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RESEARCH ARTICLE

# Spatial variability map for soil fertility of Sugarcane Research Station Farm, Cuddalore, Tamil Nadu using GIS techniques

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## Abstract

A study was conducted during 2023-2024, total of 144 surface soil samples were collected from the Sugarcane Research Station in Cuddalore, Tamil Nadu. GPS coordinates (Latitude °N and Longitude °E) were recorded for each sampling site using a Garmin eTrex Vista HCX GPS. Field maps were created and digitized according to the sampling locations. Soil samples were processed and analyzed for physicochemical properties and fertility parameters. The results showed that the soils were neutral to slightly alkaline and non-saline. Soil fertility groupings revealed low to medium organic carbon, low to medium available nitrogen, medium available phosphorus, medium to high available potassium and medium to high available sulphur. Over 80 % of the soil samples had sufficient levels of Cu, Fe and Mn, based on DTPA extractable micronutrients. However, 58 % of the soil was below the critical level for Zn, while 42 % had sufficient Zn. Nutrient index values indicated low status for organic carbon, available nitrogen and Zn, medium for available phosphorus and adequate levels for available sulphur. For micronutrients, DTPA-Mn was adequate, DTPA-Cu and Fe were high and DTPA-Zn was marginal. Thematic maps showed spatial variability across the station. To sustain soil fertility, deficiencies in areas with poor fertility should be addressed using organic or inorganic amendments. Following soil test-based fertilizer and micronutrient recommendations is essential for improving nutrient availability and maintaining soil health for sustainable crop production.

**Keywords:** Geographic Information System (GIS); nutrient status; spatial variability; thematic maps

## Introduction

The dynamic natural body known as soil is created by pedogenic natural processes that occur both during and after the weathering of rocks. It is made up of both organic and mineral components, processing certain chemical, physical, mineralogical and biological qualities with varying depths over the earth's surface and acting as a growing medium for plants (1). Soil is a heterogeneous, diversified and dynamic system whose properties are constantly changing across time and location (2). The variability of soil, a natural resource, arises from the interactions between soil formation components in the landscape. However, land use, erosion and farming can also lead to variations. The effects of land degradation brought on by erosion on the geographical variability of soil characteristics. It is well recognized that there is spatial variability in soil properties and that this variability must always be considered when doing field sampling. It is also crucial to investigate the temporal and spatial changes in these values documented (3).

The characteristics of soil differ in geography from a field to a larger region and are influenced by both extrinsic (such as crop rotation, fertility status and soil management techniques) and soil forming (also known as intense) variables (4). The variance may also be the consequence of a slow alteration in the properties of the soil brought on by landforms, geomorphic features, soil-forming processes and soil management techniques (5). It is important to monitor and quantify the variations in properties of soil in order to comprehend how land use and management practices affect soil quality.

Since soil serves as a medium for plant growth, a thorough understanding of soil is necessary for planning, monitoring and developing strategies that aim for optimal returns generated through the utilization of land, water, fertilizer and other resources. Soil and climate are the main natural elements that cause regional differences in soil fertility and crop productivity (6). The maintenance of nutrient and moisture availability must be closely monitored in order to support crop productivity and soil health over the long term.

The fertility and productivity of the soil are at danger when soil fertility continues to diminish. Every year, the loss of fertile soil and nutrients occur due to cropping pattern, leaching, erosion and other factors. Crop yields will decrease if cropping patterns are maintained without replenishing the nutrients in the soil, as this will lower the fertility of the soil. The nutritional status of soils is determined by soil testing, which also serves as a basis for the fertilizer recommendation to maximize crop productivity.

Advancements in pedometrics and digital soil mapping (DSM) have led to a major transformation in soil fertility evaluation in the 21st century (7). Cutting edge tools such as the Geographic Information System (GIS) and GPS facilitate the collection of georeferenced soil samples and the preparation of maps of nutrient variability (8). Also used for delineation of less soil fertility areas and targeted management strategies (9, 10). Combining GPS and GIS allows for the mapping of soil fertility. These methods assist in decision-making for better farming practices that lead to a balanced nutrition. GIS have proven a greater useful tool for managing databases and spatial analysis of natural resources. It is a highly effective and versatile method for automating the conversion of soil data into soil information (11). The objective of the current study is to assess the soil fertility status and its spatial variability at the Sugarcane Research Station, Cuddalore, Tamil Nadu. In order to enhance agricultural productivity and profitability without depleting natural resources, a thorough evaluation of the potential and constraints of farm soils is essential.

## Material and Methods

### Collection of soil samples

A total of 144 surface (0-20) soil samples were collected from the field of Sugarcane Research Station, Cuddalore, Tamil Nadu (Fig. 1). The geo-coordinates (Latitude °N and Longitude ° E) were recorded for each sampling site using GPS and the sample design was grid.

### Soil analysis

**a. Soil reaction and electrical conductivity:** The pH of soil was measured in water (1:2.5) after half an hour equilibration with a glass electrode pH meter. The electrical conductivity (EC) of the supernatant suspension was measured using a conductivity bridge (12).

**b. Soil organic carbon:** Soil organic carbon (SOC) was estimated by chromic acid wet digestion method (13). Weighing 0.5 g of soil was taken in a 500 mL conical flask and added 10 mL of 1 N $K_2Cr_2O_7$ and 20 mL of conc. $H_2SO_4$. Then allowed to stand for 30 minutes. Then 200 mL of distilled water, 10 mL of orthophosphoric acid and 1 mL of diphenylamine indicator were added. This was titrated against 0.5 N ferrous ammonium sulphate (Fe $(NH_4)_2$ $(SO_4)\cdot 6H_2O$) towards the end point of a bright green color.

**c. Available nitrogen:** The alkaline permanganate method (14) was used to determine the soil available N. In a distillation flask, 20 g of soil and 100 mL of 0.32 % $KMnO_4$ and 100 mL of 2.5 % NaOH was added. Twenty millilitres of 2 % boric acid with a drop of double indicator was taken in a beaker and kept near the delivery end. The distillation was carried out and the liberated $NH_3$ was collected and titrated against 0.02 N sulphuric acid. From the titre value, the soil available nitrogen was calculated.

**d. Available phosphorus:** Olsen's extractant method (15) was used to determine the available phosphorus content in the soil. Five gram of soil was added in 100 mL in a shaking bottle. To that, 50 mL of 0.5 M $NaHCO_3$ adjusted to pH 8.5 and a pinch of activated carbon (Dargo G 60) were added to the soil and shaken for 30 min. After shaking, the extract was filtered through Whatman No. 40 filter paper. Pipetted out 5 mL of the filtrate into a 25 mL volumetric flask and added 4 mL of reagent B and volume made up to 25 mL using distilled water. Kept it for half an hour for development of colour. Read the absorbance at 660 nm in a UV spectrophotometer and the available P content was calculated using a standard curve.

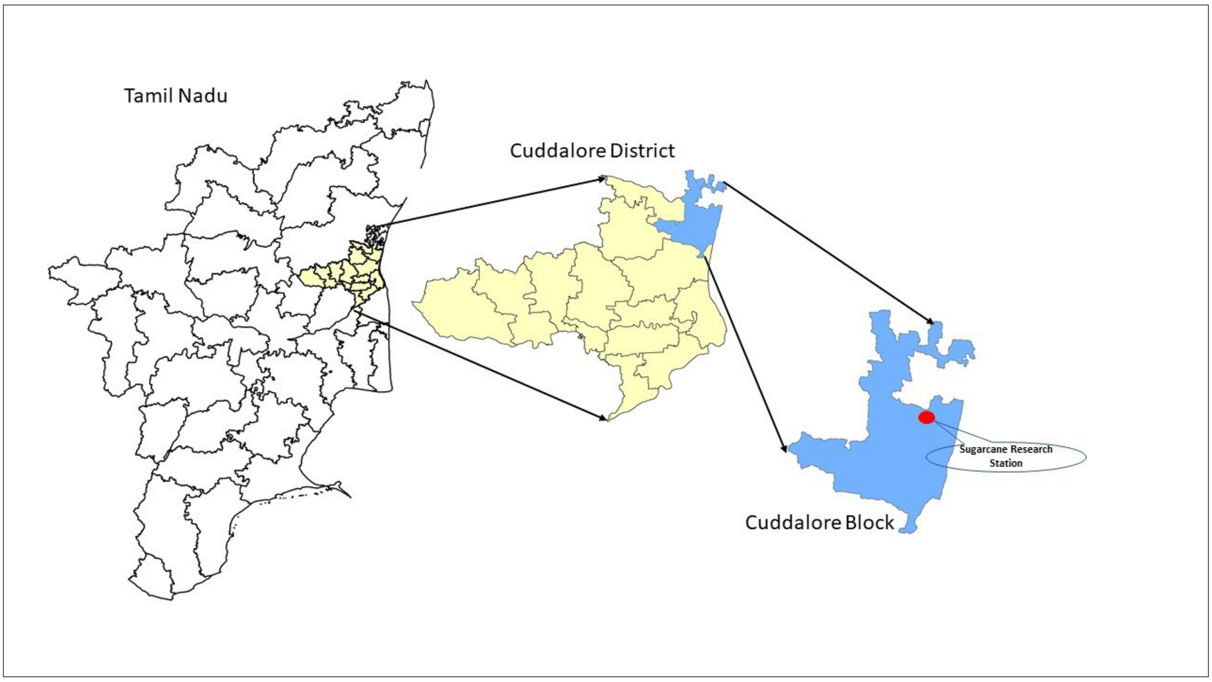


**Fig. 1.** Study area map.

**e. Available Potassium:** The neutral normal $CH_3COOHNH_4$ method (16) was used to estimate the available K content of the soil. Taken 5 g of the soil in a 100 mL shaking bottle and added 25 mL of 1 N $CH_3COOHNH_4$. Then shaken for 5 min and then filtered. Using a flame photometer, the K content was determined from the extract.

**f. Available sulphur:** Available sulphur was extracted using 0.15 % $CaCl_2$ (17). The sulphur content in the extracts was determined by turbidimetric method.

**h. DTPA extractable micronutrients:** The DTPA extract (0.005 M Diethylene Triamine Penta Acetic Acid + 0.1 M Triethanolamine + 0.01 M $CaC1_2$) method was used for estimating micronutrients, *viz.*, iron, zinc, copper and manganese. The extract was adjusted to pH 7.3 using diluted HCl. Ten grams of soil were taken into a 100 mL shaking bottle and added to 20 mL of DTPA extract. After shaking for 2 hr, it was filtered through Whatman No. 42 filter paper. The available micronutrients were estimated using an atomic absorption spectrometer (18).

After analyzing the available macro and micronutrients of the soil, the results of each soil sample were categorized as low, medium and high for organic carbon (OC) and macronutrients; as deficient, moderate and sufficient based on the critical limits for available micronutrients as followed in Tamil Nadu (Tables 1 and 2).

The following formulas were used to calculate the Nutrient Index Values (NIV) and percent sample category based on the number of samples in each category.

## Percent sample category

$$\text{Percent sample category} = \frac{\text{No. of samples in low or medium or high category}}{\text{Total No. of samples}} \times 100$$

**Table 1.** Critical levels of major nutrients

| Nutrient | Low | Medium | High |
|---|---|---|---|
| O.C. (g $kg^{-1}$) | <5.0 | 5.0-7.5 | >7.5 |
| N (kg $ha^{-1}$) | <280 | 280-450 | >450 |
| P (kg $ha^{-1}$) | <11 | 11-22 | >22 |
| K (kg $ha^{-1}$) | <118 | 118-280 | >280 |
| S (mg $kg^{-1}$) | <10 | 10-15 | >15 |

**Table 2.** Critical levels of micro nutrients

| Micro nutrient | Critical level (mg $kg^{-1}$) | Sufficient level (mg $kg^{-1}$) |
|---|---|---|
| Fe (Non calcareous soil) | 3.7 | 3.71-24.0 |
| Fe (Calcareous soil) | 6.3 | 6.31-24.0 |
| Mn | 2.0 | 2.01-12.0 |
| Zn | 1.2 | 1.21-5.0 |
| Cu | 1.2 | 1.21-5.0 |
| B | 0.5 | 0.51-2 |

## Nutrient index values and fertility rating

The percentage of soils in the low, medium and high available nutrient categories was used for calculating the nutrient index value, as represented by

$$NIV = \frac{[(P_H \times 3) + (P_M \times 2) + (P_L \times 1)]}{100}$$

Where, NIV (15) classified $P_L$, $P_M$ and $P_H$ as a percentage of soil samples with a weightage of one, two and three, respectively and correspondingly classified as low, medium, or high nutrient status.

The nutrient index values were rated into various categories *viz.*, low (<1.67), medium (1.67-2.33) and high (>2.33) for OC and available N, P and K. For available S and micronutrients, the ratings are very low (<1.33), low (1.33-1.66), marginal (1.67-2.00) adequate (2.01-2.33), high (2.34-2.66) and very high (>2.66).

## Preparation of thematic soil fertility maps

Arc-GIS software was used for creating the soil fertility maps and Microsoft Excel was used to create a database on the available nutrient status of the soil. Using a krigging geostatistical technique, the soil fertility parameters were designated with appropriate legends to create thematic maps on available nutrient status. These maps were then categorized as "Low," "Medium," and "High."

## Geostatistical analysis

Geostatistical studies consist of variography and kriging steps (19). In the variography stage the spatial structure of each soil particles were characterized by experimental semi variogram y (h) using the following equation:

$$\gamma(h) = \left(\frac{1}{2N(h)}\right) \sum_{i=1}^{N(h)} * \{Z(x_\alpha + h) - Z(x_\alpha)\}^2$$

where, N(h) = no.of pairs separated by distance interval h.

γ(h) = variogram for a distance (lag) h between observations Z (xα) and (xα +h).

A preliminary variogram surface analysis was performed to check whether there existed any zonal affect or trend in either direction. The omni directional experimental variogram for each property were then constructed. Theoretical models were fitted to these. The best fit model for both analysed properties was a spherical model using the equation:

$$\gamma(h) = C_0 + C_1\{1.5\left(\frac{h}{a}\right) - 0.5\left(\frac{h}{a}\right)^3\} \quad h \leq a$$

$$y(h) = C_0 + C_1$$

Here, a is the range, $C_0$ the nugget semivariance and $C_0$+ $C_1$ the sill or the total semivariance.

In order to see the relative contribution of nugget to total variance, we calculated the relative nugget effect (RNE) according to:

$$RNE = \left(\frac{C_0}{C_0 + C_1}\right) * 100$$

The variogram parameters extracted for each fitted model were used to interpolate the value at unsampled location by means of Ordinary kriging. The ordinary kriging is an exact interpolation technique which assumes the local stationary of the mean. Ordinary kriging uses a linear combination of observations within a predefined neighbourhood around $X_0$ (20). The Ordinary kriging estimator Z* ($X_0$) with the associated variance $\sigma^2$ ok ($X_0$) can be represented as

$$Z^{*}ok\ (X_0) = \sum_{\alpha=1}^{n(x_0)} \lambda_{\alpha}\, Z\ (x_\alpha)$$

$$\sigma^2 ok\ (X_0) = \sum_{\alpha=1}^{n(x_0)} [\lambda_{\alpha}\gamma(X\alpha - X_0) + \psi$$

Here, λα is the weight assigned to n observations, Z (xα) and ψ is the L agrange multiplier.

## Results and Discussion

### Soil physicochemical parameters

In the surface soils of different fields at SRS Farm, the pH ranged from 7.26 to 8.04. The mean pH of surface soil ranged from 7.28 to 8.05. The lowest and highest mean pH were observed in fields 24 and 16 respectively. It indicated that soil was categorised as neutral to slightly alkaline in soil reactions. The higher pH value was due to the dominance of sodium ions in exchange complex and presence of basaltic parent material and rich in basic cations (21, 22).

The electrical conductivity of the surface soil ranged from 0.08 to 0.92 dS $m^{-1}$. The mean electrical conductivity of surface soil ranged from 0.09 to 0.92 dS $m^{-1}$. It indicated that the soils were classified under the non-saline in nature, which might be due to proper land management and inherent properties of soil (23). The salt content distribution was very low might be due to the leaching combined with rainfall and free drainage conditions which favoured the removal of released bases by percolating and drainage water.

The organic carbon content in soils from different fields ranged from 2.58 to 6.44 g $kg^{-1}$ and the mean values of the organic carbon content of the soil ranged from 2.58 to 6.24 g $kg^{-1}$. Among the fields, the highest organic carbon was observed in field no. 31 (6.24 g $kg^{-1}$) and the lowest in field no. 19 (5.28g $kg^{-1}$). It indicated that the soils were classified in the low to medium category. Lower organic matter content of soil might be due to the prevailing high temperature and good aeration in soil which increased the rate of oxidation of organic matter and coarse textured soils with low in organic carbon as reported (24).

### Available macro nutrient status of the soil

The available nitrogen content in surface soil ranged from 213 to 279 kg $ha^{-1}$. The mean values of the available nitrogen content of the soil ranged from 215 to 287 kg $ha^{-1}$. The highest mean value was observed in field no. 53 (287 kg $ha^{-1}$) and the least in field no. 42 (215 kg $ha^{-1}$). The available nitrogen status of the soils was found to be low to medium in range. As majority of soils are slightly alkaline and non-calcareousness in nature, the applied nitrogenous fertilizer would have resulted in low amount of available N in the soil (25).

The available phosphorus content in surface soil ranged from 11.57 to 21.47 kg $ha^{-1}$. The mean values of the available phosphorus content of the soil were 12.10 to 20.70 kg $ha^{-1}$. Field no. 12 recorded the highest available phosphorus content of 20.70 kg $ha^{-1}$ and field no. 41 recorded the lowest content of 12.10 kg $ha^{-1}$. The available phosphorus content was found to be medium status. This may be attributed to continuous application of phosphatic fertilizers to crops, which would have resulted in build-up of phosphorus (26).

The available potassium content of the soil was found to be 190 to 363 kg $ha^{-1}$. The average value of the available potassium content in the soil was 196 to 356 kg $ha^{-1}$). The highest available potassium content was observed in field no. 16 (356 kg $ha^{-1}$) and the lowest in field no. 6 (196 kg $ha^{-1}$). In general, all the fields were medium to high in available potassium content. The higher status of available K is attributed to the prevalence of illite - a potassium mineral in these soils (27).

The available sulphur content of the soil was found to be 7.3 to 21.6 mg $kg^{-1}$. The mean value of soil available sulphur content ranged from 7.60 to 21.10 mg $kg^{-1}$. The mean value showed that field no. 72 recorded a higher available sulphur content (21.10 mg $kg^{-1}$) and field no. 35 recorded a lower available sulphur content (7.60 mg $kg^{-1}$). The data revealed that the available sulphur status of the soils in the SRS field was medium to high. These findings also supported (28).

### Available micro nutrient status of the soil

The available zinc content in surface soil ranged from 0.422 to 1.714 mg $kg^{-1}$. The mean values of the available zinc content of the soil ranged from 0.43 to 1.99 mg $kg^{-1}$. The highest mean value was observed in field no. 6 (0.43 mg $kg^{-1}$) and the least in field no. 75 (1.99 mg $kg^{-1}$). Fifty eight percent of the soil was less than the critical level and 42 % of the soil was sufficient. The conversion of zinc cations to their oxides or hydroxides at higher pH, which are known to have lower solubility might be the reason for low zinc status (29).

The available copper content in surface soil ranged from 1.22 to 7.894 mg $kg^{-1}$. The mean values of the available copper content of the soil were 1.27 to 7.61 mg $kg^{-1}$. Field no. 11 recorded the highest available copper content of 7.61 mg $kg^{-1}$ and field no. 75 recorded the lowest content of 1.27 mg $kg^{-1}$. The available copper content of the soil was found to be sufficient. Agricultural practices can add copper to soils through application of manure or inorganic fertilizers (29).

The available iron content of the soil was found to be 2.812 to 5.876 mg $kg^{-1}$. The highest available iron content was observed in field no. 53 (5.48 mg $kg^{-1}$) and the lowest in field no. 28 (3.04 mg $kg^{-1}$). About 19 % of the available iron content of the soil was found to be less than the critical level and 81 % was found to be sufficient. The spatial distribution of DTPA-Fe in the blocks of Vridhachalam, Kurinjipadi and Kammapuram in the Cuddalore district indicated that DTPA-Fe levels ranged from 5.29 to 7.98, 4.96 to 7.44 and 4.74 to 7.22 mg $kg^{-1}$, respectively (30).

The available manganese content of the soil was found to be 1.625 to 6.96 mg $kg^{-1}$. The mean value of the available manganese content in soil ranged from 1.67 to 6.75 mg $kg^{-1}$. The mean value showed that field no. 15 recorded a higher available manganese content (6.75 mg $kg^{-1}$) and field no. 43 recorded a lower available manganese content (1.67 mg $kg^{-1}$). The data revealed that 8 %of the soil was found to be less than the critical level and 92 % to be sufficient in available manganese (31).

## Percent samples for each fertility group

Tables 3 and 4 present the results of the computation of percent category samples for soil physical-chemical parameters as well as available nutrients. The pH values of soil samples were neutral (16.7 %) and slightly alkaline (83.3 %). All the soil samples were categorized under non-saline. Among the 144 soil samples, 60, 97 and 8 % of samples were grouped under the low status for organic carbon, available N and S, respectively.

**Table 3.** Percent samples under each category for pH and EC

| pH | | |
|---|---|---|
| **Acidic** | **Neutral** | **Alkaline** |
| 0 | 16.7 | 83.3 |
| **EC** | | |
| **Saline** | **Non-Saline** | |
| 0 | 100 | |

**Table 4.** Percent samples under each categoryof fertility groups

| Parameter | Percentage of samples under | | |
|---|---|---|---|
| | **Low** | **Medium** | **High** |
| Soil organic carbon | **60** | **40** | - |
| Available-nitrogen | **97** | **03** | - |
| Available-phosphorus | - | **100** | - |
| Available-potassium | - | **67** | **33** |
| Available sulphur | **8** | **69** | **23** |
| | **Deficient** | **Sufficient** | |
| DTPA-Fe, Mn, Cu | **20** | **80** | |
| DTPA-Zn | **58** | **42** | |

## Nutrient index value and fertility status

Among the 144 soil samples, 40, 3, 100, 67 and 69 % of samples are with medium status for organic carbon, available N, P, K and S, respectively. High category found to be with 33 and 23 % of samples in available K and S respectively. With respect to available Fe, Cu and Mn, 20 and 80 % of soil samples were categorized under deficient and sufficient, respectively. In available Zn, 58 and 42 % of the soil samples were categorized under deficient and sufficient, respectively (Table 5).

**Table 5.** Nutrient index value and fertility status

| Parameters | Nutrient index value | Fertility status |
|---|---|---|
| Organic carbon | 1.40 | Low |
| Available N | 1.03 | Low |
| Available P | 2.00 | Medium |
| Available K | 2.33 | High |
| Available S | 2.15 | Adequate |
| Available Cu | 2.94 | High |
| Available Zn | 1.42 | Low |
| Available Fe | 1.76 | Marginal |
| Available Mn | 2.09 | Adequate |

## Thematic soil fertility maps

By showing the proper legends for soil fertility parameters, the maps on organic carbon and available nutrient status have been generated (Fig. 2-10). In the Sugarcane Research Station in Cuddalore, Tamil Nadu, maps were generated and the spatial variability of soil fertility parameters was clearly illustrated through visual differences. Similar studies were carried out for Veeranam Command Area, Tamil Nadu (32). Similar thematic maps were created in vegetable-grown soils of Horticultural College and Research Institute, Periyakulam (33). Mapping Soil Fertility and its Spatial Variability in Central Farm soils of Horticultural College and Research Institute, Periyaluam, Theni District, Tamil Nadu Using GIS (34). Spatial variability of available iron in major groundnut growing soils of Cuddalore district, Tamil Nadu (31, 35).

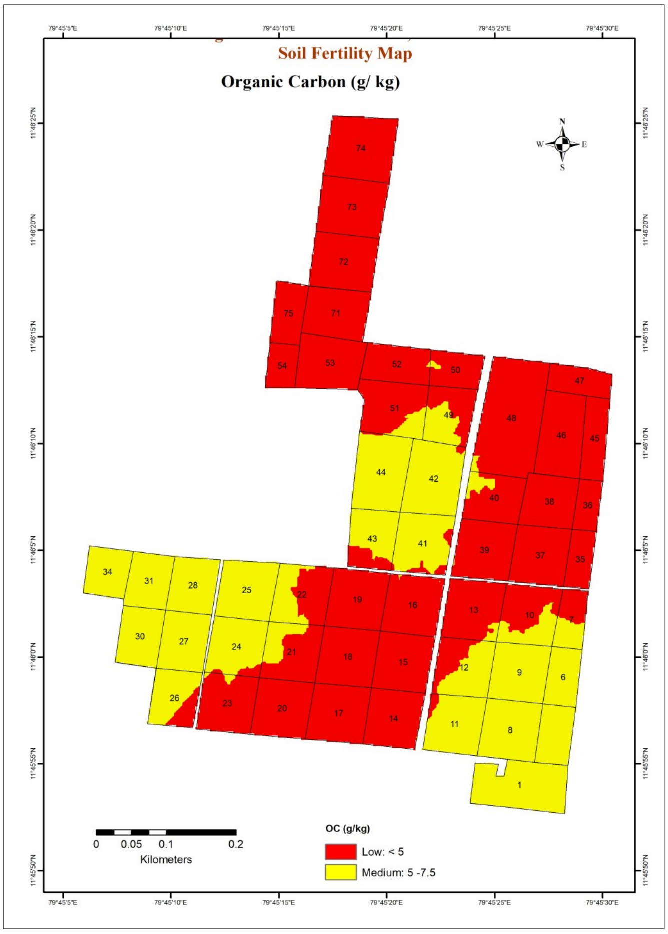


**Fig. 2.** Spatial distribution of organic carbon contents.

## Inter-relationship of soil properties

The correlation studies (Table 6) revealed that the nutrient status in the soil was positively correlated with soil parameters. The organic carbon is significantly and positively correlated with available nitrogen (0.0306**), available phosphorus (0.0796) and negatively correlated with potassium (-0.076). In micro nutrients also positively correlated with the other nutrients *viz.*, Fe (0.0257), Mn (0.0415), Zn (0.0407) and Cu (0.0285).

## Variogram construction and analysis

The experimental variogram of macro and micro nutrient, together with the fitted spherical models shows the Table 7. Macro and Micro nutrient displayed a well-defined spatial structure with their characteristics sill and range indicated as 0.121 to 0.615 and 1.16 to 1.91 respectively. Such variogram

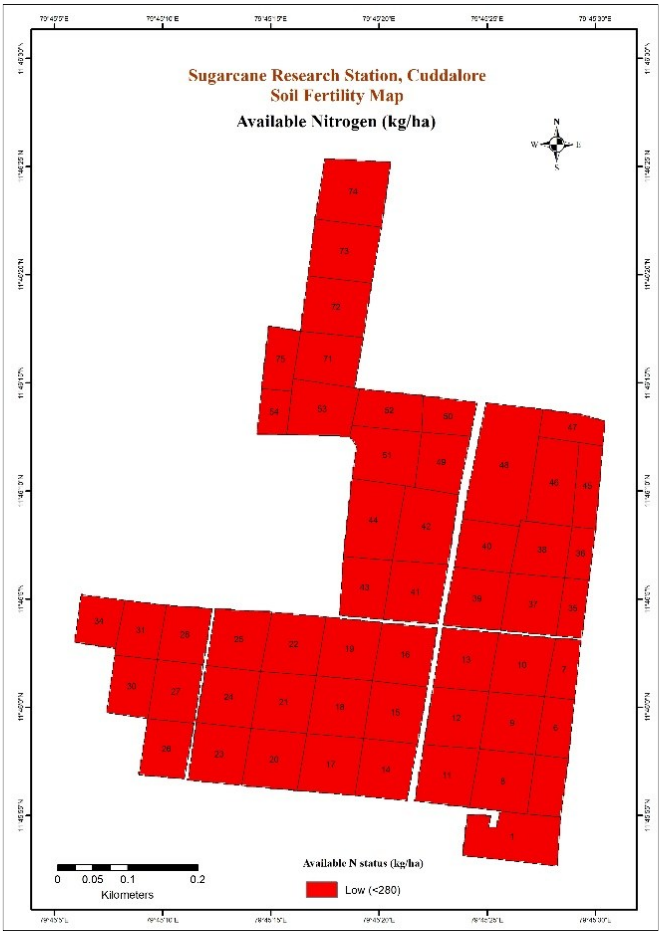


**Fig. 3.** Spatial distribution of available soil nitrogen contents.

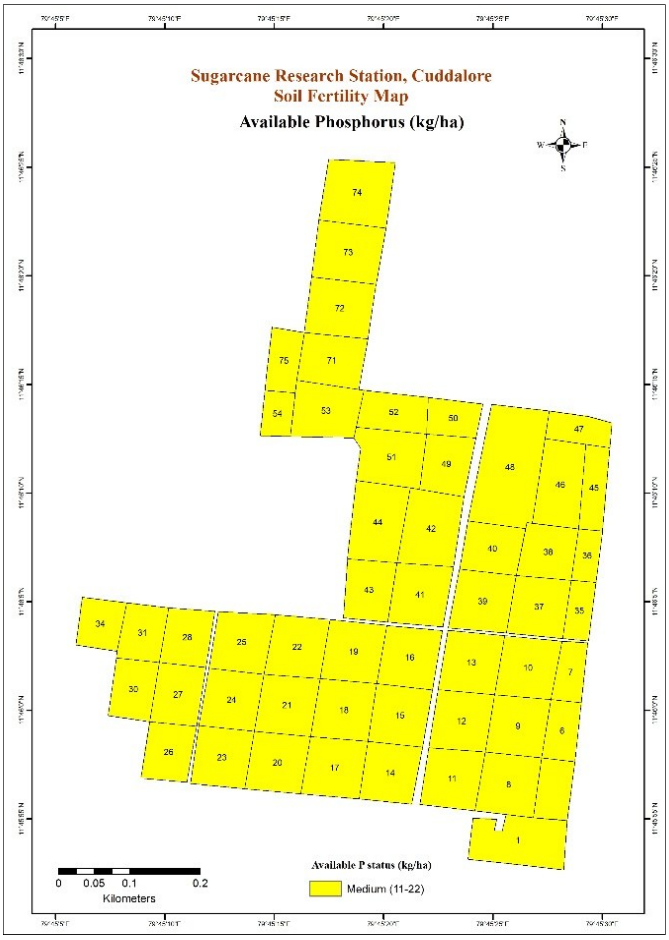


**Fig. 4.** Spatial distribution of available soil phosphorus contents.

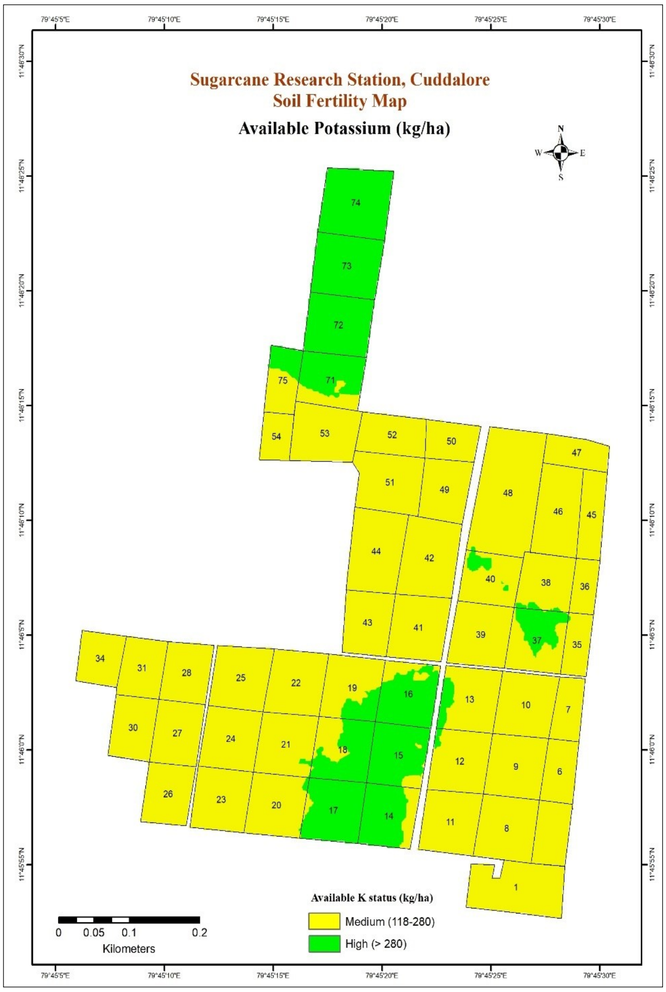


**Fig. 5.** Spatial distribution of available soil potassium contents.

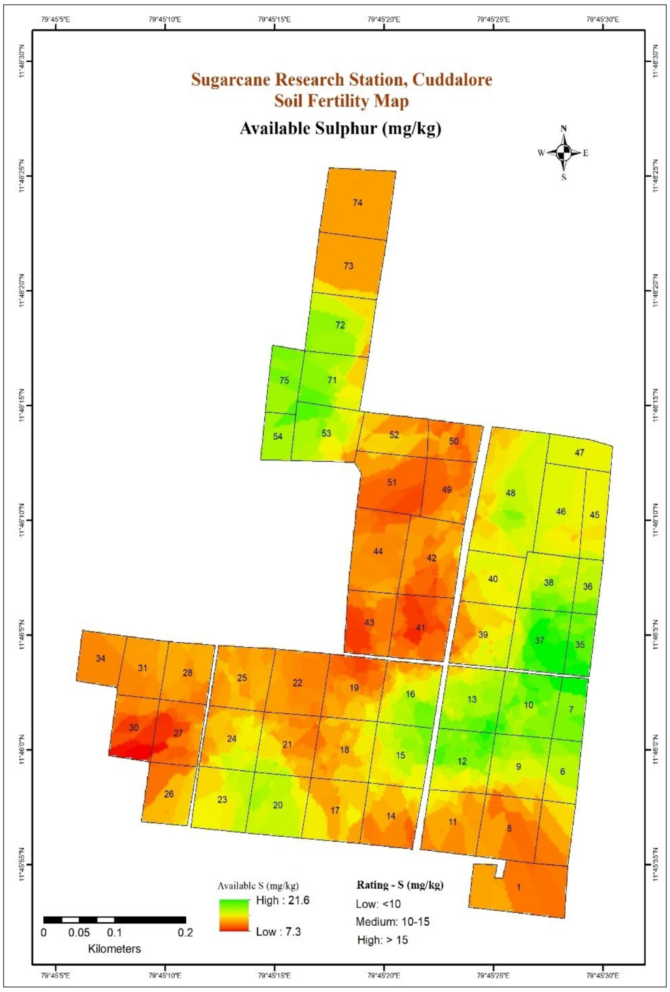


**Fig. 6.** Spatial distribution of available soil sulphur contents.

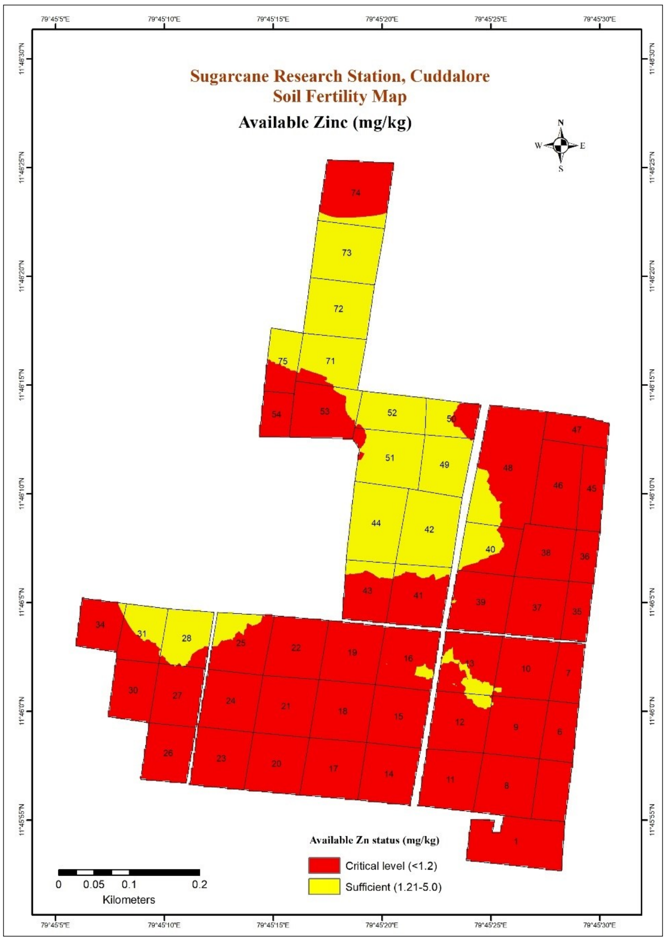


**Fig. 7.** Spatial distribution of available soil zinc contents.

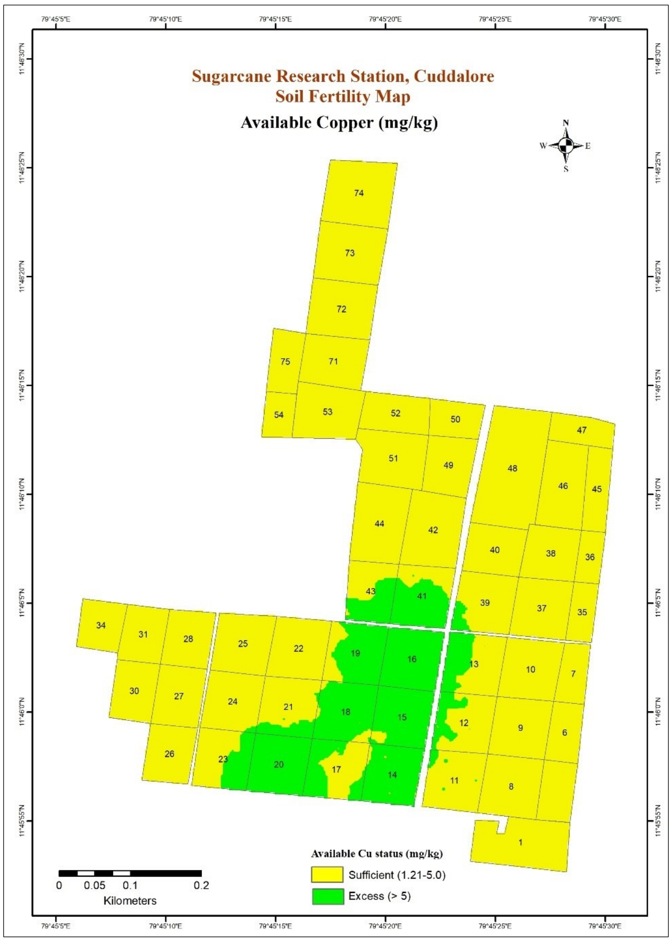


**Fig. 8.** Spatial distribution of available soil copper contents.

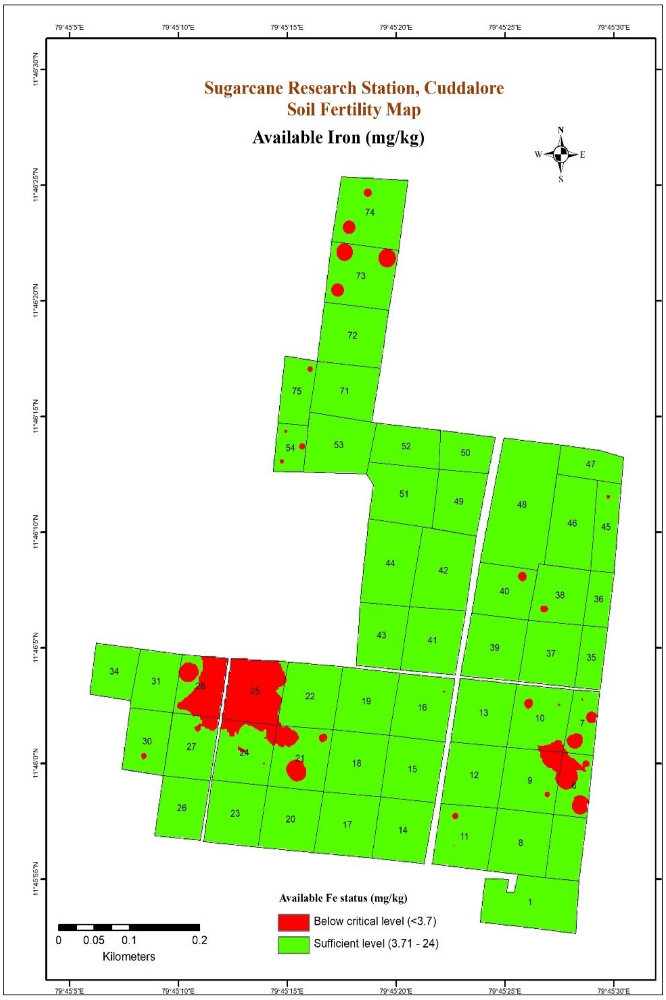


**Fig. 9.** Spatial distribution of available soil iron contents.

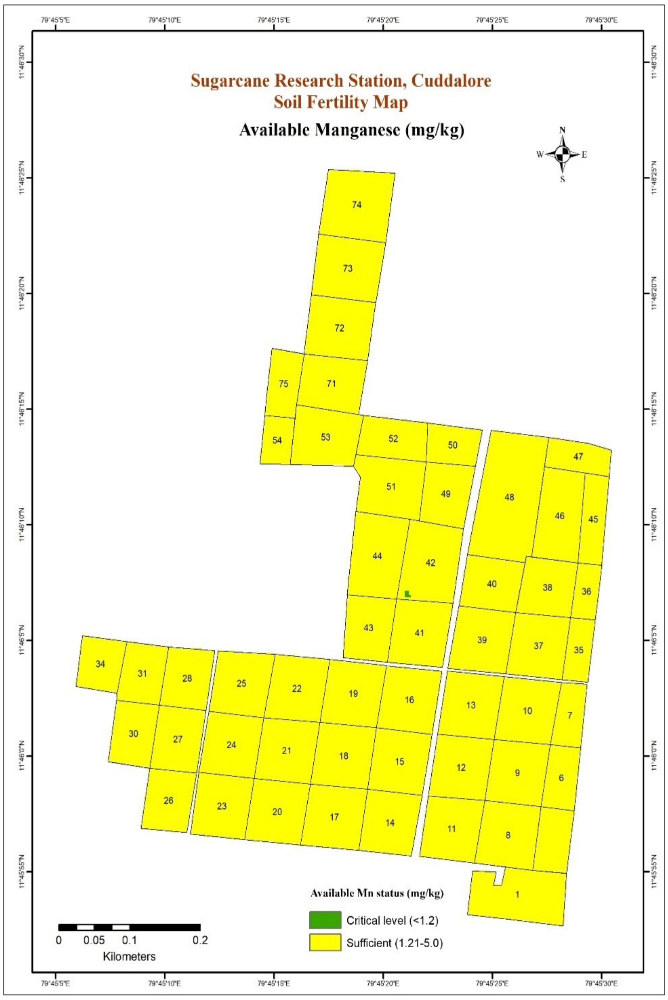


**Fig. 10.** Spatial distribution of available soil manganese contents.

**Table 6.** Correlation matrix of the soil samples of study area

| Soil properties | OC | N | P | K | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|---|
| OC | 1 | | | | | | | |
| N | 0.030614* | 1 | | | | | | |
| P | 0.083357 | 0.079688* | 1 | | | | | |
| K | -0.19351 | -0.20267 | -0.07621* | 1 | | | | |
| Fe | 0.00889 | 0.011713 | 0.06292 | 0.0257* | 1 | | | |
| Mn | 0.04604 | 0.003597 | 0.05565 | 0.0154 | 0.0415* | 1 | | |
| Zn | 0.00130 | 0.13313 | 0.0541 | 0.01313 | 0.0541 | 0.0407* | 1 | |
| Cu | 0.00672 | 0.01916 | 0.04350 | 0.0916 | 0.0350 | 0.0597 | 0.0285* | 1 |

*Correlation is significant at 0.05 level.

**Table 7.** Descriptive statistics of available macro and micro nutrient

| S.No | Property | Number | Min. | Max. | Mean | Standard deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | OC | 144 | 0.819 | 2.713 | 1.314 | 0.214 | 0.143 | 1.91 |
| 2 | N | 144 | 0.821 | 2.697 | 1.324 | 0.306 | 0.154 | 1.93 |
| 3 | P | 144 | 0.361 | 1.813 | 1.254 | 0.796 | 0.126 | 1.45 |
| 4 | K | 144 | 0.814 | 1.240 | 1.260 | 0.762 | 0.145 | 1.52 |
| 5 | S | 144 | 0.834 | 1.651 | 1.452 | 0.621 | 0.135 | 1.36 |
| 6 | Fe | 144 | 0.889 | 1.713 | 1.292 | 0.257 | 0.121 | 1.74 |
| 7 | Mn | 144 | 0.604 | 2.597 | 1.565 | 0.415 | 0.615 | 1.53 |
| 8 | Zn | 144 | 0.030 | 1.313 | 0.541 | 0.407 | 0.448 | 1.24 |
| 9 | Cu | 144 | 0.072 | 0.916 | 0.350 | 0.285 | 0.490 | 1.16 |

that the properties vary in a patchy way resulting in areas with small values and other areas with larger values shows in Fig. 1-9. The same trend of results also observed (36). The range of spatial correlation of the variogram provides average extent of these patches. The average standard error for sand and clay are 0.25 to 0.41 respectively, it will be confirmed the statistically all the properties are interlinked with each others.

## Conclusion

The soil fertility maps clearly indicated that farm soil of Sugarcane Research Station, Cuddalore is neutral to slightly alkaline and non-saline and low to medium in OC, low to medium in available N, medium in available P and medium to high in available K and S. Available Cu, Fe and Mn content of the soil is predominantly sufficient. With respect to available Zn, 58 % of the soil was less than the critical level and 42 % of the soil was sufficient. The study indicated that it is necessary to replenish the farm soil with organics, green manures and inorganic sources of nutrients for enhancing nutrient use efficiency, maximizing crop productivity and sustaining soil fertility. Hence, the adoption of the STCR-IPNS nutrient management approach will provide balanced nutrition to crops, which in turn will be helpful in maintaining soil health and enhancing the yield of crops grown on the farm.


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## Authors' contributions

GP and RJ conceived of the project and designed the experiments. GP and PR analyzed the data. GP, GA and MPS assisted the data, prepared the figures and tables and prepared the manuscript. GP, RJ and PR validated data and prepared thematic maps. RA aligned the manuscript. All authors approved the final version of the manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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