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SOIL SAMPLING AND DETERMINATION OF SOIL PHYSICAL AND HYDRAULIC PROPERTIES OF DIFFERENT SOILS

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Article Info

Abstract

Soil physical and hydraulic properties are fundamental indicators of soil functionality, influencing water movement, nutrient availability, and root growth. Accurate determination of these parameters requires precise sampling and standardized analytical procedures. This study was conducted to develop technical competency in soil sampling and to assess key soil physical and hydraulic properties across different soil types. Both disturbed and undisturbed soil samples were collected from the 0–15 cm depth following standard methods. Disturbed samples, obtained with augers, were used for the determination of soil texture, pH, electrical conductivity, and organic matter, whereas undisturbed core samples (5 cm × 5 cm) were used for the measurement of bulk density, porosity, soil moisture, and hydraulic conductivity. Soil texture was determined by the hydrometer method, and bulk density and particle density were used to calculate total porosity. Soil moisture content was estimated gravimetrically by oven-drying at 105 °C for 24 hours. Saturated hydraulic conductivity was measured using a laboratory permeameter and computed based on Darcy's Law under constant head conditions. Results revealed textural classes ranging from loam to silt loam, with bulk density values between 1.33 and 1.62 g cm^{-3} and porosity between 39% and 50%. Saturated hydraulic conductivity varied from 0.036 to 0.297 cm hr^{-1} among soil samples, indicating moderate to high permeability. These findings demonstrate the interrelation between soil structure and hydraulic behavior, providing valuable insights for soil management and sustainable agricultural practices.

Keywords:

Soil sampling, bulk density, porosity, hydraulic conductivity, soil moisture, texture.

INTRODUCTION

Soil sampling constitutes a critical methodological step in soil science, enabling the extraction of representative subsamples from heterogeneous field environments for subsequent laboratory analysis of physico-chemical and hydraulic attributes. These properties are fundamental for understanding plant nutrient dynamics, water movement, root growth, and overall soil health. Accurate and methodically sound soil sampling is essential to ensure that laboratory findings genuinely reflect in-field conditions (Moursy et al., 2022).

Two distinct sampling types are recognized that are disturbed and undisturbed samples. Disturbed samples, collected with augers, spades, or khurpas, facilitate the determination of soil texture, lime content, organic matter, and nutrient concentrations but disrupt the natural soil structure. In contrast, undisturbed samples, obtained with steel core cylinders (commonly 5 cm length × 5 cm diameter), preserve the in-situ soil matrix, enabling measurement of bulk density, porosity, water retention curves, and hydraulic conductivity (Alaoui, 2023). Undisturbed cores therefore constitute the basis for quantifying soil hydraulic properties under realistic structural conditions.

Proper sampling design and protocol safeguard the representativeness of the resulting dataset. It is essential to delineate sampling zones within a field that are homogeneous in soil type, cropping system, management history, slope, and drainage characteristics. Zones must exclude abnormal micro-locations such as furrows, wet spots, tree-shade areas, or manure heaps, which may bias the sample. In each zone, composite samples should be taken to reduce spatial variability and capture the mean condition of that unit (Ali et al., 2014).

Understanding the physical and hydraulic properties of different soils is increasingly critical in the context of sustainable crop production, efficient water management, and the mitigation of degradation risks under changing climatic conditions. Soil attributes such as bulk density, porosity, and hydraulic conductivity determine the capacity of the soil to store and transmit water and thereby influence root water uptake, nutrient availability, and susceptibility to erosion or compaction (Rahman & Mostofa Amin, 2023). Moreover, the spatial heterogeneity of soils demands robust sampling to inform modeling and management decisions; hydraulic property estimation is frequently constrained by methodological cost and temporal variability (Patil & Singh, 2016).

Hence, the present study aims to train the researcher in rigorous soil sampling methodology and to determine key soil physical and hydraulic properties of different soils. The findings will enhance understanding of soil functioning in variable-texture environments and support sustainable agronomic management. The objective of this internship-based investigation was to develop competency in proper soil sampling protocols and to determine selected soil physical and hydraulic properties across different soil types under field and laboratory conditions.

Methodology for Determination of Soil Properties

Collection of Disturbed Soil Samples

Disturbed soil samples were collected using a soil auger from a depth of 0–15 cm. The auger was marked at 15 cm to ensure uniform sampling depth. Before sampling, surface residues and stones were cleared. The auger was inserted into the soil by applying pressure and rotating clockwise to reach the plough layer, then withdrawn slowly while rotating counterclockwise as showing in Figure 2. The collected soil was placed in labeled plastic bags and transported to the Soil-Plant Head House, LRRI. Samples were air-dried, cleaned of residues and pebbles, ground, and sieved through a 2 mm mesh (Figure 1). The prepared samples were then used for analyses of soil texture, pH, electrical conductivity, organic matter, lime content, and macro- and micronutrients

Figure 1. Soil Sample taken with Auger.

Figure 2. Air Drying And Removal of Materials other than Soil from Soil Sample.

Collection of Undisturbed Soil Sampling

Undisturbed soil samplings were collected through steel cores as per methods of Blake and Hartge, (1986). Steel cores are of different sizes as shown in Figure 3. Soil core of size 5 cm length with diameter 5 cm was used. For taking core soil sample from 0-15 cm soil depth, 5 cm soil was removed and the core was put on that soil surface at 5 cm depth. With the help of core sampler, core was inserted into the soil. The inserted core was taken out along with soil. Core with intact soil was separated from core sampler. Soil was levelled with the core edges on both sides with the help of knife as shown in Figure 3. Both sides of the core were covered with its lids and tapped with paper tap and labelled with sample name or number. Soil core samples were brought to Soil Physics laboratory, LRRI, NARC. Now these core samples are ready for the determination of Soil water retention characteristics, saturated and unsaturated hydraulic conductivities, soil moisture, soil bulk density and porosity.

Figure 3. Soil Core Sampling Procedure with different Core Diameters.

Textural Analysis

Soil texture was determined using the hydrometer method as described by Bouyoucos (1962), based on Stokes' Law, which relates particle size to sedimentation velocity in a water column (Figure 4). The process involved two main steps: soil dispersion and measurement of soil suspension specific gravity. For chemical dispersion, a dispersing solution was prepared by dissolving 40 g of sodium hexametaphosphate [$(NaPO_3)_6$] and 10 g of sodium carbonate (Na_2CO_3) in 1 L of distilled water. Forty grams of soil were mixed with 60 mL of this solution and left overnight. The following day, the mixture was mechanically dispersed for 5 minutes using a mechanical shaker. The dispersed suspension was then transferred to a Bouyoucos cylinder and the volume was adjusted to 1000 mL with distilled water. The mixture was stirred for one minute with a plunger, and hydrometer readings were taken at 40 seconds (H_1 for silt + clay) and 2 hours (H_2 for clay). Blank readings (B_1 and B_2) containing only the dispersing solution were also recorded, and the final hydrometer readings were corrected by subtracting the corresponding blank values (Figure 4).

Figure 4. Components used in soil textural analysis

Calculations and Formulae Used:

H_1=Hydrometer reading at 40 second. H_2=Hydrometer reading at 2 hour.

B_1=Blank reading at 40 second. B_2=Blank reading at 2 hour.

OR

Corrected Corr. $H_1 = H_1 - B1$

Similarly, Corr. $H_2 = H_2 - B_2$.

% (Silt+ Clay) = (corrected H_1/weight of sample) ×100 Eq. 1

% Clay = (corrected H_2/weight of sample) ×100 Eq. 2

% Silt = % (Silt+ Clay) − %Clay Eq. 3

% Sand = 100 − % (Silt+ Clay) Eq. 4

Table 1. Readings obtained

	Before		After 2 hours		Soil Textural Class
Samples	**Hydrometer readings (H_1 and B_1)**	**Corr. H1 (H1 – B1)**	**Hydrometer reading (H_2 and B_2)**	**Corr. H_2 ($H_2 - B_2$)**	
Blank	1	0	1	0	
1	26	25	7	6	Loam
2	33	32	8	7	Silt Loam
3	33	32	6	5	Loam

Corrected H_1 = 25 g/L

Corrected H_2 = 6 g/L

From Eq. 1

% (Clay + Silt) = (25/50) × 100 = 50 %

From Eq. 2

% Clay = (6 / 50) × 100 = 12 %

From Eq. 3

% Silt = 50 % – 12 % = 38 %

From Eq. 4

% Sand = 100 – 50 % = 50 %

Thus, the soil particle distribution was Sand (%) = 50 , Clay (%) = 12, Silt (%) = 38

Then the textural triangle of USDA was used to find the soil textural class.

The Soil textural Class was LOAM.

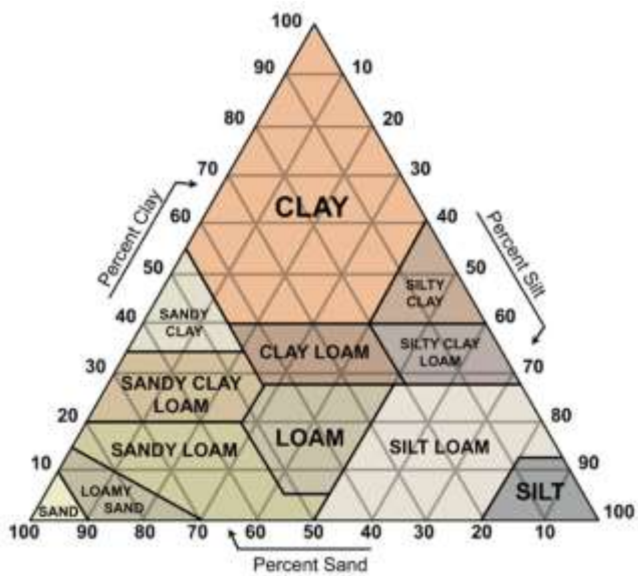


Figure 5. USDA Soil Textural Triangle

Bulk Density

Bulk density, or dry bulk density, is a property of soils and other masses of particulate material. It's the weight of the particles of the soil divided by the total volume. Thus, it should be noted that the unit of bulk density is the unit of weight over the unit of volume, for example kg/m^3 for the metric system and lb/ft^3 for the English system.

Calculating Bulk Density

Bulk density is given by the following equation:

$$\rho_b = \frac{M_{soil}}{V_t}$$

Table 2. Data to find soil bulk density

Samples	Cane wt. (g)	Core wt. (g)	Dry soil wt. (g)	Soil/core volume (cm^{-3})	Bulk Density ($g\ cm^{-3}$)
1	20.21	76.02	157.48	98.12	1.60
2	19.13	76	159.7	98.12	1.62
3	19.31	91.33	141.46	98.12	1.44
4	19.32	69.40	130.94	98.12	1.33

Soil Moisture Determination

Soil moisture refers to the amount of water held within the soil pores, which influences soil aeration, nutrient availability, and plant growth. To determine soil moisture content, about 10 g of air-dried (<2 mm) soil was placed in a pre-weighed metal can previously dried at 105 °C. The sample was oven-dried at 105 °C for 24 hours with the lid removed. After drying, the can was covered, cooled in a desiccator for 30 minutes, and reweighed to calculate the soil moisture percentage (Page et al., 1982).

Calculation

$$\text{Soil moisture} = \frac{\text{wet soil (g) - dry soil (g)}}{\text{dry soil (g)}}$$

	Can Wt (g)	Fresh Soil + Can Wt (g)	Dry Soil + Can Wt (g)	Fresh Soil Wt (g)	Dry Soil Wt (g)	Soil Moisture Wt (g)	Soil Moisture Content
1	18.55	70.34	60.61	51.79	42.06	9.73	0.23
2	19.20	95.97	80.79	76.77	61.59	15.18	0.24

Particle Density

Weighed 40 grams of oven-dry solids (Wts) in a 100-mL graduated cylinder and added 50 mL of water, ensuring there was no soil material on the inner walls of the cylinder. Stirred the mixture thoroughly with a stirring rod to displace the air and rinsed the stirring rod and the inner walls of the cylinder with 10 mL of water. Then allowed the mixture to stand for 5 minutes and recorded the volume of the soil plus 60 mL of water. On a separate sample, determined the moisture content of the soil sample and calculated the oven-dry weight of the soil. After that, added the amount of moisture to the amount of added water to obtain the total amount of water used. Finally, particle density was calculated in g/cm^3.

$$BD\frac{g}{cm^3} = \frac{wt_s}{V_s}$$

Where, Wts = Weight of oven-dry soil (g)

Vs = Volume of the solids (cm^3)

Table 3. Data to find Soil Particle Density

Samples	Flask wt. (g)	Water +flask wt. (g)	Water wt. 1 (g)	Soil+flask wt. (g)	Soil+flask +water wt. (g)	Soil wt. (g)	Water wt. 2 (g)	Soil volume (cm^3)
1	43.93	93.46	49.53	62.76	105.10	18.83	42.34	7.19
2	38.33	87.89	49.56	61.92	102.54	23.59	40.62	8.94
3	33.34	82.83	49.49	51.61	94.10	18.27	42.49	7
4	42.52	91,96	49.44	65.43	106.31	22.91	40.88	8.56

Soil Total Porosity

The total porosity of the soil was obtained from its bulk density (ρ_b) and particle density (ρ_s) by the following formula described by Lowery et al. (1996). Particle density will be assumed equal to 2.65 g cm^{-3}.

$$\phi = 1 - \left[\frac{\text{Soil bulk density}}{\text{Soil particle density}}\right]$$

Water Hydraulic Conductivity

The laboratory permeameter was a tool used to measure the saturated permeability of soil samples. Permeability, in this context, referred to the capacity of the soil to drain off water. The permeability coefficient (K-factor) was the measure of permeability and was determined, on one hand, by the geometry of the complex of pores, which depended on the texture and structure of the soil. On the other hand, it was influenced by the intrinsic features of the soil solution, such as viscosity and density.

Description of Water Flow

In this closed hydraulic setup, water is pumped from a storage cistern (1) by a circulation pump (2) through a filter (3) to an adjustable level regulator (4). The regulator maintains a constant water level and directs excess water back to the storage cistern via a return pipe. A plastic container (5) is connected to the regulator, while the cistern is covered to minimize evaporation during measurement. A saturated soil ring sample (6) is placed in a ring holder with a sieve disc on top to support uniform drainage. The ring holder is then positioned inside a container, where a plastic siphon (7) channels the water seeping from the soil sample into a burette (8) for measurement. The burettes are of varying lengths for convenient operation of their stopcocks. Finally, any excess water from the burettes is collected in a leak basin (9) and returned to the storage cistern, ensuring a fully closed and recirculating system.

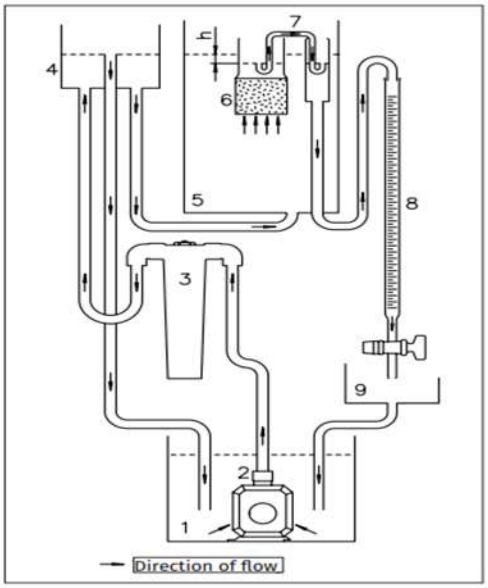


Figure 6. Flow direction of water

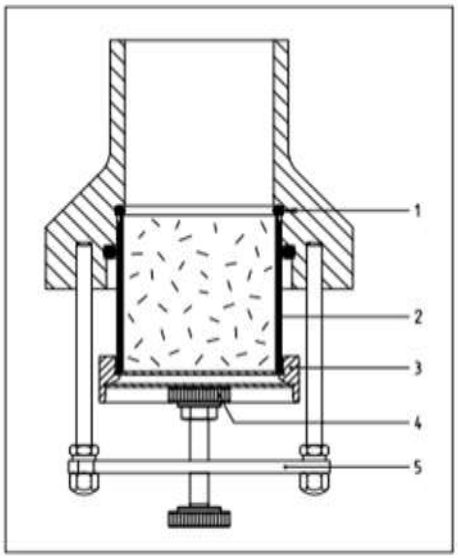
Saturation of Soil Samples

Soil samples were saturated, where open end of the core was covered with polythene sheet and placed into a water tank for 12 hours.

Hydraulic Conductivity Determination

1. The water level in the ring holders and in the container was ensured to be even. Then, the siphons, filled with water, were placed. To fill a siphon with water, the siphon was moved underwater, and it was slowly tilted to avoid air entrance. The siphon was then placed with one 'leg' in the ringholder and the other in the numbered synthetic pipe.
2. The water level in the container was adjusted to the required position by sliding the level regulator up or down. During the measurement process, a constant level difference (h) was maintained inside and outside of the ring holder.
3. The volume of water flowing through a sample was measured within a specific unit of time. Initially, the stopcock on the burette was closed, and the water level was read at eye level (in mL). Subsequently, the water level in the burette was monitored at intervals. Flow was considered stationary when a consistent volume of water flowed through the sample during a defined unit of time. To prepare for the next measurement, the burette was emptied by opening the stopcock and allowing the water to flow into the leak basin.

4. The measuring bridge, operated with both hands, was moved above the desired measurement spot. This bridge held a water level meter activated by a light signal. The rotary knob was adjusted to lower the metering pin. As soon as the measuring point made contact with the water level, a light signal indicated this, and the water level was recorded with a precision of 0.5 mm. The water levels in both the container and the ring holders were similarly recorded. These measured differences in water levels were used for each sample to calculate the saturated permeability coefficient (U.S. Environmental Protection Agency, 1986).



Darcy’s Law is used to calculate the K-factor when applying the constant head method to determine permeability.

Darcy’s Law states: $V = K * i * A * t$

Where,

V = volume of water flowing through the sample (cm^3)

K = permeability coefficient or “K-factor” (cm/d)

h = water level difference inside and outside ringholder (cm)

L = length of the soil sample (cm)

i = permeability rise gradient, or: h / L (-)

A = cross-section surface of the sample (cm^2)

t = time used for flow through of water volume V 10

L and A : constants, depending on the type of sample ring used.

V : volume measured in the burette (1 ml = 1 cm^3)

t : length of time lapse

h : calculated with the water levels measured with the water level meter

$$K = \frac{V \cdot L}{A \cdot t \cdot h}$$

Table 4. Soil Hydraulic Conductivity Data

Sample	Volume (mL)	h	L	$A=\pi r^2$	Time (hrs)	Conductivity (K) (cm hr^{-1})
1	8.5	3.5	5	19.64	17	0.036
2	8.67	3.5	5	19.64	2.5	0.252
3	10.2	3.5	5	19.64	2.5	0.297

Conclusion

The study evaluated physical and hydraulic properties of soil using standard laboratory methods to assess its suitability for plant growth and water management. Soil texture analysis classified the samples mainly as loam to silt loam, indicating balanced proportions of sand, silt, and clay that support good water retention and aeration. Bulk density ranged from 1.33 to 1.62 g cm^{-3}, showing moderate compaction suitable for root development, while total porosity (39–50%) reflected adequate pore space for air and water movement. Gravimetric soil moisture content varied between 8% and 16%, indicating differences in the soils' water-holding capacity. Saturated hydraulic conductivity ranged from 0.036 to 0.297 cm hr^{-1}, representing moderate to high permeability depending on texture and structure.

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