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Spatial mapping of soil physical and physico-chemical properties in VR gudem village of Ponduru mandal, Srikakulam district

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ABSTRACT

The present study was undertaken to evaluate the spatial distribution of soil fertility in the soils of VR Gudem village, Ponduru mandal, Srikakulam district, Andhra Pradesh, employing geospatial analytical techniques. A total of 131 geo-referenced surface soil samples were systematically collected from VR Gudem village at a regular grid interval of 150 m^2 from the 0–25 cm depth horizon. The study area is situated within the north coastal agro-climatic zone of Andhra Pradesh and is characterised by a sub-humid to semi-arid climatic regime. Collected soil samples were subjected to standard laboratory analyses for key fertility parameters. Spatial fertility distribution maps were subsequently generated under a Geographic Information System (GIS) environment using Quantum GIS version 3.40, enabling a spatially delineated representation of fertility gradients across the village. The soil texture was ranged from clay to sandy clay, water holding capacity and bulk density were ranged from 20.0 to 61.2 per cent, 1.34 to 1.61 Mg m^{-3} respectively. Soils were strongly acidic to moderately alkaline (5.10-8.36) in soil reaction, non- saline character (0.02- 0.51 dS $m^{-1.}$) and low to medium (0.15-0.72 %) in organic carbon. Spatial variability maps generated for each fertility parameter revealed the inadequacy of uniform nutrient management strategies and necessitates site-specific interventions.

Key Words: *Geo- referenced, GIS, Grid sampling, Nutrient management, Soil fertility status, Soil properties, Spatial variability maps*

Soil is far more than dirt, it's a dynamic living matrix as core function in agriculture is to support plant growth by supplying nutrients, water and physical support. This capacity is called soil fertility. Fertile soil is not simply rich soil it must supply the right nutrients, at the right time, in the right form. Fertility is constrained by three broad categories of factors: chemical (pH imbalance, nutrient deficiency, salinity etc..), physical (compaction, poor drainage, unfavourable texture) and biological (low organic matter, weak microbial communities). These constraints directly limit crop yields and input use efficiency. Traditionally, fields were managed as if uniformly fertile but no field is uniform. Soils vary enormously across even short distances due to differences in parent material, topography, erosion, climate and management. Systematic grid-based collecting soil samples at regular intervals across a field captures the spatial dimension of fertility. It allows data to be geographically referenced, turning isolated measurements into a spatially continuous picture of the soil landscape. Grid data fed into geostatistical techniques (such as kriging and inverse distance weighting) that interpolate between sample points and generate continuous spatial estimates. The result is a variability map which is a visual layer showing how fertility parameters (pH, organic carbon, available phosphorus, nitrogen, etc.) change across the landscape. The application of Global Positioning System (GPS) is a navigation and surveying technology that operates through a network of satellites, designed to accurately determine specific locations and time measurements. It functions by receiving radio signals transmitted from these satellites and can operate either instantaneously in real-time or through subsequent data analysis in post-processing mode and Geographic Information Systems (GIS), which enables the examination of regional areas through spatial distribution analysis, is widely recognized. With the growing availability of digitized

data, it has become increasingly feasible to create software capable of determining soil characteristics and generate thematic maps that illustrate soil types and nutrient levels, all integrated with GIS technology.

MATERIAL AND METHODS

Study site

The study area, VR Gudem village is located in Ponduru mandal in Srikakulam district of Andhra Pradesh (Fig.1). V R Gudem village geographically located between 83º.48'.00"E to 83º.46'.48" E longitude and 18º.18'.55" N to 18º.20'.17" N latitude with a geographical extent of 681.258 ha. The study area falls under East coast plains & Hills region (XI) and North coastal zone of Andhra Pradesh (planning commission,1989). The climate is semi-arid to subhumid tropical climate with distinct seasonal variations include summer, winter, and rainy seasons. By the end of April and May temperature shifts to peak making weather hot and dry. The monsoon season commences in July and lasts till October bringing the significant rainfall in VR Gudem village. A detailed soil survey was conducted using the survey of India toposheet on a 1: 10,000 scale base as per the procedure outlined by AIS& LUS (1970). The major crops grown in the study area are sugar cane, rice, vegetable crops, horticultural crops like cashew plantations. The main source of irrigation in the study area are wells or tube wells and tanks.

Soil sampling and laboratory analysis

Soil samples (0-25 cm) were collected after the harvest of winter crops by grid method using GPS receiver. The grid interval was fixed at 150 x 150 m^2 and 131 composite samples were collected from the field covering the whole village of Ponduru mandal, Srikakulam district. The samples were labelled, air dried, grounded and sieved through a 2-mm sieve for analysis of soil physical and physico-chemical parameters. Particle size analysis was undertaken by Bouyoucos hydrometer method by Piper (1966). Soil bulk density was determined by Majumdar and Singh (2008), soil water holding capacity was determined from Keen-Razkowski cups by Piper (1966). The

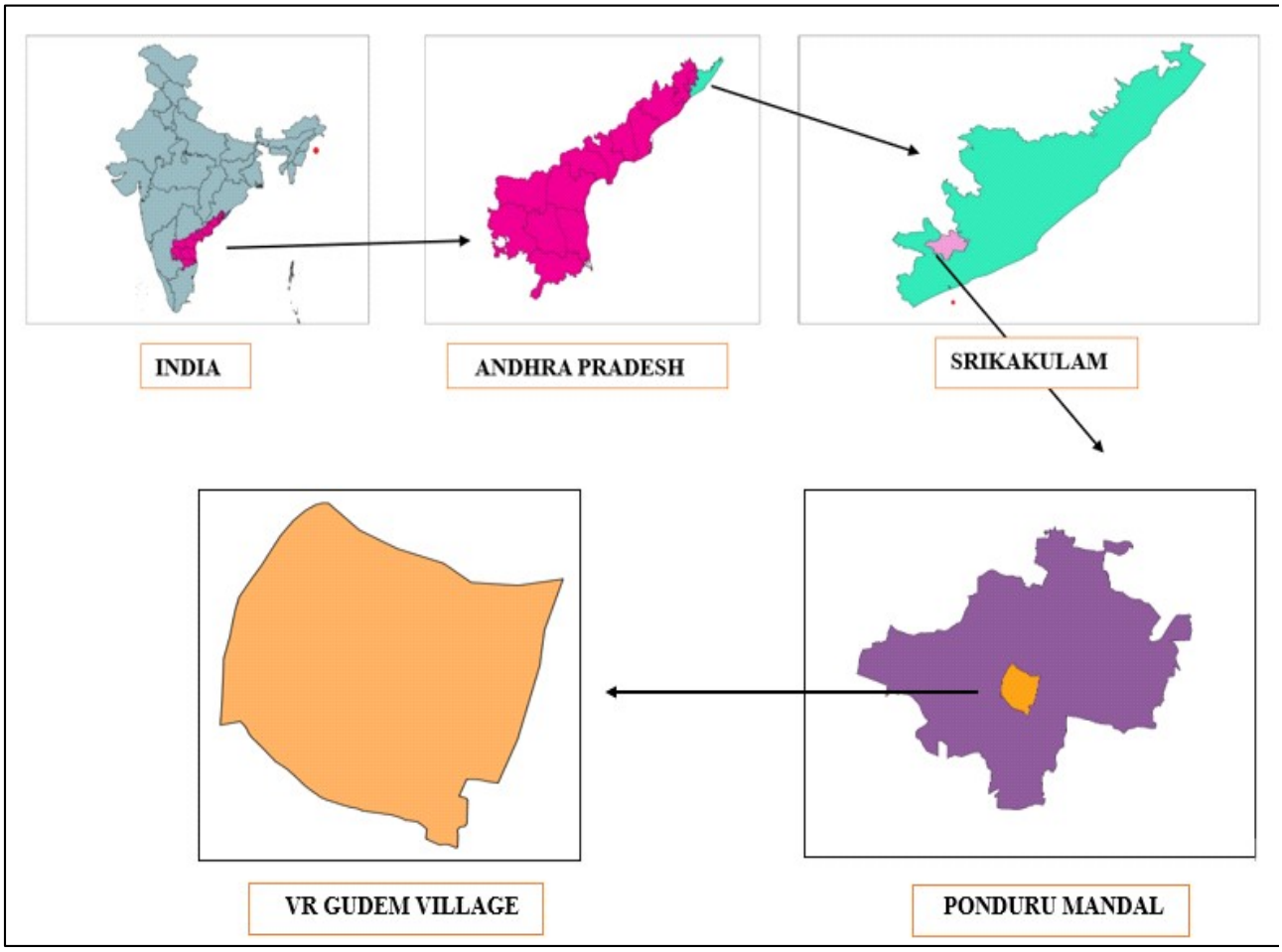


Fig.1. Location map of the study area (V R Gudem Village)

pH and electrical conductivity (EC) of soil samples were determined in 1: 2.5 :: soil: water suspension (Jackson 1973). Soil was finely ground and passed through 0.2 mm sieve and organic carbon (OC) was determined by Walkely and Black (1934). The critical limits used for classification by following criteria Table 1.

Preparation of soil fertility maps

Fertility maps illustrating the nutrient status of soil were produced by utilizing analytical data obtained from individual nutrient assessments. The location-specific point data gathered through GPS technology was subsequently converted into polygon-based spatial data by applying the inverse distance weighting (IDW) interpolation technique within the Quantum-GIS software platform.

RESULTS AND DISCUSSIONS

Physical characteristics

The data pertaining to particle size distribution in the study area revealed that significant variability in soil texture from clay (59.64%) most predominant to sandy clay (40.45%) occupying next highest areas. The clay content varied from 32.9 to 69.4 per cent, the silt content of these soils varied from 5.00 to 15.0 while the sand fractions varied from 17.6 to 60.6 per cent. The high amount of clay content can be attributed to the in-situ weathering of parent material as well as the downward movement and accumulation of clay particles through vertical migration and illuviation processes (Vedadri and Naidu *et al.,* 2018). Regarding silt content, it generally followed an inconsistent pattern across varying soil depths and this uneven distribution may be linked to differences in the extent of parent material weathering or its formation within the existing location (Kumar and Naidu, 2012). The presence of sand can be associated with the siliceous characteristics inherent in the granite-gneiss parent material.

The bulk density varied from 1.34 to 1.61 Mg m^{-3} and higher levels in the surface layers can likely be explained by the presence of coarse soil texture and a reduced level of organic matter content (Basavaraju *et al.,* 2005). The variation in bulk density found across these soils was linked to differences in moisture content and the substantial presence of expanding type clay minerals. Comparable findings were reported by Sharma *et al.* (1994) in the lower Siwaliks region of Himachal Pradesh.

The water holding capacity varied from 20.1 to 61.3 per cent and fluctuations observed in WHC can be attributed to differences in soil depth, clay composition, silt proportion and organic carbon content and may further be linked to the processes of illuviation and eluviation of finer soil fractions occurring across various soil layers (Leelavathi *et al.,* 2009).

Physico-chemical properties

The Soil reaction (pH) values of 1:2.5 soil water suspensions with majority portion in neutral

Table1. Critical limits of different parameters

Parameters	Critical limits	
Soil Texture	Sand	2-0.02 mm
	Silt	0.02-0.002 mm
	Clay	<0.002 mm
Soil Reaction (pH)	Strongly Acidic	5.1-5.5
	Medium Acidic	5.6-6.0
	Slightly Acidic	6.1-6.5
	Neutral	6.6-7.3
	Mildly alkaline	7.4-7.8
	Moderately alkaline	7.9-8.4
Electrical Conductivity (EC)	Non saline	0-2 dS m^{-1}
	Very slightly saline	2-4 dS m^{-1}
Organic Carbon (OC)	Low	< 0.5 %
	Medium	0.5-0.75 %
	high	>0.75 %

(32.8 %), strongly acidic (9.92 %), moderately acidic (6.1%), slightly acidic (17.5%), slightly alkaline (28.8 %), moderately alkaline (5.34%) and ranges between 5.10 to 8.36 and exhibited a strongly acidic to moderately alkaline range. The minimum pH values recorded under cultivated land might be due to release of organic acids during decomposition of organic matter, these acids brought to acidic pH in surface samples. Consistent findings were observed by Ram *et al*. (1999).

The electrical conductivity values ranging between 0.02 to 0.51 dS m^{-1} fall within non-saline range. The low EC in these soils was due to leaching of soluble salts by percolating water found normal EC.

The organic carbon in the soils indicated 59.5 percent under low and 40.4 per cent of samples under medium organic carbon content that exhibited values ranging from 0.15 to 0.72 per cent. The reduction in organic carbon (OC) levels is linked to the incorporation of plant residues and farmyard manure (FYM) into the surface soil horizons. Furthermore, the progressive decline of organic carbon with increasing soil depth may be attributed to the prevailing tropical climatic conditions wherein the breakdown of organic matter takes place at an accelerated rate due to elevated temperatures combined with insufficient vegetation cover, consequently resulting in diminished organic carbon levels retained within the soil profile (Nayak *et al.,* 2002). The spatial variability maps were generated using QGIS obtained from the results were depicted for soil pH (Fig. 2), EC (Fig. 3), OC (Fig.4), sand (Fig.5), silt (Fig.6), clay (Fig.7), BD (Fig. 8), WHC (Fig. 9) for VR Gudem village.

Table 2. Summary status of physical, physico-chemical properties in VR Gudem village.

	Sand (%)	Silt (%)	Clay (%)	WHC (%)	B. D (Mg m-3)	pH(1: 2.5)	EC (1: 2.5) (dS m-1)	OC (%)
Range	17.6- 60.6	5.00- 15.0	32.9- 69.4	20.1-61.3	1.34-1.61	5.10 - 8.36	0.02 - 0.51	0.15-0.72
Mean	41.7	6.64	51.5	39.5	1.49		0.19	0.46
SD	10.2	2.8	9.63	10.5	0.07	0.84	0.11	0.12

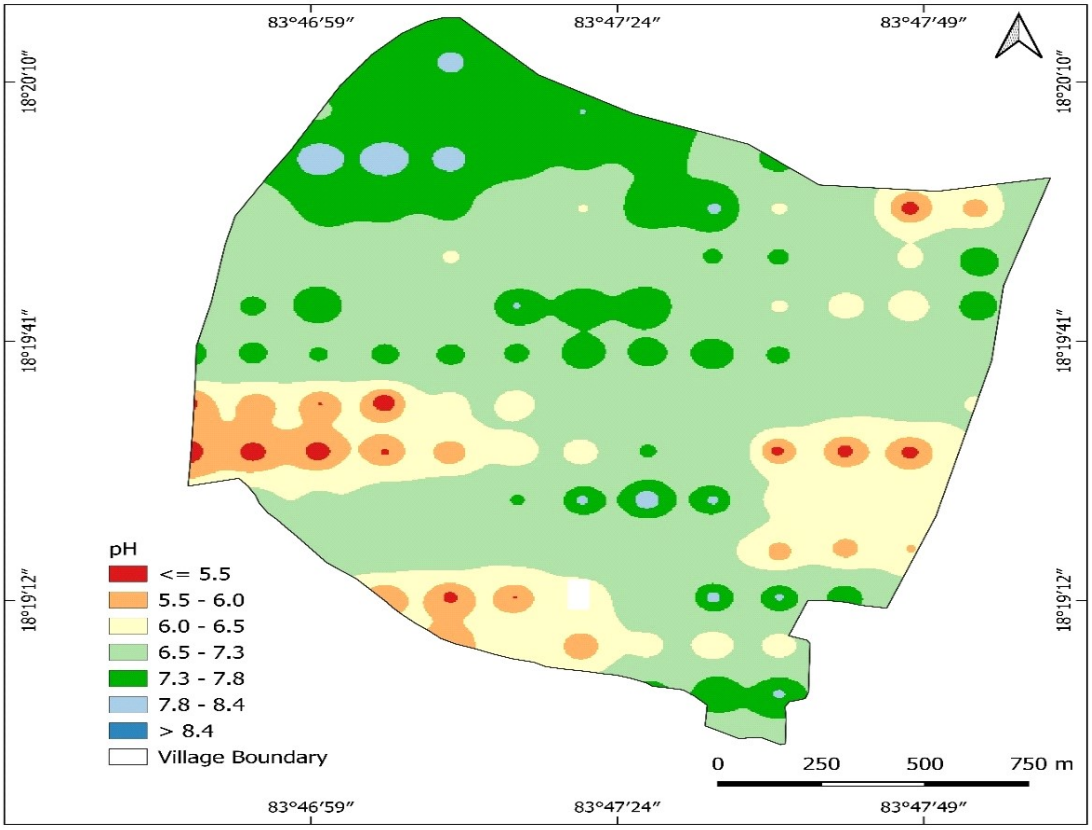


Fig. 2. Spatial variability of Soil Reaction (pH) of the VR Gudem village

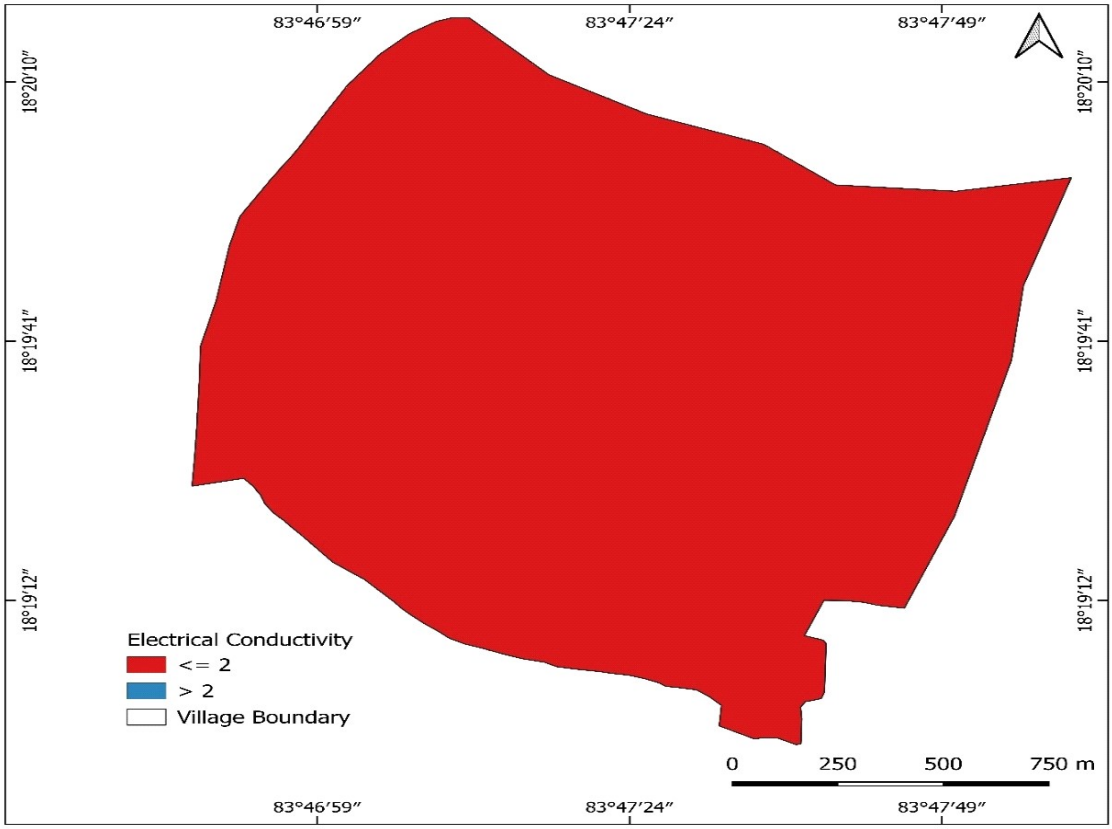


Fig.3. Spatial variability of Electrical Conductivity of the VR Gudem village

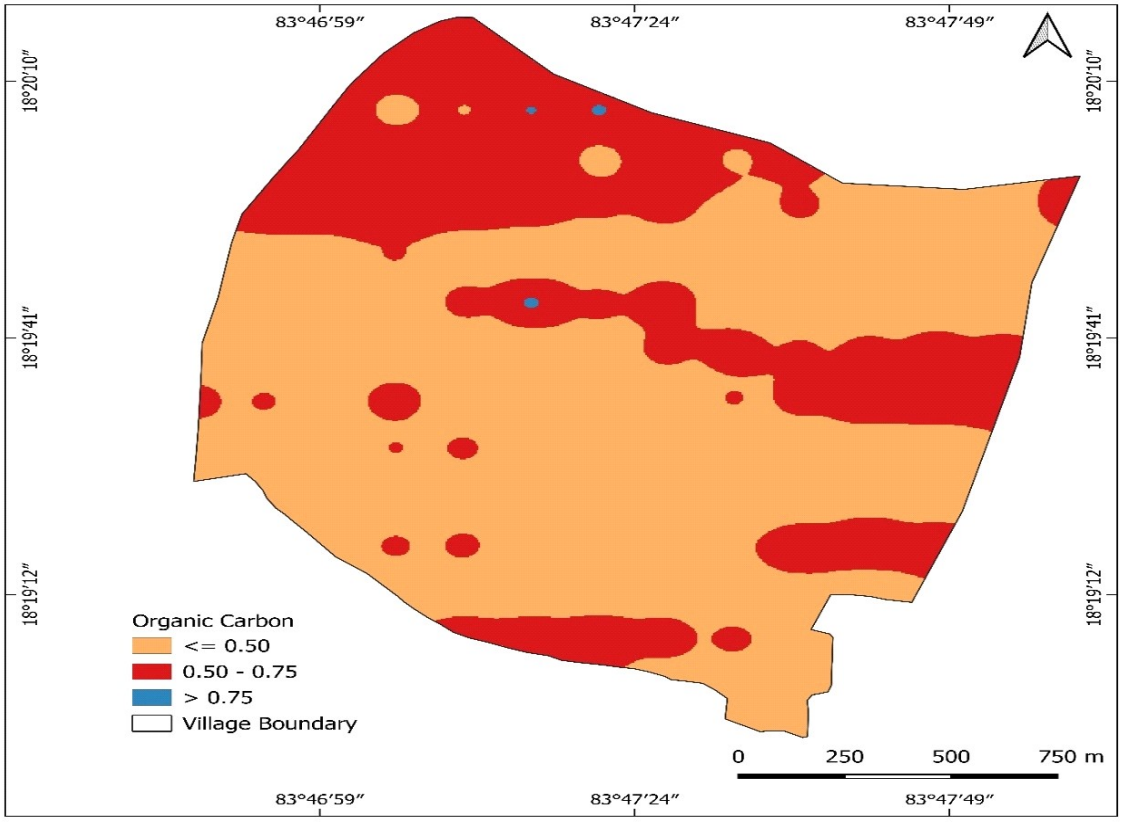


Fig.4. Spatial variability of Organic Carbon of the VR Gudem village

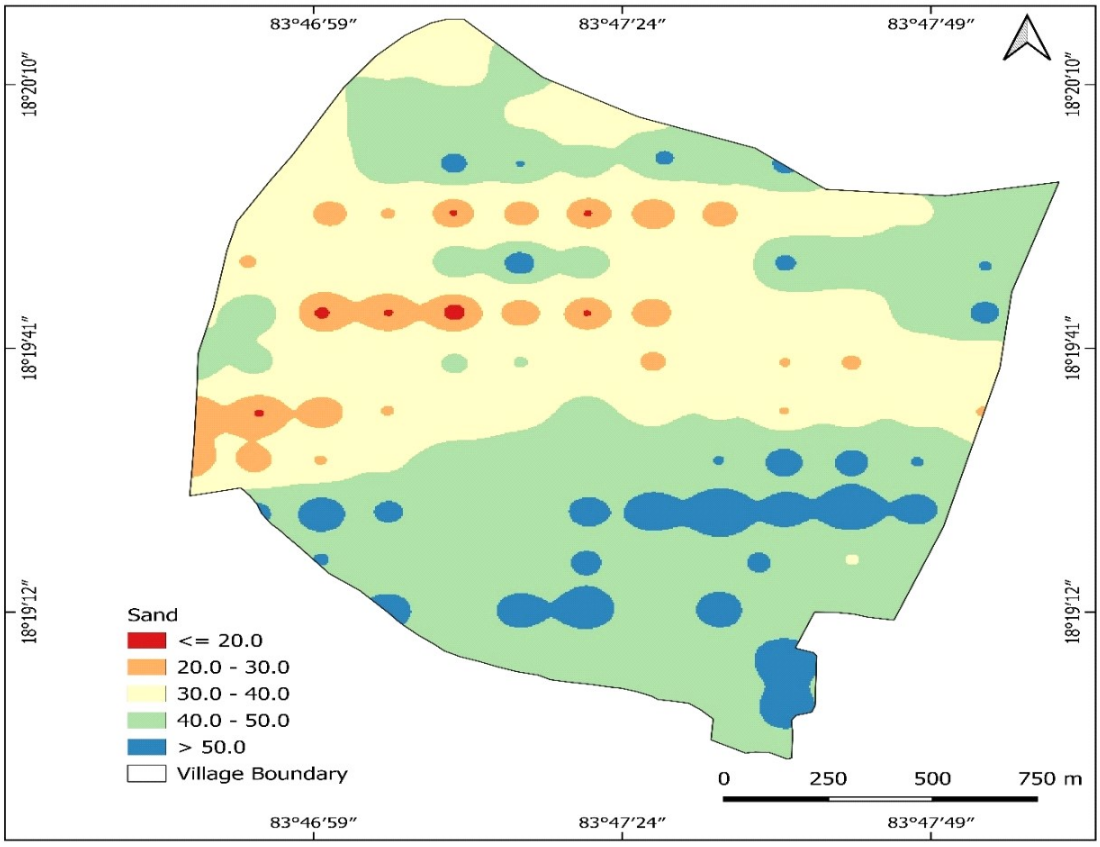


Fig. 5. Spatial variability of Sand content of the VR Gudem village

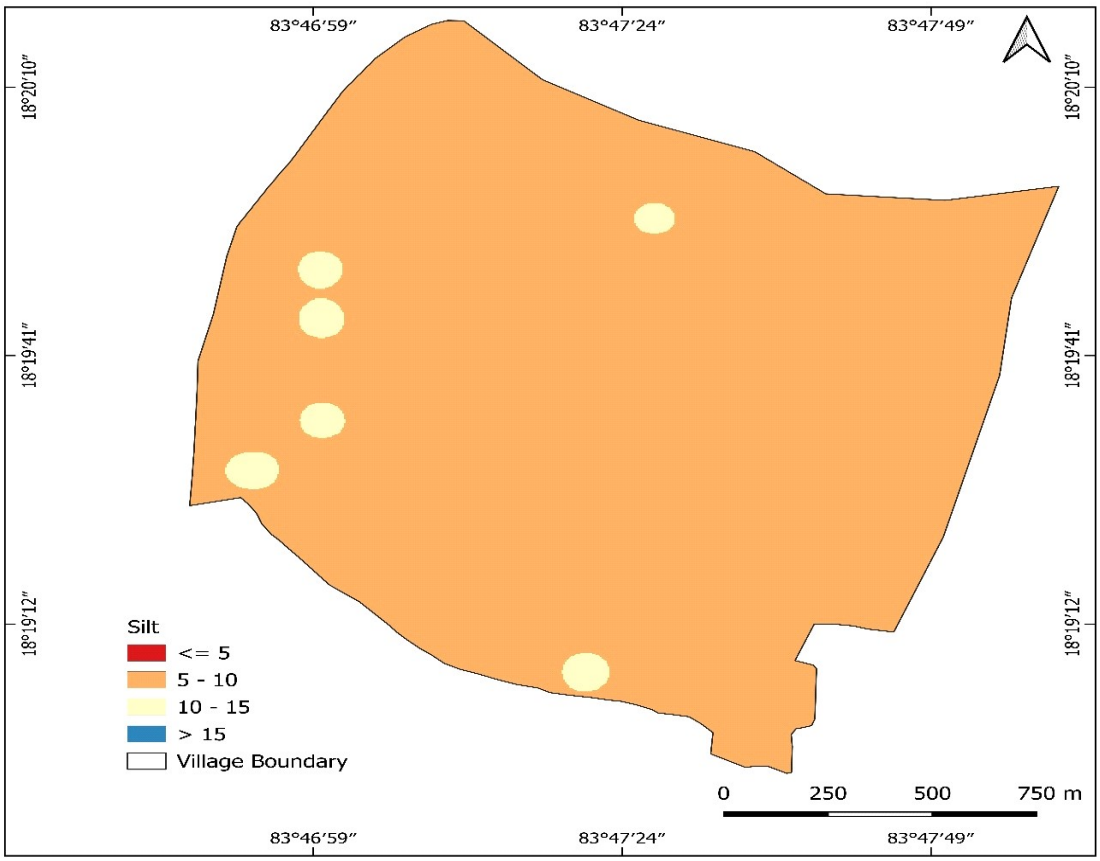


Fig.6. Spatial variability of Silt content of the VR Gudem village

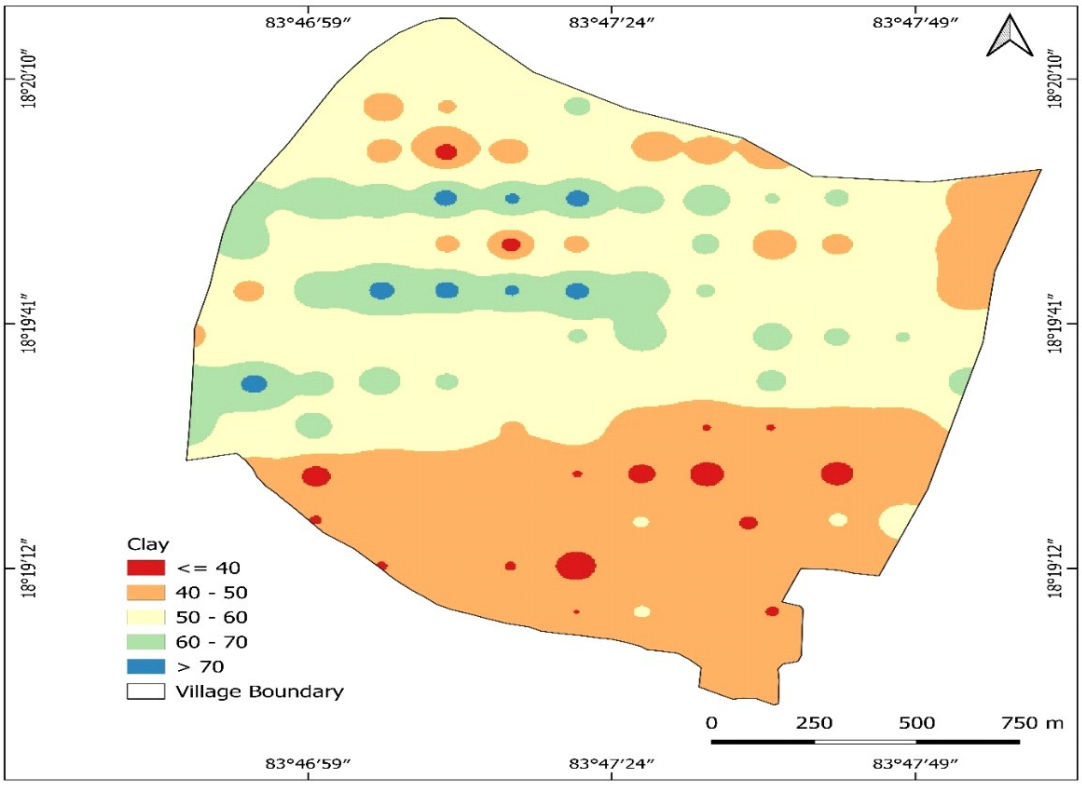


Fig. 7. Spatial variability of Clay content of the VR Gudem village

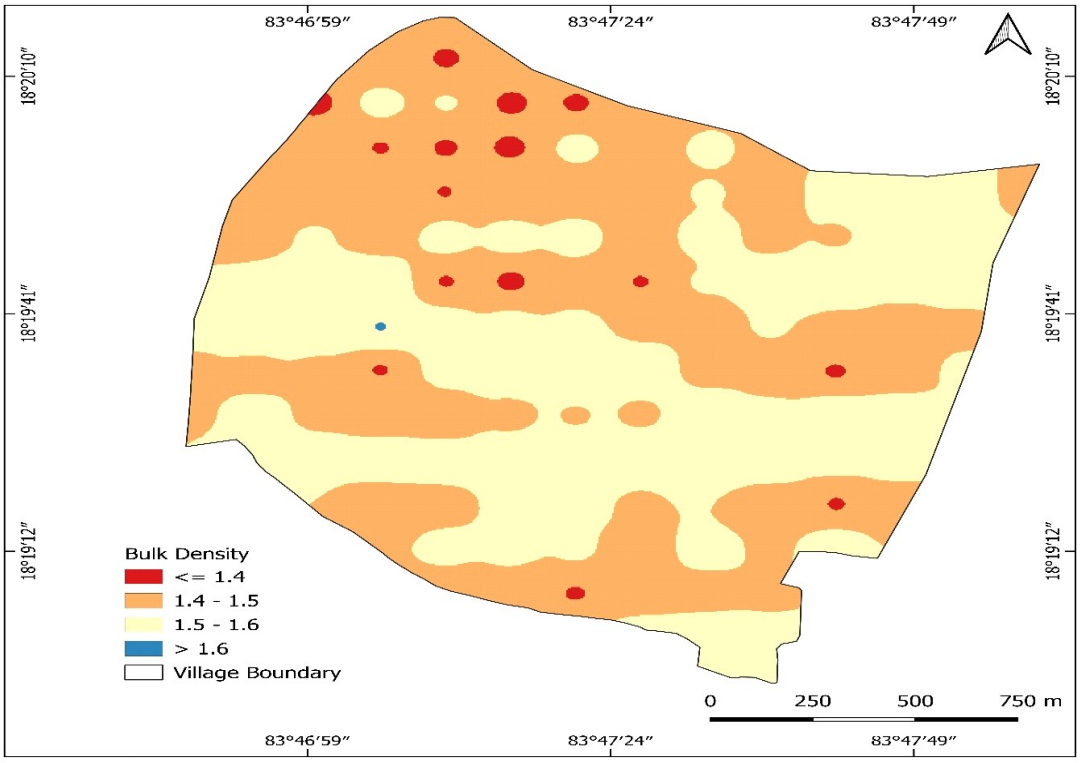


Fig. 8. Spatial variability of Bulk density of the VR Gudem village

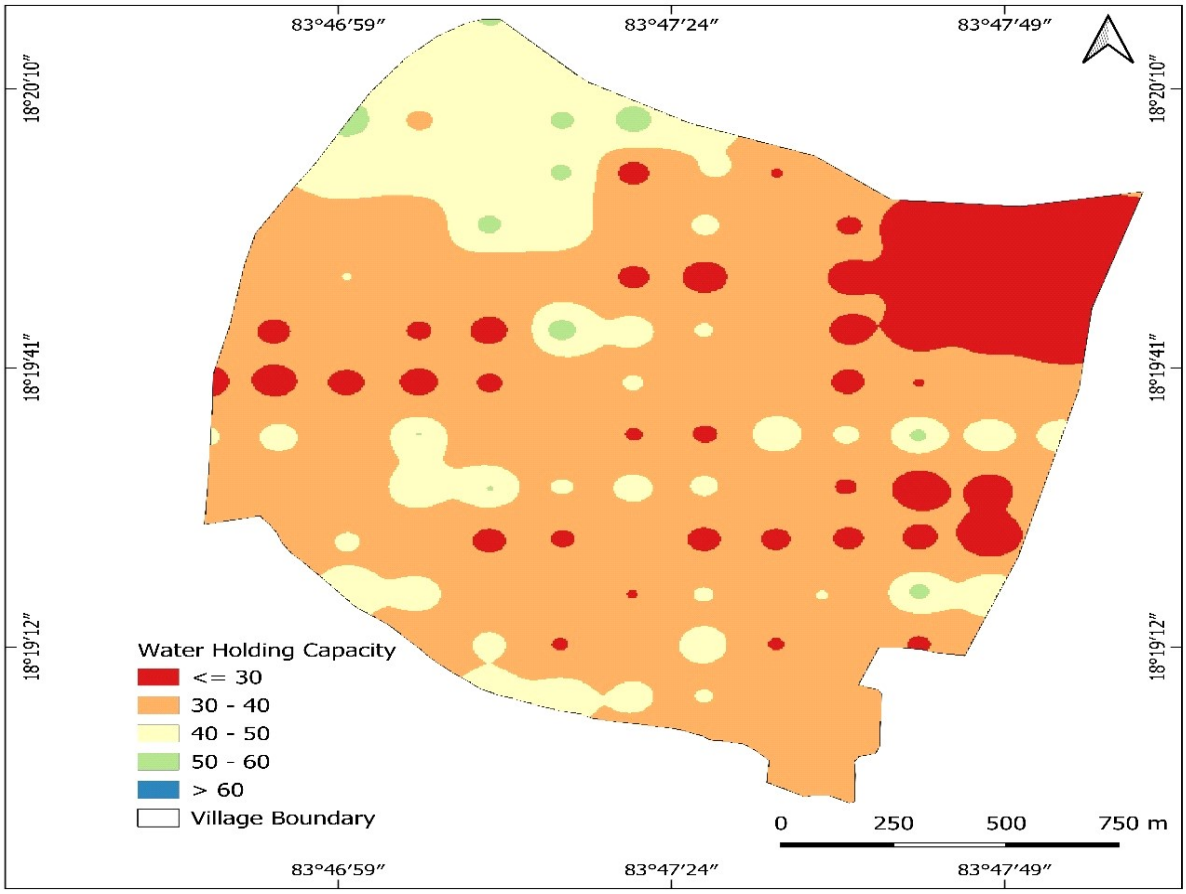


Fig.9. Spatial variability of Water holding capacity of the VR Gudem village

CONCLUSION

The current investigation reveals that the soil in soils of VR Gudem village is clay to sandy clay in texture. The soils are strongly acidic to moderately alkaline and non-saline in nature. The organic carbon ranges between low to medium in VR Gudem village. The Water holding capacity of the soil ranges between 20.0 per cent to 61.2 per cent, whereas the bulk density varied between 1.34 to 1.61 Mg m^{-3}.

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