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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 mean value of 120 kg ha^{-1} indicating low to medium status. The available phosphorus (P_2O_5) 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 (K_2O) 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 production and 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, Nagalapuram and Puttur. Prudential sugar factory zone lies in between 13° 11′ 24″and 13^0 53′49.2″ North latitudes and $79^0$11′ 49.2″ and 80^0 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, Nagalapuram 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 $NaHCO_3$ 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, P_2O_5 and K_2O. 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 geostatical tool of krigging in *Arc*GIS 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, Nagalapuram 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%) fallowed 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, Pichattur, Nagalapuram, 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, Pichattur, Nagalapuram, Puttur were 0.41, 0.47, 0.45, 0.51, 0.41, 0.41, 0.32 and 0.50 per cent, respectively (Table 1). Mapping of organic carbon by *Arc*GIS 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 > Nagalapuram > 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 NO_3-N which could have been lost by leaching (Finck and Venkateswarlu,

1982) [4]. The low nitrogen in sugarcane growing soils in their study area was reported by Ashokkumar and Prasad (2010) [2] in Ahmednagar district of Maharashtra.
Mapping of soil available nitrogen by GIS revealed that, about 98.89 per cent area was low and 1.11 per cent area was medium in available nitrogen. The CV value of 45.54 per cent indicates that, available nitrogen in soils varied spatially.

Available phosphorus (P_2O_5)
The results revealed that available phosphorus in sugarcane growing soils ranged from 19.47 to 206.1 kg ha^{-1} with a mean value of 59.7 kg ha^{-1}. Among 8 mandals the highest mean available $P_2O_5$was noticed in Nagalapuram (78.6 kg ha^{-1}) fallowed by Pichatur (70.6 kg ha^{-1}), Nagari (66.3 kg ha^{-1}), Nindra (57.2 kg ha^{-1}), K.V.B. Puram (52.8 kg ha^{-1}), Vijayapuram (50.2 kg ha^{-1}), Puttur (46.7 kg ha^{-1}) and Narayanavanam (41.6 kg ha^{-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) [3] in sugarcane growing soils of Chittoor district, Andhrapradesh.
Mapping of available P_2O_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_2O_5 in the Prudential sugar factory zone indicates that, it varied spatially.

Available potassium (K_2O)
The trend of K_2O content among different mandals were Narayanavanam > Nindra > K.V.B. Puram = Puttur > Nagari> Pichatur > Nagalapuram > Vijayapuram with a mean values of 300 > 216 > 202 = 202 > 187 > 164 > 156 > 150 Kg ha^{-1}, respectively (Table 1). Available potassium (K_2O) of the soils under investigation was ranged from low to high (42 to 585 kg ha^{-1}) with a mean value of 186 kg ha^{-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) [3] and Yamini *et al*. (2017) [17].
Mapping of available K_2O 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_2O 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, Pichattur, Nagalapuram and Puttur were 33.06, 30.25, 29.67, 29.77, 23.73, 20.9, 20.56 and 20.91 mg kg^{-1}, (Table 1) respectively. The available sulphur in the sugarcane growing soils of study area ranged from 0.5 to 59.5 mg kg^{-1} soil with a mean value of 26.42 mg kg^{-1} soil. Considering 10.00 mg sulphur kg^{-1} soil (Tandon, 1991) [14] 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) [16].
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^{-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_2O_5 (19.5 to 206.1 kg ha^{-1}) and K_2O (42 to 585 kg ha^{-1}). The available calcium (1.0 to 6.8 cmol (p+) kg^{-1} soil), magnesium (0.3 to 6.8 cmol (p+) kg^{-1} soil) and available sulphur (0.5 to 59.5 mg kg^{-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_2O_5 K_2O and S in sugarcane growing soils (0-20 cm depth) of various mandals in Prudential sugar factory zone of Chittoor district

S. No	Mandal	pH	EC(dSm^{-1})	O.C. (%)	N(Kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	S mg kg^{-1}
1.	**Nindra**							
	Range	5.3-9.4	0.01-0.26	0.01-0.75	25-288	20.6-206.1	42-515	0.5-58.5
	Mean	7.78	0.10	0.41	115	57.2	216	33.06
2.	**Nagari**							
	Range	7.32-9.19	0.07-0.25	0.09-0.74	62-326	20.6-154.6	82-488	8.0-57
	Mean	8.17	0.13	0.47	140	66.3	187	30.25
3.	**Narayanavanam**							
	Range	6.9-8.73	0.06-0.15	0.19-0.75	125-201	24.0-61.8	130-566	13.5-54.5
	Mean	7.93	0.10	0.45	166	41.6	300	29.67
4.	**K.V.B. Puram**							
	Range	6.03-8.62	0.04-0.19	0.15-0.74	38-276	20.6-134	81-585	6.5-58
	Mean	7.71	0.10	0.15	136	52.8	202	29.77
5.	**Vijayapuram**							
	Range	6.04-8.79	0.05-0.45	0.09-0.74	25-201	20.6-154.6	42-365	9.5-50.5

	Mean	7.88	0.12	0.41	101	50.2	150	23.73
6.	**Pichatur**							
	Range	6.83-8.62	0.05-0.3	0.04-0.74	50-238	20.6-154.6	46-286	7.5-59.5
	Mean	7.93	0.12	0.41	112	70.6	164	20.90
7.	**Nagalapuram**							
	Range	4.73-8.31	0.05-0.41	0.04-0.75	25-276	19.5-148.9	51-429	6.0-49.5
	Mean	7.19	0.11	0.32	124	78.6	156	20.56
8.	**Puttur**							
	Range	6.62-9.01	0.06-0.27	0.09-0.74	25-288	20.6-113.4	77-408	4.5-55
	Mean	8.22	0.15	0.50	133	46.7	202	20.91
9.	Overall range	4.73-9.40	0.01-0.44	0.01-0.75	25-326	19.47-206.1	42-585	0.5-59.5
10.	Overall mean	7.83	0.11	0.42	120	59.7	186	26.42
11.	C.V. (%)	8.75	48.79	48.76	45.54	56.80	55.86	55.31

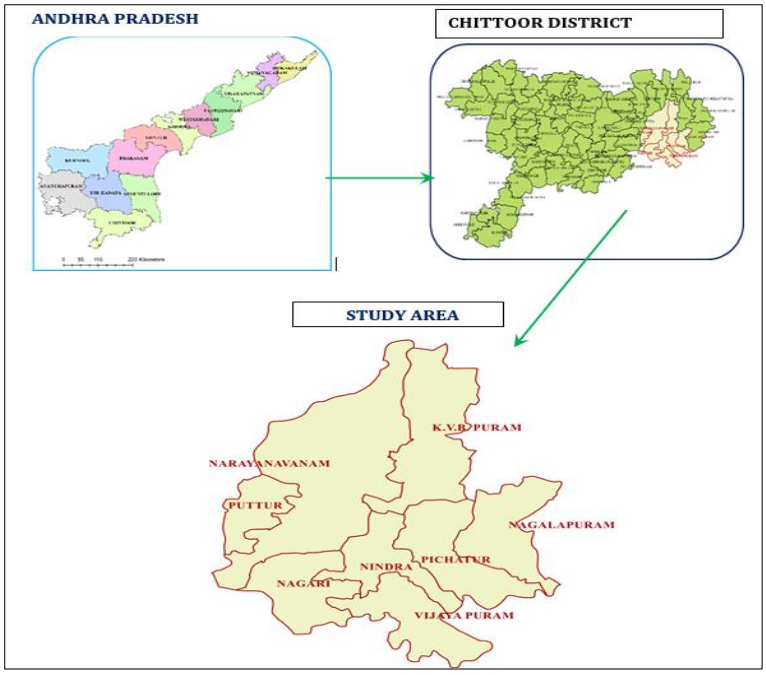

Fig 1: Location map of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

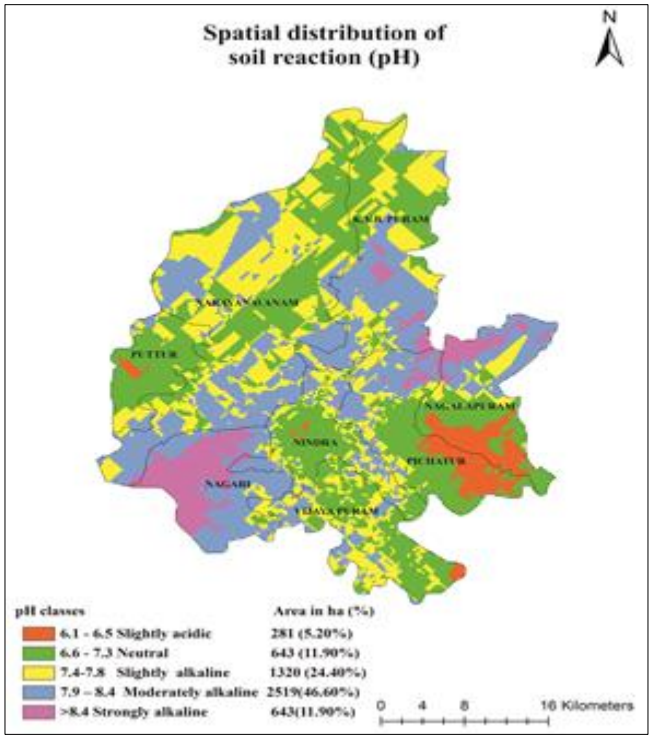

Fig 2: Soil reaction (pH) in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

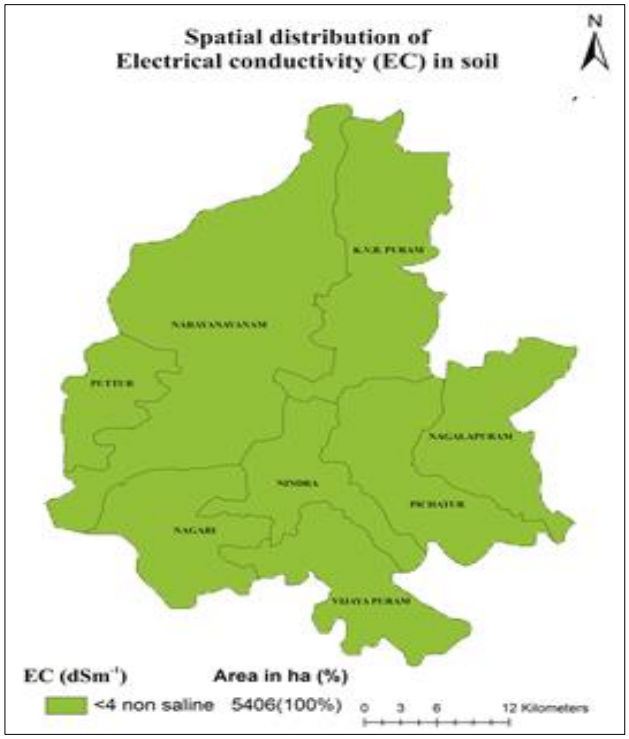

Fig 3: Electrical conductivity (EC) in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

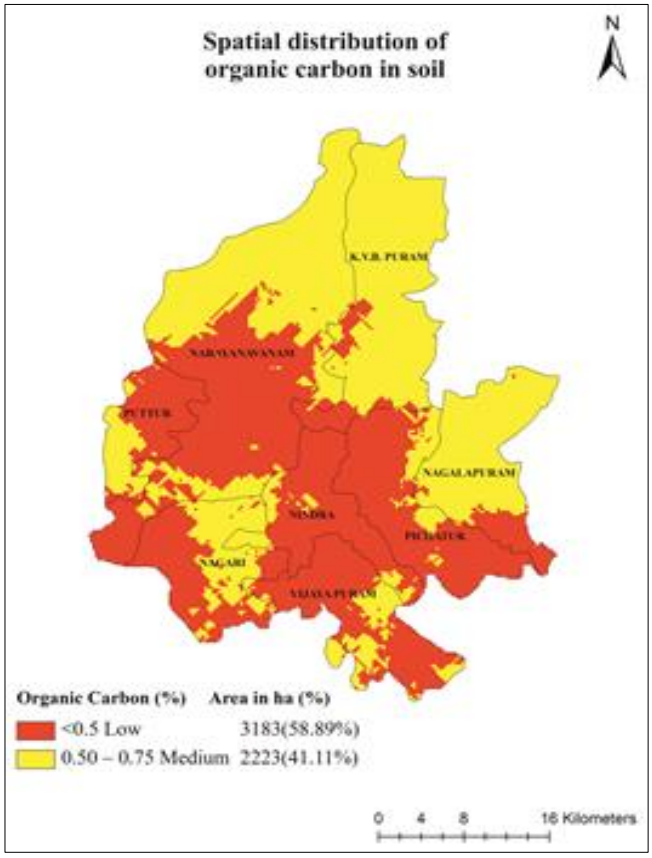

Fig 4: Status of organic carbon in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

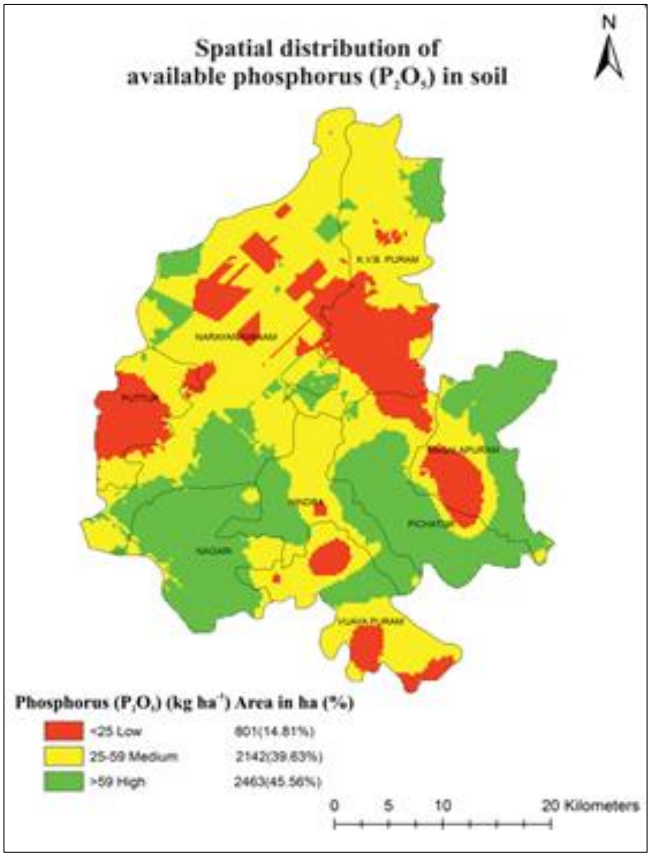

Fig 6: Phosphorus status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

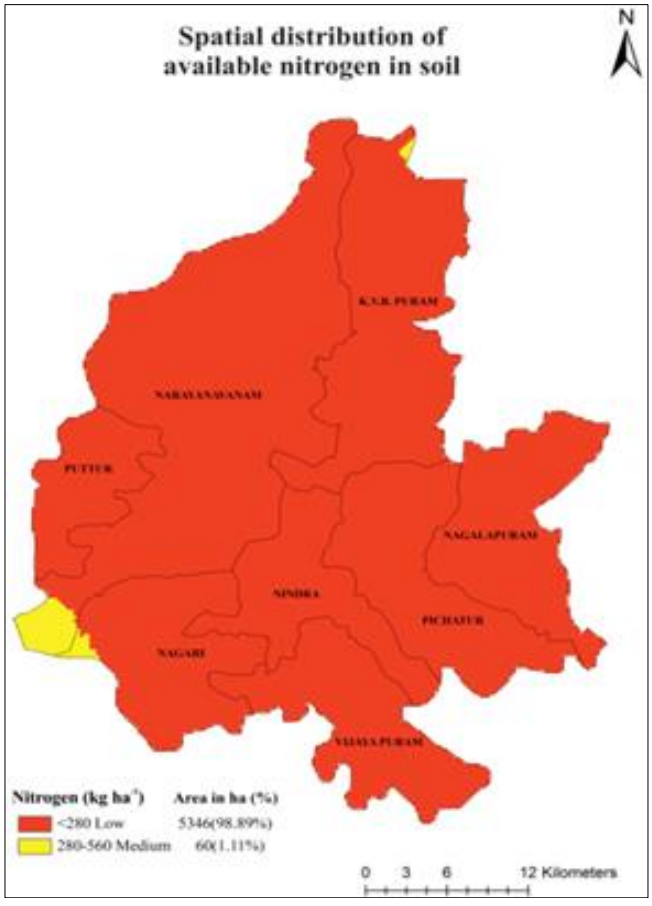

Fig 5: Nitrogen status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

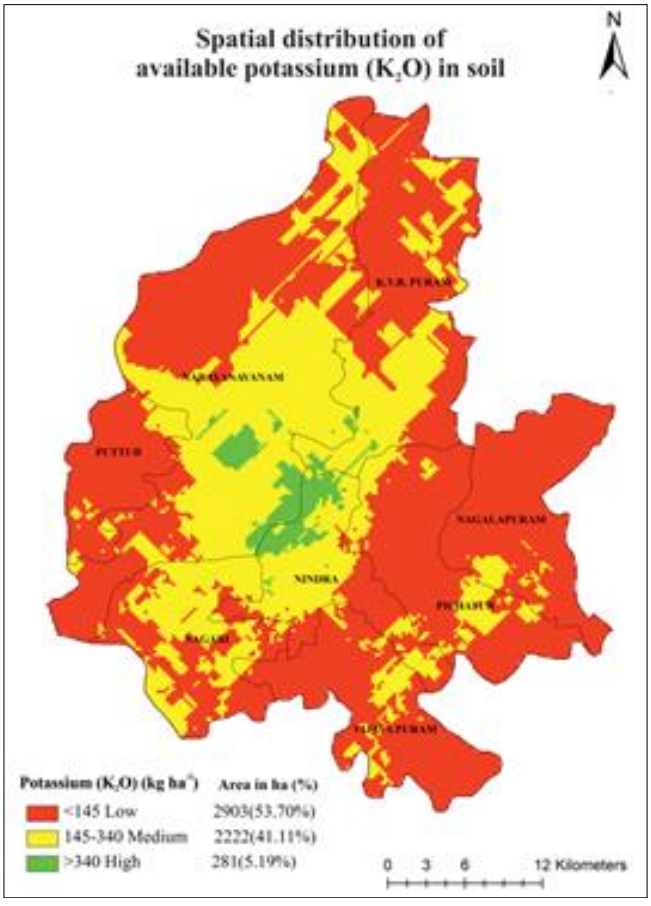

Fig 7: Potassium status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

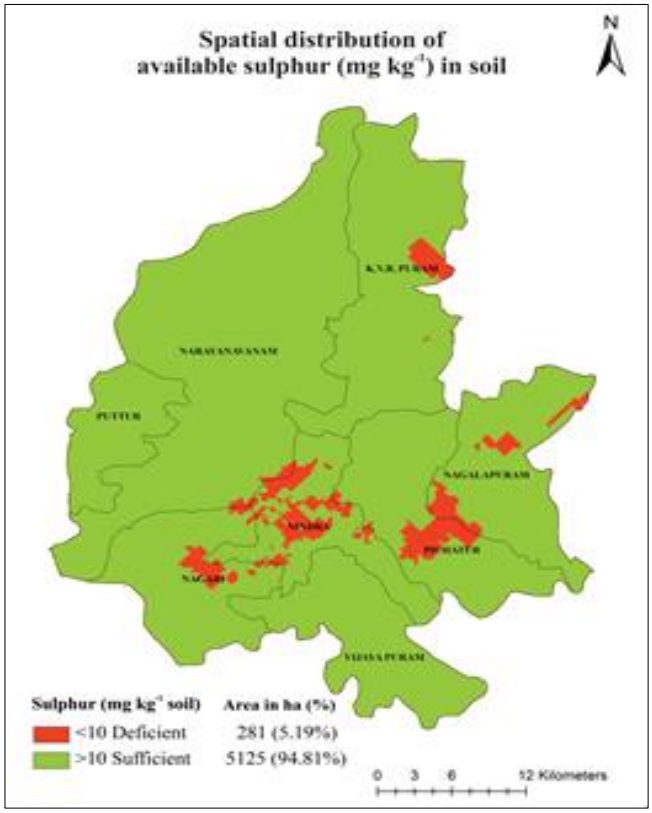

Fig 8: Sulphur status in sugarcane growing soils of various mandals in Prudential sugar factory zone of Chittoor district in Andhra Pradesh

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