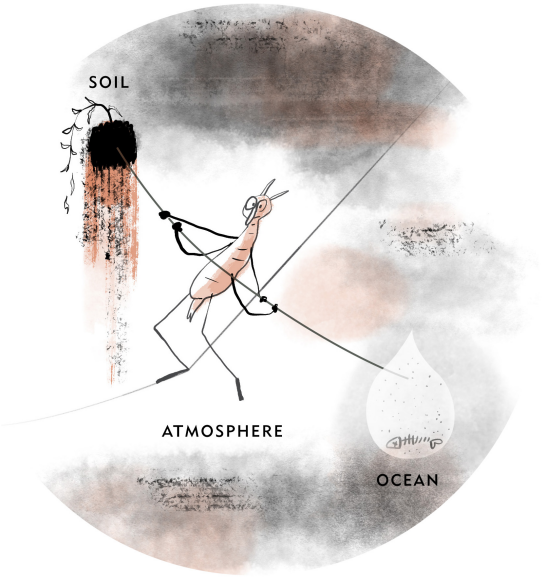
The Soil-Air Connection



This lesson was originally published in Digging into Soil: A Garden Practicum. The full guide is available for digital download at: https://www.diggingintosoil.org.

Overview: What is the relationship between soil and the Earth's atmosphere? Students will explore the connection between what happens below and above the ground. They will learn about the vital role soil plays in the carbon cycle.

Grade Level/Range: 9th- 12th Grade

Objective:
Students will learn:
Soil stores carbon and helps regulate atmospheric carbon.
Soil provides nutrients and habitats to all life on land.

Time: 4 hours

Materials:
Internet access
Chart paper or dry erase board and markers

Background Information:
Soil plays an important role in the carbon cycle. Carbon is found throughout the Earth and is a vital component of all living organisms. The amount of carbon on our planet never changes, but it cycles through different locations, from being stored in living and nonliving matter to being released into the atmosphere.

Plants take in carbon to use during photosynthesis. They then store that carbon as carbohydrates within the plant and also shuttle some of it down into the soil through their roots. The carbon given off by the roots is used as food for underground organisms. Carbon then returns to the atmosphere when plants and other living organisms respire, and also as decomposition occurs. Carbon can also be released from the soil into the atmosphere when the soil is disturbed through digging and tilling.

Additionally, carbon is stored in rocks and fossil fuels. When we burn fossil fuels carbon is released back into the atmosphere. The amount of carbon in the atmosphere impacts the overall climate on our planet. More carbon in the atmosphere leads to warmer temperatures on Earth.

Atmospheric carbon combines with oxygen to become carbon dioxide, which is a greenhouse gas. Greenhouse gases absorb and then re-emit energy back to the Earth. Therefore, the more carbon dioxide in the air, the warmer the temperatures both on land and in the oceans. The warmer temperatures also increase the amount of water vapor present in the atmosphere, increasing temperatures even more. If we want to maintain the planet in its current state, we need to balance the use of carbon so that it is getting stored at the same rate that it is getting released.

Unfortunately, human activities have led to a change in the balance between the amount of carbon stored on Earth and the amount of carbon present (as carbon dioxide) in the atmosphere. These activities include:

- decreasing the amount of plant matter taking in carbon as we have paved over and built upon previously plant-covered land.
- increasing the disturbance of soil through land clearing and tilling.

- burning increasing amounts of fossil fuels.

The oceans also play an important role in storing carbon, but for this lesson we are focusing just on soil.

For a more extensive discussion of the soil's role in the carbon cycle, check out "This Carbon Cycle" from NASA's Earth Observatory: https://earthobservatory.nasa.gov/features/CarbonCycle

Laying the Groundwork:

As a class, watch the video "The Soil Story" from Kiss the Ground, available at https://kisstheground.com/. Use this video to launch a discussion of the carbon cycle. A worksheet to help guide the discussion is available when you download the full Digging into Soils Guide at: https://www.diggingintosoil.org/.

The core message of this video is that the amount of carbon on our planet does not change, but it can be stored in different locations, including the atmosphere, oceans, biosphere, soil, and fossils. As we have released more carbon into the atmosphere we have changed the balance in the storage location of carbon, negatively impacting our environment. Kiss the Ground presents the solution of moving carbon back into the soil as a way to solve the problem of climate change.

Ask students to consider the message presented. Does this solution seem pretty simple? Is it really that simple? Try to brainstorm some real life changes we could make to decrease the release of carbon into the atmosphere and increase the sequestering of carbon into the soil. What are some of the challenges you might face making these changes?

Exploration:

Share the Global Carbon Cycle Components diagram from the U.S. Department of Energy that provides estimates on the amount of carbon cycling through the Earth each year: https://public.ornl.gov/site/gallery/detail.cfm?id=445.

Ask students to create a chart or graph that organizes this information into a different format but still provides data on how much carbon is leaving the atmosphere versus how much is entering the atmosphere each year. An example chart is available when you download the full Digging into Soils Guide at: https://www.diggingintosoil.org/.

Next, check out NASA's Global Climate Change Website, which provides data about the amount of carbon measured in the atmosphere since 2005, available at https://climate.nasa.gov/vital-signs/carbon-dioxide/. Chart the changes in CO2 levels in the last decade recorded at the Mauna Loa Observatory. In 1958, scientists began measuring atmospheric carbon dioxide levels at the top of Mauna Loa Mountain in Hawaii, providing a consistent location for data collection. This location was chosen because of its height, as well as the lack of vegetation around the testing point that helps prevent the skewing of data due to the interaction of nearby plants releasing/consuming CO2 for respiration/photosynthesis.

Compare the changes in the carbon dioxide levels with the information presented in the Carbon Cycling diagram. Make sure to point out to students that the diagram is measuring gigatons of carbon (GtC) in the atmosphere, and the NASA site is recording the monthly CO2 levels in parts per million (ppm). So to compare the two, they must convert their ppm to GtC . They can use the following conversion formula:
1 ppm by volume of atmosphere CO2 = 2.13 GtC
Source: The Carbon Dioxide Information Analysis Center from the U.S. Department of Energy Berkeley Lab: https://cdiac.ess-dive.lbl.gov/pns/convert.html
You can use the sample worksheet at the end of this lesson to direct their data collection and comparison.

To bring the discussion about carbon back to the soil, show students the PBS video "SOS: Save Our Soil," available at http://www.pbs.org/food/features/food-forward-season-1-sos-save-our-soil/. This video highlights the importance of carbon in the soil and spotlights three different efforts by researchers and farmers to add more carbon back into the soil.

Conclude the Exploration by thinking about the future. Have students read the article "How the World Passed a Carbon Threshold and Why It Matters," by Nicola Jones published in YaleEnvironment360: https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters. You can use the worksheet at the end of the lesson to guide their reading and your class discussion.

* Special Note: This lesson accepts the connection between carbon levels in the atmosphere and climate change. If you would like to dig further into the evidence behind this correlation, you can use additional data sets available on the NASA Global Climate Change website at https://climate.nasa.gov/. In addition to the charts showing increasing carbon levels in the atmosphere, you can also find data displaying changes in global temperatures, sea levels, and sea and land ice amounts. Go to https://climate.nasa.gov/, click on Facts on the menu bar at the top of the page and select Vital Signs to view all data sets.

Making Connections:

Cornell Cooperative Extension's publication, *The Carbon Cycle and Soil Organic Carbon*, found at http://nmsp.cals.cornell.edu/publications/factsheets/factsheet91.pdf, suggests five different land management practices to increase soil organic carbon content:

- conservation tillage practices (no-till or reduced tilling)
- crop residue management
- cover crops
- manure and compost amendments
- crop selection

Have students read through this publication and then evaluate all of these possible solutions in relationship to your school garden.

Divide the class into groups and have each group research the logistics behind implementing one of the practices. In their analysis make sure they include information about potential costs and time requirements, along with other benefits and challenges they think they will face. Will the implementation change how the garden looks? Will it change how they can use the garden? Will implementation have enough of an environmental impact to justify the costs? Have each group compile their findings and present them to the class. They can use the Land Management Practices to Increase Soil Carbon Worksheet available when you download the full Digging into Soils Guide at: https://www.diggingintosoil.org/. After thorough consideration, as a class decide if you will incorporate any of these practices into your garden program.

Branching Out:

Checking Your Facts

Ask students to find a recent news article on the carbon cycle and storing carbon in soil. Then have them write a synopsis of what they learned in their article about the following topics:
Does the article support the idea that the soil is key for helping regulate carbon in the atmosphere?
Does the author suggest that soil can help regulate climate change?
Does to the article quantify the impact soil can have in some way? If so, what is stated?
Where did the author get his/her data? Did he/she provide information about the source (or sources)? Is the source reliable?

They can use the Article Evaluation Worksheet available when you download the full Digging into Soils Guide at: https://www.diggingintosoil.org/. Have students discuss their findings in class. Keep a tally of the articles that support the

concept of storing more carbon in the soil, and those that do not support it. Then discuss the implications.

Here are a couple of example articles to share to get them started:
"Soil as a Carbon Storehouse: New Weapon in Climate Fight" by Judith Schwartz, Yale Environment 360, 4 March 2014.
https://e360.yale.edu/features/soil_as_carbon_storehouse_new_weapon_in_climate_fight

"Soil Carbon Storage Not the Climate Change Fix it was Thought, Research Finds" by Oliver Milman, The Guardian, 22 Sept 2016. https://www.theguardian.com/environment/2016/sep/22/soil-carbon-storage-not-the-climate-change-fix-it-was-thought-research-finds

What have they learned from these articles? Why is it important to locate multiple reliable sources on any issue? How can evidence be manipulated to support specific claims? What can you do as reader to evaluate the claims presented in an article?

Connecting Climate Change to Food Systems

Another great resource to explore as an extension on this lesson is the digital guide *Understanding Food and Climate Change* from The Center for Ecoliteracy:
https://www.ecoliteracy.org/download/understanding-food-and-climate-change-interactive-guide
Understanding Food and Climate Change uses video, photography, text, and interactive experiences to show how food and climate systems interact and how personal choices *can* make a difference. Ideal for grades 6–12 (and adults too), the guide provides connections to Next Generation Science Standards and the National Curriculum Standards for Social Studies themes. It also offers activities for student research and resources for further investigation.

Links to Next Generation Science Standards Performance Expectations:

HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS- ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including costs, safety, reliability and aesthetics, as well as possible social, cultural and environmental impacts.