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GIS-Aided Mapping of Macronutrients in the Rice Growing Soils of Karimnagar District in Telangana State, India

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ABSTRACT

A systematic set of geo-referenced 154 soil samples were collected from the Karimnagar district, Telangana state, India, covering the entire rice growing area using GPS (Global positioning system) and the maps showing the spatial variability of individual macronutrients (N, P, K and S) were generated using Arc-info GIS (Geographic information system). The soil samples were analysed for physico-chemical properties and available macronutrients. The available N status ranged from 119.17-784.0 kg ha^{-1} while the available P, K and S status varied from 12.61-88.46 kg ha^{-1}, 105.68-754.4 kg ha^{-1} and 5.85-75.5 mg kg^{-1} respectively. Analytical results and the GPS data were used for the preparation of thematic map showing spatial distribution of N, P, K and S status, mandal-wise in the district. Locations of soil sampling sites of Karimnagar district were marked on the base map on 1:50,000 scale prepared from state revenue maps and digitized using Arc-info GIS. The delineation study clearly indicated that the available N was found to be low in 61.7% of soil samples of Karimnagar district, while phosphorus is in medium status. Nearly 33.8 and 62% of the surface soils were medium and high in available K, respectively. Most of rice growing soil samples were low (39%) in available sulphur in the district. The GIS-aided thematic maps indicated that 49.73, 11.85 and 24.4% of the total geographical area of Karimnagar district was deficient in the N, P and S, respectively.

INTRODUCTION

Higher yields at balanced fertilization indicate better use efficiency of the natural resource land and energy, in the form of fertilizers and transport. It also protects the environment by better utilization of the applied nutrients. Balanced use of plant nutrients corrects nutrient deficiency, improves soil fertility, increases nutrient use efficiency and enhances crop yield and environmental quality. It is also necessary to improve the economics or profitability of fertilizer use. Nutrient imbalances in soil could be due to decreased recycling of crop residues and limited use of animal manures (Setia & Sharma 2004). Scientific advances including the global positioning system (GPS), geographic information system (GIS), inductively coupled plasma (ICP) spectrometry and geostatistics, facilitate soil nutrient mapping and provide quantitative support for decision and policy making to improve agricultural approaches to balanced nutrition and precision agriculture (White & Zasoski 1999).

With the invent of modern technologies like global positioning system (GPS), geographic information system (GIS), there is a need to develop spatial data of soil nutrient status. Introduction of scientific tools and techniques like remote sensing, GPS and GIS are essential for holistic analysis of a whole gamut of resources and quick retrieval of the data (Sharma 2004). This will also help in monitoring changes in soil nutrient status over a period of time. It can be revisited with the help of GPS, which is otherwise not possible in the random sampling.

GPS provides real time, continuous, available economic and very precise positioning technique and useful for the establishment of geodetic control survey, i.e. location of precise control points, geodynamic surveys, monitoring mass movements and geo-physical and cadastral surveys (Guo et al. 2002). The GPS can be effectively used in conducting surveys for updating the existing base maps and mapping the extent of spread of deficiency of nutrients in the soil (Sood et al. 2004). Keeping these in view, the present study was conducted during the year 2010 to diagnose macronutrient related constraints to productivity by assessing macronutrient status and their spatial variability in soils.

STUDY AREA

The Karimnagar district forming a part of southern plateau hills region, is located in the Northern Telangana Zone and situated between latitude 18°09'-19°01' and longitude 78°18'-80°15' with an area of 1182300 ha. Paddy during the 2010-11 rabi season was cultivated in 2.12 lakh hec-

tares against the normal area of 1.38 lakh hectares during the rabi season. The soils of Karimnagar district are highly heterogeneous in nature. The major soil types in this district are black soils (55%) and red sandy loam soils (45%). The rice is the predominant. Karimnagar district, epicentre of the Telangana statehood movement, is all set to become the rice bowl of the new State of Telangana with a record paddy production in the district during this rabi season. Karimnagar district has been steadily increasing its paddy production over the years since 2006 and competing with the districts of East and West Godavari and Krishna. In Karimnagar district, farmers are getting a good yield of paddy due to good drainage system, where water is aerated quickly in the fields, compared to the waterlogged fields in Andhra region. Farmers in the district are reaping yield of anywhere between 35 and 45 bags of paddy per acre of land. Currently, only 50 per cent of the area is paddy cultivated under the command areas of Sriramsagar project, and remaining is done through 3.5 lakh agricultural pumps in the district. If the Sripada Yellampalli project, Mid Manair Dam (MMD) reservoir, SRSP flood flow canal and other projects are completed, the irrigation scenario of the district would completely change with an increase in cultivation area and different varieties of crops.

MATERIALS AND METHODS

Collection of the soil samples: Totally 154 geo-referenced surface soil samples covering all the mandals in rice growing area of Karimnagar district were collected randomly at 0-15 cm depth by adopting the standard procedures of soil sample collection. The GPS data (Latitude °N and Longitude °E) were collected from each sampling site distributed over the entire Karimnagar district by using Garmin GPS 76CS model. The collected soil samples were dried, ground, sieved (2 mm sieve) and analysed for the soil pH in 1:2 soil: water suspension, using pH meter. Electrical conductivity was determined in 1:2 soils: water supernatant solutions with the help of a conductivity bridge. Organic carbon was determined by Walkley and Black method using diphenylamine indicator (Walkley & Black 1934), available N by alkaline $KMNO_4$ method (Subbaiah & Asija 1956), available P by Olsen method (Olsen et al. 1954), available K by NN NH_4OAC method using flame photometer (Jackson 1973), and available sulphur was extracted with 0.15 % $CaCl_2$ and measured by turbidity method using spectrophotometer (Williams & Steinbergs 1959).

Generation of soil maps: Karimnagar district map (1:50,000) was vectorised by using Raster to Vector software (R_2V) and then exported into Arc-GIS software. The thematic maps on distribution of the micro and macronutrients was generated by ordinary krigging module available in the submode of interpolation in the spatial analyst tools of Arc-info GIS (9.2) software. Database on soil available macronutrients and sulphur status of the study area was developed using Microsoft Excel package. The database was exported to Arc-GIS software and the thematic maps on available macronutrients status were generated. Since rice mask was not prepared, hence, the entire district was taken into consideration for map generation.

Locations of soil sampling sites of Karimnagar district were marked on base map on 1:50,000 scale prepared from State Revenue Maps and digitized using Arc-info GIS (9.2). Each soil sample was categorized into low, medium and high categories based on the ratings of available micronutrients (Bhupal Raj et al. 2009).

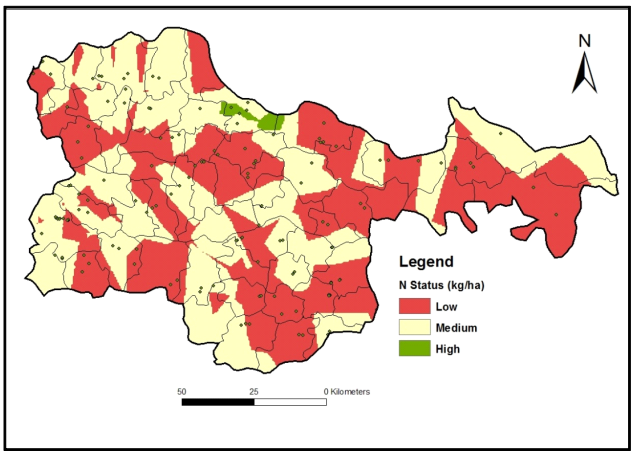

Fig. 1: Nitrogen status of the Karimnagar district soils.

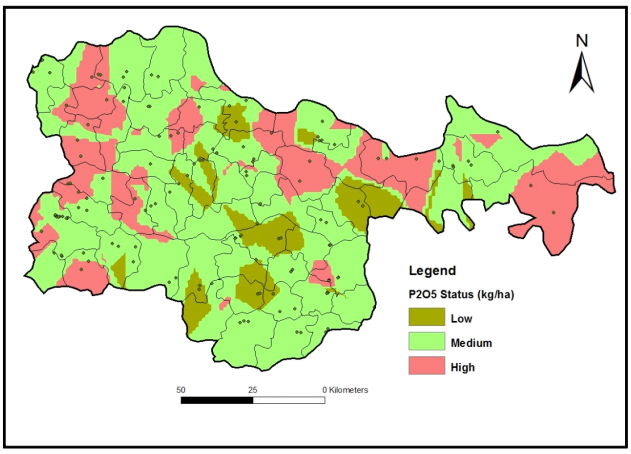

Fig. 2: Phosphorus status of the Karimnagar district soils.

RESULTS AND DISCUSSION

Soil properties in the selected fields were studied by taking samples at depths of 0-15 cm. Soil samples collected from each field separately were analysed for pH, EC, organic carbon, available N, P, K and S. The data pertaining to the fertility status of Karimnagar district are presented in Table 1 and Figs. 1 to 4.

The soils of Karimnagar district were neutral to slightly alkaline in reaction. It ranged from 6.56 to 8.33 with an overall mean value of 7.59. Least pH was recorded in Mallapur mandal (7.2) and highest pH was recorded in Mahadevpur mandal (8.09) of surface soils. The EC of 1: 2.5 soil water extract ranged between 0.02 and 1.38 dSm^{-1} with an overall mean value of 0.39 dSm^{-1} in the soils of Karimnagar district and the soils were non-saline. Highest EC was recorded in Husnabad mandal (0.16) and least was in Darmaram mandal (0.92). The organic carbon content ranged between 0.24 and 2.43% with an overall mean value of 1.00% in rice growing soils of Karimnagar district. Highest mean organic carbon was recorded in Korutla mandal (2.32%), and least in Julapally mandal (0.43%).

The available N in soils under study in Karimnagar district, ranged between 119.17 kg ha^{-1} and 784.00 kg ha^{-1} with an overall mean value of 293.25 kg ha^{-1}. Most of the soil samples were deficient in N, i.e. 61.7% of the 154 soil samples collected in the district. The rice growing soil samples were 34.41 and 3.25% falling under medium (280-560 kg ha^{-1}) and high (>560 kg ha^{-1}), respectively. The available nitrogen content was lowest (193.09 kg ha^{-1}) in Kamanpur mandal and highest (784.0 kg ha^{-1}) in Gollapally mandal. Out of 54 mandals in the district, the available nitrogen was low in soil samples of 27 mandals. The low content of organic carbon in soils resulted in low N status. Kaleeswari et al. (2012) reported nearly 34% of the surface soils of K. Myladumparai block in Theni district of Tamil Nadu state was medium in the available N and Madhavi et al. (2013) also reported that all mandals had low to medium nitrogen content with a mean value of 246.39 kg ha^{-1}, and variations in nitrogen status were mapped under GIS environment.

Available phosphorus content in soils of Karimnagar district varied from 9.63 kg ha^{-1} to 137.31 kg ha^{-1} with an overall mean value of 43.94 kg P_2O_5 ha^{-1}. The soil samples were 22.1% low in available phosphorus out of the 154 rice growing soil samples collected. Most of the samples were falling under medium (52%) to high (25.32%) in range. The available P recorded was least (12.61 kg P_2O_5 ha^{-1}) in Chigurumamidi mandal and was highest (88.46 kg P_2O_5 ha^{-1}) in Vemulawada mandal. The phosphorus status of soils was low in five mandals (mandals 9, 18, 36, 45 and 54) having less than 22.5 kg P_2O_5 ha^{-1} and medium in thirty five mandals having available P_2O_5 between 22.5 and 56 kg ha^{-1} with neutral pH (mean pH value: 7.59). Bali et al. (2010) showed that the available P content varied from 1.12 to 238 kg P ha^{-1}, however, 36.4% and 17.83% area of soils as low and medium, respectively, in available P, in Punjab state.

Available potassium content ranged between 105.68 and 754.42 kg ha^{-1} with an overall mean value of 331.96 kg K_2O ha^{-1}. Out of the 154 soil samples collected in the district, only 4.5% samples were low range, whereas most of the soil samples were medium (61.7%) to high (33.8%). Available potassium status in the soils was medium to high in all mandals expect in Gollapally mandal, which is having available potassium (107.52 kg K_2O ha^{-1}) falling under low category (Table 1 and Fig. 3). Madhavi et al. (2013) found that available K_2O content of soils ranged from 300 to 563 kg ha^{-1} and these soils had low to medium level of potassium

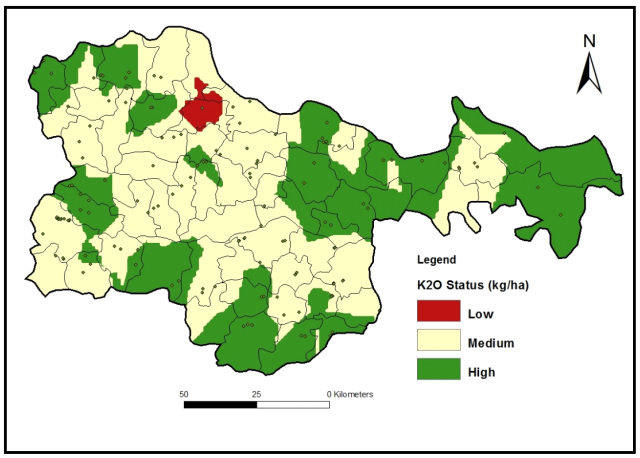

Fig. 3: Potassium status of the Karimnagar district soils.

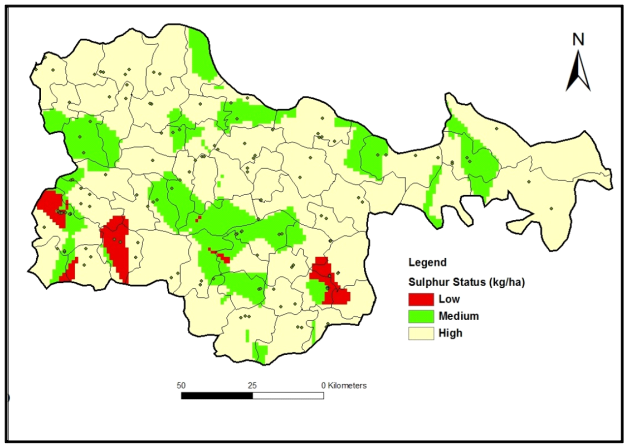

Fig. 4: Sulpur status of the Karimnagar district soils.

Table 1: Range and mean (in parenthesis) values of soil properties, available major nutrients and sulphur in different mandals of Karimnagar District.

Mandal	pH	EC (dsm^{-1})	OC (%)	N	P_2O_5 kg ha^{-1}	K_2O	S (mg kg^{-1})
Yellareddypet	7.16-7.76 (7.47)	0.43-1.19 (0.61)	1.1-2.05 (1.58)	200.6-476.32 (320.99)	20.48-73.1 (43.10)	160.8-457.52 (262.95)	5.85-18.5 (11.34)
Musthabad	7.36-7.46 (7.41)	0.27-0.34 (0.31)	1.54-1.89 (1.70)	200.5-250.8 (225.69)	40.99-91.16 (59.28)	230.80-370.0 (309.31)	12.30-36.20 (25.66)
Gambhiraopet	7.23-7.43 (7.32)	0.32-1.21 (0.56)	1.89-2.19 (2.04)	269.34-570.9 (392.13)	39.2-76.54 (54.47)	176.18-291.44 (220.41)	16.5-74.35 (35.34)
Sirsilla	7.17-7.71 (7.53)	0.42-0.52 (0.46)	1.46-2.38 (1.83)	228.5-354.5 (290.3)	14.33-70.56 (50.25)	192.28-293.62 (256.15)	6.5-43.5 (19.33)
Vemulawada	7.58 -7.86 (7.72)	0.02-0.75 (0.39)	1.35-2.43 (1.89)	216.03-390.94 (303.48)	85.53-91.39 (88.46)	168.16-261.96 (215.06)	34.0-45.5 (39.75)
Koratla	7.15-7.63 (7.43)	0.32-0.96 (0.82)	0.62-2.54 (2.32)	259.3-4678.3 (458.6)	20.2-89.6 (87.87)	135.6-302.5 (296.3)	12.4-48.7 (43.0)
Metpally	7.42-7.86 (7.76)	0.48-0.83 (0.78)	0.22-0.63 (0.57)	220.1-255.3 (247.39)	42.5-77.56 (68.59)	110.3-211.5 (197.64)	7.61-34.6 (31.50)
Kathalapur	7.38-7.63 (7.64)	0.32-0.54 (0.66)	0.3-1.35 (1.59)	170.3-225.7 (204.34)	38.97-81.15 (64.2)	123.1-232.48 (177.71)	8.5-16.5 (38.08)
Manakondur	7.16-7.34 (7.25)	0.15-0.47 (0.31)	0.77-1.34 (1.10)	200.7-312.6 (264.30)	15.55-23.2 (18.92)	192.44-275.36 (246.66)	6.0-18.5 (12.23)
Chandurthi	7.71-7.81 (7.76)	0.26-0.38 (0.32)	1.13-1.43 (1.28)	266.2-681.88 (474.04)	35.74-27.32 (31.53)	201.66-309.7 (255.68)	16.0-55.5 (35.75)
Mallapur	6.60-8.05 (7.28)	0.21-0.36 (0.29)	0.46-1.34 (0.94)	206.0-412.6 (280.99)	47.74-69.88 (73.81)	213.72-474.86 (334.24)	29.5-75.5 (55.75)
Veenavanka	7.5-7.76 (7.63)	0.17-0.53 (0.35)	1.2-1.42 (1.20)	281.8-466.2 (374.0)	51.64-52.64 (52.14)	185.58-268.16 (226.87)	27.41-46.31 (36.86)
Jamikunta	7.47-7.65 (7.54)	0.26-0.75 (0.44)	0.24-1.46 (0.89)	181.8-268.9 (236.94)	37.53-90.1 (83.48)	133.82-225.6 (172.17)	5.85-36.54 (22.19)
Hujrabad	7.5-7.64 (7.58)	0.38-0.92 (0.74)	0.68-1.12 (0.83)	234.84-259.5 (246.51)	12.03-35.61 (26.18)	198.98-403.0 (312.38)	6.05-12.8 (10.33)
Bejanki	7.31-7.71 (7.48)	0.22-0.84 (0.39)	0.35-1.10 (0.64)	250.5-439.04 (317.73)	13.66-70.11 (30.02)	172.18-339.18 (265.95)	10.5-36.2 (19.04)
Ellanthakunta	7.45-8.11 (7.82)	0.14-0.48 (0.27)	0.52-1.05 (0.71)	225.79-275.96 (255.98)	18.51-34.72 (28.49)	405.68-572.18 (516.23)	12.3-43.0 (27.93)
Koheda	7.26-757 (7.47)	0.25-0.57 (0.43)	0.85-1.51 (1.08)	219.16-225.7 (223.43)	16.88-34.04 (26.23)	185.58-398.98 (287.53)	37.95-74.35 (52.54)
Chigurumamidi	7.06-7.83 (7.51)	0.15-0.5 (0.34)	0.81-1.20 (0.99)	225.79-286.2 (246.03)	10.52-15.68 (12.61)	254.42-422.26 (348.45)	7.5-43.5 (22.50)
Husnnabad	7.29-7.81 (7.60)	0.04-0.36 (0.16)	0.65-1.53 (1.11)	225.7-488.16 (325.76)	21.95-55.55 (44.27)	463.8-577.54 (539.18)	14.91-36.91 (25.62)
Beemdevarapally	7.9-7.92 (7.91)	0.19-0.26 (0.22)	0.69-1.15 (0.92)	188.16-238.3 (213.23)	22.35-50.4 (36.37)	335.16-406.18 (370.67)	8.34-64.31 (36.32)
Yelakathurthi	7.5-8.25 (7.88)	0.22-1.37 (0.80)	1.14-1.22 (1.18)	264.0-507.1 (385.55)	26.14-30.91 (28.52)	272.18-572.18 (422.18)	28.0-71.0 (49.50)
Kheshavapatnam	7.4-7.77 (7.59)	0.15-0.17 (0.16)	0.36-1.53 (0.95)	265.4-313.36 (289.38)	25.1-50.62 (37.86)	243.7-300.32 (272.01)	41.67-52.3 (46.99)
Saidhapur	7.2-8.01 (7.61)	0.21-0.44 (0.33)	1.2-1.27 (1.24)	230.6-263.07 (246.83)	50.97-53.53 (52.25)	245.88-368.16 (307.02)	46.13-63.91 (55.02)
Kamalapur	7.31-7.68 (7.50)	0.24-0.56 (0.40)	0.39-0.63 (0.57)	118.32-258.9 (213.24)	26.31-45.21 (36.96)	224.37-279.3 (278.88)	29.46-76.4 (73.39)
Sulthanabad	7.52-8.02 (7.88)	0.18-0.28 (0.21)	0.27-1.03 (0.91)	236.8-554.23 (533.12)	33.64-52.31 (41.21)	282.3-320.1 (307.02)	32.5-57.4 (54.33)
Peddaplly	7.86-7.88 (7.77)	0.18-1.17 (0.68)	0.46-0.85 (0.66)	225.79-376.32 (301.05)	70.6-90.94 (80.77)	400.32-581.56 (490.94)	53.48-64.83 (59.16)
Ramagundam	7.78-7.96 (7.87)	0.29-0.19 (0.24)	0.57-0.91 (0.74)	225.79-288.16 (256.97)	22.62-82.38 (52.5)	232.48-431.8 (332.14)	16.87-18.89 (17.88)
Kamanpur	7.41-7.8 (7.61)	0.12-0.59 (0.32)	0.78-1.53 (1.16)	119.17-226.7 (193.09)	19.71-38.08 (28.56)	165.98-404.34 (317.19)	19.33-34.97 (27.84)

Table cont....

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Mutharam (oded)	7.26-7.57 (7.42)	0.15-1.4 (0.18)	0.55-1.4 (0.98)	256.52-338.68 (297.6)	47.0499.68 (73.36)	300.82-468.66 (384.74)	8.43-18.98 (13.71)
Manthani	6.83-8.21 (7.75)	0.17-0.28 (0.23)	0.28-0.79 (0.57)	213.24-519.16 (308.45)	27.1-95.43 (61.59)	293.62-577.54 (438.59)	12.65-51.65 (32.15)
Thadicherlla	6.9-7.85 (7.38)	0.37-0.16 (0.27)	0.6-0.69 (0.65)	213.24-226.79 (220.02)	9.63-70.56 (40.09)	226.78-270.84 (248.81)	20.03-32.68 (26.36)
Kataram	7.66-8.2 (7.93)	0.75-0.81 (0.78)	0.45-1.27 (0.86)	230.8-250.8 (240.80)	16.14-59.36 (37.75)	269.5-373.52 (321.51)	9.49-20.3 (14.90)
Mahadevpur	7.85-8.33 (8.09)	0.4-0.42 (0.41)	0.47-0.56 (0.52)	226.79-377.32 (302.05)	26.74-63.16 (44.95)	340.52-377.54 (359.03)	20.73-30.57 (25.65)
Boinipally	7.81-7.90 (7.86)	0.14-0.45 (0.23)	0.49-0.57 (0.53)	200.7-276.7 (232.73)	13.44-57.79 (35.78)	165.98-267.32 (214.34)	7.5-23.19 (17.42)
Gangadhara	6.96-7.99 (7.62)	0.1-0.33 (0.21)	0.32-0.53 (0.45)	213.24-675.61 (392.45)	20.55-37.63 (26.98)	270.84-369.5 (329.63)	16.5-45.33 (35.11)
Ramadugu	6.63-8.13 (7.74)	0.11-0.27 (0.22)	0.24-0.25 (0.49)	225.79-238-3 (232.04)	18.14-19.71 (18.92)	291.1-470.84 (380.97)	25.3-37.95 (26.27)
Pegadapally	7.5-7.85 (7.67)	0.18-0.45 (0.35)	0.31-0.64 (0.50)	200.7-278.4 (230.78)	12.32-52.19 (37.78)	138.34-204.0 (175.08)	14.67-64.31 (38.63)
Medipally	6.96-7.91 (7.44)	0.1-0.21 (0.16)	0.35-1.21 (0.78)	313.6-580.6 (447.1)	15.0-34.72 (24.86)	247.22-309.7 (278.46)	52.3-63.91 (58.11)
Raikal	6.63-8.13 (7.58)	0.11-0.33 (0.24)	0.45-1.45 (1.03)	213.24-379.75 (295.17)	24.64-49.5 (35.76)	239.18-476.2 (339.46)	53.48-73.39 (60.40)
Sarangapur	7.5-7.59 (7.55)	0.45-0.52 (0.48)	1.12-1.2 (1.16)	225.22-383.84 (304.53)	21.5-31.8 (26.65)	211.54-308.86 (260.2)	34.97-64.83 (49.90)
Dharmapuri	6.93-7.81 (7.64)	0.31-0.46 (0.38)	0.91-1.10 (1.11)	225.78-250.88 (234.15)	12.99-89.15 (62.42)	105.68-330.3 (236.67)	16.87-23.55 (23.21)
Velgatur	7.64-8.15 (7.73)	0.38-0.57 (0.28)	1.12-1.34 (1.33)	286.2-478.9 (382.55)	23.07-39.52 (31.29	237.84-258.44 (248.14)	19.33-33.52 (13.88)
Gollapally	7.65-8.02 (7.81)	0.16-0.19 (0.17)	1.16-1.72 (1.53)	283.2-791.2 (784.0)	13.6-23.5 (19.95)	104.52-132.6 (107.52)	15.46-31.46 (8.43)
Jagtial	7.85-7.89 (7.87)	0.14-0.45 (0.30)	0.61-1.54 (1.08)	237.98-475.16 (356.57)	23.82-62.27 (43.04)	376.2-482.9 (429.55)	41.67-46.13 (43.90)
Malyal	7.81-8.33 (8.01)	0.15-0.4 (0.24)	0.67-1.02 (0.9)	227.79-350.68 (269.39)	35.96-92.73 (60.29)	117.74-209.7 (177.71)	8.34-71.0 (35.78)
Dharmaram	7.6-7.77 (7.55)	0.56-0.92 (0.92)	0.64-1.27 (0.67)	238.23-563.42 (400.82)	16.67-95.95 (56.31)	196.8-272.18 (234.49)	18.98-30.57 (41.11)
Julapally	7.31-7.5 (7.51)	0.92-0.93 (0.55)	0.5-0.69 (0.43)	225.7-225.79 (225.74)	50.19-52.19 (51.4)	139.34-255.26 (197.3)	33.73-51.65 (23.19)
Choppadandi	7.5-7.71 (7.28)	0.17-0.38 (0.32)	0.35-0.64 (0.64)	125.44-295.44 (210.64)	26.73-78.96 (52.84)	281.56-369.5 (325.53)	12.65-32.68 (26.36)
Thimmapur	6.89-8.03 (7.66)	0.12-0.28 (0.20)	0.43-0.67 (0.66)	200.72-461.61 (272.89)	15.32-34.04 (24.93)	181.56-347.72 (271.37)	7.5-43.5 (24.46)
Ibrahimpatnam	7.46-8.0 (7.70)	0.16-1.17 (0.54)	0.28-1.53 (0.87)	138.68-380.19 (302.54)	22.3550.40 (32.08)	589.6-635.16 (612.38)	14.67-45.33 (35.83)
Konaraopet	6.66-8.11 (7.40)	0.14-1.38 (0.24)	0.57-1.53 (1.06)	238.33-437.98 (319.35)	23.53-97.6 (52.06)	572.18-639.18 (592.28)	8.34-71.0 (43.18)
Mutharam	7.77-7.93 (7.55)	0.18-0.40 (0.39)	0.45-1.48 (0.96)	248.1-311.18 (279.64)	32.48-90.94 (61.71)	585.58-722.26 (653.92)	52.3-63.91 (39.505)
Odhela	6.56-7.45 (7.47)	0.07-0.22 (0.31)	0.5-1.2 (1.01)	246.2-250.12 (248.16)	22.62-32.38 (27.5)	668.66-754.42 (711.54)	54.33-73.39 (41.34)
Srirampur	7.47-7.65 (7.51)	0.19-0.41 (0.35)	0.79-1.17 (0.99)	236.1-301.05 (268.57)	19.71-23.96 (21.83)	598.98-678.04 (638.51)	53.48-64.83 (40.42)
Range	6.56-8.33	0.02-1.38	0.24-2.43	119.17 - 784.0	12.61-88.46	105.68 - 754.4	5.85 to 75.5
Over all mean	7.59	0.39	1.00	293.25	43.94	331.96	31.83

content. Nearly 30 and 70% of the surface soils in Theni district of Tamil Nadu State were medium and high, respectively, in available potassium status, as reported by Kaleeswari et al. (2012).

The 0.15% $CaCl_2$ extractable sulphur is ranging widely between 5.85 and 75.5 mg kg^{-1} with an overall mean value of 31.83 mg kg^{-1} in the soils of the district. Most of the rice growing soil samples were low (39%) in available sulphur in the district. However, 30.52 and 30.4% samples were found under medium to high, respectively. And the avail-

Table 2: Area (ha) under different categories of nutrients (N, P, K and S).

Category	Area (ha)			
	N	P_2O_5	K_2O	S
Low	587984.2(49.73)	140052.9(11.85)	20197.18(1.71)	288815(24.43)
Medium	580581.4(49.11)	724408.2(61.27)	647794.6(54.79)	463780.8(39.23)
High	13734.37(1.16)	317838.9(26.88)	514308.2(43.50)	429704.2(36.34)

Note: Figures in parentheses are the percentage of the total geographical area of the district

able sulphur recorded in the soils was least (10.33 mg kg^{-1}) in Hujrabad mandal, and was higher (73.39 mg kg^{-1}) in Kamalapur mandal. Available sulphur status of soils in all the 54 mandals of the district was above the critical level of 20 mg kg^{-1} soil. Low and medium level of available sulphur in soils of the area may be due to the lack of sulphur addition and continuous removal of sulphur by crops (Pulakeshi et al. 2012).

GIS-aided mapping of macronutrients (N, P, K and S): In the present investigation based on GIS-aided mapping, 61.7% samples were found to be deficient in available nitrogen which covered 49.73% (587984.24 ha) of the geographical area of the district, whereas, 580581 ha area was medium (49.11%) with respect to N availability (Table 2). The spatial distribution of phosphorus in the study area indicated that 11.85% (140053 ha), 61.27% (724408 ha) and 26.88% (317839 ha) of area of the district was having low, medium and high respectively (Table 2 and Fig. 2). Spatially, small area 20197 ha (1.71%) of Karimnagar district was deficient in available potassium (Table 2).

CONCLUSIONS

From the study, it can be concluded that, rice growing soils of Karimnagar district in the Northern Telangana zone of Telangana state were neutral to slightly alkaline in reaction with non-saline low to high in soil organic matter content. Available nitrogen was low to medium, phosphorus and sulphur were low to high and available potassium was medium to high. Soil organic matter, available N, P, K and S were important soil fertility constraints indicating their immediate attention for sustained crop production. The GIS-aided thematic maps indicated that 49.73, 11.85 and 24.4% of the total geographical area of Karimnagar district was deficient by the N, P and S, respectively. Spatially major portion of the study area (647795 ha) in Karimnagar district had medium category (54.79%) of available K.

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