Roots and Shoots

Objective

- Students will understand the ability of plants to sequester carbon above and below ground.
- Students will measure above ground biomass by harvesting small samples, and root growth using ingrown root-cores.

Skill Level: Middle school	**Class time:** Three 45-minute periods minimum plus wait time for plant growth.

Materials

Pre-activity (Per group)
- Carbon sequestration worksheet
- Pencils for each student
- Calculators
- Meter sticks
- Yarn or string – 10 feet long

Prepare
- Wheat seeds

Biomass Yield Activity (Per group)
- 1 pair of scissors or plant shears
- Quadrat – 30 x 30 cm squares can be constructed with rulers (small hoola-hoops work well)
- Optional: garden gloves
- Pan(s) for collecting and drying
- Oven(s) for drying

Root Growth Rate (Per group)
- Two #5 plastic mesh plastic canvas sheets (13 1/4" x 22" needlework mesh)
- E6000 Adhesive or similar product (available at larger craft stores)
- Utility knives or scissors
- 2" knockout test caps (available at hardware or plumbing supply store)
- Masking tape
- Stapler and staples
- Tweezers
- Trays for separating root mass (baking pans will do)

- Bulb planter, 2" diameter soil probe
- Marker flags
- Shovels
- Rulers
- Optional: garden gloves

Standards

Disciplinary Core Idea:
LS2.A: Interdependent Relationships in Ecosystems

Performance Expectations:
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Practices	Crosscutting Concepts
☐ Asking questions / defining problems	☐ Patterns
☐ Developing / using models	☐ Cause and effect: Mechanism / explanation
☒ Planning / carrying out investigations	☐ Scale, proportion, and quantity
☒ Analyzing / interpreting data	☐ Systems and system models
☒ Math / computational thinking	☒ Energy / matter: Flows, cycles, conservation
☐ Constructing explanations / design solutions	☐ Structure and function
☐ Engaging in argument from evidence	☐ Stability and change
☐ Obtaining / evaluate / communicate	

Background Information

Introduction:

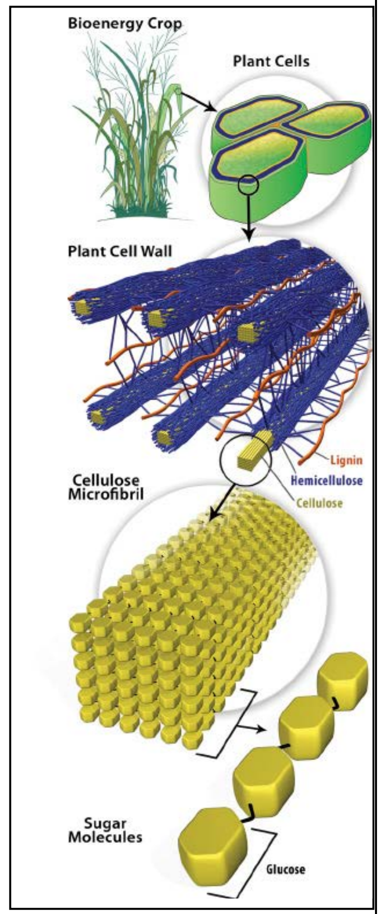
What is carbon sequestration?
Carbon is found in all living organisms and is the major building block for life on earth. In the environment, carbon exists in many forms – predominately as plant biomass, soil organic matter, geologic deposits, and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. High levels of fossil fuel combustion and deforestation have transformed large pools of carbon from fossils (oil and coal deposits) and forests into atmospheric carbon dioxide. Although oceans store most of the earth's carbon, soils contain approximately 75% of the carbon pool on land – three times more than the amount stored in living plants and animals. Soils therefore play a major role in maintaining a balanced global carbon cycle. Since most scientists believe that there is a direct relationship between

increased levels of CO_2 in the atmosphere and rising global temperatures, interest in soil carbon sequestration is attracting the attention of researchers, policy makers, farmers, and the general public. In addition, since soil plays such an important role in sequestration, scientists are looking to using soil as an alternate source of energy.

Background:

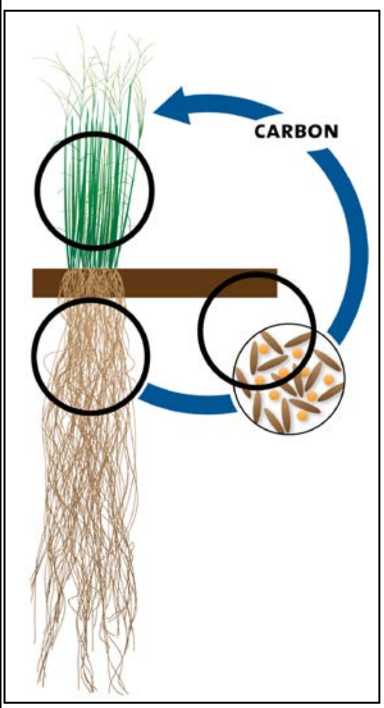
How is carbon sequestered in soils?

Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as soil organic matter (SOM). SOM is a complex mixture of carbon compounds consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and humus – carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere through respiration by soil microbes. Climatic conditions, natural vegetation, soil texture, drainage, and human land use all affect the amount and length of time carbon is stored in soil.



Some Strategies to Reduce CO_2 Emissions

Additional strategies aimed at reducing CO_2 in the atmosphere include tree planting and ocean sequestration of carbon. As forests grow, for example, they store carbon in woody tissue and soil organic matter. The net rate of carbon uptake is greatest when forests are young, and slows with time. Old forests can sequester carbon for a long time providing 8 to 20% of the global terrestrial carbon sink. This is still not enough however to counter 1.8 billion tons released into the atmosphere.



Technological strategies to reduce carbon inputs include developing noncarbon energy sources and energy-efficient fuels such as biofuels. The production of "second generation" biofuels from cellulose, for example, has the potential to decrease greenhouse gas emissions relative to gasoline or corn ethanol. Cellulosic ethanol is produced from crop residues (e.g., stalks, hulls), forestry residues (e.g., forest thinning, wood byproducts), energy crops (e.g., switchgrass), and sorted municipal wastes.

All of the above efforts combined may reduce CO_2 concentrations in the atmosphere and help alleviate the impacts of climate change.

When considering which plants to grow for sustainable biofuels, we must look at the overall carbon cycle of all the steps involved in production. These investigations focus on what happens on the surface and underground. Plants *sequester*, or capture, carbon in their leaves, stems and roots in a variety of molecules, including carbohydrates, which are kept underground after harvesting. Soil microbes may then consume those roots or pieces of dead plants and return carbon dioxide to the atmosphere through cellular respiration. Decisions farmers make as to what to plant, how to plant and how and when to harvest these crops affect soil microbial activity and decomposition rates--influencing how much and how quickly carbon from the plants is returned to the atmosphere.

When comparing potential feedstocks (crop options) and field treatments for biofuel production, scientists measure the amount of plant biomass produced above ground, the rate of root growth below ground, and the rate of carbon dioxide emissions from the soil. In this investigation we will focus on getting carbon from the atmosphere into the plant--first into the leaves and stems above-ground, and then into the roots below-ground, making comparisons between different species or growing techniques. *Net primary productivity* is useful to investigate plant growth in a given period of time. Harvesting above ground, this provides information on the potential yield. Net primary productivity in roots gives an idea of the carbon sequestration potential of different crops over a given period of time.

In this activity, you will design an experiment to measure plant growth rates in the field to gather data to help determine the best crop choice for biofuel production.

Engage

There is still much to learn about carbon sequestration. Current scientific research is examining:

- The full impacts of land use and land management on soil carbon sequestration and ways to increase the storage time of carbon in soil.
- The relationship between underlying mechanisms controlling soil structure and the storage of carbon. These include various chemical, physical, biological, mineralogical, and ecological processes.

Explore

Experiment Questions:

Have your students explore carbon sequestration by looking at the growth of wheat shoots and the roots.

Procedure:

Part 1. Pre-Assessment & Discussion (up to one 45 minute period)
Ask students to describe the difference between burning fossil fuels and biofuels (like ethanol) as it relates to the carbon cycle. How would you measure the ability of plants to take carbon dioxide out of the air? Where does the carbon go? Is it ever returned to the atmosphere?

Part 2. Constructing the core screens

1. Cut the #5 plastic canvas to the desired height and width. The standard height of an in-growth core is 15 cm. The width is determined by the size of the knockout cap. Check to be sure the canvas rolls up (without gaps) and fits snugly in the knockout cap with ½-1 inch overlap.

2. Use this sheet as your template and cut addition pieces if you will be making more than one corer.

3. Staple the end of the core screen and glue it to the test cap with E6000 adhesive. Be sure to do this (and allow it to cure) in a well-ventilated area.

4. Staple along the long axis of the column. These staples may not stay in place well, but they will function as a semi-permanent clamp.

5. Reinforce the staples with tape on the outside of the screen if necessary to hold it together.

6. Apply adhesive along the seam in the column and allow to cure (~24 hours).

7. Place upright. Allow to dry overnight.

8. Remove the tape after the adhesive has dried and check to be sure the core screen will not easily pull apart.

9. Define your study area. All cores should be dug at least one meter from the edges of plots and one meter away from other holes. Select a day to install the core screens when it has not recently rained.

10. Mark each site with a marker flag.

11. Using the long-handle bulb planter, extract a core of soil 15 cm deep. Try not to make the hole any wider than the core screen. If you dig too deep, replace some of the soil, but don't pack it down too much. Be careful to preserve the soil core you remove.

12. Working over a tray, begin to remove the roots from the soil core by carefully breaking it apart and by using the tweezers. The roots can be discarded, but save the soil.

13. Once the roots have been removed, pour the soil into the core screen. It may be helpful to work over another pan so that if soil misses the core screen, it can still be used.

14. It is okay to lightly press the soil into the screen, but pressing hard can change the consistency of the soil.

15. Place the loaded core screen into the hole you dug.

16. You may wish to create a map of your flag locations.

Removing an in-growth root core (to be completed by students)

1. At the end of the growing season or the desired interval of time, locate your flag.

2. Dig up the core using a shovel. Remove the core and some soil around it.

3. Carefully scrape off the excess soil (try not to pull exposed roots from the core) from around the core and cut the roots that are outside of the core.

4. Empty a core into the pan.

5. Separate out the roots from the soil using tweezers and by breaking the soil apart.

6. Mass the total root matter.

7. Place the roots in an oven-safe container and dry for 24 hours if possible (at least overnight) at 105 degrees C (225 degrees F).

8. Mass the total root matter again.

9. Average your results and compare to other fields.

Part 3. Data Analysis and Discussion (One to two 45 minute periods)

Students' pool, average and graph data. They should be asked to describe how the evidence they collected during their experiment supports or refutes their hypothesis. What have they learned from this investigation and what would they still like to know? Bring the discussion back to the idea of biofuels and the potential for crops to sequester carbon. They should be able to describe where carbon is stored in the field and how it moves from place to place. Discuss the potential of perennial crops both to provide a harvestable above-ground crop while sequestering carbon underground in the roots and potentially reducing atmospheric carbon levels.

Explain

Draw a diagram which demonstrates how carbon moves through your study site. Include the plants, roots, soil organisms with linking verbs describing the processes that are occurring. Drawings should demonstrate photosynthesis, carbon storage in leaf, stem, and roots, leaf and root death, decomposition of matter by microbes, and plant respiration.

Elaborate

- Dig it! The Secrets of Soil, Greenhouse Gas Calculator (Smithsonian Museum of Natural History). This interactive, animated online activity puts students in the role of a farmer, deciding what crops to grow and what farming practices to use to balance high yield with lower greenhouse gas emissions. (Click links)
- Build the *Root Depth Model* to show students the depth of various root system and potential for carbon sequestration.
- Follow the carbon cycle by focusing in on respiration from soil communities by conducting experiments using one or more of *Measuring Soil Microbial Activities* available from Great Lakes Bioenergy Research Center.

Resources

Additional Resources:

- This activity was adapted from Wisconsin's Grasslands Bioenergy Network (Click links)
- Scientific article on climate change
- The carbon cycle
- The prequel activity to this investigation.
- Growing wheat for bioethanol