Niger GLOBE Program

Soil Program

Choosing a Soil Study Site

Setting up the Soil Study Site – Activity 1

Materials / Preparation:

- Tape measure
- Soil Characterization Site Definition Sheet *(below)*
- A compass and a GPS* *(If you do not have either of these, pick the site without them and then ask a GLOBE representative to loan them to you at some point.)*
- Materials to make a simple clinometer
    - Clinometer facing sheet *(below)*
    - A piece of cardboard a little bit bigger than a piece of notebook paper
    - A piece of nylon or cotton string, 25 cm long.
    - The empty tube of a ballpoint pen
    - A washer, a coin, an old key… (something that can be hung from the string to add a little weight to it)

Lesson Plan:

Characteristics of the Study Site

1. Your Study Site should:
    a. Be located within 100 meters from your atmosphere study site, if you have one.
    b. Be located at least three meters from buildings, trees, roads, paths, or other places where soils may have been compacted or disturbed by construction.
    c. Not present any danger at the time of digging a hole to the depth of one meter.
    d. Be located in an area whose vegetation is uniform and representative of your region, if possible.

Other Considerations

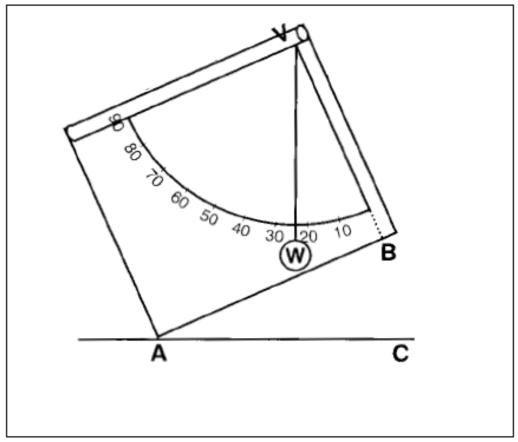
1. The size of your site:
    a. If you choose to take the humidity measurements four times per year, you must at a minimum have a site big enough to accommodate a star-shaped pattern two meters across. There should be room for a new star-shaped area each year, since you must not use the same star for two years in a row.
    b. If you are going to take humidity measurements to help scientists with the calibration of satellites, you should use a transect (a straight line 50 meters long) across a site with uniform vegetation instead of a star.
    c. If you are only going to take soil temperature measurements, set up your study site at least 10 meters from your atmosphere instrument shelter (if applicable).

Definition of your Study Site

1. As soon as you have begun work with the students, you should define your study site in order to send this data to the GLOBE Program. You can do this at the beginning of the year or at the same time you dig the study pit with the students.

Prepare the Clinometer

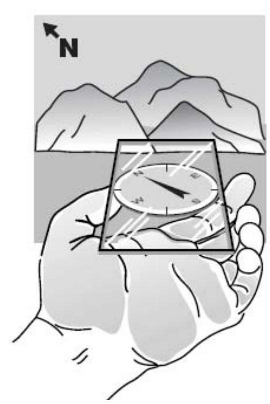
Note: If you don't have access to a photocopier, see the modified clinometer lessons in the Trees & Wood appendices for other construction options.



1. A **clinometer** is a simple tool to measure the slope of the ground (or in other cases, the height of a given object).
2. Paste or tape a copy of the clinometer *(below)* on the piece of cardboard. Make sure that the two are about the same size.
3. Punch a hole through the circle marked on the paper. Pass a 25 cm piece of string through the hole and attach its end on the back side of the cardboard.
4. With more scotch tape or a knot, attach a nut, a washer, or a coin at the other end of the string in such a way that the washer can slide back and forth across the surface of the cardboard without getting caught up on its edges.
5. Tape a drinking straw or an empty ballpoint pen tube along the line marked on the paper. Be sure the scotch tape doesn't get in the way of the ends of the straw or pen tube.

Steps to Define your Site

1. Give the site a name or number (e.g., SCS-01) and record this on the Soil Characterization Site Definition Sheet.
2. Measure the latitude, longitude, and elevation of the site with a GPS system and record this information on the Soil Characterization Site Definition Sheet. *(You can skip this step until a GLOBE representative comes to visit your school. When needed, GPS instructions are in the appendices of the Atmosphere Module.)*
3. Identify the steepest slope that crosses the area of exposed soil where you are going to dig.
   a. Find two students (A and B) whose eyes are at about the same height. Another student (C) is needed to be the "reader" and "recorder".
   b. Student A holds the clinometer and stands down slope while student B walks to the opposite side of the hole. They should be about 30 m apart (or as far apart as easily possible). Student C should stand next to student A.
   c. Looking through the tube of the clinometer, Student A looks at the eyes of Student B. Student C reads the angle of slope on the clinometer in degrees. Record this angle on the Site Definition Sheet.
4. Identify the aspect of the steepest slope:
   a. Face up the steepest slope across the exposed soil area.
   b. Hold the compass in your hand so that the red arrow is lined up with the North position on the compass.
   c. Read and record the number on the far edge of the compass housing that is pointing towards the top of the slope. (The bearing will range from 0˚ to 360˚).



5. Record “Pit” as the method used to expose the soil.
6. Record whether the site is on or off school grounds.
7. Record a description of the site location (next to the Atmospheric Study Site, etc.)
8. Describe and record the position on the landscape where the site is found (summit, side of a hill, large flat area. stream bank, etc.).
9. Describe and record the vegetation at your site (bare ground, rocks, grasses, shrubs trees, etc.)
10. Describe and record the type of parent material from which the soil was formed at the site if known (bedrock, wind sediments, glacier, river, etc.)
11. Describe and record the land use at the site (urban, agricultural, wilderness, etc.)
12. Measure and record the distance of all major objects less than 50 meters from the site (buildings, roads, paths, power poles, etc.)
13. Describe and record any other distinguishing characteristics of the site.

Soil Characterization Site Definition Sheet

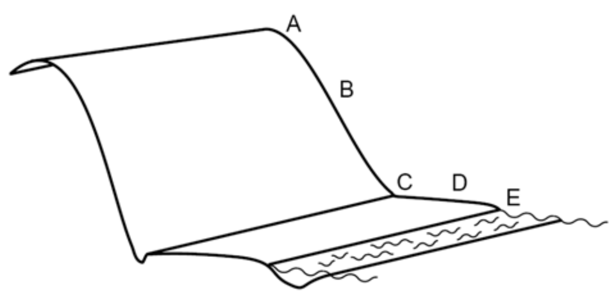
Study Site Name: SCS-_____________
Location: Latitude: ____________° ❒ N or ❒ S Longitude: ____________° ❒ E or ❒ W
Elevation: ___ meters **Slope**: _______° Aspect: _______°
Source of Location Data (check one): ❒ GPS ❒ Other ____________________________

Method (choose one):
❑ Pit
❑ Auger
❑ Near Surface

Is Soil Characterization Site:
❑ On school grounds
❑ Off school grounds

Site Location (choose one):
❑ Near the Soil Moisture Site
❑ Near the Soil Moisture and Atmospheric Study Sites
❑ Near the Atmosphere Site
❑ In the Biology Study Site
❑ Other________________

Landscape Position (choose one):
❑ A. Summit
❑ B. Slope
❑ C. Depression
❑ D. Large Flat Area
❑ E. Stream bank



Cover Type:
❑ Bare Soil
❑ Rocks
❑ Grass
❑ Shrubs
❑ Trees
❑ Other _________
____

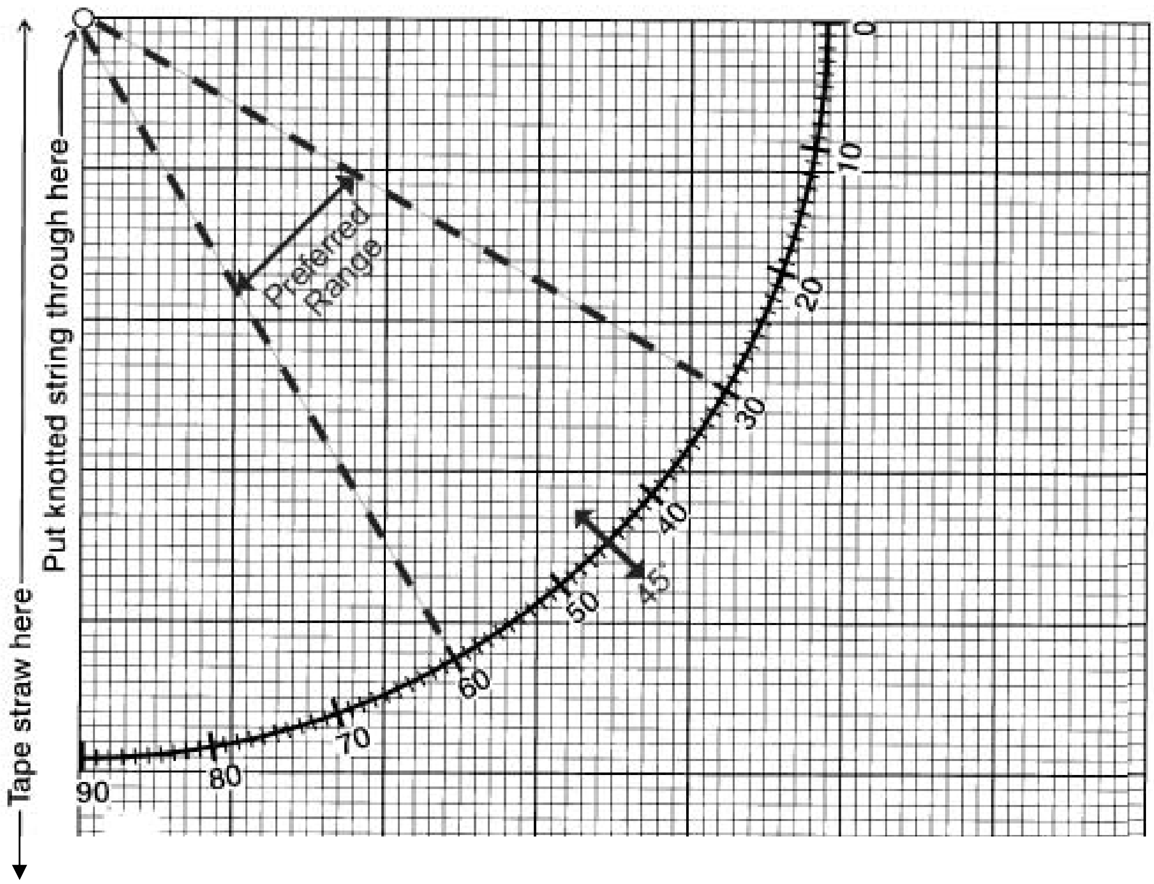
Parent Material:
❑ Bedrock
❑ Organic Material
❑ Construction Material
❑ Marine Deposits
❑ Lake Deposits
❑ Stream Deposits (Alluvium)
❑ Wind Deposits (Loess)
❑ Glacial Deposits (Glacial Till)
❑ Volcanic Deposits
❑ Loose materials on slope

Land Use:
❑ Urban
❑ Agricultural
❑ Recreation
❑ Wilderness
❑ Other
❑ Other _________________
____

Distance from Major Features: ____

Other Distinguishing Characteristics of this Site: _______________________________
____

Clinometer



Tape straw here
Put knotted string through here
Preferred Range
0
10
20
30
40
45
50
60
70
80
90

Introduction to the GLOBE Program and to Soil

GLOBE Soil – Lesson 1

Materials and Preparations:

- Matches
- List of participating GLOBE countries *(below)*
- Map of the world or a globe *(if necessary, there is a small map below)*
- Students' GLOBE notebooks

Lesson Plan:

Note: If you have already introduced the GLOBE Program during another protocol, pass directly to the GLOBE Countries of the World Game. However, it may be interesting to reform the classroom groups so that the students have the opportunity to word with others in the class besides those in their previous group.

Classroom Introductions and Group Formation

1. Pass through the class and ask each student to say his name and an interesting fact about themselves, for instance their favorite food.
2. Divide the class into groups of 5 or 6 students to take data and do group work for the rest of the sessions.
3. Give each group a name that is somehow related to the study of the soil.

Introduction to the GLOBE Program

1. Write the word "globe" on the board and ask the students "What is a globe?"
2. Explain that "GLOBE" is also the name of our program.
3. Explain that GLOBE is an acronym that stands for "Global Learning and Observations to Benefit the Environment." Write this on the board.
4. Explain that the program started in 1996. In the following 10 years it has grown and now includes over 7500 schools in 110 countries. The students of these schools have become scientists and they do environmental research on the environment. In addition, they share their data with real scientists and other schools around the world through the vehicle of the internet.
    a. Definition: The **internet** is a network that allows computers around the world to communicate. (Like cell phones and their network.)
    b. Ask the students to raise their hands if they have used the internet before. Tell them that they can visit the GLOBE program at the following website: **www.globe.gov** and that it is open to everyone.
5. At our level, the Nigerien government invited the Program GLOBE into the country in 2005 and it is now within the Department of Education managed by the Department for the Induction of Environmental Education and its Establishment in Perpetuity.

Goals of the GLOBE Program

1. The GLOBE Program has two linked objectives, **science** and **education**.
2. At out level, the program has the goal of helping you to:
   - Become good scientists
   - Better understand your environment
   - Understand the scientific method
   - Use scientific instruments
   - Take measurements and analyze them
   - Use the internet to make your data available to students and scientists around the world, and
   - Create links between science, math, technology, and the environment.
3. GLOBE student scientists study 5 aspects of their environment
   - Atmosphere
   - Water
   - Soil
   - Land cover (vegetation)
   - Seasonal changes
4. We will start with the study of the atmosphere. But first, let's play a game.

Game: Discovering GLOBE Countries around the World

1. Divide the class into teams. Tell each team to take out a blank sheet of paper.
2. Explain that GLOBE is in many countries on all of the continents.
3. Explain that you will light 2 matches in succession.
4. During the time that they burn, each team should try to write down as many country names as they can.
5. Once the second match goes out, tell the teams to stop writing and have them recopy their answers onto the blackboard. Circle the names of all the countries that host the GLOBE Program.
6. Each team earns a point for each GLOBE country that they wrote down.
7. Play a second time, but first explain that the students cannot write down or gain points for any of the countries that are already written on the blackboard.
8. After you have played a few times, add up the score and announce the winner.
9. Leave the names of the GLOBE countries on the board and ask if any students have thought of any others, and write these on the board too.
10. Show them the locations of each country that they named on a globe or on a map of the world. *(If needed, there is a small map below)*
11. ***Modification 1***: Each time that you play this game in class, show the students 5 or 6 GLOBE countries on a globe or map that they do not know. Then, in playing this game several times during the school year, the students will slowly learn many of the world's countries.
12. ***Modification 2***: Give each team a copy of the map below. Then, say the name of a country and each team attempts to place a finger on the country on their map. Give a point to each team that correctly responds and correct each team that does not.

Introduction to Soils

1. Ask the students, "Name all the things that you use during the day."
2. Write them all on the blackboard (for example: millet, shirt, bicycle, notebook, plate, wood, etc.)

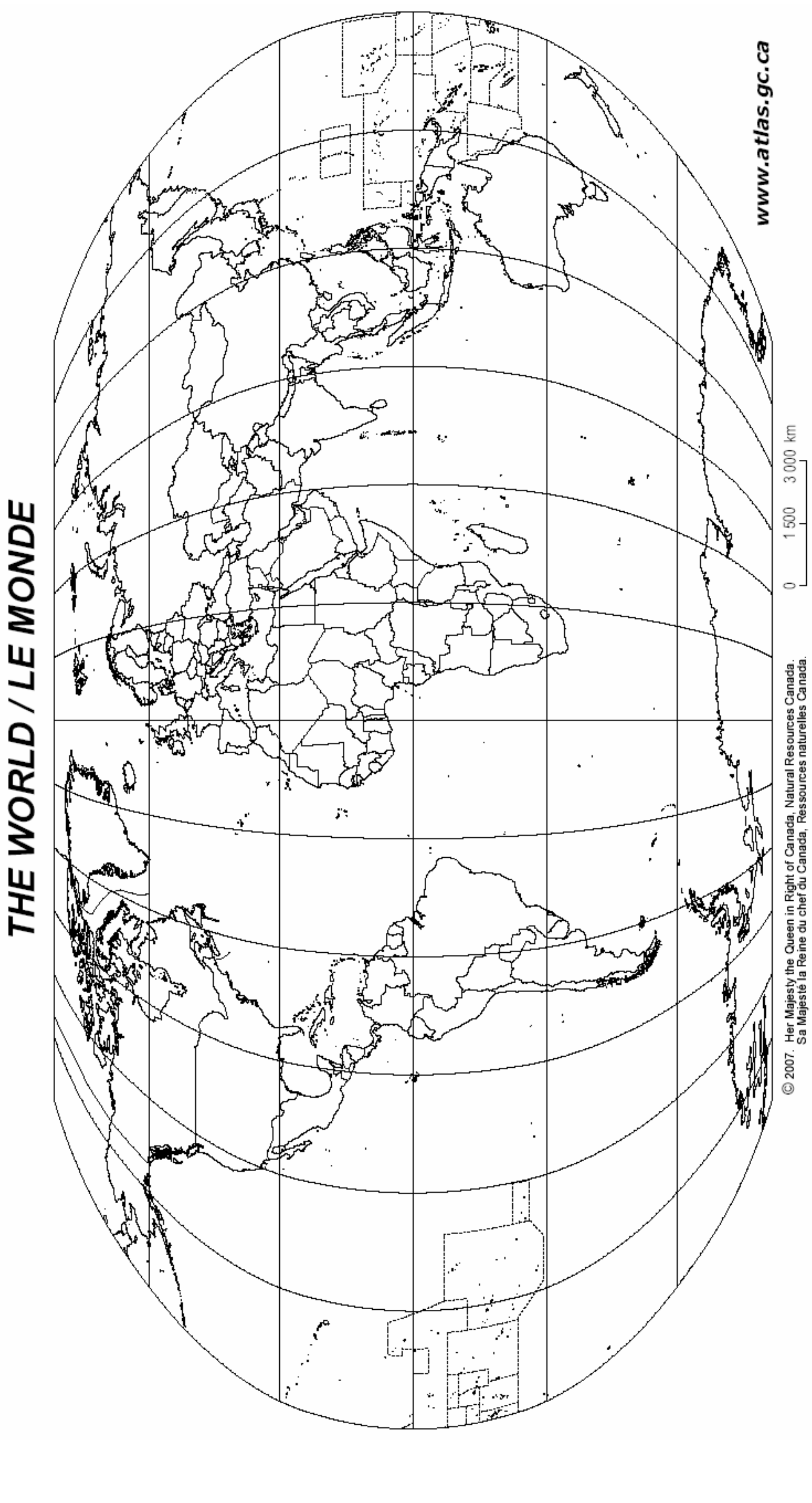
3. As soon as you have generated a good list, ask them where each of these things comes from. Help the students to trace each object back to the soil. It will be possible to do this for almost everything on the list, except the air or oxygen we use to breathe.
    a. For example: a plastic bag comes from oil that was extracted from deep in the Earth.
    b. For example: in a pencil, the graphite comes from the Earth through mining and the wood comes from a tree that takes its nutrients and water from the soil. A tree also uses the soil to hold itself upright, etc.

Game: Link Objects to the Earth

1. Ask the students to work in pairs and find an object where many of its components come from the earth. For example, a plastic bag has one component that comes from the earth, oil, but a pencil has at least 4 components that come from the earth: graphite, tin, wood, and an eraser (from trees or oil).
2. Tell them that the winner will be the pair who finds an object with the most links to the soil.

GLOBE Countries of the World

- Argentina
- Australia
- Austria
- Bahamas
- Bahrain
- Bangladesh
- Belgium
- Benin
- Bolivia
- Bulgaria
- Burkina Faso
- Cameroon
- Canada
- Cape Verde
- Chad
- Chile
- Colombia
- Congo
- Costa Rica
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Dominican Republic
- Ecuador
- Egypt
- El Salvador
- Estonia
- Ethiopia
- Fiji
- Finland
- France
- Gabon
- Gambia
- Germany
- Ghana
- Greece
- Guatemala
- Guinea
- Honduras
- Hungary
- Iceland
- India
- Ireland
- Israel
- Italy
- Japan
- Jordan
- Kazakhstan
- Kenya
- Korea, South
- Kuwait
- Kyrgyzstan
- Latvia
- Lebanon
- Liechtenstein
- Lithuania
- Luxembourg
- Macedonia
- Madagascar
- Maldives
- Mali
- Malta
- Marshall Islands
- Mauritania
- Mexico
- Micronesia
- Moldova
- Monaco
- Mongolia
- Morocco
- Namibia
- Nepal
- Netherlands
- New Zealand
- Niger
- Nigeria
- Norway
- Pakistan
- Palau
- Panama
- Paraguay
- Peru
- Philippines
- Poland
- Portugal
- Qatar
- Romania
- Russia
- Rwanda
- Saudi Arabia
- Senegal
- Serbia and Montenegro
- South Africa
- Spain
- Sri Lanka
- Suriname
- Sweden
- Switzerland
- Tanzania
- Thailand
- Trinidad and Tobago
- Tunisia
- Turkey
- Uganda
- Ukraine
- United Arab Emirates
- United Kingdom
- United States of America
- Uruguay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www.atlas.gc.ca

Creation and Characteristics of Soil

GLOBE Soil – Lesson 2

Materials / Preparations:

- Chalk
- Students' GLOBE notebooks

Lesson Plan:

Soil Comes from the Decomposition of Rocks

1. The Earth is made of rocks. Throughout the centuries, these rocks were worn down, ground up and formed into a thin layer of soil on the surface of the Earth. This layer of soil varies across the continents and is called the **pedosphere**.

Definition of Soil

1. **Soil** is a combination of three elements: minerals of different sizes, organic materials (from the decomposition of vegetable and animal matter), and empty spaces filled with air or water.
2. Soils are different everywhere in the world, and each soil is best suited for a different use.
    a. Ex: In choosing where to build a house, you should look for a soil that is solid and compact and that won't move below the foundation of the house.
    b. Ex: For a garden, you look for a soil that can hold moisture and is rich in organic materials.

The Formation of Soil is Influenced by 5 Factors

1. Its parent material
    a. This is the material from which the soil is formed such as rocks, organic material, or an old soil brought in by either a geological event, or environmental factors (wind, a river, a glacier, or a volcano).
2. The climate
    a. Environmental forces like the wind, rain, or sun decompose the parent material and affect the speed of formation or changes within a soil.
3. The organisms in it
    a. All the living beings (including animals, plants, and bacteria) affect the composition and characteristics of the soil.
4. The topography that it sits on
    a. Where a soil is located can affect what the weather does to it.
        i. For example, soils at the base of a hill receive more water than those at the top, due to runoff.
5. Chronological time
    a. The effect of all the factors happens slowly over the course of time, often over hundreds or thousands of years. The longer the period, the more time the soil has to form and/or change.

Classifying Soils

When classifying a soil, scientists use nine of its characteristics:

1. Structure – Is it in columns, cracked…
2. Color
3. Consistency – Is it soft or hard?
4. Texture – Is it smooth and fine or granular and rocky?
5. Quantity of free carbonates – Does it contain any? (Free carbonates are alkaline substances that raise the pH level of the soil)
6. Soil particle density – Is there a lot of space between the soil grains, or not much?
7. Granular distribution – Is the soil made of sand, loam, clay, or a mixture of the three?
8. pH – Is the soil acidic or basic?
9. Fertility – Is the soil well able to support plants?

We are going to see most of these things during our investigation.

Review Game

1. Ask a student from each group to come to the board.
2. Give them either a topic or an example from those they saw during the day's lesson.
3. If a topic is given (for example, pH) the students must write on the board a word or example that corresponds to the topic (for example, acidic).
4. If the teacher gives an example (like a smooth soil or a granular soil) the students must respond with the topic (texture, in this case).
5. Give appoint to each team that gets a correct answer and call on a second representative from the team.

Preparation for the Next Lesson

1. Explain that we are going to do a study of several soils that the students themselves will bring to class.
2. Tell the members of each group to bring in a soil sample. Several handfuls from each student in a plastic bag should suffice.
    a. Group 1: Soil from their own courtyards
    b. Group 2: Soil from a river or stream bank (dry or flowing)
    c. Group 3: Soil from a garden
    d. Group 4: Soil from the middle of a road
    e. Group 5: Typical soil from the countryside (bush) near them
    f. Group 6: Soil from the bottom of a deep hole (like the soil from a well that is being dug or the bottom layer of a road cut etc.) Tell them not to enter the hole themselves but to collect some of the soil that came from the hole.
3. If possible, at least one student from each group should collect a sample with a digging tool in order to remove a big chunk of soil -- that is to say, an entire sample that is not broken into pieces -- to evaluate the characteristics of the soil.

Investigation of Several Soils

GLOBE Soil – Lesson 3

Materials / Preparations:

- Soil samples that the students have brought to class
- A system of labeling the soil samples
- GLOBE Soil Color Guide *(optional)*
- A squirt bottle of water or another method of lightly moistening the soil
- A bottle of vinegar with a small hole poked in the lid
- Students' GLOBE notebooks

Lesson Plan:

Preparation

1. Tell the students to put themselves in groups and put the samples of soil in front of them. Have the students label the soil sample that they brought.
2. Exchange samples between the groups so that each group has each type of soil sample in front of them.
3. Have the students set aside a small portion of each sample to use for the free carbonates test (don't use the entire sample). Avoid touching it with bare hands.

Starting the Lesson

1. Tell the students to copy the following table in their notebooks so that they can collect data from their observations.

   Note: *This type of data is called **qualitative data** as it deals with sensory information. Data that includes numbers or quantities is called **quantitative data**.*

Data Table for Soil Samples

Location of the sample	**Sample 1:**	**Sample 2:**	**Sample 3:**
Structure			
Color (preferably in the form of codes from the GLOBE soil color book)			
Presence of roots			
Presence of stones			
Presence of free carbonates			
Consistency			
Classification of texture			

2. Choose one sample to study as an example. Do the "Seven Steps for Classifying a Soil Sample" (below) together as a class. All the students should fill in the table in their notebooks as data is collected.

   <u>Note</u>: As you follow the seven steps, read each step to the students and help them to classify the sample the first time. Most of them aren't difficult but there are one or two that require patience on the part of the teacher and the repetition of the descriptions several times. It is important that the students understand the steps of this exercise so that they can do it themselves during the investigation of the Study Pit.

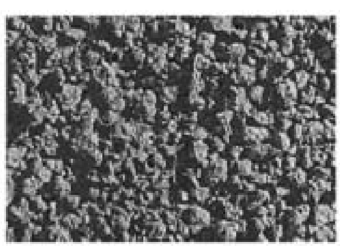
3. After finishing the first sample and filling in the table, answer any questions the students have and then choose another sample. Go through the seven steps again, with each group working together and attempting to fill in the table themselves.
4. Once you have finished with the second or third sample, ask them to respond to the following questions:
   a. Give one difference that you have observed between your first and second sample.
   b. Give one similarity hat you have noticed between the two.
   c. In your opinion, which sample would be the best to make bricks? Why?
   d. Do you have the two types of soil in your own courtyard? If not, why do you think one or both are absent?
5. At the end of this lesson, don't throw away the sample, because we will use them during the next two lessons.

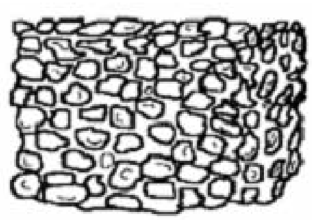
The Seven Steps for Classifying a Soil Sample

<u>First Step</u>: Structure (for soil that is not too disturbed):

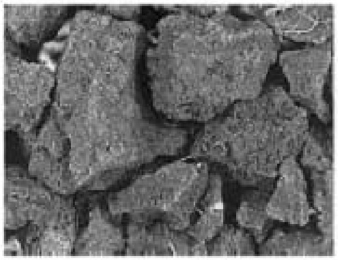
1. Ask the students to examine a non-disturbed sample closely and determine its structure.
2. The soil can be classified by the following pictures and descriptions.
3. Read each of the following descriptions to the students while they are looking at the sample. If you want, make a quick drawing on the blackboard to facilitate the students' comprehension.

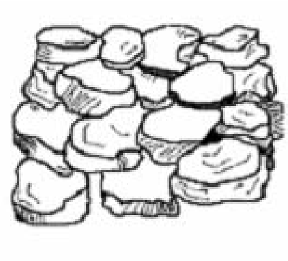
Texture With Structure:



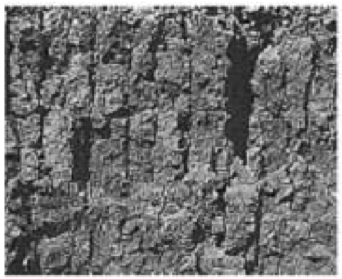


<u>Granular</u>: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.

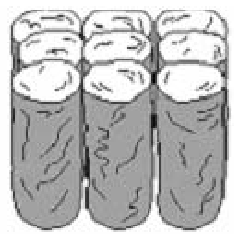




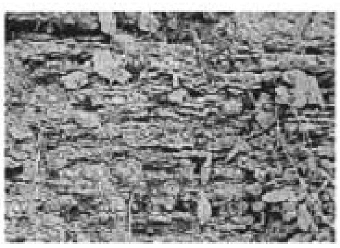
Blocky: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.

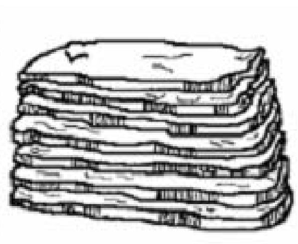


Prismatic: Vertical columns of soil that might be a number of centimeters long. Usually found in lower horizons.



Columnar: Vertical columns of soil that have a white, rounded salt "cap" at the top. Found in soils of arid climates.

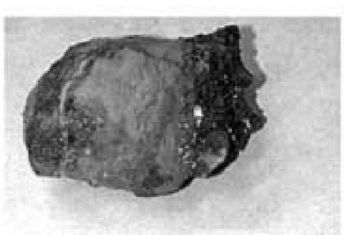


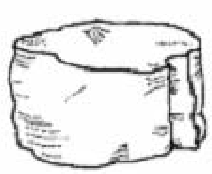


Platy: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.

Texture Without Structure:

Single Grained: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.



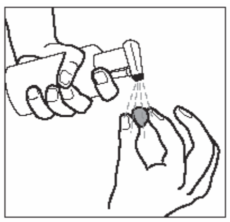
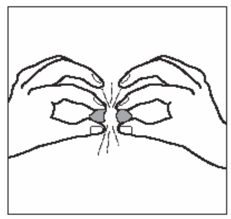
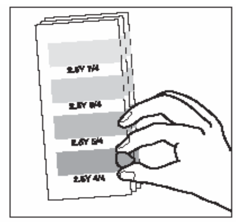


Massive: Soil has no visible structure, is hard to break apart and appears in very large clods.

***Second Step*: Color**

(*Note*: *Use a color chart if you have one. If not, ask the students to describe the color using the words that they know.)*

1. Take a ped (piece) from the horizon being studied and note whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle.
2. Break the ped and hold it next to the color chart.
3. Find the color on the color chart that most closely matches the color of the inside surface of the ped. Be sure that all students agree on the choice of color.
4. In the data table, record the code of the color closest to the soil sample.
5. It is possible that a sample contains several colors. Record a maximum of two colors if necessary, and indicate (1) the primary (main) color, and (2) the secondary color.

***Third Step*: Measurement of the Number of Rocks**

1. Observe and record if there are **none**, **a few**, or **many** rocks in the sample. Recall that a rock has a diameter greater than 2 mm.

***Fourth Step*: Presence of Roots**

1. Observe and note if there are **none**, **few**, or **many** roots in the sample.

***Fifth Step*: Presence of Free Carbonates**

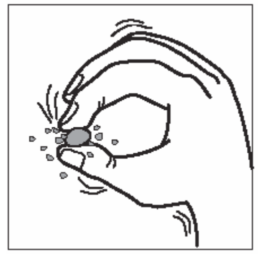
1. Ask the students to use the portion of soil that they set aside at the beginning for this test. Again, avoid touching it with bare hands.
2. Squirt a little vinegar on these soil particles and look carefully for the formation of bubbles.
3. The more carbonates that are present, the more bubbles (effervescence) you will see. Record the quantity of bubbles that formed using one of the following labels:
   - **None**: If there are no bubbles, the soil doesn't contain any free carbonates.
   - **Slight**: If you observe a very slight bubbling action; this indicates the presence of some carbonates.
   - **Strong**: If there is a strong reaction (many, large bubbles) this indicates that many carbonates are present.

***Sixth Third Step*: Consistency**

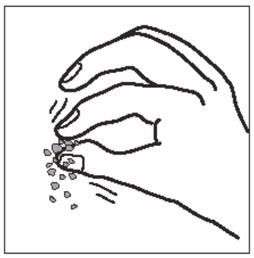
1. Take a ped (piece) of the sample and note if it is humid, dry, or wet. If the soil is really dry, moisten it a little bit.
2. Holding the ped between your thumb and forefinger, gently squeeze it until it falls apart. Take note of how hard you have to squeeze.
3. Read the following categories of consistency and record the best match in their data table.

Categories of Consistence:

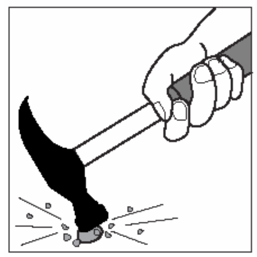
Loose: You have trouble picking out a single ped and the structure falls apart before you handle it.



Firm: The ped breaks when you apply a good amount of pressure and the ped dents your fingers before it breaks.



Friable: The ped breaks with a small amount of pressure.



Extremely Firm: The ped can't be crushed with your fingers (You need a hammer!)

Seventh Step: Texture

Note: Elementary school students may find the second part of this task difficult (Step Four of the dichotomous key below) and the teacher may find it easier to stop after simply classifying the soil as clay, loam, or sand. However, if the sample data is to be turned into GLOBE (such as for the soil pit), then the teacher will have to complete the task himself.

1. Texture is the measure of sand, loam, and clay respectively in a sample of soil. All three of these refer to the size of the particles that you find in a soil.
    a. **Clay** is the smallest size, its particles having a diameter less than 0.002 mm. It is very small!
    b. **Loam** is the name given to particles between 0.002 and 0.05 mm.
    c. **Sand** makes up small particles between 0.05 and 2 mm in diameter.
    d. If a particle is bigger than 2 mm, it is not considered soil and is instead classified as a **rock**.
2. The classification of texture is made in a rudimentary fashion through the sense of touch as the soil is rubbed between the fingers.
3. The following sequential steps are part of a dichotomous key, a system of classification following a fixed series of connected questions. Read these steps to the students just until all the samples are classified.
4. The steps of the key try to identify the soil in terms of general texture and then as a specific texture.

Dichotomous Key for the Classification of Textures of Soils

Step 1: Take a sample of soil of the size of a small egg and add enough water to moisten it. Let the water soak into the soil and then work it between your fingers until it is thoroughly moist. Once the soil is moist, try to form a ball.

If the soil forms a ball:	If the soil doesn't for a ball:
Go to Step 2.	Call it **sand**. Write this on the data sheet.

Step 2: Place the ball of soil between your thumb and index finger and gently push and squeeze it into a ribbon.

If you can make a ribbon that is longer than 2.5 cm:	If the ribbon breaks apart before it reaches 2.5 cm:
Go to Step 3.	Call it a **loamy sand**. Write this on the data sheet.

Step 3:

If the soil: - Is very sticky - Hard to squeeze - Stains your hands - Has a shine when rubbed - Forms a long ribbon (5+ cm) without breaking	If the soil: - Is somewhat sticky - Is somewhat hard to squeeze - Forms a medium ribbon (2-5 cm)	If the soil: - Is smooth - Is easy to squeeze - Is not very sticky - Forms a short ribbon (less than 2 cm)
Call it a **clay** and go to Step 4.	Call it a **clay loam** and go to Step 4.	Call it a **loam** and go to Step 4.

Step 4: Wet a small pinch of the soil in your palm and rub it with a forefinger.

If it feels very gritty every time you squeeze the soil	If it feels very smooth, with no gritty feeling	If it feels only a little gritty
Add the word sandy to the initial classification, so it becomes either **sandy clay**, **sandy clay loam**, or **sandy loam**. Write the correct one on the data sheet.	Add the word "silt" or "silty" to the initial classification. Soil texture is either **silty clay**, **silty clay loam**, or **silt loam**. Write the correct one on the data sheet.	Leave the original classification. Soil texture is either **clay**, **clay loam**, or **loam**. Write the correct one on the data sheet.

Introduction to Scientific Experiments with an Experiment on Millet Growth

GLOBE Soil – Lesson 4

Materials / Preparations:

- Six empty yoghurt bags or other bags to serve as pots
- Six different soil samples
- Millet seeds
- Water
- Ruler
- Students' GLOBE notebooks

Lesson Plan:

Review

1. Ask the students to orally summarize what they did during the last lesson.
2. Ask them to cite some characteristics of the six soil samples they looked at to help them remember that the samples were all different.
3. Explain that this time we are going to do an experiment where we will discover the quality of each soil in relation to its ability to support the growth of millet – a very important plant for the Sahel.

Explain the Scientific Method

1. Explain to the students that there is a set process that all true scientists follow when they are going to do an experiment. It is called the **Scientific Method**.
2. In general, this process has five parts *(write the key words on the board)*:
   a. **Problem**: A statement of the question that needs to be answered
   b. **Hypothesis**: A prediction of the result of the experiment
   c. **Procedure**: A step by step explanation of the process of the experiment so other scientists can exactly repeat the experiment.
   d. **Data** (and analysis of data): A scientist will do the experiment several times and take data each time, recording it in data tables found in this section
   e. **Conclusion**: An examination of the data and a decision on if the hypothesis was supported ("true") or not supported ("false") and then create another problem that builds on this experiment.
3. Say: "Today we are going to start an experiment on the fertility of different soils. **Soil Fertility** is a measure of the capacity of a soil to produce abundant harvests.

Start the Experiment

1. "What is the first step in starting an experiment?" The students respond "You start with a **Problem**."
2. "So, we have millet seeds and six different soils that you have collected before. Can you suggest the **Problem** (in the form of a question) that relates millet seeds, different types of soil, and fertility?"

3. Rather than directly giving the students the problem, take ideas from the class and in drawing out different responses, help the students to arrive more or less at the following question:

   Problem: Millet grows best in which type of soil?

4. Ask them to copy the problem under the title "Problem:" in their GLOBE notebooks.

   Note: Each student should write the experiment themselves in their own notebook if they are going to understand and learn the lesson. This method is better than telling the most intelligent student in each group to make a copy for the entire group. Even though this second method is faster, it results in only the smartest students learning the lesson and lets the other students check themselves out. The GLOBE program wants all the students in the classroom to understand science and become more intelligent. So, we encourage you to take the slower route, in which everyone learns the lesson through writing it out.

5. "And the next step of an experiment?"

   "Make a **Hypothesis**."

6. Tell the students that they are going to create Hypotheses now. "What is a Hypothesis?" If the students don't remember, explain that it is their own prediction, their own guess at the results of the experiment.
7. Each student should create and write their own Hypothesis that responds to the Problem.

   Note: Please remember that the teacher must not give the students an answer. Also, he must urge the students to do their own work so each one has their own hypothesis. At the hypothesis level, there is not a right answer so all the students' ideas should receive nothing but encouragement!

   If the students have problems with forming a hypothesis, the teacher, without telling them an answer, can guide them by explaining that their hypothesis can follow the form:

   "The millet will grow the best in soil that comes from __________ because ____."

8. "The next step is the explanation of the procedure so that other scientists can repeat the same experiment to verify the results."
9. Show the students the materials that you have collected. Ask them to think of a list of steps that can help answer the Problem and show whether their Hypothesis was true or false. With your help, the students should generate something close to the following list of steps.

   Note: Don't just give the steps to the students because the students must do some thinking for themselves in order to develop their brains. Teaching the students to think on their own is a difficult training, because if the teacher is in the habit of usually just giving the correct answer to the students and/or condemning them when they are wrong, the student stops trying to figure it out himself. At this point for the student, it becomes just a matter of waiting until the teacher answers his own question. This is a challenge faced by all teachers across the world.

The steps of the procedure:

a. Put each type of collected soil in one of the six empty yoghurt bags or empty bags of the same dimensions. They will be used as pots. Mark each bag in a way that distinguishes one from the other. Note and record your system of marking them and which soil corresponds with which mark.
b. Verify that there are holes in the bottom of each container so the excess water can drain out.
c. Plant four grains of millet in each sample of soil.
d. Arrange them outside in a location that will allow them to grow, and water them every day with the help of the students.
e. Each day before watering them, have students measure the height of each plant in millimeters. Record the height on the data table. If a plant has not yet sprouted, write 0 mm. Also, have the students write down some observations for each plant, like the color of its leaves, its apparent health, if the plant died during the night, if there are insects that are eating it … (These observations are called "metadata" for the GLOBE Program.)
f. Make observations for two or three weeks.

   Note: It might be preferable to stop taking millet measurements once you start taking data for the decomposition experiment so that the students do not get confused nor bored with all of the measurements.

g. If there is more than one shoot in a sample of soil, either weed out all except the one that you are measuring or keep two in case one dies. However, ensure that the heights of the two plants are kept apart and that one plant is not confused for the other.
h. Continue to water and measure the plants every day for three weeks.

10. If you have time, tell the students to copy these steps in their notebooks under the title "Procedure." They should at least write a summary of these steps so that they can remember what was done and so they can have something in their notebook in the form of the Scientific Method.
11. Explain that we are going to do this procedure during the next lesson.

Doing the Millet Growth Experiment

GLOBE Soil – Lesson 5

Materials / Preparations:

- Six empty yoghurt bags or other bags to serve as pots
- Six different soil samples
- Millet seeds
- Water
- Ruler
- Students' GLOBE notebooks

Lesson Plan:

Review

1. Do a short review on what you accomplished during the last lesson.

Follow the Procedure

1. Tell each group to take a bag and fill it with the soil sample they collected. Then, tell them to plant four millet seeds in the samples, following the steps of the Procedure. They should plant the grains at an appropriate depth – not more than one centimeter.
2. Return to class, and have the students create the table below on the blackboard.

Size of Plants in Centimeters

Day	**Soil 1:**	**Soil 2:**	**Soil 3:**	**Soil 4:**	**Soil 5:**	**Soil 6:**
0						
Observations						
1						
Observations						
2						
21						
Observations						

3. Tell them to copy this table in their notebooks under the title “Data and Observations.”

   Note: If you have the means, find or buy a big piece of paper (even an empty bag of cement can be cut into three pieces and taped together) and ask the students to copy the table there too. In this way you can have a data table and data set for the entire class in addition to the personal tables in their GLOBE notebooks.

4. Establish a system where a different group of students goes out the plants each day to water them and to measure their heights before returning to class and reporting the data to the other students.

Transition

1. Ask several students to talk about their favorite step during the experiment up until now. Ask each one why they like this step and why it is an important step.
2. Explain that next time, we are going to return to the classification of soils and talk about the soil horizons that you find in a soil profile.

Horizons and Profiles

GLOBE Soil – Lesson 6

Materials / Preparations:

- Empty mayonnaise jar with its lid (clean and without its label)
- Some soil from a few samples
- Water
- Students' GLOBE notebooks

Lesson Plan:

Preparation of a Small Demonstration

1. Ask a student to come to the front of the class and fill half of a mayonnaise jar with the soil of several soil samples mixed together.
2. Tell him to add enough water to fill the jar.
3. Close the jar and shake it up very well.
4. Put the jar on a table where it will not be disturbed and continue with the rest of the lesson as the soil is settling to the bottom of the jar.

Explaining the Structure of the Earth's Surface

1. Explain to the students that the soil is not one uniform mass and you see this in the different types of soil that you come to when digging a hole. Ask if the students have noticed this when looking at a hole or a well that has been dug recently.
2. In digging, you pass through different layers of earth.
   a. Definition: Each distinct layer of earth is called a **horizon**.
3. Explain that you don't find the same horizons in each location that you dig. The composition of the horizons in the earth changes across the Globe.
   a. Definition: The horizons that exist in a specific location form its **profile**.
4. At this time, return to the jar that has been settling and show the students that a profile has started to form through the action of the soil settling in the bottom of the jar.
   a. In order to increase comprehension, it would be helpful for the students to see a drawing on the blackboard that clearly shows a profile and its horizons.
5. By now, it is hoped that the students have written at least the title of the lesson and the two definitions above so that they will be ready to learn about the different types of horizons, which we go to next.

Presentation of the Horizons

Note: As the students will classify for themselves the horizons present in the study pit in a few weeks, it would be great if they wrote a sentence or two about each type of horizon in their notebooks to help them remember the different types during the following investigations. However, it is unlikely that students will see the horizons O or E in Niger so you could omit these from the students' notebooks.

1. **Horizon O**
    a. The "O" comes from the word **organic** as this horizon contains principally organic material (dead leaves, insect parts) that are in the process of decomposing.
    b. This horizon is found at the surface of the soil.
    c. It is found principally in forested areas and not in deserts or agricultural areas.
2. **Horizon A**
    a. This horizon carries an "A" because it is normally the first horizon found when digging into the earth.
    b. It is also called the **arable layer** as it is the horizon that is cultivated.
    c. It is principally composed of minerals but can also contain organic material that is completely decomposed.
    d. This horizon has a dark color.
3. **Horizon E**
    a. This layer is found only in forested zones or in very humid areas.
    b. The "E" comes from the term **eluvial** signifying that clay, minerals, and organic materials have been leached out of it as water passes through the soil. This horizon is not rich.
    c. It frequently has a grainy structure.
    d. It is often white or another color that is lighter than the colors of those that are above and below it.
4. **Horizon B**
    a. The "B" indicated that this is generally the second principal soil horizon. A profile can contain several B horizons, named from top to bottom: B1, B2, B3…
    b. It is composed of parent material that is considerably altered by atmospheric conditions.
    c. It is also called the **sub-soil**.
    d. It is also called the **horizon of accumulation** or **illuvial** as it is here that the materials leached from horizons A and E accumulate.
    e. Its coloration can either be reddish, yellow-brown, or a beige that is lighter than that of the associated A Horizon.
5. **Horizon C**
    a. The "C" signifies that is horizon is generally the third principal layer in a profile.
    b. It closely resembles the parent material without many changes.
    c. It as a massive or particular structure.
6. **Horizon R**
    a. The "R" indicates the rock layer that is often found under the pedological profile.
    b. It is possible that the soil is formed from the mother rock or that its parent material was deposited on the mother rock before the formation of any soil.

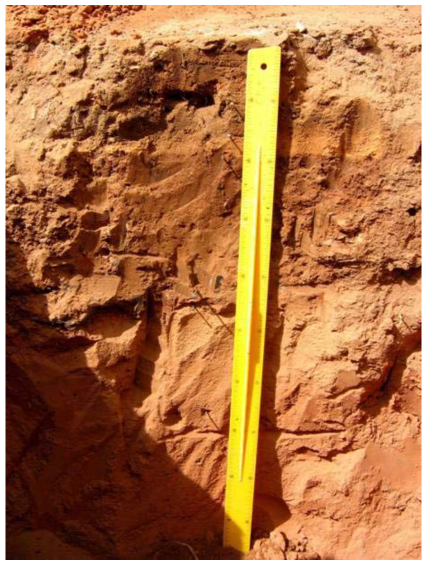
Note: Help the students to understand the order, even the existence, of each horizon in a profile is not fixed. Because of geological events, layers can be different, absent, in reversed order…

Looking at the Horizon of Clay

1. If you return a final time to the jar of settling soil, you will see a thin layer of clay that has started to form on top of the other horizons. If the jar is left still for 24 hours, you will see that this layer will completely settle out of the water and form a horizon.

Preparation for the Next Lesson

1. Explain to the students that next time, we will apply the processes that we have learned during the past few weeks and dig a soil study pit.
2. Ask students to come to the next class with digging tools, including a few spades.



The Grand Event!
– Outing to the Soil Pit

GLOBE Soil – Lesson 7

(This session requires two consecutive days plus perhaps another session afterwards for the analysis.)

Materials / Preparations:

- Digging tools
- A small bottle of vinegar with a small hole poked in the lid
- A squirt bottle filled with water or another means of dampening the wall of the pit
- A meter stick or tape measure
- A hammer
- Some nails
- Some jars or sacks that can be sealed or closed tightly to transfer soil samples back to the classroom
- A system of marking the sacks or jars
- Soil Characterization Data Sheet *(below)*
- Students' GLOBE notebooks
- A few adult volunteers that will help to guide and discipline the students in groups that are not working with you in the soil pit
- Soil color book* *(if you do not have one, skip this step or save soil samples for later use with a GLOBE Representative, or ask them to come help with your soil pit!)*
- A digital camera* *(ask a GLOBE representative)*
- Any other materials that are necessary for any other tests that you will be doing with the students, such as pH*

* *Optional Materials*

<u>Note</u>: *The data that you take during this session will be sent to GLOBE to help soil scientists throughout the world. For this reason, please ensure that your students do a good job so that they can pass on good information.*

First Day

Defining the Study Site

1. If you have not yet done so, define the study site in following the instructions "Steps to Define your Site" in the document "Choosing a Soil Study Site" at the start of the Soil Program. Include the students in this process if possible.
2. During the characterization of your site, fill in the Soil Characterization Site Definition Sheet.

Exposing the Pedological Horizons

1. At your study site, mark out a square in the soil that is 1.5 m per side. Make sure that the square is laid out in such a way that one side of the pit will be well lit by the sun.
2. Ask the students to dig a study pit to the depth of one meter within the square that you have laid out.

   <u>Note</u>*: If it is impossible to dig a pit to a depth of one meter due to rock, use a shovel or trowel to take a soil sample of the superficial layer of soil (the top 10 cm). In this way, you can still take and send some data to GLOBE despite the limitations of your surroundings.*

3. Ask the students to dig out one horizon at a time and to place each horizon in a separate pile. Each time that they arrive at another horizon, tell them to start a new pile until there is a pile for each horizon at the end of digging.
4. This process will certainly take some time. Give each student a chance to dig and change out the students that are digging often. Start digging early so the students are not working too hard in the heat of the day.

Preparation of Students' Notebooks for Data Collection

1. During the time that the students are in the process of digging the hole, the ones that are not digging can prepare their notebooks for data collection the next day.
2. Tell the students to write the title, "Study Pit: The Characteristics and Structure of Our Soil" in their notebooks followed by the date and the location of their pit.
3. Under this information, they should write, "I. Sketch of the profile of our soil" and then leave the rest of the page empty for the sketch that they will draw later.
4. On the next page, they should write the following:

   II. The study of the horizon of my group

   1) Horizon number: ________
   2) Depth of the horizon: ______cm to______ cm from the surface
   3) Structure: ______________________
   4) Color: _______________________
   5) Consistence: ____________________

6) Texture: ______________________
7) Quantity of rocks: ______________
8) Quantity of roots: _____________
9) Quantity of free carbonates: ______

5. On the next two facing pages, the students should copy the following data table for data collection. As we do not yet know how many horizons that we will find in the profile, have the students construct only the columns, categories, and at least four rows for four horizons. After digging, the students can add additional rows as necessary.

III. The horizons of the soil profile at my school

Horizon number	**Depth of the horizon**	**Structure**	**Color**	**Consistence**	**Texture**	**Amount of rocks**	**Amount of roots**	**Amount of free carbonates**	**Tentative classification of the horizon (A, B, C, O…)**

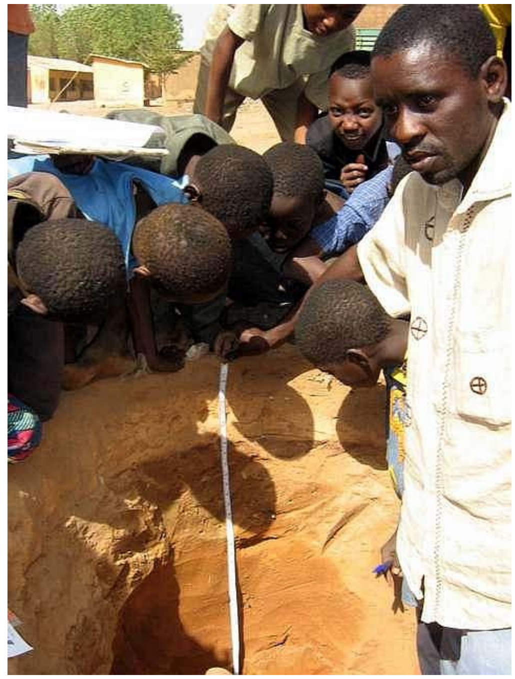
6. Finally, they write on the following page:
"IV. Conclusion: What I have learned"

Preparation for Tomorrow

1. Verify that the pit is well-dug and that it is marked with a rope or flagging to ensure that neighbors do not fall into the pit.
2. Verify that the students' notebooks are complete.
3. Verify that you have all of the necessary materials for the following day.

Second Day

Identifying and Measuring the Horizons



1. Make your way out to the pit with the students and the adult volunteers. So that each student can see the pit and make the measurements, only one group can be working in the pit at a time.
    a. This could create some discipline problems with the groups that are waiting their turn. In order to quiet the students, have an adult volunteer assigned to every one or two groups of students. Have the adults work with the students on revision or another subject while they wait.
    b. Once a group has finished their work with you in the pit and they have a soil sample in hand, they will need a little help with the characterization of their sample. Install an adult volunteer in the classroom with the instructions for soil characterization found in the third lesson. Then, once a few groups have a sample, they can go into the classroom with the volunteer so that the volunteer can read out the instructions to the groups and help them with their classification. Since the students have already completed the characterization one time, they will be able to get by even if the adult does not know the process very well.
2. Call the first group to the study pit and do the following seven steps with them:
    a. Make sure the sun shines on the profile.
    b. Use a trowel to scrape a few centimeters of soil off of the profile to expose a fresh soil face.
    c. Determine whether the soil profile is moist, wet, or dry. If the soil profile is dry, moisten it with the spray mist bottle.
    d. Going from the top of the profile to the bottom, observe the characteristics of the soil.
    e. Look carefully at the soil profile for distinguishing characteristics such as color, texture, shapes, roots, rocks, small dark nodules (called concretions), worms, small animals, insects, and worm channels. These observations will help to define the horizons.
    f. Working in a straight vertical line, place a marker (such as a nail) at the top and bottom of each horizon to clearly identify it. Be sure there is a consensus from all of the students regarding the depths of the soil horizons.
    g. Measure the top and bottom depth of each horizon beginning at the top (surface) of the profile. Start with the meter stick or tape measure at 0 cm at the top of the profile.
    h. Record the top and bottom depth of each horizon on the Soil Characterization Data Sheet.

<u>Note</u>: It is natural that once a person has done something once, he understands the concept well and has the urge to give all the answers the next time that he does it. The teacher in the pit with the students during five or six groups will have all the answers in his head and will feel the need to give all of the answers directly to the group. ***We encourage you to resist this natural temptation and to help the students do the work themselves each time.***

3. Once a group has made the measurements in the pit, ask them to take a sample of the horizon that you assign to them.
4. Ask them to go into the classroom with their sample where an adult volunteer can read steps of soil characterization to them from the third lesson in this series. The students themselves can then fill in the form that they created in their notebooks the day before, "The Soil Horizon Study for my Group"
5. Repeat these steps for all of the groups before continuing.

   <u>Note</u>: Verify that each horizon is given to at least one group. If there are more groups than horizons, give the same horizon to multiple groups. Then you can compare the results of each group during the data reporting section of the lesson to guarantee good results.

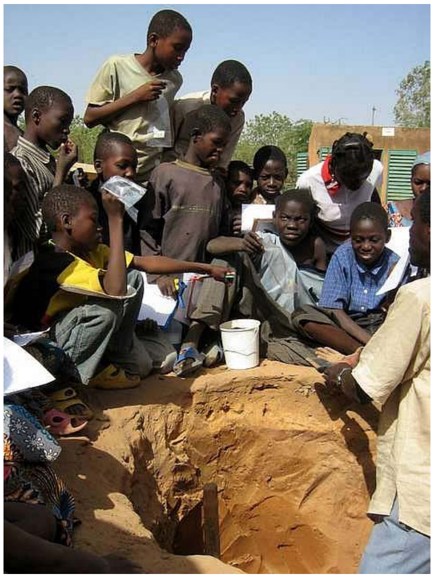
Photographing the Profile

<u>Note</u>: Ask for the presence of a GLOBE Representative during this session if you don't have a camera)

1. Place a tape measure or meter stick starting from the top of the soil profile next to where the horizons have been marked.
2. With the sun at your back, photograph the soil profile so that the horizons and depths can be seen clearly.
3. Take another photograph of the landscape around the soil profile.
4. Submit photos to GLOBE over the internet, with the help of a GLOBE representative if necessary.

Taking Soil Samples

1. If you are going to do other tests, like pH, or you are going to do a part afterwards, like color, follow the guide, "Taking Data from Soil Horizons" at the beginning of the "Lessons and Technical Activities to Send Data to the GLOBE Program" section in order to save the soil for later.



Filling Back in the Study Pit

1. Once the characterization of the profile is finished, the students must replace the soil in the reverse order that it was taken out. In other words, the soil that was taken out last must be the soil that is put back into the pit first to respect the structure of the profile at your site.

Analysis in Class (done today or during another session later this week)

1. Once all of the students have finished and have returned to class, lead a general discussion on their thoughts and what they saw without getting into their soil classifications.
2. Draw a sketch on the blackboard of the pit and label its horizons with the students' help (depths, etc).
3. Ask students to copy the data table in their notebooks under the title that they have already written in there.
4. Draw a large data table on the board that mirrors what the students have already placed in their notebooks.
5. Ask each group to come to the blackboard and report their data for the horizon that they studied. Have them place their data in the data table.
6. Ask the students at their desks to recopy this information into their notebooks at the same time.
7. Ask the students to respond to the following questions to help them see the differences between the layers:
   a. Where do you think the different layers came from?
   b. Which layer had the most roots?
      - Rocks?
      - Animal holes?
      - Insects?
   c. Which horizon was darker than the others? Lighter than the others?
   d. Are there any similarities between the horizons? What are they?
   e. Try to classify each horizon in reading the descriptions or each type of horizon from the session on horizons and profiles. Help the students to classify each layer that they saw in the profile. Add these classifications to the data table and to the sketch and ask the students to do the same thing in their notebooks.
8. Ask each student to write a paragraph-long conclusion in their notebooks under the title "What I Have Learned," which is already in their notebooks.
9. Congratulate the students on a job well done and let them go.
10. Carefully recopy the data from the blackboard onto the data sheet to turn into GLOBE either through a representative or yourself over the Internet at www.globe.gov by first entering your school's ID and password.

Preparation for the Next Session

1. Tell the students that during the next class, they will analyze the data that they have been taking during the millet growth experiment and to come to class with their qualitative and quantitative data.

Soil Characterization Data Sheet

Date of Characterization: ________ Local Time of Characterization: __________ Universal Time (UT): _________

Study Site: SCS- _________________________________ Method (choose one): ___Pit ___Auger ___Near Surface

Horizon No.	**Top Depth** (cm)	**Bottom Depth** (cm)	**Structure** (granular, blocky, platy, prismatic, columnar, single grained, massive)	**Main Color** (code from color book)	**Second Color** (code from color book)	**Consistence** (loose, friable, firm, extremely firm)	**Texture** (sand, loamy sand, sandy loam, sandy clay loam, sandy clay silt, silt loam, salty clay loam, silty clay, loam, clay loam, clay)	**Rocks** (none, few, many)	**Roots** (none, few, many)	**Carbonates** (none, slight, strong)

Returning to the Millet Growth Experiment

GLOBE Soil – Lesson 8

Materials / Preparations:

- The data table of the heights of the plants to each group
- Meter stick
- Students' GLOBE notebooks

To Do:

Presentation of Data

1. Fix the data table sheets of the heights of the plants on the blackboard or recopy the data onto the blackboard from the students' personal data sheets so the whole class can see all the data.

Make a Graph of the Data

1. Place the axes of a big graph on the blackboard.
2. Ask the students to label each axis of the graph. Try not to give the answer to the students, but force them to think a bit on their own.
3. In the end, the horizontal axis should be "Days" and the vertical axis should be "Height of the plants in centimeters".
4. Ask the students to come to the blackboard and plot the data points on the graph. Graph each plant one at a time and use a different color of chalk for each plant (different type of soil).
5. Ask the students to make a legend for which color corresponds with which plant.

   <u>Note</u>*: You could ask the students to construct the graph themselves in their notebooks before doing it on the blackboard in order to force the students to practice graphing.*

Analysis of the Graph and of the Experiment Itself

1. Pose the following questions to the students in addition to your own questions to help the students understand the graph and the experiment:
   a. Which plant grew the most?
   b. The least?
   c. Which line (growth curve) on the graph shows the most rapid slope?
   d. The most gentle?
   e. A steep slope indicates what type of growth?
   f. A gentle slope indicates what type of growth?
   g. Did all the plants start growing at the same speed?
   h. Was there a point during the two weeks where the plants started to slow down?
   i. Can you suggest a reason why some of the plants stopped to grow as well?

j. In looking at the final height and the growth speed of each plant, put the soils in order from the best to the worst for millet growth.
k. What type of soil do you have in your field?
l. Other questions…

2. Explain to the students that different plants are best adapted to diverse soil types. The fact that millet grows well in sandier soils does not mean that all plants can grow well in this soil type. For example, tomatoes prefer a very rich school that farmers have to work on very hard in order to establish it in their gardens.
3. Explain also that the contents of each soil are different. Certain soils are richer than others in terms of minerals that plants need to be healthy and grow.
   a. Above all, nitrogen and phosphorous are very important minerals that are often lacking in soils.
   b. To fix this, farmers put certain plants in their fields retain nitrogen and phosphorous, like moringa or beans.
   c. They also use fertilizer.

Write a Conclusion

1. Under the title "Conclusion" have the students write several phrases in their GLOBE notebooks on what the experience showed them and if their own hypothesis was supported or not supported.

Preparation for the Next Lesson

1. Organize the students so that at the beginning of the next session you have the following materials:
   - Six glass bottles of the same dimensions (empty jars of mayonnaise for example)
   - Organic material (compost) such as vegetable peelings from the kitchens of several families
   - Enough soil to mostly fill the six jars

Soil: The Great Decomposer

GLOBE Soil – Lesson 9

Materials / Preparations:

- 6 mayonnaise jars of the same dimensions with lids
- Water
- Vegetable peeling from the kitchen cut into uniform pieces
- Enough soil of the same type to fill the jars
- 2 empty yoghurt bags or black plastic sacks
- A labeling system for the jars with marker or small pieces of paper taped to each one
- Students' GLOBE notebooks

Lesson Plan:

1. Explain to the students that we are going to start an experiment on the decomposition of organic materials.

2. Ask them to take out their GLOBE notebooks and on a new page, write the title "An Experiment on Decomposition."

3. Then, have them write the problem of the experiment under the title of the experiment:

   Problem: What are the most favorable amounts of water and sunlight for the decomposition of organic materials in the soil?

4. Ask each student to now create his or her own hypothesis for the problem to this experiment.
   a. The students are going to write a hypothesis on which of the six following will produce the most decomposition and they will justify their prediction.
   b. The six conditions that we are going to test:
      - Dry and sunlit
      - Humid and sunlit
      - Saturated and sunlit
      - Dry and shaded
      - Humid and shaded
      - Saturated and shaded

5. After giving the students a little time to work on their own predictions and they start to give up, give them the following framework as a guide:

   > "I think that the vegetable peelings in the jar that is ____________ (write one of the six conditions), will be the best decomposed when compared to the others because __________________________."

   Note: Please remember that the teacher must not give the students an answer. Also, he must urge the students to do their own work so each one has their own hypothesis.

At the hypothesis level, there is not a right answer so all the students' ideas should receive nothing but encouragements!

6. Move on the creation of the procedure with the students. Instead of directly explaining the procedure to them, show them the materials and draw ideas from their minds on how to proceed in order to test the hypothesis and find an answer to the problem.

7. By asking leading questions and adapting the students' ideas, arrive at more or less the following procedure. The words can be different, but it is important to respect the ideas held within these steps:

   Procedure:

   a. Label each of the six jars with one of the conditions to be tested: Dry and sunlit, Humid and sunlit, Saturated and sunlit, Dry and shaded, Humid and shaded, and Saturated and shaded.
   b. Place a layer of soil in each jar about 10 cm deep.
   c. Add about 3 cm of vegetable peelings into each jar.
   d. Place three pieces of plastic bag with the dimensions of 1 cm by 3 cm into each jar.
   e. Mix well the contents of each jar.
   f. Pour water into the jars marked "saturated" until the surface of the soil mixture stays completely covered with water.
   g. While mixing, add a little water to each jar marked "humid" just until the mixture is moist. Try to avoid reaching a point where excess water is sitting in the bottom of the jar.
   h. Do not add any water to the jars marked "dry".
   i. Pierce each top with a nail at least six times to allow for the circulation of air, and then close all of the jars with their lids.
   j. Place the three jars labeled "sunlit" in the courtyard of the school in safe location where they will be undisturbed and will receive full sunlight throughout the day. It is OK to bring the jars inside at the end of the school day if necessary, but do not forget to take them back out very early in the morning.
   k. Place the three jars marked "shaded" inside the classroom out of direct sunlight.
   l. Every other day, water the soil in the "saturated" and "humid" jars in the same way as before.

      Note: During the hot season, it may be necessary to water the jars every day.

   m. At the same time as you water the jars, examine their contents. Have students record in their notebooks any changes in soil humidity, and the state of decomposition of the organic material and the plastic bags.
   n. Water and observe the jars for at least two weeks.

8. So that all of the students can participate, assign each group one of the six jars. They will be responsible for the observations and the upkeep of their jar during the two week period of observation.

9. If you have the time, ask the students to start preparing the jars and start the experiment. If not, wait until the following session.

Soil: The Great Decomposer *(continuation)*

GLOBE Soil – Lesson 10

Materials / Preparations:

- 6 mayonnaise jars of the same dimensions with lids
- Water
- Vegetable peelings from the kitchen cut into uniform pieces
- Enough soil of the same type to fill the jars
- 2 empty yoghurt bags or black plastic sacks
- A labeling system for the jars with marker or small pieces of paper taped to each one
- Students' GLOBE notebooks

Lesson Plan:

1. Do a short review on what you accomplished during the last lesson.
2. Ask the students to prepare the experimental jars under your supervision and to start the experiment.
3. Once all of the jars have been placed in their respective locations, return to the written part of the experiment with the creation of a data table.
4. Have each student copy the following data table into their GLOBE notebooks under the title "Data" and explain that they will use this data table over the next two weeks.

The conditions in my jar: ______________ and ______________

Day	Observations of humidity	State of decomposition of the plastic bags	State of decomposition of the organic material
1			
3			
5			
7			
9			
11			
13			
15			

5. If you have the means, buy a few empty cement sacks and cut them open to form a large sheet of paper for each group (one sack will be enough for three groups). Distribute the sheets and ask the groups to reproduce the data table on them as well. Hang these on the wall of the class and ask each group to fill them in over the next two weeks as they take data. This action will facilitate the analysis of the experiment in a few weeks' time.

   Note: Even though the students are taking data, the teacher also must do the same in order to monitor the quality of the students' observations. This action will also protect against the loss of any data by the students.

Preparation for the Next Lesson

1. Explain to the students that during the next session, we will turn to the concept of erosion and that they should come to class with a definition of erosion.

Investigating Erosion

GLOBE Soil – Lesson 11

<u>Note</u>: This lesson is the same as the 9th session of the Trees and Wood Protocol. If you have not already done this session with your current group of students, do it now as part of the Soil Protocol.

Materials / Preparation:

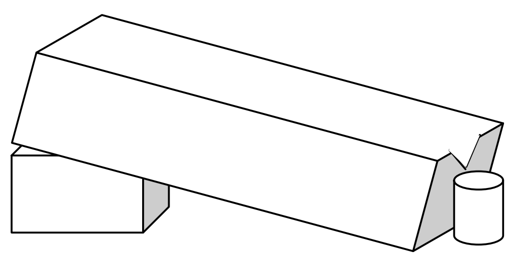
- Two cardboard boxes of the same dimensions, ideally cut to a height of 8-12 cm
- 1 plastic teapot
- Enough water to fill the teapot (divided into two equal parts)
- 2 empty mayonnaise jars (the same size) or 2 graduated cylinders
- 2 small bricks, rocks, or cardboard boxes to raise one side of each box about 10 cm
- Organic materials like leaves, straw, and grasses
- 10 small wooden sticks
- Students' GLOBE notebooks

Lesson Plan:

The Problem

1. "What is erosion?" **<u>Erosion</u>** is the loss of soil through the action of water, wind, or another natural force.
2. Explain that we are going to try to answer the problem (question), "What is the role of trees and plants in keeping the soil in place and avoiding erosion?" Tell the students to recopy this question in their notebooks under the title, "The Problem (Question) of this experiment:"
3. Say that we are going to make two boxes to do an experiment that will answer this question.
4. Explain that one of the boxes represents earth without trees and plants, and the other represents earth with trees and plants.

Construct the Two Boxes



1. Go outside with the two boxes.
2. Cut a "v" in one side of each box, like the drawing to the right.
3. Fill one of the boxes with soil to just over the bottom of the "v".
4. Pack the soil into the box so that it forms a valley shape with the bottom of the valley above the bottom of the "v".
5. Fill the other box with soil and compact it well in the same manner as the first. Then, cover it with a wide-ranging mixture of wood pieces, leaves, straw, grasses, etc. Push about 10 sticks into the soil upright, to hold the mixture in place.

6. Return to the classroom with the two full boxes.
7. Put the two boxes on a table in front of class. Put each box at an angle, raised up by a brick, rock, or cardboard box. The side with the "v"-shaped hole should be at the bottom of the incline. (*see the drawing*)

Make Hypotheses

1. Say to the students that we are now going to make **hypotheses**.
   - What is a hypothesis?
   - If they don't know, explain that it is a prediction of the results of the experiment.
   - Explain that all the good scientists in the world make a hypothesis before doing an experiment.
2. Forming a hypothesis is one of five steps of an experiment. The 5 steps are:

   1. **Describe the Problem**
   2. **Make a Hypothesis**
   3. **Explain the Procedure**
   4. **Conduct the Experiment & Take Data**
   5. **Form a Conclusion**.

3. Say that each student must write a hypothesis that responds to the question, "If you pour water into each box and you collect the water as it comes out the other end, what will be the differences in the quantities of water and soil that come out of each box?"
4. **Attention**: The teacher must not give the students an answer. Also, he must insist that each hypothesis be their own and that **there is not a right or wrong answer at this point. All the responses have value!** The teacher, without saying an answer, can guide the students by explaining that their hypotheses can follow the form below:

   "When water is added to the top of each box, the quantity of soil that comes out of the box with no groundcover will be _______ (more than / less than / equal than) than that which comes out of the box with groundcover because ___________________________________."

5. Choose 5 students to share their hypothesis with the class. *(Remember that all the hypotheses are valuable and merit encouragement!)*

Conduct the Experiment

1. Fill the teapot half-full of water.
2. Pour water into the top of one of the boxes.
3. With the empty mayo jar or graduated cylinder, collect the water that falls out of the v-shaped hole on the other end.
4. Leave the jar or graduated cylinder for several minutes. (The soil will settle at the bottom.)
5. Do the same thing with the other box.
6. While waiting for the soil to settle, tell the students to copy the following table in their notebooks below their hypothesis and under the title "Data".

	Quantity of Water (cm or ml)	Quantity of Soil (cm or ml)
Without Trees		
With Trees		

7. After the soil has settled in each jar, tell a student to measure the quantity of soil and the quantity of water that left the boxes, with a ruler in cm or with the scale on the graduated cylinder in ml.
8. Tell the students to fill in their tables with this data.

Conclusion

1. Ask the students to write 2 sentences about what happened, under the title "Observations". Ask some students to share their observations, and guide them to the idea that the box containing trees and plants was better at retaining both the soil the water than the box without trees or plants.
2. Ask the students "If trees and plants aren't there holding the soil in place, what will happen?"
   - They should respond that a lot of the soil will be lost.
3. Ask, "If the soil is lost; then what will happen?"
   - They should respond that it will be difficult to grow crops, etc.
4. Ask, "If the soil isn't retaining water, what will happen?"
   - They should respond that it will be difficult to grow crops, the land won't be green, the soil will be blown away by the wind, etc.
5. Ask, "If it is difficult to grow crops, what will happen?"
   - We will go hungry.
6. "Also, what will happen if you have a lot of soil in our water, such as in the Niger River?"
   - Death of fish, filling-up of dams, etc)
7. Ask the students to write a short two or three sentence summary in their notebooks under the title "Conclusion," including whether or not their individual hypothesis was supported or not supported by the experiment.

Returning to the Soil Decomposition Experiment

GLOBE Soil – Lesson 12

Note: Do this session at least two weeks after placing the jars in their testing locations

Materials / Preparations:

- Completed data tables
- The six study jars
- Students' GLOBE notebooks

Lesson Plan:

Data Reporting

1. Attach the large data tables for each group to the blackboard. If you have not made large data tables, draw a large data table on the blackboard and then ask each group to come up and copy their data onto it so that everyone can see the data for all the groups.

Presentation of the Data

1. Ask a member of each group to present their data to their classmates.

Leading an Analysis of the Data:

1. Start the analysis by asking, "In looking at the data on the blackboard, in which jar is the decomposition of the plastic strips the greatest?"
   - The students should respond that no jar saw any decomposition of the plastic strips.
   - Guide the students to the conclusion that plastics do not decompose (or that they decompose very slowly over hundreds of years) and that the sacks we use every day are a very large problem for us that will not go away any time soon. Explain that because of this problem, some countries have banned the sale of plastic bags and others add a tax of around 200CFA to each bag so that people cannot afford to pay for a bag every time.
2. "In which jar is the decomposition of the vegetable scraps the most pronounced?"
3. "What are, therefore, the conditions that best help the decomposition of organic matter?"
4. "In which jar is the decomposition of the vegetable scraps the least pronounced?"
5. "What are, therefore, the conditions that impede (prevent) the decomposition of organic matter?"
6. Ask the students to place the bottles in the order from least to most decomposed in looking at the data.
7. "In looking at the line of bottles and their labels, did water or shade have a larger effect on the decomposition of the vegetable matter?"
8. Add other questions in order to continue the analysis of the data by the students as necessary.

Have the Students Write out a Conclusion

1. Ask the students, "After taking the data and analyzing it, what is the next step of a scientific experiment?"
    - The students should respond, "Make a conclusion."
2. Ask the students to write a several sentence conclusion under the title, "Conclusion" in their notebooks. Also, have them explain whether or not their own hypothesis was supported or not supported by the experiment.

Imagining the Next Experiment (The Next Logical Step)

1. Explain to the students that an important part of the scientific process is to formulate a new problem from the results of this experiment.
2. Ask students to generate some new problems that build on the old experiment and that we can test with a new experiment.
3. After taking several ideas, suggest that the temperature could also play a role on the decomposition of organic materials.
4. Ask students to create a problem to test the temperature.
5. Ask them to loosely describe an experiment that would test this problem.
6. After completing this process, tell them that low temperatures slow the decomposition; therefore you need warm temperatures to have rapid decomposition.

Composting: Application of What We Have Learned

<u>Note</u>: The following step is an optional application for this or another class period. But, it would be a good way to strengthen the school through the use of the science they have learned. This information is worth presenting to your students, even if you do not start a compost pit at your school.

<u>Note</u>: You can use this lesson as the start of a school garden or a tree nursery where you require a rich soil.

1. Definition: **<u>Compost</u>** is organic matter that is well decomposed and rich in the minerals that living plants need. So, the use of compost enriches the soil and helps plants grow.
2. "If we want to create compost in our gardens so that they produce well, what conditions are necessary for quickly decomposing organic matter?"
    Response: humidity, heat, and shade (within the compost pile)
3. "What kind of trash can you put in your compost pile?"
    Response: Only organic matter like kitchen scraps, manure, dead plants and leaves, dried plant matter from the harvest…
4. Explain that for rapid decomposition, a pile of compost needs three things:
    a. Dry leaves to allow air to circulate in the pile
    b. Fresh organic material to decompose and enrich the compost (including kitchen waste and manure)
    c. Soil to allow bacteria to rapidly enter into the compost pile and decompose the organic matter.
5. Give the following steps to the students on how to construct a compost pile.
    a. Choose a location that measures 1.5 m by 1.5 m
    b. Dig a hole there of the same dimensions to a depth of 15 cm
    c. Make a 10 cm deep layer of dry leaves in the hole.
    d. Then, add a layer of organic waste that is 5 cm deep on top of the leaves.

e. Then, add a 3 cm layer of earth to the pile.
f. Water the layers to moisten them.
g. Repeat steps **C** to **F** until all of the available waste is finished. You can continue to add to the pile during the entire year until the pile is quite large.
h. Continue to water the pile once or twice each week.
i. After several months, open the pile a bit and check the state of decomposition in the pile. If all of the organic matter is well decomposed, dig it into the soil of your garden just before planting time. If they are not well decomposed, mix the contents of the pile a little each month and continue to water the pile each week until it becomes well decomposed.

Note: A pile of compost that is decomposing well feels warm to the touch as the bacteria eating the pile produce thermal energy during the process.

Review Questions

1. What can you put in the compost pile for your garden?
    - All organic matter: plant trash, manure, non-plasticized paper, dead leaves, plant stalks…
2. What should you avoid placing into your compost pile?
    - All inorganic matter: bags, plastics, iron…
    - The compost pile is not a trash heap!
3. Other questions on the process or importance of composting…

Unit Review Game: Reverse Jeopardy

GLOBE Soil – Lesson 13

Materials / Preparations:

- GLOBE notebooks
- Categories and question lists *(below)*
- Any instrument or image on which you want to base a question

Lesson Plan:

Note: This review game is very popular with students and can be adapted to any unit simply by generating appropriate categories and questions.

1. Copy the following table onto the blackboard with category variations as needed:

Horizons and Profiles	Soil Characterization	Decomposition and Compost	Thermometers	Experiments	Erosion
100	100	100	100	100	100
200	200	200	200	200	200
300	300	300	300	300	300
400	400	400	400	400	400
500	500	500	500	500	500

2. Divide the classroom into two to four teams and create a scorecard on the blackboard with the team names.
3. Give each team a noisemaker ("buzzer") that they will use to signal that they know an answer.
4. Ask a team to pick a category and the lowest point value in that column, such as "Soil Characterization for 100 points."
5. Read the question that goes with that square. For example: "A rock is defined as having a diameter larger than how many millimeters?" (The questions should become more difficult as the point values increase).
6. Any team that thinks they know the answer should make a sound with their noisemaker ("buzz in") and call on the first team that reacts.
7. That team has the chance to answer the question and if they get it right they win the points linked to the question. Optional penalty: If they answer the question incorrectly, the team loses that number of points for the question and the other teams have a chance to answer correctly by "buzzing in" once again.
8. As each question is asked, erase the points from that square on the board to show that those points have already been used.
9. The team that answers the question correctly has the chance to pick the next category and point value.
10. This continues until all of the squares are empty.

11. Then, there is one final question in the Final Round. For this question, each team can bet as many of the points that they have earned as they like. Ask them to write down the number of points that they will bet on this question on a piece of paper and then give them to you.
12. Ask the final question and have each group write down their answer on a piece of paper and give them to you as well.
13. Finally, check the written answers. For a correct answer the group earns as many points as they have bet and for an incorrect answer the group loses as many points as they have bet.
14. The winner of the game is the group that has the most points at the end of the final round.

Reverse Jeopardy Questions for the Soil Protocol

Note: Add, subtract or revise categories and questions as necessary

Category: Horizons and Profiles

100: Why does the A-horizon start with the letter A? (Because it is generally the first layer in a soil profile, OR because it's the arable layer – either answer is correct.)
200: Give a definition for the word "horizon." (A horizon is a distinct layer of earth found in the ground (in the soil profile) beneath our feet)
300: What does the "R" in the name "Horizon R" stand for? (Rock)
400: The sub-soil also has other names. Give at least one of those. (Horizon B or horizon of accumulation or Illuvial Horizon)
500: List the order of the horizons that one expects to find starting at the top of and going down a profile. ([O], A, [E], B, C, R)

Category: Soil Characterization

100: A rock has a diameter that is larger than how many mm? (2mm)
200: What is a ped? (A natural piece or unit of a soil)
300: Name the three basic soil textures. (Sand, clay, silt)
400: Loose, friable, firm, and extremely firm are all description of what characteristic of the soil? (Soil Consistence)
500: Name four of the seven soil characterization tests. (Structure, Texture, Color, Consistence, Number of rocks, Presence of roots, Presence of free carbonates)

Category: Decomposition and Compost

100: What does it mean when something decomposes? (It breaks down or it is broken down by bacteria in the soil.)
200: Why is it important to make a compost pile? (Compost is used to enrich the soil.)
300: What were the two conditions that we tested in the decomposition experiment? (Amount of water and amount of sunlight.)
400: What are the three layers that one makes in a compost pile? (Soil, leaves, organic trash.)
500: Give a good definition of compost. (Compost is organic matter that is well decomposed and rich in the minerals that living plants need.)

Category: Thermometers and Temperature (if applicable)

100: What are the units (scale) that thermometers use to measure the temperature? (Degrees Celsius.)

200: How often do we take soil temperature measurements? (At least once a week.)

300: How many times do we need to take the temperature each time that we go out to take temperature samples? (At least two times.)

400: Why do we use a spacer on the soil thermometer when we are measuring soil temperature? (To make sure that we are taking the temperature at the correct depth.)

500: Name three things that are affected by soil temperature. (The time that trees bud and the speed at which plants grow, regulation of animals' lives that live in the soil amount of decomposition in the soil, amount of water in the soil, formation of laterite, scientific uses.)

Category: Experiments

100: When a scientist is making a prediction as to the results of an experiment, what is he making? (A hypothesis.)

200: What was the Problem of the millet experiment that we did? (In what soil does millet grow the best?)

300: True or false: There is always a correct answer when making a hypothesis. (False, a hypothesis is a prediction, not an answer.)

400: What should one talk about in the Conclusion of an experiment? (A summary of what happened and whether or not the hypothesis was supported.)

500: Name three of the six conditions that we tested during the decomposition experiment. (Dry and sunlit, Humid and sunlit, Saturated and sunlit, Dry and shaded, Humid and shaded, and Saturated and shaded.)

Category: Erosion

100: What is erosion? (Erosion is the loss of soil through the action of water, wind or other natural force.)

200: What slowed down the erosion in the erosion boxes that we made? (The addition of organic material.)

300: Why is erosion bad for farming and plants? (Erosion carries off all of the rich soil that plants need to grow well.)

400: Name a negative effect that erosion has on water sources. (Fish die off, dams fill up with sediment, pumps fail…)

500: Recite your hypothesis from the erosion experiment and explain if it was supported or not.

Category: Question for the Final Round

Question: Name the five steps that one must do when conducting an experiment.
(Problem, Hypothesis, Procedure, Data, and Conclusion)

Soil Lessons and Technical Activities to Send Data to the GLOBE Program

Note: These protocols require equipment ranging from very cheap to somewhat expensive.

Note: Many of the following protocols are written for a secondary level. Thus, effective application at the primary level will require some modification and simplification at the outset.

Preparing Soil Samples

Scientific Soil Protocols – Lesson 1

Use these steps to take soil samples from the soil study pit for later use when doing other protocols.

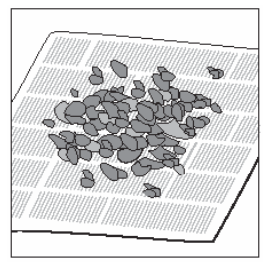
Materials / Preparations:

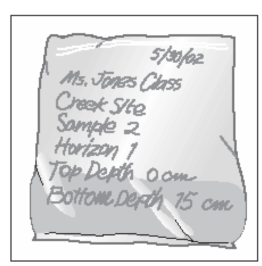
- ❑ A digging tool
- ❑ Plastic sacks to cover one's hands
- ❑ Soil sample bags or other container that can be sealed
- ❑ Marking system for the bags
- ❑ Some sheets of scrap paper
- ❑ A sieve that has a screen made out of 2 mm holes (No 10 screen)*

* *optional materials*

Steps:

1. Dig out a large soil sample from each soil horizon. Avoid the area of the soil face that was tested for carbonates and avoid touching the soil samples so that pH measurements will not be contaminated by acids on your skin.
2. Place each sample in a bag or other soil container.
3. Label each bag with the site name, horizon name, and top and bottom depths.
4. Bring these samples from the field and into the classroom or laboratory.
5. Spread the samples on separate paper plates or sheets of paper to dry in the air.
6. Put the #10 (2 mm openings) sieve on top of clean sheets of paper and pour the dry soil sample into sieve. Put plastic bags over your hands so the acids on your skin do not contaminate later measurements, like the soil pH measurement.
7. Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve or you may bend the wire mesh openings. Rocks will not pass through the mesh and will stay on top of the sieve. Remove the rocks (and other pieces of debris) from the sieve and discard. If no sieve is available, carefully remove the rocks and debris by hand (all objects over 2 mm in diameter).
8. Transfer the rock-free, dry soil from the paper under the sieve into new, clean, dry plastic bags or containers.
9. Seal the containers, and label them in the same way that they were labeled in the field (horizon name, top and bottom horizon depth, date, site name, site location). This is the soil that will be used for lab analyses.
10. Repeat steps 6-9 for all of the samples.
11. Store these samples in a safe, dry place until they are needed.





Measurement of Soil Infiltration Rate

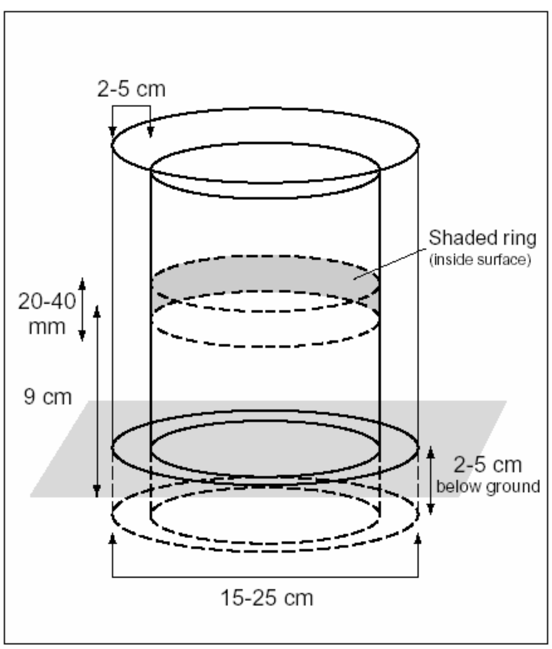
Scientific Soil Protocols – Lesson 2

Materials / Preparations:

- Two metallic cans, with one being 10 to 20 cm in diameter and the other 5-10 cm in diameter. When the smaller tube is placed inside the larger one, there should be a space of 2-5 cm separating the walls of the two. (Tomato paste cans (tins), Nescafé cans…)   (If need be, a tinsmith can make these cans for a nominal fee from scrap metal)
- Buckets or other containers to take at least 8L of water out to the study site
- Ruler
- Permanent marker or some paint
- Stopwatch or a watch with a second hand
- Block of wood
- Hammer
- A sealable container that is appropriate for the measurement of soil humidity if you are going to take soil humidity data
- Funnel
- 3 copies of Soil Infiltration Data Sheet *(below)*
- Students' GLOBE notebooks

Preparation of the Tubes

1. Cut out the bottom and the tops of the cans in order to form a cylinder.
2. Use a permanent marker or some paint to trace a timing ring on the inside of the small can. This circular band must be uniform in thickness and be 2-4 cm thick. The middle of this line must be located about 9 cm up from the bottom of the can. Some cans already have ribs in the can's shape that can help with timing, but it is nevertheless necessary to trace the timing band to avoid confusion.
3. Measure and record the width in mm of the timing band on the data sheet.
4. Measure and record the diameter in cm of both the internal and external cans on the data sheet.



Overview of the Study

1. Two concentric cans are sunken into the soil and water is poured into each of them to a depth of five centimeters. The time that it takes for the water level to descend a fixed distance of 2-4 cm is recorded and repeated. The infiltration speed indicates the ease in which water passes vertically through the soil and thus measures the risk of flooding in a given zone.

Frequency

1. Do this activity three or four times per year at the Soil Humidity Study Site.
2. Also, so this activity once at the Soil Characterization Study Site.
3. In all these cases, three measurements are taken, and all three should be taken within 5 m of one another.

Selecting Your Site

1. Choose a location for this measurement within 2-5 m of your Soil Humidity Study Site or your Soil Characterization Study Site.

Procedure for Infiltration Speed Measurement

1. Cut away any vegetation and remove any organic matter covering a zone slightly larger than the dimensions of the larger can. Try not to disturb the soil.
2. Starting with the larger can, sink the two cans 2-5cm into the soil using a twisting motion. Use a hammer if necessary, but place a block of wood between the metal and the hammer to lesson the shock. Avoid deforming the cans by hitting them too hard.
3. Measure the heights of the top and bottom of the timing band from the soil. Record these heights and complete the top part of the Soil Infiltration Data Sheet.

   Perform the following steps as quickly as possible with a team of 3 or 4 students:

4. Choose 5 students to be your assistants. One student will have the job of watch the timing belt on the inside of the can, one will be in charge of maintaining the water level of the outside of the can, one will watch the time, one will record data on the data sheet, and one will calculate the interval time based on the stop and start times. (See more details below.)
5. If you are using a stopwatch, start it now.
6. Have a student to pour water into each of the two cans just until the water level is above the timing line. Tell the student that is pouring to maintain the water in the outer ring at about the same height as the water in the inner ring without adding any water to the inner ring (The water in the inner ring should be allowed to go down naturally at its own pace). A funnel will help the student maintain the outer water level. Note that the water in the external ring drops faster than the inner ring.

   <u>Note</u>: The water must not come to the surface on the outside of the larger can. If this happens, re-sink the cans at a new location and sink the outer ring a little deeper than before or pack mud around the outer ring.

7. As the water in the internal can reaches the top of the timing line, look at the stopwatch or watch and note the time to the second. Record this value as the start time on the data sheet.
8. As the surface of the water reaches the bottom of the timing line, record the time to the second as the stop time on the data sheet.
9. Calculate this time interval by subtracting the start time from the stop time. Record this interval on a piece of scrap paper so you can keep track of the interval speeds.
10. Repeat steps 5-8 for 45 minutes or until two consecutive intervals are within 10 seconds of each other.

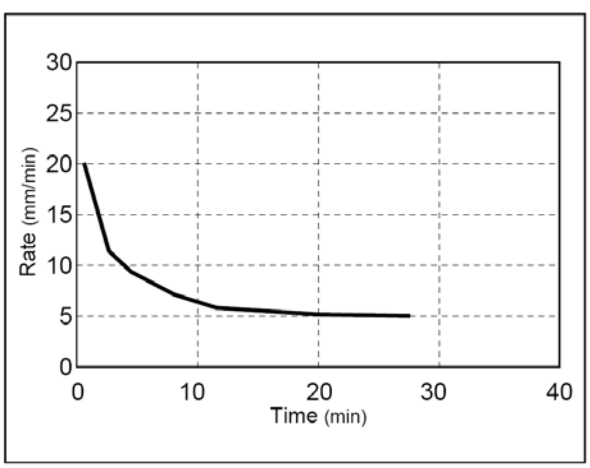
    <u>Note</u>: *Soils that are compacted or contain lots of clay will not allow water to pass through then and the water level in the cans will be almost unchanged during a 45 minute period. In this case, record the drop in the water level to the closest millimeter and record the stop time as the time that you stop your observations.*

11. If you have the means, measure the saturated soil water content of the top layer of the soil (the top 0-5 cm only) that was inside the two cans. Do this by removing the two rings and waiting five minutes before following the soil humidity procedures in Lesson 4, below (though it is only necessary to measure the humidity of one soil sample instead of three).
12. Repeat the soil infiltration measurements (steps 1-9) two more times within 5m of the first sample site.

    <u>Note</u>: *If you have three or more sets of cans, it is possible to do several measurements at the same time using three different groups of students. It is also possible to stretch these measurements out over several days as long as it does not rain between measurements. It is not necessary for all three measurements to have the same number of intervals, but do not submit incomplete trials (that is to say, sets of measurements that were interrupted due to a lack of time). If more than three sets of data are taken, submit the three best sets of data.*

Applications

1. After taking measurements, more advanced students can graph their data for the infiltration speed. See the graphing instructions inside the data sheet below. Here is an example graph from an exemplary set of data.



The value on the graph at which the curve flattens indicates the speed of infiltration of saturated soil at the site.

Following the infiltration speed measurements, you can measure soil humidity to show the level of water that can be held by saturated soil. *(Follow the procedures from the soil humidity activity, lesson 4 below.)*

Soil Infiltration Data Sheet

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection date: _____ Time: _____ (hours and minutes) check one: ❑ UT ❑ Local

Distance to Soil Moisture Site: _____ m

Sample set number: _______ Width of your reference (timing) band: _____mm

Diameter: Inner Ring: ______ cm Outer Ring: _______ cm

Heights of reference (timing) band above ground level: Upper: _____ mm Lower: _____mm

Directions:

Take 3 sets of infiltration rate measurements within a 5 m diameter area. Use a different data work sheet for each set. Each set consists of multiple timings of the same water level drop or change until 2 consecutive intervals are within 10 seconds of each other or 45 minutes is up. Record your data below for one set of infiltration measurements. The form below is set up to help you calculate the flow rate. For data analysis with elementary students, skip calculating F and H and plot Trial Number vs. Interval (E). For middle school students, plot the Flow Rate (H) on the y-axis vs. Midpoint Time (F) on the x-axis.

Observations:

Trial	A. Start time		B Start time converted into minutes	C End time		D End time converted into minutes	E Interval (min)	F Midpoint of each measurement (min)	G Water Level Change	H Flow Rate (mm/min)
#	(min)	(sec)	[min + (sec/60)]	(min)	(sec)	[min + (sec/60)]	(D-B)	$[B+(E/2)] - B_1$ *(for the 1st trial, B and B_1 are the same)*	Width of band (mm)	(G/E)
1			B_1:							
2										
3										
4										
5										
6										
7										
8										
9										

Saturated Soil Water Content below the Rings (test site) after the Experiment:

A. Wet Weight: _____ g B. Dry Weight: _____ g C. Water Weight (A-B): _____ g

D. Container Weight: _____ g E. Dry Soil Weight (B-D): _____ g

F. Soil Water Content (C/E) _________

Daily Metadata/Comments: (optional): ______________________________

Measuring Soil pH

Scientific Soil Protocol – Lesson 3

<u>Note</u>: Do this protocol once for each horizon in each soil study pit that is done.

Materials / Preparations:

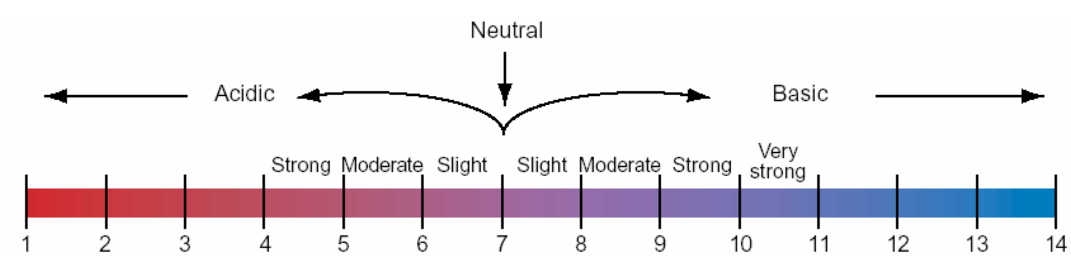
- Soil sample that has been dried and sieved
- About 1L of distilled water*
- 100 ml graduated cylinder
- Four clean containers of about 100 ml in volume
- An equal arm balance from a merchant or an electronic balance.
- The Soil pH Data Sheet (below)
- A clean spoon
- A pH meter or pH paper
- Students' GLOBE notebooks

***<u>Note</u>**: In Niger, the round bottles labeled distilled water from Côte d'Ivoire are not distilled water and are less pure than the tap water here. Also, the battery shops in Niamey claiming to have distilled water actually only have filtered water from the Caterpillar machine shop. The only true distilled water that we have identified in Niger is the locally made distilled water from CNES (20.72.39.23) in the square plastic bottles. The Total gas stations around town usually carry CNES distilled water but the OiLibya stations do not.*

Lesson Plan:

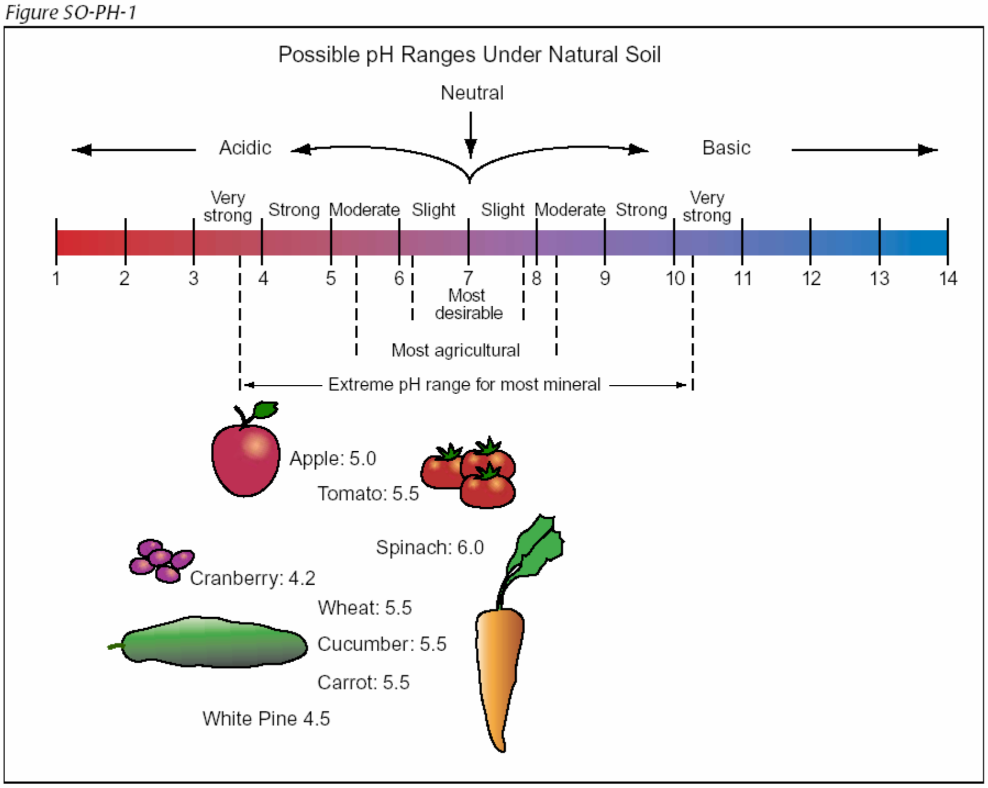
Explaining pH to the Students

1. Explain that all liquids are acidic, basic, or neutral. Pure water is neutral.
2. Give the students the following definition of pH: **<u>pH</u>** is a measurement that allows us to say whether a liquid is acidic, basic, or neutral.
3. The pH Scale ranges from 1 to 14 on a number line. Therefore, 7 (the pH of pure water) is in the center and is considered neutral. pH readings between 1 and 7 are called **<u>acidic</u>** with 1 being the strongest acid. pH concentrations between 7 and 14 are **<u>basic</u>** with 14 being the strongest base.
4. Draw the following number line on the board to help the students understand the idea of the pH scale:



5. Acids and bases have many varied and different uses. For example, many bases are used as solvents or in soaps for cleaning. Acids in our stomachs break up the food that we eat so we can absorb all of the nutrients out of the food and into our bodies.
6. If you have an upset stomach or heartburn, a glass of milk can help calm it. This is because milk is a base and it **neutralizes** (cancels out) the acids in your stomach to stop the burning.
7. So, it is important for us to know if a liquid is acidic or basic because this can help us know how to use it. We measure pH using pH paper or a pH meter.
    a. **pH paper** is chemically treated paper that undergoes a chemical reaction when it comes into contact with an acid or base. This reaction changes the color of the paper. By matching up the color change of the paper with a scale, we are able to know the pH of a liquid.
    b. A **pH meter** is a piece of electronic equipment that has two probes. When these two probes are placed into a liquid, they are able to measure the pH using electricity and then display the pH on a screen so we can read it.
8. The figure below shows the normal pH range of most soils (between 4 and 10), the range of agricultural soils (between 5 and 9), the ideal pH range for soils (between 6 and 8), and the pH of several vegetables.

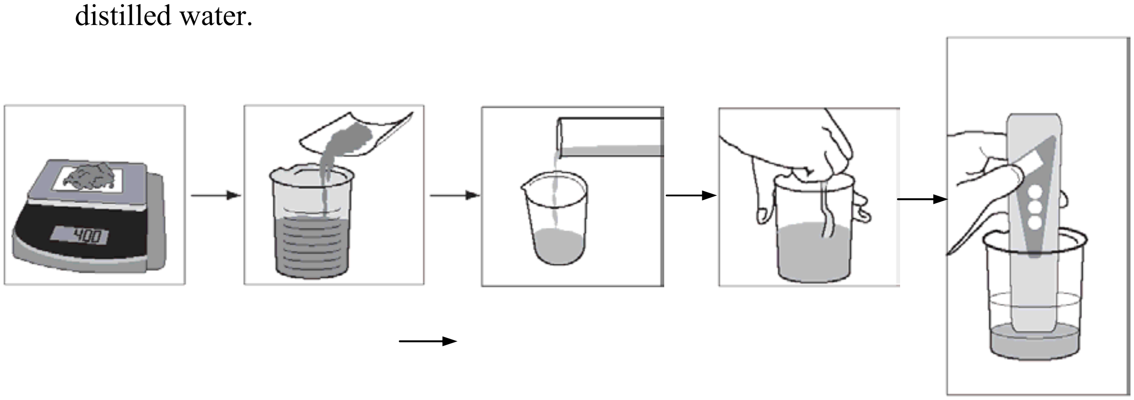
Figure SO-PH-1



Steps of the Process

<u>Note</u>: Do not touch the soil or the water with your hands.

1. In a clean cup that has been rinsed with distilled water, measure the pH of the distilled water that you are going to use.
    a. Put the pH meter (that has just been calibrated with a standard solution) in the water and record the number that appears on the screen
    b. Or dip a strip of pH paper in the water with the use of tweezers. Remove the paper after a minute and compare its color with the scale on the pH paper container.
    c. Record the pH of the distilled water on the data sheet.
2. In a clean cup that has been rinsed with distilled water, mix the dry and sieved soil with some distilled water following these steps:
    a. Using an electronic balance
        i. Mass 40 g grams of soil with the balance.
        ii. Wear clean bags on your hands if you need to manipulate the soil.
        iii. Put the soil in a clean cup. Ensure that you do not let any soil fall outside of the recipient.
        iv. Measure out 40 ml of water using the graduated cylinder and add it to the soil in the cup.
    b. With an equal arm balance
        i. Take two clean containers of the same dimensions and rinse them with distilled water. Once they are dry, place one on each tray of the balance. Add sand as necessary to one tray (not in the container) in order to balance the two.
        ii. Place some distilled water in one of the containers and then enough of the soil sample into the other container to balance out the water.
        iii. Remove the two containers from the balance and pour the water into the container containing the soil.
3. Mix the soil and the water with a clean spoon that has been rinsed with distilled water for thirty seconds. Then let the mixture rest for three minutes. Repeat these two actions (Mix and Let Rest) four more times.
4. Let the mixture rest for another five minutes so that the water has a chance to become less cloudy.
5. Measure the pH of the water in the mixture with a pH meter or pH paper.
    a. Do not dip the meter or the paper into the soil in the bottom of the cup! Hold it in the water above the mud.
6. Repeat steps 2-6 another two times for the same horizon.
7. Before continuing to the next horizon, rinse the spoon and the containers with some distilled water.



Soil pH Data Sheet

Date of sample collection: _________________

Study Site: ________________________

Horizon Number: ___________ Horizon Depth: Top _____cm, Bottom _____cm

Sample Number 1 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 2 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 3 - *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Horizon Number: ___________ Horizon Depth: Top _____cm, Bottom _____cm

Sample Number 1 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 2 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 3 - *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Horizon Number: ___________ Horizon Depth: Top _____cm, Bottom _____cm

Sample Number 1 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 2 – *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture _____

Sample Number 3 - *pH Measurement method (check one):* ❒ *paper* ❒ *meter*

A. pH of water before adding soil _____ B. pH of soil and water mixture ____

Measuring Soil Temperature

Scientific Soil Protocol – Lesson 4

Note: Use this protocol to take the temperature of the soil at depths of 5 and 10 centimeters at least one time per week. Also, take the temperature five times during two consecutive days every three months. All of this data is sent to the GLOBE Program. If you have a digital thermometer with a soil sensor, you are already taking the soil temperature at 10 cm.

Note: In order for this data to be interesting to scientists, data should be taken regularly over a long period of time.

Materials / Preparations:

- Soil thermometer with two lines traced on its wand, one at 7 cm and one at 12 cm from its tip
- A nail that is at least 12 cm in length also with lines traced at 7 cm and at 12 cm from its tip. The diameter of this nail should not overly exceed the diameter of the thermometer's wand.
- A hammer or a rock to push the nail into the soil
- About 20 cm of small PCV or plastic pipe or another material that can be used to form two spacers with lengths of 7 cm and 12 cm respectively. These will slide over the wand of the thermometer to ensure that the students take the temperature at the correct depth.
- The Soil Temperature Data Sheet (below)
- Calibration thermometer
- 500 ml container
- Permanent marker
- Students' GLOBE notebooks

Preparations Before Going to the Study Site:

Calibration of the Soil Thermometer

Note: You will need the calibration thermometer, a wrench if you have an adjustable soil thermometer, a container of at least 500 ml, and some water.

1. Put about 250 ml of water in a 500 ml container.
2. Place the calibration thermometer and the soil thermometer in the water.
3. Verify that the lower four centimeters of both thermometers are covered by water. Add more water if necessary.
4. Wait two minutes.
5. Take the temperature of each thermometer.
6. If the difference between the two thermometers is less than 2˚C, the thermometer is calibrated and you may continue on with the experiment.
7. If the difference is larger than 2˚C, wait another two minutes.
8. If the difference between the two thermometers is still greater than 2˚C, adjust the soil thermometer by turning the nut on the base of the dial with a wrench (if there is one) until the soil thermometer reading matches that of the calibration thermometer.

Making Spacers to Control the Depth of the Thermometer in the Soil

1. Measure 7 cm from the tip of the soil thermometer and mark this point on the thermometer with a permanent marker.

   Note: *Use 7 cm instead of 5 cm because the sensor of the soil thermometer is usually 2 cm up from its tip in order to protect it.*

2. Measure the distance between the base of the dial and the 7 cm mark. Make a spacer by cutting a piece of plastic pipe or wood to this length. (If you use wood, drill a hole through the wood to permit the passage of the thermometer.)
3. Insert the soil thermometer through the spacer. Seven centimeters of the thermometer should be sticking out of the end of the spacer.
4. Label this spacer, "Spacer for the 5 cm measurement".
5. Repeat steps 1-5 with the longer spacer while at the same time replacing the measurements in the instructions as follows: **7 cm** for **12 cm** and **5 cm** for **10 cm**.

Choosing a Study Site

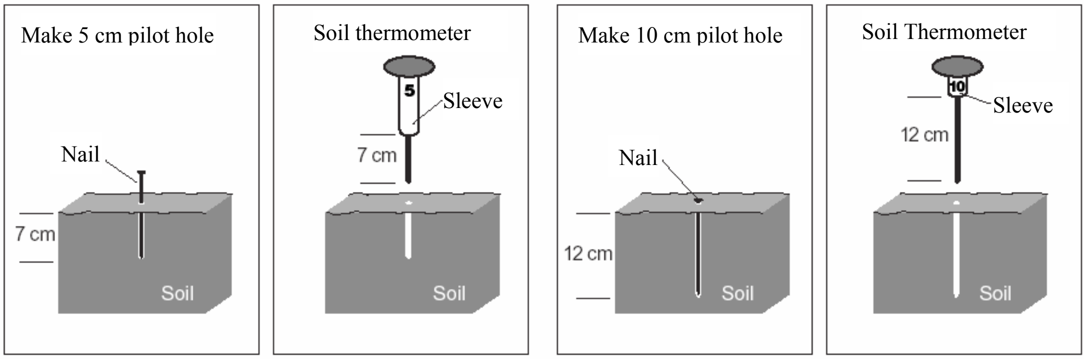
1. Choose a site near the Atmospheric Study Site or the Soil Humidity Study Site if you have one.
2. The site must be open, lit by the sun almost all day, and covered by a representative vegetation (or lack thereof) of the study site.

Lesson Plan:

Teaching the Students About Soil Temperature

1. Explain to the students that as scientists take air temperature readings every day, they also take soil temperature readings as well.
2. Ask them to propose several ideas about why it is important to know soil temperatures.
3. After taking some ideas, explain to the students that the temperature has many effects on both living and non living things. For example:
   a. Temperature affects the time that trees bud and the speed at which plants grow.
   b. Temperature regulates animals' lives that live in the soil such as
      - The emergence of insects from the soil
      - Reproduction times of animals
   c. Temperature affects the amount of decomposition in the soil
   d. Temperature affects the amount of water in the soil; especially within the first several centimeters, the layer from which many crops draw their water.
   e. Extreme heating of the soil creates the production of lots of iron oxides that turn into laterite, a dominant soil of the Sahel.
   f. Scientists use soil temperature to regulate the application of pesticides, the prediction of global warming and the monitoring of its effects, identification of ideal planting time, etc.
4. Explain that we are going to take soil temperatures using a soil thermometer one day a week at the same time each day. Also, we will take multiple measurements during two consecutive days once every three months.

How to Take Measurements Once per Week (or Once per Day)



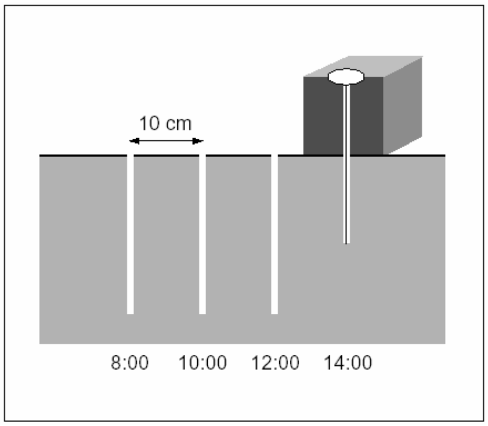
1. Go out to the study site with the Soil Temperature Data Sheet, a GLOBE notebook, the two spacers, and the soil thermometer.
2. Locate the sample site.
3. Use the marked nail to make a 5 cm deep hole into the soil. If the soil is very hard, use a hammer to make the hole 7 cm deep. Carefully remove the nail and try not to disturb the soil. If the soil cracks or buckles, thus permitting air to penetrate the soil, try once again to make an intact hole 25 cm from your first try.
4. Insert the thermometer in its spacer for a 5 cm measurement.
5. Gently push the thermometer into the hole in the soil until the spacer touches both the soil and the base of the dial.
6. Wait two minutes. Read the soil temperature on the dial and record this value in the GLOBE notebook.
7. Wait another minute. Take the temperature a second time and record it too in the GLOBE notebook.
8. If the two temperatures are less than 1.0˚C apart, record the value on the Soil Temperature Data Sheet as “Sample 1: 5 cm”. If the two temperatures are not within 1.0˚C of one another, continue to take the temperature in the GLOBE notebook every minute until two consecutive measurements are within 1.0˚C and then record this temperature on the data sheet.
9. Remove the thermometer from the soil.
10. Use the nail to deepen the hole to a depth of 12 cm.
11. Replace the spacer for the 5 cm measurement with that for the 10 cm measurement. Insert the thermometer into the hole once again until the spacer touches both the bottom of the dial and the soil at the same time.
12. Wait two minutes. Read the soil temperature on the dial and record this value in the GLOBE notebook.
13. Wait another minute. Take the temperature a second time and record it too in the GLOBE notebook.
14. If the two temperatures are less than 1.0˚C apart, record the value on the Soil Temperature Data Sheet as “Sample 1: 5 cm”. If the two temperatures are not within 1.0˚C of one another, continue to take the temperature in the GLOBE notebook every minute until two consecutive measurements are within 1.0˚C and then record this temperature on the data sheet.
15. Repeat steps 2-14 for two more holes located 25 cm from the first hole. Record this data on the data sheet as Samples 2 and 3.

<u>Note</u>: *These six samplings must be done within 20 minutes from start to finish.*

16. Wipe clean the thermometer and other apparatus.
17. Read and record the current air temperature from a thermometer in an instrument shelter (or if absolutely necessary, from a calibration thermometer that has been hanging for at least 30 minutes from a tree far from the trunk, in the shade, and at least 1.5 m above the ground).

Measure the Temperature for Two Consecutive Days Once Every Three Months

1. Go out to the study site with the Soil Temperature Data Sheet, a GLOBE notebook, the two spacers, and the soil thermometer. Fill out the upper portion of the data sheet.
2. Locate the Sampling Site. Make sure that you have enough space to make several measurements ten centimeters apart in a straight line.



3. Follow steps **3-14** from the "How to Take Measurements Once per Week" above, but this time make the holes 10 cm apart in a straight line.
   a. Repeat every 2 or 3 hours for at least five rounds.
   b. Repeat this process the following day.

Applying the Data in the Classroom

1. In addition to sending this data to the GLOBE Program, you can also use them in the classroom with your students.
2. Ask your students to make a graph of the data taken during two days of measurements (both air and soil)
   a. Ask the students, "What explains the form of the curve of the soil data?
   b. Is there a difference in shape between the soil and the air curves?
   c. Why are the soil temperatures less varied when compared to the air temperatures?
   d. Other questions…
3. Ask the students to make a graph of the soil data from several months.
   a. Ask the students, "Why are the air and soil temperatures changing over the months?
   b. Other questions…
4. Do the graphing lessons from the Atmosphere Section of this book with the students if you have not already done so, skipping over the parts that correspond directly with the atmosphere study.

Soil Temperature Data Sheet

Study Site: ____

Name of Collector/Analyst/Recorder: ____

Date: _______ Soil Thermometer: Dial ______ Digital ______ Other _____

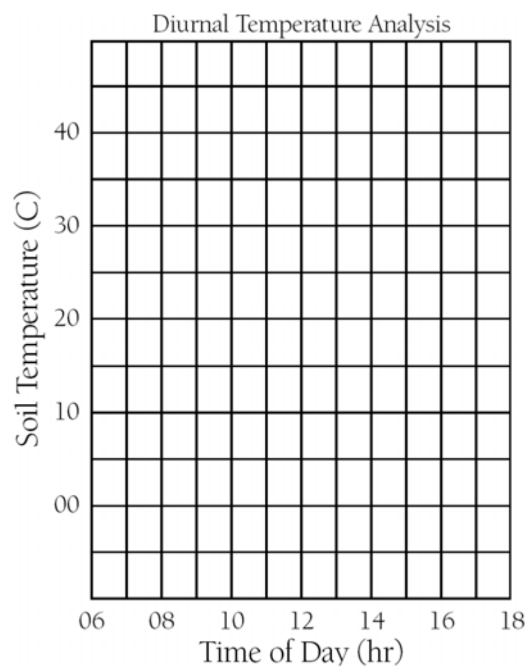
Has there been precipitation within the last 24 hours? Yes _____ No _____

Daily/Weekly Measurements

Sample No.	Local Time	Universal Time	Temp (5 cm) (ºC)	Temp (10 cm) (ºC)
1				
2				
3				

Diurnal/Cycle Measurements

Sample No.	Local Time	Univ. Time	Temp (5 cm) (ºC)	Temp (10 cm) (ºC)
1				
2				
3				
4				
5				
6				
7				
8				



Measuring Soil Humidity

Scientific Soil Protocol – Lesson 5

Note: This protocol is done one time per month at your study site including one time during the first two weeks in October and again during the fourth week in April. These last two periods are fixed for all GLOBE schools so GLOBE scientists can have a global set of data for a fixed period.

Materials / Preparations:

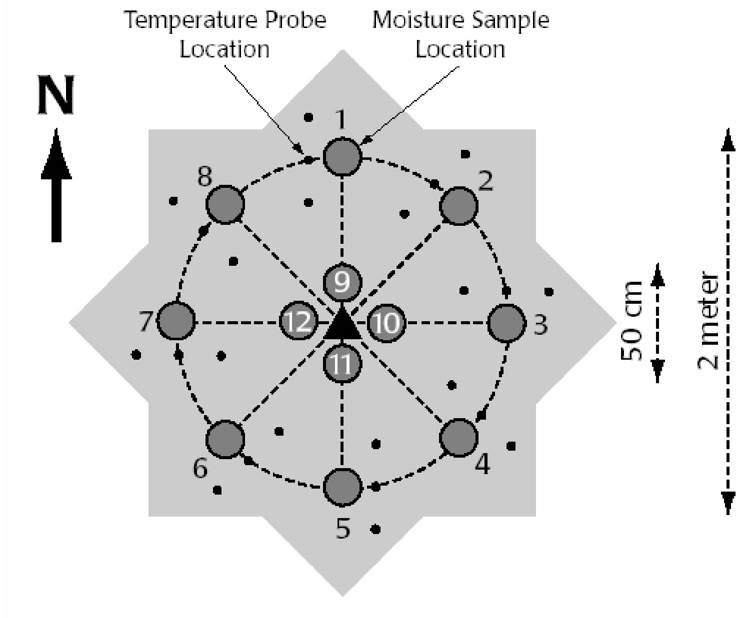
- Electronic balance with a sensitivity of 0.1 g, batteries, and a minimal capacity of 400 g
- A drying box: a black cardboard box or a box made out of black plastic that is well-ventilated and large enough to contain 14 small mayonnaise jars (*see instructions below*)
- 13 small mayonnaise jars with lids
- Ruler with a scale in millimeters
- A system for labeling the jars (permanent marker)
- Tools for digging up the soil
- Soil Moisture Site Definition Sheet *(below)*
- Soil Moisture Data Sheet - Star Pattern or Soil Moisture Data Sheet - Transect Patter *(below)*

Transect Method

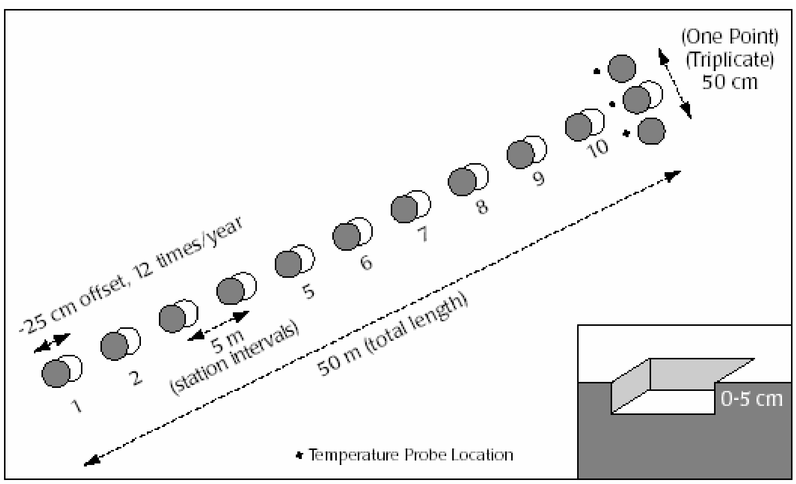
- A 50 m measuring tape or a 50 m long rope with a meter stick

Choose and Set up a Method of Sampling: Star or Transect

1. These two sampling methods exist to avoid digging a sample hole in the same place two times. A new site must be measured each time. Choose the one that best fits the needs and set-up of your school.
2. The star method is good for schools that have less space and less time. *(See image below)*.
   a. With the aid of a meter stick and a compass (optional), trace a circle that is 2 m in diameter. Mark the four cardinal points on the circle (north, south, east, and west) and place a marker in the center of the circle.
   b. Then, place four other points between the cardinal points. Then mark four points 25 cm along the cardinal axes from the center.
   c. You now have 12 measurement sites, one for each month of the year.
   d. Each year, select a new central marker within 10 m of the previous star and repeat these steps.



3. The transect (line) method helps scientists to calibrate instruments on satellites that also measure soil humidity.



   a. Lay out a 50 m transect in an open area. If possible, set up this line within 100 m of a rain gauge.
   b. Once each month, you will measure the soil humidity every 5 m along this line for a total of 13 measurements.
   c. Install a flag or another permanent marker at the ends of the transect and mark each of the sample points along the line using a ruler, a knotted rope, or another method.
   d. The orientation of the line is not important, but record it anyway on the data collection sheets.
   e. During each successive measurement cycle (the following month), move each sampling point 25 cm down the line from the last set of samples in order to avoid taking a sample from the same place twice.
4. Set up the study site for your school with or without the aid of your students before starting to teach this protocol in the classroom.

Build a Drying Box

1. To dry the soil samples, you will need a drying box
2. Build a square wooden frame that can accommodate all of the samples in their jars (6 or 13 jars depending on the method that you choose).
3. Cover the frame, other than its bottom, with a sheet of black plastic in which many ventilation holes have been cut
4. Use a plank of wood or a sheet of metal as a base for the box. The base is unimportant as long as the ensemble can be set up on rocks or another platform so it does not sit on the ground.

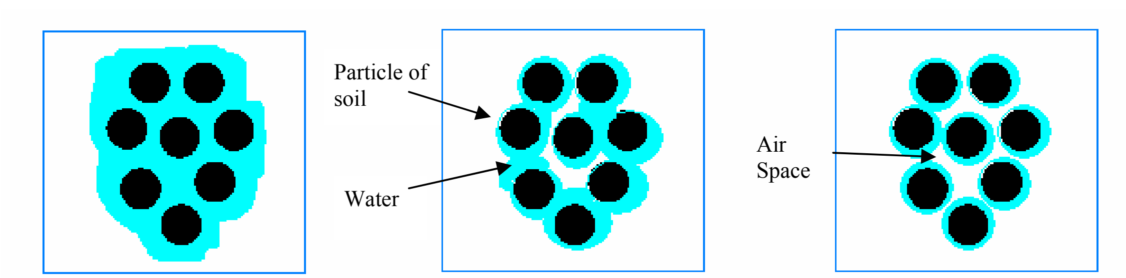
Describe the GLOBE Study Site

1. Go out to the study site with a copy of the Soil Moisture Site Definition Sheet and the instruments needed to fill it out.
2. Fill out the data sheet. If possible, include the students in this process.

Lesson Plan:

Introduction to Soil Humidity

1. The soil acts as a sponge laid across the surface of the Earth for rainstorms and other forms of precipitation. The absorbed water is held on the surfaces of the soil particles and within the spaces between the particles.



Saturated Soil: Water fills all spaces between the particles and plants have an easy time absorbing the water from the soil. Usually occurs only after a rain.
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Moist Soil: Water clings to the particles but there is also air in the soil. Plants can easily obtain water in this situation.

Dry soil: Water clings tightly to the surface of the soil particles and plants cannot absorb this water. This is past the wilting point for a plant.

Why Soil Humidity Changes

1. Plants draw their water to live from these spaces during periods of little rainfall. For example: millet can pull its water from the soil for over a week after a rainstorm before it starts to lack water.
2. Water also evaporates into the atmosphere.
3. Water also runs through the soil to become ground water. This water, deep in the Earth, feeds trees, bushes, and wells during the dry season.
   a. Soils that are saturated are holding all the water that they can and do not have any space to accept any more water. So, excess water flows over the surface of the Earth as rivers or floods.

Explaining Why This Study is Important

1. We measure soil humidity in order to understand the ability of the soil to moderate the water cycle.
2. We will also help scientists to understand the cycle of how much water is stored in the soil over the course of a year.
3. Finally, we will help scientists to calibrate their satellites through our transect sampling.

***First Step*: Describing the Procedure for Sampling by the Star Method or the Transect Method**

Helpful Hints for Both Sampling Methods

1. Label and weigh the jars before going out to the study site in order to not confuse them later.
2. **Important**: Take the mass (to the nearest 0.1 g) of each empty and labeled jar without its lid before placing soil in them. These will be used during the calculations at the end of the session.
3. For all the data collection, work quickly so that water is not lost through evaporation and heating by the sun.
4. If possible, weigh the samples an initial time at the sampling site.
5. Take the three samples from a sample site within 25 cm of each other.
6. Close the sample jars each night and during dust storms to avoid the addition of dust into the samples. This would result in an increase of the sample weight.

Procedure for Taking Samples in the Star Pattern

1. Complete the upper portion of the Soil Moisture Data Sheet- Star Pattern and verify that the mass of the empty jars is known and recorded on the data sheet.
2. Locate your sampling point on the star and cut or pull away any grass or groundcover.
3. Dig a hole that is 10-15 cm in diameter and 5 cm deep at the sample site. Leave the soil loose in the hole.
4. Remove from the loose soil any rocks larger than a pea (about 5 mm in diameter), large roots, worms, grubs, and other animals.
5. Use your trowel to fill a soil container (small mayonnaise jar) with at least 100 g of the loose soil.
6. Immediately seal the container to hold in the moisture.
7. Record the container mass and number on the data sheet next to Sample 1: 0-5 cm.
8. Remove all of the soil from the hole down to a depth of 8 cm.
9. In a clean container, collect a soil sample that contains the soil between 8 and 12 cm. Remember to remove rocks, large roots, and animals. Seal the container.
10. Record the container mass and number on the data sheet next to Sample 1: 10 cm.
11. Return remaining soil to the hole.
12. Repeat steps 3 – 11 twice in new holes within 25 cm of the original sample point filling the other four cans and recording the container numbers and masses for samples 2 and 3 at both depths. You should have six containers of soil taken from three holes.
13. Return to the classroom with the soil samples to continue this protocol.

Procedure for Sampling along the Transect

1. Complete the top part of the Soil Moisture Data Sheet - Transect Pattern.
2. Stretch out the tape measure or the knotted rope along the transect.
3. Locate the first sampling point along the transect. Sample points must fall every 5 m along the transect plus two additional samples 25 cm from one end of the transect.
4. Cut or pull away any grass or groundcover.
5. Dig a hole that is 10-15 cm in diameter and 5 cm deep at the sample site. Leave the soil loose in the hole.
6. Remove from the loose soil any rocks larger than a pea (about 5 mm in diameter), large roots, worms, grubs, and other animals.
7. Use your trowel to fill a soil container (small mayonnaise jar) with at least 100 g of the loose soil.
8. Immediately seal the container to hold in the moisture.
9. Record the sample number of the jar on the data sheet next to the appropriate sample number.
10. Continue taking samples at each sample point along the transect repeating steps 4-9. Remember to take two additional samples 25 cm on each side of the last sample site on the transect.

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Second Step: Description of the Procedure in the Classroom for the Collected Samples

1. Explain to the students the following steps:
    1. Verify that the balance is calibrated and is measuring in grams.
    2. Remove the lid of the sample container.
    3. Weigh the jar and its soil without the lid. Record the mass to the nearest 0.1g as the humid mass of that jar on the data sheet
    4. Repeat steps 2 and 3 for all the other soil samples.
    5. Transfer all of the samples in their jars to the drying box.
        a. Place the samples in their jars on the base of the drying box and cover them with the plastic frame.
        b. Put the box in the sun, preferably during the dry season or several days after a rain.

        Note: During the rainy season, the samples may not dry in the sunlight alone. In order to facilitate drying speeds, place the jars next to or even on (but not in) a traditional oven made from mud bricks. But be careful, the jars need to be warm (near 37˚), but not hot enough to burn in order to avoid burning the organic matter in the sample and loosing mass in this way. If you have access to a microwave, it can also be used to dry the samples, but seek the advice and the instructions for this from a GLOBE Representative or the GLOBE Website.

        c. Keep the samples in the sun during the entire day. After 6 hours of time and then again after 8 hours of time, weigh a sample and note the mass on a scrap of paper.
            - At the end of the day, as the sun is lessening, verify that the sample is still warm and weigh it once again.
            - If there is not a difference between this last mass and those before it, the sample is dry. Record this mass as the dry mass of the sample.

- If there is a difference in the masses, the sample is not yet dry. Close the jar overnight and place the jars in the drying box once again the next day. Weigh the sample every two hours during the day until two consecutive masses are the same. At that time, record that mass as the dry sample mass.

d. Once all of the samples are dried and massed, empty the soil from the jars and wash and dry them in preparation for the next sampling cycle.

2. It might be a good idea to practice the preceding steps with the students before going out to collect samples at the study site.

3. Calculate the soil water content with the students from the collected data.
   1. Definition: **Soil Water Content** is the measurement of the amount of water that exists in a soil sample.
      It is defined by the following equation:

      $$\text{Soil Water Content} = \frac{(\text{Wet mass} - \text{Dry mass})}{(\text{Dry mass} - \text{Mass of the jar})}$$

   2. Calculate the soil water content for each sample with the students.
      a. Normally, soil water content is between 0.05 grams of water/1 gram of soil
   3. Pose the following questions along with others to the students in order to help them understand what the data is showing:
      a. Why is there more water in the samples from 10 cm as opposed to those taken from 5 cm?
      b. Why is there a difference in soil water content values along the transect?
      c. Why is there a difference between the average of the data this month and the average of the data from three months ago? What are some factors that could account for this change?
      d. Other questions…

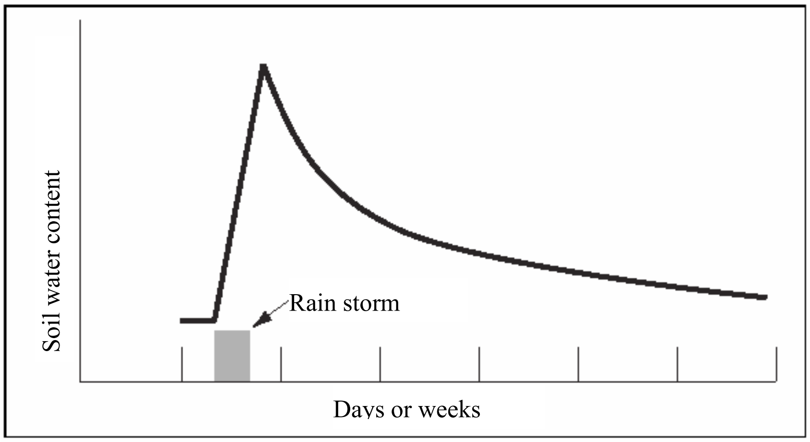
4. Once you have completed these measurements and calculations, send the data to the GLOBE Program.

Other Study Possibilities:

Rainfall

1. Take samples in a star pattern separate from the monthly star during the seven days following a rain and just before the start of the next rain. This will teach the students that the water level in the soil changes rapidly after a storm.

Example of Expected Results:



2. In doing this study in conjunction with the observation of some millet plants, you can have an idea of the wilting point of millet.
   a. Def.: The **wilting point** is the moment after a rainstorm where the particles of soil hold the water left in the soil so tightly that the plants cannot absorb any more.
   b. Watch a set of millet plants at the same time you are taking soil humidity data and note the moment that it starts to wilt. Then, in finding this time on a graph of soil water content that you have put together from your data, it is possible to identify the minimum soil water content for millet to live.

Sampling Horizons

1. Take samples from each layer in the soil pit and calculate soil water content so that the students can see the change in soil water content between horizons. Often the horizon containing the most roots has the highest soil water content and that horizon is sitting on a compact layer that water has difficulty passing through.

Soil Moisture Site Definition Sheet

Study Site: SMS-_____________

Directions from School: ____

____

Location: Latitude: ____________° ❒ N or ❒ S Longitude: ____________° ❒ E or ❒ W

Elevation: _____ meters

Source of Location Data (check one): ❒ GPS ❒ Other ______________________________

Distance to nearest rain gauge or instrument shelter: _________ m; Direction _______

Distance to nearest Soil Characterization Sample Site: _________ m; Direction _______

State of Soil Moisture Study Site:
❒ Natural ❒ Plowed ❒ Graded ❒ Backfill ❒ Compacted ❒ Other _____________

Surface Cover:
❒ Bare Soil ❒ Short grass (<10 cm) ❒ Long grass (10 cm) ❒ Other _____________

Canopy Cover:
❒ Open ❒ Some Trees within 30 m ❒ Canopy Overhead
Structures within 30 m: ❒ No ❒ Yes (describe size) ________________________

Soil Characterization: *(Take these values from the Soil Characterization Data Work Sheet for the nearest Soil Characterization Sample Site.)*

	0-5 cm	**10 cm**	**30 cm**	**60cm**	**90 cm**
Structure					
Color					
Consistence					
Texture					
Rocks					
Roots					
Carbonates					
Bulk Density					

Soil Particle Size Distribution:

	0-5 cm	**10 cm**	**30 cm**	**60 cm**	**90 cm**
% Sand					
% Silt					
% Clay					

Soil Moisture Data Sheet
- Star Pattern

Study Site: SMS-________________

Name of Collector/Analyst/Recorder: ____

Sample collection date: _______

Local Time (Hours: Min): _______ Universal Time: ________

Current Conditions: Is soil saturated? ❐ Yes ❐ No

Drying Method: ❐ in the sun ❐ 95-105° C oven ❐ 75-95° C oven ❐ microwave

Average Drying Time: _________ (hours or minutes)

Bearing from Star Center (optional): ________ Distance from Star Center: ________

Observations: ____

____

____

Near-Surface Samples:

Sample Number	Sample Depth	Container Number	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-C)	D. Container Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)
1.	0-5 cm							
	10 cm							
2.	0-5 cm							
	10 cm							
3.	0-5 cm							
	10 cm							

Soil Moisture Data Sheet
- Transect Pattern

Study Site: SMS-________________

Name of Collector/Analyst/Recorder: ____

Sample collection date: _______

Local Time (Hours: Min): ______ Universal Time: ______

Current Conditions: Is soil saturated? ❒ Yes ❒ No

Drying Method: ❒ in the sun ❒95-105° C oven ❒ 75-95° C oven ❒ microwave

Average Drying Time: _________ (hours or minutes)

Daily Metadata: (optional)

Length of Line: ________ m Compass Bearing: ______ Station Spacing: _____ m

Directions:

Transects should be 50 m long, located in an open field. Measurements are made 12 times/yr. during a regular interval of your choice. Enter the data for your samples collected between 0-5 cm (10 single samples plus 1 triple sample):

Sample Number	Offset from end of Transect (m)	Container Number	A. Wet Weight (g)	B. Dry Weight (g)	C. Water Weight (A-C)	D. Container Weight (g)	E. Dry Soil Weight (B-D)	F. Soil Water Content (C/E)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								

Soil Particle Size Distribution

Scientific Soil Protocols – Lesson 6

Note: This protocol is done once for each type of soil or for each horizon in the soil pit. This is a very interesting protocol as it identifies the type of soil that exists in a locale. However, it takes at least six days to test each soil sample (two days for each of three trials). If you have time and the means, it is worthwhile.

Materials / Preparations:

- Dried and sieved soil sample
- 500 ml graduated cylinder
- Distilled water *(in Niger, the square plastic bottles made by CNES are best)*
- A one liter bottle with a lid
- Some detergent soap that is non foaming and that contains both sodium and phosphates
- Spoon
- A container with a volume of at least 250 ml
- Calibration thermometer
- Hydrometer (may be available locally)
- 100 ml graduated cylinder
- Meter stick
- A clean plastic bag and a rubber band to seal the 500 ml graduated cylinder while shaking it
- Electronic balance or another balance capable of accurately massing 25 g.
- Soil Particle Size Distribution Data Sheet *(below)*

Lesson Plan:

Explain the Study to the Students

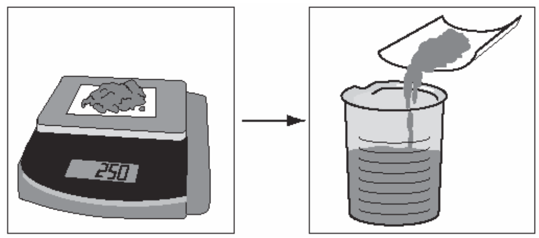
1. The amount of each particle (sand, silt, clay) in a soil is called the **soil particle size distribution** of that soil.
2. The textural characterization that we did before in the soil pit is only an estimation of the particle amounts. This protocol permits us to know exactly the values of each type of soil in our surroundings.
3. Remember that sand is the largest particle size (2.0 mm-0.05 mm in diameter), silt is the medium (0.05-0.002 mm in diameter), and clay is the smallest (<0.002 mm in diameter). Particles that are larger than 2 mm in diameter are considered rocks and are not counted as part of the soil itself.
4. When a sample of soil is suspended in water, the large, heavy particles settle first. When a soil sample is shaken, the particles of sand settle after two minutes, but the particles of silt and clay are still in suspension. After 24 hours, the particles of silt have also settled, leaving only the particles of clay in suspension.
5. In using some measurements from the sample suspended in water along with some tables, the exact percentages of each particle in the sample can be calculated.

6. We will take measurements of the suspension with a hydrometer. A **hydrometer** is an instrument that measures the relative density of a liquid.
    a. Def.: The **relative density** is a ratio which describes the mass of a liquid relative to the mass of an identical volume of water. The relative density of pure water is 1 but once you add soil to water, the relative density of the solution increases.

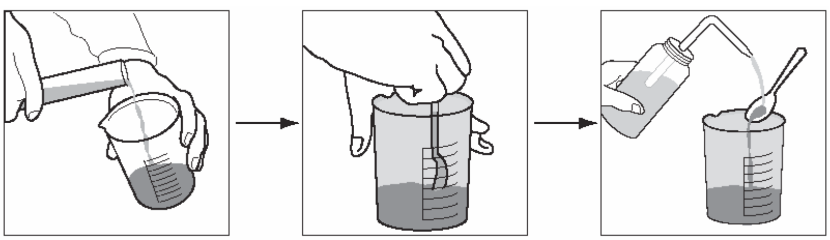
The Steps of the Process (During Three Class Periods)

1. Prepare a dispersing solution by mixing 50 g of non foaming detergent (or sodium hexametaphosphate) into one liter of distilled water. Stir or shake until all of the solids are dissolved.

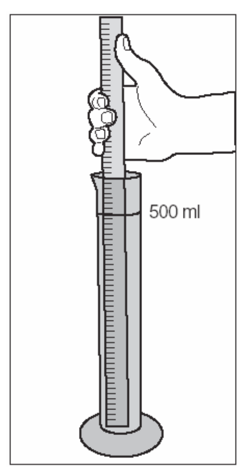
2. Weigh 25 g of dried, sieved soil and pour it into a 250 ml or larger container.



3. Add 100 ml of the dispersing solution and 50 ml of distilled water to the beaker. Stir vigorously with a spoon or stirring rod for at least one minute. Be sure the soil is thoroughly mixed and does not stick to the bottom of the beaker. Do not let any of the soil suspension spill out of the top. Rinse any soil off the spoon or stirring rod into the container using a little distilled water.

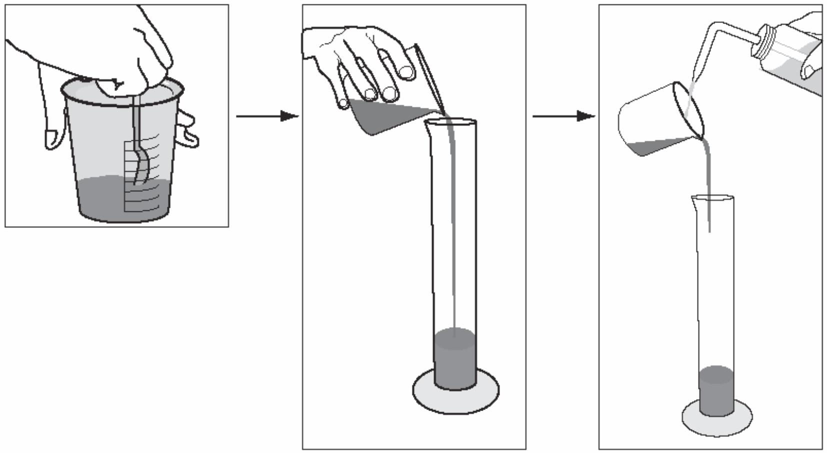


4. While the solution is resting, place a meter stick into the 500 ml graduated cylinder and measure the distance between its bottom and the 500 ml mark. Also, note the calibration temperature that is indicated on your hydrometer (15.6 or 20˚C).

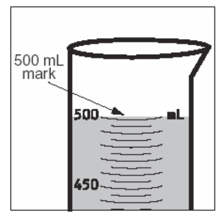


5. Complete the top section of the Soil Particle Size Distribution Data Sheet.

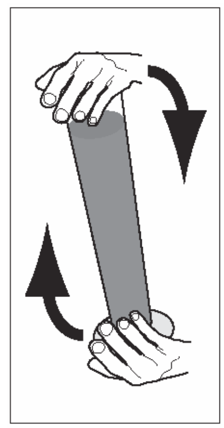
6. After at least 24 hours, stir the suspension in the container and pour it into the 500 ml graduated cylinder. Use some distilled water to rinse all of the soil out of the container and into the graduated cylinder.



7. Add enough distilled water to fill the graduated cylinder to its 500 ml mark.

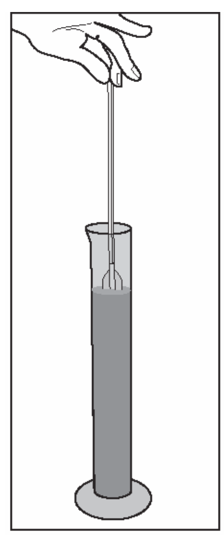


8. Seal the top of the cylinder with a new plastic bag and a rubber band or another appropriate method. Place your hand over the opening to the cylinder and mix the soil suspension vigorously by rotating the covered cylinder hand over hand at least ten times. Be sure that the soil is thoroughly mixed in the suspension and that no soil is sticking to the bottom of the cylinder. Also, try not to let any of the soil suspension leak out of the top of the cylinder.



9. Gently set the cylinder down in a safe place and immediately begin timing with a stopwatch or a clock that has a second hand.

10. Record the time that the cylinder was set down to the second. Take of the cover.



11. After **1 minute and 30 seconds** has passed, carefully lower (do not drop) the hydrometer into the cylinder and let it float in the soil suspension. Carefully steady the hydrometer to stop its bobbing motion.

12. At **exactly 2 minutes** after the cylinder was set down, read the line on the hydrometer that is closest to the surface of the soil suspension and record that number on the Soil Particle Size Distribution Data Sheet.

13. Remove the hydrometer, rinse it away from the cylinder, dry it, and gently place it down in a safe place.

14. Suspend the thermometer in the suspension for about one minute.

15. At the end of one minute, lift the thermometer from the suspension enough so that you can read the temperature and record the result on the data sheet.

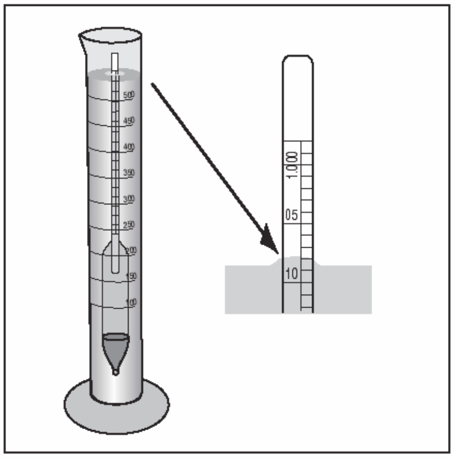


Figure-SO-PA-1

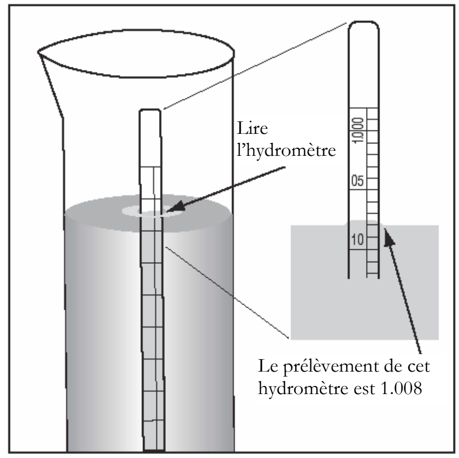


Figure-SO-PA-2

16. Rinse the thermometer off and dry it.

17. Leave the cylinder undisturbed for exactly 24 hours. After 24 hours from the moment that you placed the cylinder on the table, take another hydrometer and thermometer reading. Record the results on the data sheet.

18. Empty the cylinder. Carefully rinse and dry the hydrometer, the thermometer, the container, and the cylinder. Repeat the procedure two more times for the same horizon (soil sample) so that you have three sets of data for this sample.

Soil Particle Size Distribution Data Sheet

Date of sample collection: ___________________________

Study Site: ____

Horizon Number: _____ Horizon Depth: Top _____ cm Bottom _____ cm

Sample Number 1

Distance from 500 ml mark to base of graduated cylinder: ______cm

Hydrometer Calibration Temperature: _____ °C

A. 2 minute hydrometer reading: _____

B. 2 minute temperature: _____ °C

C. 24 hour hydrometer reading: _____

D. 24 hour temperature: _____ °C

Sample Number 2

Distance from 500 ml mark to base of graduated cylinder: _____ cm

Hydrometer Calibration Temperature: _____ °C

A. 2 minute hydrometer reading: _____

B. 2 minute temperature: _____°C

C. 24 hour hydrometer reading: _____

D. 24 hour temperature: _____ °C

Sample Number 3

Distance from 500 ml mark to base of graduated cylinder: _____ cm

Hydrometer Calibration Temperature: _____ °C

A. 2 minute hydrometer reading: ______

B. 2 minute temperature: _____ °C

C. 24 hour hydrometer reading: _____

D. 24 hour temperature: _____ °C

Calculating the Percentages of Sand, Silt, and Clay in the Sample

1. In A, enter the 2-minute hydrometer reading.	A. 2 minute hydrometer reading _______
2. In B, enter the 2-minute temperature reading.	B. 2 minute temperature reading _______°C
3. In C, enter the grams of soil/L in suspension using the hydrometer reading in A and converting it with Table SO-PA-1 on the following page.	C. Grams/L of soil (silt + clay) from table __________ g
4. In D, multiply the difference between the temperature reading (from B) and 20° C by .36 to correct for temperatures above or below 20° C	D. Temperature correction [0.36 x (B-20° C)] [0.36 x (B_____ - 20)] = _______g
5. In E, enter the sum of grams of soil/L (from C) and the temperature correction (from D).	E. Corrected silt and clay in suspension (C+D) C______ + D______ = ______g
6. In F, multiply the value for g/L of soil from E by .5 to correct for the fact that you have used a 500 ml cylinder.	F. Grams of soil (silt + clay) in 500 ml (E______ x 0.5) = ________g
7. In G, find the grams of sand in your sample, by subtracting grams of silt + clay in suspension (F) from the initial 25 g total soil in the sample.	G. Grams of sand in sample (25 g –F______) = _______g
8. In H, determine the exact percentage of sand, by dividing grams of sand by the total amount of soil (25 g) and multiplying by 100.	**H. Percent Sand** [(G______ / 25) x 100]= ______ %
9. In I, enter the hydrometer reading measurement at 24 hours.	I. 24-hour hydrometer reading _______
10. In J, enter the 24-hour temperature reading.	J. 24-hour temperature reading ______°C
11. In K, enter the grams of soil/L in suspension at 24 hours (clay) using the hydrometer reading in I and converting it with Table SO-PA-1 on the following page.	K. Grams/L of soil (clay) from table _______ g

12. In L, multiply the difference between the temperature reading at 24 hours (from J) and 20° C by .36.

L. Temperature correction [0.36 x (B-20° C)]
[0.36 x (J _____ - 20° C)] = ______g

13. In M, enter the sum of grams of soil/L (from K) and the temperature correction (from L).

M. Corrected clay in suspension (C+D)
K______ + L______ = ______g

14. In N, multiply the number in M by .5 to correct for the fact that you have used a 500 ml cylinder.

N. Grams of soil (clay) in 500 ml
(M______ x 0.5) = ______g

15. In O, determine the exact percentage of clay, by dividing grams of clay in suspension (from N) by the total amount of soil (25 g) and multiplying by 100.

O. Percent Clay
[(N______ / 25) x 100]= ______%

16. In P, determine the grams of silt by adding the grams of sand (from G) and grams of clay (from N) and subtracting the result from 25.

P. Grams of silt
[25 – (G______ + N______)] = _____g

17. In Q, determine the exact percentage of silt, by dividing grams of silt by the total amount of soil (25 g) and multiplying by 100.

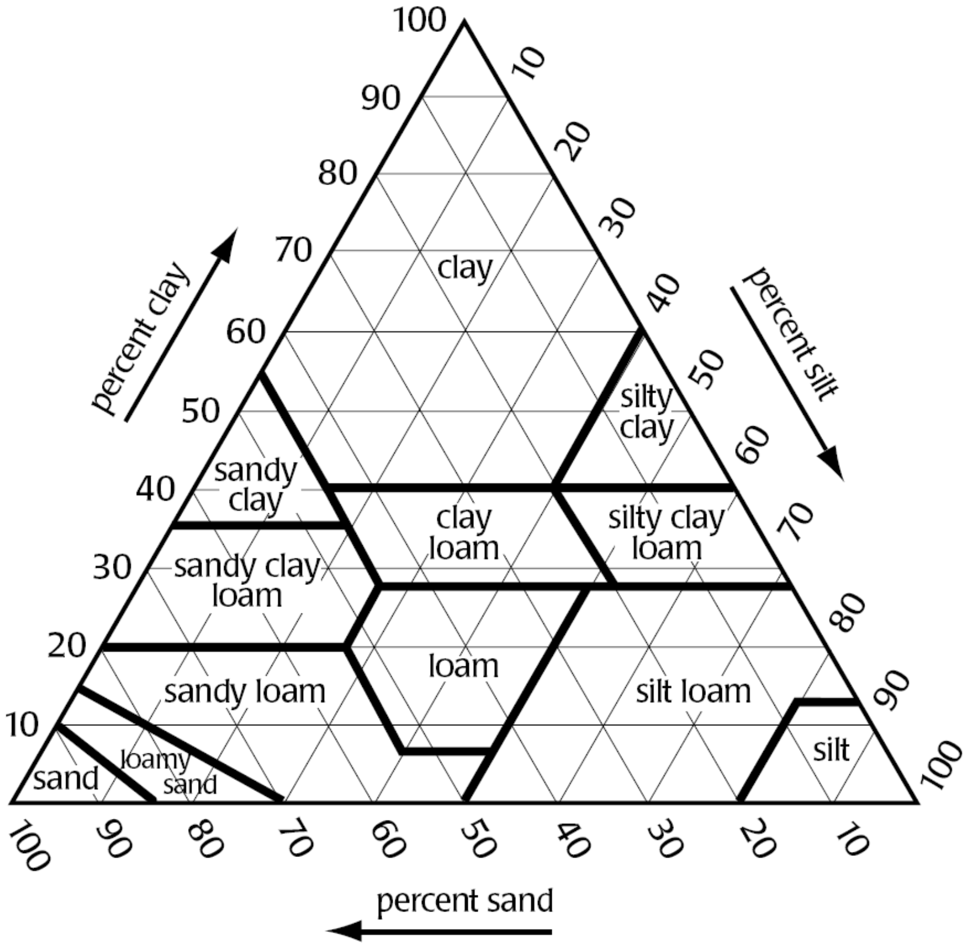
Q. Percent Silt
[(P______ / 25) x 100]= ______%

18. See the Textural Triangle to determine the Soil Texture

Conversion Table
-- Specific Gravity to Grams of Soil/L

Specific Gravity	Grams Soil/L	Specific Gravity	Grams Soil/L	Specific Gravity	Grams Soil/L
1.0024	0.0	1.0136	18.0	1.0247	36.0
1.0027	0.5	1.0139	18.5	1.0250	36.5
1.0030	1.0	1.0142	19.0	1.0253	37.0
1.0033	1.5	1.0145	19.5	1.0257	37.5
1.0036	2.0	1.0148	20.0	1.0260	38.0
1.0040	2.5	1.0151	20.5	1.0263	38.5
1.0043	3.0	1.0154	21.0	1.0266	39.0
1.0046	3.5	1.0157	21.5	1.0269	39.5
1.0049	4.0	1.0160	22.0	1.0272	40.0
1.0052	4.5	1.0164	22.5	1.0275	40.5
1.0055	5.0	1.0167	23.0	1.0278	41.0
1.0058	5.5	1.0170	23.5	1.0281	41.5
1.0061	6.0	1.0173	24.0	1.0284	42.0
1.0064	6.5	1.0176	24.5	1.0288	42.5
1.0067	7.0	1.0179	25.0	1.0291	43.0
1.0071	7.5	1.0182	25.5	1.0294	43.5
1.0074	8.0	1.0185	26.0	1.0297	44.0
1.0077	8.5	1.0188	26.5	1.0300	44.5
1.0080	9.0	1.0191	27.0	1.0303	45.0
1.0083	9.5	1.0195	27.5	1.0306	45.5
1.0086	10.0	1.0198	28.0	1.0309	46.0
1.0089	10.5	1.0201	28.5	1.0312	46.5
1.0092	11.0	1.0204	29.0	1.0315	47.0
1.0095	11.5	1.0207	29.5	1.0319	47.5
1.0098	12.0	1.0210	30.0	1.0322	48.0
1.0102	12.5	1.0213	30.5	1.0325	48.5
1.0105	13.0	1.0216	31.0	1.0328	49.0
1.0108	13.5	1.0219	31.5	1.0331	49.5
1.0111	14.0	1.0222	32.0	1.0334	50.0
1.0114	14.5	1.0226	32.5	1.0337	50.5
1.0117	15.0	1.0229	33.0	1.0340	51.0
1.0120	15.5	1.0232	33.5	1.0343	51.5
1.0123	16.0	1.0235	34.0	1.0346	52.0
1.0126	16.5	1.0238	34.5	1.0350	52.5
1.0129	17.0	1.0241	35.0	1.0353	53.0
1.0133	17.5	1.0244	35.5	1.0356	53.5
				1.0359	54.0
				1.0362	54.5
				1.0365	55.0

1. Use this soil texture triangle to define the soil type of your sample. See below for an example of how to use the triangle if you have not used it before.

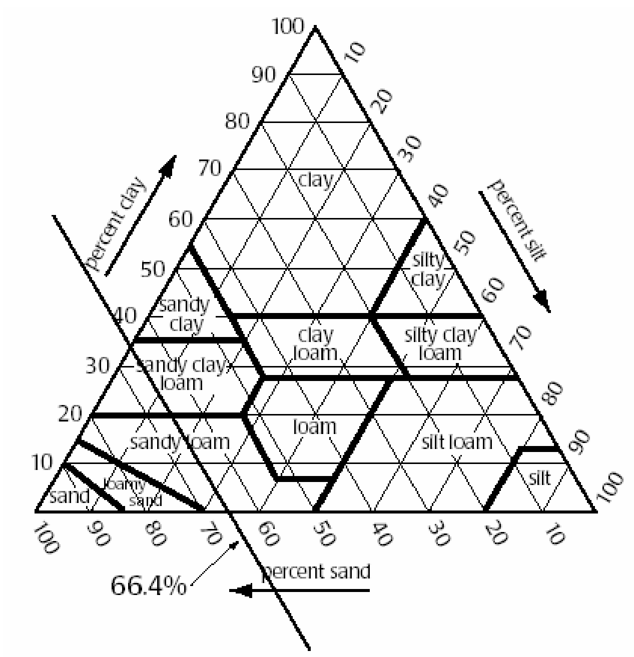


2. Example of how to use the soil textural triangle
    a. Here is a sample set of data that we will use for this example:

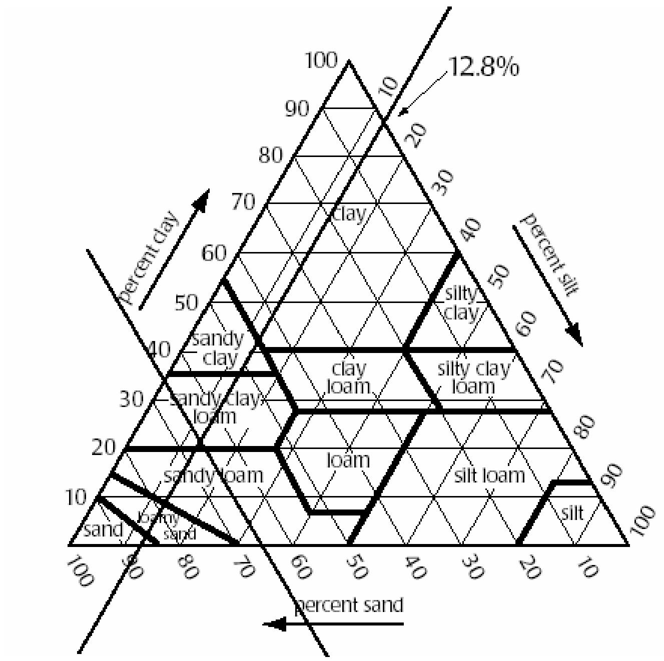
% Sand	% Silt	% Clay
66.4	12.8	20.8

    b. First, place a sheet of tracing paper over the triangle so it is protected from the pencil and can be reused.

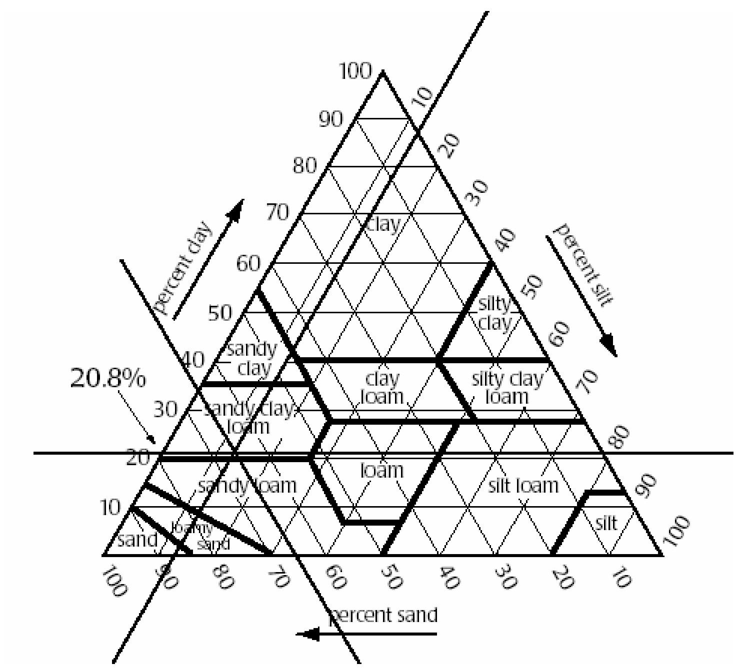
    c. Start with the side of the triangle that corresponds with the percentage of sand. Place a ruler across the triangle at 66.4% in the same sense as the lines and numbers on the Percent Sand side of the triangle. Trace a line on the paper with a pencil along the edge of the lined up ruler.



d. Then, continue on to the edge of the triangle that corresponds with the percentage of silt. Align the ruler on top of the triangle at 12.8% in the same sense as the numbers and lines that correspond with the silt side of the triangle. Following the edge of the ruler, trace a second line on the paper.



e. Finally, look at the scale for the percentage of clay and find 20.8%. Draw a third line in the same fashion as you did for the first two. This new line must intersect the other two lines at the point where they meet. If not, try again.



f. Now, see in which line of the triangle the three lines meet and read the textural class that is printed in that zone. In this example, the soil is classified as a sandy clay-loam.

% Sand	% Silt	% Clay	Soil Texture Class
66.4	12.8	20.8	Sandy Clay Loam

3. If the students have need of more practice, draw a triangle on the blackboard (with each side measuring one meter) and add the scale to the triangle with a meter stick and the lines across the triangle. Then, give the students the data from the following table so that they can practice drawing the intersecting lines on the triangle. In addition, if the table is also recopied on the board, the students can fill in the table with the values that they obtain from their work on the triangle.

	% Sand	% Silt	% Clay	Textual class
a.	75	10	15	Sandy loam
b.	10	83	7	
c.	42		37	
d.		52	21	
e.		35	50	
f.	30		55	
g.	37		21	
h.	5	70		
i.	55		40	
j.		45	10	