Assessment of soil fertility through GIS techniques and thematic mapping in rice growing areas of Jagtial district in Telangana state, India

ABSTRACT

Survey was conducted in Jagtial district of Telangana state to identify the soil fertility status of rice growing areas. Soil fertility is one of the major limiting factor for maintaining sustainability in crop yields. Totally 90 surface soil samples collected from the selected rice cultivated farmers' field. Collected soil samples were tested for texture, pH, EC, organic carbon, available N, P, K and S in order to identify the nutrient status in soils and develop the corrective measures. The soil fertility maps generated through Global Positioning System (GPS) and Arc Geographic Information System (GIS) software to formulate balanced fertilizer recommendations and to understand the spatial variability of nutrients in soil. Survey results showed that the sand was ranged from 44 to 80% and that of silt was 3 to 20 % while the range of clay was 13 to 42% and varied three textural classes viz., sandy clay loam, sandy loam and loamy sand. Soil pH was neutral to slightly alkaline (6.8 to 8.2), electrical conductivity rated as non-saline (0.23 to 0.69 dS m^{-1}), organic carbon was low-medium (0.3 to 0.6%), available-N was low (101 to 195 kg ha^{-1}), available-P was high (26.8 to 61.5 kg ha^{-1}), available-K was medium to high (120 to 449 kg ha^{-1}) and available-S was medium to high (10.0 to 26.8 mg kg^{-1}). Among these organic carbon (%) and available-N were important constraints in soil fertility in rice growing areas of Jagtial district of Telangana state.

Key words: Soil Fertility map, Nutrient status, GIS-GPS, Kriging, Interpolation and Rice.

1. INTRODUCTION

"India covers 2.4 % of land area of the world and 4% of freshwater resources. While the cultivated land has continued to remain steady at 141±2 million hectares (Mha) for last more than two decades, the per capita arable land is expected to shrink to 0.08 ha by 2025 from 0.34 ha in 1950-51. Around 120.8 Mha of land in the country suffers from various forms of degradation such as soil erosion, salinity/alkalinity, soil acidity, waterlogging, inappropriate nutrient management practices, and other complex problems" [1]. "About 5.34

giga (billion) tonnes (Gt) of soil is eroded annually at an average rate of 16.3 t ha^{-1} yr^{-1}. Imbalanced nutrient use in Indian agriculture has been responsible for poor crop yields and deterioration of soil health/fertility. Indian agriculture operates under the negative balance (between removal and addition) of about 10 million tonnes (Mt) (NPK yr^{-1}). Soils suffer from a myriad of nutrient deficiencies whose extent is to the tune of 89% for N, 80% for P, 50% for K, 41% for S, 43.4% for Zn, 20.6% for B, 14.4% for Fe, 13% for Mo, 7.9% for Mn, and 6.1% for Cu" [2,3]. "To tackle these drawbacks, central and state governments of the country initiated the Soil Health Card Scheme under "National Mission for Sustainable Agriculture (NMSA) and led to a decline of 8-10% in use of chemical fertilizers and raised the productivity of 5-6% as per the study conducted by the National Productivity Council (NPC)" [4].

"Rice (*Oryza sativa* L.) is the staple food crop of the world after wheat. India ranks second after China with rice production of 130.29 Mt and productivity of 2.81 t ha^{-1} from an area of 46.38 M ha. Telangana State rice production is 12.3 Mt with a productivity of 3.36 t ha^{-1} from an area of 3.65 M ha" [5]. "Among the Indian states, Telangana and Andhra Pradesh are the most vulnerable in terms of soil erosion and occupied second and third places accounting for nearly 40 and 42% of the total geographical area being eroded by water" [6].

In order to determine whether a soil is able to supply nutrients that are available to plants, or whether the soil is deficient in these nutrients, soil tests are frequently used. This information is used to further assessment of nutritional sufficiency/deficiency of the soil-plant system and to develop corrective measures [7]. Preset investigation was carried out to determine the nutritional limitations and nutrient status in rice growing areas in Jagtial district of Telangana State.

2. MATERIALS AND METHODS

Description of survey location and survey work

The survey work was carried out in Jagtial district, Telangana State, after harvest of rice crop during *kharif*, 2022 during the month of November. Jagtial district is geographically located at 18.7895° North latitude and 78.9120° East longitude and area of 2419 sq. km (fig.1). Its elevation is 258 m above mean sea level. Net cropped area of Jagtial district was 96.05 ha in *kharif*, 2022. The climate of Jagtial district is extreme and on an average these experience monsoon variety of climate. Summer season is intensely hot and winter is cold. The major soil types of Jagtial district are red clay soils (46.5%), red shallow loamy soils (10.9%), deep calcareous black soils (8%) and medium calcareous soils (7.1%). The total normal rainfall and actual rainfall of region are 878 mm and 1655 mm, respectively. Average minimum and maximum temperature of the year of study was 20.7°C and 33.2°C, respectively.

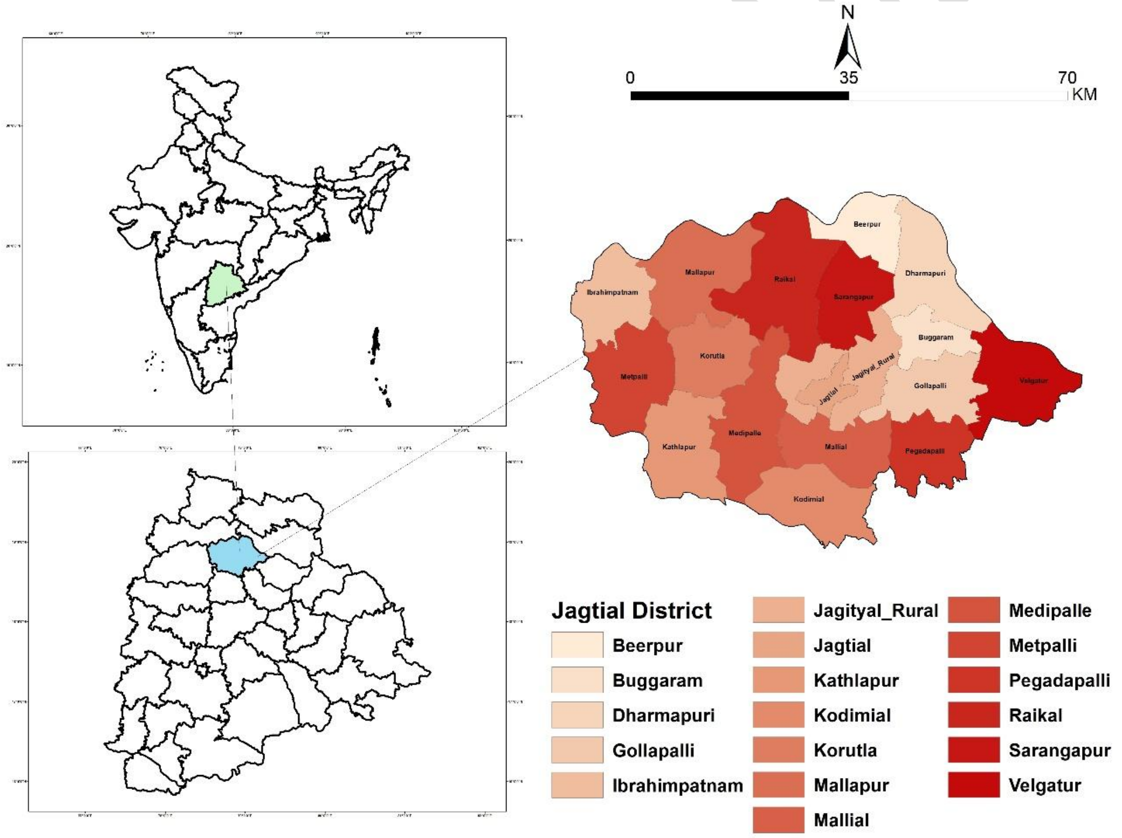

Figure 1: Location map of the study areas.

Sample collection

A survey was carried out systematically using field sampling techniques. Totally 90 representative soil samples (0-15 cm depth) were collected as five samples for each mandal by covering 18 mandals of Jagtial district along with GPS coordinates (Fig.2). All necessary precautions followed while collecting soil samples. Soil samples were taken from 4 to 5 locations in each field (based on size of the field) in a zig-zag pattern. These samples were combined to make a composite sample and extra soil was removed using the quartering method. Finally, 0.5 kg of composite samples from each sampling field was obtained.

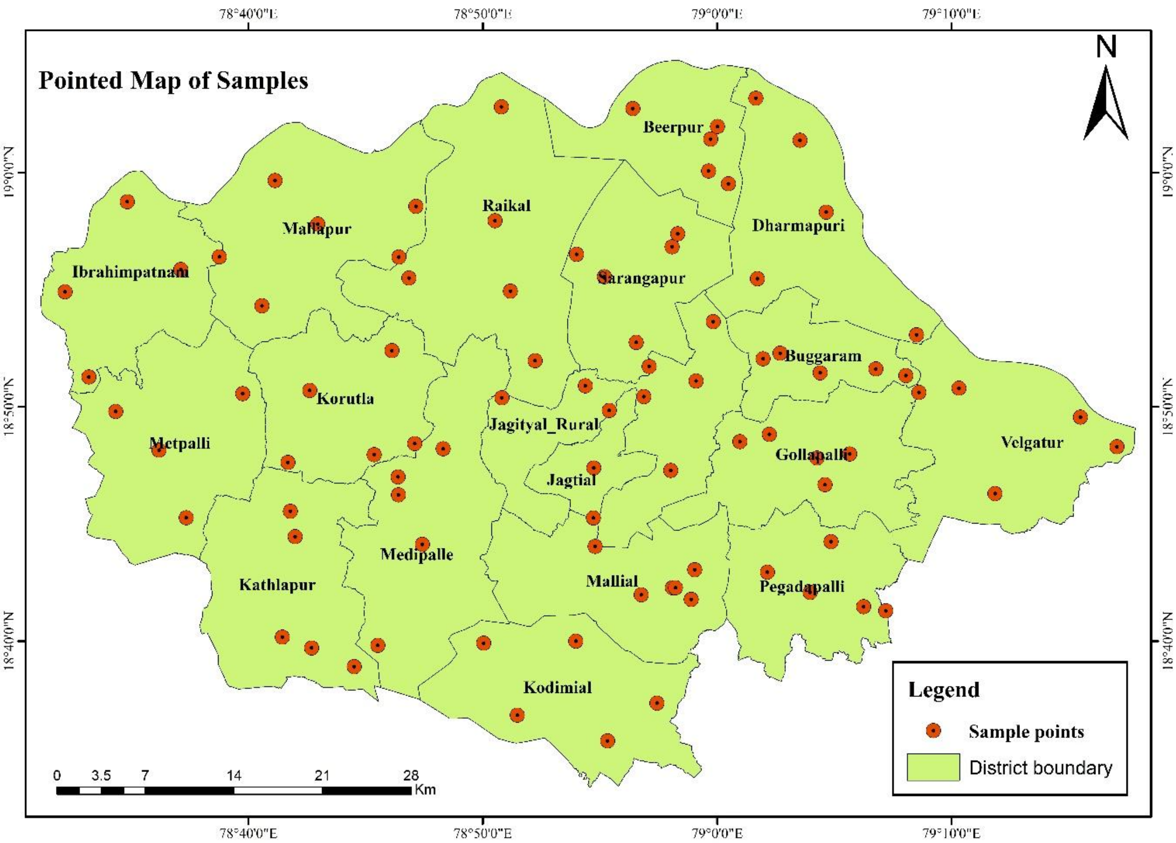

Figure 2: Location of soil sample points in rice growing areas of Jagtial district.

Laboratory analysis

All the collected soil samples were air-dried, processed and properly labelled for further analysis of various parameters. The physico-chemical properties (pH and EC) were determined by standard procedures given by Jackson [8], whereas organic carbon content was estimated by wet-oxidation method [9]. “The available nitrogen content was estimated by alkaline permanganate method as per the procedure of Subbaiah and Asija” [10]. Available phosphorus was determined by using sodium bicarbonate (0.5N $NaHCO_3$) extractant at pH 8.5, [11], available potassium was extracted by neutral normal ammonium acetate (1N

CH_3COONH_4) and measured with flame photometer [8] and available Sulphur was determined by using Rayleigh UV Visible Spectrophotometer [12].

Soil Fertility Mapping

A GPS device was used to record the geographic coordinates of each soil sample that was gathered and Arc GIS 10.8 was used to import the geo-coordinates to the base map. For finding and georeferencing the sampling locations in GIS software, the World Geodetic System 1984 (WGS84) reference coordinate system was used (Fig. 2). The data interpolation was done using the Arc toolbox. The kriging interpolation method is based on a regression of the observed Z-value of the point data and the weighted mean according to spatial covariance. The interpolation evaluates the values of variables that are not sampled from ones that are. The soil physicochemical characteristics and latitude and longitude data were imported into Arc GIS to create the base map. To generate the soil fertility maps, the standard Kriging interpolation approach was employed. The thematic soil fertility maps were classified as per the soil analysis results.

Statistical analysis:

Descriptive statistics (mean, range, standard deviation and coefficient of variation) of soil parameters were computed using the Minitab 15 package. The coefficient of variation was ranked according to the procedure of Aweto [13] where, CV ≤ 25% = low variation, CV >25 ≤ 50% = moderate variation, CV >50% = high variation.

3. RESULTS AND DISCUSSION

The soil fertility status in rice growing areas of Jagtial district was evaluated with respect to soil texture, pH, electrical conductivity, organic carbon, available-N, P, K and S.

Table1: Soil fertility status in rice growing areas of Jagtial district.

	Texture			pH	EC	OC	N	P	K	S
	Sand (%)	Silt (%)	Clay (%)		(dS m^{-1})	(%)	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	mg kg^{-1}
Mean	66.5	8.26	25.3	7.42	0.50	0.42	138	45.6	300	15.8
Max	80.0	20.0	42.0	8.25	0.69	0.60	195	61.5	449	26.8
Min	44.0	3.00	13.0	6.80	0.23	0.30	101	26.8	120	10.0
St. Dev	8.48	3.77	6.87	0.39	0.13	0.06	21.9	10.5	98.7	4.76
CV%	12.7	45.6	27.2	5.25	26.7	15.0	15.9	23.1	32.9	30.0

Table 2: Distribution of soil fertility in rice growing areas of Jagtial district.

Soil parameters	Class	Limit	No. of sample	Distribution (%)
Texture	Sandy clay loam	Sand 45-80% Silt 0-28% Clay 20-55%	48	53
	Sandy loam	Sand 43-80% Silt 0-50% Clay 0-20%	38	42
	Loamy sand	Sand 70-90% Silt 0-30% Clay 0-15%	4	5
pH	Acidic Neutral Alkaline	<6.5 6.5-7.5 7.5-8.5	0 57 33	0 63 37
EC (dS m^{-1})	Non saline	0-2	90	100
Organic carbon (%)	Low Medium High	<0.5 0.5-0.75 >0.75	78 12 0	87 13 0
Avail-N (kg ha^{-1})	Low Medium High	<280 280-560 >560	90 0 0	100 0 0
Avail-P (kg ha^{-1})	Low Medium High	<11 11-25.6 >25.6	0 0 90	0 0 100
Avail-K (kg ha^{-1})	Low Medium High	<120 120-280 >280	0 35 55	0 39 61
Avail-S (mg kg^{-1})	Low Medium High	<10 10-15 >15	0 55 35	0 61 39

Soil texture:

"Soil texture affects a number of physical and chemical properties of soils such as infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices" [14]. The soil texture of the study area was predominantly sandy clay loam (53%), while others are sandy loam (42%) and loamy sand (5%) the details are shown in table.2. distribution of soil texture classes in rice growing soils depicted in fig.3.The sand was ranged from 44.0 to 80.0% with a mean of 66.5% and that of silt was 3.00 to 20.0% with a mean of 8.26% while the range of clay (%) was 13.0 to 42.0% with a mean of 25.3% (Table.1). Similar texture classes were found by the researcher [15] in rice growing soils of Jammu Plains. The coefficients of variation between the soil samples were 12.7%, 45.6% and 27.2% for sand, silt and clay, respectively.

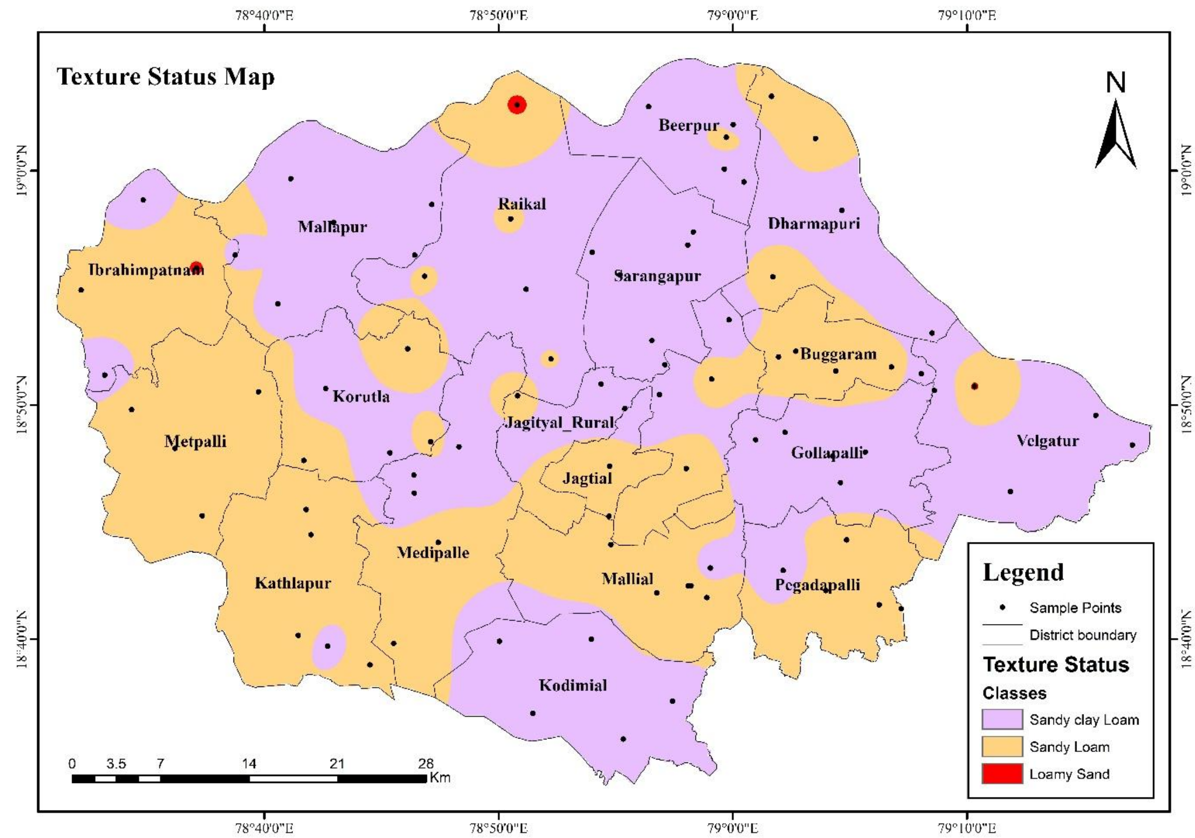

Figure 3: Soil textural status in rice growing areas of Jagtial district.

Soil reaction (pH):

“Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units and has a dominant effect on availability of plant essential nutrients” [16]. For normal growth of rice, a pH range 5.50 to 8.00 is suitable. The pH of soil was ranged from 6.80 to 8.25 with the mean value of 7.42 (Table.1). The results have shown that soil pH of study area was neutral (63%) to slightly alkaline (37%) details shown in table.2. Therefore, observed pH was suitable for rice cultivation in the majority area of the Jagtial district. Soil pH showed low variability (5.25%) in the investigated soils. The high pH value may be due to natural systems like mineralogy, climate, weathering, excess use of basic-forming fertilizers, etc. The soil fertility map showing the variation in soil pH of the study area is depicted in fig.4. Similar results were reported by researcher [17] in rice growing soils of Jagtial district, Telangana state and researcher [18] in rice growing soils of Ballia district (U.P).

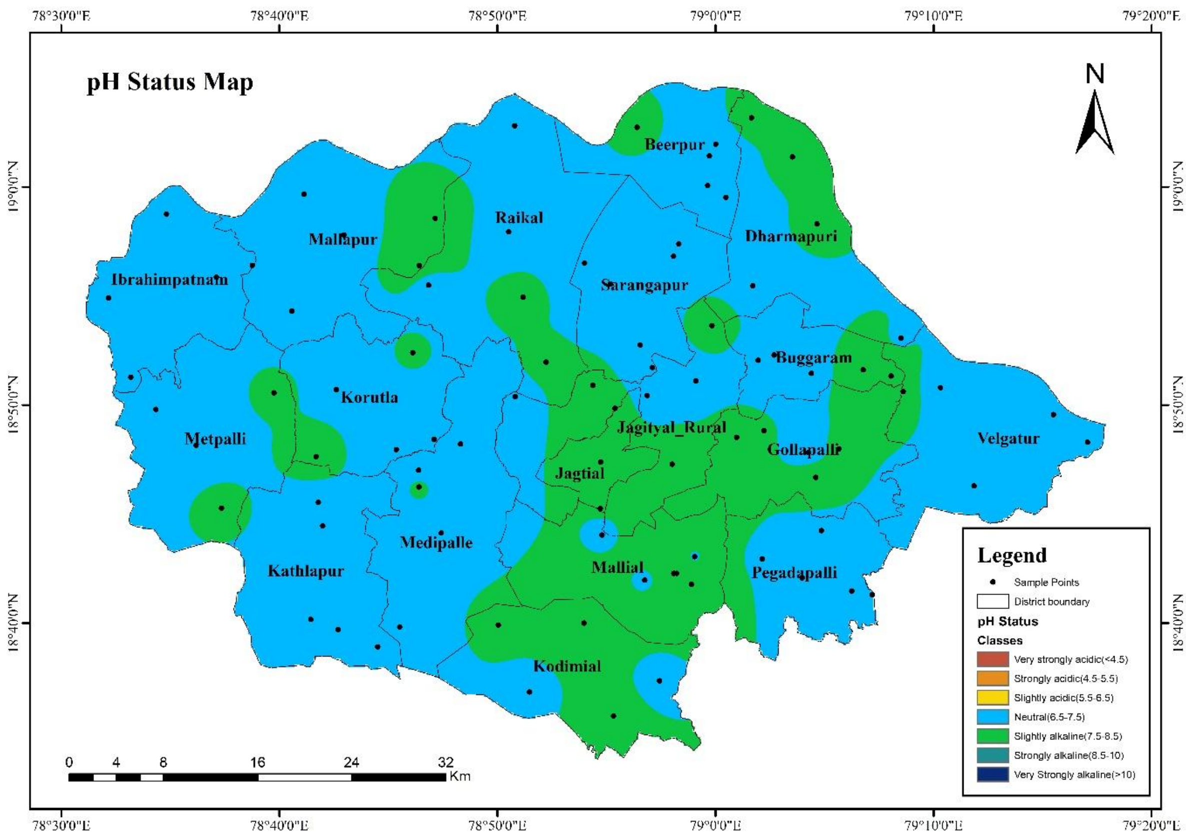

Figure 4: Soil pH status in rice growing areas of Jagtial district.

Electrical conductivity (EC)

"The electrical conductivity (EC), which measures the number of soluble salts in the soil. It is influenced by cropping sequence, irrigation, land usage, and the use of fertilisers such manure and compost. High value of electrical conductivity represents higher degree of salinity. Excessive number of dissolved salts in soil solutions causes hindrance in normal nutrient uptake process either by imbalance of ions uptake, antagonistic effect between nutrients or excessive osmotic potentials of soil solution or a combination of the three effects" [19]. In rice growing areas of Jagtial district the EC was ranged from 0.23 to 0.69 dS m^{-1} with a mean conductivity of 0.50 dS m^{-1} (Table 1). Researcher [20] discovered comparable outcomes in soils from the state of Karnataka. The results showed that all the soils of study area were non saline and suitable for paddy cultivation (Table.2; Fig.5). Soil EC showed moderate variability (26.7%) in the investigated soils.

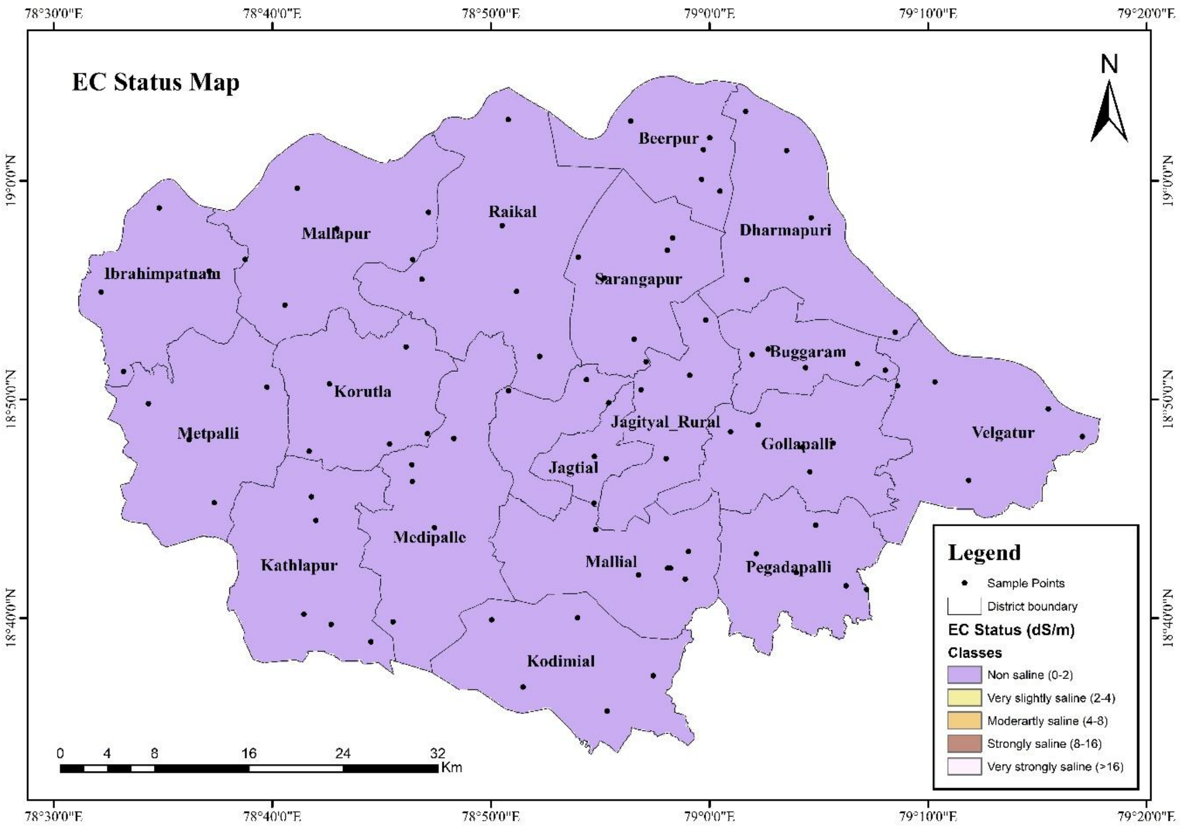

Figure 5: Electrical conductivity of rice growing areas of Jagtial district.

Soil organic carbon (%)

"In agricultural soil, organic matter plays a crucial role. It provides plant nutrients, enhances soil structure, increases water infiltration and retention, feeds the microflora and fauna of the soil, and ensures that applied fertiliser is retained and cycled" [21]. "Organic matter is a complex composition that benefits crop production, soil fertility, soil tilth and overall soil sustainability. It minimizes negative environmental impacts and thus improves soil quality" [22]. The Organic carbon was varied from 0.30 to 0.60% with a mean value of 0.42% (Table.1). However, the distribution of organic carbon content was low (87%) to medium (13%) in the rice growing area of Jagtial district (Table.2). Soil fertility map depicted in fig.6 showing the distribution of soil organic carbon in the study area. Therefore, incorporation of organic matter is important to enrich the organic carbon status in the soils. Organic carbon showed low variability (15.6%) in the investigated area. The majority of the soils in the study area had low levels of organic carbon, which may have been caused by the predominance of arid conditions, which accelerate the degradation of organic matter, along with little or no addition of organic manures and low vegetative cover on the fields, reducing the likelihood of organic carbon accumulation in the soils. Another factor contributing to the low organic carbon concentration in soils is intensive cropping. The investigator [23] in Jagtial district, Telangana state and researcher [18] in rice growing soils in Ballia district, Uttar Pradesh, also observed comparable findings.

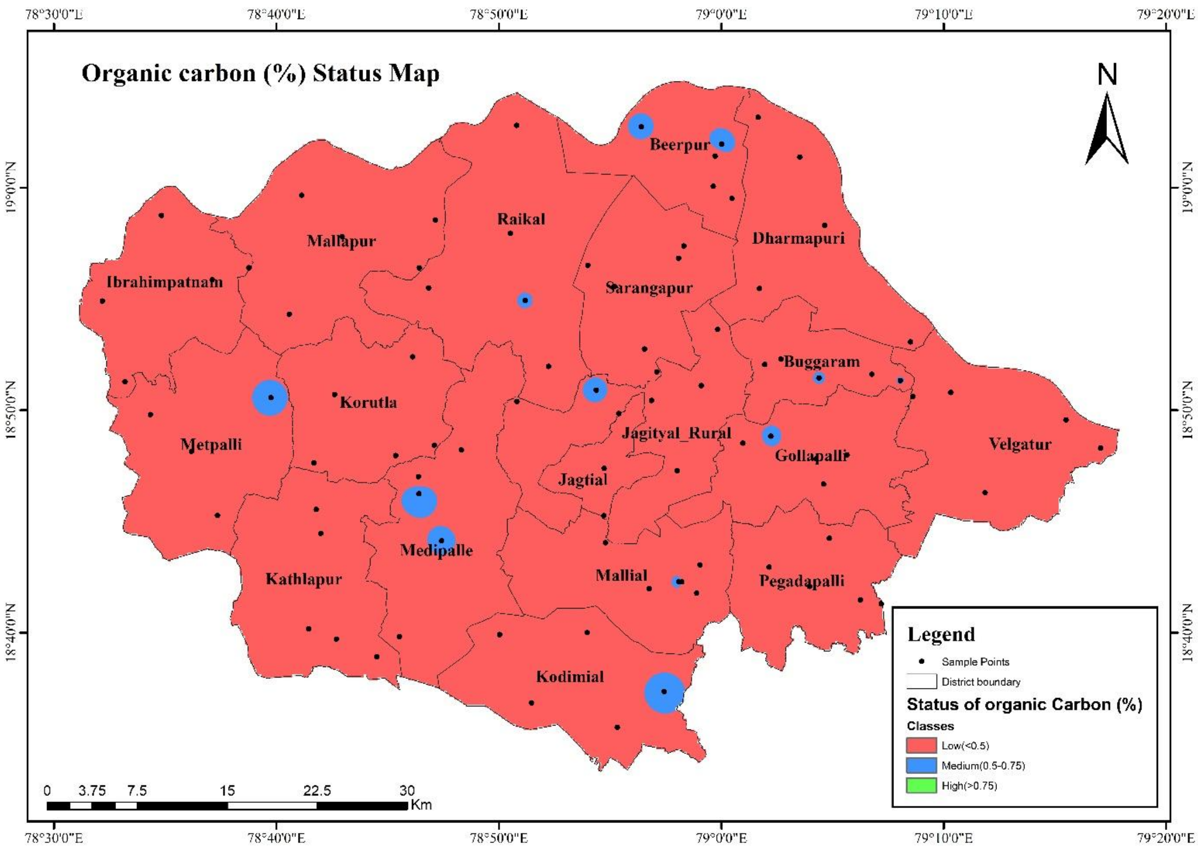

Figure 6: Organic carbon status inrice growing areas of Jagtial district.

Available Nitrogen (kg ha^{-1})

Nitrogen (N) is necessary for the growth of rice and is typically a nutrient that limits yields in the world's irrigated rice production [24]. It is pivotal in yield realization of rice. The available nitrogen content was ranged from 101 to 195 kg ha^{-1} with the mean value of 138 kg ha^{-1} (Table.1). This indicates that all the rice growing soils of Jagtial district were low in the status of available nitrogen (Table.2; Fig.7). Similar results were reported by researcher [17] in rice growing soils of Jagtial district, Telangana state. Low variability (15.3%) in available nitrogen was observed among the soils of study area. Nitrogen fertilisation may have a high response in rice farming. Soil management, varied application of FYM and fertilizer to previous crops could be attributed the low N content to soil. Nitrogen is the most limiting nutrient as its availability decreases due to volatilization losses and fixation in black soils.

Another possible reason may also be due to low organic matter content in this area due to high temperature and crop removal which facilitate faster degradation and removal of organic matter leading to N deficiency. Therefore, proper method of nitrogen management is crucial for reducing nitrogen mining in soils. Application of different organic and inorganic sources of materials should be essential for adequate supply of nitrogen.

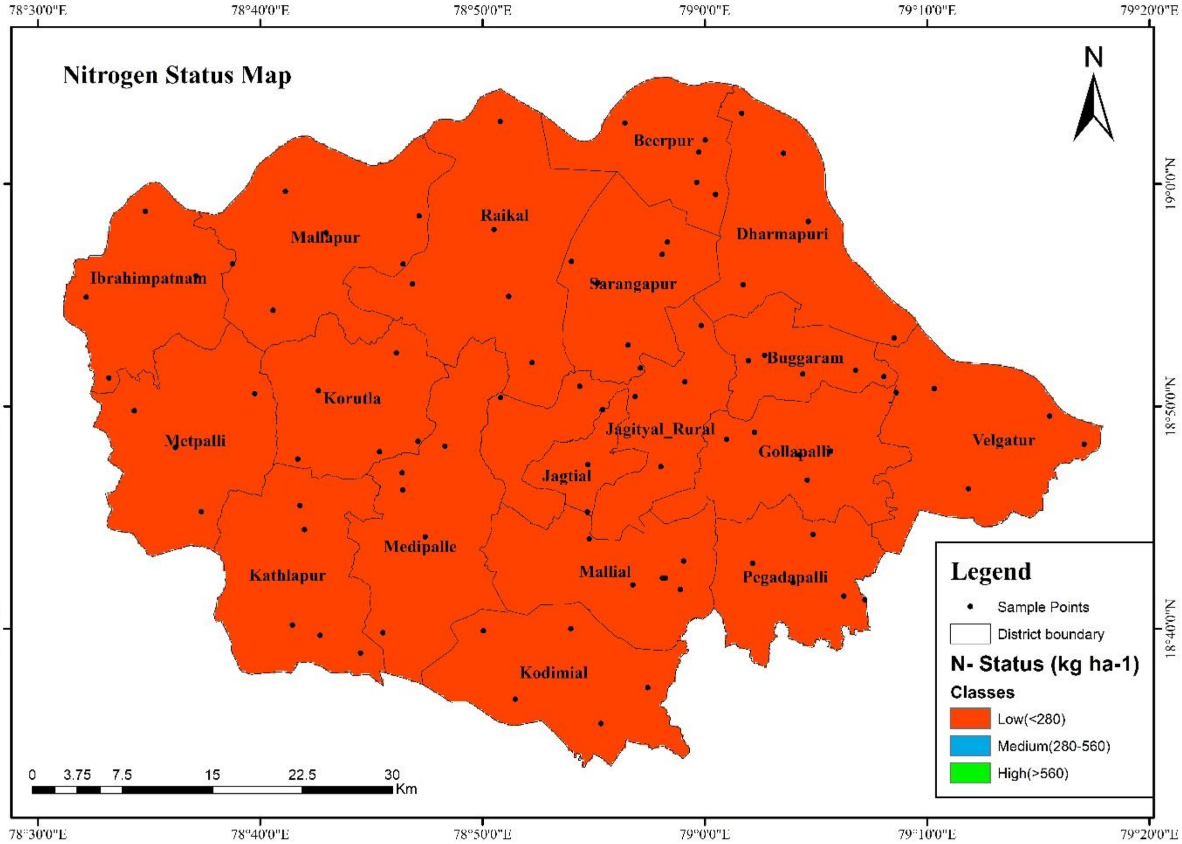

Figure 7: Nitrogen status inrice growing areas of Jagtial district.

Available phosphorus (kg ha^{-1})

"Phosphorus is referred as the master key to agriculture because lack of available P in the soils restricts the growth of both cultivated and uncultivated plants" [25]. Rice, like any other cereal, requires a considerable quantity of phosphorus for vigorous growth and high grain yield. The available phosphorus was ranged from 26.4 to 62.0 kg ha^{-1} with the mean value of 46.2 kg ha^{-1} (Table.1). This showed all soil samples have high status of available phosphorus (Table.2; Fig.8). Similar findings were made by fact finder [18] in the rice growing soils of the Ballia district (U.P.) and investigator [17] in the rice growing soils of the Jagtial district, Telangana state. There may possibility of low response to applied phosphorus on rice cultivation and also decreases the Zn availability it leads to Khaira disease. The variation in the available phosphorus of the soil is low, with coefficient of variation of 22.6%. Continuous phosphatic fertilizer application without soil testing may have led to phosphorus buildup and a high available phosphorus status in these soils [26]. Another explanation for the higher P levels in surface soils may be that phosphorus is restricted to the rhizosphere by the immobile nature of soils.

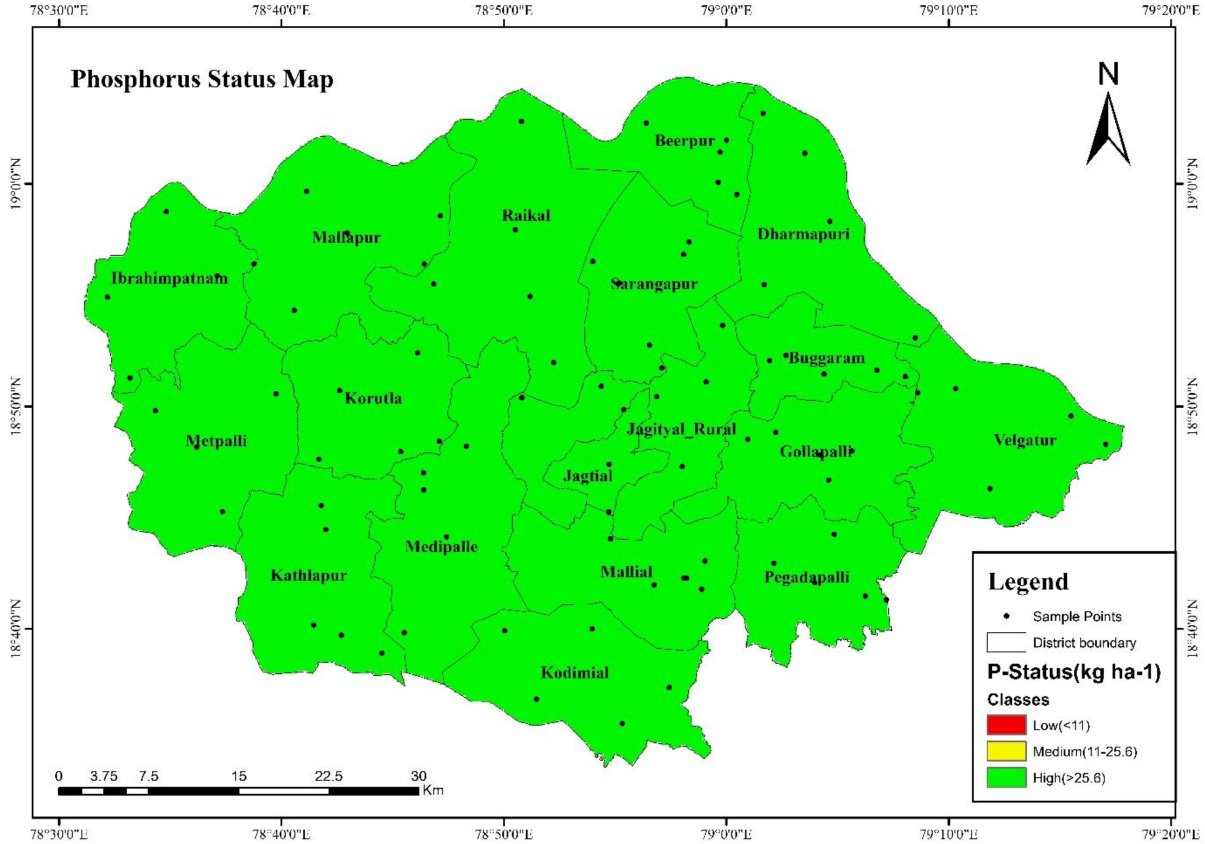

Figure8: Phosphorus status in rice growing areas of Jagtial district.

Available potassium (kg ha^{-1})

Potassium is a crucial mineral. It is essential to the majority of biochemical and physiological processes that control plant development and metabolism [27]. The available potassium content was ranged from 120 to 449 kg ha^{-1} with a mean of 300 kg ha^{-1} in (Table.1). The results indicating that 39% soils are medium and 61% samples are high in available potassium (Table.2). The generated soil fertility map shows the potassium status in rice growing soils of Jagtial district, Telangana state (Fig. 9). Similar results were observed by empiricist [18] in rice growing soils of Ballia district (U.P). There may possibility of low response of potassium application on rice. Moderate variability (32.6%) in extractable potassium was observed among the soil samples. The medium to higher content of available

K in soils may be due to the prevalence of K-rich micaceous and feldspar minerals in parent material.

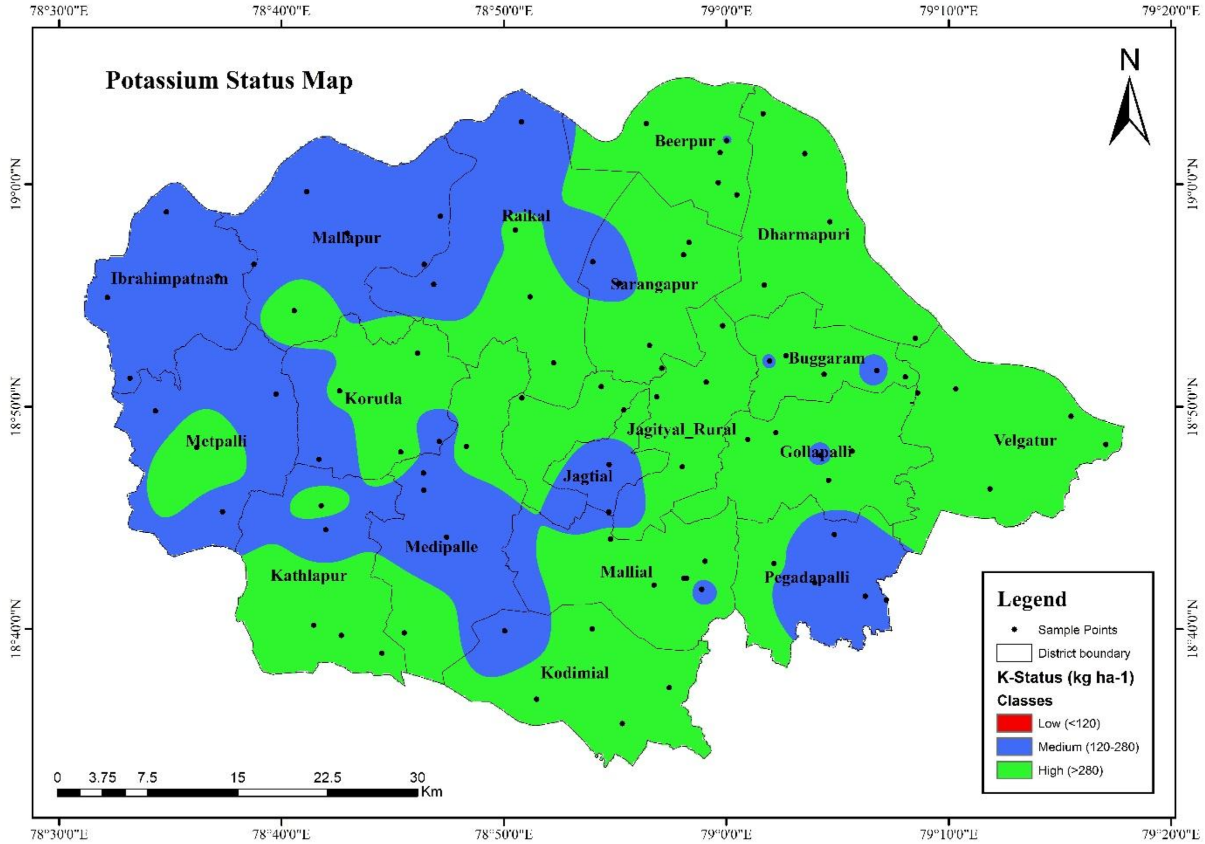

Figure 9: Potassium status in rice growing areas of Jagtial district.

Available sulphur (mg kg^{-1})

Sulphur is an essential nutrient for plants and necessary for the synthesis of proteins, chlorophyll, and some vitamins as well as the amino acids such as methionine, cystein, and cystine [28]. The available sulphur was varied from 10.0 to 26.8 mg kg^{-1} with a mean value of 15.8 mg kg^{-1} in rice growing soils of Jagtial district. (Table 1). In the study area, available sulphur was distributed medium (61%) to high (39%) in the study area (Table.2; Fig.10). Similar results were noticed by researcher [18] in rice growing soils of Ballia district (U.P) and fact finder [17] in in rice growing soils of Jagtial district, Telangana state. Surface soils had more sulphur that was readily available due to plant recycling throughout time and the subsequent buildup of organic matter [29]. There may have possibility of low response of sulphur application on rice cultivation. Available sulphur showed moderate variability (30%) in the rice growing soils of Jagtial district.

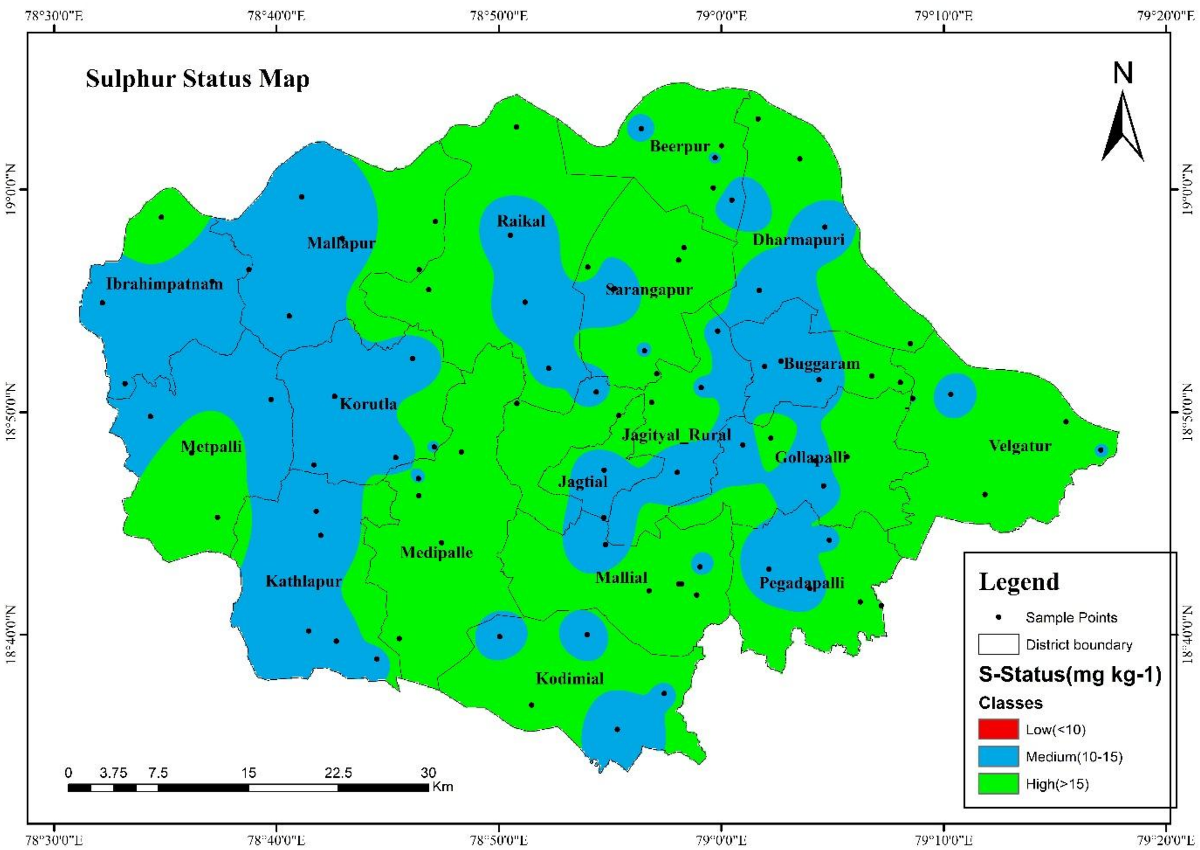

Figure 10: Sulphur status in rice growing areas of Jagtial district.

4. CONCLUSION

From the study, it can be concluded that, rice growing areas of Jagtial district in Telangana state were neutral to slightly alkaline in reaction with non-saline, low to medium in soil organic carbon content. The soils of study area was low in available nitrogen, high in available phosphorus, medium to high in available potassium and sulphur. Soil organic carbon, available-N are the important soil fertility constraints indicating their immediate attention for sustained crop production. The crops may suffer from deficiency of low and toxicity of very high plant available nutrients. Thus, proper nutrient management strategy should be adopted especially for these nutrients based on soil test report. Considering low status of organic carbon and nitrogen, incorporation of organic matter through crop residue retention, green manuring etc. can be suggested for its improvement. In order to increase phosphorus use efficiency by considering low mobility of phosphorus in soil apply P-solubilising microorganisms.

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