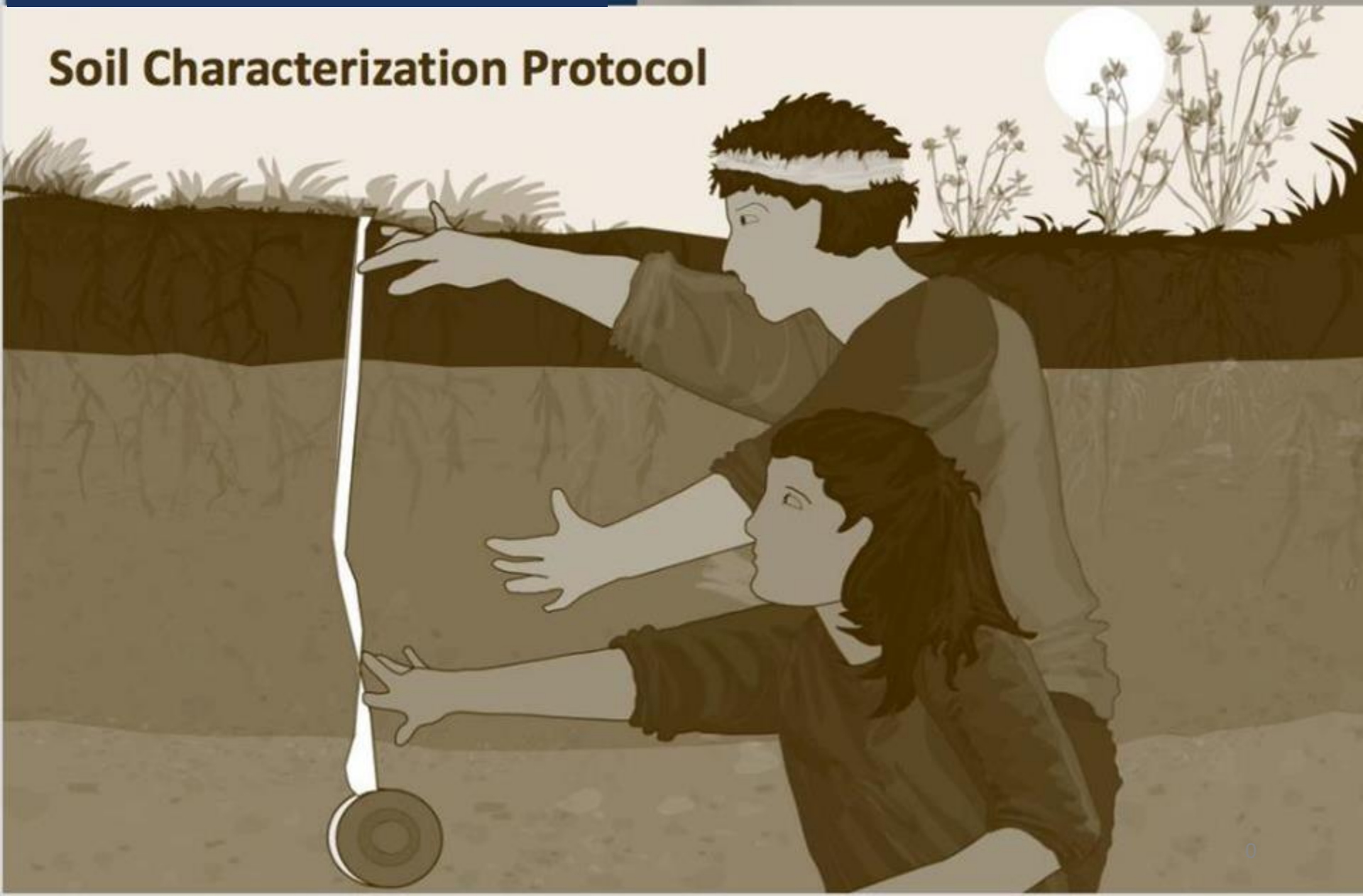
Soil Characterization Protocol



Goals and Objectives of this Module

Overview

This module:

- Describes how defining a soil characterization site supports scientific understanding of the Earth system
- Provides step-by-step instructions in how to characterize soils using this GLOBE protocol

Learning Objectives

After completing this module, you will be able to:

- Explain why soil characteristics are important
- Conduct soil characterization steps
- Report these data to GLOBE
- Visualize these data using GLOBE's Visualization Site

Estimated time needed for completion of this module: 1.5 hours

Why is defining soil characteristics important?

Soil characterization is a fundamental step in describing and analyzing soil as part of the Earth system. The characteristics you identify will help to explain the role of the soil in exchanging matter and transferring energy with the atmosphere, biosphere and hydrosphere.

Soil characterization measurements are taken for many reasons, including:

- supporting the interpretation of soil moisture and temperature, land cover, and atmosphere measurements;
- complementing and extending land cover mapping;
- developing soil maps of a region; and
- providing information for computer modeling.

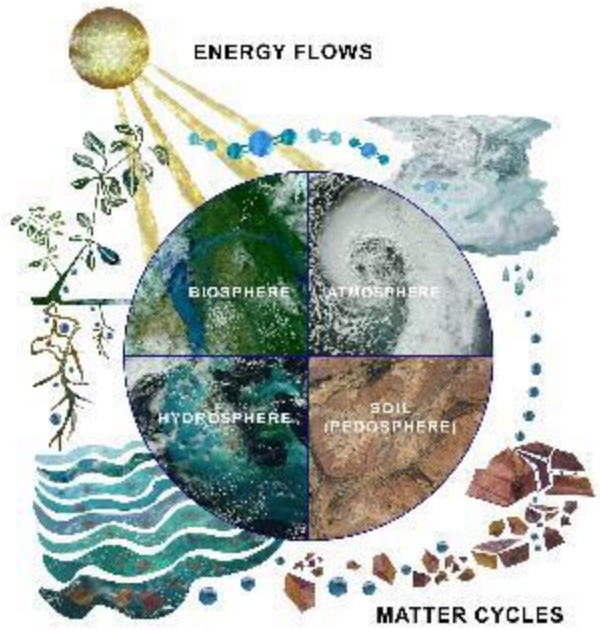


Image: Jenn Glaser and Russanne Low

Introduction to Soil Characterization

Soil can be characterized by its structure, color, consistence, texture, and abundance of roots, rocks, and carbonates. These characteristics allow scientists to interpret how the ecosystem functions and make recommendations for soil use that have a minimal impact on the ecosystem. For example, soil characterization data can help determine whether a garden should be planted or a school should be built. Soil characterization data can help scientists predict the likelihood of flooding and drought. It can help them to determine the types of vegetation and land use best suited to a location. Soil characteristics also help explain patterns observed from satellite imagery, vegetation growth across the landscape, or trends of soil moisture and temperature that might be related to weather.

Soil profile, exposed during a flood in 2013. Boulder Colorado, USA

Overview of Protocol

Time:
Preparation: 2-3 45 minute class sessions
Field: 90 minutes

Experience Level: All

Frequency:
Soil characterization measurements are taken once for a specific soil site. Collected samples can be stored for study and analysis at another time during the school year.

Prerequisites:
Selecting and Defining a Site for Soil Characterization Protocols: Exposing a Soil Profile

Documents:
Soil Characterization Protocol
Site Definition Sheet

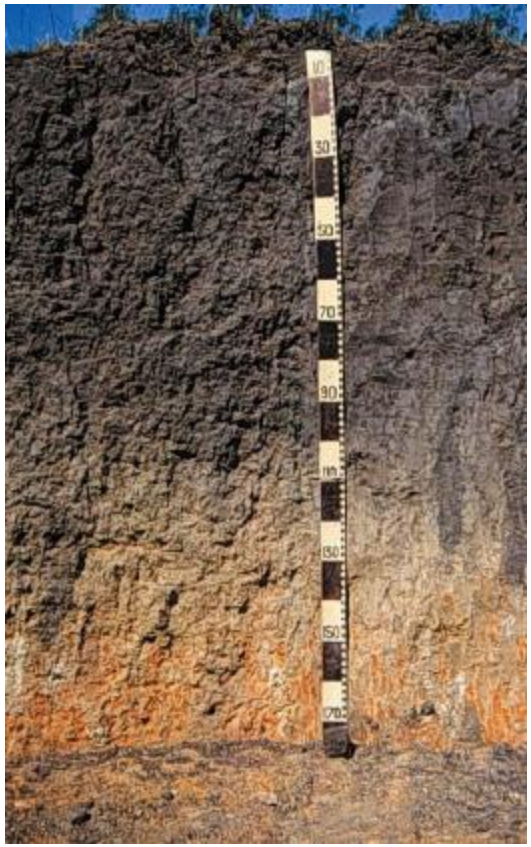
Required Materials

- Spray bottle
- Golf tees, nails or other horizon markers
- Soil color book
- Pencil, pen, marking pen
- Paper towels
- Trowel, shovel or other digging device
- Meter stick or tape measure
- Plastic bags
- Camera
- Latex gloves
- Acid bottle filled with vinegar
- Hammer
- #10 sieve (2 mm mesh openings)
- Sheets of paper or paper plates
- GLOBE Site definition sheet

What Soil Characterization Reveals:

Characteristics of the different soil horizons at depth:

- determine how water is stored in and moves through the soil;
- indicate suitability for categories of land use;
- indicate whether there is adequate drainage;
- determine what plants will grow and what nutrients are available;
- reveal the history of a site - past climates and human settlement;
- influence the local ecology and may limit what can live there.



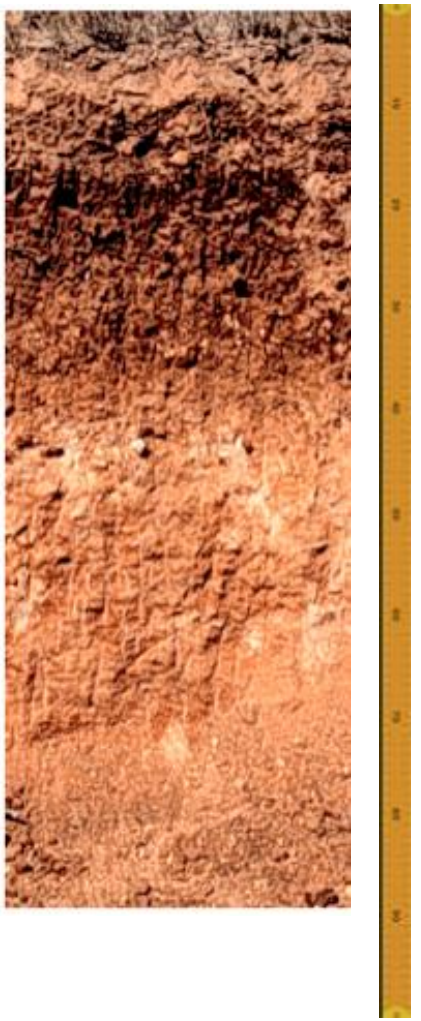
Grassland soil in Texas, USA. The dark color at the top, in the A horizon, evidences high organic content (fertility) resulting from centuries of root decomposition. Source: GLOBE Teacher's Guide.

Characterization of an Exposed Soil Profile

Follow the instructions in the Selecting, Exposing, and Defining a Soil Characterization Protocol to expose a soil profile for characterization.

These instructions apply to an exposed profile found in a road cut or erosional feature, as well as profiles exposed using the Pit method. This method is adapted for profiles exposed using the Auger Method and will follow.

Starting from the top, observe the profile to determine properties and differences between horizons.



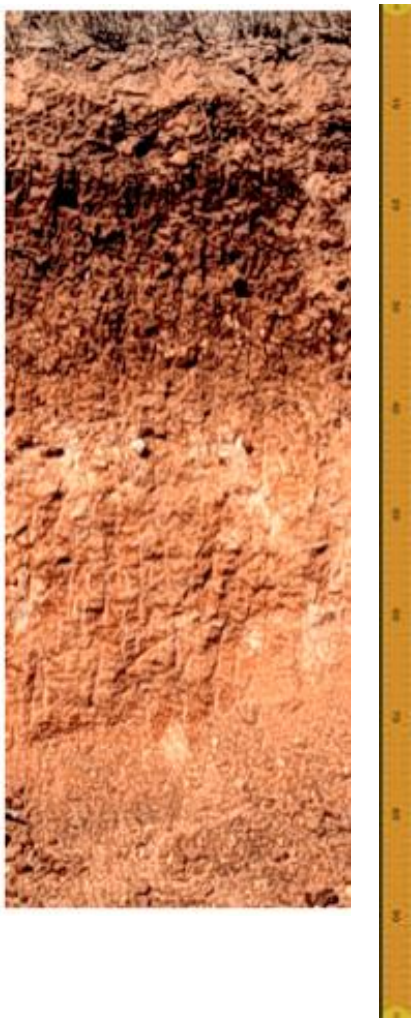
Identifying Soil Horizons

Starting from the top, you will observe the soil looking for differences between layers.

Look for: different colors and shapes, roots, the size and amount of rocks, small dark nodules (called concretions), worms or other small animals and insects, worm channels, and anything else that is noticeable.

To identify the top and bottom of each horizon, a golf tee or other marker is placed at each depth where you see a change in the appearance of the soil.

A soil layer must be at least 3 cm thick to be considered a Horizon. If you see a layer that is less than 3 cm thick, consider it a part of the horizon above or below and note this in your metadata.

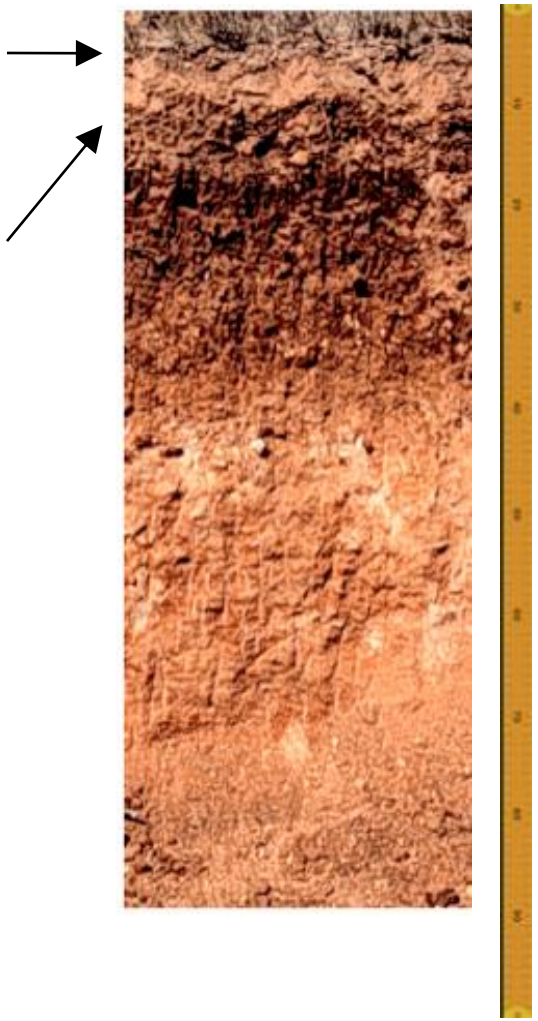


Identifying the First Horizon

The top or first horizon always starts at the surface of the soil and is always measured as 0 cm.

The bottom of the first horizon is where a difference in color, consistence, structure, chemistry, or texture is evidenced by a change in appearance.

The bottom of one horizon is the top of the next horizon down. So, where Horizon 1 ends is where Horizon 2 begins.

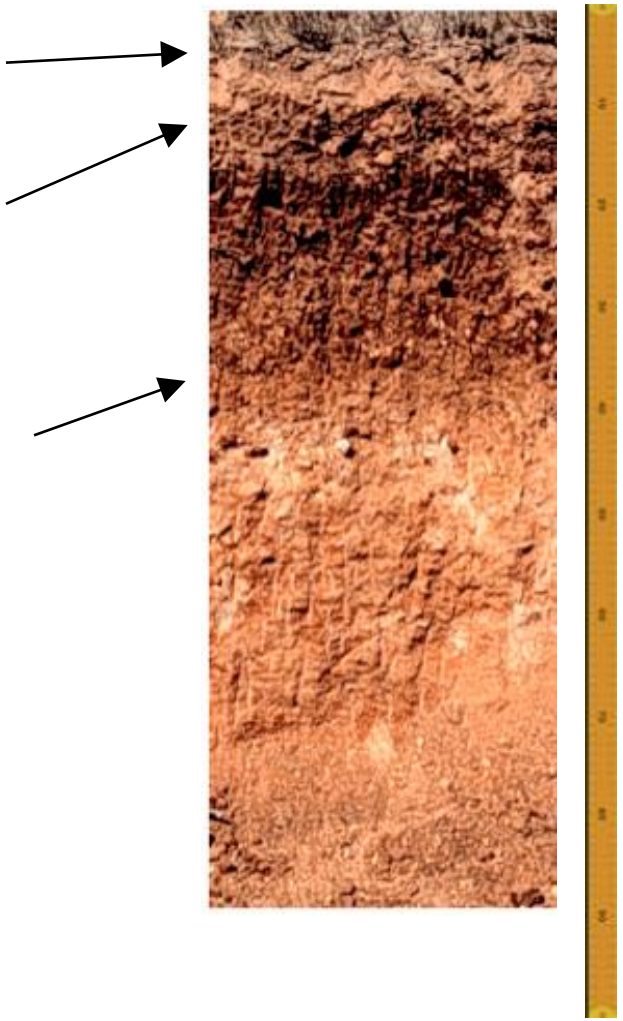


Identifying the Second Horizon

The top or first horizon always starts at the surface of the soil and is always measured as 0 cm.

Where the soil changes appearance is the bottom of the first horizon and the top of the second horizon.

Where the soil again changes in appearance is the bottom of the second horizon.



Identifying the Second Horizon (Cont'd)

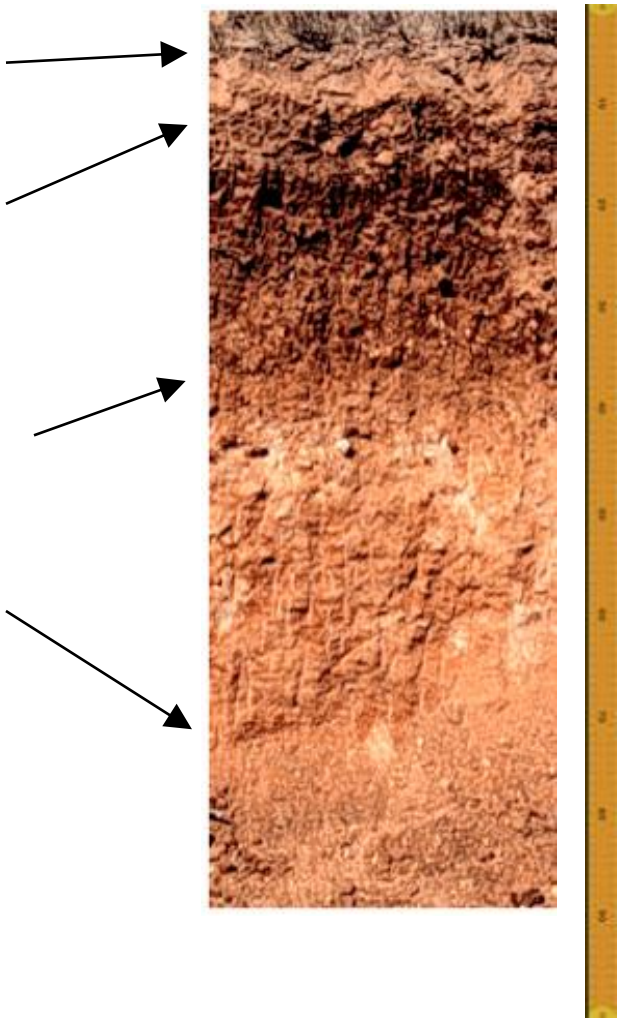
The top or first horizon always starts at the surface of the soil and is always measured as 0 cm.

Where the soil changes appearance is the bottom of the first horizon and the top of the second horizon.

Where the soil again changes in appearance is the bottom of the second horizon and the top of the third horizon.

Where the soil again changes in appearance is the bottom of the third horizon.

In this soil profile, the third horizon ends below 1 meter in depth. If your pit were only 1 meter deep, you would report in your metadata that the lowest horizon extended below your pit.



Describing Soil Horizons: Exposed Profile

Photograph the profile with a meter stick marking horizon depths and with horizons marked.

Place the 0 cm of the meter stick at the top of the profile.

Make sure the sun is shining on the profile to best show any differences in color or ped shape.

If you don't have an exposed soil profile available, you can create a profile using an auger, as described in the following slides.

Pit Image courtesy Dr. Ray Weil, University of Maryland. Labels are specific to this profile only.

Describing Soil Horizons: Auger Profile

Once the augered profile is laid out, it will yield a soil profile like the soil below the surface.

Identify the top and bottom depths of the profile's horizons and enter them into Data Entry App to set up your Soil Characterization Sample Site.

A soil layer must be at least 3 cm thick to be considered a Horizon.

If you see a layer that is less than 3 cm thick, consider it a part of the horizon above or below and note this in your metadata.

This photograph shows soil derived from auger sampling, laid out on a tarp, with soil depth adjusted according to instructions in the Selecting, Exposing and Defining a Soil Characterization Site Protocol. Golf tees are placed where each soil horizon begins and ends.

Measuring Soil Horizons in an Auger Profile

Remember, the top of the top horizon always starts with a measurement of 0 cm, so put the top of your ruler there.

The bottom of one horizon is the exact same depth as the top of the horizon directly below it.

These are the horizons you will be characterizing and sampling if you do laboratory analysis.

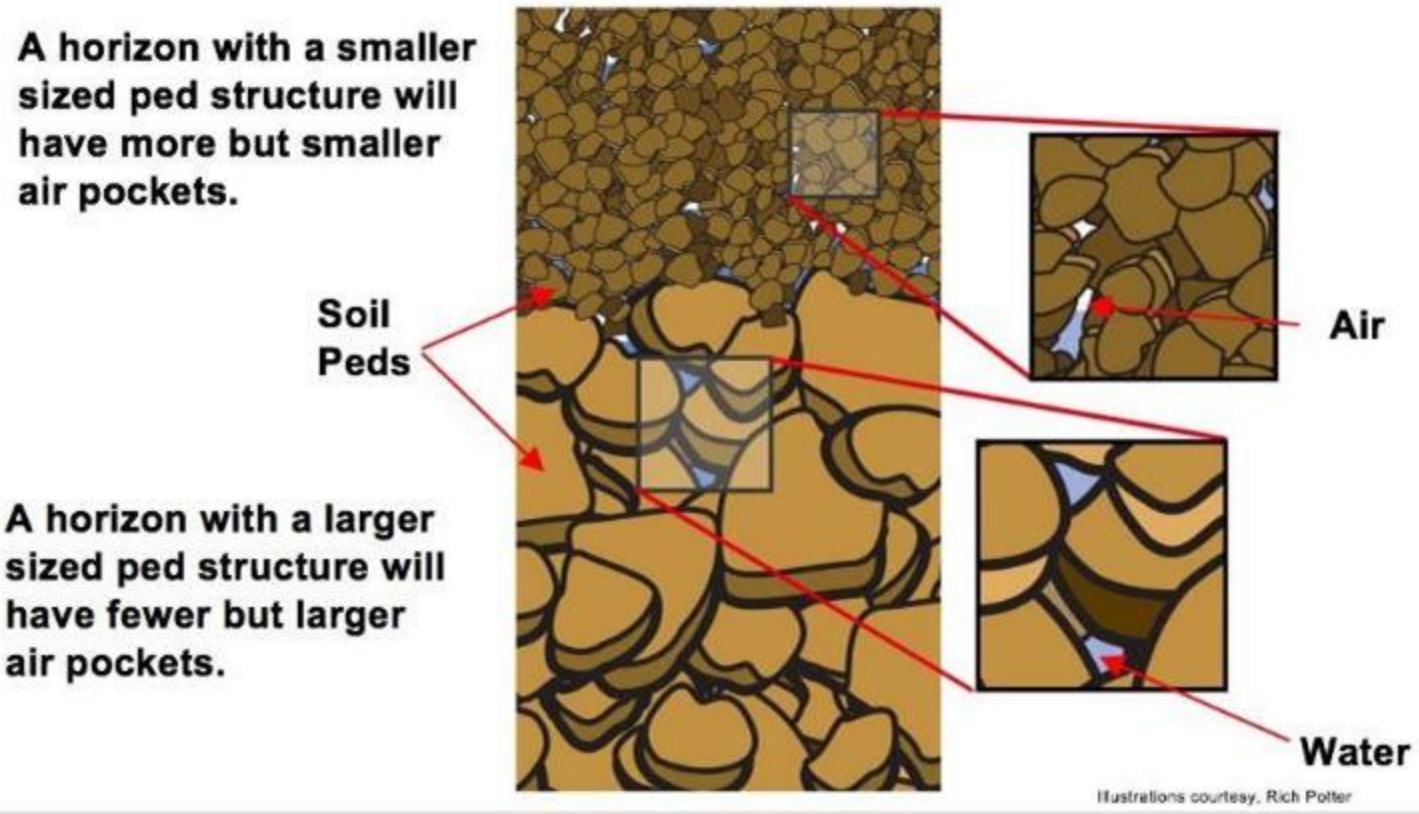
Once the profile has been analyzed and horizons identified, photograph the profile, making sure that the profile is equally illuminated by the sun (no shadows).

Augered soil profile with golf tees showing the horizons. Used with permission from Mid Valley Secondary Center, Throop, PA USA

Horizon Properties: Soil Structure

What is Soil Structure?

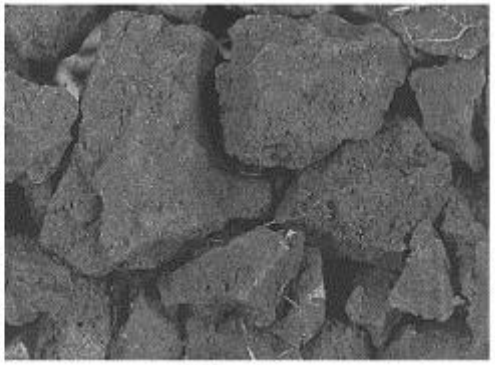
A soil horizon's structure refers to the natural shape of aggregates of soil particles, called peds, in the soil. The soil structure provides information about the size and shape of pore spaces in the soil through which water and air flow, and in which plant roots grow.



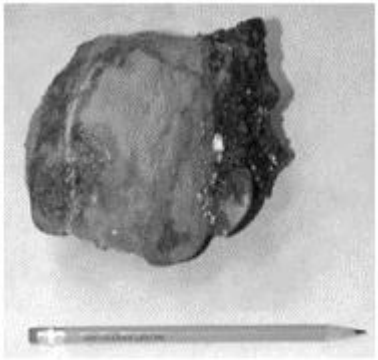
What Soil Structure Reveals

The soil structure provides information about the size and shape of pore spaces in the soil through which water and air flow, and in which plant roots grow. Here are the 7 Soil Structure Types:

Granular



Blocky



Massive

Single Grained

Prismatic

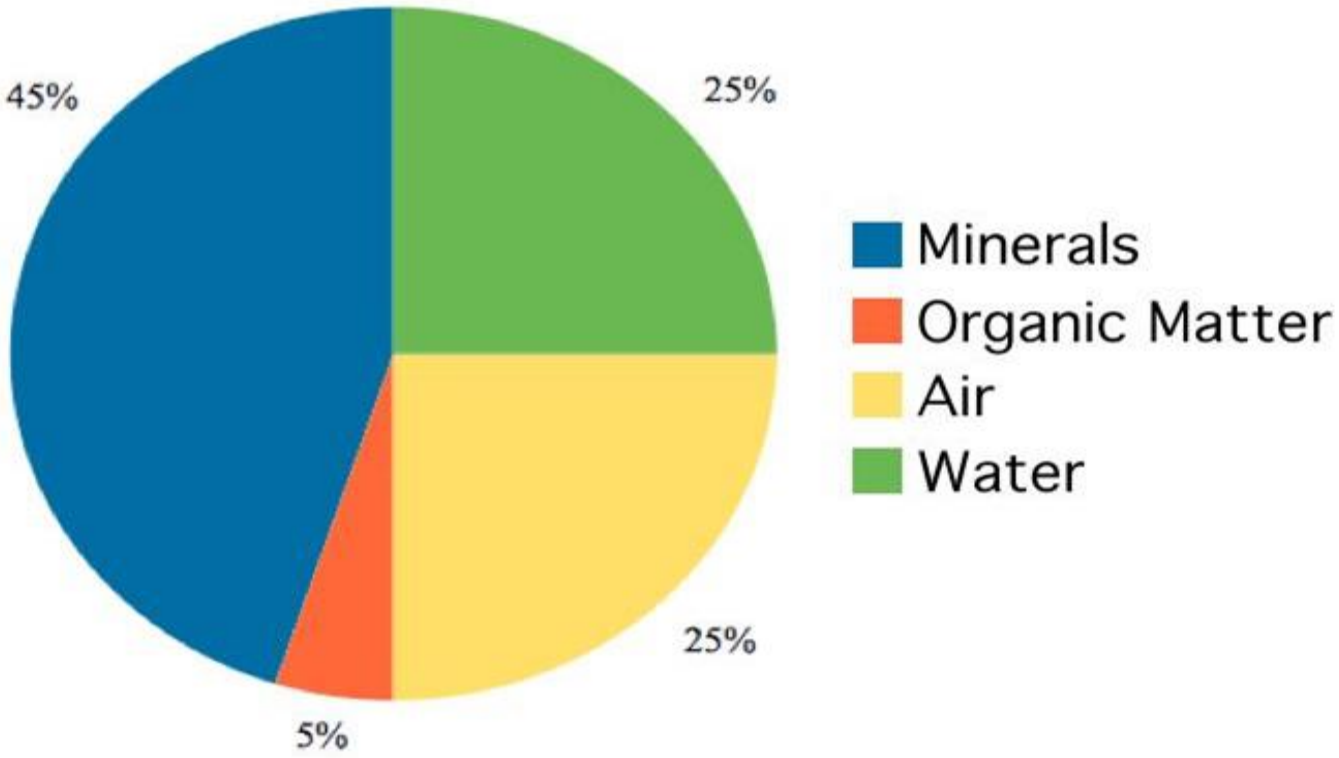
Columnar

Platy

Single Grained and Massive images courtesy Izolda Tracktenberg; other images courtesy NASA.

An Ideal Arable Soil

In an ideal arable soil, there is sufficient mineral content to allow growth and root purchase, there is sufficient water for plant water and nutrient uptake, and there is sufficient pore space for plant growth.



Examining a Ped

- For each part of this protocol, start with a clump of soil, called a "ped".
- Remember, you can change a soil's structure by doing anything other than looking at it.
- Use a trowel or other digging device to remove a soil sample from the horizon being studied.
- Hold the sample gently in your hand and look closely at the soil to examine its structure.
- Identify the soil structure of the horizon you are examining. See options in the next slides.

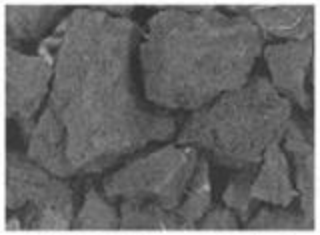
Granular and Block Structure

Soils With Structure:

Granular

Granular sample image courtesy NASA

Blocky

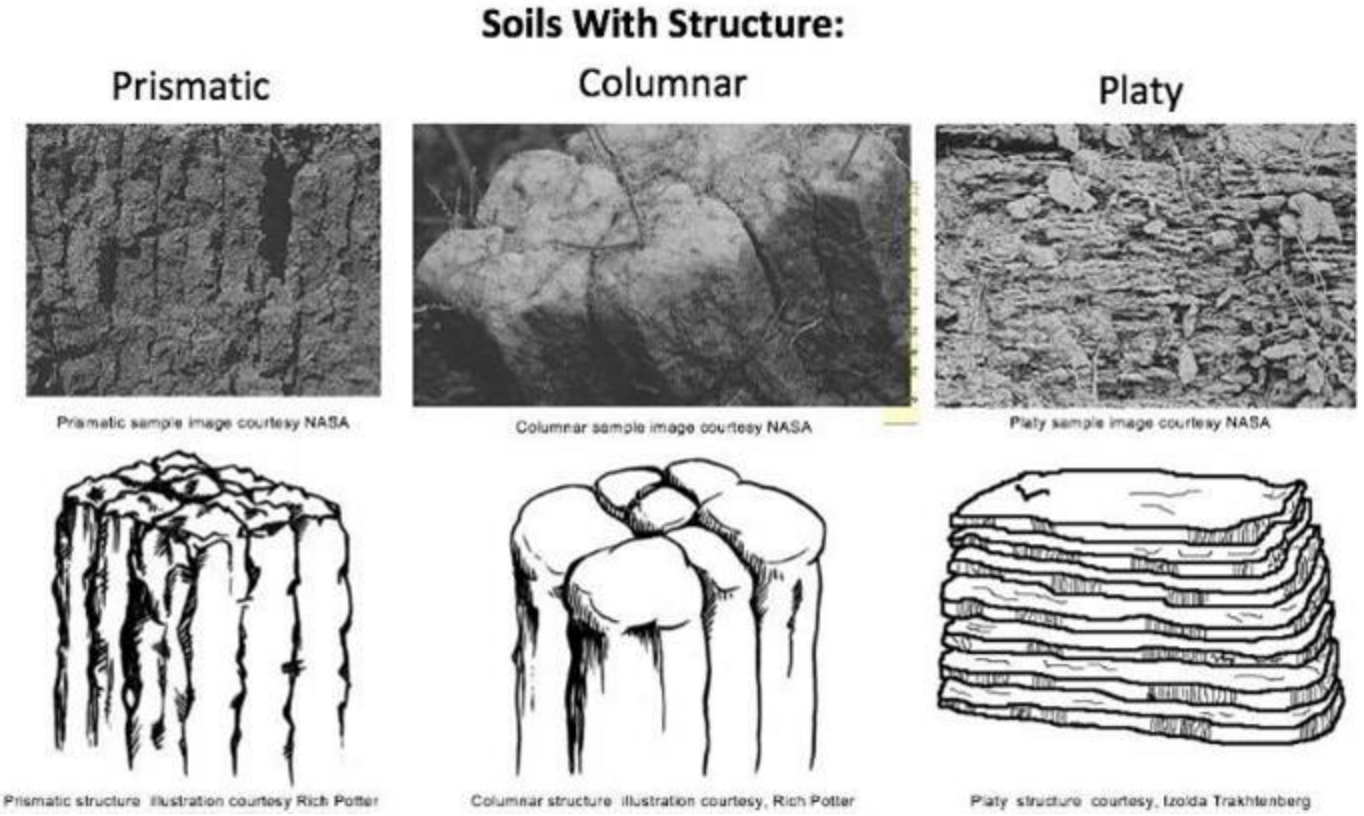


Blocky sample image courtesy NASA

Granular: 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, Columnar and Platy Structure



Prismatic: Vertical columns of soil; usually found in lower horizons.

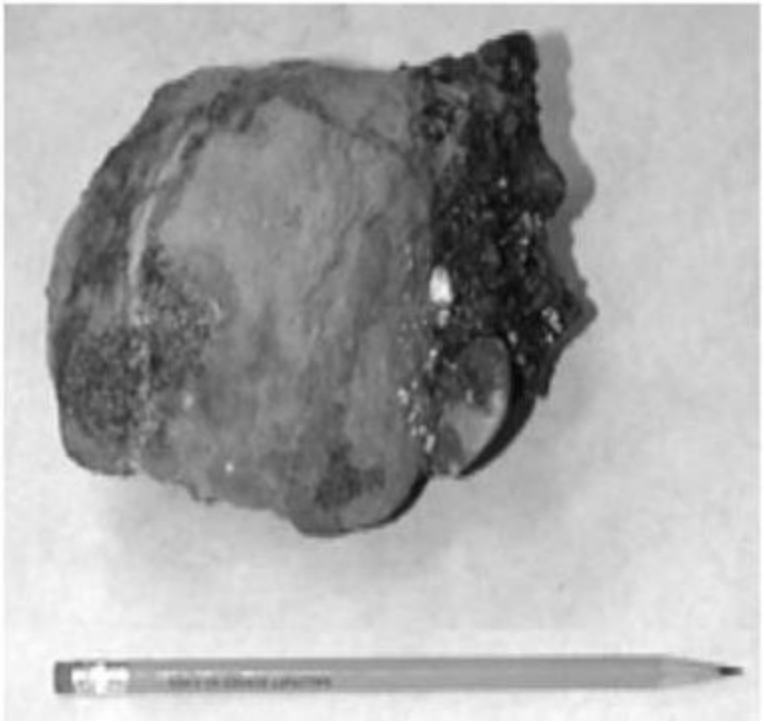
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.

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

Soil Lacking Structure

Single Grained

Massive



If the soil lacks structure, it is described as either single grained or massive. Soil with “single grained” structure always has a loose consistence.

Horizon Properties: Soil Color

What Soil Color Reveals

Soil color indicates the chemical content of the soil or the coatings on the soil particles. For instance, dark colors usually indicate the presence of organic material. The presence of iron and some other minerals can produce red and yellow soils.

Soil profile image courtesy, NRCS, USDA

High in Organic Matter

Soil profile image courtesy, NRCS, USDA

Contains Iron Oxide

Soil Color- Required Conditions and Instruments

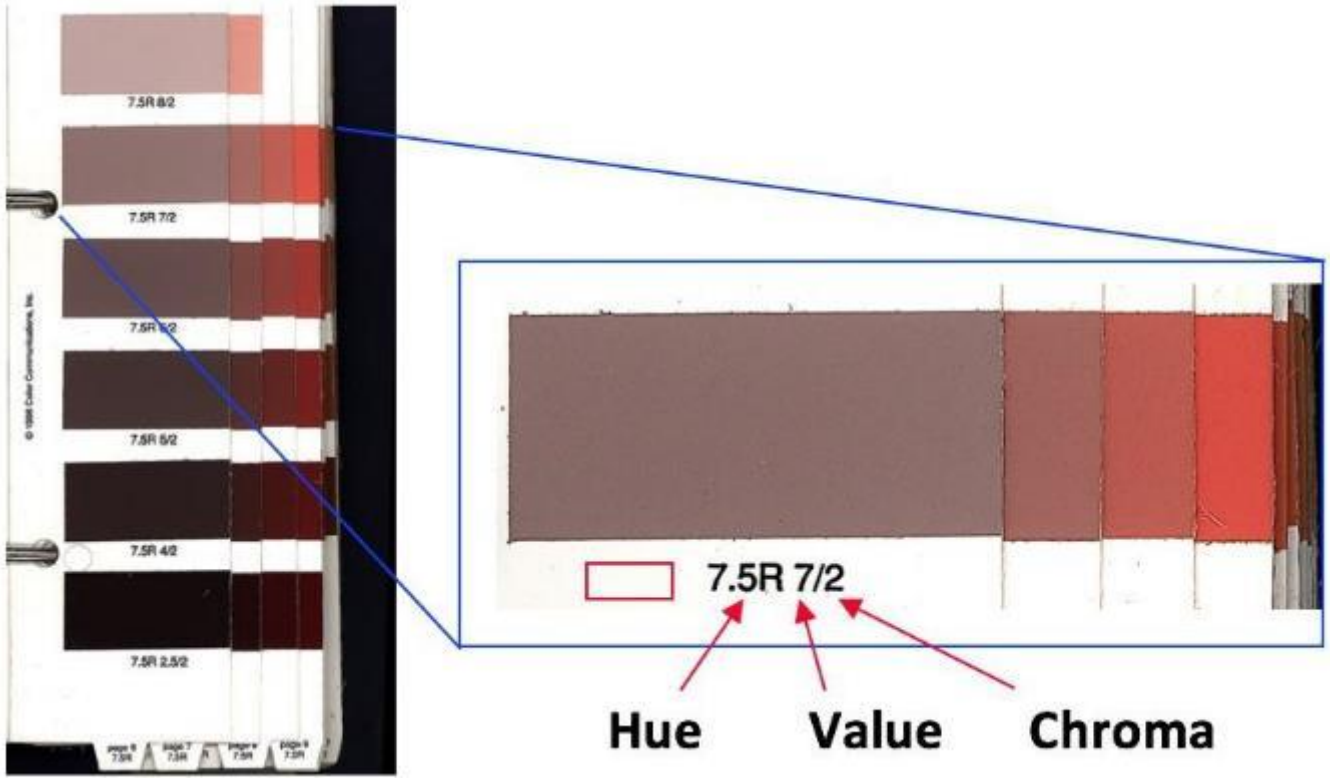
To complete the protocol, you will need:

1. Sunny day	2. Ped of soil	3. Spray mist bottle	4. GLOBE Soil Color Book
			
Observe soil color outside under the sun.	A ped is an aggregate of soil particles.	To observe soil color, moisten the ped.	Use a GLOBE-approved Soil Color Book.

Instrument Specifications: A Soil Color Book designed especially for The GLOBE Program can be purchased. It contains at least 200 colors and uses the Munsell System of Color Notation.

Soil Color- Munsell Notation

In the Munsell color system, colors are identified by three properties.



Soil Color- Hue, Value and Chroma

- **Hue** is the color's position on the Color Wheel

- **Value** is the amount of black or white added to the color. The higher the Value, the lighter the color. The lower the Value, the darker the color.

- **Chroma** is the amount of saturation of a color. The higher the Chroma, the more saturated the color.

How to Observe Soil Color- Prepare the Ped

Take a ped of soil from a horizon and note on the data entry page whether it is moist, dry or wet.

If it is dry, moisten it slightly with water from your water bottle. Wait for a minute for the water to soak into the ped.

Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining.

If the soil is too loose to form a single ped, place a sample on a trowel and complete the protocol.

Be sure no shadows fall on the color book.

How to Observe Soil Color- Steps

Break the ped and compare the color of the inside surface with the soil color chart.

Look through the entire book as some similar soil colors appear throughout the book.

Sometimes, a soil sample may have more than one color. If so record a maximum of two colors, and indicate (1) the Main (dominant color) and (2) the Other (secondary) color. This is only when your sample contains two distinctly different colors. It is not two estimates for the same color

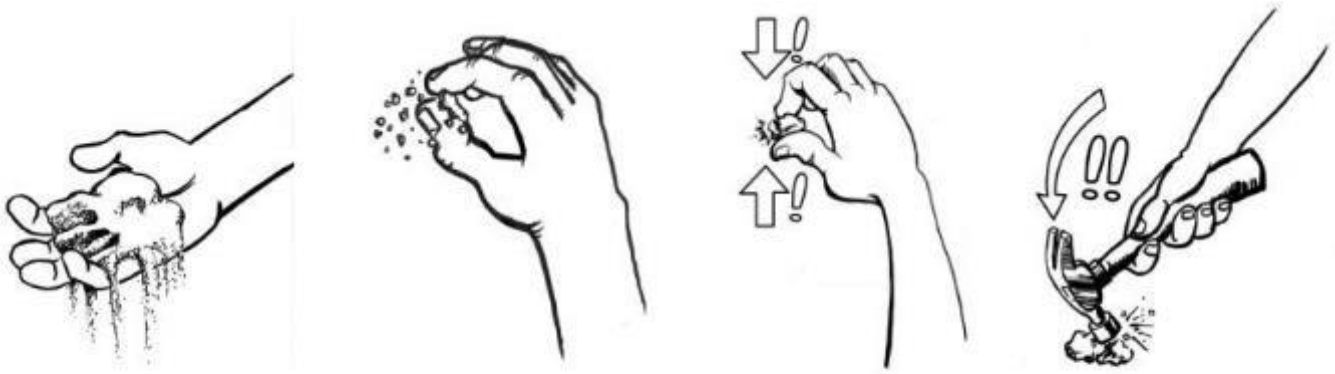
Horizon Properties: Soil Consistence

What Soil Consistence Reveals

Consistence is determined by how easily soil aggregates break apart

Whether a soil is **Loose**, **Friable**, **Firm**, or **Extremely Firm** determines how easy it is for roots, worms, or plows to pass through the soil.

It also indicates whether animals can create burrows in the ground or if the soil would collapse unless reinforced in some way.



What is Soil Consistence?

Consistence describes the firmness of the individual peds and the ease with which they break apart.

The terms used to describe soil consistence are loose, friable, firm, and extremely firm.

For example, a soil with friable consistency will be easier for roots, shovels, or plows to move through than a soil with a firm consistency. On the other hand, a soil with extremely firm consistency will be harder for roots, shovels, and trowels to move through.

To complete the protocol, you will need:

A ped of soil

A spray mist bottle

Identify Soil Consistence

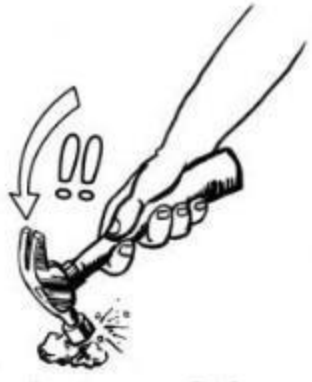
Record one of the following categories of soil ped consistence on the Soil Characterization Data Entry Page.

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

Friable
The ped breaks with a small amount of pressure.

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

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



* Soils with "single grained" structure **always** have loose consistence.

Horizon Properties: Soil Texture

Definitions of Sand, Silt, and Clay

The way a soil "feels" is called soil texture.

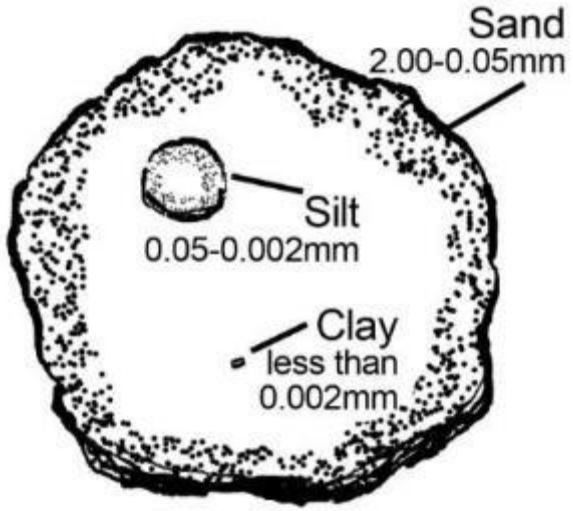
Soil texture depends on the amount of each size of particle in the soil.

Sand, silt, and clay are names that describe the size of individual particles in the soil.

-Sand are the largest particles and they feel "gritty."

-Silt are medium sized, and they feel soft, silky or "floury."

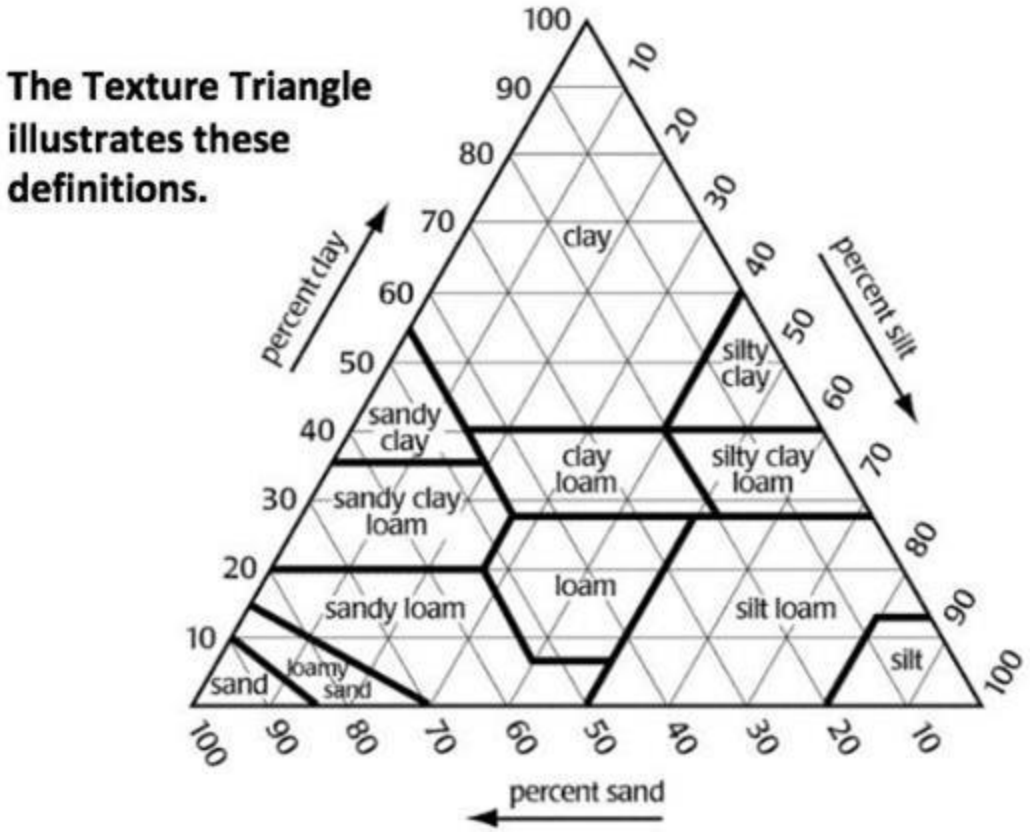
-Clay are the smallest sized particles, and they feel "sticky," and they are hard to squeeze.



Particle Size Comparison

The Soil Texture Triangle

Soils are grouped into 12 texture class names depending on how much sand, silt, and clay is in each sample.



Textural Triangle courtesy, USDA NRCS

Soil Texture: Required Equipment

To determine this soil property, you will need:

A small handful of soil

A spray mist bottle

Determining Soil Texture: Step 1: Is it Sand?

To determine soil texture by feel, use this method. Take a handful of soil and moisten it. Let the water soak in and then work the soil with your fingers. Try to make a ball with the soil.

If it does not make a ball, it is sand.

Soil texture is complete. If the soil Makes a ball, go to the next step.

Determining Soil Texture: Step 2: Is it Loamy Sand?

Squeeze the soil ball, and try to make a ribbon between your two fingers.

If the soil does not make a ribbon, call it a **Loamy Sand**, and Soil Texture is complete.

If the soil makes a ribbon, go to the next steps. First the length of the ribbon will determine whether it is a **Clay**, a **Clay Loam,** or a **Loam**

Determining Soil Texture: Step 3: Is it Clay?

Feel for clay. Does the soil stain your hands and keep its shape in your hand? Is it sticky and hard to squeeze? Is it shiny?

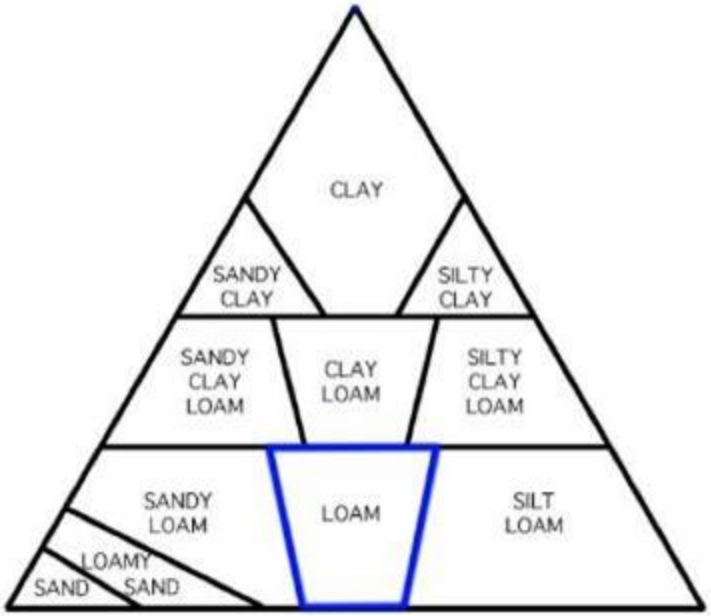
Does the sample make a **long** ribbon of about 5cm? If there is a lot of clay, it is a **Clay**, and you will feel for sand or silt in step 4.

Determining Soil Texture: Step 3: Is it Clay Loam?

If there is some clay but it is softer than a dense clay and makes a ribbon that is about 2-5 cm long, it is a **Clay Loam**, and you will feel for sand or silt in step 4. **If not**, go to the next step.

Determining Soil Texture: Step 3: Is it a Loam?

If it is very soft with just a little clay and makes a short ribbon of less than 2 cm, it is a **Loam**, and you will feel for sand or silt in step 4.

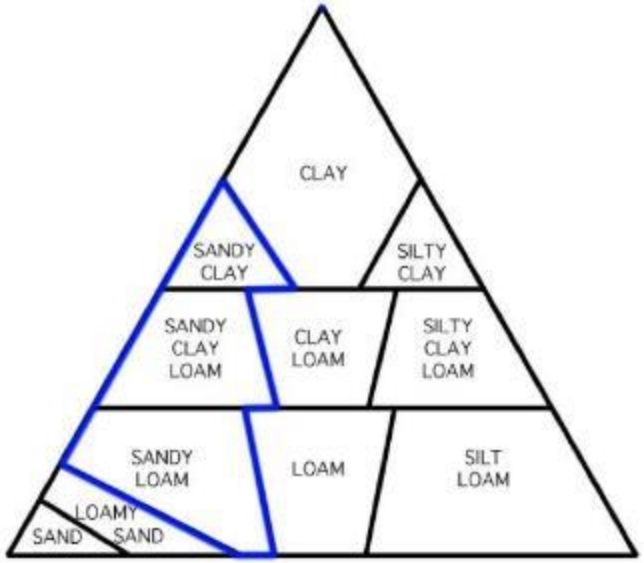


Determining Soil Texture: Step 4: Is it Sandy?

Wet a small pinch of the soil in your palm and rub it with a forefinger. If the soil feels very gritty, it is sandy.

Add the word "sandy" to your original soil texture name from step 3; it is either **Sandy Clay**, **Sandy Clay Loam**, or **Sandy Loam**. Soil Texture is complete.

If not, go to next step.



Determining Soil Texture: Step 4: Is it Silky?

If the soil feels very soft and smooth with no gritty feeling, it is silty.

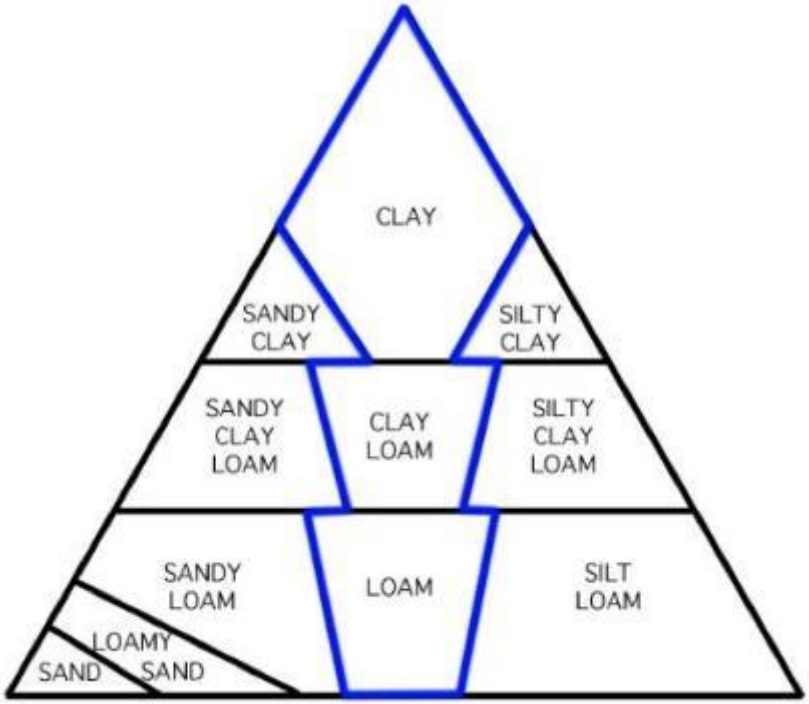
Add the word Silt or Silty to the original classification from step 3; it is either **Silty Clay**, **Silty Clay Loam**, or **Silt Loam**.

If not, go to next step.

Determining Soil Texture: Step 4: Is it Neither Sandy or Silky?

If the soil feels neither very gritty nor very soft, it is **Clay**, **Clay Loam**, or **Loam**.

Soil Texture is complete.



Horizon Properties: Roots, Rock and Carbonates

What the Presence of Roots, Rocks and Carbonates Reveals

Knowing the amount of roots in each horizon allows scientists to estimate the soil's fertility, bulk density, water holding capacity, and depth.

An estimate of the number of rocks in each horizon helps to understand the movement of water, heat, and air through the soil, root growth, and the amount of soil material involved in chemical and physical reactions.

The presence of carbonates in soil may indicate a dry climate or a particular type of parent material rich in calcium, such as limestone.

Horizon Properties: Roots

An estimate of the roots in each horizon in a soil profile illustrates the depth to which roots go to obtain nutrients and water.

The more roots found in a horizon, the more water and nutrients are being removed from the soil, and the more organic matter being returned.

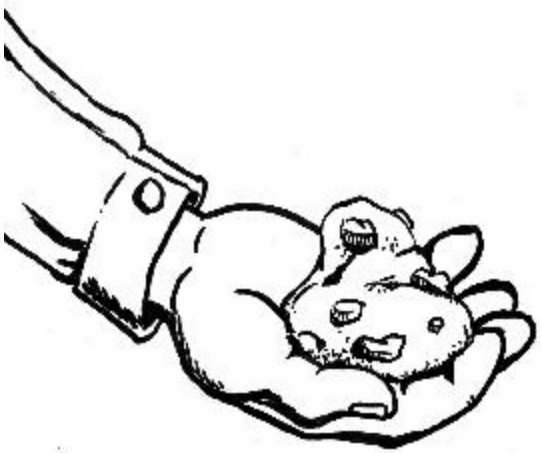
Observe and record if there are **none**, **few** or **many** roots or root fragments in each horizon.

Horizon Properties: Rocks

An estimate of the number of rocks in each horizon helps to understand the movement of water, heat, and air through the soil, root growth, and the amount of soil material involved in chemical and physical reactions.

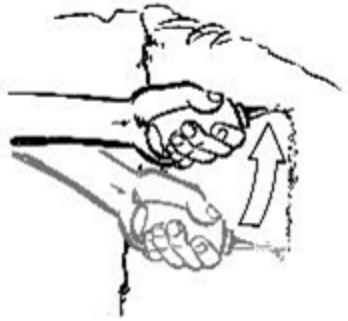
Soil particles greater than 2 mm in size are considered to be rocks or pebbles.

Observe and record if there are **none, few** or **many** rocks or rock fragments in the horizon.



Horizon Properties: Free Carbonates

The presence of carbonates in soil may indicate a dry climate or a particular type of parent material rich in calcium, such as limestone. Free carbonates often coat soil particles in soils that are basic (pH>7).



If carbonates are present, there will be a chemical reaction between vinegar (a mild acid) and the carbonates (a base) producing carbon dioxide and causing the vinegar to bubble or effervesce.

The more carbonates present, the more effervescence occurs.

Set aside a portion of the exposed soil to use for the free carbonates test. Do not touch it with your bare hands.

Open the acid bottle and squirt vinegar on the soil particles. Start from the bottom of the profile and move up.

Be sure to use caution and point the bottle directly at the soil, not toward other people, especially toward eyes.

Observing Free Carbonates

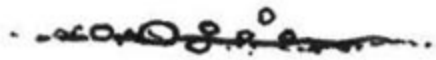
Look carefully for the presence of effervescence. The more carbonates that are present, the more bubbles (effervescence) you will observe.

Observe and record whether the effervescence is **none**, **slight** or **strong.**

None: if you observe no reaction, the soil has no free carbonates present.

Slight: if you observe a very slight bubbling action; this indicates the presence of some carbonates.

Strong: if there is a strong reaction (many, and/or large bubbles); this indicates there may be many carbonates present.



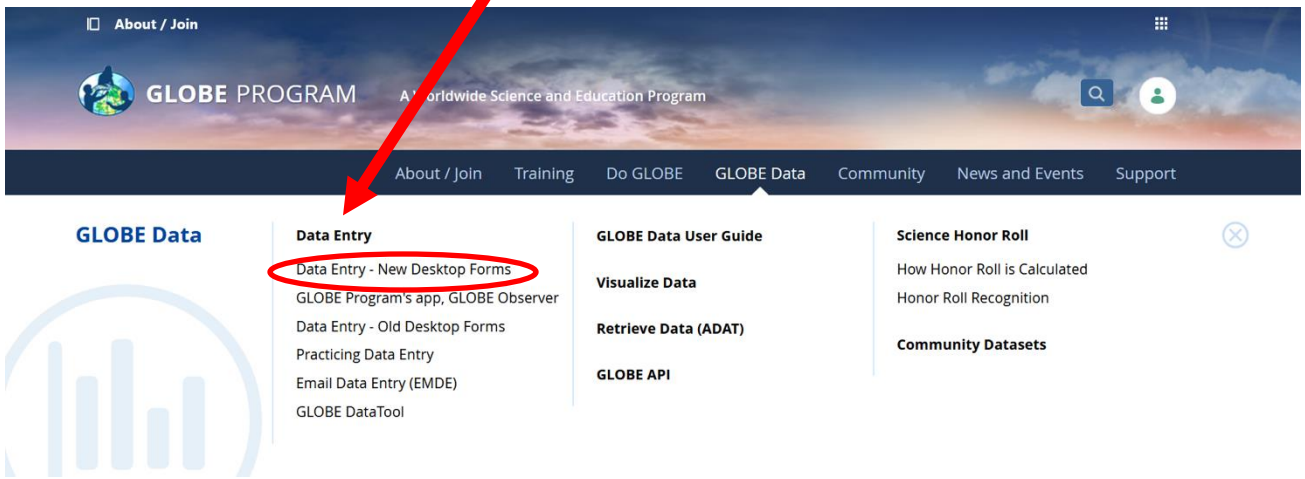
Reporting Data to GLOBE

Two Options for Uploading Data:

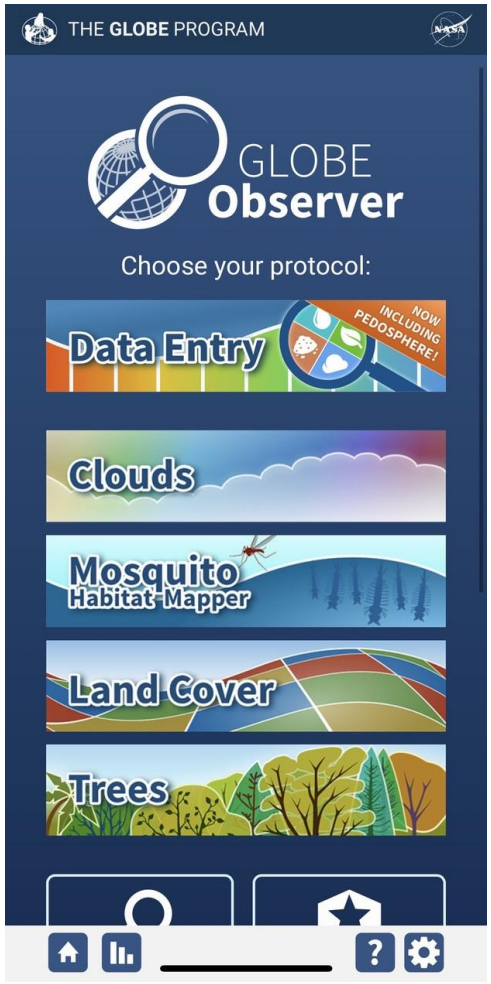
These methods all allow users to submit environmental data – collected at defined sites, according to protocol, and using approved instrumentation – for entry into the official GLOBE science database.

1. Download the GLOBE Observer mobile app from the App Store.

2. Data Entry: Visit globe.gov, click on the "GLOBE Data" tab, then underneath "Data Entry" click on "Data Entry – New Desktop Forms".



Soil Characterization Site Creation

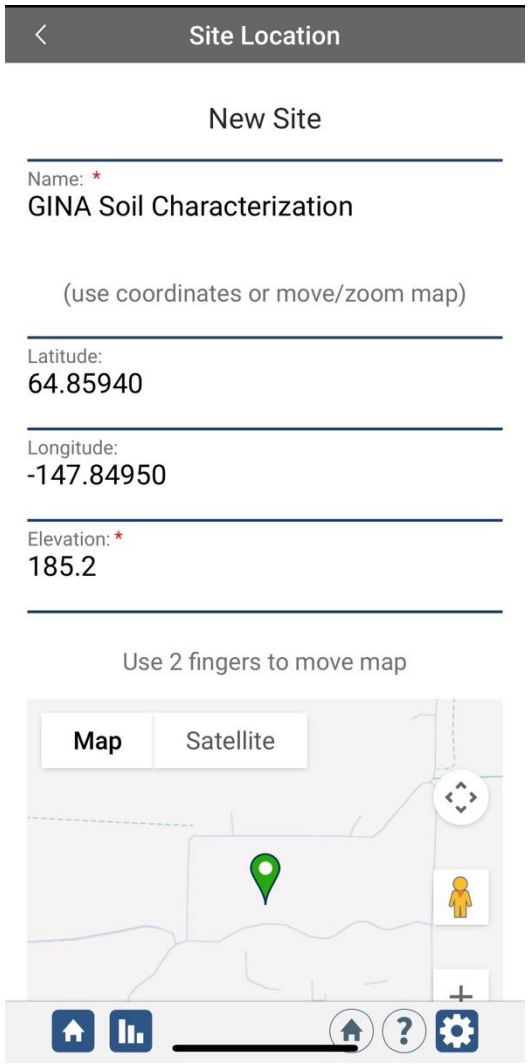


To enter you soil characterization information, you will need to create a new site.

Open the GLOBE Observer App and select “Data Entry”.

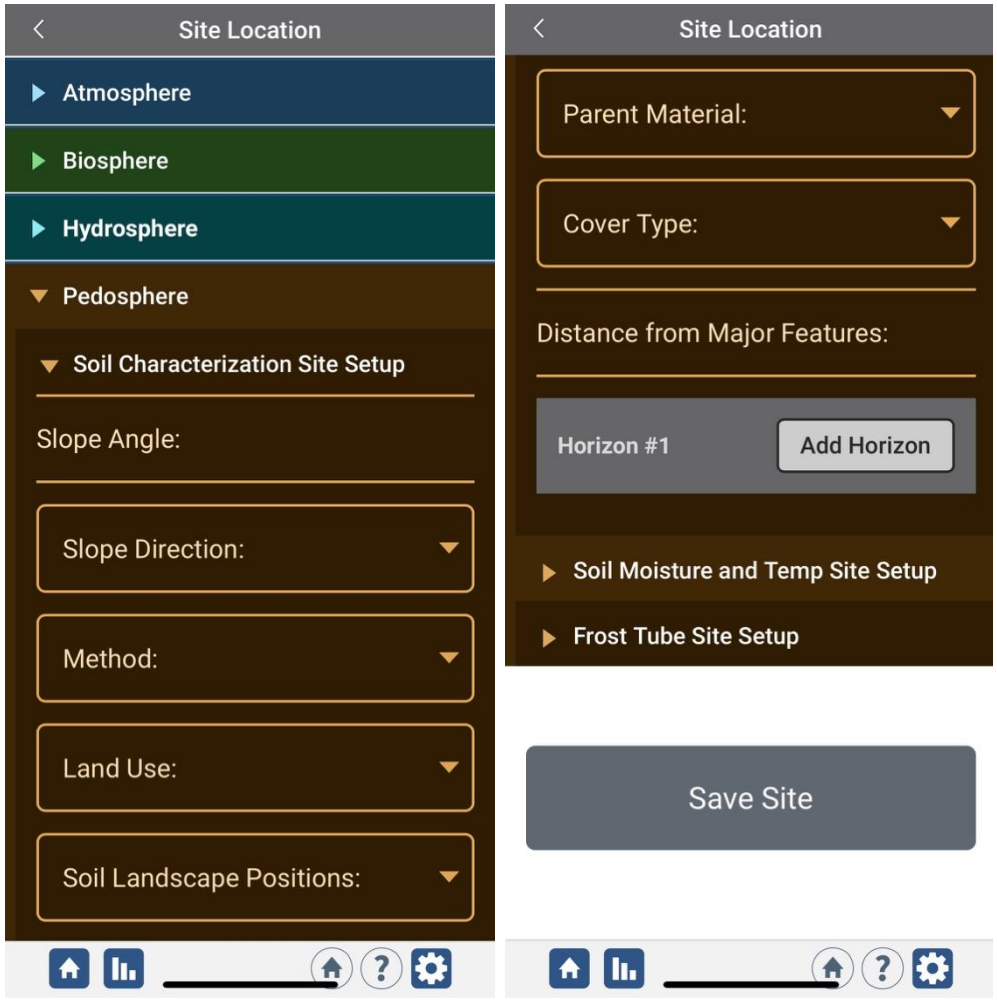
Next, click “Create/Edit My Sites”

Soil Characterization Site Creation



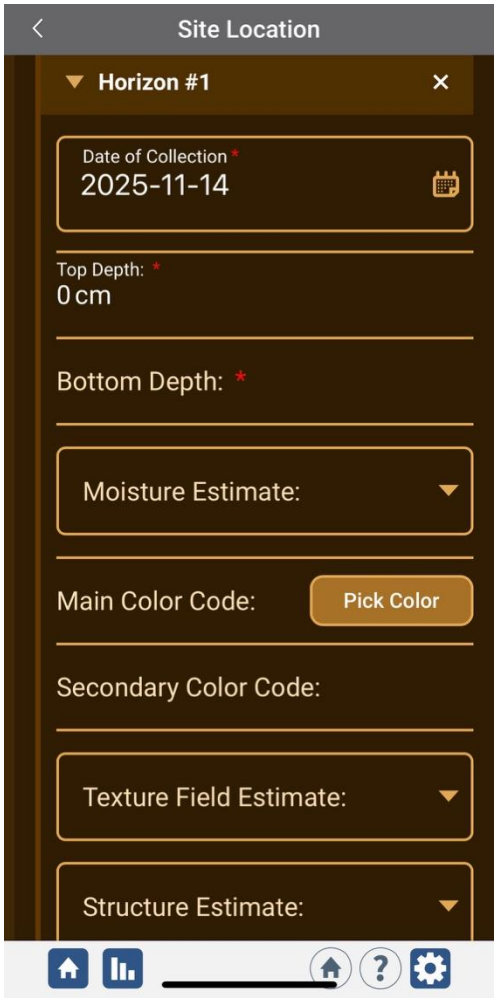
- Enter a name for your new site.
- Use the map box to make sure the green popup is in the correct site location.
- If you used a separate GPS device to locate your site, you can enter the coordinates manually.

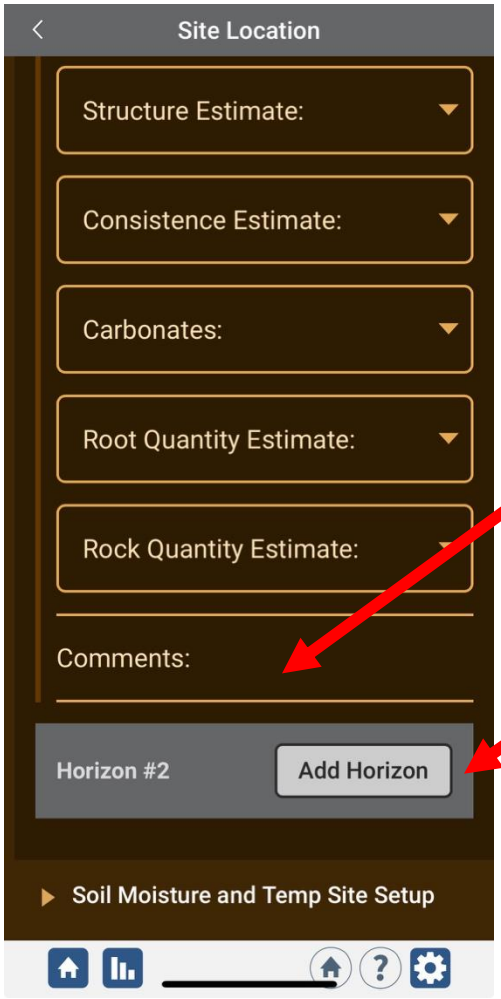
Soil Characterization Site Creation



- Scroll down to the Pedosphere tab
- Select Soil Characterization Site Setup
- Enter the site information for you new site.
- Next, select “Add Horizon”

Soil Characterization Site Creation





Under "Horizon #1", enter the depth, color, and other information about the horizon.

Add any additional information to the Comments box.

Select "Add Horizon" to enter information about the next horizon.

When finished, click "Save Site"

Soil Characterization Site Data Visualization

GLOBE Soil Characterization data visualization has several aspects that are different from the visualization of other types of data.

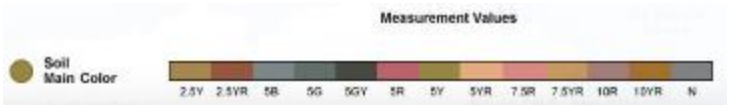
The map shows the data for the most recent soil characterization at every site since the start of this GLOBE protocol. Soil character changes slowly, often forming over centuries or longer.

If you change the date of the visualization, data taken more recently than this date will not be shown.

The depth of each horizon is important data; it is not just part of defining the horizon. So, there are visualizations of horizon depth for the top 5 horizons.

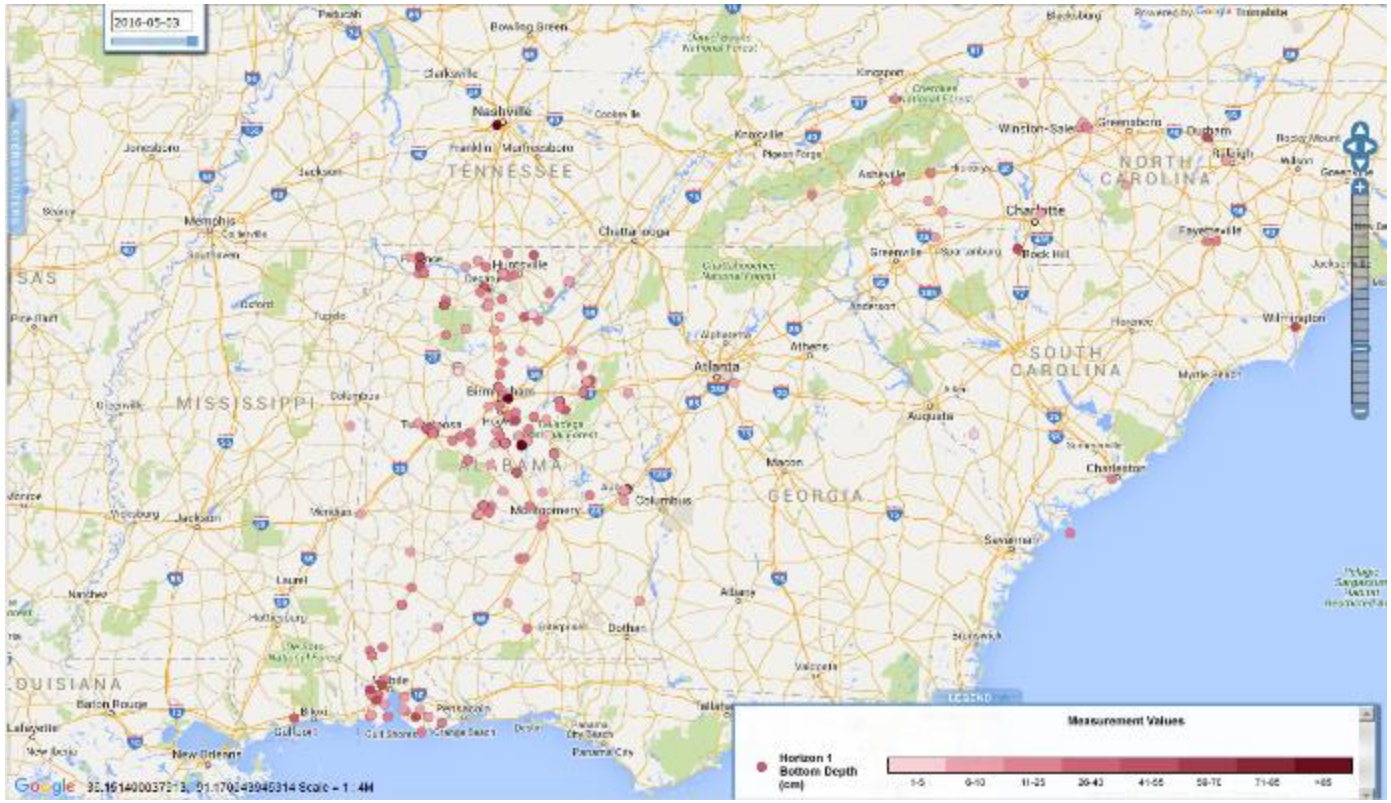
It is interesting and useful to know the soil properties for the horizons where soil moisture and temperature data are taken. There are visualizations showing which horizon occurs at these different measurement depths.

Data from multiple horizons may be displayed by opening multiple data layers and arranging them so that the layer with the smallest dots is on top. In this way, data from the layers appear in a stack (like a child's toy).



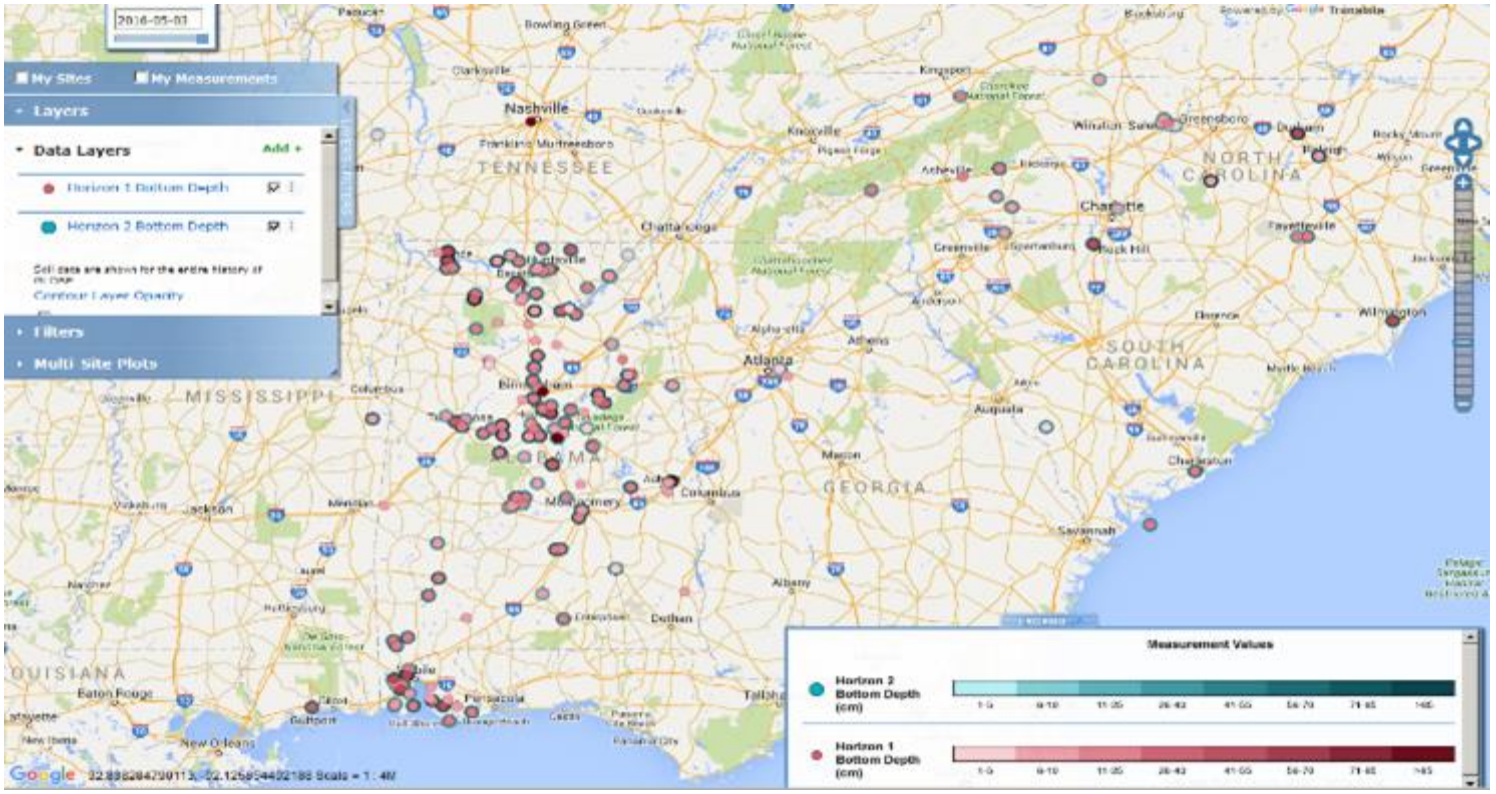
Soil Horizon 1 Depth Data Visualization

Visualization of the first horizon data shows how deep the top layer extends.



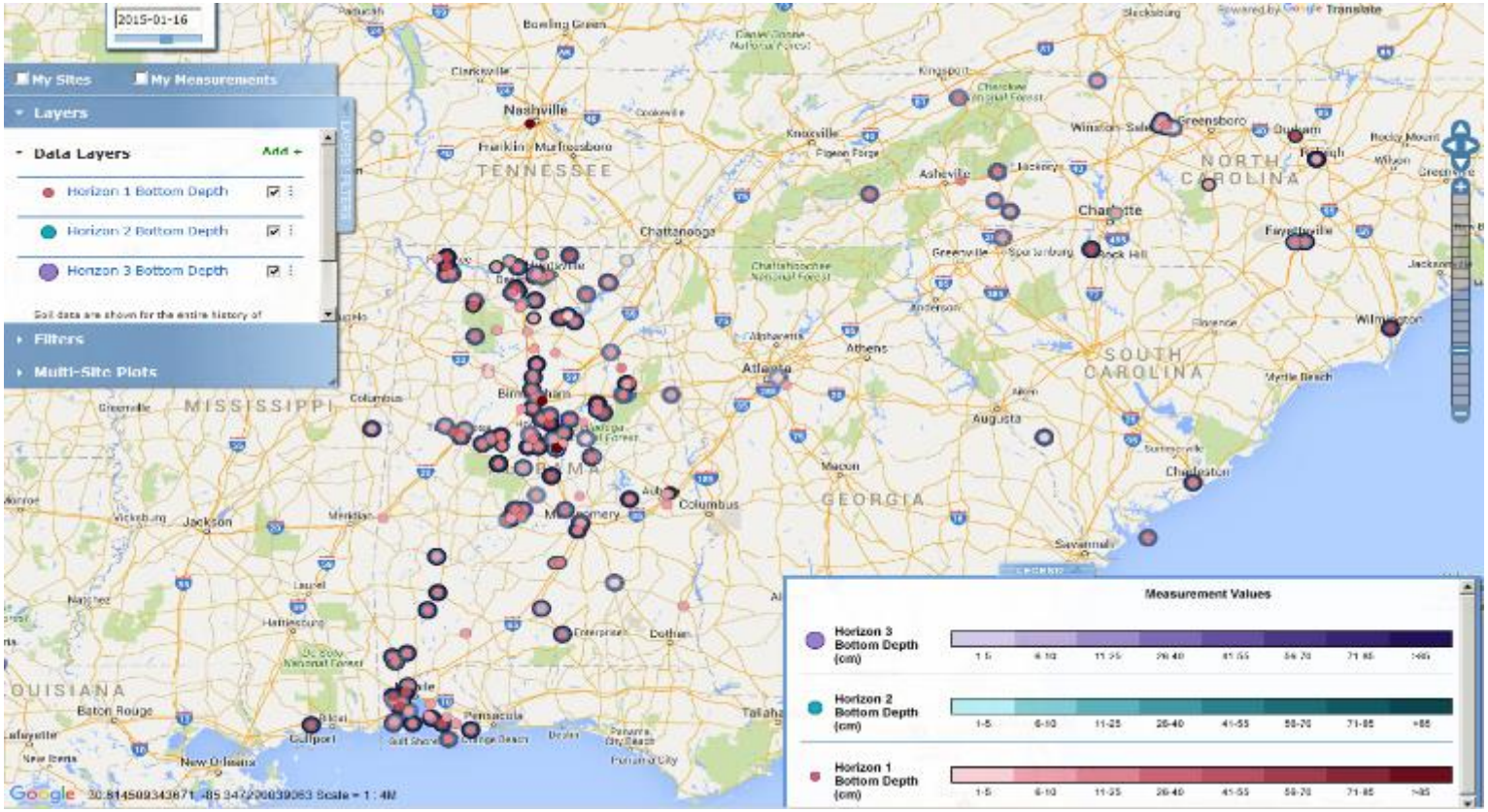
Data Visualization of Horizons 1 & 2

The map dots are different sizes so that you can compare two or more horizons at the same time by adding two data layers. Be sure to have the Horizon 1 data layer on top.



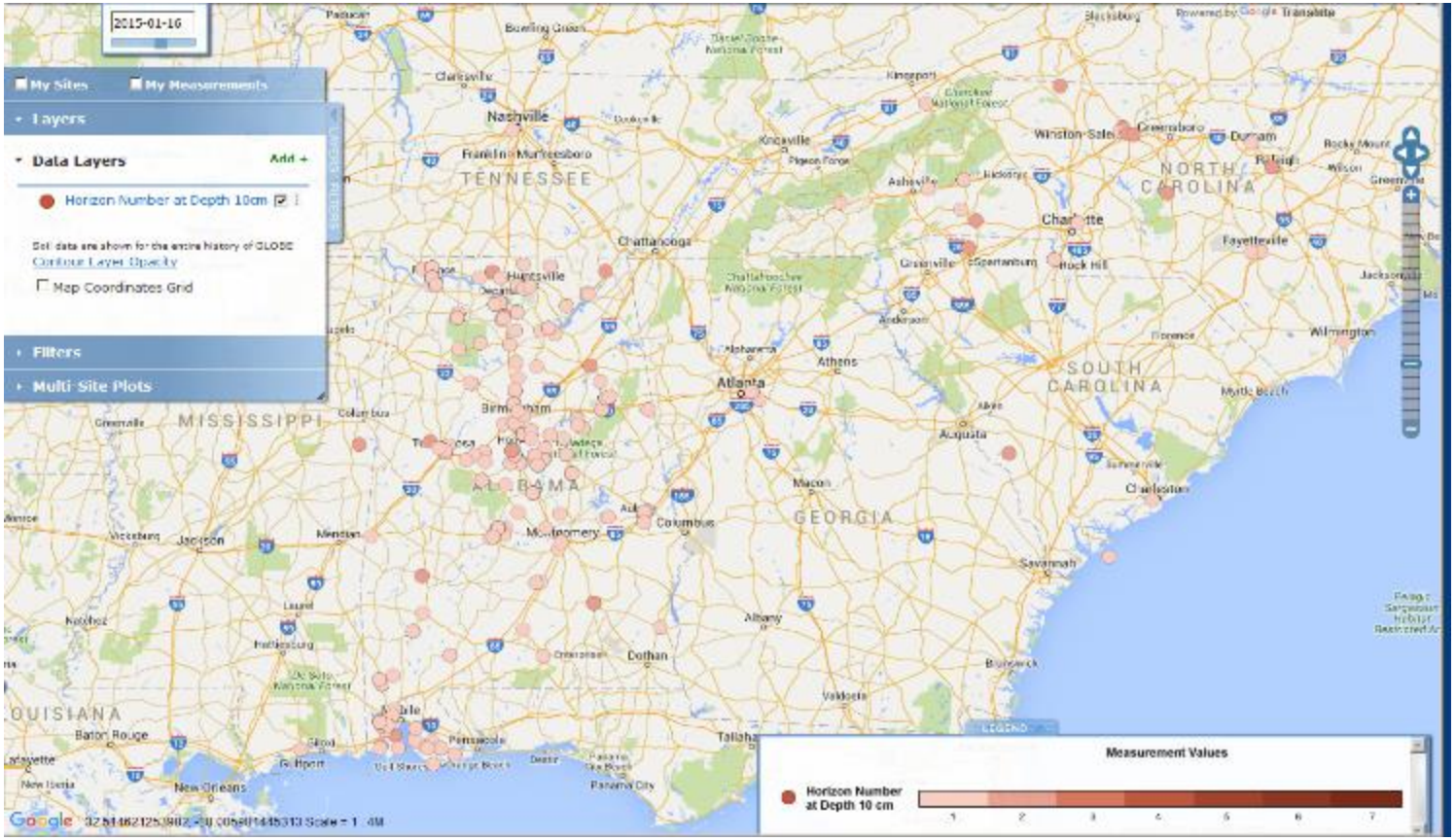
Data Visualization of Horizons 1, 2, & 3

The map shows stacks of dots with horizon 1 on top surrounded by horizon 2 with horizon 3 outermost at sites with 3 horizons reported.



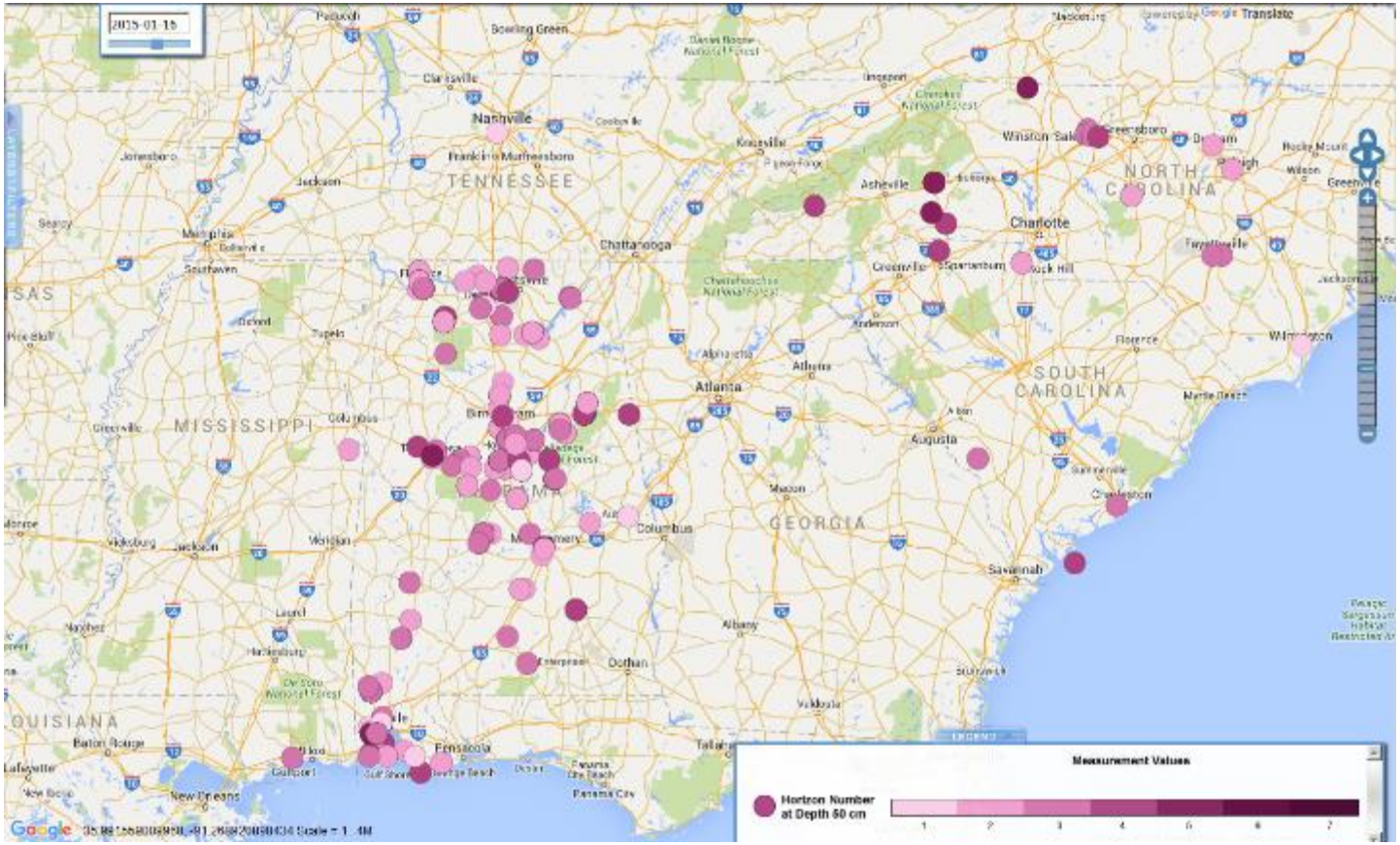
Which Soil Horizon Is at a Depth of 10 cm?

This visualization shows which soil horizon is found 10 cm deep in the soil.
Notice that most but not all sites in this region show Horizon 1 extending to more than 10 cm depth.



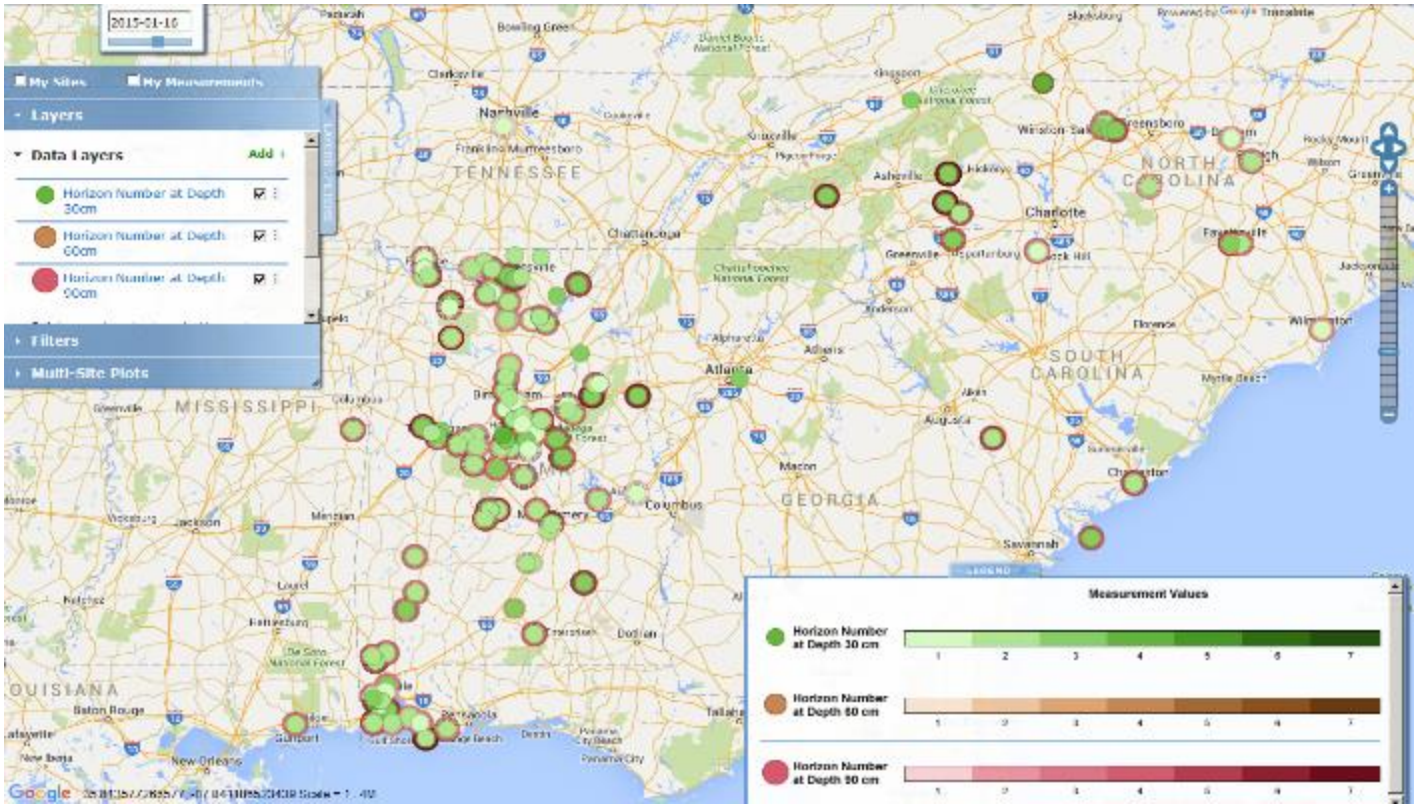
Which Soil Horizon Is at a Depth of 50 cm?

This visualization shows which soil horizon is found 50 cm deep in the soil.
This depth corresponds to the location of the deepest soil temperature sensor.



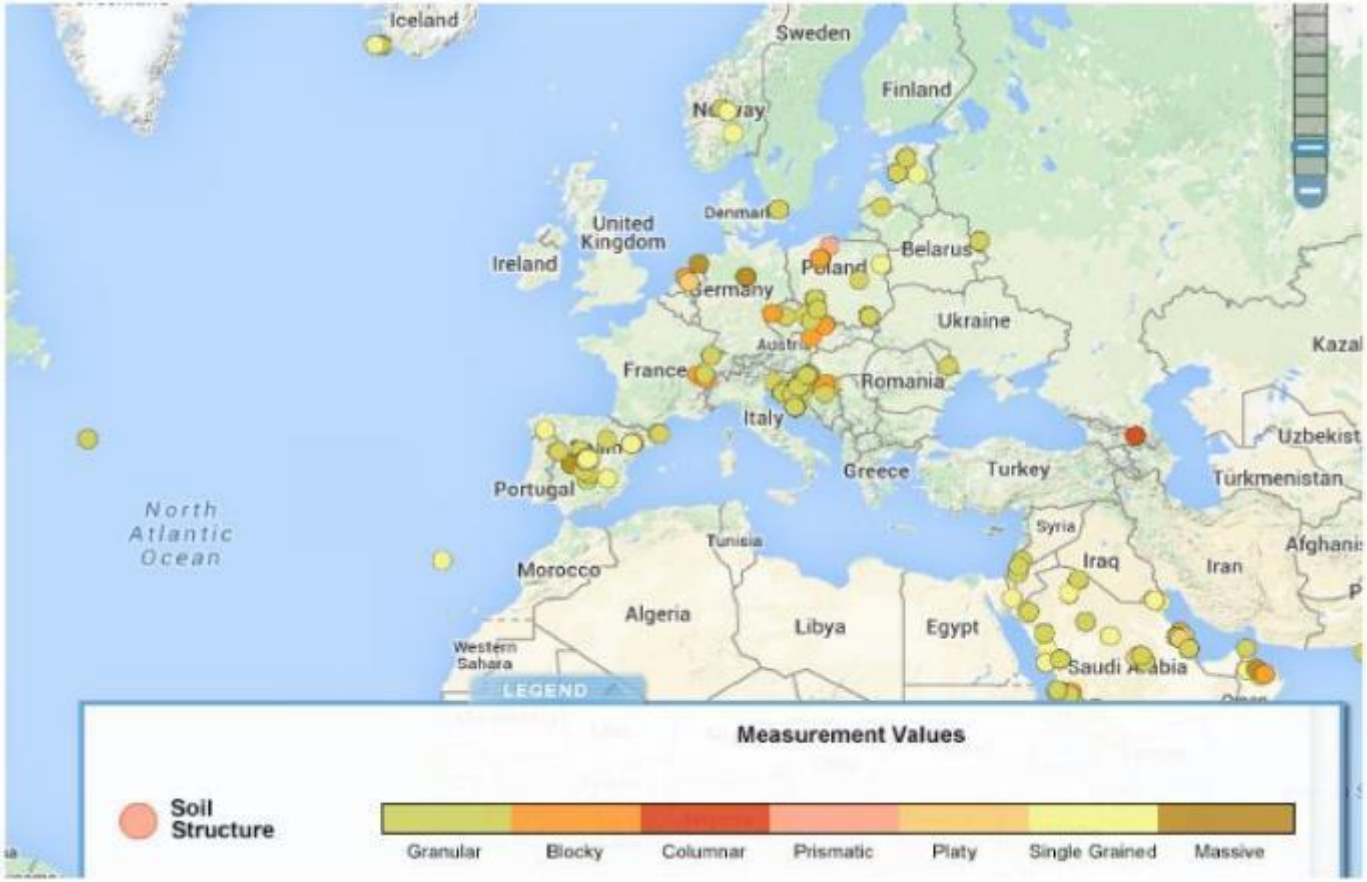
Which Soil Horizons Are at 30, 60, & 90 cm?

This visualization shows which soil horizons are found at the depths of the three deepest soil moisture measurements. Dots for the three depths are nested on top of one another.



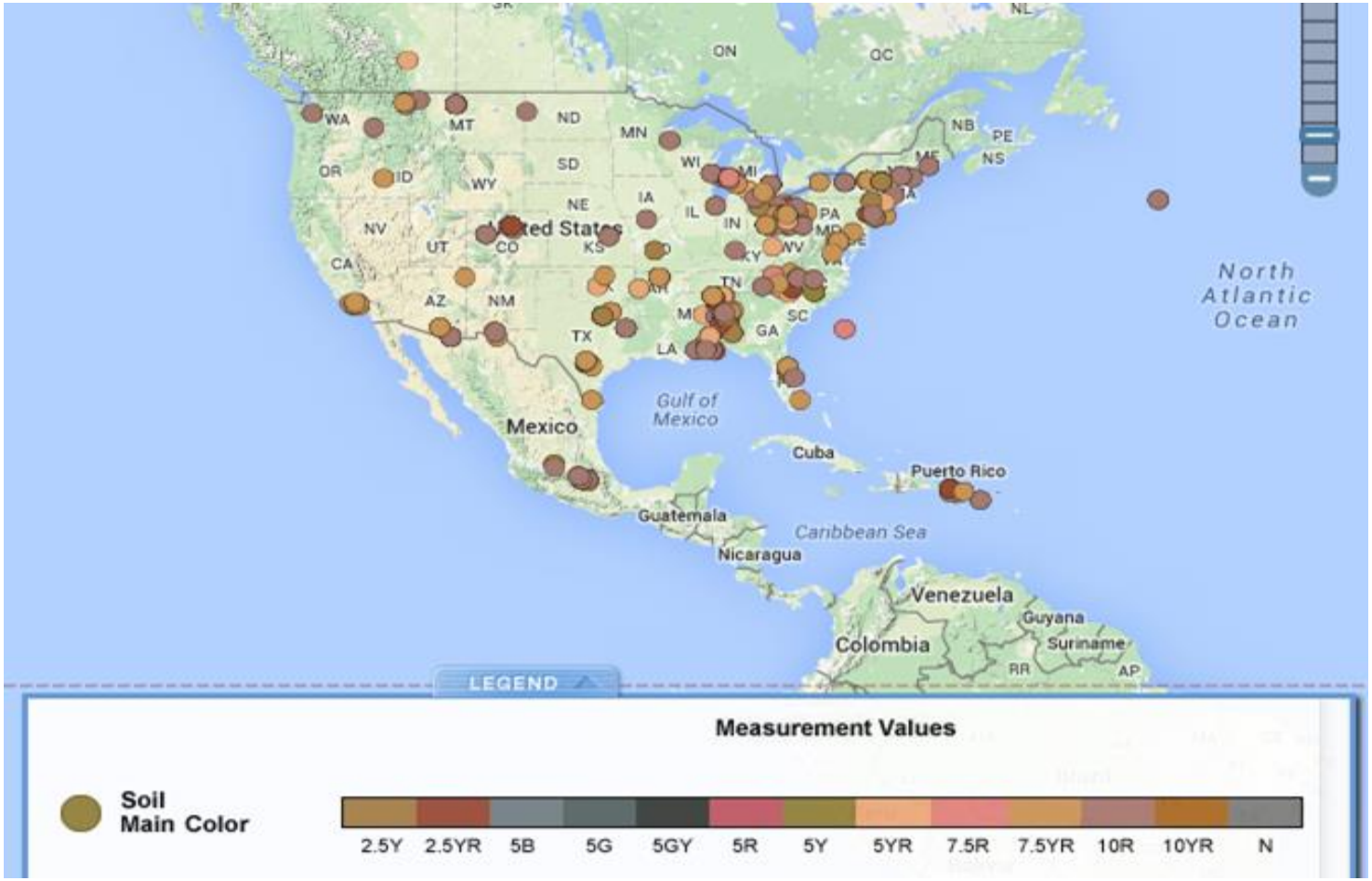
Soil Structure Data Visualization

Visualization of the first horizon data shows the soil's Structure values.



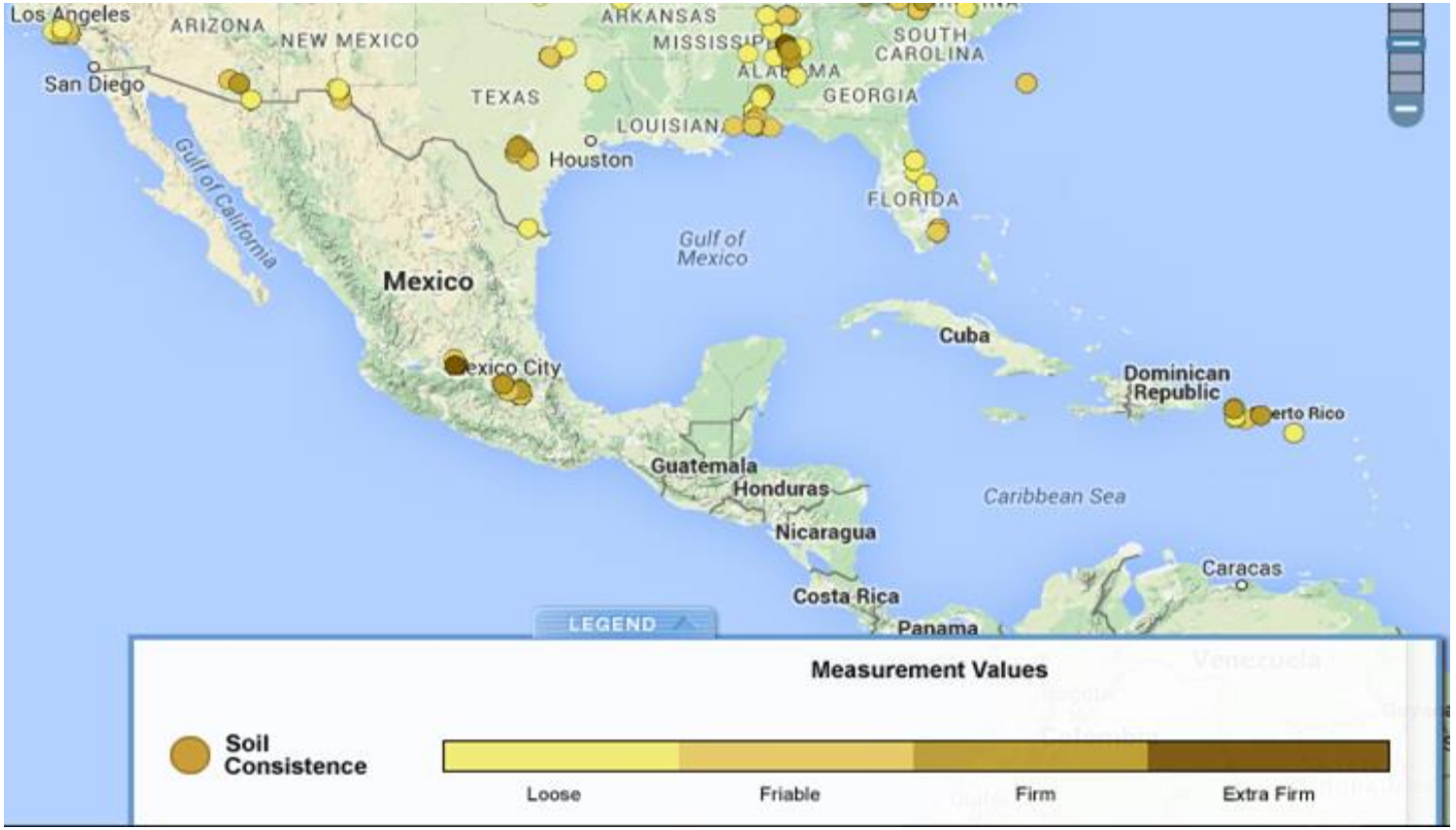
Soil Color Data Visualization

Visualization for the first horizon may provide clues as to the mineral and organic content of these soil samples.



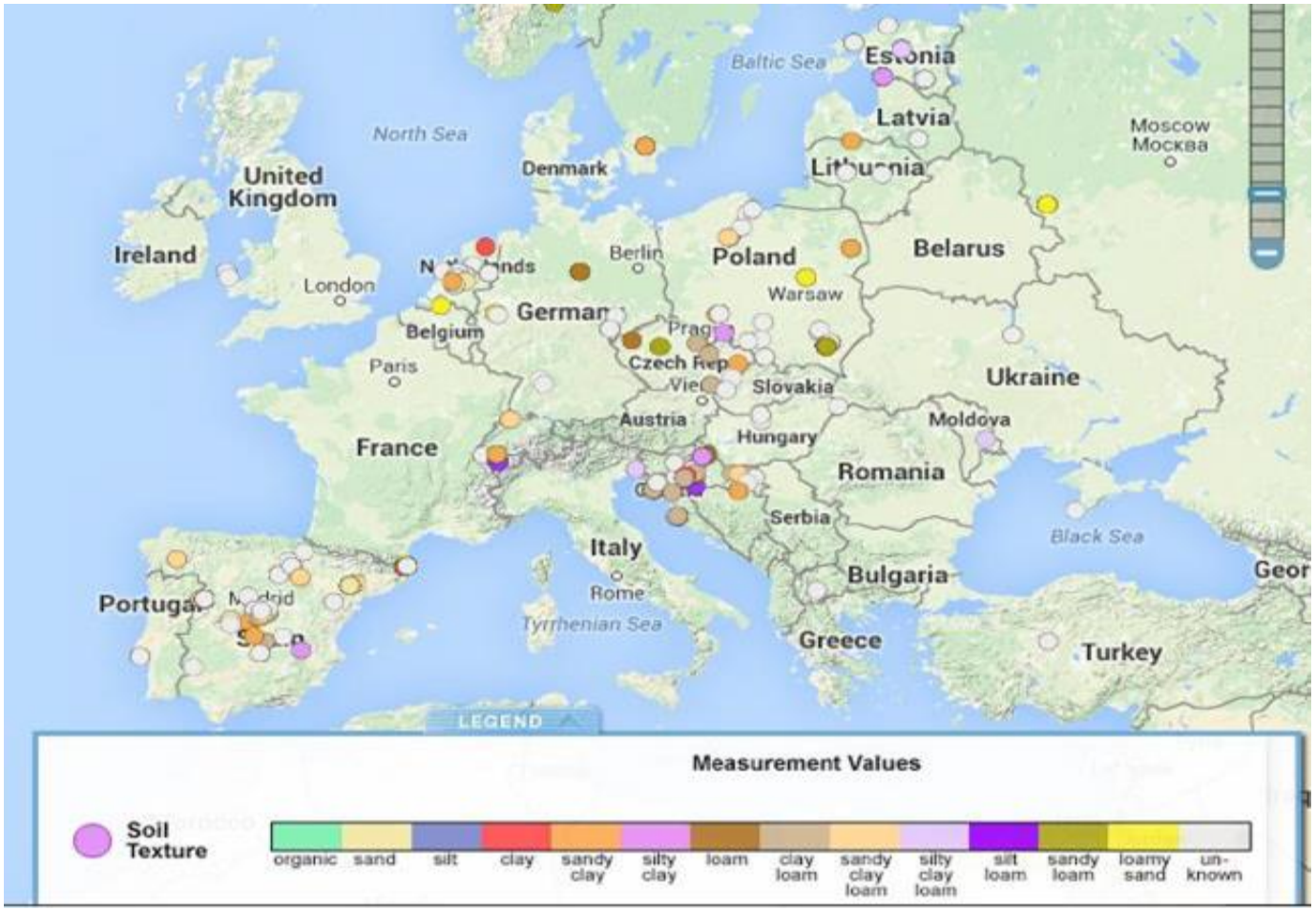
Visualizing Soil Consistence Data

Visualization for the first horizon shows Soil Consistence Measurements.



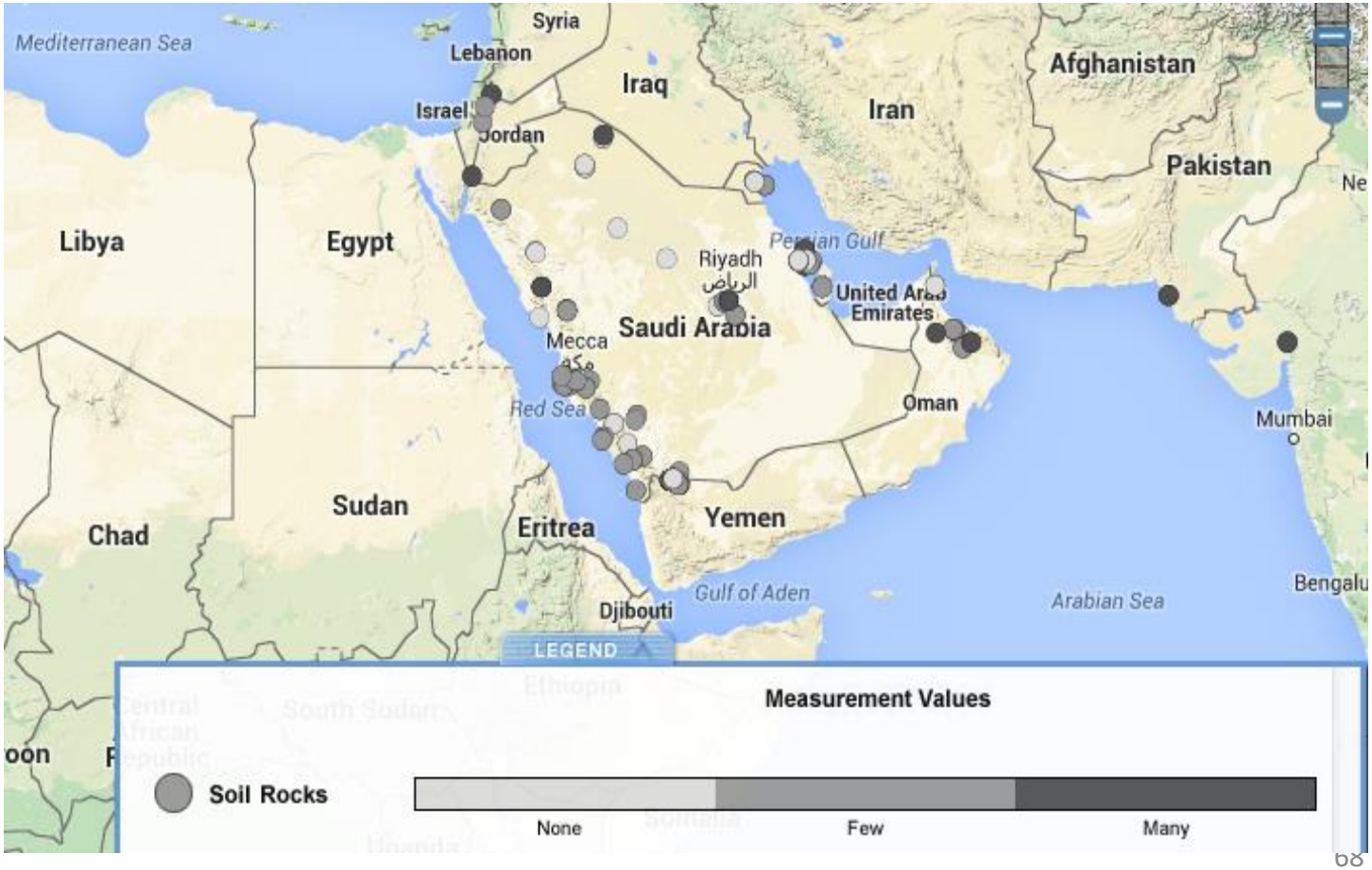
Soil Texture Data Visualization

Visualization for the first horizon shows soil's Texture By Feel.



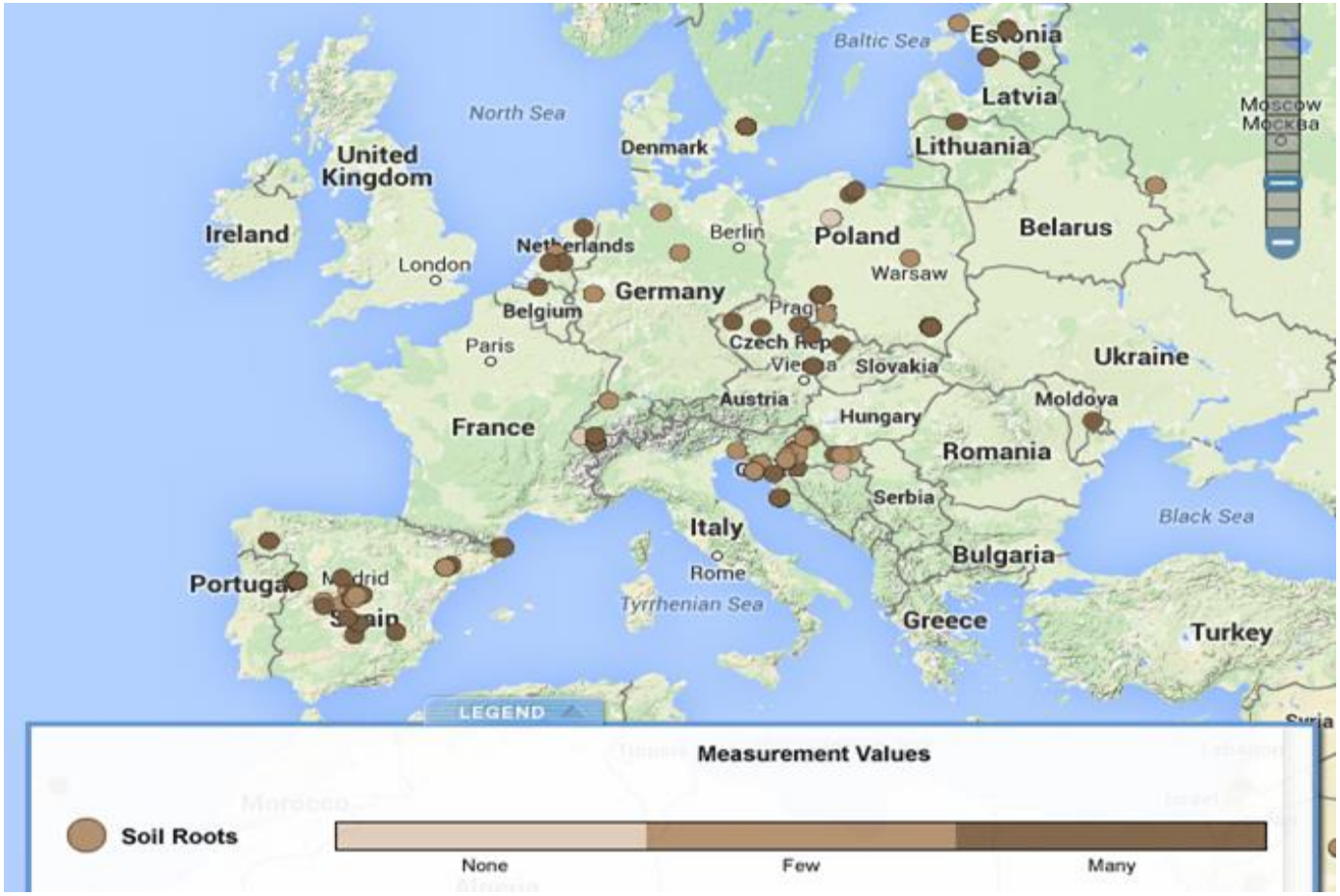
Presence of Roots in Soil Data Visualization

Visualization for the first horizon shows the soil's observed rock content.



Presence of Roots in Soil Data Visualization

Visualization for the first horizon shows the soil's observed root content.



Quiz Yourself

1. What can you learn from soil characterization?
2. You should define your sampling site at least 3 m from path or construction area- why?
3. When would you use the near surface sampling method?
4. Why is it important to take three samples when doing the near surface sampling method?
5. What do you use a compass for in this protocol?
6. A soil sampling site with natural, undisturbed vegetation is ideal. When might you decide to identify a soil sampling site in an area with a lawn or another kind of vegetation?
7. What are the advantages of using the pit sampling method? The auger sampling method?

Questions for Further Investigation

- What creates the different horizons in a soil profile?
- What natural changes could alter the soil horizons?
- How long might it take to alter the depths of the different horizons?
- How do soil profiles change from one location to another?
- How do soil horizons change from one location to another?

Frequently Asked Questions

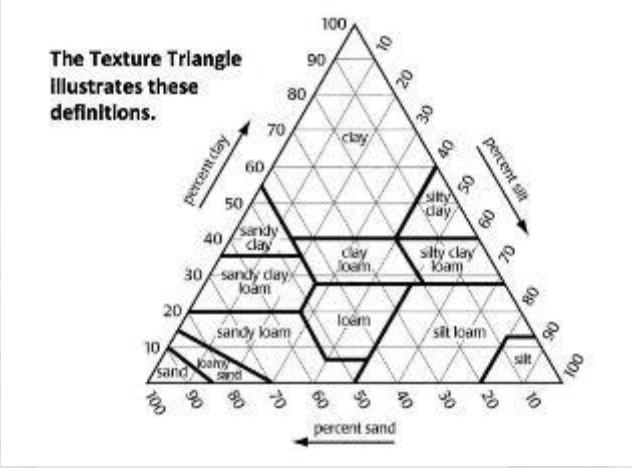
What do the numbers and letters describing the soil color mean?

- For GLOBE, the universal Munsell notation is used to identify the color of the soil.
- The system is made up of 3 symbols representing the *hue*, *value*, and *chroma* of the soil color.
- The **hue** is described by the first set of number and letter symbols in the Munsell system. Hue represents the position of the color on the color wheel (Y=Yellow, R=Red, G=Green, B=Blue, YR=Yellow Red, RY=Red Yellow).
- The **value** is the number before the slash in the Munsell system. Value indicates the lightness of a color. The scale of value ranges from 0 for pure black to 10 for pure white.
- The **chroma** is the number after the slash in the Munsell system. Chroma describes the "intensity" of a color. Colors of low chroma values are sometimes called weak, while those of high chroma are said to be highly saturated, strong, or vivid. The scale starts at zero, for neutral colors, but there is no arbitrary end to the scale.

Frequently Asked Questions (Cont'd)

What does it mean if I determine that my soil is a silty clay or a sandy loam?

The texture you determine from feeling your soil is a subjective measurement. This means that another person might not think that the soil has exactly the same texture as you do. The texture actually refers to the percentages of sand, silt, and clay present. The triangle below is called a textural triangle and can be used to determine the approximate percentages of sand, silt, and clay in your soil from the texture you determined. For a more objective measure of soil texture, you should perform the *Particle Size Distribution Protocol* in which you determine the actual percentages of sand, silt, and clay in the soil.



Please provide us with feedback about this module. This is a community project and we welcome your comments, suggestions and edits!
Questions abut this module: Contact GLOBE: help@nasaglobe.org

Slides: Izolda Trachtenberg, Dixon Butler, and Russanne Low

Photographs: Izolda Trachtenberg

Illustrations, unless otherwise identified: Rich Potter

Cover Art: Jenn Glaser, *ScribeArts*

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