LABORATORY MANUAL

OF

SOIL SCIENCE
(Soil Physics, Morphology, Genesis and Classification)

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PREFACE

This manual is designed as an aid in teaching laboratory exercises for the basic Soil Science (SSC 31B) course in the existing Three Year B.Sc. Ag. Curriculum, and for the Soil Physics, Genesis and Classification (SOIL 4211) course of the new Five Year B.Sc.Ag. Curriculum of the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal.

Twelve exercises introduce soil texture, structure, colour, densities, soil forming minerals and rocks including exercises on profile description practices and soil survey techniques. Eight exercises are designed to build student's knowledge of soil-water relationships. The exercises support theory lectures to increase understanding of the practical aspects of soil properties and their management.

We thank the IAAS/MUCIA/USAID Project for encouragement and financial support in publishing this edition of the manual. We appreciate the review work by Dr. Tej Bahadur K.C, Professor, Soil Science, IAAS, and that of Mr. Dave Krauss, MUCIA short term consultant from the Department of Crops and Soil Sciences, Michigan State University, USA. We also thank Ms. Laxmi Baral of the IAAS Computer Center for her assistance in word processing.

We invite suggestions for improvement of this manual.

August 1984
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LAB 1: SOIL TEXTURE DETERMINATION BY FEEL METHOD

Section:......   Date...........

1.0 Objective:

a. To familiarize with soil textural classes.
b. To determine soil texture by feeling with hands.

1.1 Definition:

Soil texture refers to the relative proportions of sand, silt and clay in a soil sample.

1.2 Classification of soil seperates:

Separates	Diameter Range (mm) USDA	Diameter Range (mm) International System
Sand	2.00 - 0.05	2.00 - 0.02
Silt	0.05 - 0.002	0.02 - 0.002
Clay	< 0.002	< 0.002

1.3 Properties of soil seperates:

Sand particles are easily seen with the naked eye, feel coarse and gritty. Silt particles feel soft and flour like when dry and smooth when wet. Clay particles feel greasy and sticky when wet.

1.4 Soil textural classes:

According to the United States Department of Agriculture(USDA) system of classification, there are 12 textural classes (as shown on the textural triangle in Lab No.3). Soil textural class can be determined in the field by the feel method. The amount of clay can be estimated by feeling the stickiness; by making a ball and ribbon. Soils with higher amounts of clay form longer ribbons. Feeling of grittiness and smoothness of wet soil samples indicate amounts of sand and silt respectively.

1.5 Procedure:

a. Take about 25 g of soil in the palm, add water and moisten it. Knead the soil to break down all aggregates. The soil is at proper consistency when plastic and moldable.

b. Try to form a ball and squeeze it. If the soil does not remain in a ball when squeezed, the textural class of the sample is SAND

c. Place the ball of soil between the thumb and the forefinger of your hand and gently push the soil with the thumb against the forefinger. Squeeze it upward and form a ribbon (1mm thick). If it does not form a ribbon, the textural class of the sample is LOAMY SAND.

d. If the soil forms a ribbon, then determine the size of the ribbon into either a short (<2.5 cm long), medium (2.5-5 cm long) or a long (>5 cm long).

e. Place a pinch of the soil ribbon on the palm of one hand. Add water to make it wet. Gently rub it with the forefinger of another hand to feel the grittiness or smoothness.

f. Fill in the information in Data Sheet 1.0 and use Table 1.0 below to determine the textural class of each sample.

Table 1.0: Determination of Soil Texture by Feel and Ribbon Size

Feel	Ribbon size		
	Short(<2.5cm)	Medium(2.5-5cm)	Long(>5 cm)
Gritty	Sandy Loam	Sandy Clay Loam	Sandy Clay
Neither gritty nor smooth	Loam	Clay Loam	Clay
Smooth	Silt Loam	Silty Clay Loam	Silty Clay

Data Sheet 1.0 : Observation of Soil Texture by Feel Method

Sample No	Ribbon type (short,medium,long)	Predominate wet feel (smooth, gritty or neither)	Soil Textural Class
1.	....	....	....
2.	....	....	....
3.	....	....	....
4.	....	....	....
5.	....	....	....
6.	....	....	....
7.	....	....	....
8.	....	....	....
9.	....	....	....
10.	....	....	....

1.6. Questions:

a. What is the importance of the knowledge of soil texture?

b. What is meant by heavy, medium and light textures?

c. Can soil texture in the field be changed by cultivation or other practices?

d. Indicate how each of the following is affected by soil texture:

i) Tillage

ii) Erosion

iii) Drainage

LAB 2: DETERMINATION OF SOIL CONSISTENCE

Section............ Date...........

2.0 Objective: To determine dry, moist and wet consistency.

2.1 Definition:

Soil consistence is the resistance of soil to deformation or rupture. It is determined by the cohesive and adhesive properties of the entire soil mass.

2.2 Importance:

The knowledge of soil consistence supplies information on soil texture, organic matter, the amount and nature of colloidal material and to a certain extent on soil structure. It is also important for tillage and traffic considerations.

2.3 Determination:

Soil consistence is determined at three specific moisture contents.

Wet consistence: It is determined when the soil is at or slightly above the field capacity.

Moist consistence: It is determined at moisture content approximately midway between air dry soil and field capacity.

Dry consistence: It is characterised by the rigidity or brittleness of the air dry soil.

2.3.1 Determination of wet consistence

The following terms are used to describe the consistence of a wet soil.

2.3.1.1 Stickiness:

Stickiness is the quality of adhesion to other objects. It is determined by noting the adherence of soil material when it is pressed between the thumb and the forefinger. Degree of stickiness is described as follows:

a. Nonsticky: After release of pressure, practically no soil adheres to thumb or forefinger.

b. Slightly sticky: Soil adheres to thumb and forefinger but comes off to one or the other finger rather cleanly. (It is not stretched when the fingers are separated).

c. Sticky: After release of pressure, soil materials adhere to both thumb and forefinger and tend to stretch somewhat and pull apart rather than pulling free from either fingers.

d. Very sticky: After release of pressure, soil materials adhere strongly to both thumb and forefinger and definitely stretch when fingers are pulled apart.

2.3.1.2 Plasticity:

It is the ability of soil to change shape continuously under the influence of an applied stress and to retain the impressed shape on removal of the stress. For determination of plasticity, roll the soil material between thumb and forefinger and observe whether or not a wire or thin rod of soil can be formed. Express degree of resistance to deformation at or slightly above field capacity as follows:

a. Non-plastic: No wire is formed.

b. Slightly plastic: Wire is formed but soil mass easily deformed.

c. Plastic: Wire is formed, and moderate pressure is required for deformation of the soil mass.

d. Very plastic: Wire is formed, and more pressure is required for deformation of the mass.

2.3.2 Moist consistence:

The following terminology is used to describe the consistence of moist soil:

a. Loose: Non-coherent.

b. Very friable: Soil material crushes under very gentle pressure and coheres when pressed together.

c. Friable: Soil material crushes under gentle to moderate pressure and coheres when pressed together.

d. Firm: Soil material crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

e. Very firm: Soil material crushes under strong pressure; barely crushable between thumb and forefinger.

2.3.3 Dry consistence:

The following terms are used to describe the consistence of dry soil.

a. Loose: Non-coherent

b. Soft: Soil mass is very weakly coherent and fragile; breaks to powder of individual grains under very slight pressure.

c. Slightly hard: Weakly resistant to pressure; easily broken between thumb and forefinger.

d. Hard: Moderately resistant to pressure; can be broken by hands without difficulty; not broken between thumb and forefinger.

e. Very hard: Very resistant to pressure; can be broken in hands with difficulty; not breakable between thumb and forefinger.

2.4 Determine the soil texture and consistency of given soil samples and fill in Data Sheet 2.0

Data Sheet 2.0: Observation of Soil Consistence

Sample Number	Soil Texture	Wet Consistence Stickiness	Wet Consistence Plasticity	Moist Consistence	Dry Consistence
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

2.5. Make proper interpretation of the informations in Data Sheet 2.0

2.6 Questions:

a. Define plasticity and explain why clays exhibit plastic property while sand and silt do not?

b. Why is soil consistence determined under dry, moist and wet conditions?

c. What is the application of the knowledge of consistency?

LAB 3: PARTICLE SIZE ANALYSIS BY HYDROMETER METHOD

Section:........ Date...........

3.0 Objective:

a. To understand how size of particles affects settling time.
b. To perform hydrometer method of particle size analysis.
c. To determine textural groups by use of textural triangle.

3.1 Definition:

Particle size analysis is the determination of the proportion of solid particles in different size ranges. It is also called the mechanical analysis of soils.

3.2 Principles

Dispersion: Individual soil particles must be separated from each other and remain separated during the determination of particle size distribution. The soil particles are dispersed mechanically by stirring which effectively disperses large aggregates. Use of chemicals disperses small aggregated clay groups, and it keeps the particles in dispersed condition by deflocculation. The mixture of dispersed soil particles in water is called a soil suspension.

Sedimentation: Settling rates of dispersed particles in water are measured. Large particles will settle out of suspension more rapidly than small particles. The settling phenomenon is best explained by Stoke's law which can be mathematically summarized as:

$$v = h/t = K.d2$$

Where v = velocity of fall
h = height of fall (cm)
t = time in secs
d = diameter of particle
K = constant depending on the viscosity of the dispersing medium and the acceleration due to gravity at the place of determination.

In practice, the material still in suspension at any time is measured with a hydrometer. Bouyoucos determined that after 40 seconds, sand size particles (>0.05 mm) settle and after 2 hours, particles larger than clays (> 0.002 mm) settle similarly. These principles are developed to determine particle size distribution of a soil.

3.3 Experimental procedure:

3.3.1 Demonstration of different settling times for different sized sand particles

a. Five cylinders with different sizes of sand particles (sizes to be given by the instructor) will be dispersed first.

b. You have to record the time(in secs) it takes for the sand grains to settle on the bottom of the cylinder.

c. Draw a graph to show the relationship between diameter on X-axis and the time of fall on Y-axis.

3.3.2 Determination of particle size distribution:

a. 50 g of oven dried soil is placed in a stirring cup, and the cup is half filled with distilled water after adding 50 ml of dispersing solution (The instructor will tell you how to make the dispersing solution which will be supplied ready-made to you).

b. Stir the soil for 3-4 minutes for coarse textured soils and 7-8 minutes for soils high in clay.

c. Transfer the stirred mixture to a settling cylinder and fill distilled water up to the mark (steps a, b and c have been done by the instructor and you have to proceed with (d) below).

d. Insert a rubber stopper (a plunger can be used, if available) and shake the suspension back and forth for 2 minutes or use the plunger with 5-6 gentle thorough strokes.

e. Place the cylinder on the table or take out the plunger and record the time. After 20 seconds, carefully insert the hydrometer and read the hydrometer at 40 seconds after shaking was stopped. Repeat steps (d) and (e) by all students in your group, and record the readings which are within 0.5 g of each other.

f. Remove the hydrometer and determine the temperature of the suspension. For each degree above 20 deg C add 0.25 to the hydrometer reading. For each degree below 20 deg C subtract 0.25 from the hydrometer reading. (Particles fall faster in warmer or less viscous water).

g. Re-shake the suspension and place the cylinder on the table and record the time. Take a hydrometer reading exactly two hours later. Correct for temperature as described above.

h. Complete Data Sheet 3.0 and determine texture by the use of textural triangle.

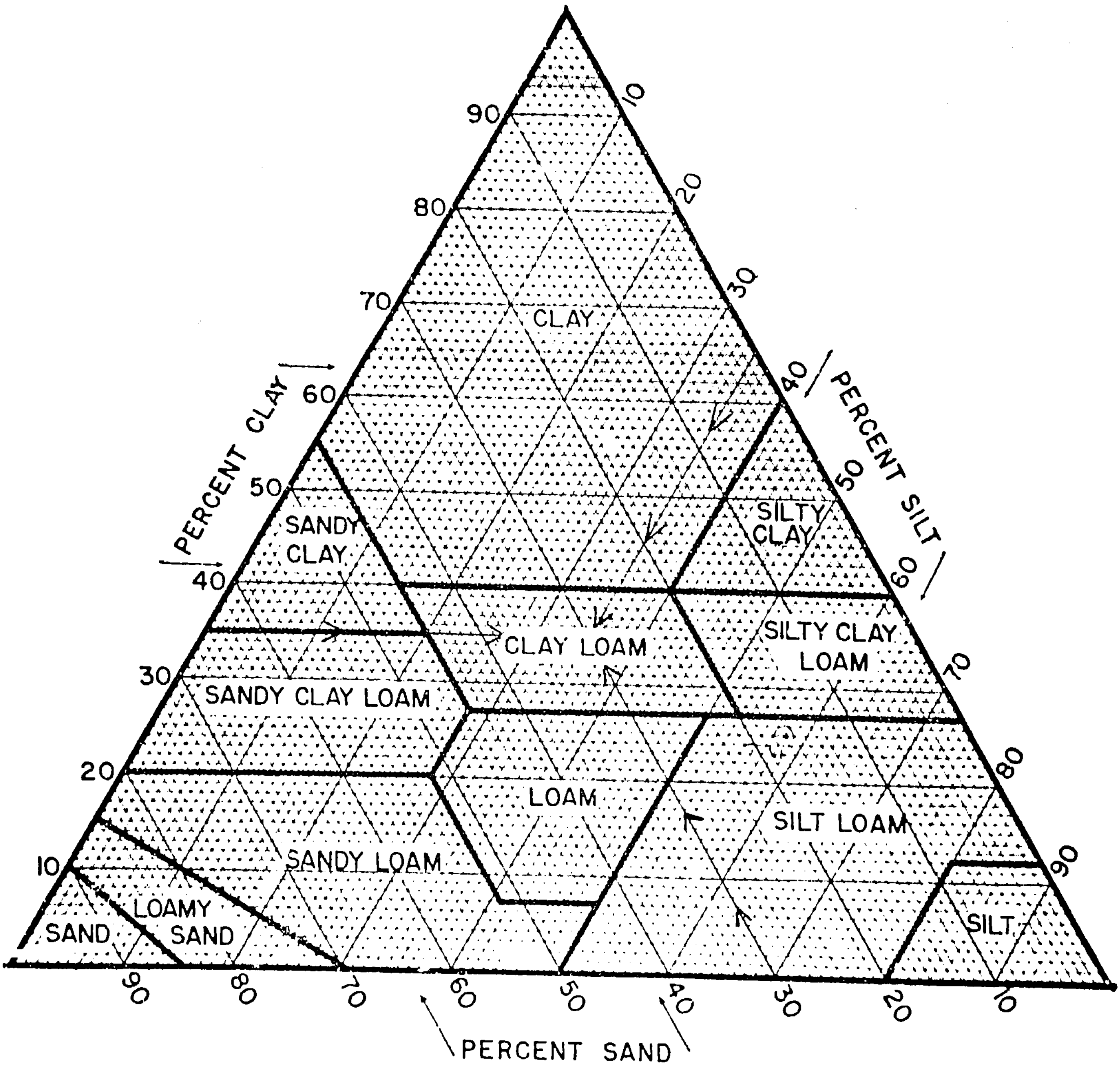
Data Sheet 3.0: Observation of Hydrometer Readings.

	Soil I	Soil II	Soil III
1. Soil weight (g)	50	50	50
2. 40-sec hydrometer reading (g/l)	--------	--------	--------
3. Temperature of suspension deg.C	--------	--------	--------
4. Corrected 40-sec hydrometer reading (g/l)	--------	--------	--------
5. 2-hour hydrometer reading(g/l)	--------	--------	--------
6. Temperature of suspension deg.C	--------	--------	--------
7. Corrected 2-hour hydrometer reading(g/l)	--------	--------	--------
8. Grams of sand (line 1-line 4)	--------	--------	--------
9. Grams of clay (line 7)	--------	--------	--------
10. % sand = (line 8)X2 =	--------	--------	--------
11. % clay = (line 9)X2 =	--------	--------	--------
12. % silt (100 -(%sand + %clay)) =	--------	--------	--------
13. Soil textural class (from textural triangle)	--------	--------	--------

3.4 Questions:

a. What is dispersion? How do you make a dispersing solution?

b. How do you disperse soil samples high in organic matter?



<u>Figure 3.0</u>: USDA Textural Triangle

3.5 Determination of Textural Groups by Use of Textural Triangle

3.5.1 Example: Refer to textural triangle in figure 3.0. Suppose, we need to determine the texture of a soil with sand, silt and clay content equal to 30%, 35%, and 35% respectively. Follow the arrow lines carefully as shown in the figure. The texture of the sample is Clay Loam.

3.5.2 Determine the textural class names of the following soils using the textural triangle (Figure 3.0).

Soil No.	Sand %	Silt %	Clay %	Texture
1	33	33	34	
2	10	68	22	
3	37	55	8	
4	52	8	40	
5	65	20	15	
6	5	75	20	
7	15	15	70	
8	35	25	40	
9	90	5	5	
10	10	45	45	
11	17	23	60	
12	37	37	26	
13	63	30	7	
14	4	56	40	
15	23	54	23	

3.6 Draw and label the hydrometer, cylinder and the plunger used in this experiment.

LAB 4: SOIL STRUCTURE DETERMINATION

Section:.......... Date...........

4.0 Objective:

a. To identify different types of soil structure.
b. To determine structural size and grades.

4.1 Definition:

Soil structure refers to the aggregation of individual soil particles into compound groups or clusters of particles. These are separated by natural lines, zones or surfaces of weakness. Individual aggregates are referred to as peds. The grade, class and type of structure is usually described for each sample. If a sample lacks structural arrangement, it is considered to be structureless.

4.2 Type of structure:

The type of structure refers to the shape of the peds (see Figure 4.0).

a. Granular structure is spherical shaped aggregates bounded by curved or very irregular surfaces which have slight or no accomodation to the faces of the adjoining ped faces. Particles are arranged around a point.

b. Subangular blocky structure is block like aggregation. The blocks are polyhedrons bounded by flattened or rounded faces and have rounded corners. The faces are casts or molds formed by the faces of the adjoining peds. Particles are arranged around a point.

c. Angular blocky structure is similar to sub-angular blocky, but the polyhedrons are bounded by flattened faces and have sharp edges or corners.

d. Platy structure is plate-like aggregates with horizontal dimensions considerably greater than the vertical dimension. Particles are arranged about a horizontal plane.

e. Prismatic structure is prism-like aggregates with vertical dimension considerably greater than horizontal dimension. Particles are arranged about a vertical line. Peds are bounded by planer vertical faces which are casts or the molds formed by the faces of adjoining peds and have flat caps.

f. Columnar structure is similar to a prismatic structure except that it has rounded caps.

g. Single grained structure has no observable aggregation. Individual particles are non-coherent and easily distinguishable.

h. Massive structure has no observable aggregation. Individual particles are coherent, but the mass lacks planes of weaknesses.

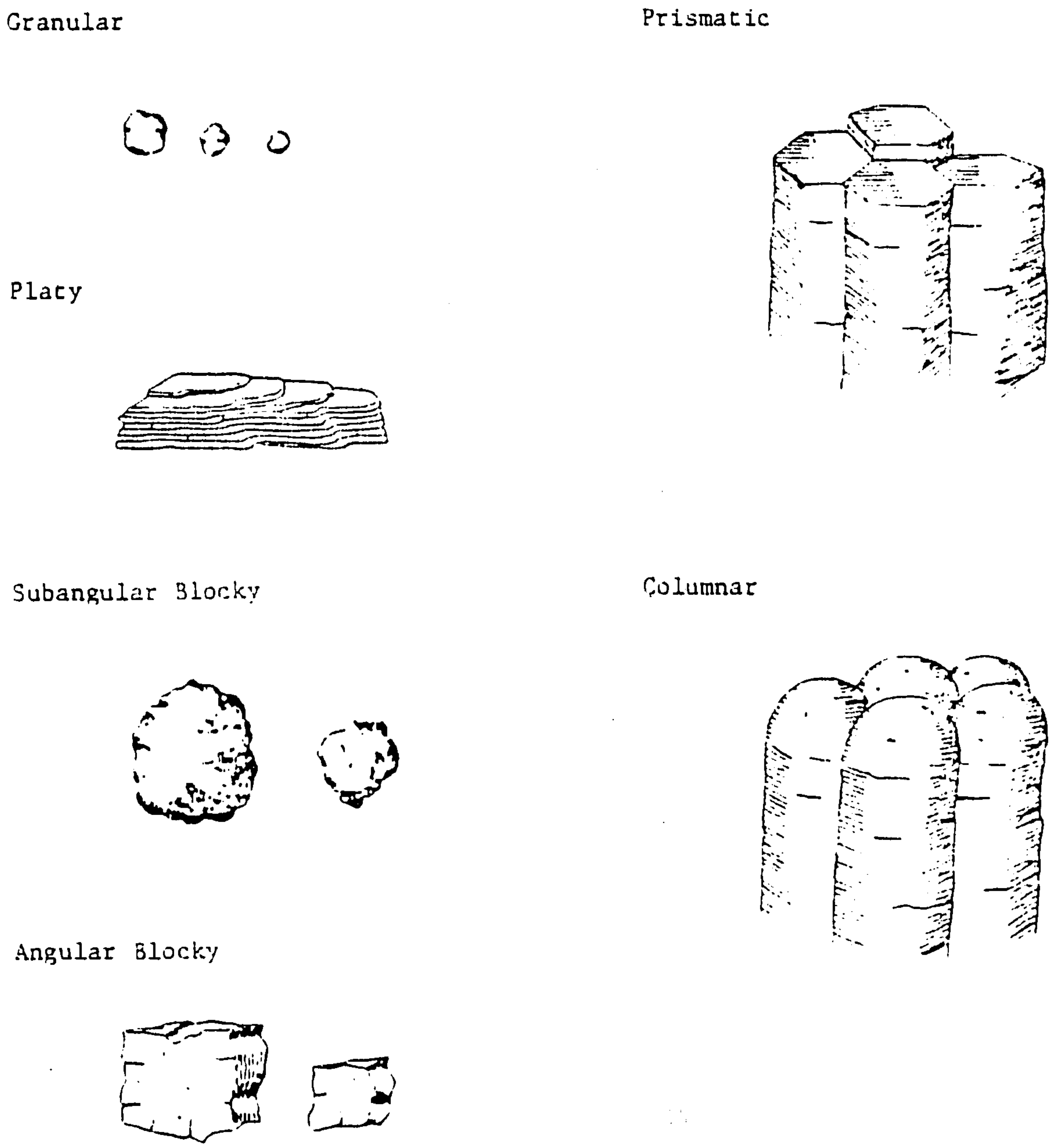


Figure 4.0: Types of Soil Structure

4.3 Grade: The grade of structure is the distinctness and durability of the peds.

a. Weak structure breaks into a few, poorly formed, indistinct peds, with some broken peds and much unaggregated material. The structure is barely observable in place.

b. Moderate structure is characterised by well formed distinct peds in disturbed soil that are moderately durable and evident, but not distinct in undisturbed soil. Disturbed soil material breaks down into a mixture of many distinct, whole peds, some broken peds and little unaggregated materials.

c. Strong structure is characterized by durable peds that are very evident in undisturbed soil, that adhere weakly to one another and that withstand displacement and become separated when the soil is disturbed. Disturbed soil consists largely of whole peds with few broken peds and little or no unaggregated material.

4.4 Sizes: Five size classes are recognized in each of the primary types.

Size class	Primary types of structure			
	Granular	Platy	Blocky(1)	Prismastic(2)
Very fine	< 1mm	< 1mm	< 5mm	< 10mm
Fine	1 - 2mm	1 - 2mm	5 - 10mm	10 - 20mm
Medium	2 - 5mm	2 - 5mm	10 - 20mm	20 - 50mm
Coarse	5 -10mm	5 -10mm	20 - 50mm	50 -100mm
Very coarse	>10mm	>10mm	> 50mm	>100mm

1/ includes angular and subangular blocky structure
2/ includes columnar structure.

4.5 Determine the structure of the given soil samples and fill in Data Sheet 4.0.

Data Sheet 4.0: Observation of Soil Structure Samples.

Sample No	Grade	Size	Type
1.	....	....	....
2.	....	....	....
3.	....	....	....
4.	....	....	....
5.	....	....	....
6.	....	....	....
7.	....	....	....
8.	....	....	....

4.6 Answer the following questions:

a. What is the significance of soil structure?

b. What kind of soil structures are associated with:

i) A1 horizon

ii) B2t horizon

iii) C horizon

c. Which structure is more desirable from the proper soil and water management point of view? What can be done to improve soil structure?

d. What is aggregate stability? What factors are responsible for the strength, as well as the weakness of the aggregates?

LAB 5: DETERMINATION OF SOIL COLOUR

Section:............ Date:............

5.0 Objective:

a. To determine soil colour with use of a Munsell Colour Chart.
b. To understand the relationship of soil colour to drainage.

5.1 Definition:

Soil colour is one of the most useful and important characteristics for soil identification, especially when combined with soil structure.

5.2 Significance:

1. Organic matter content in the soil is approximated by soil colour. Generally in temperate climates, dark coloured soils are relatively higher in organic matter than light coloured soils. Organic matter accumulation is primarily responsible for the dark soil colour of the upper horizons. In general, the soil colour of Ap horizons become darker as the natural soil drainage changes from well drained to poorly drained.

2. Many iron compounds vary in colour depending upon the aeration of the soil. Ferric or oxidized iron vary in colour from yellow to red. In well drained soils iron oxides are diffused throughout the soil. They coat many of the soil particles giving a uniform colour. Since unhydrated iron compounds are relatively unstable under moist conditions, red colour usually indicates good drainage and good aeration. Under poorly drained condition, iron compounds are in the ferrous form and tend to be blue or grey in colour. Dark brown or black manganese oxides occur in poorly drained soils as concretions or dark splotches on some of the soil peds. A mottled pattern of various shades of grey, brown and yellow occur in most poorly drained soils with seasonal fluctuations of the water table. The word "mottles" means marked with spots of colour. Mottled colours indicate impeded drainage and greyness usually increases with increase in wetness.

5.3 Colour is the combination of three factors:

1. Hue: Corresponding to spectral colours such as red, yellow and green which is the measure of the dominant wave length of the light.

2. Value (brilliance): The relative lightness or darkness of the colour, which is the measure of the total quantity of light.

3. Chroma: The relative purity of a particular spectral colour or the degree of vividness in contrast to greyness.

The symbol for hue is the letter abbreviation of the colour of the rainbow (R for red and Y for Yellow) preceeded by numbers from 0 to 10. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The middle letter range is 5, or 5 YR is the middle of the yellow red hue which extends from 10 R to 10 YR.

The notation for value consists of numbers from 0, for absolute black, to 10 for absolute white. Thus a value of 5/ is visually midway between absolute white and absolute black.

The notation for chroma consists of numbers beginning with 0, for neutral greys, and increasing at equal intervals to a maximum of about 20.

5.4. Writing Munsell notation: The sequence is hue, value and chroma. For example a notation of

10 YR 5/3 means hue = 10 YR, value = 5, and chroma = 3, and

10 R 2/1 means hue = 10 R, value = 2, and chroma = 1.

Colours are determined by comparing freshly broken or exposed surfaces with Munsell color chips. The soil colour changes with moisture content.

5.5 Mottles:

When mottles occur in soils, their dominant colours are determined by using the Munsell notation. These are described with regards to their:

a. colour contrast with the remainder of the soil matrix
b. abundance
c. size

5.5.1 Contrast may be described as faint distinct or prominant.

Faint: Indistinct mottles are recognizable only with close examination of the soil colours in both the matrix and mottles have closely related the hues and chromas.

Distinct: Although not striking, the mottles are readily seen. The hue value and chroma of the matrix are easily distinguished from those of the mottles. They may vary as much as one or two hues or several units in chroma and value.

Prominent: The conspicuous mottles are obvious, and mottling is one of the outstanding features of the horizon. Hue, value and chroma may be several units apart.

5.5.2 Abundance:

Few: Mottles occupy less than 2% of the exposed surface.

Common: Mottles occupy 2 to 20% of the exposed surface.

Many: Mottles occupy more than 20% of the exposed surface.

5.5.3 Size: Refers to the approximate diameter of individual mottles. The diameters are measured along the widest dimension.

Fine: Mottles are less than 5 mm in size.

Medium: Mottles are from 5 to 15 mm in size.

Coarse: Mottles are greater than 15 mm in size.

5.6 Use the Munshell colour chart to determine the colour of the given soil samples and fill in Data Sheet 5.Ø.

Data Sheet 5.Ø Observation of Soil Colour.

Sample Number	Colour Notation Hue	Value	Chroma	Soil Colour
1.	....	....	....	....
2.	....	....	....	....
3.	....	....	....	....
4.	....	....	....	....
5.	....	....	....	....
6.	....	....	....	....
7.	....	....	....	....
8.	....	....	....	....

5.7 Study the observations in Data Sheet 5.Ø and make proper interpretations.

5.8 Answer the following questions:

a. What does dark coloured surface soil indicate?

b. Why are the soils in most of the Nepalese hills and tars red in colour?

c. Where would mottles be most likley present, in a terraced khet or a pakho bari? Give reasons for your answer.

LAB 6: DETERMINATION OF BULK DENSITY

Section:.........   Date:..........

6.0 Objective:

a. To determine of soil bulk density
b. To perform bulk-density related calculations
c. To understand soil texture and structure relations with bulk density

6.1 Definition:

$$\text{Bulk Density} = \frac{\text{Weight of oven dry soil (g)}}{\text{Bulk volume of oven dry soil (cm3)}}$$

6.2 Equipment:

a. Core sampler
b. Core rings
c. Balance
d. Oven

6.3 Procedure:

a. Clean the stubble, grass, etc., from the soil surface and position the sampler.

b. Drive or press the sampler in a vertical soil surface far enough to fill the sampler, but not so far as to compress the soil in the confined space of the sampler.

c. Remove the sampler and the contents carefully without destroying the natural structure and without packing the soil. Shovelling along the side and under the sampler may be needed in some soils to remove the sample without disturbance.

d. Take out the core ring with the sample and trim the soil on both ends with a sharp edged knife.

e. Place the sample in an oven at 105 deg.C overnight and weigh it.

f. Four samples will be given for bulk density determination in the lab.

Sample No	Description
1.	Ap horizon with good structure
2.	Ap horizon with destroyed structure
3.	Fine sand
4.	Organic soil

g. Take the weight of the oven dry soil. Calculate the volume of the core rings and calculate the bulk density of all four soils. Fill in Data Sheet 6.0.

Data Sheet 6.0 Observation of Bulk Density.

S.N.	Sample Description	Bulk Density (g/cm3)
1.	Ap horizon with good structure	
2.	Ap horizon with destroyed structure	
3.	Fine sand	
4.	Organic soil	

6.4. Questions:

a. Calculate the weight of one hectare furrow slice, with depth of the furrow of 25 cm and a bulk density value of 1.3 g/cm3.

b. What is the significance of bulk density?

c. Discuss why sample 1 and 2 have different bulk density values?

d. Calculate the weight of a hectare-cm of soil with a bulk density of 1.2 g/cm3.

LAB 7: DETERMINATION OF PARTICLE DENSITY OF SOIL

Section:............ Date..........

7.0 Objective:

a. To determine particle density of soils by using a pycnometer.
b. To calculate soil porosity.

7.1 Definition:

Particle density (Dp) is the mass per unit volume of the soil solids.

$$Dp = \frac{\text{Weight (g) of oven dry soil}}{\text{Solid volume (cm3)}}$$

The Dp value for most of the mineral soil ranges between 2.6 and 2.70 g/cm3 with an average of 2.65 g/cm3. The knowledge of Dp is important to calculate volume weight relationships of the soil, like porosity, and void ratio. Particle density is also used in calculating settling velocity of particles of different sizes during mechanical analysis.

7.2 Equipment: Pycnometer.

7.3 Procedure:

a. Weigh a clean dry pycnometer in the air.

b. Put into it 10 g of oven dry soil.

c. Using a pipette, fill the bottle about half-full with distilled water with a stream washing any soil particles sticking to the inside of the neck into the bottle.

d. Remove the entrapped air by gently boiling the contents.

e. Leave the soil overnight in case of heavy clay.

f. Cool the contents to room temperature and fill the pycnometer with boiled, distilled water, cooled to room temperature.

g. Insert the stopper and seat it carefully.

h. Wipe dry the outside of the pycnometer with a blotter.

i. Weigh it and also note the temperature.

j. Empty the pycnometer, clean it and fill it with boiled, cooled water at the same temperature as before.

k. Replace the stopper and dry the outside of the pycnometer with a piece of cloth or blotter and weigh it.

7.5 Calculation:

7.5.1 Particle Density, Dp

$$Dp = \frac{(Ws - We)}{(Ws - We) - (Wsw - Ww)} \times dw$$

where:

We = Wt of the empty and dry pycnometer,
Ws = Wt of pycnometer + soil sample,
Wsw= Wt of pycnometer filled with soil and water,
Ww = Wt of pycnometer filled with water.
dw = density of water (g/cm3) at the observed temperature.

7.5.2 Total Porosity and % Porespace

$$\%\ \text{Solid space} = \frac{Db}{Dp} \times 100$$

% Pore space + % Solid space = 100

$$\%\ \text{Pore space} = 100 - \%\ \text{Solid space} = 100 - \frac{Db}{Dp} \times 100$$

$$\text{Total porosity (e)} = 1 - \frac{Db}{Dp}$$

Where:
Db = bulk density
Dp = particle density.

7.6 Questions:

a. A soil has a bulk density of 1.3 g/cm3 and a particle density of 2.65 g/cm3. Calculate the porosity of the soil.

b. Calculate the porosity of the soil with the following data.
oven dry wt of soil core = 286 g
volume of core ring = 220 cm3.
particle density of soil = 2.65 g/cm3.

LAB 8: IDENTIFICATION OF MINERALS

Section:............ Date:..........

8.0 Objective: To identify common minerals.

8.1 Definition:

Minerals are naturally occuring, homogeneous, mostly inorganic substances, each with a definite chemical composition and physical properties. More than 300 minerals are identified so far. Of them only a few occur in abundance in the earth's crust. The most important are: quartz, feldspar, mica, aluminium silicates of Fe and Mg, clay minerals, calcite, and gypsum.

8.2 Criteria for identification of minerals:

8.2.1 Characteristics depending upon light:

a. Colour: Many minerals have definite colours, but several of them occur in more than one colour.

b. Lustre: General appearance of a mineral in reflected light. Two types - dull - clay minerals; shining - micas.
Metallic lustre of a metal
Vitreous lusture of a glass
Adamantine lustre of a diamond

c. Transparency: Degree of penetration of light through a mineral. The minerals may be transparent (eg. mica), translucent (eg. quartz) or opaque (eg. pyrite).

d. Streak: Colour of the powder of a mineral. Streak represents the true colour of a mineral.

8.2.2 State of aggregation:

a. Crystallinity: Crystalline - crystals visible with eye or with microscope. Amorphous - complete absence of crystals.

b. Cleavage: The property of a mineral to break along parallel planes.
Basal clevage - parallel planes are also parallel to the geometric base of the mineral (eg. mica).
Right angle - occurs when cleavage planes intersect at a right angle (eg. feldspar).
Rhombic - occurs when cleavage planes intersect at an acute angle forming one corner of a rhombus.

c. Fracture: It is the property of a mineral to break along irregular surfaces.
Irregular - mineral breaks with uneven surfaces(eg. olivine).
Conchoidal- when a mineral breaks with a concave surface. which shows eccentric rings around the point of impact.
Hackly- when a mineral breaks with a sharp toothed or jagged surface.

8.4 Hardness : Resistance of a mineral to scratching.

Moh's Scale of Hardness

Mineral	Hardness	Characteristics
Talk	1	Scratched with a nail.
Gypsum	2	Just scratched with a nail.
Calcite	3	Scratched not so easily with a coin.
Fluorite	4	Easily scratched with a knife, but it does not scratch soft glass.
Apatite	5	Just scratched with a knife, and it just scratches glass.
Felo.	6	It scratches soft glass, but itself is not scratched with a knife.
Quartz	7	Scratches glass easily.
Topaz	8	Scratches quartz.
Corundum	9	Scratches topaz.
Diamond	10	Scratches corundum.

8.5 Specific gravity: It is the weight of mineral divided by the weight of an equal volume of water.

8.6 Description of selected minerals

a. Quartz(SiO_2): It is the most abundant mineral found in soil. It is very hard and has low solubility. It makes up about 13 % of the earth's crust. Quartz contributes no plant nutrients to the soil.

b. Feldspars (alumino - silicates with bases of K,Na,Ca): Feldspars account for 60% of the earth's crust. They occurs in rocks such as granites, schists, and gneiss. Upon chemical weathering they form clay minerals. The plagioclases weather more readily than orthoclase. Orthoclase ($KAlSi_3O_8$) is an important source of potassium.

c. Amphiboles and pyroxenes (silicates of Ca, Mg, and Fe): These two minerals constitute 16% of the earth's crust. They weather more rapidly, but may persist in soils as dark coloured gravel. Hornblende is a black coloured amphibole with a distinct cleavage. Auguite is a dull green pyroxene with indistinct cleavage. Augite occurs in such rocks as basalts, gabros, and granites while hornblende occurs in granites, diorites and schists.

d. Micas (alumino - silicates with K, Mg, and Fe as basic components):

Micas weather easily and form clay minerals. Biotite (black mica) and muscovite (white mica) are good sources of potassium. Biotite has more iron and magnesium than muscovite. They occur in rocks such as granite, sandstone, gneiss and schist.

e. Carbonates(CO_3): Carbonates are commonly found in limestone and marble. Calcite ($CaCO_3$) is a relatively soluble mineral. It has a perfect cleavage and gives slight effervescence with cold acid.

f. Apatite [$Ca_5(PO_4)_3(F$ or $Cl)$]: It is the original source of practically all soil phosphorus. It exists in minute grains in many rocks. It is soluble in acids.

g. Gypsum ($CaSO_4.2H_2O$): It is a very soft and fairly readily weatherable mineral. However, it accumulates in large quantities in semi-arid regions. It has rhombic cleavage.

h. Iron oxides: Many of the iron oxides are formed through chemical weathering. Hematite (Fe_2O_3) is responsible for red colour in many soils while limonite ($Fe_2O_3.H_2O$) imparts a yellow colour.

i. Clay minerals: They are formed primarily from chemical weathering of primary minerals. They occur in soils, shale and other sedimentary rocks. Clay minerals do not provide any plant nutrients directly, but they have the ability to adsorb or hold nutrient ions on their surfaces.

8.7 Questions:

a) What are the important minerals containing:

i) Potassium

ii) Phosphorus

iii) Magnesium

iv) Iron

v) Calcium

b) How do primary minerals differ from secondary minerals?

c) How would you proceed to identify an unknown mineral?

8.8 Identify the samples of minerals displayed to you by filling in the Data Sheet 8.0 below:

Data Sheet 8.0 Identification of Minerals

Sample Number	Colour	Transparency	Lustre	Crystallinity	Cleavage/ Fracture	Name of Mineral
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

LAB 9: IDENTIFICATION OF ROCKS

Section:...........   Date:...........

9.0 Objective: To identify common rocks found in Nepal.

9.1 Definition:

Rocks are aggregates of one or more minerals. They are the major components of the earth's crust. They might be solid and hard, loose or soft.

9.2 Classification of rocks:

Igneous rocks are formed by the crystallization of hot, molten magma. They are also known as primary rocks because they contain primary minerals such as quartz, feldspar and dark coloured minerals (such as biotite, augite, hornblende).

The most important distinguishing character of igneous rock is the following evidences of their formation from liquid magma.

a. Presence of interlocking grains: The mineral grains are in contact with one another so that there is no pore space between different grains (eg. granite).

b. The presence of cavities formed by the escaping of gases as the magma cools down (eg. basalt).

c. The presence of flow structure i.e. the arrangement of mineral grains in the direction of the flow of magma before cooling (eg. rhyolite).

9.2.1 Classification of igneous rock: Igneous rocks are classified on the basis of:

9.2.1.1 Their chemical composition.

a. Acid igneous rocks: They are light in colour and contain more than 65% SiO2 as silicate or silica (eg. granite and rhyolite).

b. Basic igneous rocks: They are dark in colour and contain less than 50% SiO2 (eg. basalt and gabro).

c. Neutral igneous rocks: They have 50-65% SiO2. (eg. andesite and diorite).

9.2.1.2 Their mode of occurence.

a. Intrusive igneous rock : They are formed inside the earth's surface (eg. granite and gabro).

b. Extrusive igneous rock: They are formed at or near the earth's surface (eg. basalt and obsedian).

9.2.2 Description of important igneous rocks:

a. Granite: It is a light coloured, medium to coarse grained igneous rock containing quartz and feldspar as the dominant minerals. Mica is almost always present in small grains.

b. Rhyolite: It has similar minerological and chemical composition as granite. It is fine grained and extrusive in mode of origin.

c. Gabro: It is dark coloured and coarse grained basic igneous rock which has plagioclase feldspar as the dominant mineral. It also has small amounts of pyroxines and amphiboles.

d. Basalt: It has same chemical and minerological composition as gabro, however, it is fine grained. It is dark to greenish black in colour.

e. Obsidian: is a volcanic glass. It is usually dark coloured, with acidic chemical composition and extrusive mode of occurance.

9.3 Sedimentary Rocks: It results from the deposition and recementation of weathering products of other rocks.

Most important distinguishing characters of sedimentary rocks:

a. Fragmentary structure: The presence of loose grains, broken materials from different rocks and minerals. A fairly large amount of pore space is present between grains, which are cemented together by iron oxide, silica, carbonate, or clays.

b. Stratification: Depositional layers remain visible even after the compaction of sediments (eg. shale).

c. Presence of hard parts of organism: Hard parts of dead marine organisms are often present (eg. shells in limestone).

9.3.1 Classification of sedimentary rocks:

Sedimentary rocks are classified as clastics or precipitates.

a. Clastics (or Fragmental): Sedimentary rocks formed through physical and mechanical processes. Weathered rock fragments are consolidated by the exertion of pressure and by cementing materials (eg sandstone, siltstone, shale, conglomerate).

b. Precipitates: Sedimentary rocks formed by the chemical or biochemical precipitation of ions from solution.

9.3.2 Description of important sedimentary rocks:

a. Sandstone: Contains dominantly sand sized particles (mostly quartz) bound together by various cementing agents.

b. Shales: Contains dominantly silt sized particles.

c. Shale: Contains dominantly clay sized particles. The predominant mineral is clay.

d. Conglomerate: Consists of rounded stones, pebbles or gravels cemented together by clay, $CaCO_3$, silica and iron.

e. Limestone: Formed from chemical precipitation or from skeletal remains (sea shells). The principal minerals are calcite and dolomite. Dolomitic limestone is harder than calcitic limestone.

f. Coal: It is the organic sedimentary rock formed from the remains of plants.

9.4 Metamorphic Rocks:

The natural agencies of temperature, pressure and chemical solution react with the original primary or secondary rock and change their character completely or partially. Such rocks are called metamorphic rocks.

Most important distinguishing characters:

a. Presence of foliation: Horizontal layers parallel to one another.

b. Presence of dominant mica minerials: Metamorphic rocks contain large amounts of biotite and muscovite micas (because of typical condition of temprature and pressure) which gives them silvery or shiny appearance.

c. Signs of recrystallization: High temprature and pressure induce recrystallization which gives the rock a shiny and compact look.

9.4.1 Classification of metamorphic rocks:

Metamorphic rocks are classified according to their structure and parent rock.

a. Banded(foliated) metamorphic rocks have more or less parallel layers of different minerals.

b. Nonbanded metamorphic rocks have random pattern of mineral crystals.

9.4.2 Description of important metamorphic rocks:

a. Quartzite: It is nonbanded metamorphosed sandstone. Quartz is the dominant mineral.It is very hard and weathers extremely slowly.

b. Slate: It is banded metamorphic rock derived from shale. The mineral grains derived are not visible. It forms sheets and is more compact and denser than shale.

c. Gneiss: Banded metamorphic rock derived from acidic igneous rock such as granite. This rock has alternate light and dark coloured bands. Quartz, feldspars and biotite micas are the dominant minerals.

d. Marble: A recrystallized limestone. It is more coarse grained and weathers slower than limestone.

e. Schists: Banded metamorphic rocks such as metamorphosed shale, gneiss or basic igneous rocks. Newly formed minerals such as mica, chlorite and hornblende tend to predominate.

9.5 Questions:

a. How would you distinguish between a mineral and a rock?

b. Why do we need to study rocks and minerals in soil science?

c. How do igneous rocks differ from sedimentary rocks?

d. Discuss the formation of a limestone conglomerate.

e. What are the factors causing metamorphism of rocks?

9.6 Observe the different samples of rocks displayed to you by filling in the Data Sheet 9.0 below.

<u>Data Sheet 9.0</u> Study of Rocks

Sample Number	Name of Rock	Identification Characteristics	Minerals Identified on rock	Rock Type
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

LAB 10: STUDY OF SOIL PROFILE

Section:...........   Date:............

10.0 Objectives:

a. To familiarize with the profile description technique.
b. To identify different horizons on morphological basis.
c. To inter-relate the effect of vegetation and drainage on soil development.
d. To understand the effect of drainage differences on land use and soil management.

10.1 Definition:

Soil profile: The soil profile is a vertical section of the soil through all its horizons and extends down to the parent material or to a depth of 2 meters or more in deep tropical soil.

10.2 Significance:

a. The study of a soil profile and its characteristics help to determine the agricultural value of the land.
b. It helps to diagnose such problems as salinity, alkalinity, water logging, and the presence of a hard pan in the soil and to explain their effects on use and management of soils.
c. It is a pre-requisite of soil classification.

10.3 Materials:

1) Digging tool
2) Cutting knife
3) Abeny's level
4) Measuring tape
5) Munsell colour chart
6) Dilute HCl (10%)
7) Water bottle
8) A pH kit.
9) Profile description sheets
10) Sampling bags.

10.4 Description of soil horizons: Each horizon is described for the following:

i) Horizon symbol (refer to lecture notes).
ii) Depth of each horizon.
iii) Nature of horizon boundary: Horizon boundaries vary in distinctress and in surface topography.

Distinctness: The characteristic thickness of the boundary may be described as:

Abrupt(a)- boundary less than 2.5 cm thick.
Clear(c)- boundary 2.5 - 5 cm thick.
Gradual(g)- boundary 5 - 12 cm thick.
Diffuse(d)- boundary more than 12 cm thick.

Surface topography may be described as:

Smooth(s)- The boundary is nearly a plane surface.
Wavy(w)- Pockets are wider than their depth.
Irregular(i)- Pockets are deeper than their width.
Broken(b)- The horizon boundary is not continuous.

iv) Soil colour and mottling (refer Lab No 5)
v) Soil texture - (refer Lab No 1)
vi) Soil structure - (refer Lab No 4)
vii) Soil consistence - (refer Lab No 2)
viii) Other- Such as cutans, root distribution, reaction to dil HCl, presence of concretion, hard pan etc.

O1	Organic horizon of undecomposed organic matter.
O2	Organic horizon of partially decomposed organic matter.
A1	Surface mineral horizon with an accumulation of well decomposed organic matter which coats the mineral particles and darkens the soil mass.
A2	Sub-surface horizon which has lost organic matter, clay, iron or aluminum through eluviation.
A3	Transitional to B but more like A than B.
B1	Transitional to A but more like B than A.
B2	Mineral horizon with illuvial concentration of clay, iron, aluminum, or organic matter, or alteration of parent material through physical and chemical means with formation of structure.
B3	Transition to C.
C	Relatively unaltered parent material.
R	Underlyi consolidated bedrock.

Figure 10.0: Hypothetical soil profile showing principal horizons.

10.5 Study of a soil profile in the upland:

10.5.1 Site selection: An upland soil profile (Pedon 1) will be selected in a well drained site of the IAAS South Farm (near the end of the Narayani Second Terrace).

10.5.2 The students will study the profile and complete the profile description in Data Sheet 10.0

Data Sheet 10.0: Profile Description Sheet of Pedon 1

Horizon	Depth(cm)	Texture	Colour	Structure Grade	Structure Size	Structure Type	Consistency (moist)	Horizon Boundry	Other Characters(1)

(1) Other characters include mottles, HCl reaction, etc.

General Description of the Profile Site:

Location

Soil classification:

Site position in the landscape:

Parent material:

Slope class:

Degree of erosion:

Natural drainage class:

Natural vegetation or land use:

Water table:

10.6 Questions:

a. Draw a schematic diagram of the profile you have just described.

b. What is the parent material of this site? Give its salient features.

c. What does the dark brown or reddish brown colour of the profile, without mottles or grey colour indicate?

d. What was the natural vegetation of the site before the land was brought into cultivation ? Explain with profile characters.

e. What kind of land suitability rating would you give for the following crops? Explain (suitability rating: 1=excellent 2=good 3=fair 4=poor 5=unsuitable).

Rice:

Wheat:

Corn:

Fruits:

Fish farming:

Forestry:

10.7 Study of soil profile in the low land

10.7.1 Site selection : Poorly to somewhat poorly drained soil (Pedon 2) will be selected in the lowland areas of the IAAS South Farm (old river scar in the Narayani Second Terrace).

10.7.2 Describe the profile by completing Data Sheet 10.1

10.7.3 Questions:

a. How does Pedon 2 differ from Pedon 1 in its morphology?

b. Why is there more organic matter in the surface horizon of Pedon 2 ?

c. Why are there mottles and grey colour in the subsoil horizons of Pedon 2 ?

d. What crop is this site best suited for? Explain.

e. What limitations does this site have for the production of crops such as wheat, corn and citrus? Explain for each case.

f. Draw a schematic diagram of the profile in Pedon 2.

Data Sheet 10.1: Profile Description Sheet of Pedon 2

Horizon	Depth(cm)	Texture	Colour	Structure Grade Size Type	Consistency (moist)	Horizon Boundry	Other Characters(1)

(1) Other characters include mottles, HCl reaction, etc.

General Description of the Profile Site:

Location

Soil classification:

Site position in the landscape:

Parent material:

Slope class:

Degree of erosion:

Natural drainage class:

Natural vegetation or land use:

Water table:

10.8 Study of more soil profiles in the low land.

10.8.1 Site selection: Two profiles will be studied in this lab. Pedon 3a will be selected in an organic soil area (old meander channel of the Narayani River in the IAAS North Farm, Terrace I). Pedon 3b will be selected in a mineral soil with a calcareous sub-soil in the same area.

10.8.2 Describe the two pedons by completing Data Sheet 10.2 and 10.3.

10.8.3 Questions:

a. How is Pedon 3a (organic soil) formed ? Discuss.

b. What are the fertility problems of the soils of Pedon 3a and 3b site?

c. Suggest suitable land use for both the sites.

d. How can we improve the soils of the Pedon 3 area?

e. Why does pedon 3b have a pH value of around 8.0 ?

f. Draw comparative profile sketches of both of the pedons.

Data Sheet 10.2: Profile Description Sheet of Pedon 3a

Horizon	Depth(cm)	Texture	Colour	Structure Grade Size Type	Consistency (moist)	Horizon Boundry	Other Characters(1)

(1) Other characters include mottles, HCl reaction, etc.

General Description of the Profile Site:

Location

Soil classification:

Site position in the landscape:

Parent material:

Slope class:

Degree of erosion:

Natural drainage class:

Natural vegetation or land use:

Water table:

Data Sheet 10.3: Profile Description Sheet of Pedon 3b

Horizon	Depth(cm)	Texture	Colour	Structure			Consistency	Horizon	Other
				Grade	Size	Type	(moist)	Boundry	Characters(1)

(1) Other characters include mottles, HCl reaction, etc.

General Description of the Profile Site:

Location

Soil classification:

Site position in the landscape:

Parent material:

Slope class:

Degree of erosion:

Natural drainage class:

Natural vegetation or land use:

Water table:

LAB 11: A FIELD TRIP TO KHARKHARE GHAT
(At the bank of Narayani River in Mangalpur Panchayat)

11.Ø Objectives:

a. To indentify the alluvial landform and observe three terrace levels of the Narayani River.
b. To observe the soil differences because of the age of parent material and landscape position.
c. To observe the bedrock of the Chitwan area.
d. To identify different rocks found at the bank of the Narayani River.
e. To study the soil profile at the bank (youngest terrace) of the Narayani river.

11.1 Site selection: A well drained site (Pedon 4) will be selected at the Narayani River cut, and students will perform the profile description in Data Sheet 11.Ø.

11.2 Questions:

a. How many terrace levels did you observe in your field trip? How are they formed?

b. What bedrock did you observe at this site (P4 area)? Discuss about its formation?

c. What limitations does the P4 site have for crop production? How can we improve it?

Data Sheet 11.0: Profile Description Sheet of Pedon 4

Horizon	Depth(cm)	Texture	Colour	Structure			Consistency	Horizon	Other
				Grade	Size	Type	(moist)	Boundry	Characters(1)

(1) Other characters include mottles, HCl reaction, etc.

General Description of the Profile Site:

Location

Soil classification:

Site position in the landscape:

Parent material:

Slope class:

Degree of erosion:

Natural drainage class:

Natural vegetation or land use:

Water table:

d. Sketch and label the profile in Pedon 4.

e. Study the available rocks and fill in the observation sheet below.

Data Sheet 11.1 Study of Rocks

Sample Number	Name of Rock	Identification Characteristics	Different Minerals Identified on rock
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

LAB 12: SOIL SURVEY AND MAPPING

12.0 Objectives:

a. To familiarize with the techniques of soil survey.
b. To interpret aerial photographs for soil survey.

12.1 Types of soil survey:

a. Intensive surveys: These surveys are done for special purposes. They are required to plan small scale interprises (a few to a few hundred ha) such as irrigation layouts, intensive farm and plantation managements. Information, from only vegetation, landform and air photo is not sufficient and more information must be obtained by intensive sampling. Different soil properties are measured specifically if they have a direct bearing on purposes. For example, a fruit grower might be interested to know depth and drainage characteristic of the soil. Map scale of intensive soil surveys range from 1:2,500 to 1:10,500 or more.

b. Detailed soil survey: They are also carried out for specific projects though over somewhat larger areas. More soil properties are determined than in other groups. Information is derived largely from sampling and from surface features, vegetation, drainage patterns etc. Map scales vary from 1:10,000 to 1:25,000. Field traverses and observations are made in sufficient details, but less frequently than in intensive surveys. This kind of survey provides sufficient information for interpretation of various uses of the soil.

d. Semi-detailed: It is done for a variety of purposes. Some are of special purposes in which particular soil properties are of interest (eg. geo-chemical survey). Others are of general purpose depending upon several soil properties (eg. location of new settlement and assessment of potential for agricultural developments). Map scales usually range from 1:25,000 to 1:100,000. The maps produced by the Land Resources Mapping Project in Nepal (scale 1:50000) is an example of semi-detailed survey.

c. Reconnaissance surveys: The mapping is less elaborate and soil units delineated are of a high catagory such as well defined complexes like associations. Small scale maps are used (1:100,000 to 1:500,000). Field traverses are made at wider intervals. Larger areas are surveyed rapidly. Such surveys provide broad understanding of the soils and are particularly useful in relatively new and undeveloped regions.

e. Detailed-reconnaissance: They constitute the elements of both detailed and reconnaissance surveys. The regions of better use potentialities are surveyed in detail while reconnaissance surveys are made in regions of low potentialities.

12.2 Procedure of soil surveying and mapping:

a. Inspect the project area to get an appreciation of the broad soil patterns in relation to geographic landform and characteristic landscape of the area. Some idea of soil differences can be obtained by studying aerial photographs (base map).

b. Walk over the land at regular intervals and take notes on soil differences in the base map and other related surface features such as slope gradient, evidences of erosion, vegetative cover, etc.

c. Decide where to take the observation by studying general physiography, nature of vegetative cover and drainage patterns. Note from where the soils change and deliniate the boundaries in the base map.

d. Ink the map on the boundaries drawn in the field and prepare final map in the lab.

12.3 Base maps:

The nature of the base maps vary according to the circumstances and availability like cadestral maps, aerial photographs, topographic maps, etc.

Amongst them, aerial photographs are the best because they show clear and detailed ground features, including the field boundary, elongation of roads, tracks, fences, ditches, buildings, crops, or vegetative cover, drainage pattern and geological features. They permit a 3-dimensional view of the features. When overlapping pairs of photographs are viewed in a stereoscope, many features of soil pattern and the general nature of the vegetative cover and landform are evident to a trained observer. Differences in vegetation, crop vigour, topographical and lithological changes associated with soil variation shown on the photographs enable the surveyor to place the soil inspection sites in the field to most advantageous positions so as to get the best coordinated results of direct observations on the ground and the interpretaion of the photographs. It is an economical method for obtaining base materials rapidly for large and inaccessible areas.

12.4 Work:

a. Study different base maps.

b. Survey a given parcel of land, prepare a soil map for the area and write a soil survey report on a separate sheet of paper.

12.5 Questions:

a. Name the different types of base maps that you have studied.

b. Why are aerial photographs the most useful base maps in soil surveying?

c. What is meant by map scale?

d. What is a stereo pair? What is it's use?

LAB 13: DETERMINATION OF WATER CONTENT BY WEIGHT

Section:............ Date..........

13.0 Objectives:

a. To determine water content of a soil sample on weight basis (gravimetric method)

b. To study water content distribution with depth on different soil profiles.

13.1 Principle:

Water is held in soil pores between soil particles and aggregates. Water present in a soil sample is estimated on a weight basis by determining the weight of water and the weight of the soil that is holding the water.

By definition water content by weight (θw)

= Mass of water / Mass of oven dry soil

θw is usually multiplied by 100 to express the water content in percentage.

13.2 Equipment and materials:

a. Soil auger (tube or screw) b. Scale
c. Sampling cans with cover. d. Balance e. Oven

13.3 Procedure:

a. Note the number and weigh the sampling can(with the cover) given to you (We).

b. Go to the sampling site, record the environmental condition of the soil (recently irrigated, very dry, just plowed, under shade, etc.) to be sampled. Also note the general soil texture and structure changes with soil depth. You will be responsible to take a sample from a certain depth range.

c. Take about 50 g of soil sample uniformly from the desired depth range in the can and cover it immediately.

d. Go to the lab and weigh the can with soil in it (Wws)

e. Open the lid carefully without spilling the soil, place the lid below the can and set it on a tray. The tray will be placed in the oven and dried overnight at 105 deg C by the lab attendant.

f. The lab attendant will weigh the cans with dried soil samples the next day. The weights taken against each can number will be posted on the Soil Science notice board. Please note that it is very important for you to correctly note the can and lid numbers, otherwise, there will be an error in the readings.

g. Note the oven dry weight of the soil sample + can (Ws) from the notice board and calculate water content of your sample as follows:

$$\theta w\% = [(Wws - Ws) / (Ws - We)] \times 100$$

h. Share information with your group and complete the Data Sheet 13.0 below.

Data Sheet 13.0: Observation of Soil Water Content Determination

Site description:

Soil texture, structure and approximate bulk density:

Depth range (cm)	Can Number	Empty weight (We)	Wt.of moist soil + can (Wws)	Wt.of O.D Soil + can (Ws)	Moisture content (%) (Øw%)

i. Share the information with your friends in other groups within your lab section and complete Data Sheet 13.1 below:

Data Sheet 13.1: Water Content(Øw%) at Different Sites

Depth segments	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6

j. Draw a graph (should be in the second quadrant) on a separate sheet of graph paper with depth as Y-axis and water content as the X- axis. Draw lines connecting the data points for each depth of each site. One graph should contain only the lines of contrasting sites.

k. Compare the lines for the different sites and make proper interpretations as to how water content changes with depth.

13.4 Questions:

a. Draw and compare how water content theoretically changes with depth in a freshly irrigated vs an unirrigated soil profile.

b. Draw and compare how water content theoretically changes with depth in a vegetated and a bare profile (both rain fed).

LAB 14: CALCULATION OF WATER QUANTITIES

Section:............ Date:........

14.0 Objectives:

a. Given the soil water content by weight and bulk density, the students will be able to calculate soil water content by volume and depth.

b. Apply this knowledge to solve some soil water management problems.

14.1 Purpose:

Water content by weight (Øw) is a simple soil water parameter that can be measured on soil samples as was done in the previous experiment. However, other useful soil water quantities are not so easy to determine experimentally. So these quantities are calculated on the basis of the knowledge of the soil water content by weight. Calculation of soil water in terms of depth, for example, helps us to correlate the amount of rainfall and or irrigation and crop water requirements because they are also commonly measured in terms of depth.

14.2 Definitions:

i) Water content by volume (Øv)
= volume of water/bulk volume of soil
= water content by weight(Øw) X bulk density (Db)

ii) Depth of water (Ød)
= volume of water / surface area of soil
= volumetric water content(Øv) X depth of soil(D)

14.3 Examples:

Example: 1

Given: A cube of soil (10 cm X 10 cm X 10 cm) has a total mass of 1460g of which 260g is water. Assume the density of water as 1.00 g/cm3 and the soil particle density as 2.65 g/cm3

Find: Mass water content, volume water content, depth of water, soil bulk density and soil porosity.

Solution:

Mass water content (Øw) = Mass of water / mass of dry soil
=260g / (1460g - 260g) = 260g / 1200g = 0.217

Dry mass water percentage = 0.217 X 100 = 21.7%

Bulk density (Db) = Dry mass of soil / Bulk volume of the soil
= 1200g / 1000cm3 = 1.2g/cm3

Volumetric water content (Øv) = Mass water content(Øw) X Db
= 0.217 X 1.2 = 0.26.

Volume water percentage = 0.26 x 100 = 26%

Depth of water (θd) = Volumetric water content x depth of soil
= 0.26 X 10cm = 2.6cm

Soil porosity (f) = (1 - bulk density) / particle density
= (1 - 1.2) / 2.65 = 0.547

Example: 2

Given: A soil 80cm deep has a volumetric water content of 0.12

Find: The depth of water that must be added to bring the volume water content to 0.30.

Solution: Depth of water = volume water content x depth of soil

θd (start) = 0.12 x 80 = 9.6 cm

θd (end) = 0.30 x 80 = 24 cm

θd (needed) = θd (end) - θd (start)
= 24.0 cm - 9.6 cm = 14.4 cm

14.4 Solve the following problems

i) A barrel of soil is collected which has a wet mass of 220 kg. The mass water content of the soil (θw) is found to be 0.18. Find mass of soil and mass of water.

ii) A 100 kg mass of wet soil has 18 kg of associated water. The bulk density is 1.2 g/cm3. Find the bulk volume of the soil.

iii) A soil has an initial volume water content (θvi) of 0.10 and its volume water content at field capacity (θvfc) is 0.30. How deep will a 10 cm rain wet the soil?

iv) A soil has a field capacity volume water content (Øvi) of 0.30. Its initial water content on mass basis (Øw), bulk density (Db) varied with depth and are given in the table below. Assume the density of the water to be 1.00 g/cm3. How deep will a 8 cm rain penetrate this soil?

Depth increment (cm)	Mass water content (Øw)	Bulk density(Db) (g/cm3)
00 - 05	0 - 05	1.2
05 - 20	0 - 10	1.3
20 - 80	0 - 15	1.4
80 - 100	0 - 17	1.4

v) How deep will a 5-cm rain penetrate in the profile you studied in Lab 13 (refer Data Sheet 13.0)?

14.5 Questions:

a. Define field capacity.

b. What is the advantage of expressing water content in terms of depth?

c. Refer to Data Sheet 13.1 of the previous experiment. Compute the water content in depth(Ød) of various profiles by assuming appropriate bulk density values. Draw bar diagrams to compare differences in Ød. Make proper interpretations to complete your answer.

LAB 15: STUDY OF A TENSIOMETER

Section:..........   Date...........

15.0 Objective: To understand the principle, calibration and use of a commercial tensiometer.

15.1 Description of the tensiometer:

Tensiometer is an instrument that measures matric suction of soil water (tension is an absolete term to denote negative potential). It consists of a double walled transparent plastic tube. The tube has a service cap at one end and a ceramic cup is attached at the other end. A vacuum gauge is attached near the upper end of the tube. The gauge measures vacuum in centibars.

15.2 Principle:

When the tensiometer is filled with water, the free energy of water inside the tensiometer is maximum, and hence, the vacuum gauge reading shows zero matric suction. When the ceramic cup of the tensiometer comes in contact with soil, the free energy of water inside the tensiometer is higher than the free energy of water outside in the soil (except when the soil is saturated). As a result, water will move out of the porous ceramic cup until there is equilibrium in the energy level. The drier the soil, the more water will go out of the tensiometer. When water leaves the tensiometer, the gauge needle shows the created vacuum. The needle reading corresponds to the matric suction of the soil water in centibars.

15.3 Filling:

A tensiometer always needs filling and calibration before use. Distilled and de-aired water is used to fill the tensiometer. If water contains air, small air molecules will bubble out of the water and cause an error in vacuum reading during the field use of the tensiometer. Fill the tensiometer slowly with the water tapping occassionally to remove air bubbles. After filling up, tap the tensiometer on the cap end a few times with the palm of your hand. Wash the cap end and suck the tensiometer with your mouth until a few more bubbles on the neck of the vacuum gauge is driven out. When you are sure that the system has no air, fill the tensiometer to the rim and carefully install the service cap.

15.4 Calibration:

Wrap a blotting paper or dry cloth on the ceramic cup. Keep it wrapped until the gauge shows about 50 centibars of suction. Now insert the ceramic cup in water in a beaker. The needle should fall back to zero suction. If not, repeat the drying and wetting process about three times. If the needle does not come back to zero, use an allen wrench and a screw driver to reach the needle and adjust until it shows zero suction when the cup is immersed in water.

15.5 Installation and use:

The best use of the tensiometer is to monitor water availability and schedule irrigation in the field. Properly filled and calibrated tensiometers are inserted into the soil at the proper root zone of the crop of which we want to monitor the water availability. Take a cylindrical peg of suitable length and slightly smaller in diameter than the tensiometer. Drive the peg in the soil to the desired depth. Remove the peg carefully and install the tensiometer in that hole. Firm the soil around the tube. Leave the tensiometer in the field and take periodic readings to decide when the plants need irrigation.

15.6 Procedure in the lab:

a. Observe the filling and calibration demonstration by the instructor.
b. Divide yourselves in groups and do filling and calibration of different types of tensiometers available to you.
c. Install the tensiometers in flower pots inside the lab and observe tensiometer readings every 1,2,3,5,10,15,20,25, and 30 minutes after the installation.
d. Draw a graph of tensiometer readings vs. time and make proper interpretations.

15.7 Questions:

a. What is the range of matric suction that the tensiometer will work? What happens if the matric suction of soil water is higher than the upper limit of the range?

b. How do you de-air the distilled water? Why is distilled and de-aired water needed for the tensiometer?

c. Draw and label the tensiometer displayed to you.

LAB 16: STUDY OF A MOISTURE METER

Section:......... Date.............

16.0 Objective: To understand the principle, calibration and use of a commercial moisture meter.

16.1 Description: Commercial moisture meters (Bouyoucos Moisture Meter Model 2N-2B is an example) and different types of gypsum blocks are available to monitor the availability of water in the soil. The meter is calibrated to read directly "Percent Available Soil Moisture". It does not measure the total water content of the soil by weight, but only that portion of water which the plant is able to absorb and use. 100% available soil water is the amount of water that a particular soil will hold after it has been thoroughly soaked by rain or irrigation and the excess water has been drained by gravity for a few days. At the lower end of the scale is the "Permanent Wilting Point" which represents the moisture content of the soil at which plants wilt and die. The difference between the wilting point and the field capacity, called "Available Water" is the amount of water the plants can use and is the quantity the moisture meter measures.

16.2 Principle:

Within the gypsum or nylon fiber blocks are embedded two specially treated fine mesh stainless steel screen electrodes. Such a block when buried in the soil absorbs water and releases it at approximately the same rates and amounts as that which is absorbed or given up by the soil. To a certain extent, the blocks actually become a part of the soil.

The electrical resistance of the block varies with its water content and in turn with the water content of the soil. When the block is wet, its resistance is low and as it dries, the resistance increases. Thus the water content of the soil is determined by measuring the electrical resistance of the block buried in the soil.

16.3 Installation of the blocks:

Proper location and installation of the blocks are necessary to insure accurate and reliable moisture measurements. The following procedures should be observed to install the blocks properly.

a. A representative location in each field must be chosen. The spot selected must not be too droughty or on ground that remains wet longer than most of the field.

b. Install the blocks in the root zone, the region in which most of the water absorption by the plant takes place.

c. To bury the blocks, dig a hole with an auger or other tool. The soil taken out should be kept in order, so as to be replaced in its approximate original position. Clods or compacted soil should be broken up and large stones discarded. It is desirable for the soil immediately around the blocks to be in as undisturbed and natural a state as possible. Use a pocket knife or some other sharp object, chip out a small second hole in the side of the main hole at the desired block depth making the hole no longer than the block. Soak the blocks in water to expell the air out of the pores and press the block into the slot as far as possible making sure that there is a good tight contact on all block surfaces with the soil. Repack the side slot as tightly as possible, then continue to refill the main hole by filling small amounts of original soil and tamping as frequently as possible with a 2 X 2 wood. Care should be taken not to disturb the block. Try to replace the soil in its approximate original position. The lead wires must be brought up to the surface at some convenient point where they will not interfere with tillage operations. Mark the lead wires with tags or knots which indicate the depth at which each block is placed. Most often more than one block is needed at various depths in the same vertical section.

16.4 Maintenance and use of the moisture meter and gypsum blocks

The moisture meters run on dry cell batteries. Battery replacement is necessary only when it is no longer possible to bring the meter needle to "CAL" position by rotating the adjustment knob. Battery housings can be located by opening the moisture meters on the back or on the sides.

Gypsum blocks are not durable enough and need replacement. Usually one rainy season use will make the blocks smaller due to solubility of gypsum in water. If the gypsum is cracked or badly broken or markedly dissolved, it should be discarded from further use. Small chips will not affect the accuracy. Blocks when removed from the soil should be washed, dried and stored until reused.

16.5 Method of reading the moisture meters:

Connect the lead wire terminals from the blocks to the binding posts on the meter. Press the button marked "CAL". Rotate the "CAL" knob until the meter needle is at the "CAL" line at the right hand end of the scale. The needle must always be brought to this point before taking a reading. Press the buttons to read the meter when the needle comes to rest.

16.6 Lab work:

a. Observe the demonstration of the moisture meter and the gypsum blocks. Draw and label the instrument and the block.

b. Go out in the field and observe the demonstration of installation of the gypsum blocks. Draw a figure of the placement of blocks in the soil.

16.7 Use of the moisture meter and blocks:

The moisture meter and the gypsum blocks are used to monitor the water availability to the plants and make a schedule for irrigation. As the meter indicates a block is in need of water, irrigation should be started and continued until the meter reading is 95 to 98% at the location.

The amount of water a soil can hold varies with the soil texture. Water should be applied to the various textured soils as the meter readings indicate the following percentages:

Soil Texture	Meter Reading
Sands	75%
Loamy sands	62%
Sandy loams	50%
Fine sandy loams	46%
Very fine sandy loams	43%
Loams	40%
Silt loams	30%
Clay loams	27%
Sandy and silty clay loams	25%

16.8 Questions:

a. What is the range of soil water matric suction that the moisture meter will work?

b. What are its advantages and disadvantages over a tensiometer?

c. What is "Available Water"?

d. Give advantages and disadvantages of a gypsum block.

LAB 17: OBSERVATION OF CAPILLARY PHENOMENA

Section:.......... Date:..........

17.0 Objective: To observe capillary phenomena in different size particles.

17.1 Definition: Capillary phenomena is the rise of water through soil capillaries, usually vertically upwards against the force of gravity. Rise of kerosine through the wick of a lantern and rise of ink on a blotting paper are examples of capillary rise. Water moves vertically upwards from the water table and is made available to plants through the capillary rise.

17.2 Principle: Height of rise of water in the capillary is inversely proportional to the size of the capillary. In other words, the height of rise is greater in smaller size pores and smaller in bigger size pores. Mathematically, the height of rise (H) and pore size (r) relationship can be expressed as follows:

$$H = 2T / d.g.r$$

where T = surface tension, dynes/cm2; d = water density (usually 1.0g/cm3), g = gravity acceleration (usually 980 cm/sec2); and r = capillary radius, cm

In practice, the overall capillary rise is higher in fine textured soils than coarse textured soils. However, the rate of capillary rise is faster in coarse textured soils than in fine textured soils. This is mostly due to straight alignment of the pores in coarse textured soils as compared to zigzag and discontinuous arrangement of the pores in fine textured soils.

17.4 Demonstration: A series of glass tubes packed with different textured sand is displayed on the benches. Divide yourselves into a number of groups equal to the number of glass tubes on display. Lower the tube carefully and insert the filter paper wrapped end into a beaker of water and immediately note the time. Note the height of rise in the capillaries in Data Sheet 17.0.

Data Sheet 17.Ø: Observation of Capillary Rise

Time in minutes	Height of rise(cm) in soil samples I	II	IV	V
1				
2				
3				
5				
1Ø				
2Ø				
3Ø				
6Ø				

17.5 Draw a graph with a line for each sample on height of rise vs time in minutes. Study the graph and make proper interpretation.

17.6 Questions:

a. Draw and label the experimental set-up.

b. What is the use of the knowledge of capillary rise?

c. What are the factors determining the capillary rise?

LAB 18: DETERMINATION OF SATURATED HYDRAULIC CONDUCTIVITY

Section:........... Date.........

18.0 Objective: To determine saturated hydraulic conductivity in the laboratory.

18.1 Definition:

Hydraulic conductivity is defined as the ability of the soil as a porous medium to conduct the flow of water through it. If the flow takes place when all the pores are filled with water, the saturated hydraulic conductivity is more or less a constant depending upon the size and alignment of pores. Soils with more macro-pores (sandy soils) have higher saturated hydraulic conductivity than soils with more micro-pores (clayey soils).

18.2 Principle:

Darcy's law of flow through porous medium, when applied to vertical movement of water, states that the flux(Q) of water is directly proportional to the hydraulic gradient(f). Mathematically, it can be expressed as:

$$Q = K.f$$

where K is the hydraulic conductivity.

If we measure the flux through a soil column under steady state conditions (keeping f constant), we can determine the hydraulic conductivity.

18.3 Experimental setup:

Place one filter paper at each end of the soil column. A soil column may be prepared by gently packing soil in a cylindrical container or may be an undisturbed brass core sample from a bulk density sampler. Place the column now on a ceramic funnel. Prepare a Mariotte system to maintain a constant head of water on the soil surface. An experimental setup will be demonstrated on the lab. Draw and label the experimental setup below.

18.4 Formula development:

From the experimental setup figure above, let:

L = length of soil column
D = diameter of soil column
H = height of the water on the soil surface
h1 = entry point on the soil surface
h2 = exit point on the bottom surface
V = volume of water measured in time (t)

By definition, Flux Q = V/A.t where A = surface area of the soil.

By considering the soil surface as the reference point,

Total potential at h1 = O + H = H

at h2 = I + O = -L

Potential difference between h1 and h2 = H - (-L) = H + L

Hydraulic potential gradient = (H + L)/L

Hydraulic conductivity, K = (V/A.t) / (H+L)/L

= V.L / [A.t(H+L)]

For a given dimension of the soil column at a steady state condition, L, D, and H are constant. If we make measurements of V at fixed time interval (t), the conductivity K of the soil column can be expressed as K = C.V where C is the constant for the given experimental setup.

18.5 Observation:

Measure the volume of water flowing through the soil column in fixed time interval (t) until the last two readings are approximately equal to each other. Record the observations at steady state conditions in the Data Sheet 18.0

Data Sheet 18.0: Observation of Flux at Fixed Time Intervals

Measurements	Soil Samples I	II	III
1. Sample type			
2. Column length, L			
3. Head of water, H			
4. Diameter of cylinders, D			
5. Surface area, A			
6. Time interval, t			
7. Volume readings:			
i.			
ii.			
iii.			
iv.			
8. Steady state volume, V			
9. Constant, C			
10. Hydraulic Conductivity, K			

18.6 Compare and explain the differences in hydraulic conductivities of the given soil samples.

18.7 Questions:

a. What is the importance of the knowledge of hydraulic conductivity?

b. List the factors affecting the hydraulic conductivity of soils?

c. What is hydraulic gradient? Find the formula of hydraulic gradient if we assume the reference level to be at the bottom of the soil column.

LAB 19: USE OF A DOUBLE-RING INFILTROMETER

Section:........... Date...........

19.0 Objective: To measure the infiltration capacity of a soil.

19.1 Definition:

Infiltration is the entry of water usually from the soil surface and vertically downwards. Infiltration capacity of a soil is defined as the maximum rate at which water enters the soil when water is applied faster than it can infiltrate. The infiltration capacity of a soil is higher in the beginning of an infiltration event, but it slowly decreases with time. It varies with water content, texture and structure of the soil, the vegetative cover, the type of land use and other factors. It can be used to estimate the frequency and amount of surface runoff along with information about rainfall intensities. This can also be an useful information for assessing the effect of remedial measures for erosion and flood control work.

19.2 Equipment:

The infiltration capacity of a soil can be measured with the help of a double-ring infiltrometer. The infiltrometer contains two concentric rings. The diameters of the rings can vary, but the ratio of diameter of inner ring to outer ring should be 1:2. The inner cylinder should have one centimeter marks on its inner surface. The inflitrometer to be demonstrated in this lab has diameters of 18cm and 36cm. The two cylinders are attached by four iron bridges reaching down to a depth of 8cm. The measurement of infiltration capacity by a double-ring infiltrometer requires:

1. a water supply container (10 litres)
2. a measuring cylinder (1 litre)
3. a stop watch
4. data sheets similar to Data Sheet 19.0

Other equipment needed include: a sledge, a wooden board (length 50cm) and a cheesecloth (to prevent washing or puddling on the soil surface).

19.3 Procedure of measurement:

a. Carefully remove the litter layer from an area of about 50 X 50 cm and drive the infiltrometer into the cleared soil to a depth of 5cm (on dense soils it can be less) by striking the wooden board laid across the instrument. If possible, the infiltrometer should be brought into a level position.

b. Fill up the outer ring of the infiltrometer to a height of 4cm and then gently pour 1 litre of water into the inner ring. If there is significant appearance of surface water around the instrument move to another spot.

c. Record the accumulated time of infiltration at each one-centimeter mark. In case the initial infiltration capacity is too rapid for such readings, at least record the time which was required to absorb all the water poured into the inner ring. Note the observations in Data Sheet 19.Ø.

d. Repeat steps (b) and (c) in subsequent runs until the infiltration time for one centimeter interval reaches a more or less a constant value.

19.4 Evaluation:

a. Convert all observations to rates of centimeters per hour. Write the results in Data Sheet 19.Ø.

b. Complete the informations of both accumulated time and rates, starting from the first 1 cm of absorbed water (initial infiltration capacity) up to the last one-centimeter reading (final infiltration capacity).

c. Draw an infiltration capacity curve by plotting the values of infiltration rate on the ordinate and the accumulated time on the abscissa on a separate sheet of graph paper.

Data Sheet 19.Ø Observation of Infiltration Capacity

Location of the measurement site:

Run	Accumulated Time (seconds)				Infiltration Rate (cm/hr)			
No.	1cm	2cm	3cm	4cm	1cm	2cm	3cm	4cm
1								
2								
3								
4								
5								

19.5 Questions:

a. Draw a theoretical infiltration rate vs time curve and compare with the curve obtained in this experiment.

b. What are the limitations of the double-ring infiltrometer?

c. De·.ne the terms infiltration rate, infiltration capacity, in· ltrability, and final infiltration rate.

d. Define the terms infiltration, permeability and flux.

LAB 2Ø: WATER MOVEMENT THROUGH LAYERED SOIL COLUMNS

Section:...........

Date:...........

20.Ø Objective: To understand the phenomena of water movement through layered soil columns.

2Ø.1. Principle:

Water moves faster in a course textured soil than a fine textured soil if the soil is uniform in texture throught the profile. However, in nature, soil profiles are not homogeneous. Profiles have horizons and horizons are different from one below or above due to differences mainly in texture and structure. Sometimes, a fine textured soil may be underlain by a coarse textured soil and vice versa. Presence of a crust on the surface of a soil, presence of gravel below soil profiles, and presence of Bt horizons in Alfisols are examples of layered soil conditions.

If a coarse textured soil is above and fine textured soil below, water moves faster until the wetting front reaches the boundary. The water movement then is determined by the permeability of the less porous layer. There will be a water table developed above the boundary. Conversely, if a fine textured soil is above a coarse textured soil, water moves slowly in the beginning determined by the permeability of this layer. When the wetting front reaches the boundary, water does not move faster as expected, but it slows down due to so called `bottle-neck effect'. The pores below being larger than above, remain unsaturated and hence, the flow will be slower and may even stop if the air in those macropores below can not be expelled satisfactorily.

2Ø.2 Experimental setup:

Four columns have been setup for the demonstration:

Column Number	Contents
1	Coarse gravel
2	Fine sand
3	Coarse gravel above and fine sand below
4	Fine sand above and coarse gravel below

2Ø.3 Depending upon the nature of the setup explained to you by the instructor, observe either the time it takes for the wetting front to reach the bottom of the column, or measure volume of water coming out of the profile per unit time in each case.

2Ø.4 Make proper interpretations of the observations.

20.5 Draw and label the experimental setup explained to you.

20.4 Questions:

a. Based upon this knowledge of soil water movement through layered soil columns, predict the movement of water through a crust-topped soil.

b. Give the practical usefulness of this knowledge of water movement through layered soil columns.

c. Draw theoretical pore sizes to explain the pore configuration of the four soil columns demonstrated to you.

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