What's in My Soil?

Description of the Activity

Students separate, examine and identify the major components of soil to better understand how these components give soil its unique physical characteristics.

Reason for Doing the Activity

Because the formation of soil involves the interaction of numerous physical, chemical, and biological processes, the study of soil provides an unmatched opportunity to illustrate connections between science and a systems approach to understanding earth processes.

Soil, as the basis for agriculture, is one of the most important mineral resources of a nation. Throughout history, civilizations have prospered or declined as a function of availability and productivity of soils. Few topics in the science curriculum can illustrate so well the relevance, importance, and human dependence upon earth resources.

Background

Properties of Soil Components

Sand, silt, and clay make up 40-80 percent of soil. These components are present in different proportions giving soils their different characteristics and textures. For example, a soil can have a sticky character if it contains mostly clay particles, velvety smooth if it has high silt content, gritty if it contains mostly sand, or spongy if it is high in organic matter.

Some soil components may constitute a small, but important percentage of the whole. For example, the organic component *humus* possesses important textural characteristics that allow good infiltration of precipitation.

Though humus normally makes up only 5 percent of the soil or less, it is an essential source of nutrients and adds important textural qualities that are critical for plant growth. Humus, which is rich in nitrogen, is the result of the cycle of plant and animal growth and decay. Besides plant matter, humus includes *macroscopic* organisms (such as insects and other arthropods, and worms), and *microscopic* organisms (such as bacteria). Humus also acts as a buffer against changes in pH.

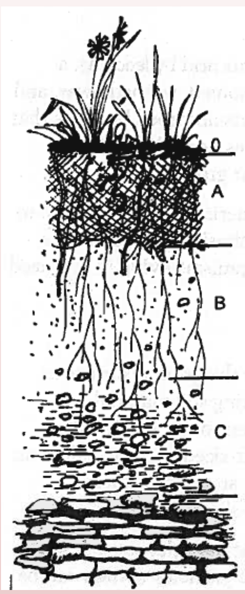
Animal life contributes to soil development in two ways: it adds to humus by helping decompose dead plant and animal material, and by adding organic matter and nitrogen to the soil through its body wastes and by its own death and decomposition. Organic matter provides air space, insulation, and food for many soil-dwelling creatures. It also reduces surface runoff by absorbing water (as much as 2 pounds of water per pound of humus).

Sand helps increase permeability and lightness of the soil. Sand does not maintain nutrients or water very well (perhaps a mere 4 ounces of water per pound of sand) but helps water move downward toward the water table.
Silt has high capillarity, pulling water upward from the water table to plant roots.

Clay, though often thought to be undesirable, is critical to a good soil composition due to its water-holding capacity and cation exchange capacity.

Cations are positively charged ions, and cation exchange capacity is a measure of the exchange sites in the soil which is influenced by the amount and type of clay and the amount of organic matter. Cation exchange influences the ability of a soil to retain important nutrients. Important nutrients include nitrogen (N), phosphorus (P), and potassium (K) (which represents the "NPK" values found on fertilizer labels) plus calcium, iron and magnesium.

Soil Profiles



The grouping of identifiable layers of different components and characteristics that make up a soil in a given area is referred to as a *soil profile.* Each individual soil layer is referred to as a *horizon,* termed 0, A, B, and C.

• The 0 Horizon, is usually a thin top layer of organic material—dead leaves, plants or grasses that have collected and begun to break down.

• The A horizon, or "topsoil," is dark-colored, rich in nutrients, and lies directly below the 0 horizon. Most soil-dwelling animals and plants are found in this layer, and their presence helps loosen and aerate this horizon.

• The B horizon, or "subsoil," lies beneath the A horizon. Although this horizon can contain sandy or silty layers, it is mostly characterized by clay-sized particles. This layer is usually much more compact than the A horizon. If a B horizon is thin or missing because weathering processes have not been at work long enough, a soil is said to be immature. If a soil profile contains at least three layers above the unweathered bedrock, it is said to be mature.

• The C horizon exists beneath the B horizon. The C horizon has no properties typical of the overlying horizons, but it has been affected by weathering processes such as oxidation. It is composed of unconsolidated material that may or may not be like the material from which the soil presumably formed. Directly underneath this horizon, and therefore beneath the entire soil profile, lies consolidated bedrock.

• Water and air are also critical components of soil, sometimes comprising up to 40 percent of the soil volume. Water, because of its cohesive characteristics, helps hold soil particles together. Plants and other organisms living in soil need both air and water to survive.

• Water's ability to sort sediment according to size provides an effective means by which the components of a soil can be analyzed.

Particle and Sieve Sizes*

Sand	Geological Size Range (2.00-0.05 mm)	Soil Science Range (2-.02 mm)
Coarse Sand (Sieve #4-#10/10-35)	2.00-0.5 mm	4.75-2.4 mm
Medium Sand (Sieve #10-#40/35-60)	.5-0.125 mm	2.4-.42 mm
Fine Sand (Sieve #40-#/60-230)	0.125-0.062 mm	0.42-0.07 mm
Silt	0.05-0.002 mm	0.02-0.002 mm
Clay	<0.002 mm	<.002 mm

* Sieve sizes originated as a description of a mesh woven by so many threads per inch. The larger the sieve size, the greater the number of threads per inch. Note that size range varies somewhat according to professional organization. Geological size range is from the United States Geological Survey. Soil Science size range is from the Unified Soil Science Classification.

Grade Level

Secondary School \Middle School (depth of interpretation and analyses of results can be adjusted accordingly.)

Amount of Time Needed for this Activity

2 class periods (some previous collection and set-up time also required)

Materials

[Note: Both the *Graded Bedding* activity and this, *What's in my Soil* activity use 4' transparent plastic fluorescent bulb covers as separation columns.]

Materials for each student group

Activity Sheet A: Separation

Activity Sheet B: Observations

Activity Sheet C: Computations

Activity Sheet D: Good Soil Mix

Activity Sheet E: 3-Point Diagram

Activity Sheet F: Grain Size

One, 4' plastic column, one end sealed

Cloth or heavy duty plastic bags larger than a sandwich bag (for crushing soil into fine particles). Book, wooden block, rolling pin or other heavy item for crushing soil. (Should have at least a ½ - ¾ cup of dry, crushed soil sample.)

3-5 cups water/detergent solution (see below for mixing directions)

Powdered electric dishwasher detergent (not hand washing soap, laundry soap, or laundry detergent)

Baking soda

Water

1 small Styrofoam coffee cup for measuring (usually 1 cup)

Ring stands or duck tape (see below)

Squeeze bottle for washing soil down sides of tubes

Funnel (cut from the spout end of a plastic gallon milk bottle for dumping soil mix into tubes)

Preparation of Water/Detergent Solution

In a convenient container, such as a 1 gallon milk jug or a bucket, mix powered dishwasher detergent with water and then add baking soda, in the following proportions:

1 gallon water to 1/4 tsp (1.25 ml) powdered dishwashing detergent to 1/4 cup (62.5 ml) baking soda. Each group will need 4 cups of this mixture. (Baking soda is a dispersing agent used to separate the organics out of the soil samples. It reacts with the air in the organics to make them float to the top of the column. Powdered dishwasher detergent contains sodium phosphate, which also acts as a dispersing agent providing good particle separation. Regular dish soap will not have the same effect as it is too sudsy. The sodium phosphate separates clay and silt from sand and organic materials, critical when using the settling method to separate particles.)

[Note: More is not better! Too much detergent will keep particles in suspension for too long. You want as much soil to settle overnight as possible, and clay sized particles are so small and light they can easily stay in suspension for more than 24 hours if too much detergent is used.]

Getting Ready

- Samples of soil will be needed for this activity. Students can bring a sample from home or samples can be collected in the course of a field trip. If students collect the soil samples, have them bring in slightly more soil than you will need (approximately 1 cup) and have them transport it in closed plastic bags.

- It is helpful to have the soil dry so spread it out thinly and leave it to dry for a day or two. (Process can be hurried along by placing the spread out soil on a heater or in a slightly warm oven.)

Then, before actually beginning this activity with students, do the following:

- Test the column with water (80% to 90% full) to ensure a tight fit of the stopper.

Day 1

Procedures

1. Have students put the dry soil back into heavy duty plastic or cloth bags for separating into smaller particles. (Soil can be broken up by tapping the bag against a wall or table or by tapping the bag with book, wooden block or even a rolling pin. Soil must be dry to loosen the particles so that there are no large clumps of material going into the tubes. Do not crush gravel or sand since this would create size fractions not representative of the original sample. Students will need approximately ½ – ¾ cup of the mixed dry soil. (Small paper, plastic or Styrofoam cups are good containers for this amount of soil.)

[You may wish to introduce marked variations in soil samples by adding some coarse sand, fine sand, silt, or clay to a basic mix. A mix of coarse yellow builder's sand, fine white "play" sand, and common red clay can give a very colorful and striking separation.]

Begin the sorting process. Have the students follow Activity Sheet A: What's in My Soil?-Separation.

2. Stand 4-foot plastic tubes on the floor, supported and fastened securely in an area where they can remain undisturbed overnight. It is important that the soil mixture produces visible layers. Ring stands are ideal to keep the columns upright, but, if they are not available, use masking or duct tape to secure the columns to any stable object such as the side of a desk, table or chair. (It is advisable to stand the tubes in a bucket or other container where they will not be moved once activities begin.)

3. Pour the pre-mixed detergent solution into each group's tube or give each group 4 cups of the solution to pour into the tubes themselves.

4. Soil material should then be dropped into the tube with one quick dump so that all particles have equal opportunity to arrive at the bottom first. Adding the soil too slowly will prevent distinct layers from forming. Don’t pour it in slowly! (A funnel made from the wide mouth bottle neck portion of a gallon plastic jug will help students dump the mixture into the column quickly and easily.) Although you do not want to shake the column you can rinse the dry soil stuck on the wet sides of the tube with a bit more solution sprayed from a squeeze bottle.

5. Let the settling tubes stand overnight (or, better yet, over the weekend) so that more of the particles have time to settle out. Be sure the tubes are well secured and cannot be moved.

Day 2

On returning to the tubes after settling time has elapsed, students will observe a layer consisting only of organic material.

Determine and plot component percentages. Have the students follow Activity Sheet B: What's in My Soil?-Observations and Activity Sheet C: What's in My Soil?-Computations.

Procedures

1. Have students measure and record the thickness of the humus layer, the clay layer, and the silt layer.

Day 2

Procedures (con't)

2. Add all the thicknesses together to get the total thickness of humus plus particle layers.

3. Calculate the percentage of humus. *(Thickness of humus layer divided by total thickness* x *100)*

4. Have students compare their humus contents with those of other groups.

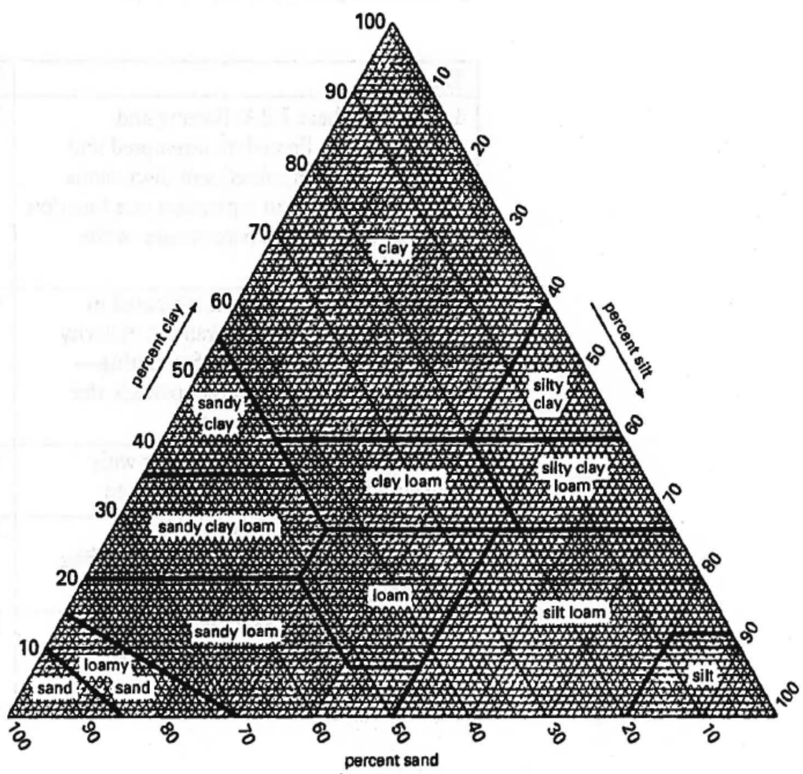
5. Have students review Activity Sheet D: What's in My Soil?-Good Soil Mix, then plot their data on Activity Sheet E: What's in My Soil?- 3-Point Diagram.

[Note: The 3-point (ternary) diagram is provided so that students can see the composition of their soil and how close it may be to the "good soil mixture" in the center of the diagram. Soils closer to the center are better for growing plants because that mixture allows, among other things, far better water infiltration and retention than soils falling outside the center.]

6. Have all students plot their soil data on a single three-point diagram to see what similarities and differences exist between the samples. The following figure is a more detailed three-point diagram, which breaks out names for different proportions of sand, silt, and clay.

7. Discuss how different environments (i.e., a forest as opposed to an open area) may contribute to the differences in soil composition.

8. Point out that there is only a small percentage (0-5 percent) of humus in most soils.



9. Point out that the various calculated percentages represent volume. Ask the students how they could determine the various percentages by weight?

Activity Sheet A: What's in My Soil?-Separation

Materials for each group

Activity Sheet 2·4A: What's in My Soil?-Separation

Activity Sheet 2·4B: What's in My Soil?-Observations

Activity Sheet 2·4C: What's in My Soil?-Computations

Activity Sheet 2·4D: What's in My Soil?-Good Soil Mix

Activity Sheet 2·4E: What's in My Soil?-3-Point Diagram

Activity Sheet 2·4F: What's in My Soil?-Grain Size

1 4' plastic column, one end sealed

½ cup dry soil sample, crushed to a powder

3-5 cups water/detergent solution

Masking or duct tape

Bottle-top funnel

1. At your teacher's direction, pound or crush a dry soil sample to eliminate any clumps or clods.

2. Stand the plastic column (with plugged end at bottom) upright on the floor inside a bucket or other container to hold leaks. Attach to a ring stand or tape the column to a desk or chair to make certain it remains upright.

3. Pour water in the column.

4. With one quick dump, pour all of the soil into the water filled column. The column should not be disturbed.

5. Allow the column to remain undisturbed overnight.

Activity Sheet B: What's in My Soil?-Observations

Observe the soil that settled in the bottom of the column of water. You should find three noticeable layers. (If one layer appears to blend into another, choose one line that would best separate them.) The bottom layer is sand, the top layer is clay, and the layer in between is silt.

1. Why do you think the clay and silt settled on top of the sand?

2. The material floating near or on top of the water is organic material called humus (HYOU-muss). Why do you think it is floating near the top of the water column?

3. Sand, silt, and clay are the components of a mineral soil. Measure the height of each layer and record your findings below.

Clay = ___________ cm

Silt = ___________ cm

Sand = ___________ cm

Total height of soil in tube = ___________ cm

Activity Sheet C: What's in My Soil?-Computations

Compute the percent (%) volume for each of the mineral layers by dividing the height of each layer by the total height and then multiplying your answer by 100.

Here's how to set up the problem:

$$\frac{\text{Height of Layer}}{\text{Total Height of Soil}} \times 100 = \_\_\_\_\_\_ \%$$

1. Compute the percent by volume for Sand.

$$\frac{\text{Height of SAND Layer}}{\text{Total Height of Soil}} \times 100 = \_\_\_\_\_\_ \% \text{ Sand}$$

2. Compute the percent by volume for Silt.

$$\frac{\text{Height of SILT Layer}}{\text{Total Height of Soil}} \times 100 = \_\_\_\_\_\_ \% \text{ Silt}$$

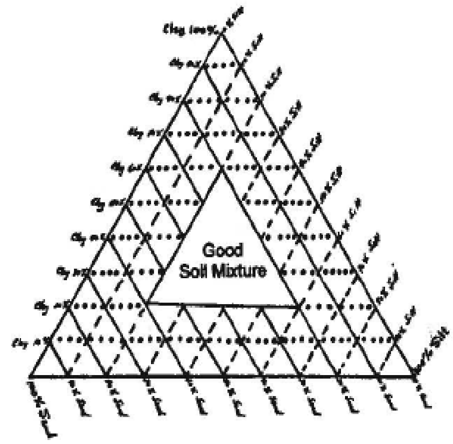
3. Compute the percent by volume for Clay.

$$\frac{\text{Height of CLAY Layer}}{\text{Total Height of Soil}} \times 100 = \_\_\_\_\_\_ \% \text{ Clay}$$

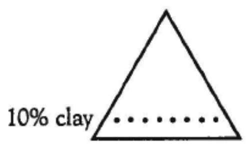
Activity Sheet D: What's in My Soil?-Good Soil Mix

Does your sample qualify as a "good" soil mixture? Good soil is a combination of organic matter and inorganic particles (sand, silt, and clay). To determine whether you had a good mix of inorganic particles, plot your component percentages on a 3.point diagram. Before you plot your percentages on Activity Sheet 2·4E, read through the following sample computation.

The left side of the soil triangle represents the percentage of clay, the right side is the percentage of silt, and the bottom side is the percentage of sand.

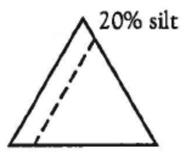


Here's how to plot a soil mix that is 10% clay, 20% silt, and 70% sand



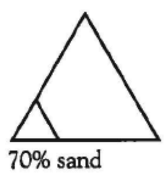
Clay: 10%

Mark the 10% spot on the clay side of the triangle. Then, with a ruler, draw a line straight across the triangle (following the direction of the dotted lines).



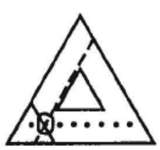
Silt: 20%

Mark the 20% spot on the silt side of the triangle. With a ruler, draw a straight line across the triangle (following the direction of the broken lines).



Sand: 70%

Mark the 70% spot on the sand side of the triangle. With a ruler, draw a straight line across the triangle (following the direction of the solid lines).



Circle the intersection of the three lines. Since the intersection falls outside the "Good Soil Mixture" triangle, the soil sample is not considered a good mix.

On Activity Sheet 2-4E, plot the percentages of your soil mix. Fill in the percentages from Activity Sheet 2-4C: % Clay____ % Silt____ % Sand____.

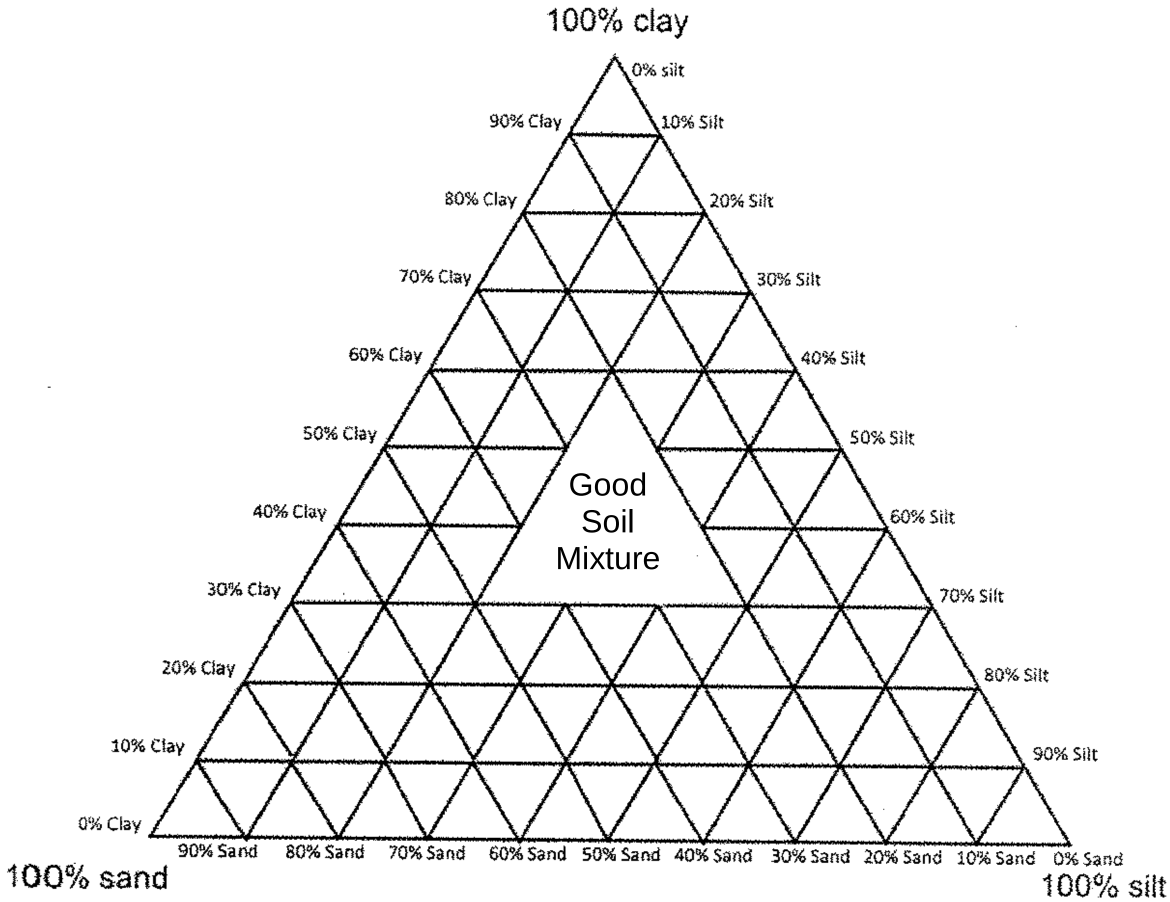
Circle the intersection of your three lines and then answer the following questions:

1. Did your soil qualify as a "Good Soil Mixture"?

2. If not, how could you change it to make it a good mixture?

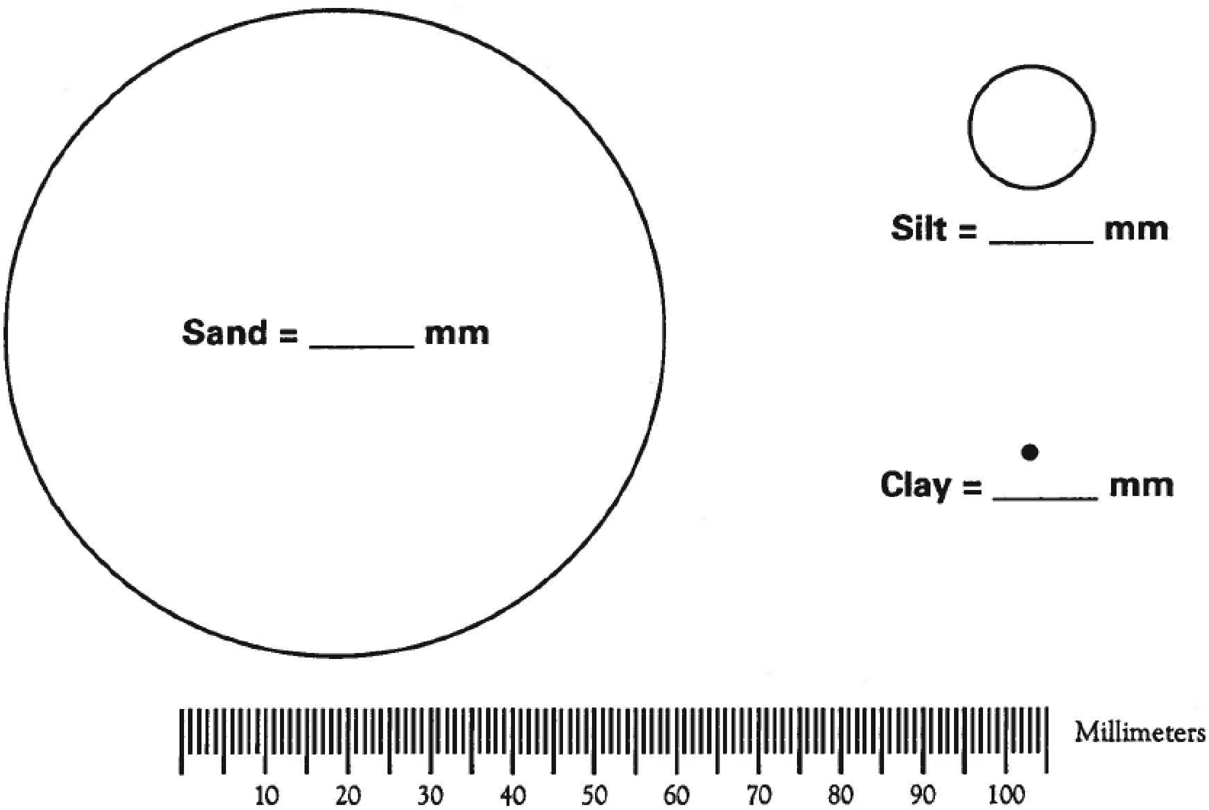
3. Why is it important to have a good mixture?

Activity Sheet E: What's in My Soil?- 3-Point Diagram



Activity Sheet F: What's in My Soil?-Grain Size

Silt and clay are so small compared to sand, that it is difficult for us to see individual particles with the naked eye. Let's compare the relative sizes of fine sand, silt, and clay, using the three "blown, up" models below. These are actual size relationships.



Using the scale, measure and record the diameter of each model and complete the following:

The diameter of the sand particle is ____. It is ____ times larger than clay.

The diameter of the silt particle is ____. It is ____ times larger than clay.

The diameter of the clay particle is ____.

MATERIAL	DIAMETER (Average range in . . .)	
	Millimeters	microns
Fine Sand	0.40–0.05	400–50
Silt	0.05–0.002	50–2
Clay	less than 0.002	less than 2