The Pharma Innovation Journal 2023; 12(3): 1234-1238

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(3): 1234-1238

www.thepharmajournal.com
Received: 07-12-2022
Accepted: 18-01-2023

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Soil fertility mapping of arecanut growing areas in Sirsi Hobli of Uttara Kannada district, Karnataka

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Abstract
Sirsi taluk is having highest area in traditional arecanut growing belt but low productivity is a serious concern which may be due to sustained nutrient requirement and low nutrient use efficiency. So there is a need to assess soil fertility status of arecanut holdings. Geo- referenced 150 surface soil samples were collected from arecanut gardens of 42 villages of Sirsi hobli, Uttara Kannada district, and were analysed for soil chemical parameters. The fertility status revealed that the soils were slightly acidic to neutral in soil reaction, non-saline and high in organic carbon content. The macro nutrient availability showed low available N (100%), low to high available P (24%, 74% and 3%) and medium available K (99%) and sufficient in exchangeable Ca and Mg and medium to high in available S (56% and 94%). With regards to micronutrients, the soils were deficient in Zn (28%) and sufficient in all other micronutrients *viz*., available Fe, Cu and Mn. Using the all database creation, thematic maps for all the parameters were prepared using QGIS 3.8 software. By overlaying all the nutrient maps, management zone map/ constraint map was prepared, which indicated that the overall study area was poor in available N and deficient in available Zn.

Keywords: Arecanut, soil fertility assessment, sirsi taluk, Soil fertility maps

Introduction
Arecanut (*Areca catechu* L.), a member of the palmaceae family, is one of the most successful commercial plantation crops planted in India's humid tropics. India is both the world's top producer and user of arecanut. In India arecanut is grown on 0.734 mha with yield of 1.1 MT/ha (GOI, 2020). Karnataka, Kerala, and Assam account for about 85 percent of the arecanut-growing area. During 2018-19 Karnataka state alone contributed in terms of area 4, 64, 582 ha, production 6, 20, 348 tonnes with productivity of 1.34 tonnes per hectare (DOH, 2021) [4]. Among different districts in Karnataka, Uttara Kannada is leading in productivity of arecanut with 2.5 t/ha. Within Uttara Kannada district, Sirsi taluk has highest area (8592 ha) but productivity is 2.55 t/ha only. (DOH, 2021) [4]

Traditional arecanut growing soils are typically slightly acidic in nature, which may be attributed to parent material, drastic weathering under humid conditions, and significant precipitation, all of which favour the process of laterization. Though the arecanut can be cultivated in a number of soil types, largest area under the crop is found in gravelly laterite soils in Sirsi hobli (Ramachandra and Ganapathy, 2007) [13]. The arecanut is being grown on a variety of soils in different agro climatic zones of Karnataka. The areca cultivation also helps in enhancing carbon stocks both as a woody crop biomass on surface and as humus in soils (Nagaraja *et al.*, 2018) [9]. The areca yield varies with their fertility status and management practices. One of the most important factors influencing crop productivity is soil fertility (Raj *et al.*, 2012) [12]. The capacity of soil for sustainable production also depends on its fertility status. The overall crop growth and development are influenced not just by total nutrients present, but also by the availability of nutrients to growing crop plants (Shreekanth *et al.*, 2018) [15]. So there is a need for systematic and periodic assessment for nutrient deficiencies and sufficiency for major, secondary as well as micronutrients. So the soil test data is the most accurate information on the availability of plants nutrients and to adjust the fertilizer recommendations to various crops. In this regard, a modern tool such as global positioning system will help to understand the status of soil fertility spatially. Geographic Information System (GIS) is a powerful tool which helps to integrate many type of spatial information such as agro-climatic zone, topography, land use, soil management, etc. to derive useful information (Adornado and Yoshida, 2008) [1].

Furthermore, GIS generated maps serve as a decision support tool for nutrient management (Iftikar *et al.* 2010) [1]. A number studies on soil fertility mapping have been documented (Ravikumar *et al.*, 2010) [14] but no study was made to map the soil fertility status of arecanut growing of Sirsi hobli for macro and micronutrients.

Even though, Sirsi taluk is having highest area in traditional arecanut growing belt but low productivity is a serious concern which may be due to sustained nutrient requirement and low nutrient use efficiency. So there is need to assess the soil fertility and organic carbon status which is used to measure organic matter content, nutrient distribution and health of the soil in arecanut growing areas. Uttara Kannada district is having undulating terrain with high elevation and soil fertility attributes are known to be affected by different geomorphological parameters like slope, aspect and elevation.

Material and Methods

Location of the study area

Sirsi hobli is located on Western Ghats hilly region of Uttara Kannada district. It has a geographical extent of 160.61 sq.km in which 60 percent is occupied by forest land (Ramachandra and Ganapathy, 2007) [13]. Sirsi hobli lies between 14º 62 º N latitudes and 74. 85º E longitudes and with an elevation of 579 m above mean sea level.

Climate: The climate in Sirsi is tropical climate strongly influenced by the south-west monsoon. The average temperature in the study area is 28-32 °C and average rainfall is 2450 mm.

Topography: Topographic parameters like slope, elevation and aspects were derived from 90m resolution Digital Elevation Model (DEM) of Shuttle Radar Topographic Mapper (SRTM) downloaded from USGS website

Vegetation: Majority of Sirsi taluk is covered with green vegetation, major part of vegetation is Western Ghats dense forest which covers about 60 percent.

Soil type: The soils of district are derived from ancient metamorphic rocks which are rich in iron and manganese (Pascal, 1988). The soils of the district are alluvial type in coastal and lateritic and granite soils in upghat areas (Ramachandra and Ganapathy, 2007) [13]. The lateritic soils are highly leached, reddish brown in colour, shallow to medium in depth and loamy in texture. Red sandy loams are poor in water holding capacity, and are therefore well drained, and acidic.

Collection of samples

A total of 150 surface soil samples were collected from 42 villages at depth of 0-30 cm and assigned unique sample number. Geographical location of each plantation recorded using hand held GPS and basic information about the holdings like, age of plantation, variety, spacing, nutrient management practices and average dry nut yield obtained in q/ha.

Analysis of samples

The collected soil samples were air- dried and sieved through 2 mm sieve (0.2 mm sieve for organic carbon) and analysed for soil chemical parameters *viz*., pH and EC (Jackson 1973) [6], organic carbon (Walkley and Black, 1934) [18], available N (Subbiah and Asija, 1956) [16], available P, K and exchangeable Ca and Mg (Jackson 1973) [6], available S and DTPA- Zn, Fe, Cu, and Mn (Lindsay and Norvell, 1978) [8].

The analytical results of each soil sample was categorised as low, medium and high for organic carbon (OC) and major nutrients while for exchangeable Ca and Mg and micronutrients as deficient and sufficient based on the critical limits.

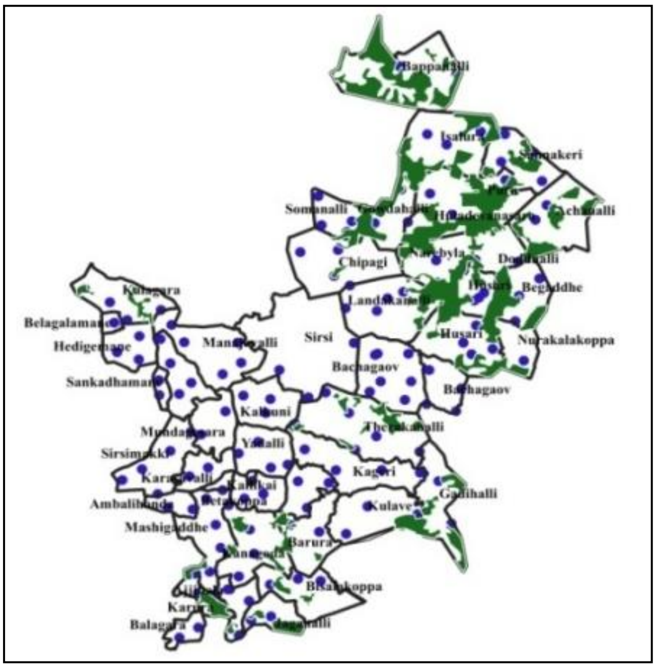

Fig 1: Distribution of soil samples masked with forest area.

Generation of thematic soil fertility maps

Database on soil available nutrient status was generated in Microsoft by using QGIS software version 8.3. The point data was interpolated using ordinary krigging interpolation technique to prepare continuous map for different parameters using Smart Map plugin in QGIS. Semivariogram parameters like sill, nugget and range were derived by adjusting maximum distance and lags and then used models like linear, spherical, exponential or Gaussian to interpolate. Model which gave better R^2 value and least RMSE was chosen for interpolation. Interpolated map was grouped into different categories based on standard nutrient ranges. By overlaying all the nutrient maps, management map was prepared.

Result and discussion

Soil pH

The soil pH of the study area ranged from 5.68 to 6.83 (slightly acidic to neutral). Soil pH of all 150 samples were found to be slightly acidic category (Fig 2a) with pH of 113 samples between 5.5 to 6.5 and 37 samples were > 6.5 pH (Table 1). It may be due to influence of acidic parent material and climatic factor like heavy rainfall (Anthanarayana and Perur, 1973 and Rao, 1992) [2] and undulating terrain coupled with heavy rainfall leads to more runoff and leaching of bases from surface soil causes acidic nature of soil. (Vasundhara *et al.* 2021) [17].

Soil EC

The EC of the soil samples ranged from 0.02 to 0.21 dSm^{-1}

and it is non-saline in nature (Fig 2b). Among all the 150 samples, EC of 145 samples were <0.2 and 5 samples were between 0.2-0.4 dSm^{-1} (Table 1). Because of this heavy rainfall, all the basic cations like Na^+ leached out from soil and there will be no accumulation of salts in soil profile resulting in low EC

Organic carbon

Organic Carbon content of study area ranged from 0.51 to 3.39 percent (medium to high) (Fig 2c). Among all the 150 samples, 9 samples were in medium range (0.50-0.75% OC), 141 samples were in high category (>0.75% OC) (Table 1). This is because of regular addition of organic matter and its rate of decomposition and also less cultural operations.

Available Nitrogen

The available nitrogen content of the soils of Sirsi area ranged from 55.15 to 114.35 kg ha^{-1} (low) (Fig 2d). All the 150 samples were in low category (Table 1). This may be because of leaching of nitrate nitrogen due to heavy rainfall coupled with undulating terrain causes leaching loss of availability of nitrogen, low mineralization, crop uptake and loss of applied fertilizers. The nitrogen removal by arecanut crop is 236kg per hectare by the plant (Bhat and Sujatha, 2012) [3].

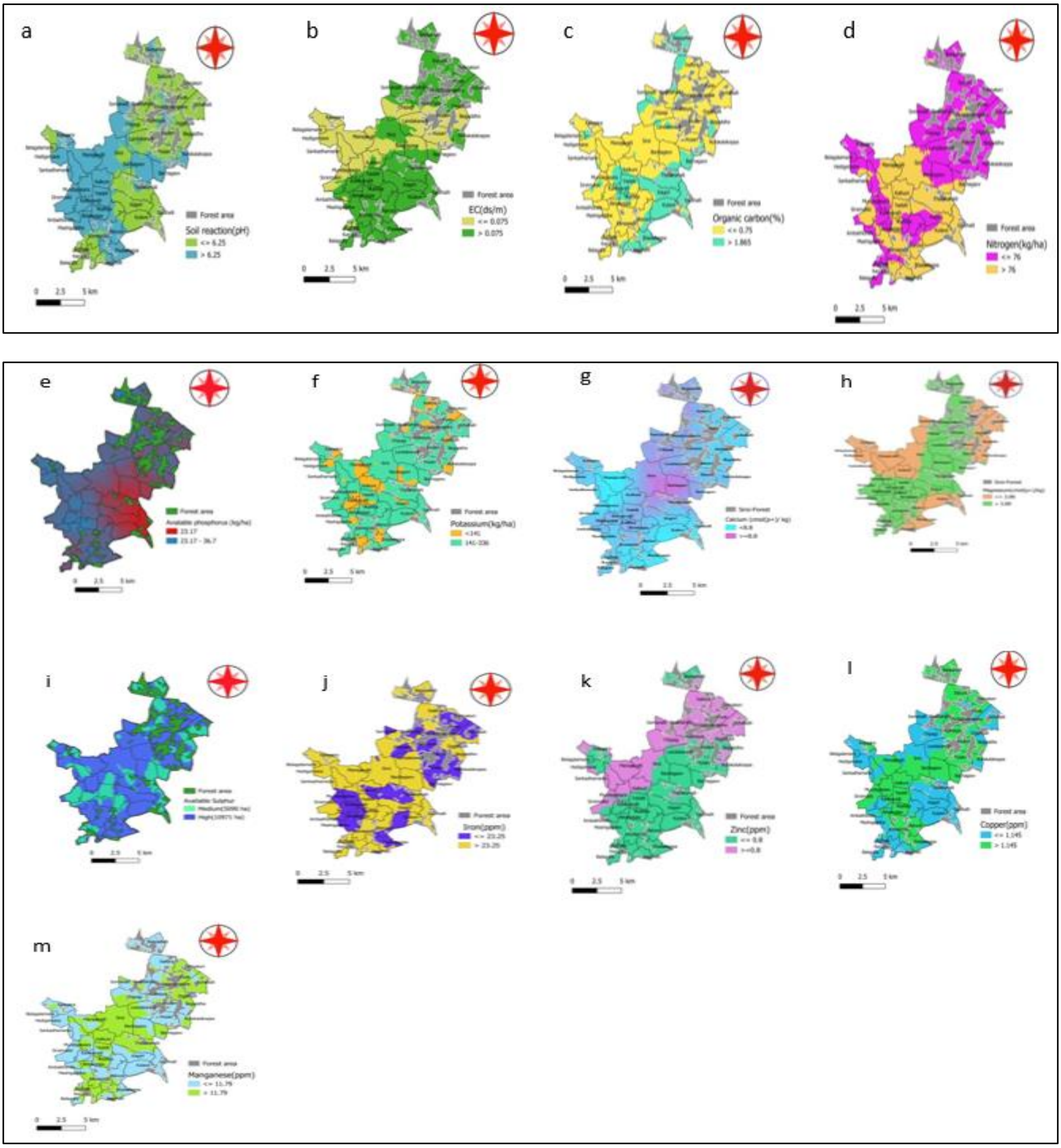

Fig 2: Soil fertility maps for soil parameters

Table 1: Number of samples under different soil parameter category

Nutrient category	Low	Medium	High
pH (1:2.5)	150 (100%)	0.0	0.0
EC (dSm^{-1})	150 (100%)	0.0	0.0
OC (%)	0.0	9(6.00%)	141 (94.00%)
N ($kg\ ha^{-1}$)	150 (100%)	0.0	0.0
P_2O_5 ($kg\ ha^{-1}$)	36 (24.00%)	111 (74.00%)	3 (2.00%)
K_2O ($kg\ ha^{-1}$)	1 (0.67%)	149 (99.4%)	0.0
S (ppm)	0.0	56 (37.4%)	94 (64.6%)
Ca (c mol (p^+) kg^{-1})	0	0	150 (100%)
Mg (c mol (p^+) kg^{-1})	0	0	150 (100%)
Zn (ppm)	41 (27.4%)	0.0	109 (72.6%)
Fe (ppm)	0.0	0.0	150 (100%)
Cu (ppm)	0.0	0.0	150 (100%)
Mn (ppm)	0.0	0.0	150 (100%)

Available phosphorus

The available phosphorus in study area ranged from 10.74 to 59.12 kg ha^{-1} (low to high) (Fig 2e). Among 150 samples, 36 samples are in low range (< 22.5 kg ha^{-1}) and 73% of the samples (111) were in medium (>22.5-56.0 kg ha^{-1}) and remaining 3 of the samples were showed high (Table 1). These variations in phosphorus in arecanut gardens due to phosphorus supply through various external sources. (Kumar *et al*, 2017a) [1].

Available potassium

The available potassium content in the study area ranged from 113.01 to 271.71 kg ha^{-1}(low to medium) (Fig 2f). Among 150 samples, 1 sample was in low range (<141 kg ha^{-1}) and 149 samples were medium (141-336 kg ha^{-1}) in potassium content ((Table 1). This may be because regularly adding K fertilizers, and organic manures like FYM and vermicompost and also domination of 1:1 type Kaolinite clay mineral, which is having low K fixation. Arecanut is the heavy feeder of potassium (90kg/ha) (Bhat and Sujatha, 2012) [3].

Exchangeable Ca and Mg

The exchangeable calcium content in soils of Sirsi hobli area ranged from 4.9 to 12 cmol (p^+) kg^{-1} (Fig 2g). The exchangeable magnesium ranged from 2.0 to 5.8 cmol (p^+) kg^{-1}. (Fig 1h) All the 150 samples of Ca and Mg was sufficient in range (Table 1). This may be because of regular application of lime (CaCO3), dolomite Ca Mg $(CO3)_2$ to soil (Prabhudev *et al.*, 2017) [11].

Available Sulphur

The available sulphur content in the soils ranged from 10.85 to 34.28 ppm (Fig 2i). Among the soil sample collected, 56 samples fall under medium range (10-20 ppm) and 94 samples were in high category (>20 ppm) (Table 1). It might be attributed to addition of sulphur containing fertilizers, organic matter content and soil pH (Reddy 2012) [1].

Available Micronutrients

The available micronutrients namely Fe (10.48 to 36.90 ppm), Mn (2.60 to 21.22 ppm) and Cu (0.20 to 2.18) were found above the critical limits except Zn (0.20 to 2.0 ppm) (Fig 2j, k, l, m) (Table 1). This may be attributed to higher solubility of these micronutrients under slightly acidic condition and it also due to higher organic matter status which helps to retain micronutrients through chelation. All the 150 samples were sufficiency range in available Fe, Cu and Mn. Available zinc was found to be deficient. Among 150 samples, twenty seven percent (41) of the samples showed deficiency in available zinc. This may be due to high pH as well as high annual rainfall received in this region causes leaching losses of available zinc (Jyothi *et al*. 2010) [7].

Management zone / constraint area

Management zone map/ constraint map depicted in Fig 3. Among all the 5 zones, available N was low (71.47 kg/ha) in the entire Sirsi hobli region. To overcome N deficiency of the arecanut soil, application of inorganic nitrogen fertilizers and coated fertilizer like neem-coated urea, sulphur- coated urea can be add to reduce the losses after applied to the field and addition of organic manures can also be done to increase the available nitrogen. Though the soils are acidic, among the micronutrients, zinc was found to be deficient in some areas of Sirsi hobli. It might be due to the heavy rainfall which causes leaching losses of nutrients and also management factors less usage of micronutrient fertilizers. Zinc sulphate can be added on need basis to correct the zinc deficiency of the arecanut soil.

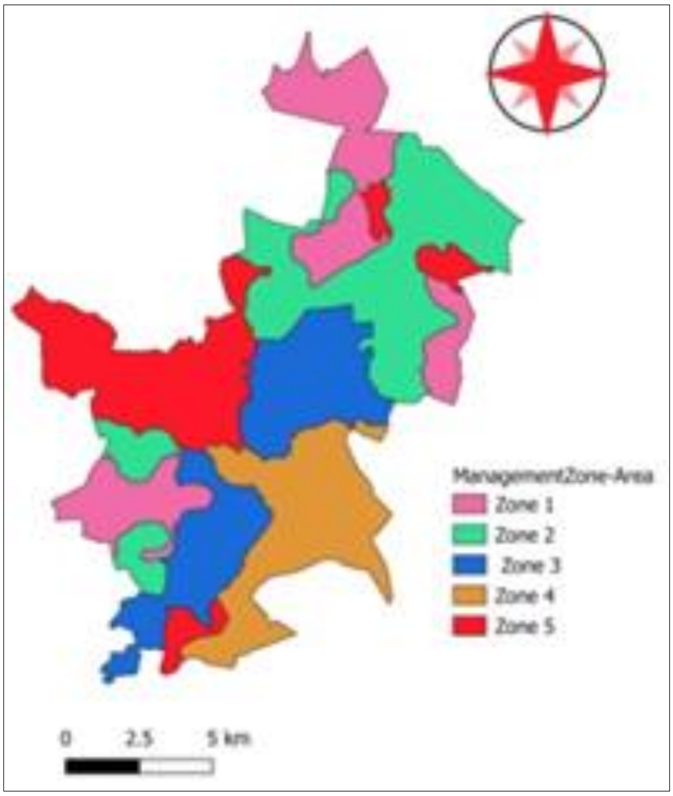

Fig 3: Management zone / constraint area map

Conclusion

It was observed from present study that, majority of the soils in study area exhibited slightly acidic with non- saline nature and high in organic carbon content. With respect to fertility status soil were poor in available N, low to medium in available phosphorus and potassium. The arecanut soils of Sirsi hobli had sufficient exchangeable calcium and magnesium. Similarly, available sulphur of study area was medium to high status. Micronutrients like Fe, Mn and Cu were found to be sufficient except Zn. Soil organic carbon stock ranged from 20.23-190.34 tones/ha.

Major nutrients like available N was found to be deficient and exchangeable Ca and Mg showed more than sufficiency range in all the five delineated management zones. With respect to micronutrients, Zn was found to be deficient. All the other nutrients were found medium to high status in arecanut soils of Sirsi hobli.

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