Soil quality mapping in the groundnut belt of erstwhile Mahabubnagar District, Telangana, India using GIS

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The present study was conducted during *rabi* season of 2019–20 based on the crop colonies concept, where the highly and marginally potential regions for groundnut were delineated with an objective of soil fertility assessment in the crop area in order to determine the yield gaps and constraints for low yields in marginally potential areas. Soil samples collected at 35 GCP sites through preliminary crop survey in homogenous, contiguous groundnut areas at the time of crop-cut experiments were analysed in the laboratory for soil quality parameters. The results revealed that the soils were slightly saline (pH: 7.50–8.50) with low saline EC (<0.25 dS m^{-1}), high organic carbon content (>0.75%), acutely deficit available nitrogen (<100 kg ha^{-1}), high phosphorus (>24.6 kg ha^{-1}), medium potassium (108–280 kg ha^{-1}) and low sulphur (<10 mg kg^{-1}). The DTPA extractable micronutrients – zinc, manganese and copper were sufficiently high (Cu > 0.20 mg kg^{-1}; Zn > 0.65 mg kg^{-1} and Mn > 2 mg kg^{-1}), while iron was low (<4 mg kg^{-1}). Based on the results of laboratory analysis soil quality maps were generated using QGIS software, wherein each parameter was grouped into several classes based on USDA soil classification employing IDW interpolation technique.

Keywords: Crop colonies, groundnut, micronutrients, soil quality maps, yield gaps.

IT is well established that remote sensing and GIS can be used in the assessment of soil quality by generating maps for large areas which help in managing soil resources and using them optimally for preventing degradation of soil health[1]. The Government of Telangana in association with the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Regional Centre, Bengaluru delineated the state into crop colonies based on the local weather conditions, nature of the soil, water and other resources, and prepared maps with mandal-wise cropping patterns, production and productivity for all the major crops of Telangana. According to these maps, the state has been divided into three zones – highly potential, moderately potential and marginally potential under each crop[2].

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Groundnut (*Arachis hypogaea* L.) is an important oilseed and supplementary food crop of the world. According to a report[3], groundnut was sown in around 4.75 lakh ha in 2019 compared to the previous year of 4.59 lakh ha. Among the states, Telangana ranked first in area coverage with 1.16 lakh ha, followed by Karnataka (1.07 lakh ha), Tamil Nadu (0.99 lakh ha), Andhra Pradesh (0.66 lakh ha) and Odisha (0.70 lakh ha)[4]. Groundnut acreage in Telangana extended to 1.43 lakh ha and in the Southern Telangana Zone, the crop extended to 1.15 lakh ha (ref. 5). Groundnut is one of the preferred crops for most of the resource-poor farmers of Telangana, especially in the erstwhile Mahabubnagar district, where both highly and marginally potential areas exist. The marginally potential areas are characterized by high spread and low productivity. If the constraints for low productivity in marginally potential areas are identified, then it would help researchers and policy makers to formulate interventions and develop plans to increase productivity in this region. Hence, the present study was taken up in the groundnut belt of erstwhile Mahabubnagar using GIS during *rabi* 2019–20 to assess the soil quality and generate soil quality maps.

Material and methods

Study area

The study area lies between 15°55′–17°20′N lat. and 77°15′–79°15′E long. The average normal rainfall in the district is 604 mm and most of it is received during the southwest monsoon. In 2011, however, rainfall was hardly 64% of the state average (940 mm)[6].

The soil of the district can be classified into three broad groups, i.e. red soil, black cotton soil and chalka or mixed soil. The predominant soil is the chalka dubba which is about 70% of the total area[6].

Methodology

To generate soil quality maps, 35 Ground Control Point (GCP) locations were pinned in contiguous groundnut regions representative of the study area using GNSS viewer mobile application. At the selected GCP locations, surface

Table 1. Classes assigned for soil parameters for mapping soil quality in the study area[15]

Soil/water parameters	No. of classes assigned	Details of classes according to USDA classification
pH (1 : 2.5)	7	<4.00: Very strongly acidic 4.50–5.50: Strongly acidic 5.50–6.50: Slightly acidic 6.50–7.50: Neutral 7.50–8.50: Slightly alkaline 8.50–10.0: Strongly alkaline >10.0: Very strongly alkaline
EC (dSm^{-1})	4	C1: <0.25 – low saline C2: 0.25–0.75 – medium saline C3: 0.75–2.25 – doubtful C4: >2.25 – not useful
Organic carbon (%)	3	<0.50: Low 0.50–0.75: Medium >0.75: High
Soil available N (kg ha^{-1})	3	<280: Low 280–560: Medium >560: High
Soil available P_2O_5 (kg ha^{-1})	3	<10.0: Low 10.0–24.6: Medium >24.6: High
Soil available K_2O (kg ha^{-1})	3	<108: Low 108–280: Medium >280: High
Soil available S (mg kg^{-1})	3	<10.0: Low 10.0–15.0: Medium > 15.0: High
DTPA extractable micronutrients (mg kg^{-1})	Critical limit	Cu: 0.20 Zn: 0.65 Fe: 4.00 Mn: 2.00

soil samples were collected from a depth of 0–15 cm in the centre of the field at the time of crop-cut experiments. The soil samples were analysed in the laboratory for soil fertility parameters, viz. pH, electrical conductivity (EC), organic carbon (OC), available nitrogen, phosphorus, potassium, sulphur and diethylene triamine penta-acetic acid (DTPA) extractable micronutrients (iron, manganese, copper and zinc) following the standard procedures. The results of the laboratory analysis were imported into QGIS software and a point file including GCP locations and soil-analysis results was generated in ESRI shapefile format. Using the point file and Mahabubnagar boundary shape file, soil maps were generated using inverse distance weighing (IDW) interpolation and employing kriging function for each soil quality parameter; the classes were assigned for the parameters based on standard USDA soil classification (Table 1). Next the mandal boundary and revenue division maps were overlaid for detailed analysis of the maps. Similar procedure was followed for the generation of all soil maps (Figure 1).

Results and discussion

Groundnut is an exhaustive crop and depending upon the yield, it removes a large amount of macro and micronutrients. According to previous studies, to produce 2.0–2.5 tonne ha^{-1} of economic yield, the crop requires 160–180 kg N, 20–25 kg P, 80–100 kg K, 60–80 kg Ca, 15–20 kg S, 30–45 kg Mg, 3–4 kg Fe, 300–400 g Mn, 150–200 g Zn, 140–180 g B, 30–40 g Cu (refs 7–12). The soil data analysed for pH, EC, OC, soil available N, P_2O_5, K_2O, S, Fe, Mn, Cu and Zn are presented in detail in the following sections. Based on the results of laboratory analysis, a total of nine soil quality maps were generated using the QGIS software.

Soil pH

The interpolation of pH data between 35 sample locations mapped the soils characteristically as slightly alkaline. The soil pH map pertaining to groundnut regions in the erstwhile Mahabubnagar district indicated greater expanse of slightly alkaline regions occupying an area of 45.71% (Figure 2). Similar pH results were reported by NBSS&LUP, which conducted soil fertility studies in the cotton-growing mandal of Thimmajipet in erstwhile Mahabubnagar district. The soils were reported to be slightly alkaline in nature[13]. The slightly acidic and strongly alkaline reaches were up to 14.29% and 5.71% respectively (Table 2). Soil

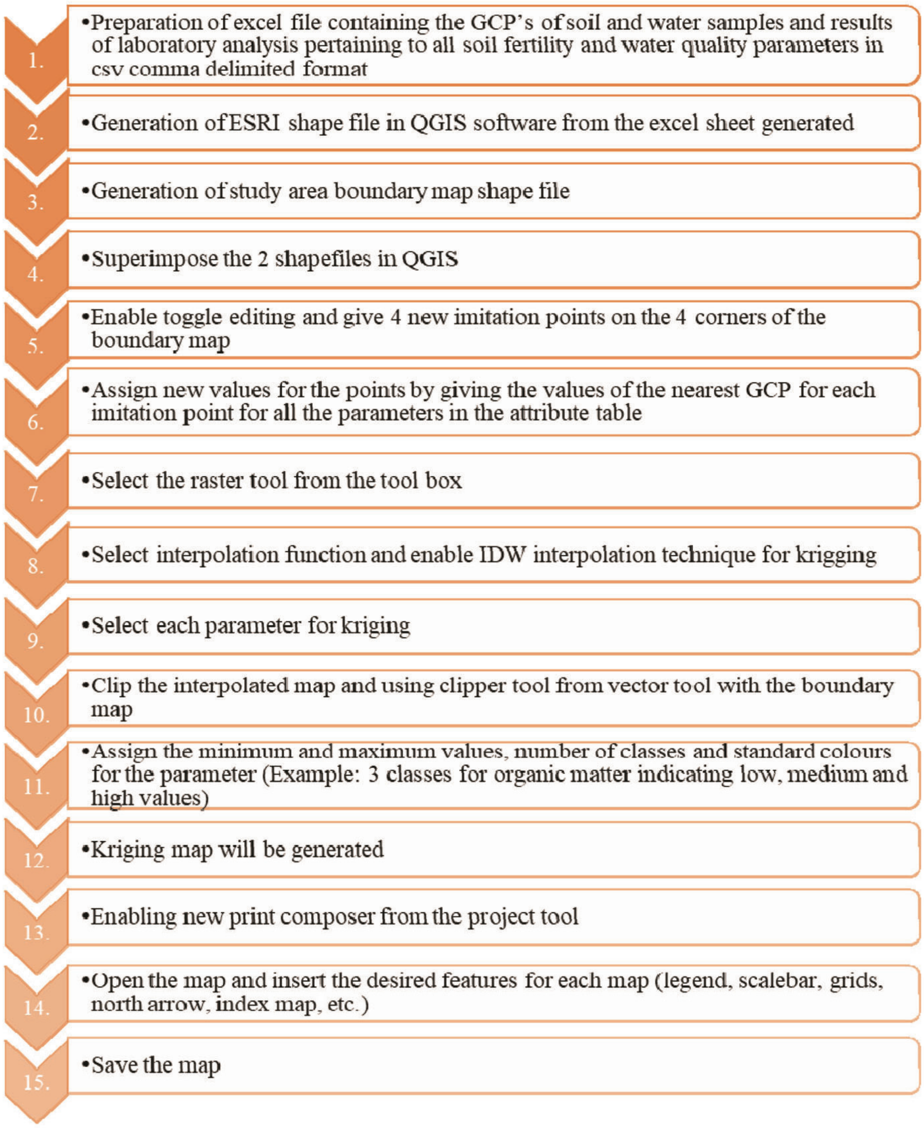

Figure 1. Generation of soil fertility maps using kriging and interpolation.

pH elicited from the analysis ranged from 5.50 to 8.55 with a mean value of 7.45. Therefore, pH of the groundnut belt may be rated as slightly alkaline and this can be attributed to characteristic light soils, especially dubba chalkas in the entire study area. Further, soil pH values above 5.0 and below 8.5 are ideal for groundnut cultivation. Hence it can be concluded that soils in the groundnut-growing regions of erstwhile Mahabubnagar district have suitable pH for cultivation of the crop.

Soil EC

Soil EC in the study area ranged from 0.11 to 0.75 dS m^{-1} with an average value of 0.26 dS m^{-1}, showing that the soils were low to medium saline and assuring a good crop-growing condition. Almost 60% of the soils in the groundnut belt were rated as low saline and 40% as medium saline (Table 2). The fertility gradient of these soils therefore is labelled as low saline, which is favourable for groundnut cultivation. Similar results were obtained in the study taken up at Kalwakurthy mandal of erstwhile Mahabubnagar district, indicating that the soils were non-saline in most of the study area favouring crop production[14]. The NBSS&LUP study in cotton-growing soils of Thimmajipet mandal also reported that the soils were less saline in nature[13]. The soil EC map indicated vast extent of low-saline soils in the groundnut belt, with few stretches of medium salinity in Narayanpet and few parts of Gadwal, Nagarkurnool and Mahabubnagar divisions of erstwhile Mahabubnagar district (Figure 3). Few exceptions were Jadcherla mandal of Mahabubnagar division, and Veepangandala and Gopalpet mandals of Wanaparthy division, which recorded medium saline soil, but have been interpolated and mapped into low saline category.

Table 2. Soil classification under different parameters as per the classes assigned for soil quality mapping of the study area

Soil parameter	No. of classes obtained	Particulars of the classes obtained	No. of samples under each class	Percentage of area covered under each class
Soil pH (1 : 2.5)	4	Slightly acidic	5	14.3
		Neutral	15	34.3
		Slightly alkaline	16	45.7
		Strongly alkaline	2	5.71
Soil EC (dSm^{-1})	2	Low saline	19	54.3
		Medium	16	45.7
Soil OC (%)	2	Low	4	11.8
		High	31	88.0
Soil available nitrogen (kg ha^{-1})	3	Extremely low	21	60.0
		Very low	13	37.1
		Low	1	2.85
Soil available phosphorus (kg ha^{-1})	3	Low	4	11.4
		Medium	6	17.14
		High	25	71.4
Soil available potassium (kg ha^{-1})	3	Low	10	28.6
		Medium	22	62.9
		High	3	8.57
Soil available sulphur (mg kg^{-1})	2	Very low	18	51.4
		Low	17	48.6
Soil available iron (mg kg^{-1})	2	Low	16	45.71
		Medium	19	54.29

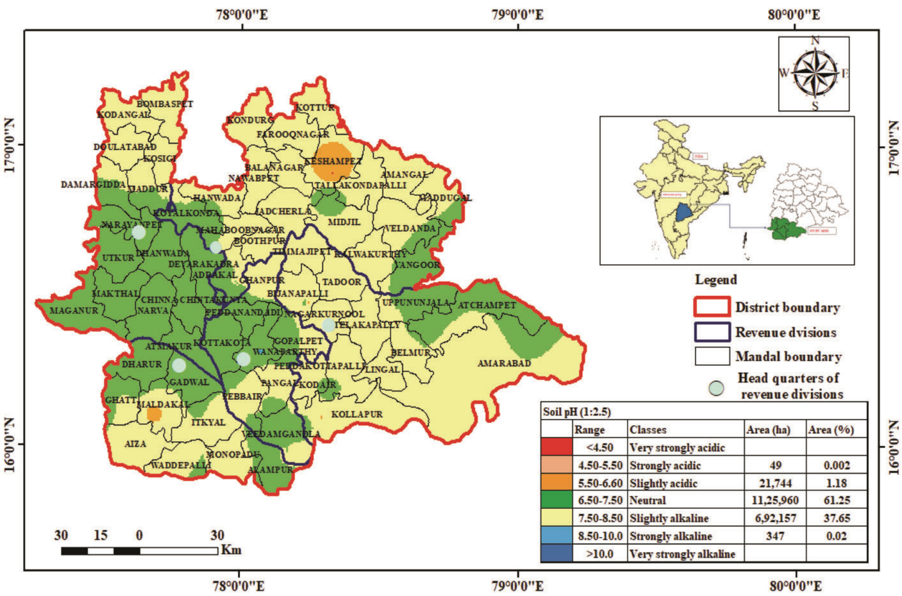

Figure 2. Soil pH (1 : 2.5) map of groundnut belt in the erstwhile Mahabubnagar district, Telangana, India.

Soil organic carbon content

The soils of erstwhile Mahabubnagar district were high in OC content, which ranged from 0.16% to 1.83% with a mean value of 1.12%. The soil map depicting OC content was in agreement with the soil test values indicating high OC content throughout the district, with few low patches in Tadoor, Gopalpet, Wanaparthy and Maldakal mandals (Figure 4). About 88% of the soils in the groundnut-growing regions exhibited high OC content and 11.76% had low OC content (Table 2). As the soil samples for estimating the OC content were drawn immediately after harvest of the crop, they reflected high OC content due to the presence of undecomposed organic matter in the samples. Also, the cropping scenario in the groundnut zone indicated that in around 90% of the regions, soils were

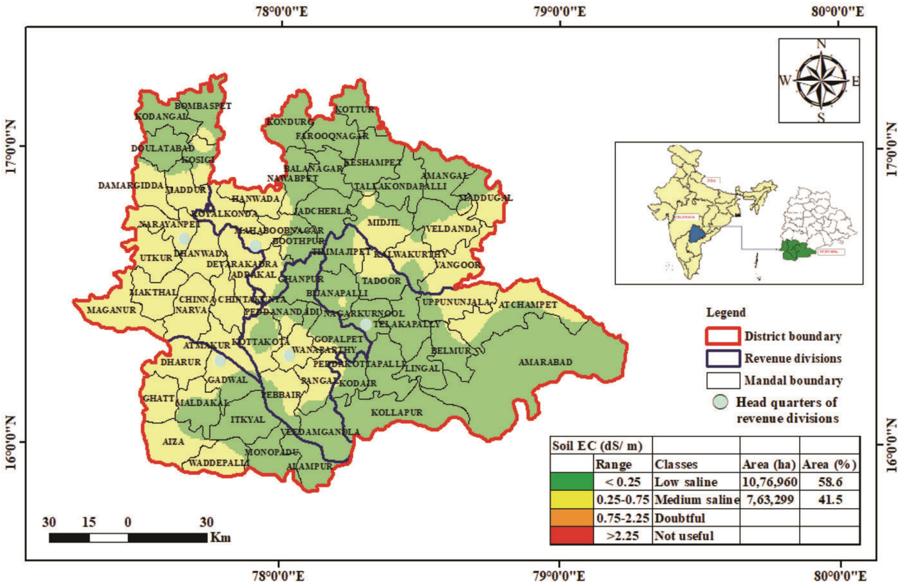

Figure 3. Soil EC (dS m^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

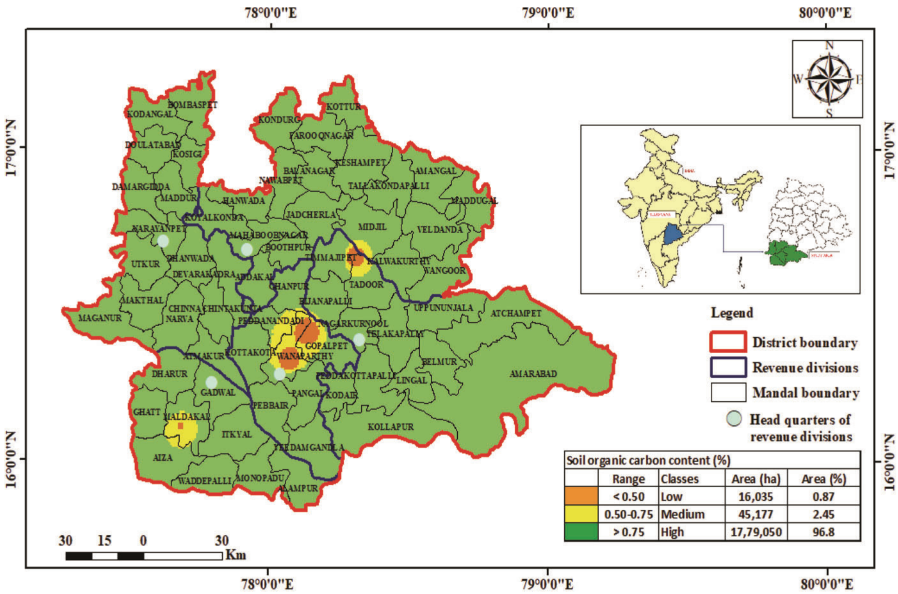

Figure 4. Soil organic carbon (%) map of groundnut belt in the erstwhile Mahabubnagar district.

kept fallow during *kharif* and the crop sown during *rabi* was incorporated into the soil after harvest. Enrichment of the soil organic pool through incorporation of legume crop and very low cropping activity and soil disturbance might have reflected in high OC content of the groundnut belt.

Soil available nitrogen

Contrary to soil OC, the entire study area was characterized as low in available nitrogen. The nitrogen content in soils ranged from 38.9 to 230 kg ha^{-1} with an average value of 97.0 kg ha^{-1} (Figure 4). This is less than the critical limits suggested by National Research Centre for Groundnut (NRCG) (160–180 kg of N ha^{-1}), indicating that available nitrogen is deficit in the study area. The study in the Thimmajipet mandal cotton-growing areas also mentioned that the soils were acutely deficit in available nitrogen[13]. Of the 35 sample locations, 60% of the regions were categorized to have nitrogen content <100 kg ha^{-1}, whereas 37.14% and 2.85% were found to have nitrogen content in the range 100–200 and 200–280 kg ha^{-1} respectively (Table 2).

In spite of high organic matter, soils of erstwhile Mahabubnagar district being light in texture are prone to degradation. Also, tropical temperatures of the region aid in

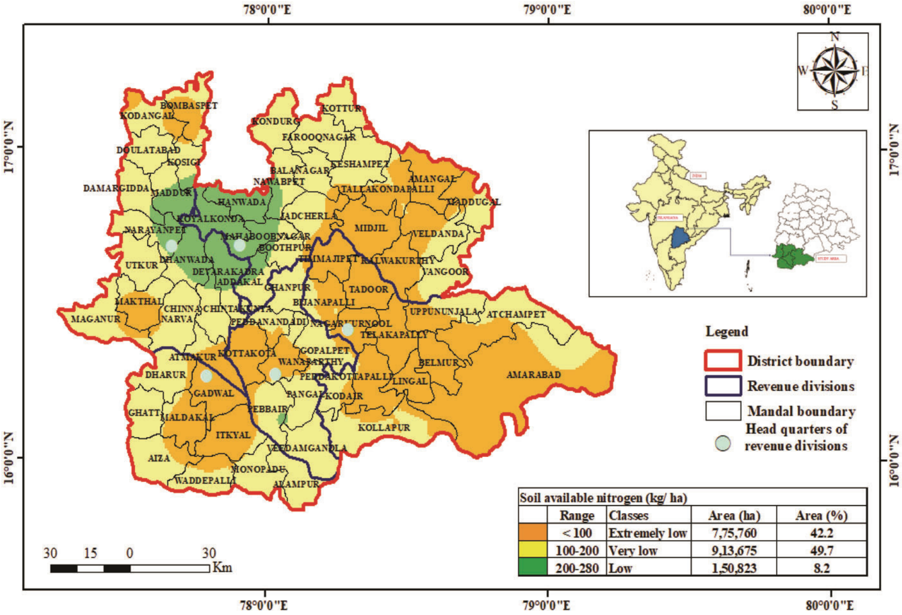

Figure 5. Soil available nitrogen (kg ha^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

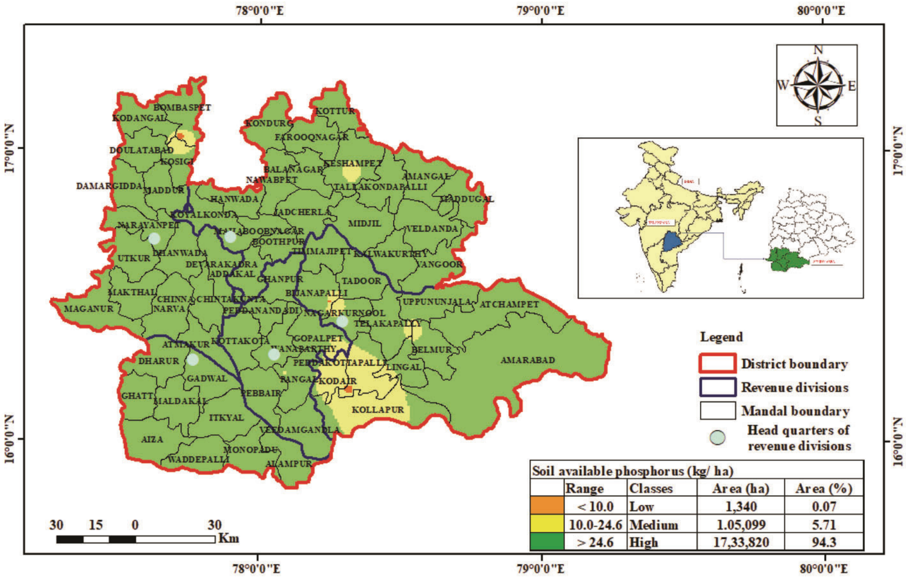

Figure 6. Soil available phosphorus (kg ha^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

rapid mineralization of organic matter when compared to its rate of accumulation, the main source of nitrogen in the soil. Under tropical conditions, organic carbon is lost in the form of carbon dioxide due to accelerated activity of microorganisms. The only way to improve nitrogen content in the soils is to apply organic manure in judicious quantities. In addition, it has been observed that in almost 75% of the regions, about 23 kg less than the recommended dose of nitrogen is being applied to the crop according to the survey conducted in the groundnut belt. Except for Jadcherla and Nagarkurnool mandals, the entire district was interpreted as low in soil available nitrogen (Figure 5).

Soil available phosphorus

The soils in the study area reported available soil phosphorus ranging from 6.66 to 70.18 kg ha^{-1}, with an average value of 35.02 kg ha^{-1}. This depicts high available phosphorus in the entire study area, except few problematic soils with high salt content. According to the critical limits (20–25 kg of P ha^{-1}) of NRCG, it is assumed that the available P is sufficient for obtaining good groundnut yields. About 71.43% of erstwhile Mahabubnagar district was found to have high available phosphorus, and 17.14% and 11.43% with medium and low available phosphorus contents respectively (Table 2). In spite of

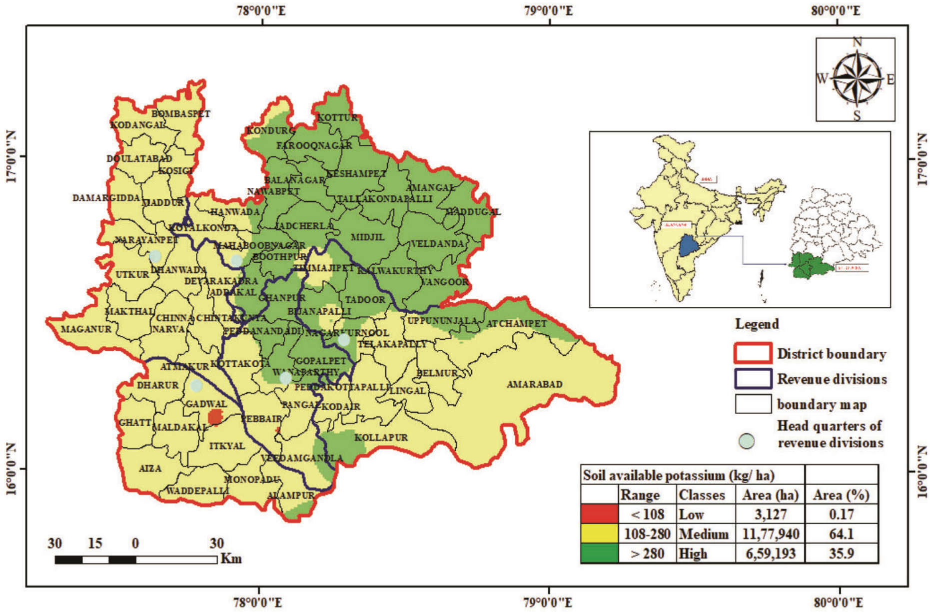

Figure 7. Soil available potassium (kg ha^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

higher uptake, higher availability of phosphorus in the soils may be attributed to excess application of phosphorus fertilizers than the recommended doses in almost half of the groundnut-growing regions in the study area. Further, residual activity of phosphorus is well known, which might have resulted in increased amounts of phosphorus in the soil. About 90% of the study area was found to have high available phosphorus (Figure 6). Thus, it would be best to supplement the crop with phosphorus only after taking into account of the available soil phosphorus.

Soil available potassium

Soil available potassium in the groundnut belt showed huge variation and ranged from 72.0 to 1093 kg ha^{-1}, with a mean value of 268 kg ha^{-1}. The available K was above the critical limits (80–100 kg of K ha^{-1}) sufficient for good growth of the groundnut crop. A similar study conducted at Kalwakurthy mandal of erstwhile Mahabubnagar district reported that the average potassium content in the study area was 188 kg ha^{-1}, with low to medium content in the soil[14]. The results reveal that 62.9% of the regions had medium available soil potassium, while 28.6% and 8.57% were categorized with low and high available soil potassium respectively (Table 2). The overall fertility gradient for soil available potassium in the groundnut belt may be rated as medium.

The soil available potassium map grouped the entire central and northeastern regions of erstwhile Mahabubnagar district into high available zone (Figure 7). Whereas the southern, western and northwestern parts were mapped as medium zone with two low points in Gadwal and Veepangandla mandals respectively, with regards to soil potassium. The soil map generated by averaging soil test values of the sample locations differed with the soil test results and depicted the fertility gradient with equally spread regions of medium and high soil potassium content. Keeping the above results in view, interventions to improve crop yields in marginally potential zones must include application of potassium to the crop according to the recommended dose, while potassium application in the highly potential zone must be according to the soil test analysis.

Soil available sulphur

Groundnut being an oilseed crop requires sulphur to increase oil content in the kernels. An overview of the soil test results indicated that available sulphur in the soils of erstwhile Mahabubnagar district ranged from 4.02 to 7.84 kg ha^{-1} with an average value of 5.81 kg ha^{-1}, depicting low sulphur status which is in accordance with the critical limits (15–20 kg S ha^{-1}) as suggested by NRCG. The low sulphur status in the study area may be attributed to insufficient application of this nutrient (Table 2) and coarse texture of the soils. In line with the soil test values, soils of erstwhile Mahabubnagar district were mapped as low in available soil sulphur with very low regions in Wanaparthy, Gopalpet, Ghattu, Kodair, Kollapur, Telkapally, Lingal, Peddakothapally, Amrabad, Achampet, Uppununtala, Vangoor and Keshampet mandals (Figure 8).

Soil available micronutrients

The soil available manganese, copper and zinc in the groundnut growing belt of erstwhile Mahabubnagar

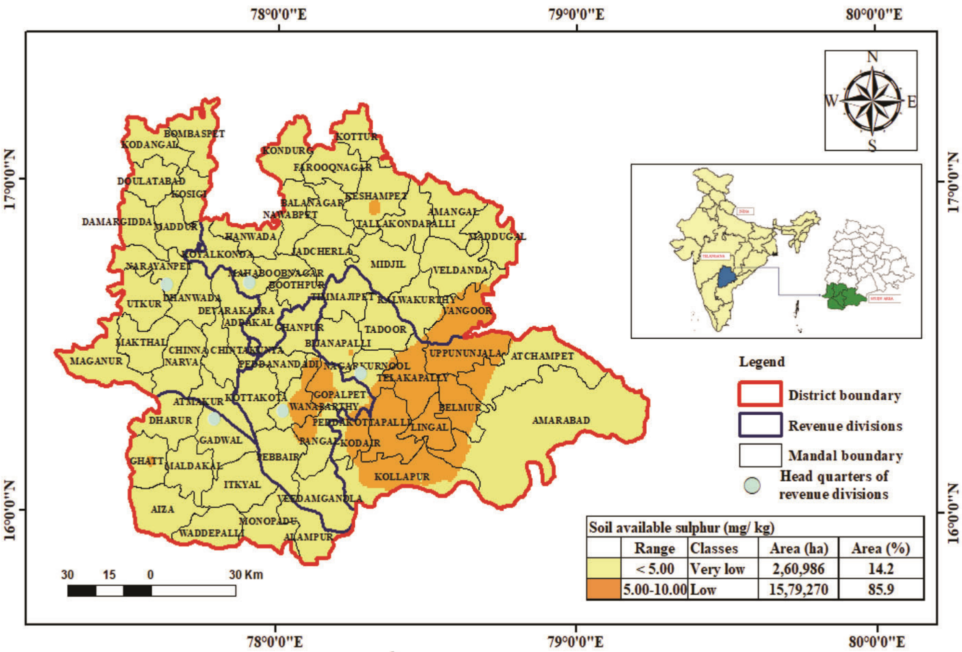

Figure 8. Sol available sulphur (mg kg^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

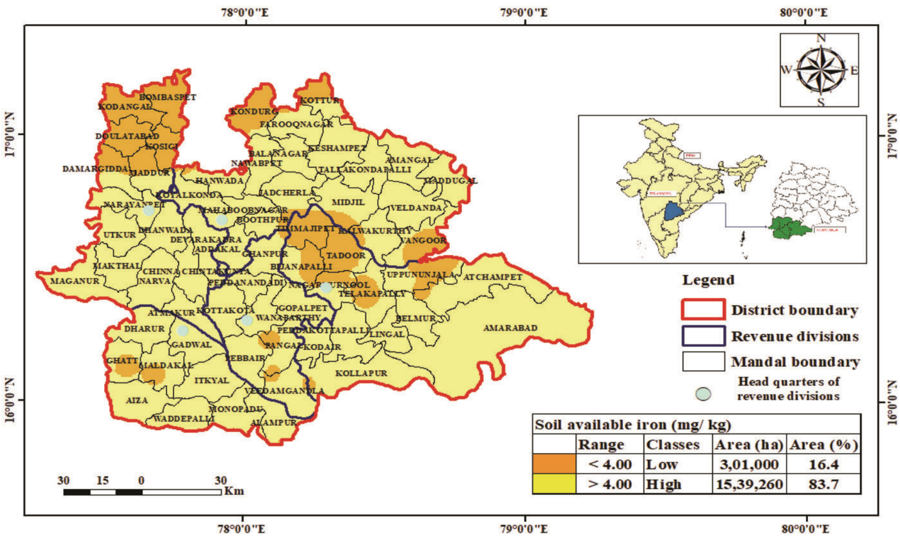

Figure 9. Soil available iron (mg kg^{-1}) map of groundnut belt in the erstwhile Mahabubnagar district.

district were found to be above the critical limits, except for iron. The mean available micronutrients were found to be sufficiently high and above the critical limits (3–4 mg Fe ha^{-1}; 3–4 mg Mn ha^{-1}; 0.3–0.4 mg Cu ha^{-1}), except zinc, which was lower than the critical limit (1.5–2.0 mg ha^{-1}) for groundnut crop as suggested by NRCG[7]. The soil available manganese ranged from 1.69 to 31.69 mg kg^{-1}, with an average value of 7.48 mg kg^{-1}. The soil available copper ranged from 0.20 to 5.77 mg kg^{-1}, with a mean value of 0.91 mg kg^{-1}. Similarly, the soil available zinc ranged from 0.53 to 3.64 mg kg^{-1}, with a mean value of 1.58 mg kg^{-1}. Ranjit *et al.*[14] obtained similar results during *rabi* season 2015–16, where the available Fe, Mn, Cu and Zn ranged from 6.55 to 13.52, 5.60 to 13.40, 0.26 to 1.47 and 0.38 to 1.50 mg kg^{-1} with mean values of 9.80, 8.88, 0.71 and 0.75 mg kg^{-1} respectively, at Kalwakurthy mandal. The soil manganese, copper and zinc did not show much variation and were found to be sufficient throughout the district. High OC of soils in the groundnut regions may be responsible for greater availability of micronutrients.

Among the micronutrients tested, soil available iron showed variations in the groundnut belt. The soil available iron content ranged from 1.25 to 18.36 mg kg^{-1}, with a mean value of 6.14 mg kg^{-1}. Based on the average value, fertility gradient of the soils may be classed as high with regard to soil available iron. However, it was observed that in 45.7% of the study area, soil iron content was low (Table 2).

Due to no deviations in manganese, copper and zinc contents, the respective soil maps were not generated. However, map for soil available iron content was generated with two classes, viz. low (<4 mg kg^{-1}) and high (>4.0 mg kg^{-1}) (Figure 9). According to the soil test values, the entire district was mapped as high in soil iron content with low patches in parts of Maldakal, Ghattu, Veepanagandla, Kollapur, Uppununtala, Vangoor, Telkapally, Lingal, Bijinapally, Tadoor, Thimmajipet, Nagarkurnool, Bomraspet, Kodangal, Kosgi, Doultabad and Maddur mandals.

Conclusion

The soils of the study area analysed after the harvest of groundnut crop were slightly alkaline (7.50–8.50), low saline (<0.25 dS m^{-1}) and had high OC content (>0.75%). Majority of the areas (60.0%) were found to have nitrogen <100 kg ha^{-1}, high phosphorus (>24.6 kg ha^{-1}), medium potassium (108–280 kg ha^{-1}), low sulphur (<10.0 mg kg^{-1}) and low iron (<4.00 mg kg^{-1}; in 45.7% of the areas). All other micronutrients were sufficient (Cu ≥ 0.20 mg kg^{-1}, Zn > 0.65 mg kg^{-1} and Mn > 2.00 mg kg^{-1}). The soil analysis results thus show lack of balanced nourishment. Hence, employing balanced fertilization along with application of organic manure will increase the yield and productivity of groundnut in the marginally potential crop colonies of erstwhile Mahabubnagar district, Telangana.

Conflict of interest: The authors declare that they have no conflict of interest.

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