International Journal of Research in Agronomy 2025; SP-8(8): 82-88

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(8): 82-88
Received: 17-05-2025
Accepted: 19-06-2025

Banoth Pavani
Department of Soil Science and Agricultural Chemistry, College of Agriculture, PJTAU, Rajendranagar, Hyderabad, Telangana, India

Sukruth Kumar T
Principal Scientist, AICRP on MSPE, ARI, Rajendranager, Hyderabad, Telangana, India

Pavan Chandra Reddy K
Principal Scientist, AICRP on STCR, ARI, Rajendranager, Hyderabad, Telangana, India

Mahadevappa SG
Senior Scientist, ACRC, ARI Rajendranager, Hyderabad, Telangana, India

Corresponding Author:
Banoth Pavani
Department of Soil Science and Agricultural Chemistry, College of Agriculture, PJTAU, Rajendranagar, Hyderabad, Telangana, India

Assessment and spatial mapping of soil fertility status in rice-growing soils of Manjeera command area, Sangareddy district, Telangana

Banoth Pavani, Sukruth Kumar T, Pavan Chandra Reddy K, Mahadevappa SG

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8Sb.3487

Abstract
A soil-crop nutrient survey was conducted in Manjeera flowing area of Sangareddy district, Telangana during Rabi, 2024 to study the fertility status of Rice growing soils. Georeferenced soil samples were collected from 100 sites covering 9 mandals during flowering stage. Soil physical and physico-chemical properties were analysed. In the study area, sand, silt and clay content ranged from, 22.2-49.3%, 11.2-40.2% and 30.4-43.5% respectively. The soils were strongly acidic to slightly alkaline in reaction (5.24-8.30), non-saline (0.01-2.54 dS m^{-1}) and low to high in organic carbon (4.12-7.89 g kg^{-1}).
Soil Nutrient Status: Available nitrogen, phosphorus, potassium contents ranged from 113.40 to 252.00 kg ha^{-1}, 13.38 -58.73 kg ha^{-1}, 132.48-397.91 kg ha^{-1} respectively.
Soil Fertility Mapping: Soil fertility maps were prepared considering the low/deficient, medium and high/sufficient range of surface soil macronutrients (N, P and K) under QGIS 3.40.8. Soil fertility maps showed that soils of the study area were mostly low in available nitrogen, medium to high in available phosphorus and medium to high in available potassium. Regular soil testing is crucial to monitor the variations in nutrient levels and formulation of appropriate management strategies to address it.

Keywords: Soil fertility status, nutrients, physico-chemical properties, maps, rice, GIS

1. Introduction
Rice (*Oryza sativa* L.) serves as a staple food for over half of the world's population and holds a critical role in global food security, particularly in Asian countries such as India. Telangana, owing to its favourable agro-climatic conditions and widespread irrigation infrastructure, ranks among the major rice-producing states in the country. The state boasts approximately 89.84 lakh hectares of cultivable land and contributes around 207.08 lakh tons of food annually (DES, 2023) [6]. Within Telangana, the Sangareddy district, nourished by the Manjeera River, constitutes a prominent rice cultivation zone, where soil fertility is a key determinant of sustainable productivity.
However, the growing pressure of increasing population, climate variability, and declining water availability presents significant challenges to rice-based production systems. These stressors not only threaten the sustainability of rice cultivation but also endanger long-term food security. In this context, understanding the physico-chemical properties and nutrient status of soils is imperative to identify areas requiring specific nutrient management for enhanced productivity.
Geospatial tools, particularly Geographic Information System (GIS)-based soil fertility mapping, provide an effective approach for integrating spatial variability with soil data. This enables precise delineation of nutrient-deficient zones and supports the formulation of site-specific nutrient management strategies. Despite the critical importance of such data, there is a lack of systematic and detailed studies on the fertility status of rice-growing soils along the Manjeera River in Sangareddy district.
Therefore, the present investigation was undertaken to assess the physico-chemical properties and soil nutrient status in the rice-growing areas of the Manjeera command region in Sangareddy district, Telangana. The findings of this study aim to contribute toward sustainable rice production by guiding effective soil fertility management practices.

2. Materials and Methods

A survey was conducted during Rabi 2024 in rice growing soils of Sangareddy district (13.70 sq km) which is situated between 17.6294^0 N and 78.0917^0 E. Sangareddy district comes under semi-arid climate with an annual average rainfall of 843.2 mm. The highest mean monthly rainfall of 197.2 mm is recorded in July and lowest of 3.7 mm in December. The district experiences an average annual maximum and minimum temperature of 33.3^0 C and 20.5 °C with annual relative humidity varying from about 61% to 93% in the morning to 21% to 64% in the afternoon (TSDPS, 2023).

Total of 100 soil and leaf samples were collected from rice growing areas covering 9 mandals of manjeera flowing areas in Sangareddy district during the flowering stage of rice crop. GPS points were recorded for each sampling site (Fig. 2.). Soil and crop nutrient status was determined along with the physical and physico chemical properties of the soils. Surface soils were analysed for soil texture analysis, pH, EC, OC, available N, P and K Soil fertility mapping for N, P and K was carried out under QGIS 3.40.8. The analyses were carried out following standard procedures furnished in Table 1. The statistical analysis was carried out using Microsoft excel.

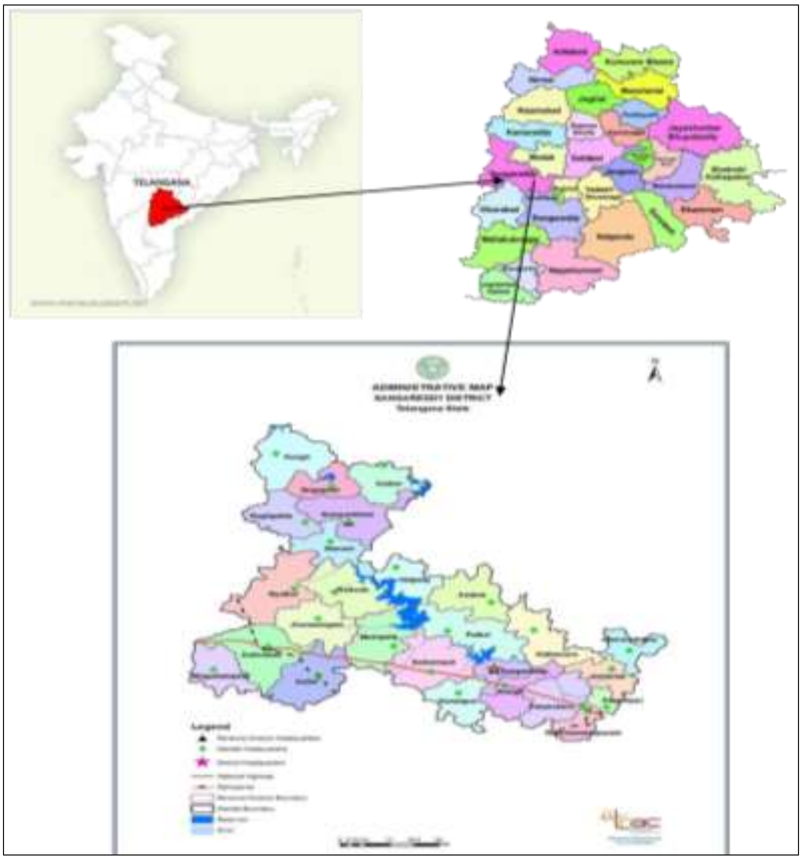

Fig 1: Location Map of the Study Area

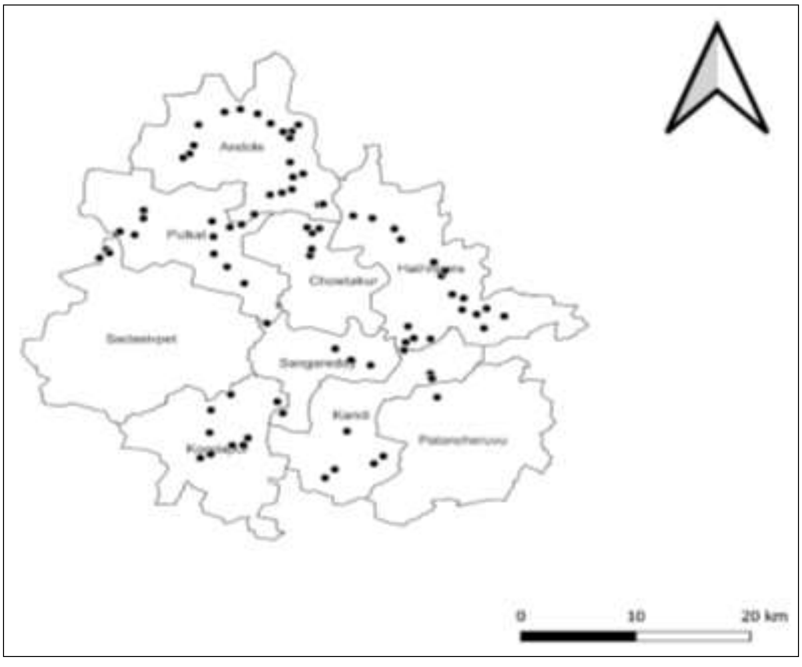

Fig 2: Location of the sampling sites of Rice growing soils

Table 1: Details of the analytical methods followed for soil and plant analysis

S. No.	Parameter	Method or reference
Physical properties		
1	Soil Texture	Hydrometer method (Bouyoucos, 1962) [4]
Physico-chemical properties		
2	Soil pH (1:2.5 soil water suspension)	Digital pH meter (Jackson,1973) [12]
3	Soil EC (dS m^{-1}) (1:2.5 soil water suspension)	Conductivity meter (Jackson,1973) [12]
4	Organic Carbon (g kg^{-1})	Wet Oxidation Method (Walkley and Black, 1934) [35]
Chemical properties		
5	Available N in soil (kg ha^{-1})	Alkaline permanganate method (Subbaiah and Asija, 1956) [31]
6	Available P in soil (kg ha^{-1})	Olsen's method (Olsen *et al*., 1956) [19]/ Bray's method (Bray and Kurtz, 1945) [5] of extraction followed by spectrophotometric method
7	Available K in soil (kg ha^{-1})	Extraction with neutral normal ammonium acetate followed by flame photometer method (Jackson, 1973) [12]

3. Results and Discussion

3.1 Physical Properties of Rice Growing Soils

3.1.1 Soil Texture

On an average, the soils of the study area Rice growing soils of Sangareddy district contained 34.5 per cent sand, 21.9 per cent silt and 43.5 per cent clay. The sand content ranged from 22.2-49.3 per cent, silt content ranged from 11.2-40.2 per cent and clay content ranged from 30.4-43.5 per cent. The different textural classes reported were sandy clay loam, Clay and Clay loam (Table 2). The mean composition of each class revealed that clay had a balanced proportion of sand (32.49 %), silt (16.17 %), and clay (51.34 %), making it favourable for rice cultivation. Clay loam exhibited a sand content (33.14 %) with silt (31.15 %) and clay (35.71 %), while sandy clay loam presented moderate sand (45.40 %), silt (18.80 %), and clay content (35.80 %). Similar results were reported by Ye *et al.* (2024) [38] in paddy fields of China, Ramprasad *et al.* (2013) [24] in rice growing soils. Textural classes of all the collected surface soil samples demonstrated their suitability to grow rice. The wide variation in textural classes might be due to different soil forming processes, in-situ weathering and translocation of clay.

Table 2: Mean Percent Composition of Sand, Silt and Clay According to Soil Texture Class in Rice-Growing Soils

Sand %	Silt %	Clay %	Texture Class
32.49	16.17	51.34	Clay
33.14	31.15	35.71	Clay loam
45.40	18.80	35.80	Sandy Clay Loam

3.2 Physico-chemical Properties of Rice Growing Soils

3.2.1 Soil pH

The soils of rice growing areas of Sangareddy district were strongly acidic to slightly alkaline in reaction with pH ranging from 5.24-8.30 with a mean of 7.31 (Tables 3). The wider pH range was observed due to the continuous leaching can remove basic cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) from topsoil Nagassa and Gebrekidan (2003) [18]; Singh and Agarwal (2003) [29], lowering buffering capacity and driving pH shifts. At the same time, carbonate or bicarbonate salts from irrigation water or in-situ carbonate precipitation (e.g. $CaCO_3$) can accumulate Balapande *et al*. (2007) [2], increasing soil alkalinity by raising pH. Moreover, repeated paddy cultivation in flooded/alkaline water conditions promotes bicarbonate build-up and exchangeable base ions, reinforcing slightly alkaline conditions over time Fageria *et al*. (2008) [7] and Reddy *et al*. (2021) [25]. Similar findings were observed by Kumar and Varma (2005) [13] and Rajasekhar *et al*. (2023) [23].

3.2.2 Electrical Conductivity (dS m^{-1})

The electrical conductivity (EC) of soils in the study district ranged from 0.01 to 1.26 dS m^{-1}, with an average value of 0.24 dS m^{-1} (Table 3). These values indicate that the soils are generally non-saline, which is favourable for optimal rice growth and productivity. Warhade *et al*. (2022) [36] similarly reported that paddy fields in the semi-arid regions of Telangana typically exhibit non-saline conditions, primarily due to effective irrigation management and moderate annual rainfall. Supporting this, Reddy *et al*. (2013) [26] observed comparable EC levels in adjacent districts, reinforcing the notion that the region's soil salinity is minimal and suitable for rice cultivation.

The Sangareddy district, where the study was conducted, receives moderate rainfall ranging between 750-900 mm annually. This level of precipitation is generally adequate to leach accumulated soluble salts beyond the crop root zone, especially in well-drained soils or fields under controlled irrigation systems. The combination of moderate rainfall and proper drainage helps maintain low salinity levels in surface soils, preventing the adverse effects of salt accumulation on crop growth and soil health. According to IP *et al*. (1988) [11], such leaching processes are essential in semi-arid zones, where salinity risks are higher in poorly managed or low-rainfall areas.

3.2.3 Organic Carbon (g kg^{-1})

The organic carbon content in the soils of the study area varied from low to high, ranging between 4.12-7.89 g kg^{-1}, with a mean value of 5.55 g kg^{-1} (Table 3). This variation reflects differences in organic matter input and decomposition rates across the rice-growing fields. According to Sowjanya *et al*. (2022) [30], the lower levels of organic carbon observed in some locations may be attributed to the rapid mineralization and degradation of organic matter under the semi-arid climatic conditions prevalent in the region. High temperatures and well-aerated soils typically accelerate microbial activity, resulting in quicker decomposition of organic residues.

Conversely, rice is commonly cultivated under flooded or waterlogged conditions, which create anaerobic environments that slow down the decomposition process. This anaerobic condition promotes the accumulation of organic matter in the topsoil, contributing to higher organic carbon content in some areas Sahrawat (2004) [27]. Thus, the observed variability in organic carbon levels across the study area likely results from the combined influence of climate, soil moisture regimes, and management practices such as residue return and organic amendments.

3.3 Chemical Properties of Rice Growing Soils

3.3.1 Available Nitrogen

The soils of Sangareddy district were observed to be low in available nitrogen, with values ranging from 113.40 to 252.00 kg ha^{-1} and an average of 178.84 kg ha^{-1} (Table 3). These results indicate a general nitrogen deficiency across the rice-growing regions of the district. Similar trends have been reported by

Vasu *et al*. (2016) [34]; Reddy *et al*. (2021) [25] and Sowjanya *et al*. (2022) [30] who also noted low nitrogen availability in soils of similar agro-ecological zones.

The low nitrogen status in these soils can primarily be attributed to the low organic carbon content, which is a major reservoir of nitrogen in soils. In the semi-arid climate of Sangareddy, high temperatures and low organic matter inputs accelerate the decomposition and mineralization of organic residues, resulting in reduced accumulation of stable organic nitrogen forms. This, in turn, limits the natural nitrogen-supplying capacity of the soil.

Moreover, the limited application of nitrogenous fertilizers by farmers, either due to economic constraints or lack of awareness of site-specific nutrient requirements, further exacerbates nitrogen deficiency. In addition, nitrogen is highly mobile and susceptible to various loss mechanisms under field conditions. These include volatilization losses as ammonia, particularly in high pH or poorly incorporated urea applications; leaching of nitrate-N, especially in light-textured or irrigated soils and denitrification under flooded or anaerobic rice-growing conditions. Furthermore, chemical and microbial immobilization processes, which temporarily bind nitrogen in unavailable forms, also reduce the pool of plant-accessible nitrogen. Surface runoff during rainfall or irrigation events can also carry away soluble nitrogen compounds, particularly in sloping or poorly managed fields Pulakeshi *et al*. (2012) [22] and Patil *et al*. (2017) [21].

3.3.2 Available Phosphorous

The soils of the study area exhibited a wide variation in available phosphorus content, ranging from 13.38 to 58.73 kg ha^{-1}, with a mean value of 28.12 kg ha^{-1} (Table 3). This variation suggests the presence of both phosphorus-medium and phosphorus-rich zones within the rice-growing soils. Comparable findings have been reported by Vasu *et al*. (2016) [34] and Reddy *et al*. (2021) [25], who observed similar trends of low nitrogen and medium to high phosphorus levels in soils of Telangana.

The lower phosphorus content in some soils can be attributed to several factors that reduce phosphorus availability despite its presence in the soil. One of the primary reasons is the fixation of phosphorus by clay minerals and oxides of iron (Fe) and aluminium (Al), particularly in slightly acidic to neutral soils. In calcareous soils, the presence of excess free calcium carbonate ($CaCO_3$) further reduces phosphorus availability by forming insoluble calcium phosphate compounds. These chemical reactions render a substantial portion of added or native phosphorus unavailable to plants.

On the other hand, higher levels of available phosphorus in some locations may result from the element's inherent immobility in soils. Since phosphorus moves very slowly through the soil profile, it tends to accumulate in the rhizosphere, especially under repeated fertilizer applications. The indiscriminate or excessive use of phosphorus-rich fertilizers such as di-ammonium phosphate (DAP) and other complex formulations can lead to phosphate buildup over time, particularly when application rates exceed crop uptake. Vandana *et al*. (2021) [35] also noted such trends of phosphorus accumulation in intensively cultivated areas.

3.3.3 Available Potassium

The soils of the surveyed rice-growing areas exhibited a considerable variation in available potassium content, ranging from 132.48 to 397.91 kg ha^{-1}, with a mean value of 217.89 kg ha^{-1} (Table 3). This wide range indicates the presence of both potassium-medium and potassium-high zones across the landscape. Similar observations were made by Vasu *et al*. (2016) [34] and Reddy *et al*. (2021) [25], who reported medium to high levels of available potassium in soils across various agro-climatic zones of Telangana.

The generally medium to high potassium availability in these soils can be attributed to the mineralogical composition of the parent material, particularly the dominance of potassium-bearing minerals such as mica and feldspars. These minerals undergo gradual weathering and release potassium into the soil solution, thereby maintaining an adequate supply over time. The intensity of weathering, especially under semi-arid conditions with alternating wet and dry cycles, enhances the breakdown of these primary minerals, leading to increased potassium availability.

In addition, higher potassium content in the surface horizons may be influenced by several other contributing factors. The decomposition of plant residues and organic matter can release labile forms of potassium, which are readily available for plant uptake. Moreover, localized application of potassium-containing fertilizers, particularly in intensively cultivated areas, can lead to potassium accumulation in the plough layer. Capillary rise of groundwater in areas with shallow water tables can also contribute to the enrichment of potassium in surface soils, as potassium dissolved in subsoil moisture moves upward during dry periods and accumulates near the surface Vandana *et al*. (2021) [33] and Ghode *et al*. (2020) [10].

Table 3: Mandal wise soil physico-chemical and chemical properties of the study area.

Mandal	p H	EC	OC	N	P	K
Andole	7.47	0.25	5.58	171	25.98	206.28
Choutakur	7.43	0.37	5.10	187.4	26.57	230.93
Sadasipet	7.39	0.11	5.49	186.5	39.25	223.00
Sangareddy	7.3	0.28	5.78	179.6	30.99	226.28
Pulkal	7.29	0.13	5.39	179.3	24.60	211.68
Patancheruvu	7.41	0.24	5.67	171.2	30.26	308.89
Kondapur	7.16	0.19	5.04	198.5	26.53	247.74
Kandi	7.61	0.2	6.11	202.2	26.90	245.18
Hathnoora	6.99	0.21	5.61	161.3	30.36	166.36

*EC: Electrical conductivity (dS m^{-1}), OC: organic carbon (g kg^{-1}), N, P, K: available nitrogen, phosphorus, potassium (kg ha^{-1})

3.4 Mandal-wise Soil Fertility Maps of Rice-Growing Soils from the Study Area

The mandal-wise soil fertility maps were developed based on the mean values of the soil nutrient data presented in Table 3. These maps provide a visual representation of the spatial distribution of key nutrients across the rice-growing regions of the study area. The analysis revealed considerable variability in soil fertility status among different mandals.

Available nitrogen was predominantly low throughout the study area, indicating a widespread deficiency that could limit crop productivity if not supplemented through appropriate fertilization practices. Available phosphorus exhibited a wide variation, ranging from medium to high across different mandals, suggesting that some areas possess adequate phosphorus reserves while others require additional inputs to meet the crop demand. Similarly, available potassium showed variability from medium to high, reflecting differences in parent material, soil mineralogy, and past fertilizer management practices among the surveyed mandals.

Soil fertility maps showed that available nitrogen was low, available phosphorus was medium to high, available potassium was medium to high in range. (Figs. 4, 5 and 6) Prananto *et al*. (2024) [206].

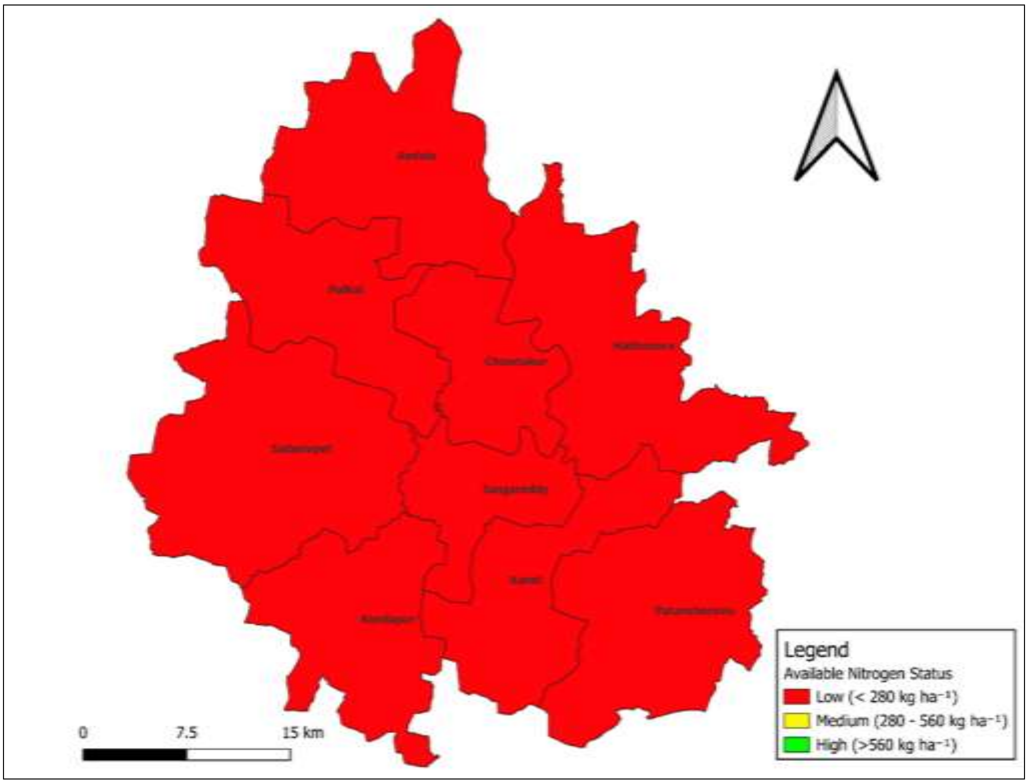

Fig 4: The Available Nitrogen status in rice growing soils.

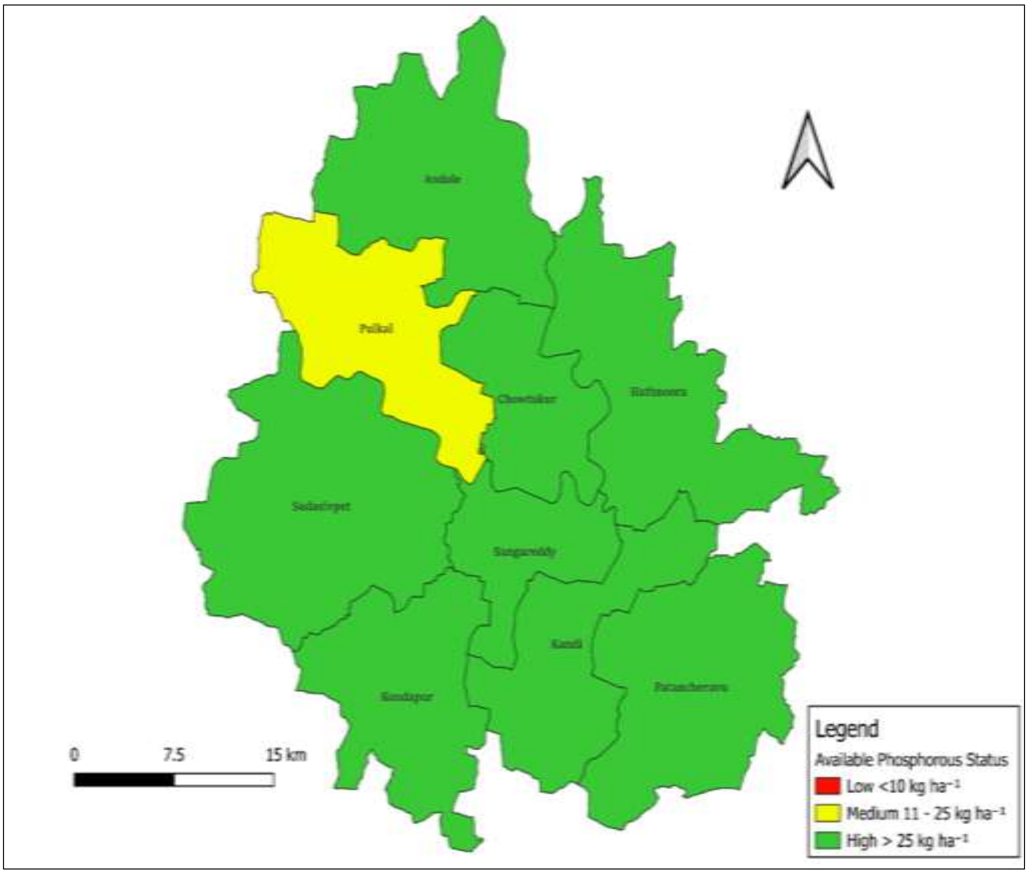

Fig 5: The Available Phosphorous status in rice growing soils.

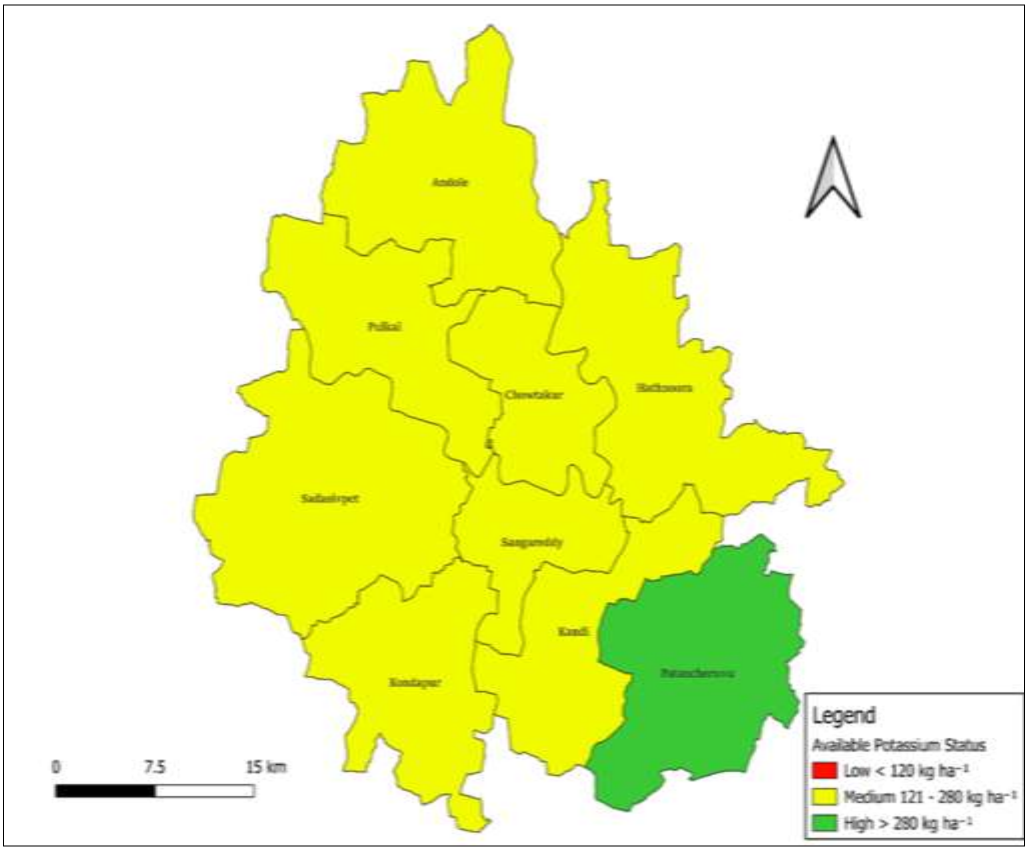

Fig 6: The Available Potassium status in rice growing soils.

4. Conclusion

The soil fertility assessment of rice-growing soils of Manjeera flowing area in Sangareddy district during Rabi 2024 revealed wide variability in soil properties and nutrient availability. The soils exhibited diverse textural classes, ranging from sandy loam to clay, with pH values spanning from strongly acidic to slightly alkaline. Organic carbon levels were predominantly low to high, and soils were largely non-saline. Critically, all sampled soils were deficient in available nitrogen, while phosphorus and potassium levels varied from medium to high.

The spatial soil fertility maps generated using GIS tools clearly illustrated nutrient distribution patterns, enabling the identification of deficient zones. These insights underline the importance of adopting site-specific nutrient management strategies, particularly for nitrogen, to improve crop productivity and sustain soil health. Regular soil testing, judicious use of fertilizers, and incorporation of organic matter are essential to address nutrient imbalances and support sustainable rice cultivation in the region.

5. Disclaimer (Artificial Intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

6. Acknowledgements

The authors acknowledge the grant support and laboratory facility provided by Institute of Soil Health Management, Agriculture Research Institute, PJTSAU, Rajendranagar, Hyderabad to conduct this research.

7. References

1. Alloway BJ. Copper and zinc in soils: a review. In: Micronutrient Deficiencies in Global Crop Production. Springer; 2008. p. 1-34.
2. Balpande HS, Challa O, Prasad J. Characterization and classification of grape-growing soils in Nasik district, Maharashtra. Journal of the Indian Society of Soil Science. 2007;55:80-83.
3. Black GR, Hartge KH. Bulk density. In: Klute A, editor. Methods of soil analysis, Part 1 - Physical and Mineralogical Methods. 2nd ed. Agronomy Monograph 9. Madison: American Society of Agronomy - Soil Science Society of America; 1986. p. 363-382.
4. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal. 1962;54:464-465.
5. Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in soils. Soil Science. 1945;59(1):39-46.
6. Directorate of Economics and Statistics. Planning Department, Ministry of Agriculture - Global Agricultural Information Network. 2023.
7. Fageria NK, Baligar VC. Ameliorating soil acidity of tropical oxisols by liming for sustainable crop production. Advances in Agronomy. 2008;99:345-399.
8. Fageria NK, Baligar VC, Jones CA. Growth and mineral nutrition of field crops. Boca Raton: CRC Press; 2010.
9. FN P. The chemistry of submerged soils. Advances in Agronomy. 1972;24:29-96.
10. Ghode MK, Vaidya PH, Pawar YS, Adkine SA, Bagmare RR. Vertical distribution of available macro and micronutrients in cotton growing soils of Nanded District, Maharashtra. International Journal of Current Microbiology and Applied Sciences. 2020;9(2):3059-3064.
11. IP A. Salt-affected soils and their management. Moscow University Soil Science Bulletin. 1988;39:99-110.

12. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall India Pvt. Ltd; 1973.
13. Kumar P, Verma TS. Characterization and classification of some rice growing soils of Palam valley of Himachal Pradesh. Agropedology. 2005;15(2):80-85.
14. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal. 1978;42(3):421-428.
15. Lindsay WL, Schwab AP. The chemistry of iron in soils and its availability to plants. Journal of Plant Nutrition. 1982;5(4-7):821-840.
16. Marschner H. Mineral nutrition of higher plants. San Diego: Academic Press; 1995.
17. Muhr GR, Datta NP, Sankarasubramaney H, Laley VK, Donahue RL. Critical soil test values for available N, P and K in different soils. Soil Testing in India. 2nd ed. New Delhi: USAID Mission in India; 1965. p. 52-56.
18. Nagassa W, Gebrekidan H. Influence of land management on morphological, physical and chemical properties of some soils Bako, western Ethiopia. Agropedology. 2003;13:1-9.
19. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular of United States Department of Agriculture. 1954;939.
20. Prananto JA, Minasny B, Weaver T. Rapid and cost-effective nutrient content analysis of cotton leaves using near-infrared spectroscopy (NIRS). PeerJ. 2021;9:e11042.
21. Patil PL, Kuligod VB, Gundlur SS, Jahnavi K, Nagaral IN, Shikrashetti P. Soil fertility mapping in Dindur sub-watershed of Karnataka for site specific recommendations. Journal of the Indian Society of Soil Science. 2016;64(4):381-390.
22. Pulakeshi PHB, Patil PL, Dasog GS, Radder BM, Bidari BI, Mansur CP. Mapping of nutrients status by geographic information system (GIS) in Mantagani village under northern transition zone of Karnataka. Karnataka Journal of Agricultural Sciences. 2012;25:332-335.
23. Rajashekhar D, Madhavi A, Surendra Babu P, Ramprakash T, Vani KP, Srinivasa Chary D. Soil fertility status of paddy growing red soils of Central Telangana Zone districts, Telangana, India. The Journal of Research, PJTSAU. 2023;50(4).
24. Ramprasad M, Govardhan V, Rao VP, Surekha K, Bhave MHV. Characterization and classification of rice growing soils of Central Telangana region of Andhra Pradesh. Journal of Research ANGRAU. 2013;41(2):52-58.
25. Reddy GK, Sharma SHK, Jayasree G, Hussain SA, Triveni S, Neelima TL. Soil fertility mapping of Patancheru area, Sanga Reddy district Telangana by using GPS-GIS. The Journal of Research PJTSAU. 2021;49(4):50-60.
26. Reddy MM, Padmaja B, Veeranna G, Reddy DVV. Response of aerobic rice to irrigation scheduling and nitrogen doses under drip irrigation. Journal of Research ANGRAU. 2013;41(2):144-148.
27. Sahrawat KL. Organic matter accumulation in submerged soils. Current Science. 2004;88(5):735-739.
28. Shukla K. Soil micronutrient pools and their transfer to paddy-crops in semi-arid agro-ecosystems, Central India. Soil and Tillage Research. 2018;180:164-174.
29. Singh IS, Agrawal HP. Characterization and classification of some rice growing soils of Chandauli district of Uttar Pradesh. Agropedology. 2003;13:11-16.
30. Sowjanya J, Kishore AJ. Soil carbon sequestration for sustainable agriculture. Innovations in Sustainable Agronomic Practices. 2020;6:148-173.
31. Subbaiah BV, Asija GL. Rapid procedure for the determination of available nitrogen in soil. Current Science. 1956;25:226-230.
32. Tandon HLS. Secondary and micronutrient recommendation for soils and crops—a guidebook. New Delhi: Fertiliser Development and Consultation Organisation; 1989. p. 22.
33. Vandana S, Reddy PVRM, Nagamadhuri K, Reddy PM. Soil fertility status of Gudipala mandal of Chittoor district, Andhra Pradesh for site specific recommendations. Andhra Pradesh Journal of Agricultural Science. 2021;7(2):76-80.
34. Vasu D, Singh SK, Duraisami VP, Jangir A, Butte PS. Fertility status of cotton (*Gossypium hirsutum*) growing soils in Thimmajipet mandal, Mahabubnagar district, Telangana. Andhra Pradesh Journal of Agricultural Sciences. 2016;2(1):10-15.
35. Walkley AJ, Black IA. Estimation of soil organic carbon by the chromic acid titration method. Soil Science. 1934;37:29-38.
36. Warhade RM, Karthikeyan K, Tiwary P, Naitam RK, Kumar N. Characterization and classification of some typical cotton growing soils of Samudrapur block of Wardha district, Maharashtra. Journal of the Indian Society of Soil Science. 2022;70(2):142-148.
37. Weather and Climatology of Telangana. Telangana State Development Planning Society (TSDPS) and Directorate of Economics and Statistics (DES). Planning Department, Ministry of Agriculture - Global Agricultural Information Network. 2022.
38. Ye C, Zheng G, Tao Y, Xu Y, Chu G, Xu C, Chen S, Liu Y, Zhang X, Wang D. Effect of soil texture on soil nutrient status and rice nutrient absorption in paddy soils. Agronomy. 2024;14(6):1339.