Survey on Soil Fertility Mapping Using GIS And Remote Sensing

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Abstract- *Agriculture is the main occupation in India. To save water and to increase the yield of crops, efficient method of irrigation and agricultural management must be used as they requireaccurate and up-to-date information about different parametersof soil such as morphologic (size and shape of the watershed, drainage parameters, topography), soil fertility and their features, land use and land cover, etc. Remotely sensed data through satellite sensing technology and Geographic Information System (GIS) meets both these requirements and are ideal tools for mapping of such spatial informational needs. The present study focuses on the important parameters required for soil fertility mapping using the accuracy and ease of GIS technology with additional spatial data acquired through remote sensing. This paper also focuses on the methods of integrating such parameters to generate an index for determining the overall fertility of soil based on which composite thematic maps can be generated.*

Keywords- Soil Fertility, QGIS, Soil Nutrient, Remote Sensing, GIS.

I. INTRODUCTION

Agricultureis the largest source of livelihoods in India. 70 percent of its rural households still primarily depend on agriculture for their livelihood[9].The efficient growth of crops is primarily dependingon the soil fertility. Soil nutrients are the major factor for soil fertility which helps for the efficient plant growth. Soil nutrient has become a necessary resource to be upgrade further over the past years due to rapid growth in usage of chemical fertilizer and pesticide, disposal of waste product from domestic and industrial sector on land etc. Nowadays soil resource is facing damage due to lack of amount of soil nutrient present in the soil. Because of this problem of soil nutrient degradation, farmers are unable to produce required amount of crops in efficient way. Knowing fertility or nutrient statues of soils can be useful for farmers to manage their soil's fertility by applying some methods on soil and farmer can grow crop according to fertility of their soil which is suitable for particular fertility level[1]. Soil quality is equally important as that of crop production. Topographic maps, aerial photographs, remote sensing data provide useful tool for geomorphic analysis of region and help in the soil mapping. Therefore, on the basis of GPS-GIS system and Remote sensing, detailed soil fertility evaluation can be made to make the best use of soil for crop production [2,3]. GPS-GIS are advanced tool for studying on site specific nutrient management which can be efficient use for monitoring soil fertility status of a region, and it is useful for ensuring balanced fertilization to crop [2]. Geographic Information System (GIS) is a computer-based tool for mapping and analysing feature events on earth. GIS technology integrates common database operations, such as query and statistical analysis, with maps. GIS manages location-based information and provide tools for display and analysis of various statistics, including population characteristics, economic development opportunities, and vegetation types. GIS allows us to link databases and maps to create dynamic displays. Additionally, it provides tools to visualize, query, and overlay those databases in ways not possible with traditional spreadsheets. These abilities distinguish GIS from other information systems, and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. There are many types of GIS software, some are open source and some are licensed. Among all GIS software, most commonly used software are Arc GIS, QGIS, SAGA GIS, Grass GIS, GeoMedia, MapInfo etc. GPS is location system administrated by US military which helps to determine the exact position of an object on the earth surface in term of geographical coordinate [3].Remote sensing is the art and science of making measurements of the earth using sensors on airplanes or satellites. These sensors collect data in the form of images and provide specialized capabilities for manipulating, analysing, and visualizing those images. Remote sensed imagery is integrated within a GIS.

The fertility of soil playsimportant role in increasing crop production in the soil. It comprises not only in supply nutrient but also in their efficient management. For mapping of soil fertility, soil tested data generated by the soil testing laboratory will be helpful[2].

I.I. Soil Fertility

Soil fertility refers to the ability of a soil to sustain agricultural plant growth, i.e. to provide plant Nutrient and result in sustained and consistent yields of high quality crop. It is measured according to the amount of soil fertility measurement parameters present in the particular soil[7].

I.II.Major Parameters Needed to measure Fertility of Soil

Both chemical and physical properties of soil is needed for the analysis of soil fertility. Knowing soil fertility of land before growing crop is efficient for crop production. Soil fertility is the major factor for the plant growth. Different type of soil parameters is needed for the soil fertility analysis; they are

Soil pH:

Soil pH is a measure of the acidity and alkalinity in soils. pH levels range from 0 to 14, with 7 being neutral, below 7 acidic and above 7 alkaline. The optimal pH range for most plants is between 5.5 and 7.0 [8].

Nitrogen (N):

Nitrogen is a key element for the plant growth. It is found in all plant cells, in plant it is found in proteins and hormones, and in chlorophyll.Atmosphere nitrogen is used as source of soil nitrogen [8].

Phosphorus (P):

It is the factor of soil nutrient which helps for plant to growth and provide a mechanism. For providing a plant formation [8].

Potassium (K):

The potassium is the important soil fertility nutrient. It helps to transform the water into the plant. Potassium is an essential nutrient for plant growth. It is classified as a macronutrient because plants take up large quantities of potassium during their life cycle and growth [8].

Organic Compound (OC)

Soil organic matter comprises all living soil organisms and all the remains of previous living organisms in their various degrees of decomposition. The living organisms can be animals, plants or micro-organisms, and can range in size from small animals to single cell bacteria only a few microns long [8].

Soil Moisture:

Soil moisture is the important factor of soil fertility. The Water contained in soil is called soil moisture. The water is graspedwithin the soil pores. Soil water is the major component of the soil in relation to plant growth. If the moisture content of a soil is ideal for plant growth, plants can readily absorbsoil water. Not all the water grasp in soil, is available to plants. Much of water remains in the soil as a thin film [8].

Sulphur(S):

Sulfur also acts as a soil conditioner and helps reduce the sodium content of soils. Sulfur born in fertilizer assists in seed oil production, but the mineral can accumulate in sandy or overworked soil layers.

It is typically considered a secondary macronutrient (along with calcium and magnesium), but is essential for maximum crop yield and quality. Sulfur is often ranked immediately behind nitrogen, phosphorus, and potassium in terms of quantity taken up [8].

Zinc (Zn):

Most zinc in soils is held in unavailable forms, such as metallic oxides and other mineral complexes Plant-available zinc exists as the cation Zn in soil solution. Zinc concentration in soil is affected by the composition and weathering of the parent material, soil organic matter level, soil pH, and concentrations of other nutrients. Course-textured and highly weathered soils generally have lower concentrations of available zinc [8].

Iron(Fe):

Iron is the fourth most abundant element found in soil though it is largely present in forms that cannot be taken up by plants. Iron, in small amounts, is essential for healthy plant growth and is classed as a micronutrient. It is important for the development and function of chlorophyll and a range of enzymes and proteins [8].

Copper(Cu):

Copper (Cu) is one of eight essential plant micronutrients. Copper is required for many enzymatic activities in plants and for chlorophyll and seed production. Deficiency of copper can lead to increased susceptibility to diseases like fergot, which can cause significant yield loss in small grains. Most Minnesota soils supply adequate amounts of copper for crop production [8].

Manganese (MN):

Magnesium is an essential plant nutrient. It has a wide range of key roles in many plant functions. One of the magnesium's well-known roles is in the photosynthesis process, as it is a building block of the Chlorophyll, which makes leaves appear green.Magnesium deficiency might be a significant limiting factor in crop production [8].

Boron(B):

Boron (B) is a micronutrient that is essential for cell wall formation and rapid growing points within the plant, such as reproductive structures. Interestingly, while higher plants require B, animals, fungi and microorganisms do not need this nutrient [8].

Parker's Nutrient Index:

In order to compare the levels of soil fertility of one area with those of another it is necessary to obtain a single value for each nutrient. Here the nutrient index introduced by Parker et. al. 7 is useful. The percentage of samples in each of the three classes, low, medium and high is multiplied by 1,2 and 3 respectively. The sum of the figures thus obtained is divided by Total Number of Samples using following equation [9]:

$$\text{Nutrient Index} \Rightarrow \frac{\text{No. of Samples (Low)} \times 1 + \text{No of Samples (Medium)} \times 2 + \text{No. of Samples (High)}}{\text{Total Number of Samples}}$$

Soil Property	Unit	Range		
Soil pH	pH unit	<6.o(Acidic)	6.1-8.0(Neutral)	>8.0(Alkaline)
Electrical Conductivity	dS/m	<1.0(Normal)	1.0-2.0(Critical)	>2.0(Injurious)
Organic Carbon	%	<0.5(Low)	0.5-0.75(Medium)	>0.75(High)
Available Nitrogen(N)	kg/ha	<280(Low)	280-560(Medium)	>560(High)
Available Phosphorous(P2O5)	kg/ha	<10(Low)	10-25(Medium)	>25(High)
Available Potassium(K2O)	kg/ha	<110(Low)	110-280(Medium)	>280(High)
Available Sulphur(S)	ppm	<10(Low)	10-30(Medium)	>30(High)
Exchangeable Calcium(Ca)	meq/100g	<1.5(Low)	1.5-4.5(Medium)	>4.5(High)
Exchangeable Mg	meq/100g	<1.5(Low)	1.5-4.5(Medium)	>4.5(High)
Available Zinc(Zn)	ppm	<0.6(Low)	0.6-1.0(Medium)	>1.0(High)
Available Manganese (Mn)	ppm	<2.0(Low)	2-3(Medium)	>3.0(High)
Available Iron(Fe)	ppm	<0.2(Low)	0.2-0.6(Medium)	>0.6(High)
Available Copper(Cu)	ppm	<4.5(Low)	4.5-5.5(Medium)	>5.5(High)
Nutrient Index	Index	I	II	III

Table 1.1 : Rating Chart for Soil Test Values and their Nutrient Indices [9].

II. LITERATURE SURVEY

[1] Dhayalan, Muthu Selvam, Ramraj, "MAPPING AND ANALYSIS OF SOIL FERTILITY USING REMOTE SENSING AND GIS; A Case Study of Tharangambadi Taluk, Nagappatinam District", International Journal of Engineering Research and General Science, Volume 4, Issue 3, May-June, 2016.

In this paper, the soil fertility map was prepared to recommend the proper fertilizer according to soils for farmers. Soils are depleted and reached the critical level of deficient soil nutrients. So in order to solve this problem soils were sampled from 25 random locations. Samples were analyzed for macro nutrients and micro nutrients by using the standard procedures. Parker's (1951) method of calculating Nutrient Index (NI) values was used to indicate fertility status of soils for mapping. And lastly the digitized soil fertility map was prepared using ArcGIS software.

[2] Anjali Kalidas Kadam, "GPS-GIS BASED SOIL FERTILITY MAP OF COLLEGE OF AGRICULTURE

FARM, KARAD", International Journal of Engineering Research and General Science, 2015.

In this paper, study was carried out to know the fertility status of soils of College of Agriculture Farm, Karad. By using GPS-GIS technology and to correlate soil properties with the available nutrients and to evaluate the fertility index of College of Agriculture Farm, Karad. They found out the value of chemical and physical properties of soil of the district, they are soil ph. value, electrical conductivity, organic carbon content, calcium carbonate, available N, P, k, micronutrients, exchangeable cations, available Sulphur, boron, CEC, soil color from the surface soil sample (0-22.5cm depth) collected from cultivable area of college of Agriculture farm, Karad by use of standard survey technique. Soil fertility maps based on GPS-GIS reading and fertility status of soil of College of Agriculture Farm, Karad were prepared by employing Arc GIS 9.3 software and IDW (3D) method. The maps are presented in plates from plate 2 to plate 34. The Parker's nutrient index is used to compare soil conditions within a given region by categorizing the area into low, medium and high.

[3] Ammannawar Prashant Babasaheb, "GPS-GIS BASED SOIL FERTILITY MAPS OF PATHARDI TEHSIL, DIST-AHMEDNAGAR", department of soil science and agricultural chemistry, post graduate institute mahatma phule krishi vidhyapeeth rahuri-413 722 2015.

In this paper, the soil fertility maps for Pathardi Tehsil,Dist-Ahmednagar was prepared. One Hundred ninety-nine soil samples were collected to delineate the sufficiency and deficiency areas of macro and micronutrients. The soil samples were analyzed for pH, EC, OC, CaCO3, exchangeable Ca, Mg and available N, P, K, S, Fe, Mn, Zn, Cu, B and Mo. Six Tier Rating methods were used to categorize the samples of soil and Parker's Soil Fertility Index was used to indicate fertility status of soils for purpose of mapping. And lastly based on the Analytical and GPS data the soil fertility map was created using GIS technology.

[4] Nahak Truptimayee, Mishra Antaryami, Saren Subhashis and Pogula S., "GPS AND GIS BASED SOIL FERTILITY MAPS OF RANITAL KVK FARM AND IDENTIFICATION OF SOIL RELATED PRODUCTION CONSTRAINTS", International Journal of Agriculture Sciences, Department of Soil Science and Agricultural Chemistry, Orissa University of Agriculture and Technology, Bhubaneswar, 751003, Odisha, 2016.

In this paper, detailed soil fertility status of the Ranital Krishi Vigyan Kendra (KVK) farm was investigated during 2014-15 and soil related crop production constraints were identified for proper utilization of farm land. Total 58 numbers of geo-referenced (GPS based) composite surface soil samples (0-15cm) were collected from 6 blocks of KVK farm located at Ranital in Bhadrak district of Odisha, India. Soils were analyzed for mechanical composition, pH, EC, OC, available N, P, K, S and micronutrients like B, Fe, Mn, Cu, and Zn. Coordinate points were recorded by GPS instrument. Base map of the KVK farm was digitized and geo-referenced. Polygons were superimposed on the geo-referenced map. Latitude, longitude and the data resulted from the soil analysis were entered into attributed table and processed in ArcGIS software to produce thematic soil fertility maps.

[5] Djeneba Dembele, "INTEGRATION OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN SOIL FERTILIY MANAGEMENT IN MALI", Kwame Nkrumah University of Science and Technology (Knust), Kumasi, Ghana, School of Graduate Studies, Department of Crop and Soil Sciences, October 2015.

The main purpose of this study was to use remote sensing and GIS as decision support tool for appropriate soil fertility management practices, a key factor for improving soil fertility and increase sorghum and millet yields on smallholder farms in Mali. The integration of remote sensing, GIS and conventional georeferenced field sampling facilitated the assessment of spatial distribution for mapping of the baseline and dynamic changes in vegetation, soils and their physical and chemical properties, cropping systems and land use. These maps can be used to guide the development and implementation of integrated soil fertility management strategies for sustainable crop production in the Siguidolo area.

[6] Shruti Y, Praveen GS, Geetha GP, Sathish A, and Ramakrishna Parama VR, "ASSESSMENT OF SOIL NUTRIENTS AND RECOMMENDATION OF BALANCED FERTILIZERS FOR ENHANCING CROP PRODUCTIVITY USING REMOTE SENSING AND GIS",Journal of Pharmacognosy and Phytochemistry, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India, 2017.

In this paper they estimated the pH of the soils in this micro watershed ranged from strongly acidic to neutral where 44.7 per cent of area (217 ha) is moderately acidic followed by slightly acidic (31.41 %) and strongly acidic (19.13 %). Since major portion of watershed is acidic in nature, application of organic matter is recommended. In case of strongly acidic soils lime application is recommended. Organic carbon content and available phosphorus is low in 50 per cent and 29.6 per cent of the area whereas available potassium and sulphur are medium in range. The available zinc, iron and manganese are in sufficient range. The areas which are low in nutrient status (OC and P) needs to be improved by adding organic manures (FYM/Compost) and phosphate fertilizers preferably rock phosphate in acidic soils.

II.I. Comparison Table

Table 2.1: Comparison from Literature Survey

Title of the Paper	Techniques Used	Parameters used
MAPPING AND ANALYSIS OF SOIL FERTILITY USING REMOTE SENSING AND GIS; A Case Study of Tharangambadi Taluk.	GIS, remote sensing, GPS, Parker's Soil Nutrient Index (SNI).	PH,nitrate, phosphorus, potassium, iron, manganese, zinc, copper.
GPS-GIS BASED SOIL FERTILITY MAP OF COLLEGE OF AGRICULTURE FARM, KARAD.	GIS, GPS, Parker's fertility index.	PH, EC, $CaCO_3$,, OC, nitrogen, phosphorus, potassium, calcium, magnesium, boron, Sulphur, iron, manganese, copper, moisture, soil color.
GPS-GIS BASED SOIL FERTILITY MAPS OF PATHARDI TEHSIL, DIST-AHMEDNAGAR.	GIS and GPS, Parker's fertility index.	PH,N, P, K, S, Fe, Mn, Zn, Cu, B, MO, Ca and Mg, OC.
GPS AND GIS BASED SOIL FERTILITY MAPS OF RANITAL KVK FARM AND IDENTIFICATION OF SOIL RELATED PRODUCTION CONSTRAINTS.	GPS andGIS.	PH, EC, OC, N, P, K, B, Fe, Mn, Cu, Zn.
INTEGRATION OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN SOIL FERTILIY MANAGEMENT IN MALI.	GIS and remote sensing.	PH, N, P, K ,C, OC, soil texture.
ASSESSMENT OF SOIL NUTRIENTS AND RECOMMENDATION OF BALANCED FERTILIZERS FOR ENHANCING CROP PRODUCTIVITY USING REMOTE SENSING AND GIS.	GIS and remote sensing.	PH, organic carbon, nitrogen, phosphorus, potassium, iron, zinc, copper, magnesium, Sulphur, calcium, manganese.
COMMON PARAMETERS:		PH, nitrogen(N), phosphorus(P), potassium(K), calcium(Ca), magnesium(Mg), Sulphur(S), iron(Fe), manganese(Mn), copper(Cu), organic carbon(OC).

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