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Assessment of spatial variability of soil fertility status of Nagarjuna Sagar Left Bank command area in Nalgonda district, Telangana using GIS-GPS

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Abstract
The study was carried out to know the soil fertility status of Nagarjuna Sagar Left Bank Command area, of Nalgonda district, Telangana by using GPS-GIS technology during the year 2020-2021. The pH of soils of Nagarjuna Sagar Left Bank Command area varied from 6.21 to 9.62, most of the soils were found to be moderately alkaline to very alkaline (78.23%) while EC varied from 0.17 to 4.33dS m^{-1}, most soils were found to be high saline to very high saline (97.54 %) in salinity. Organic carbon content varied from 0.15 to 1.16% and categorized as low (30.4%), medium (66.6%) and high (3.0%). The soil available nitrogen, phosphorus and potassium in study area varied between 100.0 to 450.0, 10.3 to 71.2 and 25.5 to 1115.9 kg ha^{-1}, respectively. The soils were low (50.1%) and medium (49.9%) in available nitrogen, with respect to available phosphorus low (0.1%), medium (87.2%) and high (12.7%). In case of available potassium low (0.2%), medium (21.7%) and high (78.1%). The exchangeable calcium and magnesium ranged from 6.2 to 16.2 and 3.2 to 9.8 cmol (p+) kg^{-1}, respectively. The available sulphur varied from 0.32 to 29.9 mg kg^{-1}. The soils were low (0.5%), medium (67.1%) and high (32.4%) in available sulphur content. The soils were sufficient (100.0%) in exchangeable calcium and magnesium, respectively. Available Zn, Cu, Fe and Mn were deficient in 97.49%, 94.95%, 99.63% and 99.01% soil samples respectively.

Keywords: Soil fertility status, Nagarjuna Sagar Left Bank, Telangana, GIS-GPS

Introduction

Soil is the most precious natural resource and reservoir for the all the vital nutrients for crop growth. It is not renewed in short period. Soil fertility mapping is becoming most important and dynamic tool for the planning the best suited nutrient management practices (Brady and Weil, 2004). It is therefore very essential to maintain the soil fertility status of soil, which form the basis for fertilizer recommendation for the sustainable crop production and to reduce the crop production constraints.

Most of the times soil sampling will be done without geographic reference. The results of such samples will be of little use and continuous monitoring of soil fertility status will be very difficult. Indian agriculture in recent years progressed dramatically owing to modernization, mechanization and use of advance technologies. Using these advance technologies like GIS, GPS and remote sensing we can evaluate the spatial variability of soil fertility for precise nutrient management in a large area easily and effectively in very less time. Global Positioning System (GPS) helps in evaluating the soil fertility status of soil time to time and also helps in with making critical decisions on nutrient management (Patil *et al.*, 2017) [16]. Geographical Information System (GIS) is the tool of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and displaying of spatially referenced data for solving complex planning and management problems (Bernhardsen, 1999) [2]. It aids to manipulation of different variable data useful for handling multiple data of diverse origin. As soil fertility evaluation is a basic requirement for the sustainable and effective planning of the particular area. Soil fertility maps helps in knowing the nutrient status of soil and nutrient demand of the crop.

Studies on soil fertility status of Nagarjuna Sagar Left Bank Command area in Nalgonda district, Telangana was scarce. As such information is not available for Nagarjuna Sagar Left Bank command area in Nalgonda district, Telangana and is essential in planning soil fertility management on an area basis.

The proposed study was planned with the objective of identifying available nutrients constraints in soils of Nagarjuna Sagar Left Bank Command area in Nalgonda district, Telangana in Southern Telangana Zone of Telangana state.

Materials and methods
Study area
The study was carried out at Nagarjuna Sagar Left Bank Command area in Nalgonda district. It is situated in south of Telangana state and comes under Southern Telangana Zone. The site is located at $16^0$59' 34.43"N, $79^0$19'15.25" E on top left and 16^0 49' 56.64" N, $79^0$41'53.44"E. in Nalgonda district. The region experiences hot and dry summer throughout the year except during the south west monsoon season. The average rainfall in the district is 772 mm. About 71% of the annual rainfall is received by the district during south west monsoon (i.e., June to September).

Sample collection and analysis
GPS based soil samples (102 No.) of 0-20cm depth were collected from Nagarjuna Sagar Left Bank Command area of Nalgonda districts. Soil samples collected from each of the sites were dried under shade. The air dried samples was then pounded with wooden pestle and mortar and passed through a 2 mm sieve and then stored for determination of various soil properties. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973) [7]. Organic carbon (OC) was determined using the procedure given by Walkley-Black (1934) [29]. Available nitrogen (N) was estimated by alkaline permanganate method (Subbiah and Asija, 1956) [26]. Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen *et al*., 1954) [13]. Available potassium (K) was determined using the ammonium acetate method (Jackson, 1973) [7]. Available sulphur (S) was measured using 0.15 percent calcium chloride ($CaCl_2.2H_2O$) as an extractant (Chopra and Kanwar, 1991). Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA using the procedure outlined by Lindsay and Norvell (1978) [9]. Variability of data was assessed using mean standard deviation and coefficient of variation for each set of data. Availability of N, P, K and S in soils were interpreted as low, medium and high and that of Ca, Mg, Zn, Fe, Cu and Mn interpreted as deficient and sufficient by following the criteria given in table 1.

The results obtained from the physico-chemical and chemical analysis of the soil samples collected at 102 soil sampling points in Nagarjuna Sagar Left Bank Canal area using GPS in the study area were used for the generation of soil fertility maps employing the kriging coefficient and interpolation techniques in Arcgis software, wherein each soil quality parameter was designated in to several classes. Kriging is a geo-statistical interpolation method which deals with the distance and degree of variation between known data points when estimating values in unknown areas. A kriged estimate is a weighed linear combination of known sample values around the point to be estimated.

Table 1: Rating for soil organic carbon and available nutrients

S. No.	Nutrient / parameter	Rating			Reference
		Low	Medium	High	
1.	Organic Carbon (%)	<0.5	0.5-0.75	>0.75	Ramamoorthy and Bajaj (1969) [21]
2.	Available Nitrogen (kg ha^{-1})	<280	280-560	>560	
3.	Available P_2O_5 (kg ha^{-1})	<22.9	22.9-56.3	>56.3	Muhr *et al*. (1965) [11]
4.	Available K_2O (kg ha^{-1})	<129.6	129.6-336	>336.0	
5.	Available Sulphur (mg kg^{-1})	<10	10-20	>20	Hariram and Dwivedi (1994) [6]
		Deficient		Sufficient	
6.	Available Calcium (cmol (p^+) kg^{-1} soil)	<1.5		>1.5	Tandon (1991) [28]
7.	Available Magnesium (cmol (p^+) kg^{-1} soil)	<1.0		>1.0	Tandon (1991) [28]
8.	Available Zinc	<0.6		>0.6	Lindsay and Norvell, 1978 [9]
9.	Available Copper	<0.2		>0.2	
10.	Available Iron	<4.5		>4.5	
11.	Available Manganese	<1.0		>1.0	

Results and discussion
Soil reaction
Optimum soil reaction should be near neutral. The soils were slightly acidic to very alkaline with pH ranging from 6.12 to 9.62 with a mean of 7.95, standard deviation of 0.58 and CV of 7.36. (Table 2). The spatial variability of pH pertaining to study area depicted in Figure 1. The pH of 0.03 per cent (15 ha) was slightly acidic, 1.36 per cent (738 ha) was neutral, 20.38 per cent (11028 ha) was slightly alkaline and 78.23 per cent (42332 ha) was moderately alkaline to very alkaline in soil reaction. The neutral to very alkaline nature of the soils might be due to high exchangeable bases (Sitanggang *et al.*, 2006; Pulakeshi *et al.*, 2014) [25, 19]. Soil reaction (pH) generally affects the solubility of minerals and can influence the plant growth by stimulating activity of beneficial microorganisms (Amara and Patil, 2014) [1].

Electrical conductivity
The conductance of a soil gives a clear idea of the soluble salts present in the soil. In the present study, the electrical conductivity was low saline to very high saline in range (Figure 2). The EC varied between 0.17 to 4.33 dS m^{-1} with mean of 2.01dS m^{-1}, SD of 1.26 and CV of 62.68 (Table 2). The spatial variability of EC in study area depicted in Figure. The EC of 0.02 per cent (9 ha) was low saline, 2.46 per cent (1332 ha) was moderately saline, 49.58 per cent (26834 ha) was high saline and 47.94 per cent (25946 ha) was very high saline. Similar study taken by Masoud *et al.* (2019) [10] and mapped the soil salinity using spectral mixture analysis of landsat 8 OLI images in Dakhla Oasis, Egypt and estimated the salinity it is in the range of 0.52–53.9 dS m^{-1} with an average of 14 dS m^{-1} and the alkalinity varied from 6.99 to 8.9 with an average of 7.7.

Soil organic carbon
The organic carbon content of the soils in the study area ranged from low to high, but majority of the samples contained medium organic carbon content (Figure 3). The

organic carbon content of soil samples in study area ranged from 0.15 to 1.16 with a mean of 0.56 per cent, SD of 0.19 and CV of 33.67 (Table 2). Spatial variability map of organic carbon generated by GIS revealed that 30.4 per cent (16458 ha) of the study area was low in organic carbon, 66.6 per cent (36020 ha) was medium and 3.0 per cent (1634ha) was high in organic content in soils of study area. Similar findings were recorded by Swapnil *et al*. (2012) [27] in soils of Savli micro-watershed of Wardha district, Maharashtra were organic carbon content ranged between 0.41 to 1.86 per cent.

Available macronutrients

Available nitrogen

The available nitrogen content of the soils ranged from low to medium (Figure 4). Binita *et al.* (2009) [3] also found the Similar observations. The available nitrogen content varied between 100.0 to 450.0 kg ha^{-1} with mean of 278.2 kg ha^{-1}, SD of 87.0 and CV of 31.27 (Table 3). The spatial variability of available nitrogen in study area depicted in Figure. The nitrogen content of 50.1 per cent of area (27096 ha) was low and 49.9 per cent of area (27011 ha) was medium. The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases. The results are in agreement with those reported for northern dry zone soils by Prabhavati *et al.* (2015) [17] and Patil *et al.,* (2016) [15].

Available phosphorus

The available phosphorus content of the soils ranged from low to high with majority of samples were medium in phosphorus (Figure 5). The available phosphorus content of the study area soils ranged between 10.7 to 71.2 kg $ha^{-1}$with a mean, SD, CV of 32.6 kg ha^{-1}, 12.45, 38.2 respectively. 6.1 (Table 3).The spactial distribution of available phosphorus pertaining to study area soils were depicted in Figure revealed that it was high in area of 57 ha (0.1 per cent) and medium in area of 47212 ha (87.2 per cent) whereas low in 6851 ha (12.7 per cent). Sashikala *et al.* (2019) [23] also reported similar observation in soils of Tatrakallu village, where available phosphorus ranged from 2.00 to 512.00 kg ha^{-1} with an average and SD values of 208.79 and 124.20, respectively. The CV of 59.33 per cent for available phosphorus distribution in the village indicates that, it varied spatially. Semi-arid environment and continuous use of high analysis fertilizers especially DAP without knowing the crop requirement and soil availability in the study area resulting in the phosphorus build up and contributing towards high medium level available phosphorus status in the soils of study area.

Available potassium

The available potassium status of the soils ranged from low to high, with majority of samples being highin available potassium (Figure 6). The available potassium content in study area soil samples ranged from 25.5 to 1115.9 kg $ha^{-1}$with a mean value of 477.5 kg ha^{-1}, SD of 247.4 and CV of 51.8 (Table 3). Mapping of available potassium by using GIS (Figure) revealed that total area under low range was 130 ha (0.2 per cent), medium was 11722 ha (21.7 per cent) and high range were 42265 ha (78.1 per cent).These results confirmed the finding as reported by Prasad *et al.* (2020) [18] they noticed that available potassium varied from 149.18 to 916.61 kg ha^{-1} with mean and median of 434.11 and 431.42 kg ha^{-1}, respectively with a standard deviation of 155.16.

Available sulphur

The available sulphur content of the soils of the study area ranged from low to high, but most of the samples were medium in available sulphur (Figure 7). The available sulphur content in study area ranged between 0.32 to 29.9 $mgkg^{-1}$with a mean, SD, CV of 12.31 mg kg^{-1}, 5.73, 46.57 respectively (Table 4). The spactial distribution of available phosphorus pertaining to Nagarjuna Sagar Left Bank Command area depicted in Figure 7 revealed that it was high in area of 271 ha (0.5 per cent) and medium in area of 36334 ha (67.1 per cent) whereas low in 17514 ha (32.4 per cent). Kumar *et al.* (2019) [8] also reported the similar findings with the available sulphur in the soils ranged from 5.12 to 35.93 mg kg^{-1} (low to high) with the mean value 16.14 mg kg^{-1}. The total sulphur in soil was present in organic combination; therefore soils which are rich in organic matter will have high level of sulphur and also coarse texture soils have low amount of sulphur than fine textured soils due to leaching losses and adsorption of sulphates on organic matter leads to unavailable to plants. The results indicated that sufficiency of available sulphur was directly proportional to organic sulphur content of soil.

Available calcium and magnesium

The available calcium content in study area ranged between 6.2 to 16.2 c mol (p^+) kg^{-1} with a mean, SD, CV of 11.56 c mol (p^+) kg^{-1}, 2.10, 18.16 respectively. The spatial distribution of available calcium pertaining to Nagarjuna Sagar area depicted in Figure 8 revealed that it was sufficient in all samples. The available magnesium content in study area ranged between 3.2 to 9.8 c mol (p^+) kg^{-1} with a mean, SD, CV of 5.9 c mol (p^+) kg^{-1}, 1.37 and 23.23 respectively. The spatial distribution of available magnesium pertaining to Nagarjuna Sagar area depicted in Figure 9 revealed that it was sufficient in all samples. Similar findings were reported by Parhad *et al.* (2018) [14] in eastern part of Port Said near Malaha, Dhule district in Maharashtra.

Available micronutrients

Available manganese

The available manganese content of the Nagarjuna Sagar Left Bank Command area region ranged from 0.12 to 2.13 ppm with a mean of 0.64 ppm, SD of 0.30 and CV of 46.05 (Table 5) . The Mn content in area of 99.01 per cent (53584 ha) was deficient and 0.99 per cent (537 ha) was sufficient in soils (Figure 13). Similar findings were reported by Ramesh and Rao (2005) [22] and Nandy *et al*. (2012) [12].

Available iron

The available iron content in Nagarjuna Sagar Left Bank Command area varied from 0.68 to 6.56 ppm with a mean of 3.15, SD of 1.10 and CV of 34.78 (Table 5).The iron content in area of 99.63 per cent (53917 ha) was deficient and 0.37 per cent (202 ha) was sufficient in soils (Figure 12). The low Fe content in most of the samples may be due to precipitation of Fe because of high pH it decreased its availability. Similar observation was reported by Sashikala *et al.* (2019) [23].

Available zinc

The available zinc content of Nagarjuna Sagar Left Bank Command area soils ranged between 0.08-1.05 ppm with mean, SD and CV of 0.45, 0.18 and 40.48. respectively (Table 5). The spatial distribution map (Figure 10) of available zinc revealed that zinc content in area of 97.49 per cent (57764 ha) was deficient and 2.51 per cent (1357 ha) was sufficient in soil samples. However, since some of the soils were alkaline in nature might have resulted to precipitation of zinc as hydroxides and carbonates under alkaline pH range. Therefore, their solubility and mobility may decrease, hence resulting in reduced availability as observed in the study area. Available Zn in soils decreased with increase in pH. Since, most of the soils are alkaline and low in OC, Zn might have been precipitated as hydroxides and carbonates, as a result their decreased solubility and mobility might have reduced the availability of Zn. Similar findings were reported by Satish *et al.* (2018) [24].

Available copper

The available copper content of Nagarjuna Sagar Left Bank Command area soils samples ranged from 0.05 to 0.45 ppm with the mean of 0.16, SD of 0.08 and CV of 52.18 (Table 5). The spatial variability of available copper pertaining to Nagarjuna Sagar area revealed that study area had 51386 ha (94.95 per cent) was deficient and 2735 ha (5.05 per cent) was sufficient in soil samples (Figure 11). Raghupathi (1989) [20] reported that the available copper content ranged from 0.4 to 1.2 ppm. Similar results have also been observed by Patil *et al.* (2016) [15].

Conclusion

From the study, it can be concluded that, soils of Nagarjuna Sagar Left Bank Command area in Southern Telangana Zone of Telangana shown considerable spatial variability in the soil parameters in the study area except for available Ca and Mg. pH was slightly acidic to very alkaline with low to very high saline in nature. Alkaline soils in the study area need immediate attention for their management to arrest further degradation. Soil organic carbon content was low to high. Available N was low to medium, available P and K was low to high, and available S was low to high. Regarding available micronutrients, were almost deficient in the most of the soils. The fertility status of nutrients in study area revealed that pH, EC available N and micronutrients were important soil fertility constraints indicating their immediate attention for sustained crop production. Also, the fertility maps prepared were very helpful in knowing spatial fertility management in the Nagarjuna Sagar Left Bank Command area.

Table 2: Physico-chemical properties in Nagarjuna Sagar Left Bank Command area

Statistics	pH	EC (dS m^{-1})	OC (%)
Mean	7.95	2.01	0.56
Range	6.12 - 9.62	0.17 - 4.33	0.15 - 1.16
SD	0.58	1.26	0.19
CV	7.36	62.68	33.67

Table 3: Available primary nutrients status in Nagarjuna Sagar Left Bank Command area

Statistics	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})
Mean	278.24	32.58	477.52
Range	100 - 450	10.3 - 71.2	25.5 - 1115.9
SD	87.00	12.45	247.38
CV	31.27	38.23	51.81

Table 4: Available secondary nutrients status in Nagarjuna Sagar Left Bank Command area

Statistics	Avail. S (mg kg-1)	Ca^{+2} (c mol (p$^+$) kg^{-1})	Mg^{+2} (c mol (p$^+$) kg^{-1})
Mean	12.31	11.56	5.90
Range	0.32 - 29.9	6.2 - 16.2	3.2 - 9.8
SD	5.73	2.10	1.37
CV	46.57	18.16	23.23

Table 5: Available minor nutrients status in Nagarjuna Sagar Left Bank Command area

Statistics	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
Mean	0.45	0.16	3.15	0.64
Range	0.08 - 1.05	0.05 - 0.45	0.68 - 6.56	0.12 - 2.13
SD	0.18	0.08	1.10	0.30
CV	40.48	52.18	34.78	46.05

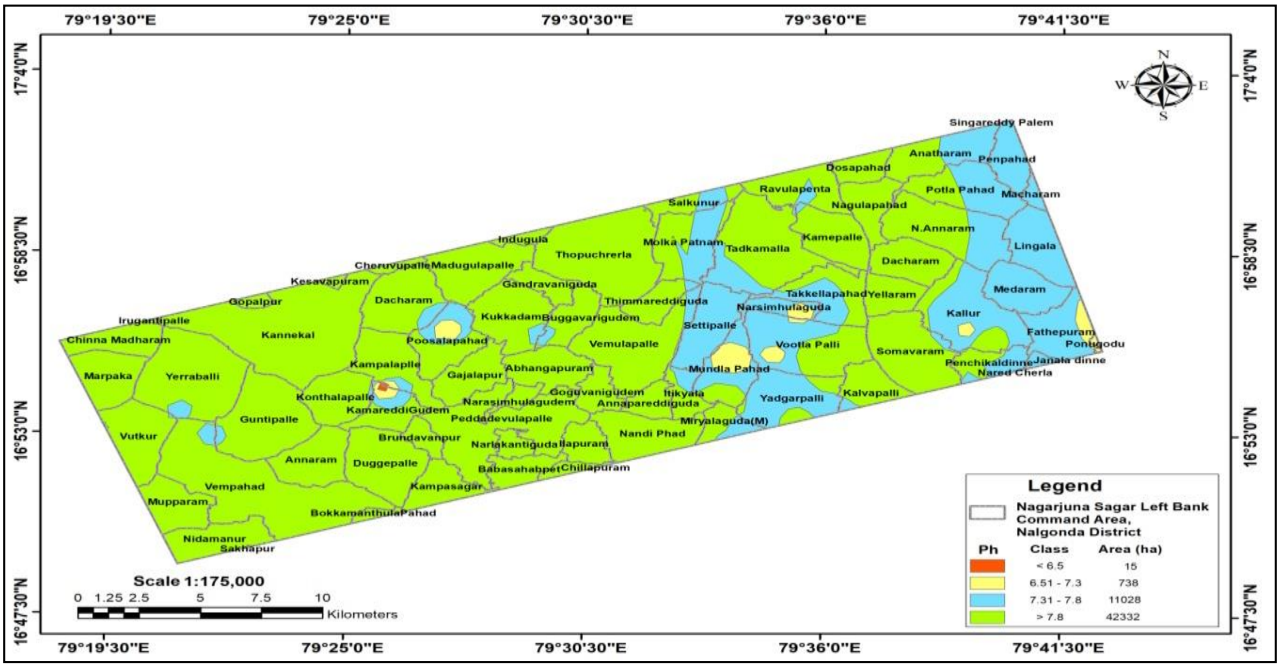

Fig 1: Status of pH in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

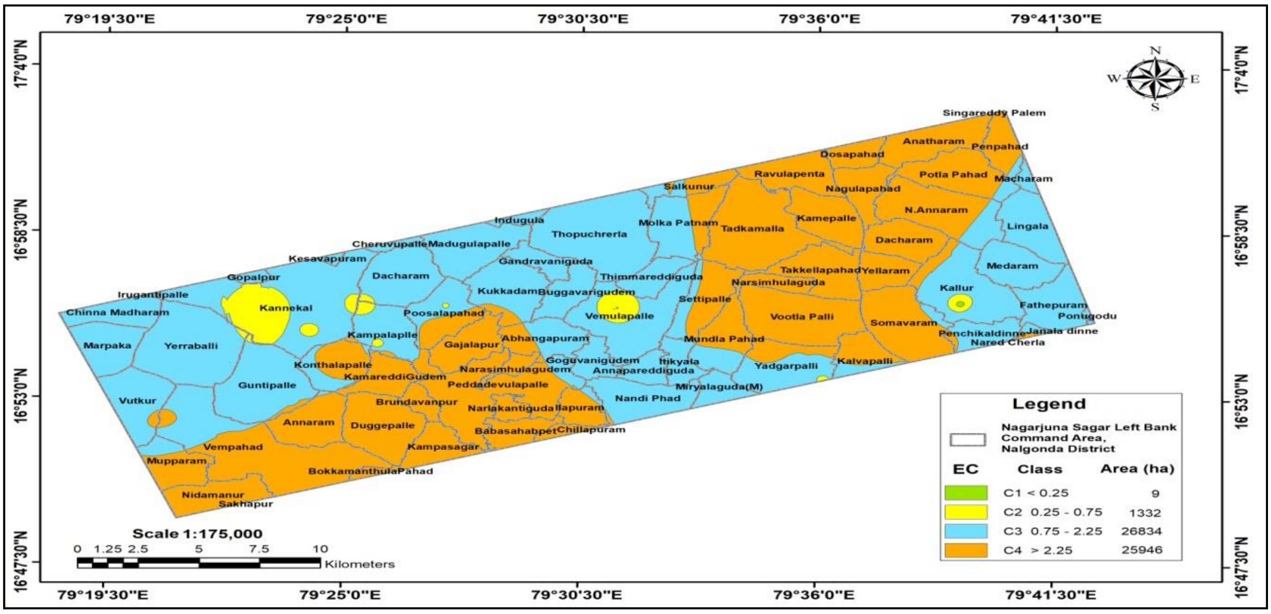

Fig 3: Status of EC in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

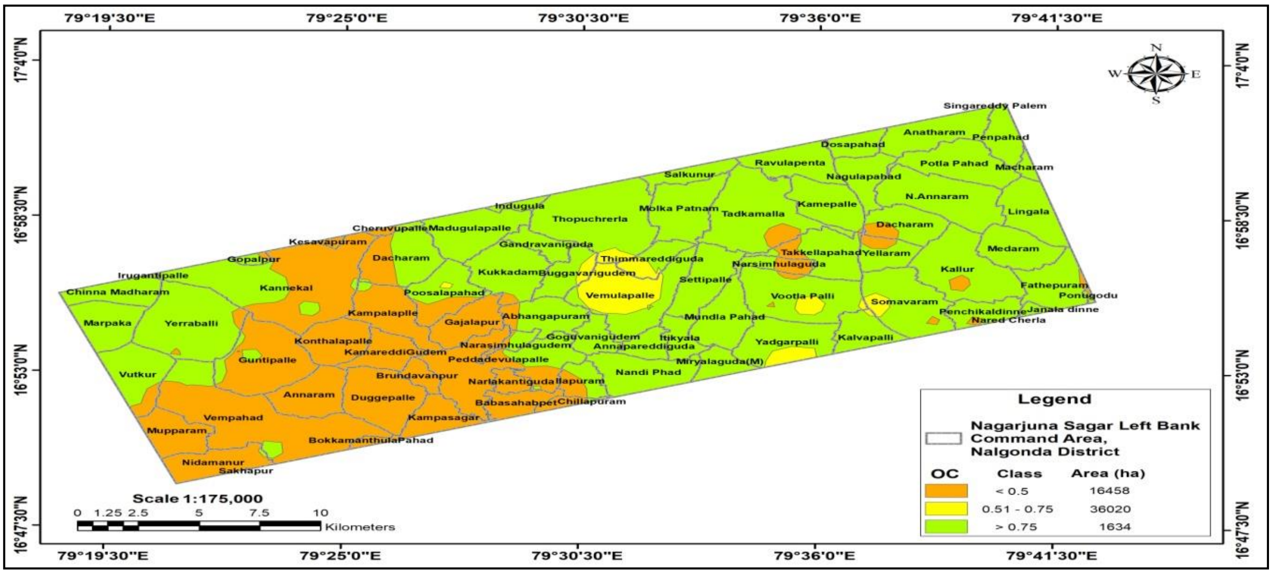

Fig 3: Status of OC in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

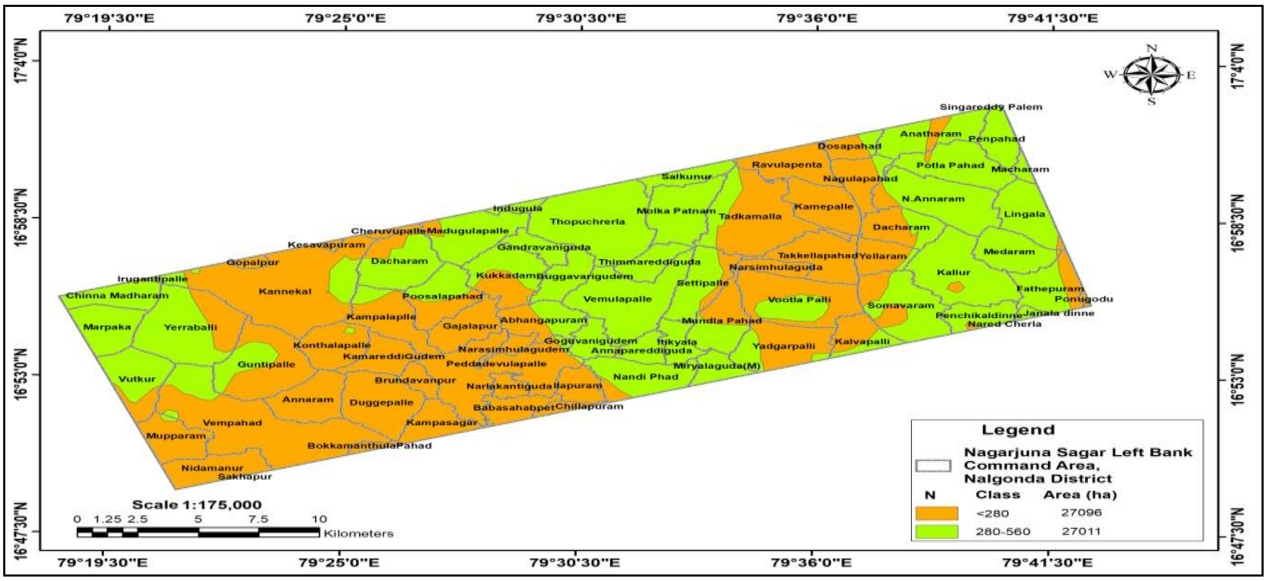

Fig 4: Status of available N in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

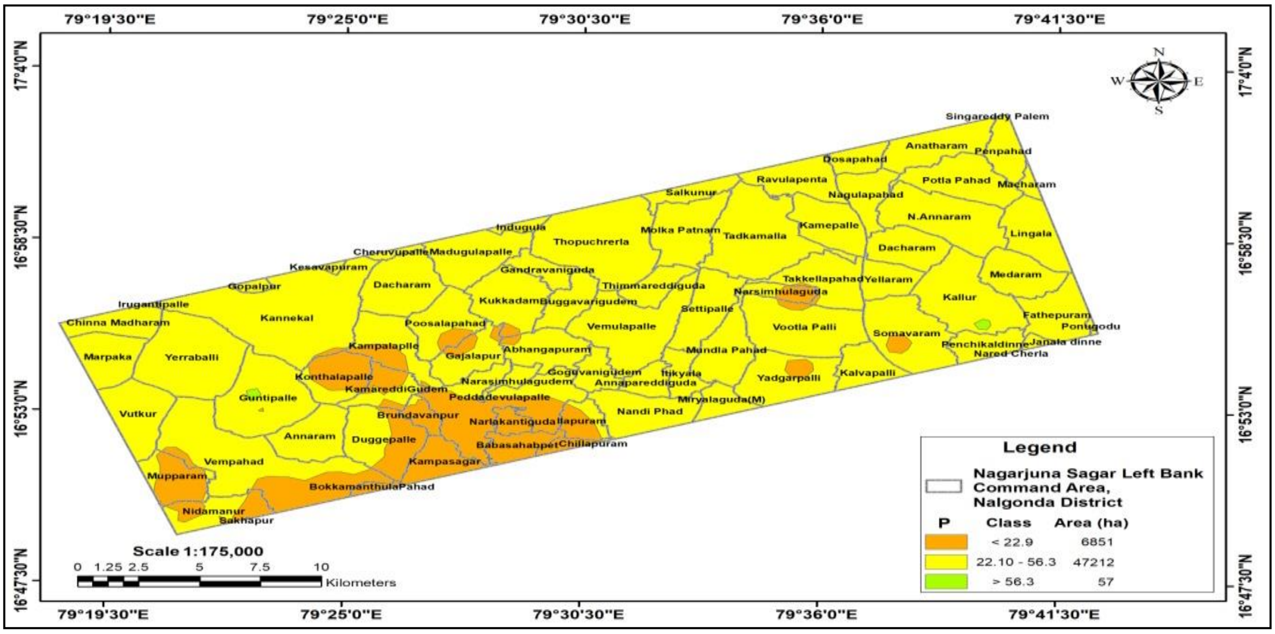

Fig 5: Status of available P in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

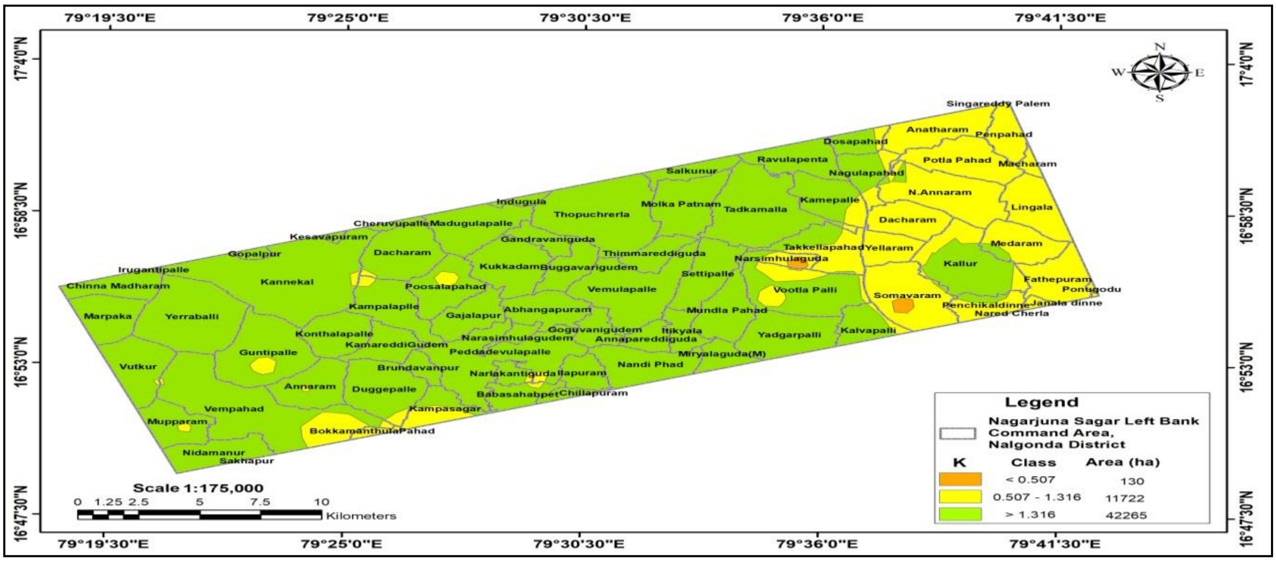

Fig 6: Status of available K in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

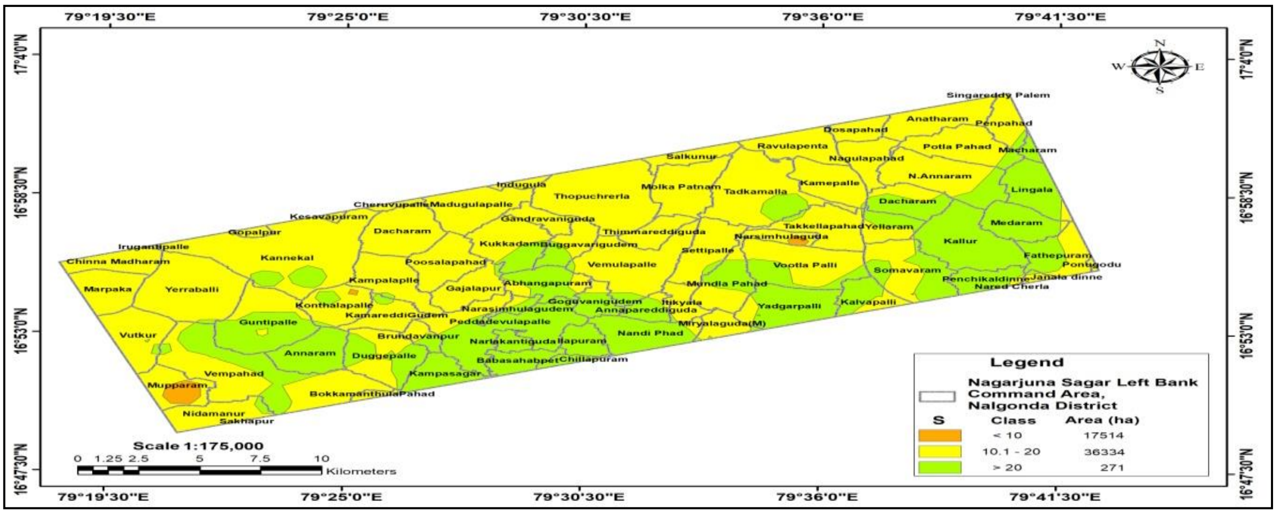

Fig 7: Status of available S in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

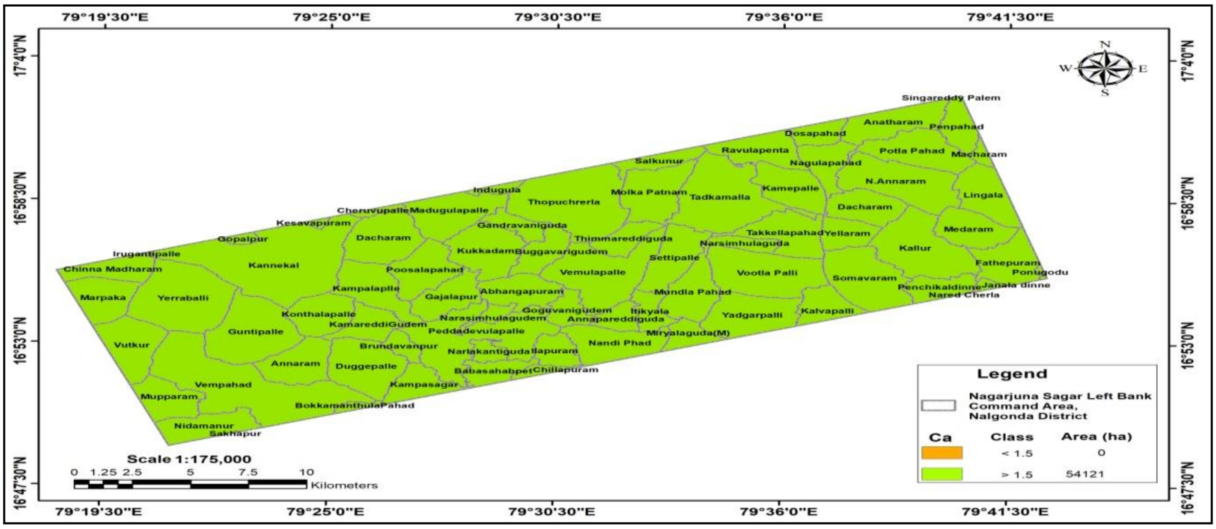

Fig 8: Status of calcium in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

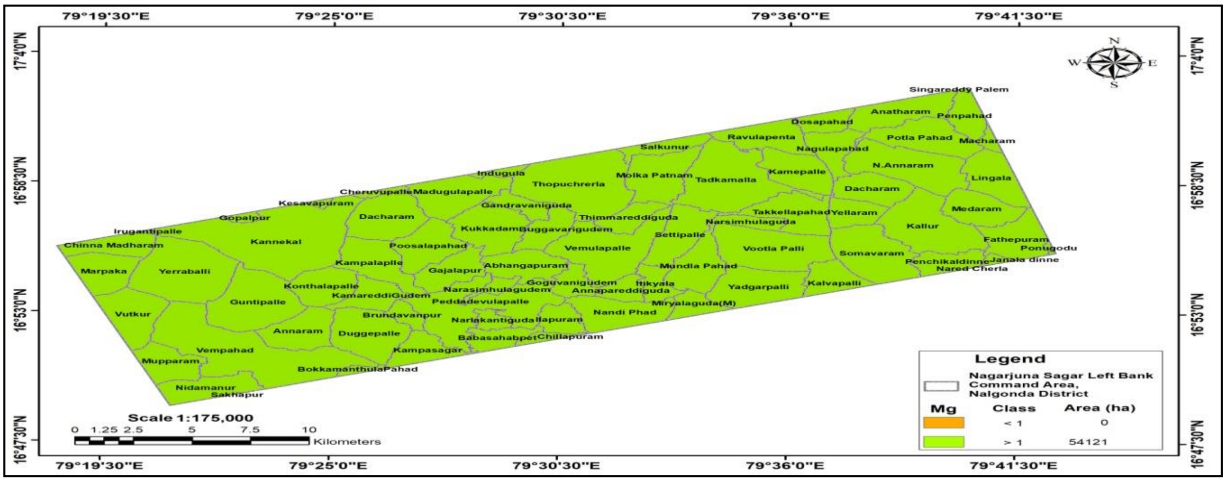

Fig 9: Status of Magnesium in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

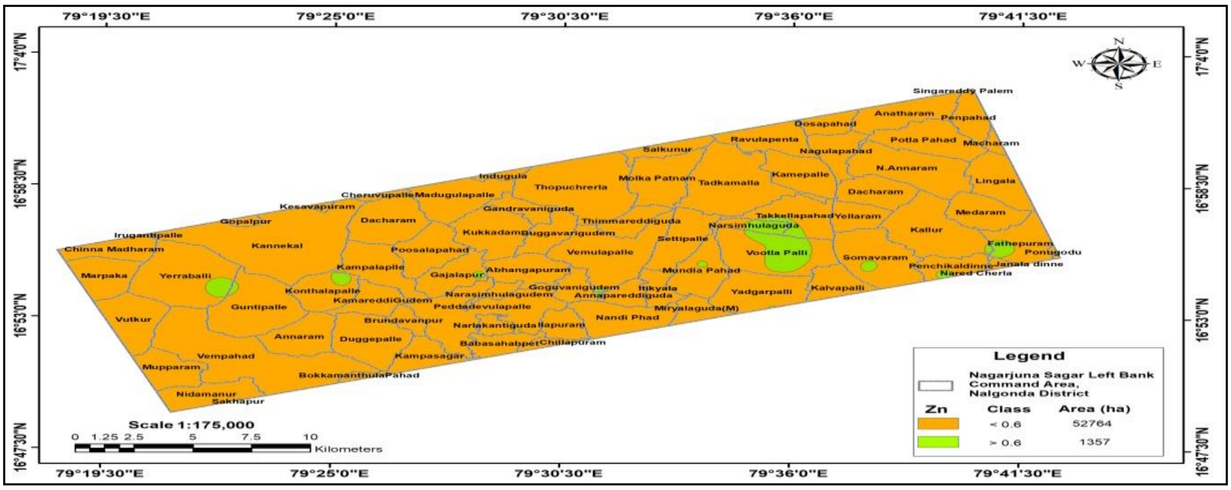

Fig 10: Status of available Zinc in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

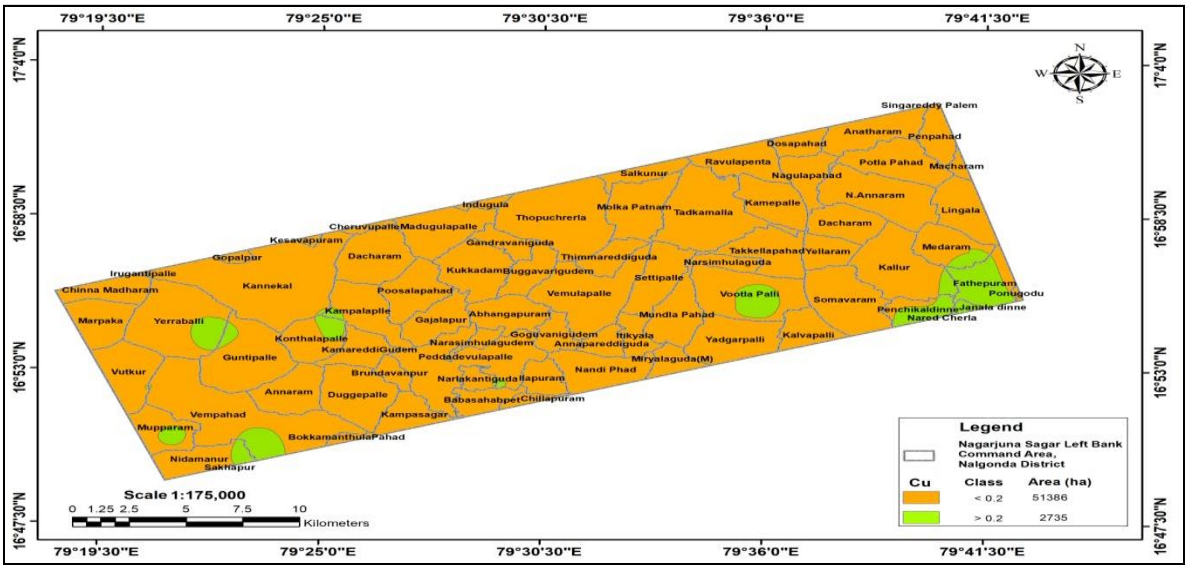

Fig 11: Status of available Copper in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

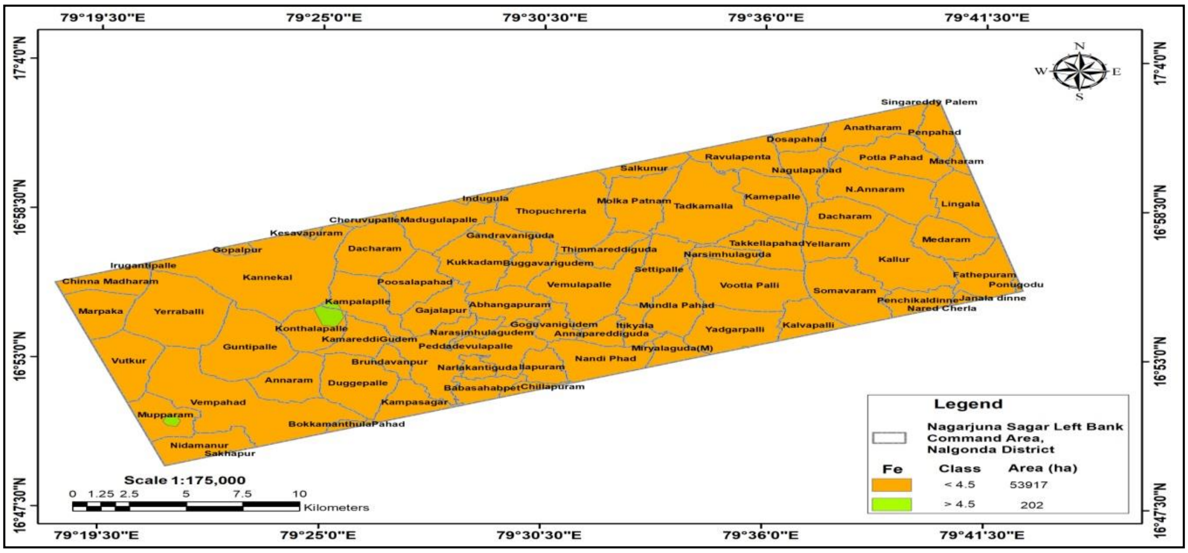

Fig 12: Status of available Iron in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

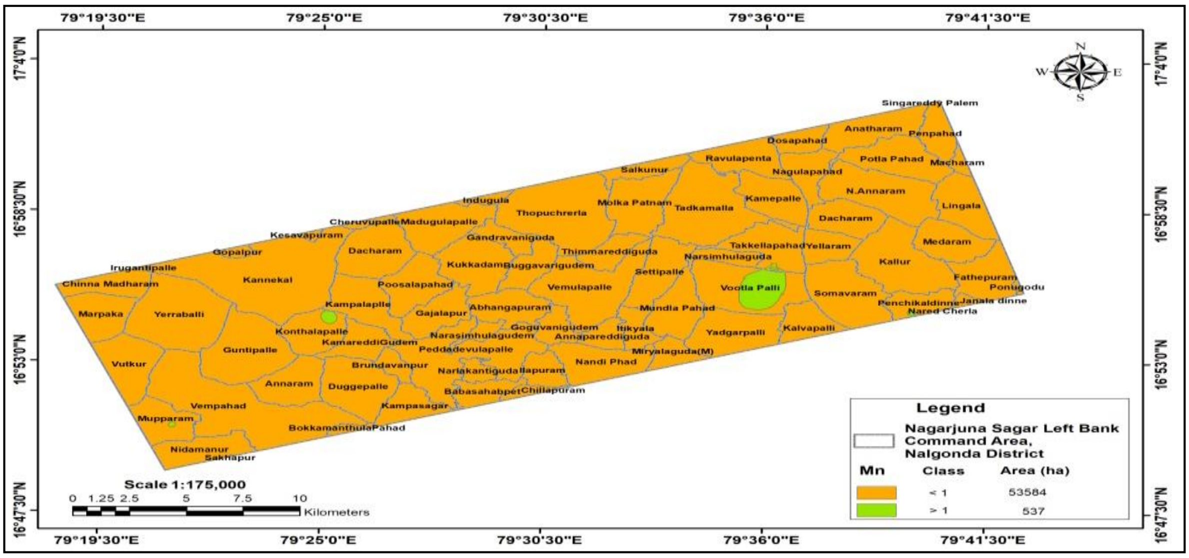

Fig 13: Status of available Manganese in the soils of Nagarjuna Sagar Left Bank Command area, Nalgonda district, Telangana state

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