**The Life Below our Feet: Getting Down and Dirty with Soils**

Joint Science Education Project Graduate Fellow

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**Overview**

Soils are one of the most important natural resources on this planet. By supporting life and cycling water, carbon, and other essential elements, soils help drive important Earth systems and support human civilizations. In this lesson, students will delve into the world of soil science by collecting their own soil cores and analyzing the cores for water, organic matter, and total carbon content by soil strata. Students will learn how soils link many of Earth’s systems including the biosphere, geosphere, hydrosphere, and atmosphere and how soils can tell scientists a lot about a location’s natural history and climate.

**Next Generation Science Standards**

* HS-LS2 Ecosystems: Interactions, Energy, and Dynamics
  + – 4: Using mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
  + – 5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
* HS-ESS2 Earth’s Systems
  + -2: Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.
  + -6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

**Focus Question**

Why are soils important, especially when studying global carbon cycling and storage?

**Objectives**

In this lesson, students will:

* Learn about soil forming processes and soil structure.
* Collect their own soil samples/cores
* Analyzing soils for water and organic matter by soil strata by calculating mass loss after drying and burning, respectively.
* Calculate and model water, organic matter, and carbon content within a soil profile.

**Total Time Required**

Two ~60 min. class periods, 1 for collecting soils and the other for burning dried soil samples. Class sessions will need to be at least 2 days apart in order to allow enough time for the soil samples to dry.

**Background**

Soil is utilitarian, ecological, and pedological by its very nature. Soil is utilitarian as it relates to important industries such as agriculture and engineering. For example, when deciding to build a new home, engineers must consider soil type when deciding where to place a very heavy foundation that a building will sit on for many years to come. If the ground is likely to be extremely wet or poorly drained due to clay-rich soils, the building will not be stable and will start to collapse soon after completion. Soils also provide important ecological services by supporting plant growth, both physically and through the transfer of water and nutrients across soil medium. Soil also plays an important role in removing, filtering, and storing pollutants. And finally, soil is a pedological process in that it is formed from many different geological processes including physical, chemical, and biological weathering, organic matter accumulation, and leaching.

There are five main soil forming processes: climate, biota, relief, parent material, and time. These processes, working together, help shape the foundations of terrestrial ecosystems and help shape the landscape. Soils are dynamic, constantly changing and responding to changes over time, especially changes in climate. Additionally, as soils age, they form distinct soil horizons which create a soil profile with a topsoil and subsoil forming above the older parent material.

Soil is also an extremely important part of global carbon cycling. Approximately 80% of terrestrial carbon budgets are currently stored in soils. That translates to more than 3 times the amount of carbon in the atmosphere! Most of the carbon stored in soils is organic, meaning that is comes from living or dead organisms, while about a third of soil carbon is stored in an inorganic form (*i.e.* limestone and carbonate minerals).

*Permafrost and Soil Carbon*

A particularly sensitive soil to ongoing climate change is permafrost. Permafrost is defined as earth material that has been permanently frozen for more than two years and only forms in areas where the Mean Annual Temperature (MAT) is at or below 0o C. Above the permafrost layer you’ll find the active layer where temperatures during the summer months are above freezing, 0o C. The higher the MAT, the more of the ground will be above 0o C, hence a deeper active layer. However, as temperatures increase in the Arctic, active layers are becoming deeper and deeper, and in some areas permafrost is beginning to rapidly thaw. Therefore, permafrost is thought to be affected by climate change because its presence and stability is directly related to air temperature.

Most of the permafrost today formed during the last few ice ages and has remained through the warmer interglacial periods of the last 10,000 years. During permafrost formation, plants and animals are often buried in thick layers of organic soil and frozen for hundreds to thousands of years, thereby trapping large stores of carbon in these frozen arctic soils. Ongoing research of arctic permafrost has suggested that approximately twice as much carbon is stored in permafrost as is currently contained in the atmosphere. However, as permafrost begins to warm and thaw, these once dormant soils become active and start to decompose. On the negative side, the degradation of stored organic material in arctic soils can release carbon (as either CO2 or CH4) to the atmosphere that otherwise would have been stored in the ground for hundreds or thousands of years, yet on the positive side frozen organic soils may fertilize and enhance plant growth. Therefore, understand what will happen when permafrost begins to thaw is an important consideration for arctic scientists.

*Relating Cellular Respiration/Decomposition to Combustion*

In biology, we learn that photosynthesis and cellular respiration are reciprocal processes. Additionally, soils actively respire during decomposition, as microbes and other soil organisms break down older organic material and release CO2 back into the atmosphere. In this lesson, students will use combustion as a proxy for soil decomposition by collecting soil cores and burning off the carbon to investigate the carbon content of commonly found local soils.

**Resources/Materials**

* Introduction Power Point
* Trowel or small shovel for collecting soil samples
* Brown paper bags
* Drying oven (optional, can air dry samples for ~7 days if one is not available)
* Crucible (that can be placed over a Bunsen burner)
* Stand for placing the crucible over the burner
* Bunsen burner
* Metal stirrer
* Balance/scale
* Student worksheet (see below)

**Preparation**

Identify a good area near your school where you can collect soil samples. Ideally this will be a relatively undisturbed natural area where soils can be removed from the ground relatively intact (i.e. avoid gravel pits).

**Procedures**

*First Class Period*: Start the lesson my asking students to define soils. What makes up soil? Why are soils important? How do scientists study soil?

After students have had a chance to think a bit about soils, start with the supplied Introductory Power Point (JSEP soils 2017.ppt). Go through the slides, stopping at the animation breaks to ask students questions. Students should also be able to fill out some of the answer spaces provided in the attached worksheet.

Next, students will head outside to collect soil samples at the predetermined location. Here, the class can divide into smaller groups (2-4 students depending on class size and supplies) and each group will be responsible for digging a small soil pit and collection samples. Follow the “Field Methods” section on the worksheet. Students should sketch out a soil profile and include the depth of the organic layer, depth of the mineral layer (if present), and depth of the rooting zone. After students have completed the soil profiles, each group will then subsample soil segments for laboratory analysis. Take a soil sample of approximately 20 g from 0-5, 5-15, 15-25, 25-35, 35-45 cm below the surface. Finally, ask students to cover back up their holes before heading back to the classroom.

Back in the classroom, have students weigh each soil segment. Record the “wet weight” in the data table, as this will be used to calculate gravimetric moisture loss. Samples with then dried in the oven at 100o C for 24 hours (if a drying oven is not available, soils can be air dried for 7 days).

*Second Class Period*: Students should return to the same groups that they collect soils. Once in small groups, students will reweigh their now dry soil samples. Record “Dry Weight” on the datasheet in the corresponding soil segment. Now, the students are ready to burn their samples over a Bunsen burner in a crucible.

Following the “Lab Methods” section of the worksheet, students will carefully grind soils and weight out approximately 5 grams of soils to burn. Make sure the students are recording the weight of the empty crucible and the weight of the crucible plus unburned soil. Under supervision, have the students turn on their burners and burn the soils for approximately 10 min. Please note that this may smell, so do this portion of the lab in a well-ventilated space. After most of the organic matter has burned off and the crucible has cooled down (approximately another 10 min), students will reweigh the crucible and soil. Repeat this process for the other soil layers. If time is limiting, you can have each student group burn a different layer from the same core and then complete the corresponding worksheet table as a group exercise.

Once all of the data has been recorded in the data table, students will then calculate the amount of water, organic matter, and carbon in the soils using the provided equations:

**% Gravimetric moisture (soil water content) = (Wet weight – Dry weight)/ Wet weight**

**%OM= 100-[ { (‘weight after burning’ – ‘weight of crucible’ ) / (‘weight before burning’ – ‘weight of crucible’) } X100]**

**%C= %OM / 1.72**

Finally, have students complete the observation and conclusion section of the worksheet. Come back together as a class to summarize your findings discuss the results.

**Optional Assessment**

Worksheets can be turned in for a lab grade in order to see if the students understood the key concepts of soil science and the mathematical equations required to model soil water, organic matter, and carbon content.

**JSEP Fellow Video**

<https://www.youtube.com/watch?v=fiVGD6dsjGc>

**Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Soil Notes:**

In each box below, describe in your own words the three ways in which soil can be defined.

|  |
| --- |
| Utilitarian |
| Ecological |
| Pedological |

List at least three factors that influence the make-up of a soil:

1.

2.

3.

What useful services do we get from soil? List at least three.

1.

2.

3.

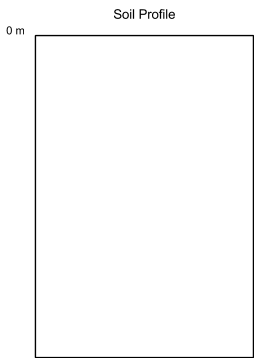
**Measuring carbon in soils by Loss on Ignition**

Now we will estimate how much carbon is stored in soils outside our classroom. Loss on Ignition (LOI) analysis is used to determine the organic matter content (%OM) of a soil sample. LOI calculates %OM by comparing the weight of a sample before and after the soil has been ignited. Before ignition the sample contains OM, but after ignition all that remains is the mineral portion of the soil. The difference in weight before and after ignition represents the amount of the OM that was present in the sample.

A few days prior to our laboratory experiment we will collect soil using a soil corer. We will dig one hole and each group will take samples from various depths. Soils will then be labelled and transported back to Dartmouth College where they will be dried.

**Field Methods:**

1. Start digging your hole. First remove the upper layer, including the leaf litter, until you see the top of the soil profile where the soil material is cohesive.
2. Dig a hole about 50 cm so that you can see the entire soil profile. Feel the soils and see if you can identify the different soil layers. Where is the soil the most solid? The least solid? Where are most of the roots located?
3. Draw a soil profile – 0 cm is the soil surface where the soil material is cohesive. Include root zone, soil with humus (organic material) and mineral soils.  Think about whether there is clear separation between the layers. How do you think these soils formed?

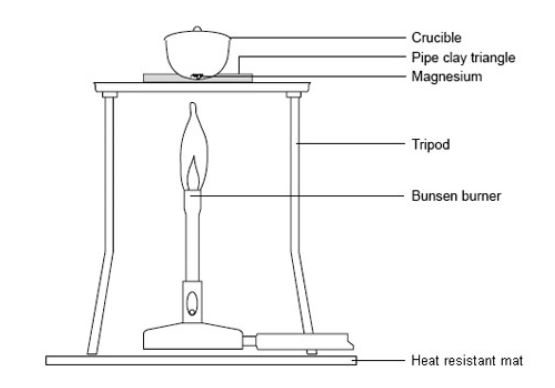


4. Take a soil sample of approximately 20 g from 0-5, 5-15, 15-25, 25-35, 35-45 cm below the surface.

5. Bring your samples back to the classroom and weigh each soil segment. Record the “Wet Weight Whole” in the data table. Samples with then dried in the oven at 100o C for 24 hours (if a drying oven is not available, soils can be air dried for 7 days).   
6. Cover your hole back up.

**Lab methods**:

Now that your soil samples are dried we can find out how much carbon is contained in these soils. Each group will get two burners and a set of crucibles to complete this activity. Be sure to record all data in the table below!

1. Reweigh now dry soil samples for each layer. Record in the “Dry   
   Weight Whole” section of the data sheet.
2. Grind up dried soil samples by placing a small chunk of soil in a plastic bottle with some rocks. Shake for about 5-10 min. Make sure the samples are thoroughly homogenized (mixed) and as small as possible. Remove any large rocks (>5 mm) or big sticks and/or roots.

Soil

Figure 1 Example of laboratory set-up for Loss-On-Ignition

1. Weigh the empty crucible and record its weight in the data table. Add ~5 g of oven dry, crushed soil sample to the crucible and reweigh and record.
2. Burn the sample in the crucible for at least 10 min with a Bunsen burner. THIS MUST BE DONE OUTDOORS OR WITH OPEN WINDOWS AND UNDER SUPERVISION!
3. Reweigh the crucible with the remaining burned soil. Calculate the loss of burning and fill out the table below.

**Loss of burning = (Crucible + dry soil weight) – (Crucible + burned soil)**

1. Calculate the % of organic material (% OM) suing the following equation and fill out the table below:

**%OM= 100-[ { (‘weight after burning’ – ‘weight of crucible’ ) / (‘weight before burning’ – ‘weight of crucible’) } X100]**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Soil Sample (depth segment)** | **Wet Weight Whole(g)** | **Dry**  **Weight Whole(g)** | **Crucible (g)** | **Crucible + dry soil weight (g)** | **Crucible + burned soil (g)** | **Loss of burning (g)** | **% OM** |
| 0-5 cm |  |  |  |  |  |  |  |
| 5-10 cm |  |  |  |  |  |  |  |
| 10-15 cm |  |  |  |  |  |  |  |
| 15-20 cm |  |  |  |  |  |  |  |
| 20-25 cm |  |  |  |  |  |  |  |
| 25-30 cm |  |  |  |  |  |  |  |

**Observations and conclusions**

How can we figure out how much water was in each soil layer? Which soil layer held the most water?

To convert organic matter content into soil carbon content, we can use a conversion factor of 1.72, such that:

Total Organic Carbon(%) = Organic Matter (%)/1.72.

Which layer had the highest carbon content? Why?

How do soils store carbon? What do you think happens to soil carbon if soils are disturbed (i.e. tilled, flooded, covered by buildings)?