Investigating Soil Texture and Infiltration

Objective: Students will explore soil texture and infiltration rates through hands-on testing to determine how different soil types affect water movement. These skills will help them analyze outdoor soils to assess if a location is suitable for a rain garden.

Standards:

- **NGSS PE:** MS-ESS2-2, MS-ESS2-4, HS-ESS2-5, HS-ESS3-4
- **SDGs:** 6 – Clean water and sanitation, 11 – Sustainable cities and communities, 13 – Climate action

Materials

- two different soil samples, one mostly sandy and one mostly silt and clay, in labeled containers. Can create soil samples with specific proportions of sand, silt, and clay using individual samples Soil Samples - AgClassroomStore
- sand
- water
- 2 clear containers with straight sides and lids, such as Mason Jars
- paper towels
- rulers
- clear plastic cups
- large mixing trays or plates
- soil texturing flow chart and triangle: 2016 Soil Texture flow Chart.pdf
- block of wood, optional
- sledge or hammer – something to push the ring into the soil
- plastic wrap
- timer (phone)
- 6-inch ring* Soil Infiltration Ring (Steel) – Conservation Demonstrations | Rainfall

* Another size ring will work, but you will need to calculate the amount of water that will correlate with 1" by measuring the diameter of your ring in inches, and using the formula:

Volume in inches = Area x height x (milliliters: inch^3)

$$= 2\pi r^2 \times 1 \times 16.387 \text{ml/in}^3$$

Table 1. Volume of water required based on ring size.

Ring diameter (inches)	Volume of water
4	206 ml or 7 oz.
5	322 ml or 11 oz.
6	463 ml or 16 oz.
7	631 ml or 21 oz.
8	824 ml or 28 oz.
9	1043 ml or 35 oz.

Prepare

For the settling jar demonstration, label the lids of two clear jars with "sample 1" and "sample 2." Fill each with about a cup of the respective soil sample. Add water until each jar is three-quarters full. Then add a few drops of dish soap and shake the jars. Allow the mixtures to settle for at least 24 hours.

Engage

1. Soil Texture Observation: Provide participants with two distinct soil samples. Lead a guided discussion:
    - How are these soils similar and different?
    - How do these soils feel (gritty, smooth, sticky)?
    - How might these soils behave differently when exposed to water?

2. Infiltration Demonstration:
    a. Place equal volumes of the two soil samples in identical containers with small drainage holes in the bottom. Set both containers on a tray.
    b. Pour a set amount of water (determined by container size) into each and time how long it takes for the water to infiltrate.
    c. Compare and discuss differences in infiltration rates.

Explore

Have students conduct hands-on soil texture assessments using the following methods, and then utilizing the USDA Soil Texturing Field Flow Chart.

1. Initial Feel Test: For each soil sample, take a dry sample and rub it between fingers. Observe texture.
    - Gritty (sand-dominant)
    - Silky (silt-dominant)
    - Sticky and moldable (clay-dominant)

2. Moisture Test:
    a. Add a small amount of water to the soil and knead until it holds together. Note the relative amounts of water required for each soil to hold together.
    b. Observe how the soil changes as water is added.

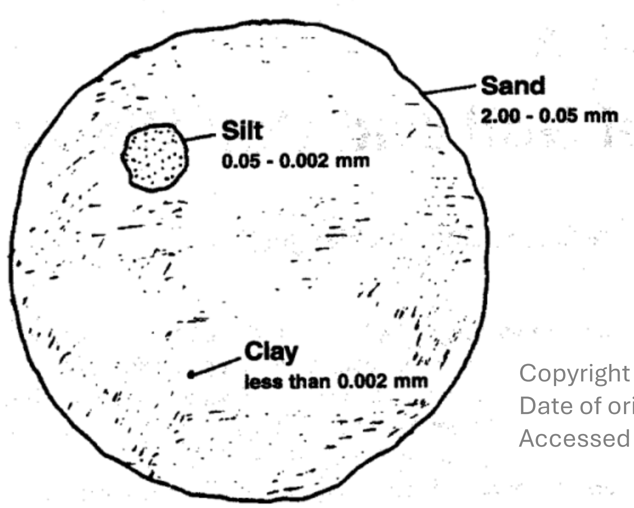
3. Ribbon Test:
    a. Roll the moist soil into a ball and press it between the thumb and forefinger to form a ribbon.
    b. Measure the length of the ribbon before it breaks.
    c. Use the Soil Texturing Flow Chart to determine clay content.

Explain

1. Elicit student ideas as to why the soils have different feels and ribbon lengths.

2. Introduce the concept that soil's interaction with water is influenced by multiple factors, including soil texture, which is determined by the relative proportions of sand, silt, and clay particles.

3. Explain that soil is made up of three primary particle sizes, each influencing soil properties in different ways:
    a. Sand – Largest particles (0.05–2.0 mm in diameter)
        - Feels gritty due to large, coarse particles.
        - Drains quickly because large spaces exist between grains.
        - Poor at retaining nutrients since water washes them away.
    b. Silt – Medium-sized particles (0.002–0.05 mm in diameter)
        - Feels soft and silky, like flour.
        - Holds more water than sand but still drains relatively well.
        - Provides better nutrient retention than sand.
    c. Clay – Smallest particles (less than 0.002 mm in diameter)
        - Feels sticky and smooth when wet, and hard when dry.
        - Drains very slowly due to tiny spaces between particles.
        - Holds onto nutrients effectively but can become compacted.



4. Use an image or diagram to compare the relative sizes of sand, silt, and clay, and discuss real-world examples, such as:
    - Sandy soils are common in deserts and along coastlines, where water quickly drains.
    - Silt-rich soils are often found in river valleys and floodplains, making them fertile for farming.
    - Clay soils are prevalent in wetland areas and tend to retain water for long periods.

5. Settling Jar Analysis:
    a. Guide students through analyzing their soil settling jars (prepared in Engage). Ask them to observe how the soil layers have settled (overnight, if possible). Explain:
        - Sand settles first (within minutes) because it is the heaviest and has the largest particles. This forms the bottom layer.
        - Silt settles second (within an hour), forming the middle layer.
        - Clay remains suspended the longest (up to 24 hours or more), eventually forming the top layer. However, some very fine clay particles may stay suspended indefinitely.
        - Organic material floats at the top, if present.

    b. Measure and classify the soil texture:
        1. Use a ruler to measure the thickness of each layer.
        2. Calculate the percentage of each particle type by dividing each layer's height by the total height of the soil.
        3. Use the Soil Texture Triangle to determine the soil texture of the sample based on the sand, silt, and clay percentages.

6. Infiltration and Rain Gardens:
    a. Elicit student ideas for why soil texture matters and what it might impact:
        - Why is infiltration important for preventing flooding and runoff?
        - What might happen if a rain garden is placed in an area with heavy clay soil?

    b. Guide students in a discussion that mimics components of CERR to connect their findings thus far to infiltration and rain garden suitability. Ask students to make a **claim** as to how soil texture affects infiltration. Have students provide specific **evidence** to back up their claim and provide their **reasoning**. Also, prompt students to come up with a potential **rebuttal** to their claim.

    c. Demonstrate the infiltration procedure using sand in the lab:
        1. Push a 6-inch diameter ring halfway into a container of sand.
        2. Line the soil inside the ring with plastic wrap and pour 463 mL (1 inch) of water on top. (If your ring is a different size, calculate the amount of water that 1 inch would correlate to as described in the materials section.)
        3. With a timer at the ready, carefully remove the plastic wrap to avoid disturbing the soil and start the timer.

4. Stop the timer when the water is gone and the surface of the soil just glistens.
5. Repeat steps 2-4.
6. Calculate infiltration rate using the equation below and the second time collected in step 5.

d. Optionally, and if you have enough soil samples, have students carry out infiltration tests on the two samples.
e. Discuss how real-world rain garden locations depend on infiltration tests. If soil drains too slowly, modifications such as amending the soil with compost or sand may be necessary.

Elaborate

1. Using Web Soil Survey (WSS):
    a. Introduce WSS as a tool used by landowners to assess soil properties. WSS provides soil data based on a combination of remote sensing, field sampling, laboratory analysis, and historical records. While some locations have been directly analyzed in the field, much of the data is derived from broader soil mapping efforts and modeling, meaning site-specific conditions may vary. Soil interpretations in WSS are projections based on regional trends and known soil properties.
    b. Have students go through the Digital Soil Analysis with Web Soil Survey handout to assess the soil within your area of interest for a rain garden installation.

2. Discussion Questions:
    - How does the WSS data compare with hands-on observations?
    - What local soil types are best or worst for a rain garden?
    - Based on the data, would this site be a good location for a rain garden? Why or why not?

Evaluate

1. Conduct field tests at potential rain garden sites.
    a. Soil Texture Test: Collect a soil sample (at least 6 inches deep) and determine the soil texture.
    b. An infiltration test can be conducted if it hasn't rained in the last 24 hours. At the site, clear plant residue or trim vegetation to expose the soil surface. Use a wooden block and mallet to drive a 6-inch diameter metal ring into the soil about 2 inches deep. Follow the procedure described above to determine the infiltration rate. See full procedure here: Measuring Infiltration Rate in the Field | TSU

2. Student reflection questions for each potential site:
    a. How did the field test results compare with classroom texture tests and Web Soil Survey (WSS) data? What similarities or differences did you notice?
    b. Based on your observations, is this site suitable for a rain garden? Why or why not?
    c. If the site is not ideal, what soil modifications (e.g., adding organic matter, aerating, amending with sand) could improve infiltration and rain garden performance?

3. Class Discussion:
    a. Which soil textures (or particle types) are best suited for a rain garden, and why?
    b. If a site has poor drainage, what modifications could be made to improve water infiltration?
    c. How does soil texture influence stormwater runoff and flooding in both urban and natural landscapes?
    d. In designing a community-wide stormwater management plan, how could soil data and infiltration rates help determine the best locations for rain gardens or other green infrastructure?
    e. How might climate, land use, and soil properties interact to affect water movement in different environments?

Investigating Soil Texture and Infiltration

Objective: You will explore soil texture and infiltration rates through hands-on tests to see how different soil types affect water movement. This will help you analyze outdoor soils and determine if a location is suitable for a rain garden.

Soil Sample Analysis

1. Record observations of two soil samples, including how they look and feel.

2. Moisture Test:
   a. Slowly add a few drops of water to the soil sample.
   b. Knead the sample in your palm until it holds together but is not muddy.
   c. Observe how the soil changes as water is added.

3. Ribbon Test: Roll the moist soil into a ball and then press it between your thumb and forefinger to form a ribbon. Note how long the ribbon was before it broke.

4. Use the Soil Texturing Field Flow Chart to identify the soil texture.

5. Analize the soil in a jar demonstration.
   a. Record observations of each sample.
   b. Use a ruler to measure the thickness of each layer.
   c. Calculate the percentage of each particle type by dividing each layer's height by the total height of the soil.
   d. Use the Soil Texture Triangle to determine the soil texture of the sample based on the sand, silt, and clay percentages.

6. Infiltration Demonstration
   a. Take notes about the experimental set up.
   b. Record observations of the demonstrations.
   c. Calculate Infiltration Rate using the formula:
   Infiltration Rate = 1 / [(minutes for infiltration to occur/60) + (seconds for infiltration to occur/3600)]
   d. Imagine carrying out the procedure on the two soil samples instead of sand. How might the results be similar and different for each sample?

Web Soil Survey

1. Using the Web Soil Survey handout, explore the soil in your area, especially in potential rain garden locations.
2. Record notes here.
3. Save relevant maps by selecting “print” and saving the PDF.

Collecting Soil Data for Potential Sites

1. Collect and Analyze Soil Samples
    a. Dig 6 inches deep at each potential site and collect approximately two cups of soil.
    b. Use one cup to conduct a soil texture analysis by feel.
    c. Use the second cup for a settling jar test (to determine sand, silt, and clay composition).

2. Conduct Infiltration Tests
    a. Near the sampling location, set up the infiltration experiment.
    b. Conduct the test twice.
    c. Use the second test result to calculate the infiltration rate (inches per hour).

Analysis

1. Describe your soil analysis for each potential site.
2. How did the field test results compare with Web Soil Survey (WSS) data? What similarities or differences did you notice?
3. Based on your observations, are the locations you tested suitable for a rain garden from a soil perspective? Why or why not?
4. If a site is not ideal, what soil modifications (e.g., adding organic matter, aerating, amending with sand) could improve infiltration and rain garden performance?

Observations and Data of Soil Samples 1 and 2

	Sample 1	Sample 2
Look		
Feel		
Infiltration Demonstration		
Moisture Test		
Ribbon Test		
Soil Texture from Flow Chart		
Soil in a Jar Observations		
Soil in a Jar Measurements		
Soil Texture from Soil in Jar		

Digital Soil Analysis with Web Soil Survey

Rain gardens capture runoff from impervious surfaces, allowing water to infiltrate rather than overwhelm drainage systems. Proper site selection ensures effective infiltration and prevents pooling. Web Soil Survey (WSS), a free online tool from the USDA Natural Resources Conservation Service, provides detailed soil data, including texture, drainage class, permeability, and infiltration rates. By analyzing these properties, users can assess whether a site can effectively absorb stormwater or if modifications, such as adding organic matter or amending soil structure, are needed.

Getting Started with Web Soil Survey

1. Navigate to the WSS website (https://websoilsurvey.sc.egov.usda.gov/).

2. After reading the introductory text on the homepage, click on the green "START WSS" button to enter the application.

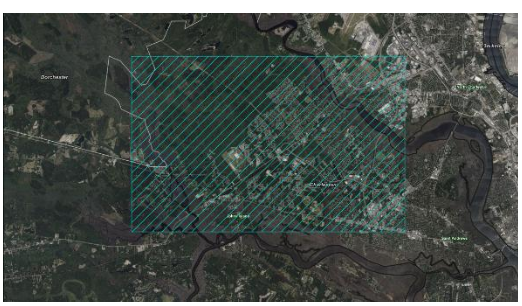
3. Become acquainted with the toolbar by hovering over each icon.

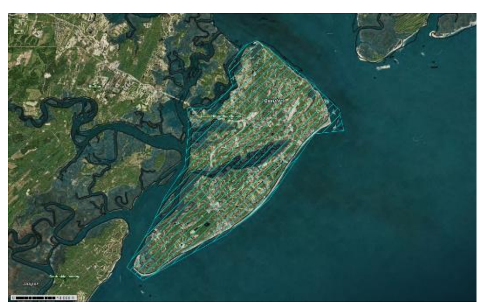
4. You will first need to select an Area of Interest (AOI) that is less than 100,000 acres. Use the Quick Navigation toolbar on the left to move the map to your desired location. Select an option suitable for your use, the most likely of which are:
    a. Address. Type in a complete address, a city and state, or a zip code then click "View."
    b. State and County. Make selections, then click "View."

5. Use the Zoom In and Zoom Out icons until the entire AOI is visible on your screen.

6. Use the AOI rectangle or AOI polygon icons on the toolbar to create an AOI that is less than 100,000 acres. An error message will pop up if the AOI is too large, at which point you can select again.

7. The selected AOI will fill with blue diagonal lines upon a successful selection. Also, information will populate on the left toolbar including the acreage for each county and the total acreage within the AOI.





8. Click on the “Soil Map” or “Soil Data Explorer” tab along the top to view soil data options. Within the Soil Data Explorer tab, there are additional tabs which contain interpretations related to “Suitabilities and Limitations for Use,” “Soil Properties and Qualities,” and “Ecological Sites.”

Assessing Site Suitability Using Select Interpretations

9. For each of the soil interpretations below, navigate to the interpretation on the left panel, read about it using the “View Description” button, and then “View Rating” to learn more about the selected AOI.
    a. Soil Texture
    Soil Properties and Qualities > Soil Physical Properties > Surface Texture

    b. Hydraulic Conductivity
    Soil Properties and Qualities > Soil Physical Properties > Saturated Hydraulic Conductivity

    c. Depth to Water Table
    Soil Properties and Qualities > Water Features > Depth to Water Table

    d. Hydrologic Soil Group
    Soil Properties and Qualities > Soil Qualities and Features > Hydrologic Soil Group

    e. Drainage Class
    Soil Properties and Qualities > Soil Qualities and Features > Drainage Class

    f. Flooding Frequency
    Soil Properties and Qualities > Water Features > Flooding Frequency

    g. Ponding Frequency
    Soil Properties and Qualities > Water Features > Ponding Frequency

10. To save print maps, select “Printable Version” in the top left, and then “View”. A new webpage will open with the map, key, and description. Adjust what is included in the report, including map features, using the legend in WSS.

11. To save a map or an AOI, select “Link” on the very top toolbar. Save the URL or bookmark it for later use.