

Assessment of soil physical and physico-chemical properties under major cropping systems of Jaggaiahpet mandal, NTR district, Andhra Pradesh using geospatial tools

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ABSTRACT

Random soil survey was conducted in Jaggaiahpet mandal, NTR district and collected 150 representative surface soil samples (0-30 cm) with GPS locations in 24 villages of the mandal covering the major cropping systems *viz.* rice-rice, rice-fallow, cotton-maize, chilli-fallow, fallow-pulse and assessed for soil physical and physico-chemical properties. Soil physical properties like soil texture, bulk density, water holding capacity, hydraulic conductivity and aggregate stability and physico-chemical properties like soil reaction (pH), electrical conductivity, organic carbon and CEC were analysed. The analytical data was statistically interpreted for range and mean and delineated spatial variability maps for soil reaction (pH), electrical conductivity and organic carbon was made by using QGIS 3.42 software. Soils were neutral to slightly alkaline with most being non-saline. The majority of soil contain low to high organic carbon content. The variability in cation exchange capacity was ranged from 9.07 to 67.41(c mol (p⁺) kg⁻¹). The majority of the soils were clay textured (82.6%) with WHC ranging from 21.78 to 66.94 per cent. The wide variation observed in WHC could be are to differences in sand, silt, clay and organic carbon contents Hydraulic conductivity varied between 0.22 and 2.58 cm h⁻¹. Among the system studied, the fallow-pulse system recorded the lowest mean bulk density (1.15 Mg m⁻³) likely due to the greater biomass contribution from leguminous crops. The rice-fallow system exhibited the highest mean aggregate stability at 62.88 per cent which might be due natural restoration processes or consistent addition of organic matter from crop residues that help in bind soil particles together.

Keywords: *Stability, Organic carbon and Spatial variability*

Soil is one of the most vital and non-renewable natural resource that supports plant growth, regulates water and serves as a foundation for agricultural productivity. Understanding the physical and physico-chemical characteristics of soil in different cropping system is essential for sustainable land use planning and efficient crop production. Physical properties such as soil texture, water holding capacity, aggregate stability, bulk density and hydraulic conductivity influence root penetration, water availability and aeration. Similarly, physico-chemical properties like soil reaction (pH), electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC) significantly affect nutrient availability, microbial activity and overall soil fertility. Assessment of these parameters enables informed decision-making in agriculture, especially under site-specific nutrient and water management practices. When integrated with Geographic Information System (GIS) tools such as

QGIS, this approach allows for the generation of spatial variability maps that visually represent the distribution of key soil properties. These maps serve as valuable tools for precision agriculture, helping to optimize inputs and enhance productivity while maintaining soil health. The present study was undertaken to evaluate the soil physical and physico-chemical properties using geospatial tools in Jaggaiahpet mandal of NTR district Andhra Pradesh in major cropping systems.

MATERIAL AND METHODS

The study area was taken up in Jaggaiahpet mandal which is one of the 20 mandals in NTR district of Andhra Pradesh in India. The mandal occupies a geographic extent of about 246.7 km². The climate of the study area is tropical with average annual rainfall of about 1012 to 1148 mm and with an average temperature of 30.9°C. The mandal lies in

between 16°17'57.18" Northern latitude and 80°25'55.06" of the Eastern longitude. Major soil types of the study area were black cotton soil (57.6 %), sandy clay loams (22.3 %) and red loams (19.4 %). A small percentage (0.7%) of sandy soils is also present along the coast with undulated topography. The proposed study area occupies an important place in agriculture and industry with a cultivable area of 13,833 ha of which net cultivable area was 8017 ha with principal crops *viz.* paddy, cotton, maize, blackgram, groundnut and vegetable crops.

Soil samples were collected during summer using a hand-held GPS device. Sampling was to a depth of 30 cm by digging a V-shaped cut with a spade. Three to five samples were collected from each sampling unit by cutting a thick slice of soil (2.5 cm) from top to bottom of exposed face of 'V' shaped cut and placed in the container. Using quartering method composite soil sample was obtained which was collected in the clean polythene bag with proper labelling. They were shade dried for few days, pounded using wooden hammer and sieved through 4mm and 2 mm sieve and kept ready for analysis. The mechanical analysis was carried out by Bouyoucos Hydrometer method. The sand (2-0.02 mm), silt (0.02-0.002 mm) and clay (<0.002 mm) fractions were calculated using hydrometer readings. The textural classes were determined on the basis of different proportions of sand, silt and clay using the textural triangle of USDA (Baruah and Barthakur, 1997). The water holding capacity of soil samples were determined by following Keen Raczowski's method as described by Piper (2002) and the results were expressed as percentage. Bulk density of soil is the oven dry mass per unit volume of soil. It was determined by core method (Blake *et al.* 1965) Undisturbed soil samples collected with cylindrical core sampler were used for the determination of saturated hydraulic conductivity in the laboratory by constant head method as per the procedure outlined by Jalota *et al.* (1998). Aggregate stability was determined by using Yoder's apparatus (Wet sieving method). The soil reaction (pH) and electrical conductivity (EC) in ratio of 1:2.5 soil water extract were measured using standard procedures as described by Jackson (1973). Organic carbon (OC) was determined using wet oxidation method as outlined by Jackson (1973). The cation exchange capacity of the soil samples was determined by

saturation a known weight of the soil with 1 N sodium acetate (pH 8.2) (Bower *et al.* 1952). Ratings for pH, EC and OC were given in table 1 and 2. The results obtained from the physico-chemical analysis (pH, EC and OC) in soil samples in study area were used to generate spatial variability maps by applying Inverse Distance Weighted (IDW) as interpolation tool in QGIS3.42 software, where procedure is represented in Figure 2.

RESULTS AND DISCUSSION

Soil Texture

The study area comprised of mainly three different textural classes, *viz.* clay, sandy clay and sandy clay loam. The critical analysis of data indicated that 82.7 per cent of soil samples were found to be clay, 14 per cent were sandy clay and 3.3 per cent of soils were sandy clay loam in texture. Similarly, Ajeet *et al.* (2023) reported sandy loam to sandy clay loam texture in sugarcane growing areas of Samastipur district of Bihar. Among the cropping systems, highest mean sand content (38.19 %) was recorded in rice-rice system, silt (7.97 %) in chilli-fallow and clay (61.77 %) in rice-fallow system. Conversely the lowest mean sand content (30.73 %) was observed in rice fallow cropping system while the lowest silt (6.84 %) and clay content (54.97 %) were found in rice-rice cropping system. Overall, clay was dominant textural class across most villages, sandy clay loam was dominant in Tripuravaram (> 60% sand) while sandy clay was the major texture in Balusupadu, Tirumalagiri, Vedadri, Gandrai, Tripuravaram, Jaggaiahpet, Mohammadpeta, Gowravaram, Chillakallu, Annaram with varied cropping systems. The variation in soil texture might be due to variation in topographic position, nature of parent material, *in-situ* weathering, translocation of clay and age of the soils.

Water holding capacity

The water holding capacity of soils in different cropping systems of the study area varied from 21.78 to 66.94 per cent with a mean of 37.28 per cent. Among the cropping systems, wide variation in water holding capacity was observed in rice-fallow cropping system (23.17 to 66.94 %) with highest mean value of 40.98 per cent followed by fallow-pulse (26.11 to 55.36, 38.47 %), chilli-fallow (21.78 to 53.06, 37.51 %), cotton-maize (26.43 to 56.17, 37.44 %) and the

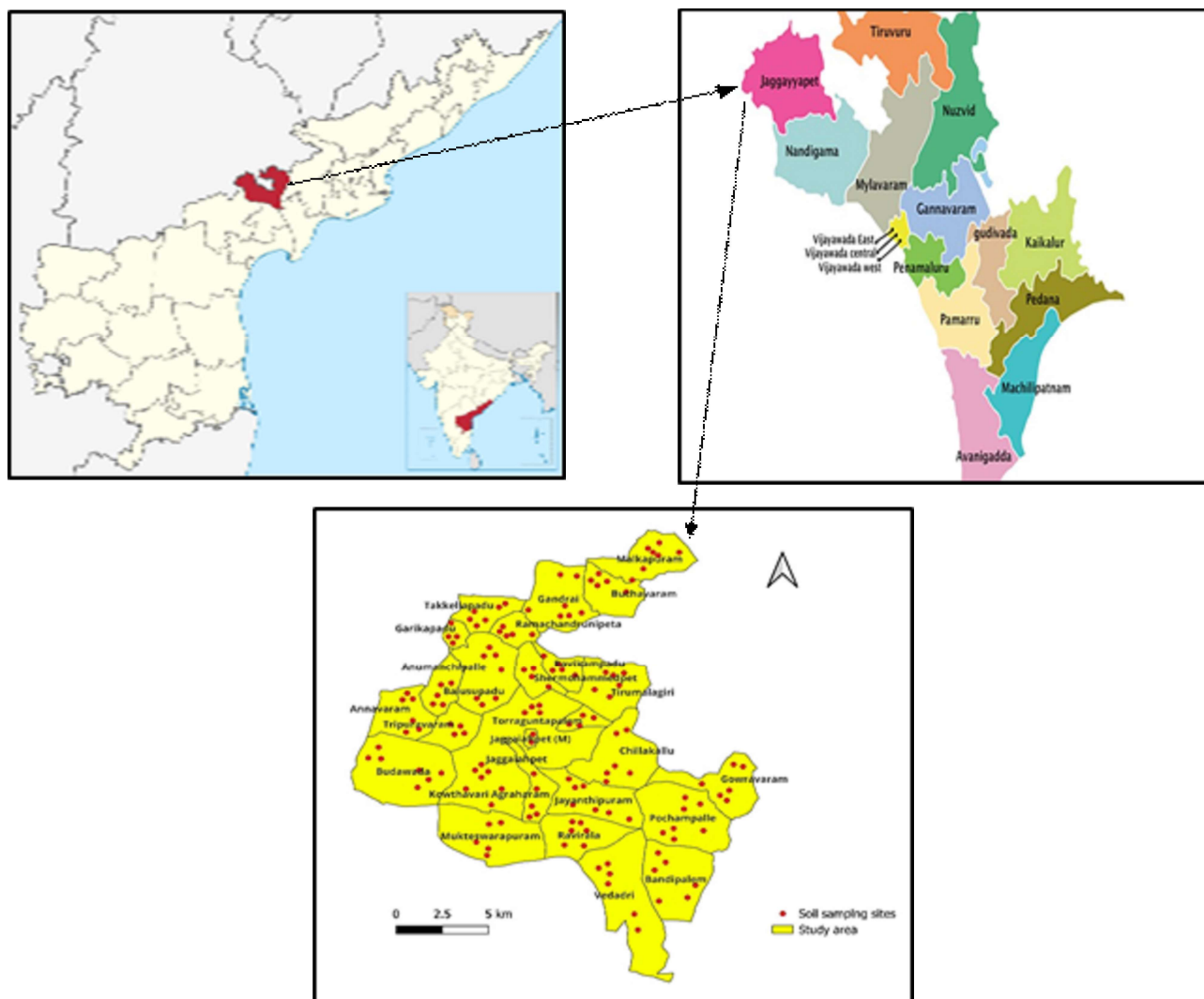


Fig 1. Distribution of soil and water sampling sites

lowest mean value was observed in rice-rice cropping system (22.25 to 48.87, 33.97 %). Lower water holding capacity values (<30%) were recorded in soils of Tripuravaram, Tirumalagiri, Mohammadpet, Annavaram, Balusupadu, Anumanchipalli, Tirumalagiri, Gandrai and Vedadri where the sand content was >35 per cent. The results obtained confirmed that water holding capacity values are lower in soils with more sand and less organic carbon content. The wide variation in WHC of soils might be due to variation in sand, silt, clay and organic carbon contents. The results were in agreement with the results of Thangaswamy *et al.* (2005) in soils of Sivagiri village in Chittoor district of Andhra Pradesh.

Bulk density

The bulk density of soils of study area among the cropping system varied from 0.23 to 1.87 mg m⁻³ with a mean value 1.21 mg m⁻³. The rice-rice

cropping system recorded the highest mean bulk density of 1.29 mg m⁻³, with values ranging from 0.23 to 1.87 mg m⁻³. The relatively highest bulk density in rice-rice cropping system suggest that continuous rice cultivation, particularly under puddled conditions, may lead to increased soil compaction and reduced pore space. In contrast, the fallow-pulse system exhibited the lowest mean bulk density of 1.15 Mg m⁻³, followed closely by the chilli-fallow and rice-fallow systems with values of 1.17 and 1.18 Mg m⁻³, respectively. The addition of greater amount of biomass from leguminous crops likely contributed to lower bulk density in cropping systems that included legumes, as the biomass made the soil looser, more porous and reduced its mechanical compressibility. Cropping systems other than rice-rice are typically associated with less intensive tillage which can promote better aggregation, enhance soil organic matter retention, improve soil structure and reduce compaction. The

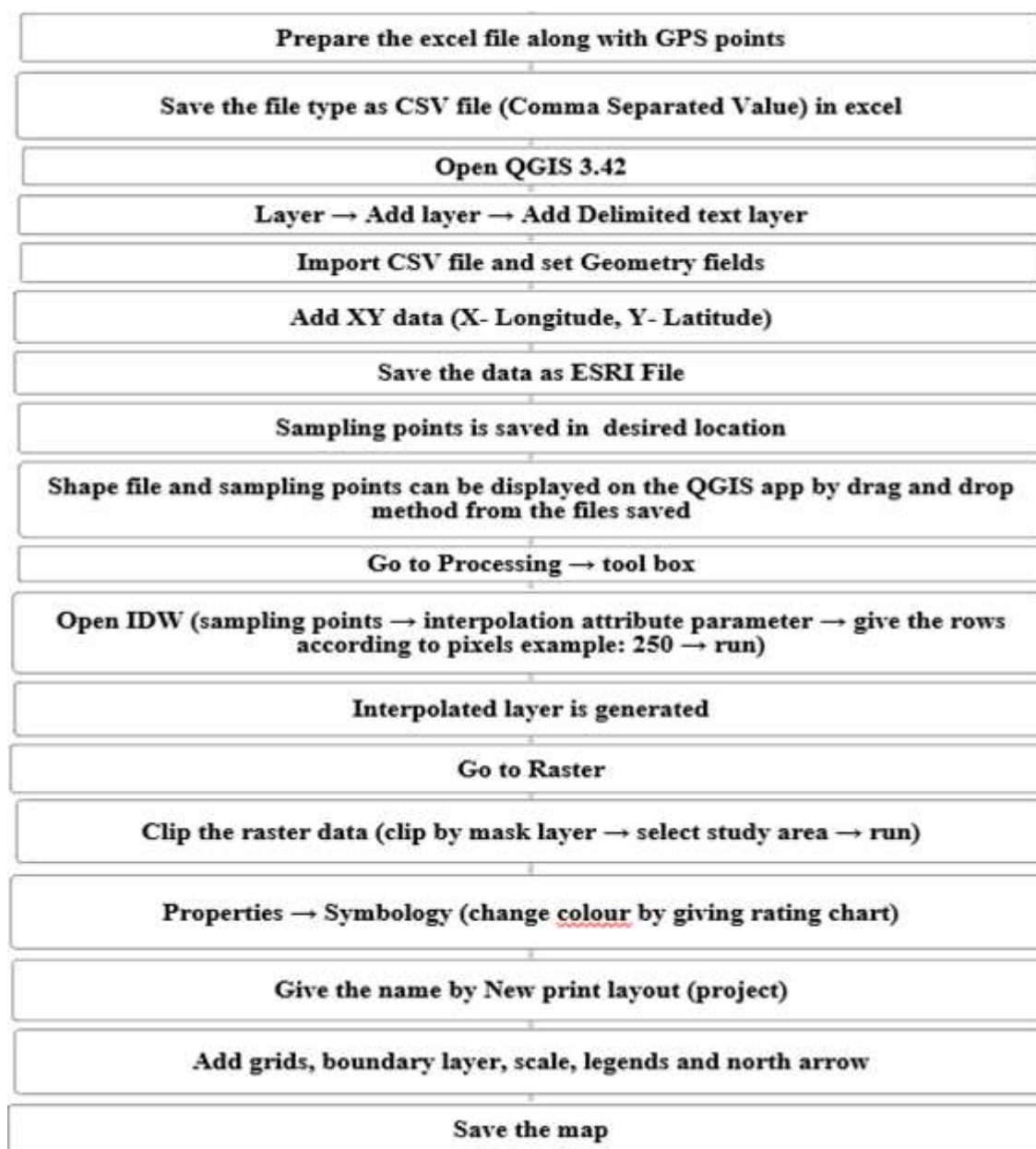


Figure 2. Procedure for generation of fertility maps in QGIS 3.42 software

rice-fallow system showed the least variability in bulk density (coefficient of variation of 9.35%), indicating consistent soil conditions under this management. Similar results were also reported by Ratnam *et al.* (2001) in non-rice growing areas of Andhra Pradesh.

Aggregate stability

The overall per cent water stable aggregates in present study area varied from 15 to 88 with a mean of 58.86. The wide variation in values of water stable aggregates among the cropping systems indicated strong influence of crop management on soil structure. The rice-fallow system showed the highest mean aggregate stability of 62.88 per cent, closely

followed by the fallow-pulse system (61.43%) and the rice-rice system (59.95 %). This might be due to benefit from either fallow periods that allow for natural restoration or consistent organic matter addition from crop residues, which help in binding soil particles together. However, the chilli-fallow system recorded the lowest aggregate stability of 52.41 per cent and this might be due to lower organic matter return and frequent soil disturbance. The higher per cent water stable aggregates in the study area suggested relatively strong and stable soil structure. Overall, systems that include pulses or fallow periods appear to support better soil aggregation, which is essential for reducing erosion, improving infiltration and supporting

Table 3. Physical properties of soils under different cropping systems in Jaggaiahpet mandal of NTR District

S.No.	Name of the village	Sand (%)	Silt (%)	Clay (%)	WHC (%)	Bulk Density (Mg m-3)	Hydraulic conductivity (cm h-1)	Percentage water stable aggregates
A. Rice-rice cropping system								
1	Range	17.40-62.40	5.00-15.00	27.60-72.60	22.25-48.70	0.23-1.87	0.10-2.66	15.00-88.00
2	Mean	38.19	6.84	54.97	33.97	1.29	0.86	59.95
3	SD	12.22	2.71	11.43	6.54	0.23	0.77	18.08
4	CV	32	39.56	20.8	19.26	17.63	89.69	30.17
B. Rice-fallow cropping system								
1	Range	7.40-52.40	5.00-15.00	42.60-82.60	23.17-66.94	1.01-1.43	0.10-1.56	30.00-74.00
2	Mean	30.73	7.5	61.77	40.98	1.18	0.58	62.88
3	SD	12.04	3.3	11	10.48	0.11	0.4	10.72
4	CV	39.17	43.96	17.81	25.58	9.35	68.83	17.05
C. Cotton-maize cropping system								
1	Range	17.40-47.40	5.00-25.00	47.60-72.60	26.43-56.17	1.01-1.85	0.21-2.00	32.00-88.00
2	Mean	35.11	7.71	57.17	37.44	1.21	0.61	59.29
3	SD	10.03	3.9	8.35	6.79	0.21	0.52	13.53
4	CV	28.55	50.56	14.6	18.13	17.46	85.24	22.83
D. Chilli-fallow cropping system								
1	Range	7.40-67.40	5.00-20.00	27.60-72.60	21.78-53.06	1.01-1.67	0.14-2.56	20.00-78.00
2	Mean	34.12	7.97	57.28	37.51	1.17	0.85	52.41
3	SD	13.05	3.99	11.56	6.34	0.18	0.72	14.15
4	CV	38.25	49.99	20.18	16.89	15.28	85.1	26.99
E. Fallow-pulse cropping system								
1	Range	12.40-47.40	5.00-10.00	42.60-77.60	26.11-55.36	0.99-1.63	0.22-2.58	27.00-86.00
2	Mean	35.97	6.9	57.12	38.47	1.15	0.77	61.43
3	SD	10.14	2.49	9.61	7.59	0.17	0.68	17.61
4	CV	28.19	36.03	16.81	19.73	14.71	88.32	28.66

sustainable crop production. Similar variation in aggregate stability in different rice based cropping system was reported by Rajpoot *et al.* (2021).

hydraulic conductivity

Significant variation in hydraulic conductivity was observed among the cropping systems. The rice–rice system exhibited the highest mean hydraulic conductivity value of 0.86 cm h⁻¹, with a wide range from 0.1 to 2.66 cm h⁻¹ and followed by chilli–fallow system (0.85 cm h⁻¹), varied from of 0.14 to 2.56 cm h⁻¹. While the lowest value was recorded in rice–fallow (0.58 cm h⁻¹) varying from 0.10 to 1.56 cm h⁻¹ suggest rice- rice cropping systems may promote higher water transmission through soil. The high

variation in hydraulic conductivity may be linked to soil texture differences, management intensity and structural heterogeneity (Soinne *et al.* 2023). Effective land management practices that minimizes compaction and enhance soil aggregation could help to improve and stabilize the hydraulic conductivity among the cropping systems.

Soil Reaction (pH)

The soils of the study area were neutral to moderately alkaline in soil reaction varied from 6.6-8.0 and with mean pH value of 7.4. (Table 4). Out of 150 soil samples collected, 40 (26.67%) soil samples were found to be neutral, 109 (72.66%) soil samples

Table 4. Physico-chemical properties of soils under different cropping systems in Jaggaiahpet mandal of NTR District

S.No.	Name of the village	pH	EC (dS m ⁻¹)	OC (%)	CEC (c mol (p+) kg ⁻¹)
A. Rice-rice cropping system					
1	Range	6.6-8.0	0.06-0.94	0.14-0.61	9.07-65.34
2	Mean	7.4	0.33	0.37	38.4
3	SD	0.2	0.22	0.11	12.74
4	CV	3	68.01	30.54	33.18
B. Rice-fallow cropping system					
1	Range	6.8-7.6	0.13-0.45	0.22-0.56	22.68-44.41
2	Mean	7.4	0.27	0.37	34.45
3	SD	0.2	0.08	0.11	6.57
4	CV	2	30.45	29.51	19.06
C. Cotton-maize cropping system					
1	Range	6.8-7.7	0.10-0.49	0.12-0.60	23.88-67.41
2	Mean	7.4	0.26	0.39	41.18
3	SD	0.2	0.09	0.14	11.82
4	CV	2.8	35	35.04	28.69
D. Chilli-fallow cropping system					
1	Range	6.8-7.7	0.03-0.44	0.18-0.81	11.32-53.17
2	Mean	7.4	0.24	0.39	32.81
3	SD	0.2	0.1	0.13	9.61
4	CV	2.7	44.32	34.52	29.29
E. Fallow-pulses cropping system					
1	Range	6.8-7.6	0.10-0.32	0.11-0.68	24.18-54.20
2	Mean	7.4	0.22	0.45	40.67
3	SD	0.2	0.05	0.19	8.75
4	CV	2.6	22.88	42.83	21.51

were slightly alkaline and 1 (0.67%) sample found to be moderately alkaline. The mean pH value 7.4 remained consistent among the cropping systems indicating that the soils in the study area maintained a stable reaction. This pH is favorable for the optimum availability of most plant nutrients and microbial activity. Such stability in soil pH indicates the absence of significant issues related to soil reaction, making the soils well suited for cultivating a wide range of crops. The results were in agreement with those of Sudha Rani and Jayasree (2014) in intensively rice growing areas of Guntur district and Rajpoot *et al.* (2021) in Northern hill region of Chhattisgarh.

Electrical Conductivity (EC)

The EC values ranged from 0.03 to 0.94 dS m⁻¹, with a mean of 0.27 dS m⁻¹ indicating that the soils were non-saline in nature. The low EC values might be due to leaching of soluble salts by heavy rainfall. Among the cropping systems, the electrical conductivity (EC) values ranged from 0.06 to 0.94 dSm⁻¹ in rice-rice, 0.13 to 0.45 dSm⁻¹ in rice-fallow, 0.10 to 0.49 dSm⁻¹ in cotton-maize, 0.03-0.44 dSm⁻¹ in chilli-fallow and 0.10 to 0.32 dSm⁻¹ in fallow-pulse cropping systems. The highest mean of EC recorded in rice-rice cropping system (0.33 dS m⁻¹) followed by rice-fallow cropping system (0.27 dS m⁻¹),

cotton-maize cropping system (0.26 dS m^{-1}), chilli-fallow cropping system (0.24 dS m^{-1}) with the lowest mean observed in fallow-pulse cropping system (0.22 dS m^{-1}). Similar, non-saline nature of the soil samples were earlier reported by Mandal and Gosh (2022).

Soil organic Carbon

The overall organic carbon content of the soils of study area varied from 0.11 to 0.81 per cent and with a mean of 0.39 per cent. Based on the critical limits suggested by (Ramamoorthy and Bajaj 1969), Out of 150 soil samples in five different cropping systems, 117 (78 %) soil samples were low in organic carbon, whereas 32 (21.33 %) soil samples were medium and one (0.67 %) soil sample was high in per cent carbon content. The low organic content in the soil was attributed to the prevalence of tropical climate where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, leaving less organic carbon in the soil (Sireesha and Naidu 2013). The fallow-pulse cropping system recorded the highest mean organic carbon content 0.45 per cent, indicating better organic matter accumulation, likely due to the inclusion of legumes and fallow phases that enhance residue return and microbial activity. The chilli-fallow and cotton-maize systems followed with mean organic carbon values of 0.39 per cent, showed moderate levels. Rice-rice and rice-fallow had the lowest mean organic carbon (0.37 %), indicating potential depletion of organic matter due to intensive cultivation and residue removal or due to low input of farm yard manure and crop residues as well as their rapid rate of decomposition under high temperature. Similar results were reported in Nagapattinam taluk of Tamilnadu.

CONCLUSION

From this study, the evaluation of physical and physico-chemical properties of soils in Jaggaiahpet mandal has revealed notable variations noticeable differences across the study area. Most soils were clayey in texture, which supports better water retention and structural stability. The soils were generally neutral to slightly alkaline and non-saline, making them suitable for a wide range of crops. Organic carbon content ranged from low to high, indicating the potential benefit of incorporating organic amendments to maintain soil fertility. The Spatial distribution maps generated using

QGIS clearly illustrated the key soil properties such as pH, EC and OC vary across the study area. These findings emphasize the importance of regular soil testing and the use of geospatial tools for precise soil fertility management and promoting sustainable agricultural practices.

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