iron toxicity and iron toxic plant contains deficient level of N, P, K, Ca & Mg. Black soils in Odisha occur in parts of Kalahandi, Bolangir, Koraput (Kalimela), Ganjam (Aska), Puri (Balugaon), Angul and Padmapur area covering 0.96 Mha, usually contain more than 30 per cent clay with cracks in summer and swells on wetting. The sandy and coarse loamy coastal soils have electrical conductivity 15-25 dS m^{-1} and are characterized by chlorides of Na, Mg, and Ca. The red, laterite and lateritic group soils in the state of Odisha constitute more than 75 per cent of the total land area. Various soil productivity constraints affecting the agricultural production in the state of Odisha includes low pH and low cation exchange capacity, low organic matter content and low available N & K status, deficiency of Ca, Mg & S as well as micro nutrients like Zn, B & Mo, inherent deficiencies and fixation of soluble P, toxicity of Fe, Al & Mn.**

With this background, a study was undertaken in two blocks of Koraput district for mapping the secondary and micro-nutrients in agriculture soils during 2012-2014. Surface soils (0 to 30 cm) was investigated for Ca, Mg along with diethylene-triamine pentaacetic acid (DTPA)-extractable Zn, Cu, Mn, Fe and hot water extractable S and B in relation to some chemical properties in approximately 280 representative soils. Secondary data of soil nutrients from 2012-2014 and the digital boundary map of Koraput district were collected from State Soil Testing Laboratory and National Information Center respectively. Then the soil nutrient data were linked with the sampling spots' Geo-coordinates in the GIS software. The analyzed soil nutrient data (mean variation in available Ca and Mg were 2.68- 3.14 and 1.14 - 1.38 ppm, respectively and that of DTPA-extractable Zn, Cu, Mn, Fe and hot water extractable S and B were 0.48 - 1.26, 1.14- 3.25, 18.17- 20.36, 37.77 - 48.77 and 16.21 - 25.55, 0.44 - 0.57 ppm, respectively. The GIS maps were generated in the CSV (Comma Separated Values) format and were incorporated into the Arc-GIS software to prepare the Interpolated maps by giving low to high range values to expresses the soil nutrient status in different colour exhibits. The soil fertility maps show that most of these nutrient elements are either in low or very low concentrations and at some places it is data deficient. This study thus ascertains the level of nutrient depletion and can find ways for management of such nutrients in this area.

Keywords: Agricultural soil; secondary nutrient; micro-nutrient; soil fertility maps

I. INTRODUCTION

The total land area of the world exceeds 13 billion-hectare but less than half of it can be used for agricultural activity including grazing. Potentially arable land constitutes 3031 million ha of which 2154 million ha are potentially cultivable in developing countries and 877 million ha are in developed countries. About 1461 million ha is cultivated of which 784 million ha & 677 million ha are in developing and developed countries respectively [1]. A new study has revealed that a majority of the soils in India are deficient in secondary nutrients and micronutrients vital for both plant and human health.

With the growing realization that agro-forestry is a practical, low cost alternatives for food production as well as environmental protection, forest departments of many countries are integrating agro-forestry programmes with conventional silvicultural practices [2]. Most agro-forestry systems constitute sustainable land use and help to improve soil in a number of ways. Some of these beneficial effects are evidenced in a number of experiments carried out in different parts of the world [3,4]. Through agro-forestry, many countries could not only minimize the land degradation but also increased the production [5,6,7]. It is a new area of study with a potential for assuring land sustainability. But we are lagging behind in this context.

The study – conducted by the Indian Institute of Soil Science (IISS), a key research body of the Indian Council of Agricultural Research – found that the soils of as many as 174 districts across 13 states were deficient in secondary nutrients like sulphur and micronutrients like zinc, boron, iron, manganese and copper. The chemical analysis of 70,759 soil samples collected from Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Odisha, Punjab, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal found zinc to be deficient by 39.9 per cent and sulphur by 27.8 per cent. The boron deficit was found to be 20 percent while iron, manganese and copper were deficient by 12.9, 6 and 4.3 percent, respectively [8]. The consistently low yield of almost all crops in states like Odisha, West Bengal, Gujarat and Bihar despite application of nitrogen, phosphorus, potassium and zinc has been attributed to the deficiency of boron. The removal of secondary nutrients and micronutrients was found to be the highest in the trans-Gangetic part of the Indo Gangetic plains, the food bowl of the country. Tamil Nadu recorded the maximum zinc deficit of 62.2 per cent while West Bengal was the lowest at 8.5 per cent
(*http://www.dailymail.co.uk/indiahome/indianews/article-*

2738639/Most-Indian-soils-deficient-crucial-nutrients.html#ixzz3CpWAIR65).

The conservative estimates showed that the demand for food grains would increase from 192 million tonnes in 2000 to 355 million tonnes in 2030. Contrary to increasing food demands, the factor productivity and rate of response of crops to applied fertilizers under intensive cropping systems are declining year after year. The current status of nutrient use efficiency is quite low in case of P (15-20%), N (30-50%), S (8-12%), Zn (2-5%), Fe (1-2%) and Cu (1-2%) due to deterioration in chemical, physical and biological health of the soils [9]. Continuous cropping leads to decline in organic C levels by 50-70% to equilibrium levels dictated by climate and precipitation. The major reasons identified for soil health deterioration are: wide nutrient gap between nutrient demand and supply, high nutrient turn over in soil-plant system coupled with low and imbalanced fertilizer use, emerging deficiencies of secondary and micronutrients in soils, soil acidity, nutrient leaching in sandy soils, nutrient fixation in red, laterite and clayey soils, impeded drainage in swell-shrink soils, soil salinization and sodification etc.

With the advent of Remote Sensing technology satellite data are being used for mapping, monitoring and assessment of various soil resources in given areas. Space- borne remotely sensed data being repetitive and multispectral in nature is an ideal choice for use in monitoring database management tool offering solutions for planning and problem analysis related to biodiversity. Remote Sensing and GIS techniques are becoming fast and effective tools for extracting information of complex and dynamic natures. Keeping all these things, on the basis of reviews, an effort has been made to highlight the nutrient status of Koraput district so that it may serve as a tool for further research, planning or development works.

II. MATERIALS AND METHODS

The present study is aimed at use of Remote Sensing and Geographical Information System (GIS) techniques for representation of nutrient status in soils of Koraput district of Odisha.

A. Site Selection

Two blocks namely Koraput and Semiliguda in Koraput district (Fig.1) have been selected for the study. Soil samples were collected from different locations in these blocks during post harvest season. The co-ordinates of the sampling points were collected through hand held Global Positioning System (GPS). In Koraput block 14 major panchayats comprising of 42 villages and in Semiliguda block 17 panchayats comprising of 84 villages were selected for the purpose. At the initial stage soil samples from the year marked villages were collected from points whose Geo Coordinates were noted by a GPS. These collected samples were processed, labelled and analysed in the Soil Testing Laboratory at Semiliguda during the year 2012-2014. The analysis was carried out following standard methods of analysis as prescribed and accepted by IARI (Indian Agricultural Research Institute). The various parameters such as available nutrients i.e.Calcium (Ca), Magnesium (Mg), Manganese (Mn), Sulphur (S), Copper (Cu), Zinc (Zn), Boron (B), Iron (Fe) have been carried out as per guidelines of IARI.

B. Analysis of soil samples

The DTPA (Diethylene triamine pentaacetic acid) extraction of the soil samples were carried out for extracting the available nutrient element estimation which are under reference. The standard graph was prepared by using standard solution of different nutrient elements and the observed data for the particular nutrient was found out from the standard graph. The soil samples (5gm) were first prepared with DTPA (100ml) which was then filtered and the filtrate was collected. The extractant (DTPA) can extract all available nutrient elements bound to the soil particles. The estimation in the extractant was done using Atomic Absorption Spectrophotometer based on the principle of emission spectroscopy.

C. Preparation of digital soil fertility map of Koraput and Semiliguda

The map showing the boundary of Semiliguda and Koraput blocks of Koraput district was obtained from National Information Centre (NIC). The map was scanned and taken into the Arc-GIS software. This map was then Geo referenced using Arc- GIS tools by taking reference points using a toposheet of 1:50,000 scale. The block boundary of the two blocks was digitized using on screen digitization method in GIS platform. The sampling locations collected through GPS were put in the map and a base map was prepared sharing the boundary of the blocks and sampling locations. The soil data for each locations were gathered in Excel format. Then the soil data were linked with the sampling points in GIS software. The analysed soil data in the excel format was converted to CSV format for incorporation in the Arc-GIS software. By right clicking over the Geo-referenced map a set of tables appear where these CSV data were inserted. The soil sampling points (from where samples were taken) then appear in small denotations inside the map. By clicking the individual points inside the map the characteristic properties in the CSV format were displayed. A base map displaying the location of soil samples were prepared first. Soil characteristics like available Calcium (Ca), available Magnesium (Mg), available Manganese (Mn), available Sulphur (S), available Copper (Cu), available Zinc (Zn), available Boron (B),available Iron (Fe) were expressed by giving low to high range values in different colour exhibits.

III. RESULTS AND DISCUSSION

Agriculture is the backbone of Indian economy contributing about 40% towards gross national production and providing livelihood to about 70% of the population. Therefore for a primary agrarian country like India accurate and timely information on biodiversity status can only help sustainable crop production to meet the demand for food. This can be achieved if the natural resources like soil and water are well managed. For the best management practices to be followed one have to visualize the existing condition as well as feasibility of improved management which can support to achieve the target. Soil nutrient is the most important factor which sustains the growth of all plant life on earth starting from the agricultural cops to forests (Table 1).

The present world population of 6 billion is expected to reach 8 billion by the year 2030. It is expected that most of the increase in population would occur in developing countries here. Nearly 1 billion people suffer from chronic malnutrition. Many developing countries face major challenges to achieve food, fibre, fodder, fuel, income, equity and social justice in a sustainable manner, considering available per capita land area, severe scarcity of fresh water resources and particular socio-economic conditions. Higher crop productivity, income, employment and environmental services will have to be achieved from the land that is already being farmed. The Indian population, which increased from 683 million in 1981 to 1210 million in 2010, is estimated to reach 1412 million in 2025 and to 1475 million in 2030. To feed the projected population of 1.48 billion by 2030 India need to produce 350 million tonnes of food grains [8]. The expanded food needs of future must be met through intensive agriculture without much expansion in the arable land. The per capita arable land decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.08 ha in 2025 and to 0.07 ha in 2030. So the current food-grains production of 218 mt (2009-10) is produced from the net arable land of 141 m ha. Soil and water management form the basis for sustainable system of productive agriculture.

This research work highlights the preparation of digital soil nutrient status map in two major blocks of Koraput district (namely Koraput and Semiliguda). The soils of these areas are mainly Red and Laterite having a high composition of Iron and Aluminium. The basic characters of these soils are well drained, low water holding capacity, highly acidic, very good fixation of phosphate nutrients. These soils were considered rich in plant nutrients during last two decades, but with advancement of technology and improved economic conditions of the local population, the heavy exploitation of natural resources of these soils has taken place within a very short period. This has reflected on sudden changes in the biodiversity. The major problem of low yield was expected due to depletion of micronutrients and trace elements such as Ca, Mg, Mn, S, Cu, Fe, Zn, B.

The Map for Calcium (Ca^{2+}) indicates the Calcium micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig.2). Each point in the map shows the Calcium status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Calcium (Ca^{2+}) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo-colours to show the variation in the status of Calcium (Ca^{2+}). The variation in the average amount of Calcium (Ca^{2+}) ranged from 2.676260 ppm to 3.137460 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Magnesium (Mg^{2+}) indicates the Magnesium (Mg^{2+}) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig. 2). Each point in the map shows the Magnesium (Mg^{2+}) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Magnesium (Mg^{2+}) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo colours to show the variation in the status of Magnesium (Mg^{2+}). The variation in the average amount of Magnesium (Mg^{2+}) ranged from 37.767300 ppm to 48.773200 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Copper (Cu) indicates the Copper micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig.3). Each point in the map shows the Copper (Cu) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Copper (Cu) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo colours to show the variation in the status of Copper (Cu). The variation in the average amount of Copper (Cu) ranged from 1.143280 ppm to 3.248240 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Iron indicates the Iron (Fe^{2+}) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig.3). Each point in the map shows the Iron (Fe^{2+}) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Iron (Fe^{2+}) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made with different pseudo colours to show the variation in the Iron (Fe^{2+}) status. The variation in the average amount of Iron (Fe^{2+}) ranged from 37.767300 ppm to 48.773200 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Manganese (Mn^{2+}) indicates the Manganese (Mn^{2+}) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig.3). Each point in the map shows the Manganese (Mn^{2+}) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Manganese (Mn^{2+}) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo colours to show the variation in the status of Manganese (Mn^{2+}). The variation in the average amount of Manganese (Mn^{2+}) ranged from 18.165000 ppm to 20.362800 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Sulphur (S) indicates the Sulphur (S) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig.3). Each point in the map shows the

Sulphur (S) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Sulphur (S) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo-colours to show the variation in the status of Sulphur (S). The variation in the average amount of Sulphur (S) ranged from 16.213900 ppm to 25.553600 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Zinc (Zn) indicates the Zinc (Zn) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig. 3). Each point in the map shows the Zinc (Zn) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Zinc (Zn) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo colours to show the variation in the status of Zinc (Zn). The variation in the average amount of Zinc (Zn) ranged from 0.483167 ppm to 1.256870 ppm which is shown in the legend of the map with different pseudo colour ranges.

The Map for Boron (B) indicates the Boron (B) micronutrient status in the Koraput and Semiliguda blocks of Koraput district (Fig. 3). Each point in the map shows the Boron(B) status of individual sampling sites under study representing the value in ppm (parts per million). The Interpolated map for Boron (B) expresses the soil characteristic which is prepared by interpolating the CSV data format to the map using spatial analysing tool. Five continuous intervals are made using different pseudo colours to show the variation in the status of Boron (B). The variation in the average amount of Boron (B) ranged from 0.438796 ppm to 0.571277 ppm which is shown in the legend of the map with different pseudo colour ranges.

Soil resource inventory gives an idea of its potentialities and limitations for effective exploitations. The soil maps are required on different scales to meet the requirement of planning at various scales. Soil degradation (loss of biodiversity) refers to a decline in the soil's natural ability for sustenance of vegetation through adverse changes in its physicochemical attributes [10]. Several soil characters have been mapped and monitored using IRS satellite data following both visual and digital techniques [11]. Precision agriculture also known as prescription farming which is a need of the hour, Variable Rate Technology (VRT) and Site Specific Agriculture (SSA) is considered as the agricultural system of the 21st century. Agro-biodiversity studies involve the integrated technologies such as GPS, GIS, VRT crop models and yield monitors. Accurately prepared digital soil maps depicting the biodiversity within the soil can translate results of soil properties i.e. secondary and micronutrient status to a spatial coverage for whole field.

From the data it is very clear that most of these nutrient elements are either in low or very low status and at some places it is beyond available state. Individual nutrient element analysis for each sample has been placed in the Arc-GIS software to plot a Interpolated map indicating it's available status in a low to high colour format. These maps can be well studied to ascertain the level of nutrient depletion and management of such nutrients in that area. This type of expression of natural resource characters definitely helps to study the effects of the changing soil characteristics on the biodiversity of the area.

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TABLE 1. IMPORTANCE OF SECONDARY AND MICRONUTRIENTS FOR PLANTS

Nutrients		Importance
Secondary Nutrients	Calcium(Ca^{2+})	· Utilized for Continuous cell division and formation · Involved in nitrogen metabolism ·Reduces plant respiration ·Aids translocation of photosynthesis from leaves to fruiting organs ·Increases fruit set ·Essential for nut development in peanuts ·Stimulates microbial activity in the soil
	Magnesium(Mg^{2+})	·Key element of chlorophyll production ·Improves utilization and mobility of phosphorus ·Activator and component of many plant enzymes ·Directly related to grass tetany ·Increases iron utilization in plants ·Influences earliness and uniformity of maturity
Micronutrients	Copper(Cu^{2+})	·Catalyzes several plant processes ·Major function in photosynthesis ·Major function in reproductive stages ·Indirect role in chlorophyll production ·Increases sugar content ·Intensifies colour ·Improves flavour of fruits and vegetables
	Iron(Fe^{2+})	·Promotes formation of chlorophyll ·Acts as an oxygen carrier ·Reactions involving cell division and growth
	Manganese(Mn^{2+})	·Functions as a part of certain enzyme systems ·Aids in chlorophyll synthesis ·Increases the availability of P and Ca
	Sulphur(S)	·Integral part of amino acids ·Helps develop enzymes and vitamins ·Promotes nodule formation on legumes ·Aids in seed production ·Necessary in chlorophyll formation (though it isn't one of the constituents)
	Zinc(Zn^{2+})	·Aids plant growth hormones and enzyme system ·Necessary for chlorophyll production ·Necessary for carbohydrate formation ·Necessary for starch formation ·Aids in seed formation
	Boron(B)	·Essential of germination of pollen grains and growth of pollen tubes ·Essential for seed and cell wall formation ·Promotes maturity ·Necessary for sugar translocation ·Affects nitrogen and carbohydrate

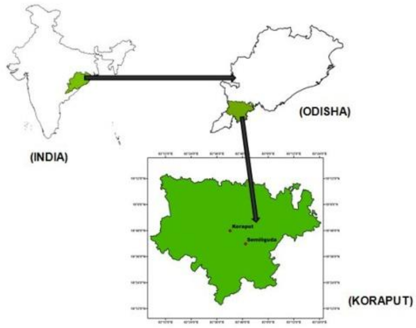

Fig 1. Map showing the sampling sites

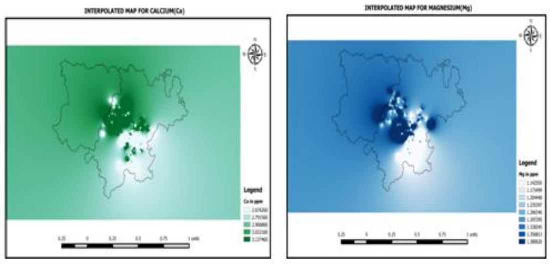

Fig. 2: Map showing secondary nutrients status in the sampling sites

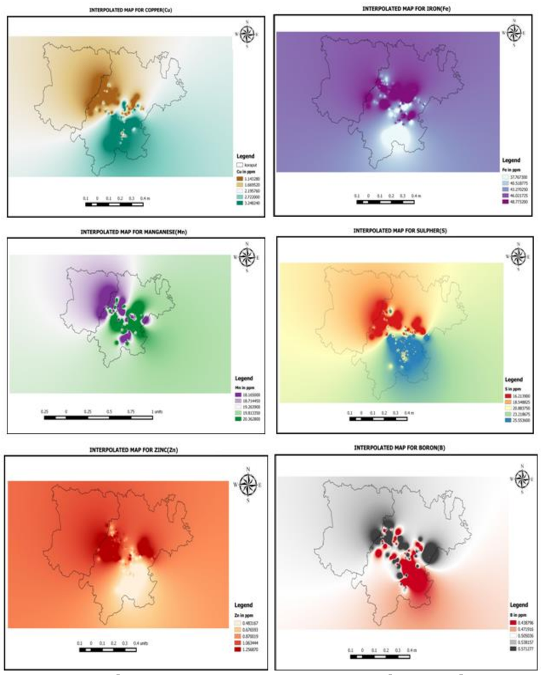

Fig. 3. Map showing micronutrient status in the sampling sites