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Mapping of macronutrients status by geographic information system (GIS) under *Ceiba pentandra* plantation

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ABSTRACT

A study was conducted to assess available macronutrient status of soils of Theni district in Tamil Nadu under *Ceiba pentandra* plantation by geographic information system (GIS) technique. Soil samples were drawn from 106 surface (0-15 cm) and sub-surface (15-30 cm) kapok plantation and analysed for their fertility status and mapped by geographic information system (GIS) technique. The pH of surface soil was acidic to neutral and sub-surface was neutral to alkaline. Soil organic matter content was medium to high in surface and low to medium in sub-surface soil. Available nitrogen was very low to marginal in surface and very low in sub-surface soil; the status of phosphorus was high in both surface and sub-surface soil and available potassium was very high in surface and marginal in sub-surface soil.

Keywords: Geographic information system (GIS); global positioning system; nutrient mapping; soil fertility status

INTRODUCTION

Intensively cultivated soils are being depleted with available nutrients. Therefore assessment of soil fertility status needs to be carried out to increase the productivity of perennial tree species. Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are usually not useful for the site specific recommendations and subsequent monitoring. Soil available nutrient status of an area using global positioning system (GPS) helps in formulating site specific balanced fertilizer recommendation, other management strategies and also to understand the status of soil fertility spatially and temporally. Many mapping studies prevail in agriculture but mapping of fertility status under plantation is not available hence the proposed study was planned with the objective of identifying the soil fertility status under kapok plantation in Theni district of Tamil Nadu.

Optimal utilisation of soil resources is necessary to maintain sustained productivity of soils over a long period of time. Information on soil resources relating to their spatial extent, variability, availability and usage of nutrients is required for optimum utilisation. Development of technology like geographic information system is providing valuable support to handle voluminous data being generated through conventional and spatial format and for integration of these data sets (Rao 2007, Vadivelu 2007). The application of geospatial technology involving the use of global positioning system (GPS) and geographic information systems (GIS) has greatly improved the old traverse techniques and forest soil fertility studies using remote sensing and GIS techniques have been reported by many workers (Solanke et al 2005, Oza et al 2006, Bhagat 2009).

The scope of afforestation would extend beyond just planting of trees to planting of the right types of trees at the right places which would require soil fertility investigation to confirm the soil fertility status that would support the particular tree types (Moshki and Lamersdorf 2010). Soil fertility and management have been found essential to determine the type of forest trees to be planted as tree types influence soil properties (Ritter 2009, Sartori et al 2007).

MATERIAL and METHODS

The Theni district is located between north latitude 9º 30' and 10º 30' and east longitude 77º 00' and 78º 30' with an area of 2889 sqkm. The average rainfall of the district is 833.5 mm. Minimum temperature prevailing is 24°C and maximum temperature is 38°C. Sandy Loam, clayey and alluvial soils are the major textural soils found in the district. Theni district comprises of eight blocks namely Myladumparai, Bodinayakanur, Cumbum, Periyakulam, Theni, Andipatti, Chinnamanur and Uthamapalayam.

Total 106 samples were collected from surface (0-15 cm) and sub-surface soil (15-30 cm) randomly under kapok plantation in different villages in 8 blocks of the district. The global positioning system (GPS) data (Latitude ºN and Longitude ºE) were collected from each sampling site distributed throughout Theni district by using Garmin GPS (76CS model). Processed soil samples were analysed for available nutrients by following standard analytical techniques (Jackson 1973).

Soil analysis

The soil samples were air-dried and sieved through 2 mm sieve and analyzed for various soil parameters by adopting standard procedures as below:

Soil pH: For determination of soil pH, 20 g soil was taken in a 100 ml beaker and 50 ml of distilled water was added to it. The solution was stirred for 30 minutes and soil pH was measured using glass electrode digital pH meter (Jackson 1973).

Electrical conductivity (EC): For determination of EC the same soil suspension prepared for determination of pH was used. After recording the soil pH the suspension was allowed to settle in the beaker until a clear supernatant was obtained. The EC of the soil obtained from 0-15 and 15-30 cm was determined using electrical conductivity meter (Jackson 1973).

Organic carbon: Organic carbon in the soil samples was determined according to modified Walkley and Black method as described by Jackson (1967) and is detailed below:

One gram of soil sample was taken in 500 ml conical flask and10 ml of 1N $K_2Cr_2O_7$ solution was added to it using a pipette. The flask was swirled and 20 ml concentrated H_2SO_4 was added. The flask was left for 30 minutes for oxidation of soil organic carbon; the contents were diluted with 200 ml water; 10 ml of 85 per cent H_3PO_4, 0.2 g NaF powder and 30 drops of diphenylamine indicator were added to it. The non-reacted $K_2Cr_2O_7$ in the conical flask was titrated with 0.5N ferrous ammonium sulphate (FAS) solution. The colour was dull green in the beginning which turned to turbid blue as titration proceeded and finally became brilliant green at the end point. Blank titration was done in the same manner. Soil organic carbon (%) was then determined using following formula:

$$\text{Soil organic carbon (\%)} = \frac{\text{meq } K_2Cr_2O_7 - \text{meq of FAS} \times 0.39}{\text{Dry weight of soil (g)}}$$

Available soil nitrogen: Depth-wise available nitrogen content in soil was determined taking five gram soil by alkaline $KMnO_4$ method as described by Subbiah and Asija (1956).

Available phosphorus: Available phosphorus in soil samples was determined taking 2.5 g soil by Olsen's method (Olsen et al 1954) using 0.5N $NaHCO_3$ solution as an extractant and developing the blue colour using ascorbic acid as described by Murphy and Riley (1962). The intensity of blue colour was recorded by spectrophotometer at 882 sm. Available P content (ppm) was obtained from standard curve developed in the range of 0 to 0.4 ppm P solutions.

Available potassium: The available potassium in soil was determined taking five gram soil by extraction with neutral normal ammonium acetate solution and K concentration was determined by flame photometry method as described by Jackson (1973).

Fertility status of N, P, K and S is given in Table 1.

Theni district map (1:50,000) was vectorized by using Raster to Vector software (R2V) and then exported into Arc-GIS 9 software. In creating the attribute table the soil parameters which included the coordinates specifying the latitudes and longitudes of all the sampling point locations and the soil properties were entered as a table in Excel software and saved in a dBASE IV (DBF 4) format. The table was automatically linked to the digital map generated from the data and ArcView, statistical analysis run to calculate the minimum and maximum values to obtain the average values of soil properties for soil depth categories of 0 to 15 and 0 to 30 cm depth. The database was exported to Arc-GIS 9 software and the thematic maps on pH, organic carbon and macronutrient status were generated. The thematic maps at block level were generated for showing status of pH, organic carbon and macronutrients based on nutrient status range in the district. Different colours were used to depict the nutrient range.

RESULTS and DISCUSSION

The thematic map on soil pH clearly indicates that the surface soil showed neutral pH in all the blocks except Bodinayakanur (acidic pH) and it was neutral to alkaline in sub-surface soil. The alkalinity was found only in Periyakulam block .The pH of surface soil samples was acidic to neutral which ranged from 6.25 to 7.95 with a mean value of 7.42 and at sub-surface soil pH was neutral to alkaline which ranged from 6.80 to 8.18 with a mean value of 7.78. Bodinayakanur block recorded the lowest mean pH value of 6.53 (Table 2, Fig 1). Bodinayakanur is a hilly area having the altitude of 756 MSL where the soil is excessively drained and subjected to severe erosion and run off. The bases present in the soil would have been leached down to the lower soil layers which might have resulted in acidic pH of the soil. 88 per cent soil samples collected from eight blocks of Theni district recorded neutral pH. The pH increased with the increasing depth. Lower pH at surface soil under agroforestry systems than sole cropping might be due to substantial addition of organic matter to the surface soil under trees and release of organic acids during litter decomposition which was also reported by Prasadini and Sreemannarayana (2007) in an agri-silvicultural system. Liaghat and Balasundram (2010) has discussed the use of GIS in precision farming to produce a production based farming system that was designed to increase long term, site-specific and whole-farm production efficiency, productivity and profitability.

Soil organic matter content was medium to high in surface soil ranging from 0.51 to 0.88 per cent with a mean value of 0.70 per cent and low to medium in sub-surface soil ranging from 0.39 to 0.66 per cent with a mean value of 0.51 per cent (Table 2, Fig 2). The organic carbon

Table 1. Soil fertility rating for available nutrients

Nutrient	Fertility rating		
	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Nitrogen (kg/ha)	<280	280-450	>450
Phosphorus (kg/ha)	<11	11-22	>22
Potassium (kg/ha)	<118	118-280	>280

content decreased with increasing depth under kapok plantation. The soil organic carbon was higher in surface soil which might be due to addition of litter and loss of organic matter which was minimized from erosion as trees protect the soil. The soil enrichment with organic carbon under tree-based systems could be due to several factors such as addition of litter, recycling of annual fine root biomass and root exudates and reduced oxidation of organic matter under tree shades.

Perusal of the thematic map on available nitrogen status under kapok plantation clearly indicates that the available nitrogen content was under low and medium status in surface soil and low in sub-surface soil. The low status in surface soil might be due to continuous crop removal. Kapok being perennial tree crop absorbs soil available nitrogen for its biomass production. Available nitrogen (very low to marginal) in surface soil ranged from 210.0 to 346.8 kg/ha with a mean value of 247.7 kg/ha and in sub-surface soil (very low) ranged from 184.8 to 264.4 kg/ha with a mean value of 217.0 kg/ha (Table 2, Fig 3). The available nitrogen decreased with increasing depth under kapok plantation. In Tamil Nadu the soil available nitrogen status is low. However available nitrogen status was higher in the surface soil and lower in the sub-surface soil. This might be due to the addition of litter components and upon decomposition the organic matter would have improved the available nitrogen status in the surface soil under kapok plantation.

Thematic map with regard to phosphorus availability in different blocks of Theni district under kapok plantation clearly illustrates the high available phosphorus status in surface soil and medium and high category in sub-surface soil. This might be due to the fact that the pH of the soil was neutral in all the blocks and litter addition would have improved the phosphorus content of the soil. Available phosphorus (high) status in both surface soil ranged from 25.2 to 50.9 kg/ha with a mean value of 33.3 kg/ha and in sub-surface soil from 20.5 to 45.4 kg/ha with a mean value of 26.2 kg/ha (Table 2, Fig 4).

Table 2. Range and mean values of physico-chemical properties in surface (0-15 cm) and sub-surface (15-30 cm) soil layers in different blocks of Theni district under kapok plantation

Block	pH		Organic carbon (%)		Available nitrogen (kg/ha)		Available phosphorus (kg/ha)		Available potassium (kg/ha)	
	0-15 cm	15- 30 cm	0-15 cm	15- 30 cm	0-15 cm	15- 30 cm	0-15 cm	15- 30 cm	0-15 cm	15- 30 cm
Myladumparai	6.32-7.80 (7.27)	6.94-8.05 (7.65)	0.68-0.88 (0.78)	0.46-0.66 (0.56)	255.2-346.8 (302.2)	190.4-251.6 (220.0)	27.0-50.9 (36.6)	20.7-45.4 (30.5)	241.3-349.6 (310.0)	230.4-271.6 (250.0)
Bodinayakanur	6.25-6.80 (6.53)	6.80-7.10 (7.00)	0.64-0.79 (0.73)	0.51-0.66 (0.56)	291.2-327.6 (305.2)	234.8-264.4 (249.3)	30.7-45.4 (38.3)	24.5-36.2 (30.2)	282.4-329.8 (308.6)	228.9-259.2 (245.5)
Cumbum	7.15-7.94 (7.70)	7.76-8.18 (8.00)	0.62-0.74 (0.71)	0.42-0.52 (0.46)	254.8-308.0 (289.7)	198.8-244.4 (217.8)	27.2-37.8 (32.0)	20.5-32.5 (23.5)	291.7-319.2 (308.0)	221.4-268.0 (241.0)
Periyakulam	7.25-7.93 (7.69)	7.85-8.18 (8.04)	0.56-0-75 (0.64)	0.39-0.58 (0.49)	210.0-257.6 (231.5)	184.8-218.4 (202.9)	25.2-50.9 (33.0)	20.8-36.5 (24.9)	204.4-316.0 (272.9)	181.2-283.4 (226.7)
Theni	7.27-7.75 (7.49)	7.65-7.98 (7.85)	0.63-0.76 (0.72)	0.48-0.58 (0.52)	212.8-257.6 (237.6)	194.4-235.2 (208.9)	28.9-38.0 (32.0)	22.5-30.7 (25.4)	261.7-316.2 (296.5)	223.7-249.7 (235.5)
Andipatti	7.22-7.95 (7.59)	7.72-8.08 (7.95)	0.64-0.79 (0.71)	0.47-0.64 (0.54)	221.2-241.6 (229.7)	198.8-212.8 (203.7)	25.2-38.4 (32.5)	21.8-28.8 (25.2)	251.1-318.8 (293.0)	210.3-258.1 (228.6)
Chinnamanur	7.16-7.90 (7.61)	7.84-8.08 (7.97)	0.51-0.78 (0.65)	0.42-0.53 (0.49)	229.6-271.6 (246.1)	201.6-238.0 (217.2)	25.2-36.2 (29.4)	22.5-28.8 (25.2)	247.2-322.7 (297.0)	192.6-248.6 (225.4)
Uthamapalayam	7.22-7.88 (7.54)	7.60-7.98 (7.81)	0.65-0.76 (0.71)	0.48-0.56 (0.53)	218.4-263.2 (239.6)	201.6-224.0 (216.0)	28.8-37 (32.4)	21.5-29.7 (24.6)	284.8-330.1 (305.2)	221.6-261.4 (241.3)
District range	6.25-7.95	6.80-8.18	0.51-0.88	0.39-0.66	210.0-346.8	184.8-264.4	25.2-50.9	20.5-45.4	204.0-349.6	181.2-283.4
District average	7.42	7.78	0.70	0.51	247.7	217.0	33.3	26.2	298.9	236.8