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Geospatial characterization and mapping of physical and morphological properties of lateritic soils

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ABSTRACT

A GPS-GIS based soil survey of the Agronomy Research Farm, College of Agriculture, Dapoli, Maharashtra was carried out during 2024-25 to characterize the physical and morphological properties of the soils. Geo-referenced surface (0-30 cm) and sub-surface (30-45 cm) soil samples were collected from 91 locations (182 samples) using a differential GPS and analysed for soil colour, bulk density, particle density and texture. The 10YR hue dominated the farm (48.35 per cent surface and 45.05 per cent subsurface), followed by 5YR and 7.5YR; reddish brown was the commonest surface colour (20.88 per cent) and dark yellowish brown the commonest subsurface colour (24.18 per cent). Bulk density ranged from 1.10 to 1.39 Mg m⁻³ (mean 1.25) in the surface and 1.11 to 1.39 Mg m⁻³ (mean 1.27) in the sub-surface, and no sample exceeded the root-restrictive limit of 1.4 Mg m⁻³. Particle density ranged from 2.14 to 2.68 Mg m⁻³ (mean 2.48) and 2.12 to 2.70 Mg m⁻³ (mean 2.51) in the surface and subsurface, respectively. Mean sand, silt and clay were 52.62, 18.02 and 29.36 per cent in the surface and 51.18, 17.55 and 31.27 per cent in the subsurface. Sandy clay loam (83.52 per cent) and sandy clay (16.48 per cent) were the only textural classes. Spatial distribution maps were prepared using ArcGIS 10.8.1.

Keywords: GIS, GPS, Lateritic soils, Physical properties, Morphological Properties

Introduction

Soil is the foundation of crop production, and its physical condition governs root growth, aeration, water movement and nutrient retention. Physical properties such as texture, bulk density and particle density, along with morphological features such as colour, reflect the parent material, weathering and management history of a soil. Sampling every field to assess such properties is rarely feasible because of the cost, time and labour involved, so systematic geo-referenced sampling is required to describe the spatial variability of a region. Information generated with GPS-assisted sampling can enable the creation of thematic maps to inform site-specific land and nutrient management (Gaikwad *et al.*, 2024). In the Konkan region, soils are lateritic, formed from the intense weathering of Deccan basalt under heavy rainfall, and they differ from the black and red soils of the Deccan plateau in colour, texture and density. The present study was therefore undertaken to characterize and map the soil colour, bulk density, particle density and texture of the Agronomy Research Farm.

Material and methods

2.1 Location of the study area

The Agronomy Research Farm, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth (DBSKKV), Dapoli is located in Ratnagiri district of Maharashtra, at about latitude 17°45' N and longitude 73°10' E, at an altitude of 250 m above mean sea level. The farm lies between a hill range on the north and the Dapoli-Harnai road on the south (Fig. 1). The total area is 29.57 ha, of which 21.70 ha is under cultivation and 7.87 ha is occupied by roads, dams and drainage. The farm is on the lateritic plateau of the Konkan region, with a gentle to moderate slope from north to south. The climate is humid sub-tropical, with an average annual rainfall of about 3500 to 4000 mm, received mainly from the South-West monsoon (June to September). The mean maximum temperature is about 35 °C (May) and the mean minimum about 15 °C (December). The soils are derived from lateritic parent material formed by intense leaching of Deccan basalt, are shallow to moderately deep (20 to 100 cm), and are classified as Ultisols/Inceptisols (Pawar, 1993) [1]. The farm is used for agronomic trials on rice, maize, green gram, okra, finger millet, brinjal, mustard, onion, watermelon, tomato and sugarcane, and includes a mango orchard.

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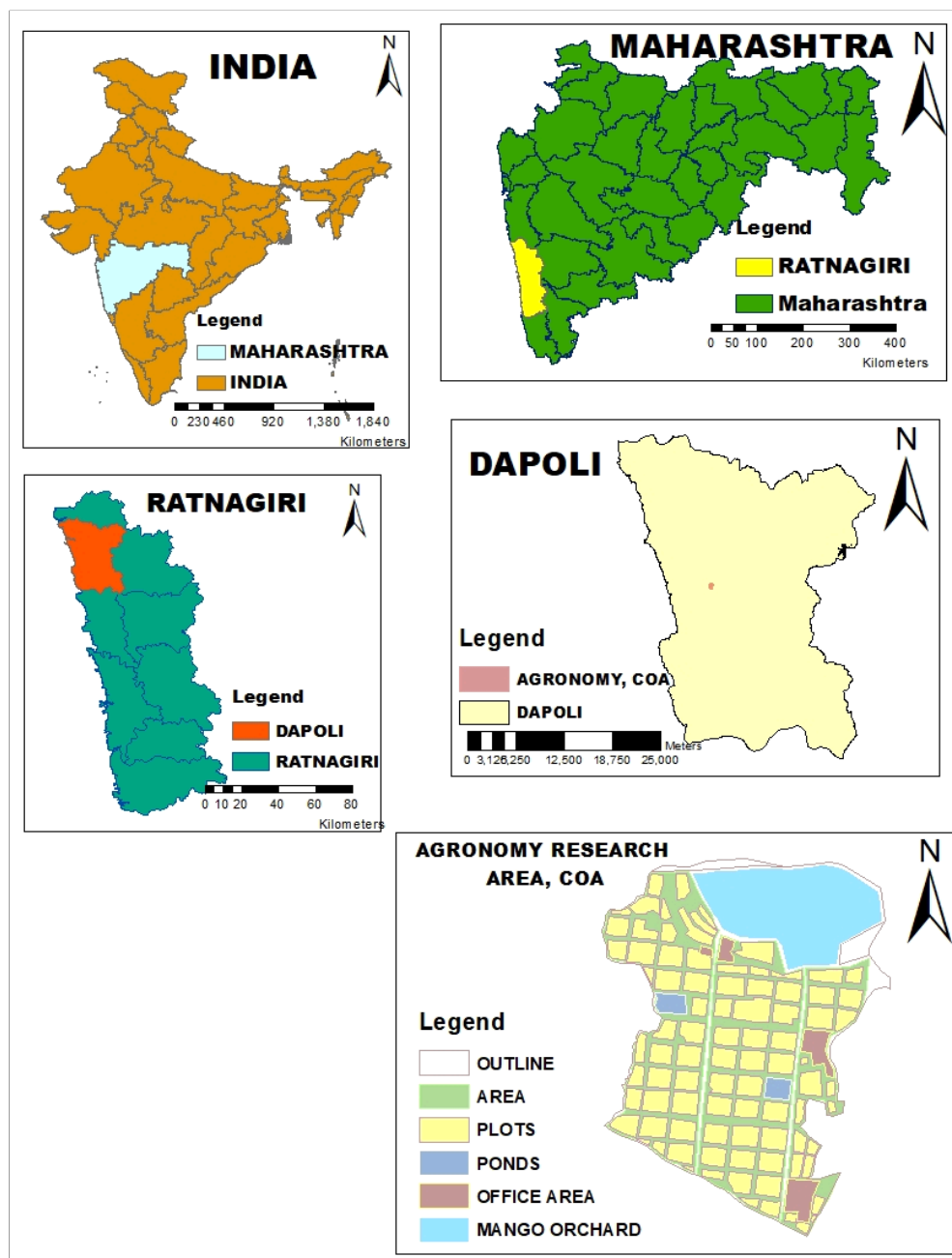


Figure 1. Study area of the Agronomy Research Farm, DBSKKV, Dapoli.

2.2 Soil sampling, preparation and laboratory analysis

A detailed soil survey was carried out during 2024-25 using a base map at a scale of 1:4000. Sampling sites were fixed on a systematic grid so that all plots, management zones and topographic positions were represented, without crowding of sites. The latitude and longitude of each site were recorded with a differential GPS. Surface (0-30 cm) and sub-surface (30-45 cm) samples were collected from 91 locations, giving 182 samples. The cropping pattern, previous crop and fertilizer and manure history were recorded at each site. Samples were collected with a wooden peg, labelled, air-dried in shade, ground with a wooden mortar and pestle, and passed through a 2 mm sieve (100-mesh sieve for mechanical analysis).

Soil colour was recorded with the Munsell colour chart (Munsell Colour, 2000) [2]. Bulk density was determined by the soil clod method and particle density by the pycnometer method (Black, 1965) [3], and texture (sand, silt and clay) by the Bouyoucos hydrometer method (Bouyoucos, 1951) [4]. Textural classes were assigned using the USDA textural triangle.

2.3 Preparation of maps and statistical analysis

Sample coordinates and analytical values were entered in ArcGIS 10.8.1 (Esri Inc.), and continuous surfaces were generated by Inverse Distance Weighting (IDW) interpolation and then reclassified into thematic classes. Range, mean, standard deviation (SD) and coefficient of variation (CV) were calculated for each parameter following Panse *et al.* (1967) [5].

3. Results and discussion

The salient physical properties of the surface and subsurface soils are summarized in Table 1.

Table 1. Salient physical properties of soils of the Agronomy Research Farm ($n = 91$ per layer)

Particulars	Layer	Range	Mean	SD	CV (%)
Bulk density (Mg m^{-3})	Surface	1.10 - 1.39	1.25	0.052	4.21
	Subsurface	1.11 - 1.39	1.27	0.056	4.44
Particle density (Mg m^{-3})	Surface	2.14 - 2.68	2.48	0.100	4.02
	Subsurface	2.12 - 2.70	2.51	0.103	4.11
Sand (per cent)	Surface	45.07 - 59.97	52.62	4.29	8.17
	Subsurface	45.32 - 58.03	51.18	3.31	6.47
Silt (per cent)	Surface	11.13 - 27.28	18.02	4.36	24.21
	Subsurface	11.02 - 26.91	17.55	4.18	23.83
Clay (per cent)	Surface	20.58 - 40.61	29.36	5.62	19.15
	Subsurface	25.13 - 42.40	31.27	4.06	12.96

3.1 Soil colour

Soil colour of all 91 surface and 91 subsurface samples is presented in Table 2. The 10YR hue was the most frequent (48.35 per cent surface and 45.05 per cent subsurface), followed by 5YR (29.67 and 27.47 per cent) and 7.5YR (20.88 and 25.27 per cent), while 2.5YR occurred in only 1.10 per cent of surface and 2.20 per cent of subsurface samples. The most frequent surface colour was reddish brown (20.88 per cent), followed by yellowish brown and dark yellowish brown

(17.58 per cent each); dark brown was the least common (4.40 per cent). The subsurface was dominated by darker classes: dark yellowish brown (24.18 per cent), dark brown (20.88 per cent), dark reddish brown (15.38 per cent) and reddish brown (9.89 per cent). Very dark brown (10YR 2/2 and 7.5YR 2.5/3) was found only in the subsurface (7.69 per cent), at plots 9, 43, 49, 65, 76, 80 and M3. The darker colour observed in the subsurface horizon of lateritic soils may be attributed to variations in iron oxide distribution, moisture retention and differences in mineral composition along the soil profile.

Table 2. Distribution of soil colour classes (Munsell) in surface and subsurface soils

Colour class	Surface (No.)	Surface (%)	Subsurface(No.)	Subsurface(%)
Reddish brown	19	20.88	9	9.89
Yellowish brown	16	17.58	4	4.40
Dark yellowish brown	16	17.58	22	24.18
Brown	11	12.09	6	6.59
Yellowish red	9	9.89	4	4.40
Light yellowish brown	8	8.79	3	3.30
Strong brown	8	8.79	3	3.30
Dark brown	4	4.40	19	20.88
Dark reddish brown	-	-	14	15.38
Very dark brown	-	-	7	7.69
Total	91	100.00	91	100.00

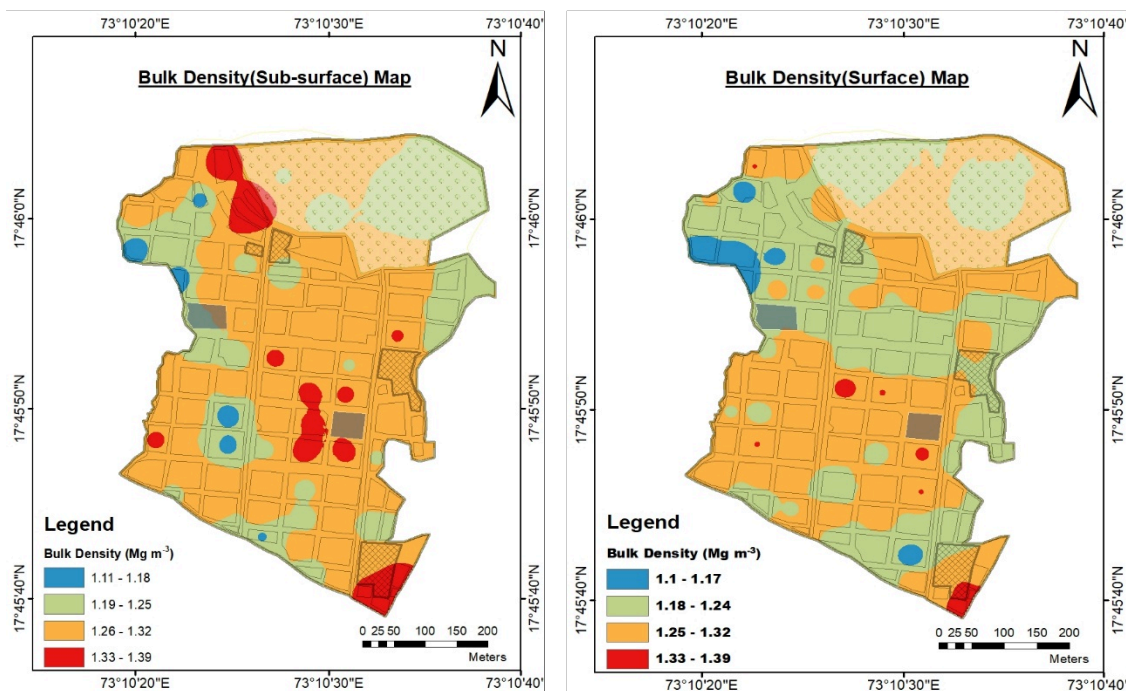
Colour in most samples was darker (lower Munsell value) in the subsurface than in the surface. The darkest surface colour (10YR 3/3, dark brown) occurred at plots 9, 34, 49 and 80, with plot 9 also having the darkest subsurface colour (10YR 2/2). The lightest colour (10YR 6/4, light yellowish brown) was recorded in eight surface samples (including plots 3, 4 and 5) and in subsurface plots 5, 44 and 48. The dominance of reddish brown, yellowish brown and strong brown colours in the 10YR, 5YR and 7.5YR hues is typical of the lateritic soils of the Konkan. Patil *et al.* (2018) [6], describing the lateritic soils of Ratnagiri, Sindhudurg and Raigad districts, which form under hilly terrain, humid climate, dense vegetation and an annual rainfall of about 3200 mm, noted that red to reddish-brown Munsell hues are commonly recorded in their surface horizons. Reddish colours (5YR and 2.5YR) could relate to the abundance and relative dominance of iron oxides such as hematite, which characteristically produces a red hue in highly weathered tropical soils. The yellowish-brown 10YR hues could relate to more dominance of goethite and hydrated forms

of iron oxides. Both these are consistent with the known association between colour and iron-oxide mineralogy. Hence, dark colours in some subsurface horizons may relate to variation in wetness, organic matter concentration and redistribution of iron compounds during weathering. (Schwertmann, 1993; Viscarra Rossel *et al.*, 2010) [7, 8].

3.2 Bulk density

Bulk density of the surface soils ranged from 1.10 to 1.39 Mg m^{-3} with a mean of $1.25 \pm 0.052 \text{ Mg m}^{-3}$ (CV 4.21 per cent), and that of the subsurface soils from 1.11 to 1.39 Mg m^{-3} with a mean of $1.27 \pm 0.056 \text{ Mg m}^{-3}$ (CV 4.44 per cent) (Table 1). In the surface layer 84.62 per cent of samples were in the ideal range ($<1.3 \text{ Mg m}^{-3}$) and 15.38 per cent in the satisfactory range ($1.3\text{--}1.4 \text{ Mg m}^{-3}$); in the subsurface the corresponding values were 75.82 and 24.18 per cent. No sample exceeded the root-restrictive threshold of 1.4 Mg m^{-3} (Arshad *et al.*, 1996) [9]. The spatial variation is shown in Fig. 2.

2a. 2b.



[Fig. 2a. Bulk density of surface soils (left) and Fig. 2b. bulk density of subsurface soils (right)]

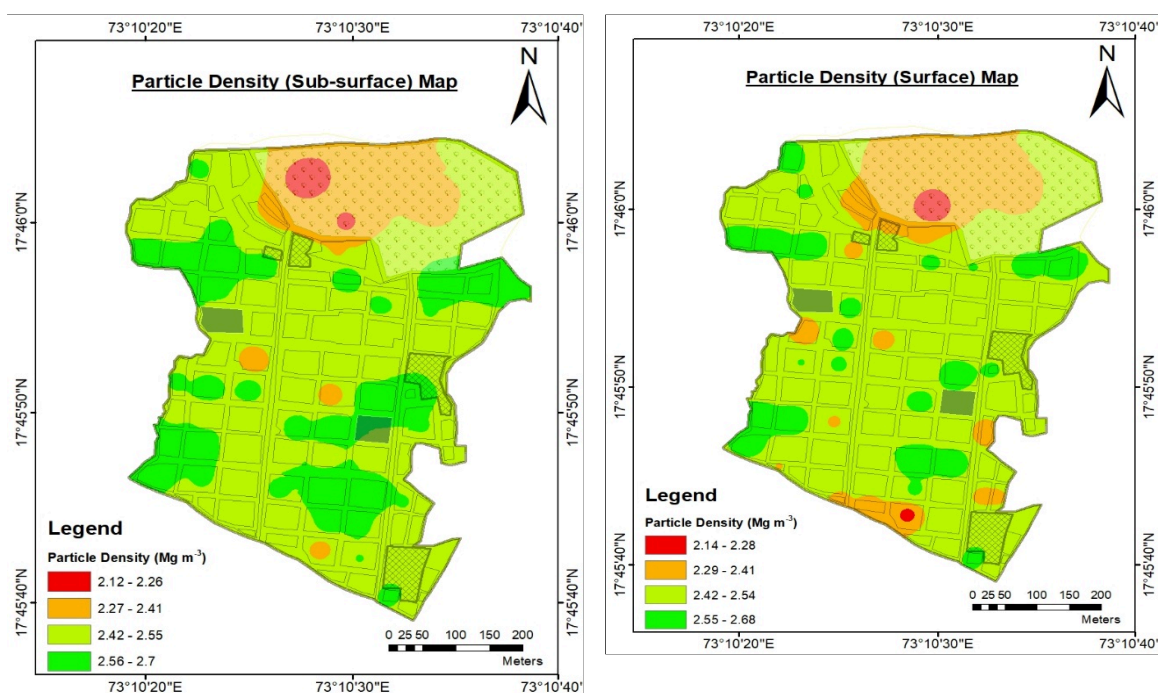
The value of the mean surface bulk density (1.25 Mg m^{-3}) is identical to that ($1.09\text{--}1.48 \text{ Mg m}^{-3}$, mean 1.25) of Sankpal (2008) [10] for the surface lateritic soils of the Agricultural Research Station, Phondaghat, and the range here fit within his range of $1.09\text{--}1.50 \text{ Mg m}^{-3}$ for the lateritic soils of Phondaghat. (Dabke, 1987) [11]. Lower values were observed by Mahajan (2001) [12] for the South Konkan soils studied in mango orchards ($0.99\text{--}1.34 \text{ Mg m}^{-3}$, mean 1.20) and by Revendkar (1990) [13] at Awashi, Ratnagiri ($0.99\text{--}1.18 \text{ Mg m}^{-3}$, mean 1.07), due to the open and granular nature of lateritic soils and to higher organic matter. Salunkhe *et al.* (2023) [14] classified the whole of Ratnagiri district in the highly suitable class for bulk density in a geospatial analysis, which concurs with the result here. Sankpal (2008) [10] found no definite trend in bulk density with depth in lat-

eritic profiles, whereas bulk density here was marginally higher in the subsurface layer, which may be attributed to lower organic matter and greater compaction under the overlying soil. The soils are therefore largely non-restrictive to root proliferation, with only marginal compaction at a few locations.

3.3 Particle density

Particle densities of the surface soils ranged from 2.14 to 2.68 Mg m^{-3} with a mean of 2.48 Mg m^{-3} (SD 0.100 ; CV 4.02 per cent), and that of the sub-surface soils from 2.12 to 2.70 Mg m^{-3} with a mean of 2.51 Mg m^{-3} (SD 0.103 ; CV 4.11 per cent) (Table 1, Fig. 3). These means are marginally less than the 2.60 to 2.70 Mg m^{-3} generally quoted for mineral soils, and the surface layer was slightly lighter than the sub-surface.

3a. 3b.



[Fig. 3a. Particle density of surface soils (left) and Fig. 3b. particle density of subsurface soils (right).]

The values are similar to those obtained in lateritic soils of the Konkan region. Shinde *et al.* (2010) [15] observed 2.31 to 2.64 Mg m^{-3}

m^{-3} (mean 2.46) in lateritic soil of okra, [Suryavanshi \(2010\)](#) ^[16] 2.34 to 2.54 Mg m^{-3} in mango orchards of Sindhudurg, [Mahajan \(2001\)](#) ^[12] 2.26 to 2.83 Mg m^{-3} (mean 2.51) in South Konkan mango orchards, and [Dabke \(1987\)](#) ^[11] 2.21 to 2.53 Mg m^{-3} in the Phondaghat benchmark soils. [Revendkar \(1990\)](#) ^[13] found a higher range of 2.43 to 2.72 Mg m^{-3} (mean 2.58) at Awashi. Slightly higher values at depths, can be explained by [Chavan et al. \(1995\)](#) ^[17] who obtained 2.45 to 2.66 Mg m^{-3} in the 0-30 cm layer and 2.48 to 2.74 Mg m^{-3} in the 30-60 cm layer of lateritic soils of Ratnagiri when cultivating forest species, and attributed it to difference in organic matter and mineral constituents of a soil profile. According to [Patil et al. \(2018\)](#) ^[6], density of the solid fraction of lateritic soils is controlled by large amounts of concentrated iron and aluminium oxides as well as

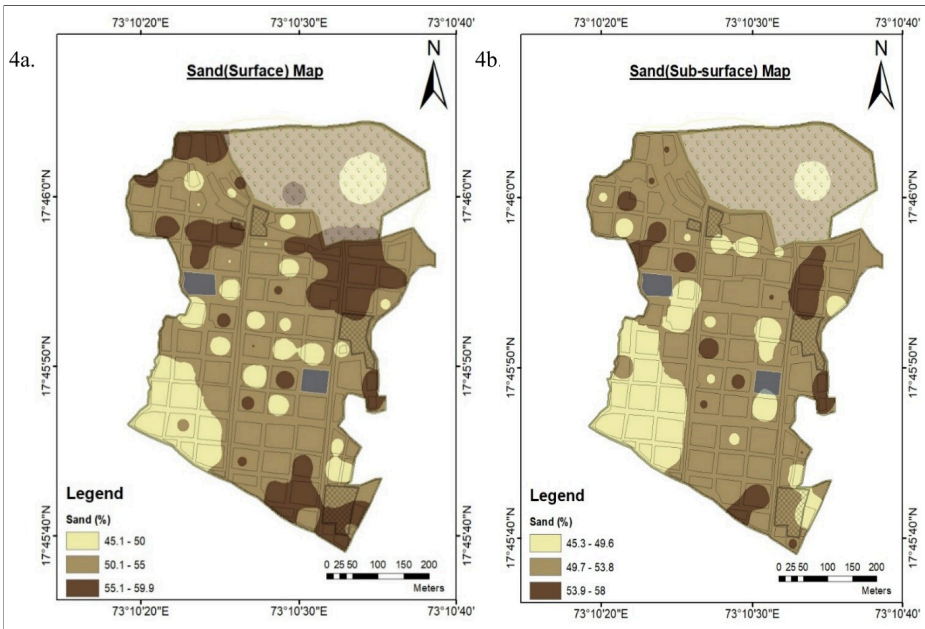
kaolinitic clay, and probably the smaller particle density here is associated with organic matter and lighter mineral fractions present in the surface profile.

3.4 Soil texture

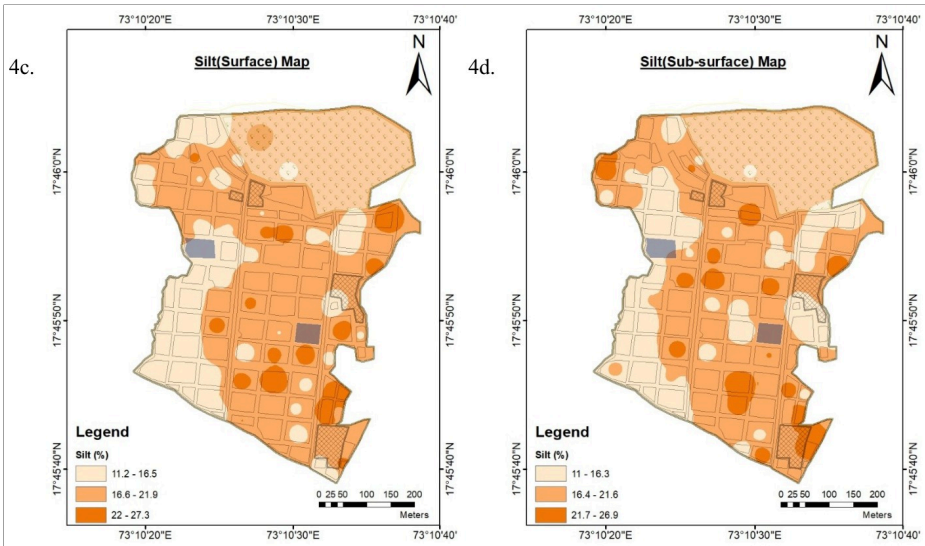
The mean sand, silt and clay contents were 52.62, 18.02 and 29.36 per cent in the surface layer and 51.18, 17.55 and 31.27 per cent in the subsurface layer ([Table 1](#)). The slightly higher clay in the subsurface probably resulted from illuvial transfer. The CV was highest for silt (24.21% and 23.83%) and lowest for sand (8.17% and 6.47%), meaning the coarser part of the soil stayed about the same across the farm, while the finer part changed depending on the land’s shape and drainage. Based on the textural triangle the soils were classed as either sandy clay loam or sandy clay ([Table 3](#), [Fig. 4](#)).

Table 3. Distribution of soil samples under different textural classes

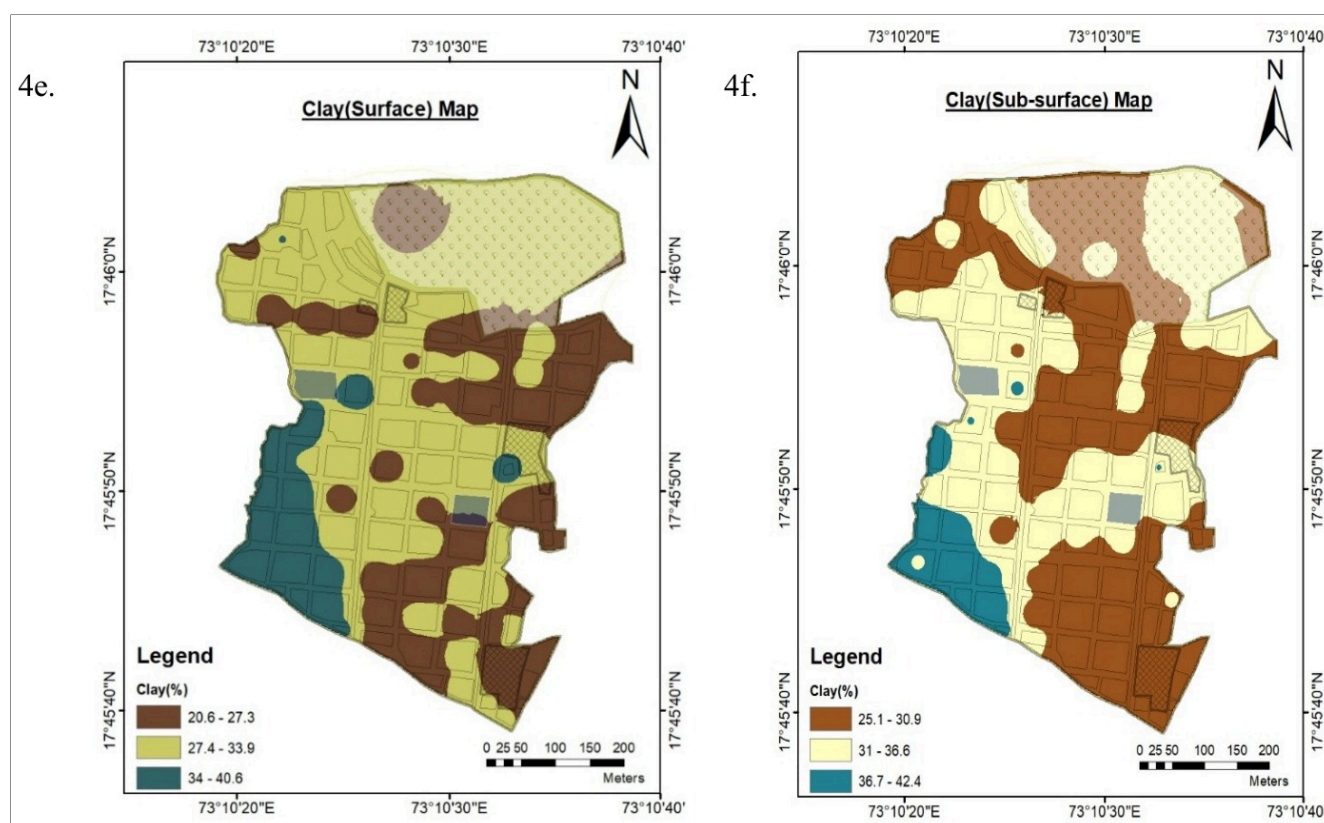
Textural class	Surface (No.)	Surface (per cent)	Subsurface (No.)	Subsurface (per cent)
Sandy clay loam	76	83.52	76	83.52
Sandy clay	15	16.48	15	16.48
Total	91	100.00	91	100.00



[Fig. 4a. Sand content of surface soils (left) and Fig. 4b. subsurface soils (right).]



[Fig. 4c. Silt content of surface soils (left) and Fig. 4d. subsurface soils (right).]



[Fig. 4e. Clay content of surface soils (left) and Fig. 4f. subsurface soils (right).]

Sandy clay loam dominated in both layers, and sandy clay was confined to one block of the farm. This falls within the sandy clay loam to clay range given by Patil *et al.* (2018) [6] for Konkan lateritic soils. Thawakar (2014) [18], in a survey of 210 villages, found soils of Sindhudurg and Thane to be mainly sandy clay loam, those of Ratnagiri loam and those of Raigad sandy loam (mean sand 53.02, silt 26.97 and clay 20.05 per cent). Mean sand, silt and clay of 52.23, 17.24 and 30.71% (sandy clay loam) in orchard soils of Ratnagiri was found by Joshi (2012) [19]. Very similar results were reported by Pawar (2012) [20] for sandy clay loam to clay loam in orchards in Sindhudurg, by Shinde (2006) [21] in sandy clay loam to clay in lateritic soils in Ratnagiri and Sindhudurg districts (sand 44.24-56.33, clay 24.19-42.21%), and by Dongale *et al.* (1987) in lateritic soils of the Konkan (up to clay loam to clay). Coarser textures were found by Salunkhe *et al.* (2023) [14] in Ratnagiri, where soils were mostly loamy sand, sandy loam and sandy clay loam. The present sand range (45.07-59.97%) in the farm is slightly narrower than the 23.5-65.5 % reported by Mahajan (2001) [12] and 23.73-83.05% by Thawakar (2014) [18] in Konkan district, possibly reflecting the smaller area of a single farm in the present study.

4. Conclusion

The soils of the Agronomy Research Farm, DBSKKV, Dapoli were dominated by 10YR, 5YR and 7.5YR hues, with reddish brown the commonest surface colour and dark yellowish brown the commonest subsurface colour, the subsurface being generally darker. Bulk density averaged 1.25 and 1.27 Mg m⁻³ in surface and subsurface was non-restrictive for root growth in both samples, and particle density averaged 2.48 and 2.51 Mg m⁻³ and was less than for most mineral soils. Soils were sandy clay loam (83.52 per cent) to sandy clay (16.48 per cent), with consistent sand and variable silt. The GPS-GIS maps provide a spatial baseline for site-specific soil and water management and nutrient management on the farm.

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