LABORATORY 1

SOIL TEXTURE

I   Objectives

Determine soil texture by mechanical analysis using the pipette method.
Estimate soil texture by the feel method.

II   Introduction

A   General

Soil texture is the relative proportion of **sand**, **silt**, and **clay** in a soil. Within each of these soil **separates** there is a continuum of particle sizes. Thus, there is a particle size distribution in soil ranging from the largest sand particles to the smallest clay particles. Texture is considered to be a permanent characteristic of a soil since weathering only very slowly changes particle size. Furthermore, cultivation and other management practices do not alter the sizes of individual soil particles. In some cases, however, erosion or deposition may rapidly alter the particle size distribution.

Texture is an important property of soils because particle size determines the surface area of solids per unit volume or mass of soil. Texture also influences the pore size distribution in soil. A sandy soil is dominated by large individual soil particles and, therefore, has a relatively small total surface area and large pore spaces between soil particles. At the other extreme, a clay soil consists of tiny individual particles and has a large total surface area but small pore spaces. However, small soil particles tend to be associated with one another to form **aggregates** of soil particles. Thus, the pore space in a clay soil consists of small intraaggregate pores and much larger interaggregate pores. In fact, the total volume of pore space per unit volume of soil (**porosity**) of a sandy soil is actually smaller than the porosity of a clay soil.

Many chemical and physical processes in soil occur at the surface of soil particles. For example, the surface of soil particles is the site of a physicochemical reaction known as **ion exchange**. The negative (and, in some cases, positive) charge carried by certain soil particles is balanced by surface adsorbed cations (or anions). In ion exchange, an ion in solution exchanges for a surface adsorbed ion of like charge. Ions adsorbed in this way serve as a reservoir of nutrients for plant growth.

Adsorbed ions also complicate the matter of determining soil texture by mechanical analysis. Adsorbed ions, though in very close proximity to the surface of soil particles, are often not really bound to the soil particles. Rather, these exist as a diffuse layer –highest concentration nearest the surface and decreasing moving away from the surface. The nature of this diffuse layer is affected by the type of ion and the total concentration of ions in the soil solution. In turn, the interaction of adjacent soil particles is affected by the diffuse layer. For example, small soil particles in a concentrated solution of Ca^{2+} tend to be closely associated with one another (*flocculated*), whereas in a dilute Na^+ solution, small soil particles tend to be independent of one another (*dispersed*). It is crucial in a mechanical analysis to have soil particles thoroughly dispersed and independent.

B   Definition of Soil Separates

Separate	*Diameter (mm)*
Very coarse sand	2.00 - 1.00
Coarse sand	1.00 - 0.50
Medium sand	0.50 - 0.25
Fine sand	0.25 - 0.10
Very fine sand	0.10 - 0.05
Silt	0.05 - 0.002
Clay	Less than 0.002

Particles larger than 2.0 mm in diameter are not considered in determining soil texture.

C   Principle Underlying a Mechanical Analysis

Soil particles suspended in solution settle out at a rate that depends on the size of the particles –the larger the particle, the faster it settles. Settling rate is given by Stokes' Law

$$v = (2/9) \, (D_S - D_L) \, g \, r^2 / \eta$$

where

v is settling velocity	(cm / s)
D_S is particle density	(g / cm^3)
D_L is water density	(g / cm^3)
g is acceleration due to gravity	(cm / s^2)
r is radius of particle (cm)	
η is water viscosity	(g / cm-s)

Given that v is distance / time, the time required for all sand-sized and all silt-sized particles to settle a distance of 10 cm in water at room temperature can be calculated. Substituting appropriate values in Stokes' Law gives

Very fine sand (0.050 mm)   48 s
Silt   (0.002 mm)   8 h

Thus, if you completely disperse a sample of soil in water and agitate the suspension so that at time zero sand, silt and clay particles were uniformly distributed in the water, an aliquot of the suspension taken at 48 s and above the 10 cm depth will contain only silt and clay particles, no sand. Similarly, an aliquot taken at 8 h will contain only clay particles. From these two aliquots, percentages clay, silt and sand (since percentages clay, silt and sand sum to 100) can be determined.

D   Use of Textural Triangle to Determine Textural Class

Soils are grouped into textural classes on the basis of the percentages of sand, silt, and clay. Soils within each textural class have similar soil properties and the class name reflects the relative influence of each soil separate on the properties of that soil. For a soil to be called a sand, it must contain over 85% sand, but soil must contain only 40% clay in order to be classified as a clay. Loams have properties resulting from about equal influences of sand, silt and clay, but the loams contain more sand and silt than clay.

The textural triangle (Figure 1) contains twelve textural classes, each of which can be comprised of various combinations of sand, silt, and clay. Each leg of the triangle represents either sand, silt, or clay and is divided into percentages from 0 to 100% since a soil may contain any percentage of a soil separate as long as the total percentage of the three separates equals 100. Each leg of the triangle then represents the base or 0% value for one of the three soil separates. To determine the textural class of a soil based on a mechanical analysis, draw a line at the appropriate percentage for each separate across the triangle, parallel to the base for that separate (one line parallel to each base). If done correctly, the three lines will intersect at one point within a section of the triangle containing the correct textural class name.

III
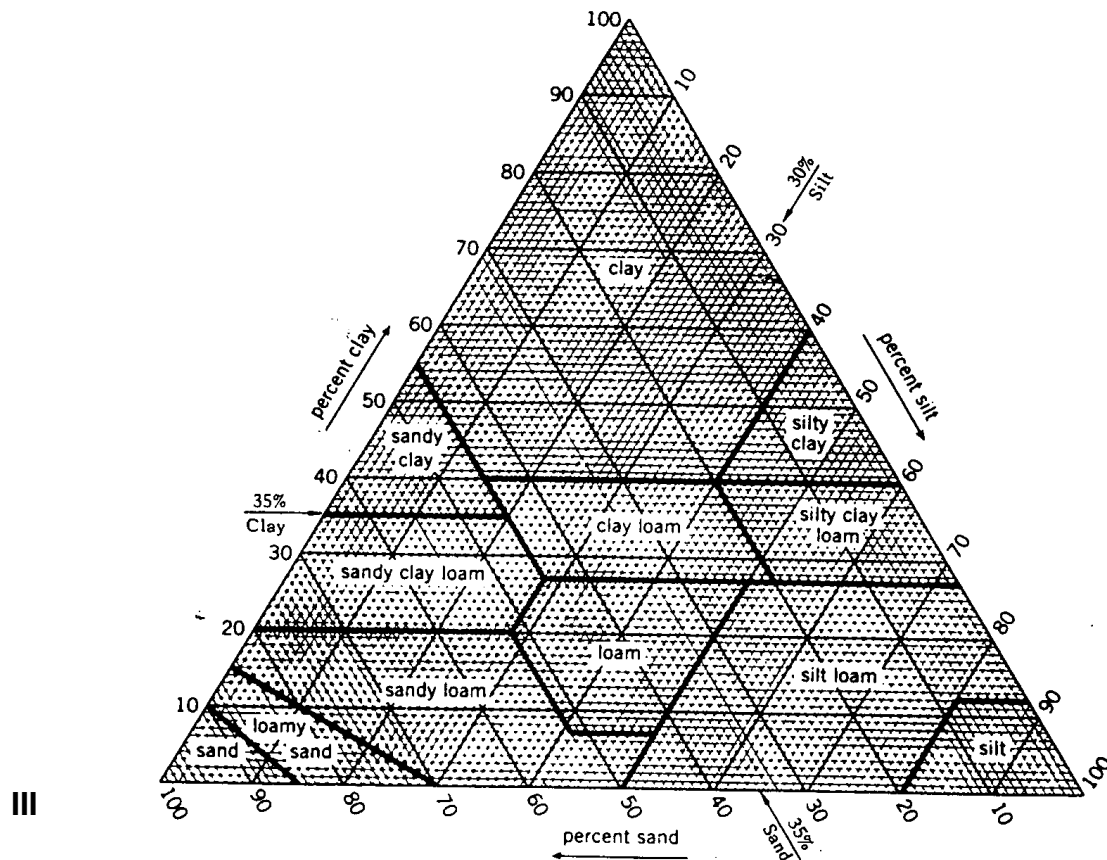
Procedures

A   Mechanical Analysis by the Pipette Method

To determine the relative masses of sand, silt and clay in the soil sample (thus, the texture) the combined mass of silt plus clay in the first aliquot and the mass of clay in the second must be determined. Also, the initial total volume of suspension and aliquot volume must be known. Pipetting a known fraction of suspension to an evaporating dish and boiling off the water is all that is done beyond dispersing the soil sample in water.

For an accurate mechanical analysis of soil, the soil sample must be completely dispersed so that each particle settles individually rather than as part of a aggregated clump. Addition of Na^+ to the soil-water suspension forces exchange of Na^+ for adsorbed flocculating cations such as Ca^{2+}. Soil particles with a diffuse layer saturated with Na^+ tend to act as individual particles in suspension and settle at rates dependent on their radii.

4

1. Weigh out 20 g (to nearest 0.01 g) of soil and transfer to a shaker cup.

2. Fill with water to a depth of 10 cm and add 5 mL Na hexametaphosphate. Stir for 5 minutes.

3. Pour contents into a 500 mL graduated cylinder. Use a stream of water from a wash bottle to transfer soil remaining in cup. Bring volume to 500 mL.

4. Cover top of cylinder with parafilm. Put palm of hand over top, grasp bottom of cylinder and invert several times to re-suspend soil.

5. Set on bench top, begin timing, gently remove parafilm and take a 25 mL aliquot from the upper 10 cm of suspension at 48 s. *A mark on the pipette at 10 cm from the tip serves as a good guide for depth.*

6. Transfer aliquot to a weighed (record mass in Table 1) evaporating dish and put in oven at 105 C. Higher temperature than boiling is needed due to presence of solutes. Label evaporating dish "silt + clay". Also, write your lab group number on the evaporating dish.

Since it takes 8 h for all silt size particles to settle 10 cm, a mechanical analysis by the pipette method cannot be completed within the time allowed for this lab. However, the steps in this procedure can be followed and approximate results obtained in shorter time.

7. Take the second 25 mL aliquot after only 40 min but from upper 5 cm of the suspension. *Mark pipette 5 cm above tip.*

8. Transfer aliquot to weighed, labeled evaporating dish and put in oven at 105 C.

After 40 min, all silt greater than 0.005 mm diameter will have settled to below 5 cm. Thus, the second aliquot contains some silt (0.005 to 0.002 mm diameter) as well as clay.

9. To demonstrate flocculation, add 5 mL of $CaCl_2$ solution to the suspension after taking second aliquot. Cover the top of cylinder with parafilm, invert several times, then set on bench top. Observe what happens.

10. Dispose of suspension and soil into waste bucket, not down sink drain.

11. At the beginning of the next lab, remove evaporating dishes from oven, cool and weigh. Record the net weight of the first evaporating dish as combined silt and clay in 1/20 of the soil-water suspension. The net weight of the second is assumed to be 1/20 of the clay.

12.   Calculate percentages of each of the separates as

% clay   = (20 x mass of clay in aliquot / total mass of soil) x 100 %

% silt   = (20 x [mass of silt + clay - mass of clay] / total mass of soil) x 100%

% sand   = 100 % - (% silt + % clay)

The 20 g sample of soil used, even though air-dry, contained adsorbed water from the atmosphere. Depending on fineness of texture and organic matter content, adsorbed water accounts for up to several percent of total air-dry weight of soil. You should use the **oven-dry mass** of soil in the above calculations. Convert air-dry mass to oven-dry by

oven-dry mass = air-dry mass / (1.00 + [moisture % / 100 %])

Your instructor will provide air-dry moisture %. Air-dry moisture % is determined by weighting an air-dry soil sample before and after drying at 105 C for 24 h.

13.   Use the textural triangle to assign a textural class name.

B   Soil Texture by Feel

It is often necessary for soil scientists to determine soil texture in the field. Since a mechanical analysis is impractical, they must estimate texture by only feeling soil. Properly calibrated fingers are accurate to within a percent or two of a mechanical analysis.

Put about 10 g of soil in palm
Add water dropwise to form a workable putty

↓

Put ball of soil between thumb and forefinger and form ribbon of soil

↓

No ribbon forms	< 1 inch ribbon	1 - 2 inch ribbon	> 2 inch ribbon
Sand Loamy Sand	Sandy Loam Silt Loam Loam	Sandy Clay Loam Silty Clay Loam Clay Loam	Sandy Clay Silty Clay Clay
↓	↓	↓	↓
Add more water	Add more water	Add more water	Add more water
↓	↓	↓	↓
Hand only wet **Sand**	Gritty feel **Sandy Loam**	Gritty feel **Sandy Clay Loam**	Gritty feel **Sandy Clay**
or	or	or	or
Hand soiled **Loamy Sand**	Smooth feel **Silt Loam**	Smooth feel **Silty Clay Loam**	Smooth feel **Silty Clay**
	or	or	or
	Neither **Loam**	Neither **Clay Loam**	Neither **Clay**

Practice the above key with the different soils provided. The various soils grade into each other which often makes the decision as to texture difficult.

IV   Worksheet

Air-dry moisture % of soil   _____

Oven-dry soil mass = 20.00 g / (1 + [air-dry moisture % / 100 %])   _____

Mass of dish + (oven-dry silt + clay residue)   _____
Mass of dish   _____
Mass of (oven-dry silt + clay residue)   _____

Mass of dish + clay residue   _____
Mass of dish   _____
Mass of clay residue   _____

Total silt + clay = 20 x (oven-dry silt + clay residue)   _____
Total clay = 20 x clay residue   _____
Total silt = total silt + clay   – total clay   _____

% clay = (total clay / oven-dry soil mass) x 100 %   _____
% silt = (total silt / oven-dry soil mass) x 100 %   _____
% sand = 100 % - clay % - silt %   _____

Textural class _____