Delineation and geographic information system (GIS) mapping of soil macronutrients status in sugarcane growing tracts of prudential sugar factory zone in Chittoor district, Andhra Pradesh

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Abstract

Soil fertility mapping with specific reference to macronutrients was carried out by analyzing 270 geo-referenced soils collected from 8 mandals of sugarcane growing soils of Prudential sugar factory zone, of Chittoor district in Andhra Pradesh. Soils were analyzed for pH, EC, OC and available macronutrients (N, P, K and S). Soil reaction varied from acidic to strongly alkaline (4.73 to 9.40). However, electrical conductivity (EC) remains within safe range for crops (<4 dSm⁻¹). SOC varies from 0.01 to 0.75 per cent with a mean value of 0.42 per cent. The available nitrogen content was found to be in the range of 25 to 326 kg ha⁻¹ with a mean value of 120 kg ha⁻¹ indicating low to medium status. The available phosphorus (P₂O₅) content in soils varied from 19.5 to 206.1 kg ha⁻¹ with a mean value of 59.7 kg ha⁻¹ and indicated that their fertility class was low to high status. Potassium (K₂O) availability was found to be to be in the range of 42 to 585 kg ha⁻¹ with a mean value of 186 kg ha⁻¹ and indicated that their fertility class was low to high status. The available sulphur content was found to be in the range of 0.5 to 59.5 mg kg⁻¹ with a mean value of 26.42 mg kg⁻¹ and indicated that their fertility class was low to high status.

Keywords: Sugarcane, fertility maps, GIS and GPS

Introduction

Sugarcane is the main sugar producing crop that contributes more than 75 per cent to the total sugar pool at the global level. India, being the world’s second largest producer after Brazil, is producing nearly 15 and 25 percent of global sugar and sugarcane, respectively. Indian sugar industry is playing a lead role in global sugar market contributing significantly to the socio-economic development of the nation. Area coverage, production and productivity of sugarcane in India are 5.0 million ha, 3.4 lakh million tones and 69.4 tonnes ha⁻¹, respectively (2015). In Andhra Pradesh 1.22 million ha of area is occupied by sugarcane with productivity of 0.9 lakh million tonnes and 75.7 tonnes ha⁻¹, respectively (sugarcane.dac.gov.in/Statistics APY. pdf, 2015). The sugarcane cultivation in Chittoor district is to an extent of 26,000 ha with a productivity of 79.05 t ha⁻¹. Poor soil fertility and inappropriate nutrient management strategies are the important major constraints contributing to poor production, malnutrition and eco-system degradation. Thus any soil fertility evaluation research must provide highly valuable information that can be used to eliminate the above problems with suitable fertilizer recommendation. The fertility management (fertility evaluation & fertilizer recommendation) in agriculture, global positioning system (GPS) and geographic information system (GIS) technologies have been adopted for better management of land and other resources for sustainable crop production (Palaniswami et al., 2011) [9]. Fertilizer is one of the costliest inputs in agriculture and the use of right amount of fertilizer is fundamental for farm profitability and environmental protection (Mahendra, 2010) [7]. Inventory of the available macro and micronutrient status of the soils help in demarcating areas where the application of particular nutrient is needed for profitable crop production (Sood et al., 2009) [11]. The soil fertility maps for fertilizer recommendation with a support to calculate fertilizer doses based on soil test values interactively. However generation of soil fertility maps for the sugarcane growing areas in Chittoor district of Andhra Pradesh is virtually lacking and hence present investigation was carried out to study the macronutrient status and to prepare soil fertility maps by using GIS approach in Prudential sugar factory zone in Chittoor, A.P.
Material and Methods

The study area (Chittoor district) is under semi arid climate and located in southern agro climatic zone of A.P. Prudential sugar factory zone is a part of Chittoor district and it consists of eight mandals viz., Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichatur, Nagalaparum and Puttur. Prudential sugar factory zone lies in between 13° 11′ 24″ and 13° 53′ 49.2″ North latitudes and 79° 11′ 49.2″ and 80° 11′ 24″ East longitudes. Two hundred and seventy soil samples were collected at depth of 0-20 cm from sugarcane growing areas in Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichatur, Nagalaparum and Puttur mandals of Prudential sugar factory zone by following random sampling technique during the month of November, 2017. The exact sample location was recorded by using hand held GPS. The collected soil samples were analysed for available macronutrients as per the procedure.

Soil Reaction (pH) of the soil samples were determined in saturated paste using Systronics pH system 361 (Jackson, 1973) [6]. Electrical conductivity of the soil samples were determined in saturated paste using Systronics conductivity meter 306 (Jackson, 1973) [6] and expressed the result in dSm⁻¹. The organic carbon content of the 0.5 mm sieved soil samples were estimated by Walkley and Black's wet oxidation method as outlined by Jackson (1973) [6] and expressed the result in per cent. Available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [12]. The available P was extracted with the 0.5 M NaHCO₃ extractant and determined by using ascorbic acid as reducing agent (Olsen et al., 1954) [8] and the available K in the soils was extracted by employing Neutral normal ammonium acetate and determined by aspirating the extract into the flame photometer (Jackson, 1973) [6]. Available sulphur was determined by extracting with 0.15 per cent calcium chloride followed by development of turbidity with barium chloride (Hesse, 1971) [5]. The available nutrient status in soil samples were rated as low, medium and high categories as per the limits suggested by Ahmed et al. (2007) [1] for available N, P₂O₅ and K₂O. The available calcium and magnesium were classified based on the critical limits proposed by Tandon (1989) [13] and available sulphur was classified based on the critical limits proposed by Tandon (1991) [14].

The base map that was prepared by using google earth image of the Prudential sugar factory zone, Chittoor district was used for preparation of thematic maps for various parameters such as, available nitrogen, phosphorus, potassium calcium magnesium and sulphur by adopting geostatistical tool of krigging in ArcGIS 9.3.1 environment.

Results and Discussion

Physico chemical characteristics

Soil Reaction (pH)

The soil reaction values in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district viz., Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichatur, Nagalaparum and Puttur varied from 5.3 to 9.4, 7.32 to 9.19, 6.9 to 8.73, 6.03 to 8.62, 6.04 to 8.79, 6.83 to 8.62, 4.73 to 8.31 and 6.62 to 9.01, respectively (Table 1). Mapping of soil reaction (pH) by GIS technique resulted in five soil reaction classes viz., slightly acidic (6.1-6.5), neutral (6.6-7.3), slightly alkaline (7.4-7.8), moderately alkaline (7.9-8.4) and strongly alkaline (> 8.4). Major proportion of the Prudential sugar factory zone was moderately alkaline (46.60%) followed by slightly alkaline (24.40%), neutral (11.90%), strongly alkaline (11.90%) and slightly acidic (5.2%). The CV (8.75%) of soil pH indicates that it did not vary spatially in the Prudential sugar factory zone. Soil reaction, in general, varied from acidic to strongly alkaline (4.73 to 9.40). The variation in soil pH might be attributed to the variation in nature of parent materials and degree of weathering. The higher pH values could be ascribed to the comparatively less leaching of bases in sandy clay loams than that in other coarse textured soils. Similar findings were reported by Devi and Naidu (2015) [3] Andhra Pradesh, respectively.

Electrical Conductivity (EC)

The mean EC values in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district namely Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichatur, Nagalaparum, Puttur were 0.10, 0.13, 0.10, 0.10, 0.12, 0.11, 0.15 dSm⁻¹, respectively (Table 1). The CV (48.79%) of EC values indicated that salt content in Prudential sugar factory zone varied spatially. The EC values ranged from 0.01 to 0.44 dSm⁻¹ with a mean value of 0.11 dSm⁻¹ indicating the presence of very low amount of soluble salts. All the soils under the study area were non-saline in nature as the EC of soils was far below 4 dSm⁻¹. The low EC in the sugarcane growing soils was due to excess leaching of soluble salts and free drainage conditions which favoured the removal of salts by percolating and drainage water. All the soil samples in the present study have favourable EC for crop growth. Similar findings were reported by Ashokkumar and Prasad (2010) [2] in sugarcane growing soils of Ahmednagar district in Maharashtra.

Organic Carbon (OC)

The mean organic carbon values in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district namely Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichatur, Nagalaparum, Puttur were 0.41, 0.47, 0.45, 0.51, 0.41, 0.41, 0.50 per cent, respectively (Table 1). Mapping of organic carbon by ArcGIS revealed that, about 58.89 per cent area was low and 41.11 per cent area was medium in organic carbon content. The CV value of 48.76 per cent indicates that, organic carbon in the soils varied spatially in the Prudential sugar factory zone. The organic carbon in these soils was ranged from 0.01 to 0.75 per cent with a mean value of 0.42 per cent. The lower organic carbon content in these soils might be due to the prevalence of tropical conditions where the decomposition of organic matter occurs at a faster rate coupled with low vegetative cover thereby leaving less organic carbon in the soils. These findings were in good agreement with the findings of Somasekharbabu et al. (2016) [10].

Available nitrogen

The available nitrogen varied from 25 to 326 kg ha⁻¹ with a mean value of 120 kg ha⁻¹ indicating low to medium status. The trend of N content among different mandals were Narayanavanam > Nagari > K.V.B. Puram > Puttur > Nagalaparum > Nindra > Pichatur > Vijayapuram with a mean values of 166 >140 > 136 > 133 > 124 > 115 > 112 >101 Kg ha⁻¹, respectively (Table 1). The low available nitrogen status of these soils might be attributed to the low organic matter content. Further, the semi-arid conditions of the area might have favoured rapid oxidation and lesser accumulation of organic matter releasing more NO₃-N which could have been lost by leaching (Finck and Venkateswarlu,
Available phosphorus (P\textsubscript{2}O\textsubscript{5})

The results revealed that available phosphorus in sugarcane growing soils ranged from 19.47 to 206.1 kg ha\textsuperscript{-1} with a mean value of 59.7 kg ha\textsuperscript{-1}. Among 8 mandals the highest mean available P\textsubscript{2}O\textsubscript{5} was noticed in Nagalapuram (78.6 kg ha\textsuperscript{-1}) followed by Pichathur (70.6 kg ha\textsuperscript{-1}), Nagari (66.3 kg ha\textsuperscript{-1}), Nindra (57.2 kg ha\textsuperscript{-1}), K.V.B. Puram (52.8 kg ha\textsuperscript{-1}), Vijayapuram (50.2 kg ha\textsuperscript{-1}), Puttur (46.7 kg ha\textsuperscript{-1}) and Narayanavanam (41.6 kg ha\textsuperscript{-1}) (Table 1). Presence of the considerable amount of phosphorus in sugarcane growing soils might be due to the continuous use of phophatic fertilizers and adopting good management practices. The lower available phosphorus content could be attributed to the fixation of releasing phosphorus by clay minerals and oxides of iron and aluminium. These findings were in line with results of Devi and Naidu (2015) in sugarcane growing soils of Chittoor district, Andhrapradesh. Mapping of available P\textsubscript{2}O\textsubscript{5} by GIS revealed that, about 14.81 per cent, 39.63 per cent and 45.56 per cent of study area was found to be low, medium and high in phosphorus status, respectively. The CV of 56.80 per cent for available P\textsubscript{2}O\textsubscript{5} in the Prudential sugar factory zone indicates that, it varied spatially.

Available potassium (K\textsubscript{2}O)

The trend of K\textsubscript{2}O content among different mandals were Narayanavanam > Nindra > K.V.B. Puram = Puttur > Nagari > Pichathur > Nagalapuram > Vijayapuram with a mean values of 300 > 216 > 202 = 202 > 187 > 156 > 150 Kg ha\textsuperscript{-1}, respectively (Table 1). Available potassium (K\textsubscript{2}O) of the soils under investigation was ranged from low to high (42 to 585 kg ha\textsuperscript{-1}) with a mean value of 186 kg ha\textsuperscript{-1}. The low available potassium content was recorded by 41.11 per cent of study area (2222 ha) could be ascribed to continuous growing of crops with non application potash fertilizers over a period of time, intensively growing of high yielding varieties and non application of the organic manures. These findings were in agreement with the findings of Devi and Naidu (2015) and Yamini et al. (2017). Mapping of available K\textsubscript{2}O was done with GIS and it indicated that, about 55.70 per cent, 41.11 per cent and 5.19 per cent of study area was found to be low, medium and high in available potassium, respectively. The CV of 55.86 per cent for available K\textsubscript{2}O indicates that, it varied spatially in the Prudential sugar factory zone.

Available sulphur (S)

The mean available sulphur in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district viz., Nindra, Nagari, Narayanavanam, K.V.B. Puram, Vijayapuram, Pichathur, Nagalapuram and Puttur were 33.06, 30.25, 29.67, 29.77, 23.73, 20.9, 20.56 and 20.91 mg kg\textsuperscript{-1}, (Table 1) respectively. The available sulphur in the sugarcane growing soils of study area ranged from 0.5 to 59.5 mg kg\textsuperscript{-1} soil with a mean value of 26.42 mg kg\textsuperscript{-1} soil. Considering 10.00 mg sulphur kg\textsuperscript{-1} soil (Tandon, 1991) as the critical limit for normal plant growth, it may be inferred that about 94.81 per cent of study area (5125 ha) was found to be sufficient in available sulphur. The higher sulphur in these soils might be due to the continuous application of fertilizers like single super phosphate. These results were in confirmation with those reported by Vijayakumar and Haroon (2013).

By using GIS approach fertility map for available S was prepared. The map showed that, about 5.19 per cent study area was deficient and 94.81 per cent area was sufficient in the available sulphur. The CV of 55.31 per cent for available sulphur indicates that, in the Prudential sugar factory zone available sulphur varied spatially.

Conclusion

The results lead to a conclusion that the available nitrogen in sugarcane growing soils was low to medium (25 to 326 kg ha\textsuperscript{-1}), which might be due to the low addition of organic matter and rapid oxidation of added organic matter. The sugarcane growing soils were low to high in available P\textsubscript{2}O\textsubscript{5} (19.5 to 206.1 kg ha\textsuperscript{-1}) and K\textsubscript{2}O (42 to 585 kg ha\textsuperscript{-1}). The available calcium (1.0 to 6.8 cmol (p+)) kg\textsuperscript{-1} soil), magnesium (0.3 to 6.8 cmol (p+) kg\textsuperscript{-1} soil) and available sulphur (0.5 to 59.5 mg kg\textsuperscript{-1} soil) were found to be deficient to sufficient in sugarcane growing soils. Soil nutrients maps would be highly useful in improving our understanding regarding native and extent of nutrient problems and this can aid in developing appropriate nutrients management strategies leading to better yield and environmental stewardship, which ultimately would be helpful in determining their relationship with animal and human health.

Table 1: Physico chemical (pH, EC and O.C.) and available N, P\textsubscript{2}O\textsubscript{5}, K\textsubscript{2}O and S in sugarcane growing soils (0-20 cm depth) of various mandals in Prudential sugar factory zone of Chittoor district

<table>
<thead>
<tr>
<th>S. No</th>
<th>Mandal</th>
<th>pH</th>
<th>EC (dSm\textsuperscript{-1})</th>
<th>O.C. (%)</th>
<th>N (Kg ha\textsuperscript{-1})</th>
<th>P\textsubscript{2}O\textsubscript{5} (kg ha\textsuperscript{-1})</th>
<th>K\textsubscript{2}O (kg ha\textsuperscript{-1})</th>
<th>S mg kg\textsuperscript{-1}</th>
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<tbody>
<tr>
<td>1.</td>
<td>Nindra</td>
<td>Range</td>
<td>5.3-9.4</td>
<td>0.01-0.26</td>
<td>0.01-0.75</td>
<td>25-288</td>
<td>20.6-206.1</td>
<td>42-515</td>
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<td></td>
<td>Mean</td>
<td>7.78</td>
<td>0.10</td>
<td>0.41</td>
<td></td>
<td>115</td>
<td>57.2</td>
<td>216</td>
</tr>
<tr>
<td>2.</td>
<td>Nagari</td>
<td>Range</td>
<td>7.32-9.19</td>
<td>0.07-0.25</td>
<td>0.09-0.74</td>
<td>62-326</td>
<td>20.6-154.6</td>
<td>82-488</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>8.17</td>
<td>0.13</td>
<td>0.47</td>
<td></td>
<td>140</td>
<td>66.3</td>
<td>187</td>
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<td>3.</td>
<td>Narayanavanam</td>
<td>Range</td>
<td>6.9-8.73</td>
<td>0.06-0.15</td>
<td>0.19-0.75</td>
<td>125-201</td>
<td>24.0-61.8</td>
<td>130-566</td>
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<tr>
<td></td>
<td>Mean</td>
<td>7.93</td>
<td>0.10</td>
<td>0.45</td>
<td></td>
<td>166</td>
<td>41.6</td>
<td>300</td>
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<td>4.</td>
<td>K.V.B. Puram</td>
<td>Range</td>
<td>6.03-8.62</td>
<td>0.04-0.19</td>
<td>0.15-0.74</td>
<td>38-276</td>
<td>20.6-134</td>
<td>81-585</td>
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<tr>
<td></td>
<td>Mean</td>
<td>7.71</td>
<td>0.10</td>
<td>0.15</td>
<td></td>
<td>136</td>
<td>52.8</td>
<td>202</td>
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<tr>
<td>5.</td>
<td>Vijayapuram</td>
<td>Range</td>
<td>6.04-8.79</td>
<td>0.05-0.45</td>
<td>0.09-0.74</td>
<td>25-201</td>
<td>20.6-154.6</td>
<td>42-365</td>
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<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
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<td>6.</td>
<td>7.88</td>
<td>6.83-8.62</td>
<td>0.12</td>
<td>0.05-0.3</td>
<td>0.41</td>
<td>0.04-0.74</td>
<td>101</td>
<td>50-238</td>
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<td>7.</td>
<td>7.93</td>
<td>4.73-8.31</td>
<td>0.12</td>
<td>0.05-0.41</td>
<td>0.41</td>
<td>0.04-0.75</td>
<td>112</td>
<td>25-276</td>
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<tr>
<td>8.</td>
<td>7.19</td>
<td>6.62-9.01</td>
<td>0.11</td>
<td>0.06-0.27</td>
<td>0.32</td>
<td>0.09-0.74</td>
<td>124</td>
<td>25-288</td>
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<tr>
<td>9.</td>
<td>8.22</td>
<td>4.73-9.40</td>
<td>0.15</td>
<td>0.01-0.44</td>
<td>0.50</td>
<td>0.01-0.75</td>
<td>133</td>
<td>25-326</td>
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<tr>
<td>10.</td>
<td>7.83</td>
<td>Overall range</td>
<td>0.11</td>
<td>Overall mean</td>
<td>0.42</td>
<td>Overall mean</td>
<td>120</td>
<td>Overall mean</td>
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<td>11.</td>
<td>8.75</td>
<td>C.V. (%)</td>
<td>48.79</td>
<td>C.V. (%)</td>
<td>48.76</td>
<td>C.V. (%)</td>
<td>45.54</td>
<td>C.V. (%)</td>
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</table>

Fig 1: Location map of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

Fig 2: Soil reaction (pH) in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

Fig 3: Electrical conductivity (EC) in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh
Fig 4: Status of organic carbon in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

Fig 5: Nitrogen status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

Fig 6: Phosphorus status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

Fig 7: Potassium status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh
Fig 8: Sulphur status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

References