Soil Physical Properties of TNAU-Research Farms, Coimbatore

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ABSTRACT
The physical properties of 14 pedons representative of various soil series in the research farms of TNAU, Coimbatore were studied during 2017-19. The depth of soils ranged from shallow (<65 cm) to very deep (>150 cm). Soil depth was shallow in a steep slope, whereas deep soils were found in nearly level to very gently sloping plain. The texture of the surface and subsurface soils ranged from sandy clay loam to clay. The bulk density of the surface and subsurface soil samples ranged from 1.09 to 1.78 Mg m⁻³ irrespective of the depth. Higher bulk density has been recorded in the subsurface than in the surface layer. The hydraulic conductivity of the pedon soil sample varied from 0.40 to 8.69 cm hr⁻¹ and decreased with increasing depth. The infiltration rate ranged from 0.80 to 13.75 cm hr⁻¹ represented moderate to very rapid category. Low moisture and medium-textured soil recorded the highest infiltration rate, whereas clay dominated soil showed a low infiltration rate. The total porosity of soil varied from 36.18 to 50.99 per cent irrespective of soil depth with the capillary and non-capillary porosity of 26.70 to 39.76 per cent and 3.42 to 16.59 per cent respectively.

Keywords: TNAU farms, soil physical properties, soil series, porosity and hydraulic conductivity.

INTRODUCTION
Soil physical properties are recognized as the key to soil fertility and crop production. The amount of plant nutrients present in the soil gives only a unilateral picture of its productive potential. The physical conditions of the soil, on the other hand, regulates movement and retention of air and water, microbiological activities, the emergence of seedlings, penetration of roots, timeliness of tillage operations and above all the availability of plant nutrients which is vital for better plant growth. The poor and adverse conditions of formative factors like organic matter, microorganisms, cations and soil colloids coupled with determination factors like cultivation, irrigation, weather etc., cause adverse soil physical conditions, which decreases crop growth and yield. Hence a study was conducted to assess the physical properties of soils in TNAU farms.

MATERIAL AND METHODS
The farm maps of TNAU were used as a base material, and grid survey was undertaken at each farm. Based on the morphological characteristics and physiography, fourteen geo-referenced pedons were examined at Orchard (two), Eastern Block (two), Millet Breeding Station (one), Cotton Breeding Station (one), New Area (one), Botanical Garden (two), Wetland (two), Paddy Breeding Station (two) and Coconut Farm (one). Soil Profile Description was done according to the Soil Survey Staff (1951) and collected core and bulk soil samples from individual layers. In situ infiltration measurements were also taken in all the fields. The soil samples were analyzed for various soil properties by adopting standard procedures. Land capability classification was done based on Klingebiel and Montgomery’s (1961) criteria. The geo-referenced location points of pedons are furnished in Table 1.

RESULTS AND DISCUSSION
Morphological characteristics of soils (Table 2)
Marked differences were observed in soil depth, colour, texture, structure, concretions, and special features like clay films. Parent material topography and climate played a very important role in the changes in soil morphology Manickam et al. (1973) and Khan and Ram. (1977). The process of erosion and deposition of soil materials were found to be regulated by the physiographic position, as reported by Bipul Deka et al. (2009).

The depth of the soils ranged from shallow (<65 cm) to very deep (>150 cm). Soil depth was shallow in a steep slope, whereas deep soils were found in nearly level to very gently sloping plain. The depth of different pedons studied varied from 65 cm to 127 cm and found to have moderately shallow to deep solum.
Table 1. Geo-referenced location points of pedons of AC & RI, Coimbatore

| Pedon  | Field                             | Latitude (°N) | Longitude (°E) | Altitude (msl) |
|--------|----------------------------------|---------------|----------------|----------------|
| Pedon 1| Orchard - Fd.No. 5               | 11.00941      | 76.93192       | 426.7          |
| Pedon 2| Orchard - Orchard - West         | 11.00995      | 76.93357       | 426.7          |
| Pedon 3| Eastern Block - NA 9             | 11.00689      | 76.93606       | 426.6          |
| Pedon 4| Eastern Block - 37E              | 11.01703      | 76.93759       | 426.6          |
| Pedon 5| Millet Breeding Station - 7B     | 11.02337      | 76.92808       | 426.6          |
| Pedon 6| New Area - 4B                   | 11.02405      | 76.92645       | 426.5          |
| Pedon 7| Cotton Breeding Station - P1     | 11.02397      | 76.93014       | 426.6          |
| Pedon 8| Botanical Garden – 10 B          | 11.01970      | 76.93139       | 426.6          |
| Pedon 9| Botanical Garden – 10 E          | 11.01998      | 76.93542       | 426.6          |
| Pedon 10| Paddy Breeding Station - C Block| 11.00015      | 76.92175       | 426.6          |
| Pedon 11| Paddy Breeding Station - I Block| 11.00068      | 76.92242       | 426.6          |
| Pedon 12| Wetland - A Block               | 11.00141      | 76.92571       | 426.6          |
| Pedon 13| Wetland - M Block               | 11.00186      | 76.92625       | 426.6          |
| Pedon 14| Coconut Farm                    | 11.01121      | 76.93492       | 426.7          |

The texture of surface soils was clay in pedon 1, 3 and 11; sandy clay loam in pedons 5, 6, 7, 9 and 10, loam in pedon 4, 12 and 13, silty clay loam in pedon 2, sandy loam in pedon 8, clay loam in pedon 14 respectively. The texture of subsurface soils was also varied with clay texture in pedons 1, 3, 11, and 14, clay loam in pedons 2 and 12, sandy clay loam in pedons 4, 6, and 10, sandy loam in pedons 7, 8 and 9 and sandy clay in pedon 5.

The texture of surface and subsurface soils ranged from sandy clay loam to clay. The wide variation in soil texture was caused by topographic position, nature of parent material, in-situ weathering, and translocation of clay and age of soils as explained by Varaprasad Rao et al. (2008). The change in texture of subsurface soil was due to the process of illuviation and mixing of horizons. The transportation of soil from upland to low land by water movement is responsible for textural variation from sandy loam to clay particle size distribution.

The soil structure of most of the pedons were subangular blocky and varying in different depth of profile. Pedon 1, 4, 5, 6, 7, 11, 12, 13 and 14 has subangular blocky structure in surface soils. Pedons 2, 3, 8, 9, and 10 had prismatic, crumby and angular blocky structure, respectively. The subangular blocky structure was observed in pedons with medium to heavy texture. In subsurface soil, all pedons having subangular blocky to medium angular blocky structure in different depth. Sawhney et al. (2005) reported that in soils with good base saturation percentage, particularly concerning Ca tended to form blocky structure either angular or subangular.

**Physical Properties**

**Soils of Eastern block**

Two profile pits were dug up, and depth-wise soil samples were collected and analyzed for soil physical properties. The results revealed that the bulk density values ranged from 0.81 to 1.71 Mg m$^{-3}$ irrespective of depth. The subsurface soil samples collected from the field No.37E recorded low bulk density value, and higher bulk density of 1.71 Mg m$^{-3}$ was recorded in field NA 9, that too in subsoil (40 - 60 cm depth). This may be due to the compaction of subsoil by continuous use of heavy machinery.

The data on hydraulic conductivity ranged from 1.62 to 3.70 cm hr$^{-1}$ which was moderately slow almost in both the profiles. Generally, black soils are found to possess low hydraulic conductivity due to high clay content, which leads to low infiltration rate resulting in runoff and erosion of soil and nutrients. The infiltration rate ranged from 2.60 to 5.40 cm hr$^{-1}$ with the higher value recorded in Field NA 9 and lower in Field No.37.

The total porosity of soils varied from 33.39 to 49.50 per cent irrespective of soil depth. The capillary and non-capillary porosity ranged from 19.92 to 31.98 per cent and from 9.52 to 20.28 per cent respectively, which showed that there was no physical constraint.

The moisture storage capacity of soils ranged from 10.56 to 14.95 cm m$^{-1}$ which falls under low to high moisture storage capacity ratings. Maximum water storage capacity was registered in the Field No.37E, which may be attributed to the fact that soils have high capillary porosity.

**Soils of Wetland**

The bulk density values of the profiles in A and M blocks of wetland varied from 0.76 to 1.28 Mg m$^{-3}$. There was an increase in bulk density up to one-meter depth in A block profile whereas, in M block, it showed an inconsistent trend. The maximum bulk density value was recorded in block A and minimum in block M. The results on hydraulic conductivity revealed significant variation with increasing depth in both the profiles. It ranged from 0.40 to 2.12 cm hr$^{-1}$ for different layers of both the profiles and decreased with increasing depth in both the profiles.
Table 2. Textural class of TNAU farms soils

| Horizon (cm) | Clay (%) | Silt (%) | Sand (%) | Textural Class | Horizon (cm) | Clay (%) | Silt (%) | Sand (%) | Textural Class |
|-------------|----------|----------|----------|---------------|-------------|----------|----------|----------|---------------|
| 1. Orchard  |          |          |          |               | 2. Eastern block |          |          |          |               |
| Fd.No. 5    | 0-25     | 52.2     | 19.0     | 26.0 Clay     | 0-20        | 32.1     | 49.3     | 16.9 Clay  | Silty Clay loam |
|             | 25-50    | 35.4     | 10.8     | 48.4 Sandy Clay | 20-35       | 38.8     | 43.8     | 15.7 Clay  | Silty Clay loam |
|             | 50-70    | 51.9     | 10.3     | 32.5 Clay     | 35-55       | 37.6     | 39.1     | 16.7 Clay  | Clay loam      |
|             | 70-100   | 40.2     | 11.5     | 44.6 Clay     | 55-80       | 61.4     | 12.8     | 22.4 Clay  | Clay loam      |
| Fd.No. 6    | 0-20     | 47.3     | 8.7      | 37.2 Clay     | 0-20        | 23.6     | 40.5     | 30.7 Loam  | Loam           |
|             | 20-40    | 44.7     | 12.0     | 38.8 Clay     | 20-40       | 24.7     | 36.2     | 38.6 Loam  | Loam           |
|             | 40-60    | 48.9     | 15.0     | 30.5 Clay     | 40-60       | 32.7     | 12.7     | 48.4 Sandy clay | Sandy clay loam |
|             | 60-80    | 51.4     | 8.5      | 33.9 Clay     | 60-80       | 31.2     | 8.5      | 55.7 Sandy clay | Sandy clay loam |
|             | 2. Eastern block | 0-20 | 30.9 | 7.8 | 60.3 Sandy clay loam | 0-28 | 22.6 | 11.5 | 61.8 Sandy clay loam |
|             | 20-48    | 37.9     | 8.0      | 48.4 Sandy clay | 28-48       | 31.9     | 12.4     | 51.9 Sandy clay | Sandy clay loam |
|             | 48-75    | 31.4     | 6.1      | 57.5 Sandy clay loam | 48-65       | 31.9     | 15.0     | 44.3 Sandy clay | Sandy clay loam |
|             | 75-100   | 43.9     | 8.0      | 42.8 Sandy clay | 65-112      | 16.7     | 18.8     | 67.7 Sandy clay | Sandy clay loam |
|             | 100-150  | 41.8     | 11.1     | 44.3 Sandy clay | 65-112      | 16.7     | 18.8     | 67.7 Sandy clay | Sandy clay loam |
| Fd. No. 7 B |          |          |          |               | 3. Millet Breeding Station (Fd. No. P1) |          |          |          |               |
|             | 0-15     | 28.7     | 6.3      | 60.3 Sandy clay loam | 0-15 | 11.5 | 14.4 | 67.7 Sandy clay | Sandy clay |
|             | 15-47    | 22.2     | 11.0     | 63.1 Sandy clay loam | 15-47 | 13.6 | 15.2 | 68.9 Sandy clay | Sandy clay |
|             | 47-65    | 15.7     | 14.3     | 63.6 Sandy clay | 47-65       | 14.9     | 12.2     | 68.8 Sandy clay | Sandy clay |
|             | 65-112   | 34.9     | 15.0     | 47.5 Sandy clay loam | 65-112      | 16.7     | 18.8     | 57.7 Sandy clay | Sandy clay |
|             | 7. Botanical Garden | 0-19 | 28.7 | 6.3 | 60.3 Sandy clay loam | 0-19 | 30.9 | 7.8 | 54.6 Sandy clay loam |
|             | 19-41    | 22.2     | 11.0     | 63.1 Sandy clay loam | 19-45       | 37.9     | 8.0      | 48.4 Sandy clay | Sandy clay |
|             | 41-57    | 12.4     | 18.7     | 63.6 Sandy clay | 45-57       | 31.4     | 6.1      | 57.5 Sandy clay | Sandy clay loam |
|             | 57-110   | 15.7     | 14.3     | 63.6 Sandy clay | 57-110      | 43.9     | 8.0      | 42.8 Sandy clay | Sandy clay |
| Fd. 10 B   |          |          |          |               | 8. Paddy breeding Station |          |          |          |               |
|             | 0-20     | 45.0     | 23.9     | 28.2 Clay     | 0-20        | 25.0     | 32.4     | 39.9 Loam  | Loam           |
|             | 20-38    | 40.0     | 24.9     | 32.6 Clay     | 20-38       | 30.3     | 32.6     | 34.3 Clay  | Clay loam      |
|             | 38-81    | 42.5     | 25.0     | 27.8 Clay     | 38-81       | 33.7     | 30.8     | 33.0 Clay  | Clay loam      |
|             | 81-104   | 41.2     | 28.6     | 25.9 Clay     | 81-104      | 36.9     | 28.4     | 32.1 Clay  | Clay loam      |
|             | 104-127  | 42.5     | 31.3     | 23.0 Clay     | 104-127     | 34.9     | 31.8     | 30.3 Clay  | Clay loam      |
| Fd. No. 10 E |          |          |          |               | 9. Wetland   |          |          |          |               |
|             | 0-20     | 26.3     | 29.0     | 40.9 Loam     | 0-20        | 32.5     | 33.5     | 30.3 Clay  | Clay loam      |
|             | 20-38    | 10.5     | 24.7     | 59.9 Sandy loam | 20-38       | 45.5     | 16.6     | 33.3 Clay  | Sandy clay     |
|             | 38-81    | 19.8     | 16.6     | 60.9 Sandy loam | 38-81       | 50.0     | 9.8      | 36.0 Clay  | Clay loam      |
|             | 81-104   | 25.0     | 17.1     | 55.1 Loam     | 81-104      | 42.5     | 22.7     | 32.4 Clay  | Clay loam      |
|             | 104-127  | 16.0     | 16.4     | 40.2 Sandy loam | 104-127     | 48.0     | 18.3     | 31.0 Clay  | Clay loam      |

The porosity values though varied with profiles and different depths, the non-capillary porosity was less compared to the corresponding capillary porosity. The total porosity was varied from 47.24 to 58.64 per cent irrespective of profiles and soil depths. The capillary and non-capillary porosity ranged from 43.36 to 4.40 per cent and from 2.01 to 5.13 per cent, respectively. The infiltration rate was moderately slow for both the profiles (0.92 to 0.94 cm hr⁻¹) with a very high water storage capacity (20.0 to 27.90 cm hr⁻¹).

**Paddy Breeding Station (PBS)**

The soils of PBS were found to be very deep, exceeding a soil depth of 127 cm. The bulk density was ranged from 0.99 to 1.24 Mg m⁻³ and found to decrease with increasing depth.
| Field No. | NA 9 | Field 37E | B | 4B | 10E | M Block | A Block | 81-104 | 104-127 | 81-104 | 104-127 |
|----------|------|----------|---|----|-----|---------|---------|-------|--------|-------|--------|---------|
| F.C      | 1.60 | 1.71     | 1.52 | 1.31 | 1.28 | 1.43     | 1.55     | 1.63  | 1.33  | 1.29  | 1.45   | 1.55    |
| PWP      | 2.52 | 2.31     | 2.49 | 1.94 | 2.42 | 0.96     | 1.25     | 2.08  | 0.823 | 1.42  | 1.72   | 1.72    |
| A.W      | 49.50| 34.87    | 40.61| 49.90| 46.92| 45.31    | 45.31    | 47.91 | 35.94 | 24.62 | 45.38  | 45.38   |
| Moisture | 13.14| 13.38    | 13.77| 14.29| 12.65| 10.73    | 10.72    | 14.72 | 12.38 | 15.55 | 14.16  | 14.16   |
| Porosity | 31.90| 38.79    | 33.77| 45.25| 34.27| 40.57    | 30.83    | 41.13 | 31.18 | 32.47 | 34.93  | 34.93   |
| Storage  | 17.76| 19.36    | 18.45| 14.29| 12.65| 7.47     | 9.92     | 6.78  | 4.76  | 4.79  | 6.49    | 5.85    |
| Density  | 19.36| 15.34    | 13.29| 9.26 | 6.58 | 5.78     | 6.14     | 6.89  | 5.56  | 5.40  | 7.17    | 6.07    |
| Conductivity | 10.51| 15.13    | 12.95| 9.53 | 6.15 | 4.90     | 6.39     | 5.38  | 5.08  | 4.10  | 9.19    | 5.91    |
| Moisture | 10.51| 8.12     | 7.89 | 4.65 | 2.99 | 3.71     | 3.56     | 3.12  | 2.92  | 2.99  | 3.12    | 3.12    |
| Porosity | 19.36| 15.34    | 13.29| 9.26 | 6.58 | 5.78     | 6.14     | 6.89  | 5.56  | 5.40  | 7.17    | 6.07    |
| Storage  | 17.76| 19.36    | 18.45| 14.29| 12.65| 7.47     | 9.92     | 6.78  | 4.76  | 4.79  | 6.49    | 5.85    |

**Table 3. Soil Physical Properties of TNAU farm soils**

(F.C – Field Capacity; PWP – Permanent Wilting Point; A.W – Available Water)
The hydraulic conductivity was very low in all layers, with the values of 0.40 to 1.02 cm hr⁻¹. Bottom layers registered low hydraulic conductivity when compared to top layers. The total pore space percentage varied from 47.35 to 59.12 irrespective of different layers of soil profiles, and the maximum was recorded in Block No. I. The non-capillary pore percentage was low compared to capillary porosity. The capillary porosity was more than 44 per cent in all the horizons, whereas non-capillary porosity was even less than 5 per cent. The rate of infiltration was moderately slow (0.80 to 0.87 cm hr⁻¹), and the moisture storage capacity was very high (27.55 and 34.84 cm m⁻¹). The obvious reason may be the high clay content and capillary porosity in all the depths of profile.

Millet Breeding Station

The bulk density ranged from 1.31 to 1.63 Mg m⁻³ and the variation in bulk density was inconsistent with soil depth. The hydraulic conductivity ranged from 0.199 to 2.08 cm hr⁻¹. The porosity values though varied with different depths, the non-capillary porosity was less compared to capillary porosity. The range of total porosity was 40.61 to 49.90 per cent. The capillary and non-capillary porosity ranged from 33.77 to 45.25 per cent and from 3.28 to 6.78 per cent, respectively. The moisture storage capacity was medium (13.96 cm m⁻¹) with the infiltration rate of 13.75 cm hr⁻¹ in field number 7B, which falls under a moderately rapid category.

Table 4. Land Capability Classification (LCC) of the TNAU Research Farms, Coimbatore

| Farm                        | Depth | Texture | Slope | Erosion | pH | LCC   |
|-----------------------------|-------|---------|-------|---------|-----|-------|
| Eastern Block               | II    | II      | I     | I       | I   | II    |
| WetLand                     | I     | III     | I     | I       | I   | I     |
| Paddy Breeding Station      | I     | III     | I     | I       | I   | I     |
| Millet Breeding Station     | I     | II      | I     | I       | I   | I     |
| Cotton Breeding Station     | I     | II      | I     | I       | III| I     |
| New Area                    | II    | II      | I     | I       | I   | I     |
| Botanical Garden            | I     | II      | I     | I       | II  | I     |
| Orchard                     | II    | II      | I     | I       | II  | I     |
| Coconut Farm                | I     | III     | I     | I       | I   | I     |

Cotton Breeding Station

The bulk density ranged from 1.46 to 1.65 Mg m⁻³ irrespective of soil depth and no definite trend with soil depth was observed. A higher bulk density of 1.65 was recorded in the subsoil horizon of field number PI. The data on hydraulic conductivity showed slow to moderately slow permeable nature of the soil (0.34 to 4.11 cm hr⁻¹). But deeper layer of soil showed higher value of hydraulic conductivity (4.11 cm hr⁻¹).

Regarding pore space percentage, it ranged from 28.71 to 44.71 and decreased with increasing soil depth. The capillary porosity contributed 80 - 85 per cent of total porosity and the remaining by non-capillary porosity. The moisture storage capacity registered (10.40 cm m⁻¹) was medium while the infiltration rate was 11.85 cm hr⁻¹ which falls under rapid rating.

New Area

The soils of New Area are shallow in nature with the soil depth of less than 65 cm. The profile of field No. 4B showed a shallow depth of 65 cm having 3 layers only. The bulk density varied from 1.33 to 1.50 Mg m⁻³ and increased with increasing depth. The hydraulic conductivity was very slow to moderately slow with the range of 0.125 to 0.823 cm hr⁻¹. The porosity percentage varied from 35.94 to 46.92 and increased as the depth increased. The capillary porosity was 31.18 to 40.57 per cent, and non-capillary porosity was 4.74 to 12.65 per cent. The water storage capacity was 10.47 cm m⁻¹ which is in medium status. The infiltration rate was rapid, with 14.50 cm hr⁻¹.

Botanical Garden

The soil depth was 110+ cm with 4 layers. The bulk density increased with increasing soil depth with a range of 1.27 to 1.75 Mg m⁻³. The hydraulic conductivity varied from 0.242 to 3.87 cm hr⁻¹ and surface horizon recorded the maximum and decreased with subsurface horizons. The total porosity varied widely (33.11 to 45.38 per cent), and inconsistent distribution was recorded in soil depths. The capillary porosity was found to be 26.62 to 42.10 per cent with the non-capillary porosity of 2.65 to 10.45 per cent. The infiltration rate was rapid, with a range of 12.20 to 12.50 cm hr⁻¹. The water storage capacity of the profile was 9.01 to 16.66 cm m⁻¹ which was very high. This might be due to high clay content and high capillary porosity.

Orchard

Two soil profiles were opened at Field No. 5 and Orchard West. The bulk density values of different
profiles varied widely, ranging from 1.58 to 1.92 Mg m\(^{-3}\). There was an inconsistent trend in bulk density with increasing soil depth. The results on hydraulic conductivity showed slow to rapid rate (0.11 to 12.45 cm hr\(^{-1}\)), and the highest value was recorded in field No. 5 where the hydraulic conductivity was 12.45 and 12.38 cm hr\(^{-1}\) respectively in surface (0-25 cm) and subsurface horizons (25-50 cm).

The increased bulk density and decreased hydraulic conductivity may be due to continuous cultivation of fruit trees over the years without tillage operations. The pore space percentage varied from 27.62 to 43.61 irrespective of different fields and depths. The capillary porosity was 24.34 to 39.49 per cent and non-capillary porosity was 3.26 to 9.21 per cent. The infiltration rate ranged from 8.03 to 15.20 cm hr\(^{-1}\) which is moderately rapid to a rapid rate. The water storage capacity varied from 16.73 to 23.04 cm hr\(^{-1}\) and higher value recorded in orchard west.

Coconut Farm

One profile pit was opened, and the soil analysis data showed inconsistent values with increasing depth with respect to bulk density and hydraulic conductivity. However, hydraulic conductivity was higher (4.56 cm hr\(^{-1}\)) in top horizon, whereas subsoil layers registered very low hydraulic conductivity (1.20 to 1.44 cm hr\(^{-1}\)). The bulk density values ranged from 1.42 to 1.48 Mg m\(^{-3}\).

The total porosity was 40.12 to 48.20 per cent, and more than 85 per cent was contributed by capillary porosity. The infiltration rate was moderately slow, with a value of 2.16 cm hr\(^{-1}\). The moisture storage capacity was very high (23.65 cm m\(^{-3}\)).

CONCLUSION

Based on soil limitations and soil physical related properties like texture, depth, slope, erosion, drainage, and nature of the substrate, farm soils of Wetland, Paddy breeding station, Millet breeding station, Cotton breeding station, New area, Botanical garden and Coconut farm were classified into Class I land capability with no limitations. In contrast, soils of Eastern block and Orchard were classified into Class II land capability sub-class due to limitation of soil texture.

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