Digging into Soil

A GARDEN PRACTICUM

Written by KidsGardening.org

IN PARTNERSHIP WITH

The Lower Sugar River Watershed Association

Illustrated by Rob Dunlavey

KidsGardening.org

Since 1982, KidsGardening has led the youth gardening movement. As a national nonprofit, we are striving to improve nutritional attitudes, educational outcomes, social and emotional learning, and environmental stewardship in youth across the country through garden-based learning. Our mission is to create opportunities for kids to learn though gardening, engaging their natural curiosity and wonder by providing inspiration, community know-how, and resources.

The Lower Sugar River Watershed Association

The Lower Sugar River Watershed Association is a nonprofit volunteer conservation organization based in south central Wisconsin, dedicated to the care and enjoyment of water resources and to empowering citizens with experience and knowledge to steward land and water resources in the Lower Sugar River Valley.

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DIGGING INTO SOIL

INTRODUCTION

Our fast-paced, technology-driven society, spends very little time thinking about one of the most important natural resources on earth — soil. We pave over it to create new roads, we clear the vegetation and compact it when we build new housing, and pollute it with chemicals. Careless treatment of soil and land is not a new phenomenon. History books fully document the demise of civilizations that poorly managed their soils. The past solution that worked for our ancestors, to move to land with untouched soil, is no longer an option. Due to rapid land development and occupation associated with human population growth, we are nearing maximum capacity of our harvestable lands. We must change our perception that soil is a limitless resource and begin treating it as the finite, fragile and precious resource that it truly represents.

Gardening is an extraordinary, tangible way to gain an appreciation and respect for soil. From germination to harvest, the quality of your garden soil directly influences the health and growth of your plants. Cultivating a school garden to use for demonstration and experimentation purposes creates a living laboratory for effective hands-on learning for kids of all ages.

Digging into Soil: A Garden Practicum is an activity guide written by KidsGardening in cooperation with The Lower Sugar River Watershed Association as a complement to the booklet *"S" is for Soil*. We encourage the use of both books as companions, but they can be used together or independently. *Digging into Soil* has been written to help educators use a garden program to teach students about soil. The target audience for *Digging into Soil* is grades 9 -12 and the activities are linked to high school level Next Generation Science Standards. The lessons can be adapted for middle school ages too. The goal of these companion resources is to cultivate a new generation that is inspired to make collective choices that preserve and improve existing soil resources. The authors are convinced that the future depends on caring citizens making environmentally sound decisions, and this means they need basic knowledge about soil and our impact on these systems. Beyond basic knowledge, they must also feel connected to the soil so they are motivated to find and implement solutions needed to protect this precious resource. Soil can no longer be viewed as a commodity used to create industrial products like a tool in a factory where short-term economic gains trump its long-term health. Soil is much more than just sand, silt and clay. It is a complex system critical to our health, well-being, and survival. Healthy soil is fundamental to healthy life on earth!

The lessons in this guide are intended to bring a students' understanding of soil to life. Opening their eyes to the intricate system under our feet and inspiring their participation in protecting, regenerating and restoring soils will ensure a healthy planet in our future. The lessons are sequenced so that the topics build on each other. However, the activities can be used independently, in any order. *The Digging into Soil* lesson plans include:

Lesson 1
The 411 on Soil

Summary: What is soil? Why is it important? Through this lesson students will be given an overview of soil and discover that healthy soils are part of a larger system that is both complex and truly alive. They will explore why soils are critical to all life on Earth.

Lesson 2
It's ALIVE!

Summary: What lives in soil? Healthy soils are teeming with life, from microscopic bacteria and fungi to large mammals like moles and voles. In this lesson students will explore the many organisms that call soil home.

Lesson 3
In the Beginning

Summary: Where do soils come from? Students explore the origins of existing soil and how new soil is made.

Lesson 4
Texturally Speaking

Summary: Students will discover how soil texture is used to define soils and group them into categories for practical application.

Lesson 5
Sleuthing Soil Structure

Summary: What is soil structure? This lesson will provide an in-depth look at how soil structure impacts its functionality.

Lesson 6
Horizons Happen

Summary: The movement of water, minerals and organic matter within soil leads to the formation of distinct layers with common properties. What can we learn from these soil layers, also known as soil horizons?

Lesson 7
The Soil - Air Connection

Summary: 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.

Lesson 8
The Soil - Water Connection

Summary: What is the relationship between soil and water? Students will learn about the crucial role soil plays in the water cycle and its importance in keeping our water supply clean.

Lesson 9
Leaving Our Mark on Soils

Summary: How have humans impacted soils? Students will explore how human actions alter soil and investigate some of the negative impacts of human activity. They will also learn about ways we can remediate damaged soils.

Lesson 10
Save Our Soil

Summary: How can humans protect existing healthy soils? How can humans improve soils? In this lesson students will both learn about and find ways to share knowledge of how to protect this important natural resource.

How to Use the Guide

Each lesson begins with a summary and basic background information that can be used by educators or students along with objectives, key terms, links to Next Generation Science Standards Performance Expectations, links to “S” is for Soil book, estimated time for completion, materials list and a related quote for thought and discussion. To fully engage students in the topic, there are three distinct activities for them to participate in for each lesson, which include:

Laying the Groundwork – The lesson will begin with an activity and discussion to grab students’ attention with a real-world connection so that they can see the relevance of what they are going to be learning before completing the exploration. Through the use of written and video media to spark their interest, the Laying the Ground activities will provide a practical foundation for understanding the concepts presented.

Exploration - Each Exploration includes hands-on activities for teaching about the basic soil system principles presented in “S” is for Soil. Many of these explorations can be conducted in either indoor or outdoor classrooms and with or without a school garden.

Making Connections – The final activity for each lesson provides instructions for conducting garden-based experiments to reinforce the concepts presented in the exploration. Although the lesson can be completed without this component if school garden space is not available, these activities will allow students the chance to practice and demonstrate their understanding of the target concepts. The goal of this activity is to provide students with a personal connection between soil and their every day lives.

At the conclusion of each lesson, you will find ideas for follow up projects and activities that can be conducted to extend students’ understanding of the topic.

Along with each lesson’s activities, your students may also want to track their explorations using a journal. At the end of each lesson plan, you will find a journal worksheet that can be used as an additional teaching aid as you work through the Digging into Soil guide.

LESSON 1
The 411 on Soil

Summary

What is soil? Why is it important? Through this lesson students will be given an overview of soil and discover that healthy soils are part of a larger system that is both complex and truly alive. They will explore why soils are critical to all life on Earth.

Objectives

Students will learn:

- Soil is the top, thin layer of earth.
- Soil is comprised of inorganic matter formed from the breakdown of rock, along with decomposing organic matter. It is also home to millions of living organisms.
- Soil is key for growing food, cleaning water and air, and providing a habitat for living organisms of all shapes and sizes.
- Disruption of soil life can lead to devastating results.

Link to *"S" is for Soil*

- What is Soil? (Don't Call It Dirt)
- How Durable are Healthy Soils?

Key Terms

Soil: Soil is the top layer of the Earth's surface that is comprised of both minerals and organic matter.

Soil system: The soil system describes the complex network of life in soil, including micro- and macro-organisms and plant roots. The organic matter within soil is very important to its health, working to both sustain existing soil and also to create new soil.

Link 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-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Time

Laying the Groundwork: 15 minutes
Exploration: 2 hours
Making Connections in the Garden: 2 hours

Materials

- Internet access
- Lesson worksheets
- Paper and graph paper
- Pencils and/or colored pencils
- Long measuring tape

Quote for Thought and Discussion

"Essentially, all life depends upon the soil.... There can be no life without soil and no soil without life; they have evolved together."

— Charles E. Kellogg
USDA Yearbook of Agriculture, 1938

Background Information

Soil is the top layer of the Earth's surface that is comprised of both minerals and organic matter. The mineral particles are derived from rock broken down over thousands of years by climatic and environmental conditions (rain, glaciers, wind, rivers, animals, etc.). The organic matter of the soil is derived from decaying and decayed remains of once-living plants and animals.

Soil is also teeming with life, including microorganisms such as bacteria and fungi (in healthy soils you can find billions in a single teaspoon!) and larger animals such as worms and sowbugs. Many of these underground inhabitants feed on remains of plants and animals, breaking down their tissues. In the process, they create pore spaces within the soil and release nutrients that plants need, and the cycle begins again.

Soil plays many important roles in our global ecosystem. To name just a few, soil:

- holds nutrients and water needed by most plants. Plants then provide the foundation for all animal life on our planet as both a food source and source of oxygen.
- serves as a home for many organisms, from tiny bacteria to larger burrowing animals.
- catches and filters groundwater. It also impacts surface water collection and distribution.
- stores carbon and helps regulate the balance of chemicals in our atmosphere that ultimately impacts our climate.

Laying the Groundwork

As a class, watch the You Tube video "The Importance of Soil" from The Chicago Botanic Garden, available at https://www.youtube.com/watch?v=qMFo5fxE8Bs. You can use The Importance of Soil Worksheet at the end of this lesson to help students gather facts about soil as they view it. Use the video to introduce them to the role of soil in our environment. After the video, launch a class discussion by asking thought-provoking questions such as Why do we need soil? Where do we find soil? What would a world without soil be like?

The Soil Science Society of America offers a similar and slightly shorter video titled "Soils Sustain Life," available at https://www.youtube.com/watch?v=vDL6F6GkAzI, that can be used in addition to or in place of the video from The Chicago Botanic Garden.

Exploration

One of the best ways to fully understand the importance of healthy soil for a society is to find out what happens when healthy soil disappears. In the United States, the Dust Bowl event of the 1930s is an excellent example of what happens when the natural landscape of an area is disturbed.

Prior to the spread of homesteads and farming in the nineteenth century, much of the American Great Plains region was home to prairies of native grasses fed on by herds of grazing animals. The roots of the grasses provided a strong network that kept the soil in place when strong winds blew, and the animals provided a constant source of organic matter to return lost nutrients to the soil. The native grasses were very resilient during times of drought.

As farmers moved in, they fenced in (or out) the animals and plowed the fields to remove the native grasses in order to plant field crops. Although at first the existing soil retained some of its structure and fertility, the process of tilling and harvesting field crops ("The Great Plow-Up") quickly destroyed both. The situation reached crisis level when a drought hit in the 1930s. Although certainly not the first drought in this region, the field crops the farmers planted could not survive, and there was no longer a strong network of native grass roots to keep the dry soil from eroding. The result was massive storms of dust and significant soil loss.

❶ Explore events surrounding The Dust Bowl with your students. The PBS special "The Dust Bowl" by Ken Burns, available at http://www.pbs.org/kenburns/dustbowl/, offers a collection of videos that helps this natural disaster come alive for students. For a good overview, have the class watch the videos "Dust Bowl Preview," "Intro," and "Uncovering the Dust Bowl," found at http://www.pbs.org/kenburns/dustbowl/watch-videos/#2219206510 . This website also offers photos and firsthand stories of folks who lived in the Midwest during this time; encourage your students to explore these on their own.

❷ Examine the data. Continue your exploration of The Dust Bowl by looking at data published about this event. The Earth Institute at Columbia University conducted a study examining whether the dust storms themselves contributed to making the drought worse by impacting climatic conditions. A summary of the report can be found at:

The Earth Institute at Columbia University. "Did Dust Storms Make 1930s Dust Bowl

Drought Worse?" ScienceDaily, 4 May 2008. https://www.sciencedaily.com/releases/2008/04/080430152030.htm
The full research article of the study is available at:

"Dust and Sea Surface Temperature Forcing of the 1930s 'Dust Bowl' Drought" by B.I. Cook, R.L. Miller, and R. Seager. Geophysical Research Letters. Vol 25:8. 22 April 2008.
http://onlinelibrary.wiley.com/doi/10.1029/2008GL033486/pdf

Determine which of the references above is the best match for the skill level of your students, and then either make copies of the study or allow students to access the study electronically. Also, provide them with a copy of the corresponding worksheet at the end of this lesson plan to help them assess the information presented.

Before they begin reading the study, explain that the research was based on the use of computer models. Scientists studying historic environmental phenomena are often challenged by a lack of recorded data and limited tracking tools. One of the ways they overcome this challenge is to create computer models using existing data collected by modern-day tools. The models are based on patterns found through the collected data. The scientists then input different variables and run simulations that help them understand what might have happened in the past and predict what might happen in the future.

After students complete the guided worksheet, discuss their answers — especially their answers to the final question: Why is it important to document the fact that human actions can impact weather and climate?

❸ After studying the many aspects of the Dust Bowl, ask students to respond to the following quote from writer Timothy Egan through a class discussion or essay:
The Dust Bowl is "a classic tale of human beings pushing too hard against nature, and nature pushing back."

❹ In follow-up, your class can investigate additional examples of how soil conditions have negatively impacted human populations. An excellent resource for further exploration into this topic is the book *Dirt: The Erosion of Civilizations* by David Montgomery (University of California Press, Berkley, 2007).

Making Connections in the Garden

The first step in planning any garden is to conduct a site analysis, a process that includes evaluating and collecting information about soil conditions. As a class, move through the following steps for your potential or existing garden site to lay the groundwork for a sustainable garden program.

Although a site analysis is normally conducted before a garden is installed, if you already have an existing garden the site analysis can be used as a way to evaluate your current space to make recommendations for updates or expansion. After learning about the importance of soil and control of erosion, encourage students to make special note of areas with exposed soil, as well as the drainage conditions at the site.

STEPS FOR CONDUCTING A SITE ANALYSIS

❶ Inventory of Existing Features

Start by sketching your garden space from a bird's-eye view. Using a piece of blank paper, outline the property lines and all the existing features. Next, use a large tape measure to take accurate measurements of these features and record the information in the appropriate places on your sketch. Begin with the perimeter, and then measure any hardscape features such as sidewalks, sitting areas, and fencing. Make sure to note the location of the nearest water source. Then measure the location of existing plant materials and landscape beds, and identify and label the plants, noting their approximate height and width.

Also locate features you may not be able to see, including underground utilities such as electricity, sewer, and water lines. You don't want to dig into these lines or plan large or permanent structures that may interfere with them. Contact school maintenance staff or utility companies for assistance. Utility companies offer a free service called Call Before You Dig that you can reach by dialing 811. With one call you can have all utility lines marked with flags within a couple of days. More information about the service is available at http://call811.com/.

❷ Summary of Site Conditions

Once you have measured and sketched important features, take time to observe your space. Look at the ground and check out the soil. Study the areas beyond your perimeter and overhead. Answering the following questions can help you get started:

- Does it look like the soil drains well, or is it hard and compacted?
- Can you see signs of drainage patterns or areas of poor drainage, such as standing water?
- Which direction is south? Southern and western exposures typically receive the most sunlight. Use a compass to determine east, south, west, and north and note the directions on your sketch. From which direction will the sun move across the space?
- Are there any trees or buildings that will shade the garden? If yes, at what time and for how long?
- Does the ground have any notable dips or depressions? Determine the slope of the land. Can you see evidence of how and where water drains away from the site after a rain? (If it is not obvious, try to schedule time to view the space during or immediately after a rain.) Do you need to take measures to prevent erosion?
- In what direction does the wind usually flow?
- Are there any views you'd like to block, such as a busy road or a dumpster? Do you need to be concerned about the security of the site?

❸ Compile Your Findings

Use graph paper to compile the information you collected to create a base map of your existing or future garden space. Your site analysis will come in handy when you begin to design your garden.

Extension

One positive result of The Dust Bowl was a greater focus on understanding the importance of our soil and interest in developing techniques to prevent catastrophic conditions in the future. Although some of the technologies developed are not necessarily sustainable or environmentally friendly (such as the increased use of groundwater for irrigation), the United States government has dedicated a considerable amount of time and money for studying the impacts of our farming techniques on soil and water conservation and offering recommendations for best practices.

Two tools developed to help understand the impact of land management decisions are APEX (Agricultural Policy/Environmental eXtender Model) and EPIC (Environmental Policy Integrated Climate Model). Both can be found at https://epicapex.tamu.edu/.

APEX is a watershed simulation model designed to explore land management strategies on a small scale for landscapes and small farms. You can share the APEX Prezi presentation with your students; it is available at https://epicapex.tamu.edu/apex/. Explore the list of model components and capabilities on the APEX landing page.

EPIC is a computer model designed to simulate how growing various crops may impact soil productivity and erosion. It is used to predict how different management decisions by farmers related to soil, water, and fertilizer and pesticide applications will impact soil loss, water quality, and crop yields.

Both the APEX and EPIC models are available for download by educators, if you have the time and expertise to explore it further. However, if you do not want to take your lesson to that level of complexity, you can present these models as a jumping-off point to discuss the value and challenges of using computer models to make land management and farming decisions. Ask students to ponder, How accurate are computer models? Do they have any limitations? Do you think the models presented above were designed to help protect the environment or to maximize production? What are the benefits of developing a model for analysis? What are the drawbacks of relying on models to make land use decisions?

If the EPIC and APEX models are a bit too advanced for your students, Journey 2050 is an additional online sustainable agriculture simulation available. Developed by Nutrien in cooperation with a number of agricultural education organizations in both Canada and the United States, Journey 2050 was specifically developed for schools and can be downloaded at: http://www.journey2050.com/.

References

"The Importance of Soil" by The Chicago Botanic Garden, 22 August 2013. https://www.youtube.com/watch?v=qMFo5fxE8Bs

"Soils Sustain Life" by the Soil Science Society of America, 21 November 2014. https://www.youtube.com/watch?v=vDL6F6GkAzI

"The Dust Bowl" by Ken Burns, PBS, 2012. http://www.pbs.org/kenburns/dustbowl/

The Earth Institute at Columbia University. "Did Dust Storms Make 1930s Dust Bowl Drought Worse?" ScienceDaily, 4 May 2008. https://www.sciencedaily.com/releases/2008/04/080430152030.htm

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Call Before You Dig. http://call811.com/

EPIC: Environmental Policy Integrated Climate Model and APEX: Agricultural Policy/Environmental eXtender Model. https://epicapex.tamu.edu/

Journey 2050. Nutrien. http://www.journey2050.com/

The Importance of Soil

WORKSHEET

Gather answers to the following questions as you watch “The Importance of Soil” from The Chicago Botanic Garden at https://www.youtube.com/watch?v=qMFo5fxE8Bs.

❶ According to this video, is soil a living system?

❷ What are some of the components of the soil system listed in this video?

❸ What are some of the reasons presented in this video to support the statement “soil is one of our most important natural resources?”

❹ Based on this video, in what ways do humans disturb the soil system?

Did Dust Storms Make 1930s Dust Bowl Drought Worse?

WORKSHEET

Answer the following questions after reading one or both of the following:

The Earth Institute at Columbia University. "Did Dust Storms Make 1930s Dust Bowl Drought Worse?" ScienceDaily, 4 May 2008. https://www.sciencedaily.com/releases/2008/04/080430152030.htm

"Dust and Sea Surface Temperature Forcing of the 1930s 'Dust Bowl' Drought" by B.I. Cook, R.L. Miller, and R. Seager. Geophysical Research Letters. Vol 25:8. 22 April 2008. http://onlinelibrary.wiley.com/doi/10.1029/2008GL033486/pdf

Background

Scientist have discovered that periodic drought conditions in Midwest regions of the United States are related to changes in the sea surface temperatures (SSTs) found in tropical areas of the Pacific Ocean. Using computer models to explain this connection, they discovered that the drought of the 1930s leading to The Dust Bowl was much more severe and further north in location than should have been expected. Researchers have suggested that human actions increased the amount of loose soil particles in the air, impacting the intensity and location of the drought.

❶ According to the article, why was the drought of the 1930s more severe than can be explained by the low rainfall of the drought?

❷ What are some of the examples of poor land use practices that are noted by the authors?

Did Dust Storms Make 1930s Dust Bowl Drought Worse?

WORKSHEET (CONTINUED)

❸ Dust in the atmosphere can decrease precipitation. It does this by reducing the radiation that reaches the land surface, decreasing the amount of evaporation from surface water sources and plant transpiration — ultimately reducing the moisture available for condensation and precipitation. Draw a picture (or pictures) that demonstrates this disruption of the normal water cycle.

❹ Based on the article, did humans cause the drought of the 1930s?

❺ Why is it important to document the fact that human actions can impact weather and climate? How does your answer relate to current discussions around climate change?

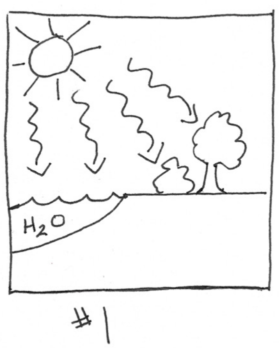
Did Dust Storms Make 1930s Dust Bowl Drought Worse?

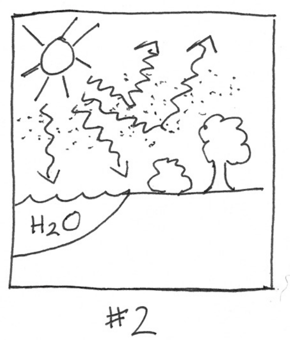
WORKSHEET ANSWERS

❶ Poor land management.

❷ Farmers replaced native prairie grasses with wheat. When the drought hit, the wheat died and left the soil bare and vulnerable to erosion.

❸





#1. Under normal conditions, radiation hits land surfaces, causing evaporation of water from surface water sources such as lakes and rivers and from plants through transpiration.

#2. Dust in the air disrupts normal radiation from reaching land and decreases evaporation of water into the air.

❹ No, the drought would have happened regardless; however, human actions made it worse.

❺ Many answers are possible. One example: The study supports the idea that human actions can result in changes to weather and climate. It teaches us that we must take responsibility for our actions. If we can negatively impact our environment then we must search for ways to mitigate these impacts and, if possible, try to return conditions back to their natural state.

Digging into Soil

JOURNAL PAGE

Name:______________________________

Date:_______________________________

Lesson #:____________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 2
It's ALIVE!

Summary

What lives in soil? Healthy soils are teeming with life, from microscopic bacteria and fungi to large mammals like moles and voles. In this lesson, students will explore the many organisms that call soil home.

Objectives

Students will learn:

- There are millions of microbes, soil insects, worms, and soil fungi living in healthy soil.
- Soil organisms help break down the organic and inorganic matter in the soil, providing nutrients for plants. In some cases, they also help with the delivery of the nutrients to the plants.
- Soils that are treated with excessive amounts of fertilizers, insecticides, and weed killers may become lifeless, decreasing their ability to sustain healthy plant growth.

Link to *"S" is for Soil*

- Soils Are Truly Alive
- Dead Soils May Not Be Truly Dead
- You Are What You Eat Isn't Exactly Accurate
- Who Really Needs Soil Anyway
- Complexity That Rivals Brain Surgery
- Trillions of Soil Microbes Are Now Out of Work

Key Terms

Microorganism: This is an organism, often consisting of a single cell, which can only be seen with a microscope. Microorganisms in the soil include bacteria, fungi, algae, and protozoa, among others.

Soil Food Web: This describes the intricate and interdependent food chains of organisms that live underground.

Link to Next Generation Science Standards Performance Expectations

HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

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.

Time

Laying the Groundwork: 30 minutes
Exploration: 2 hours
Making Connections in the Garden: 2 hours

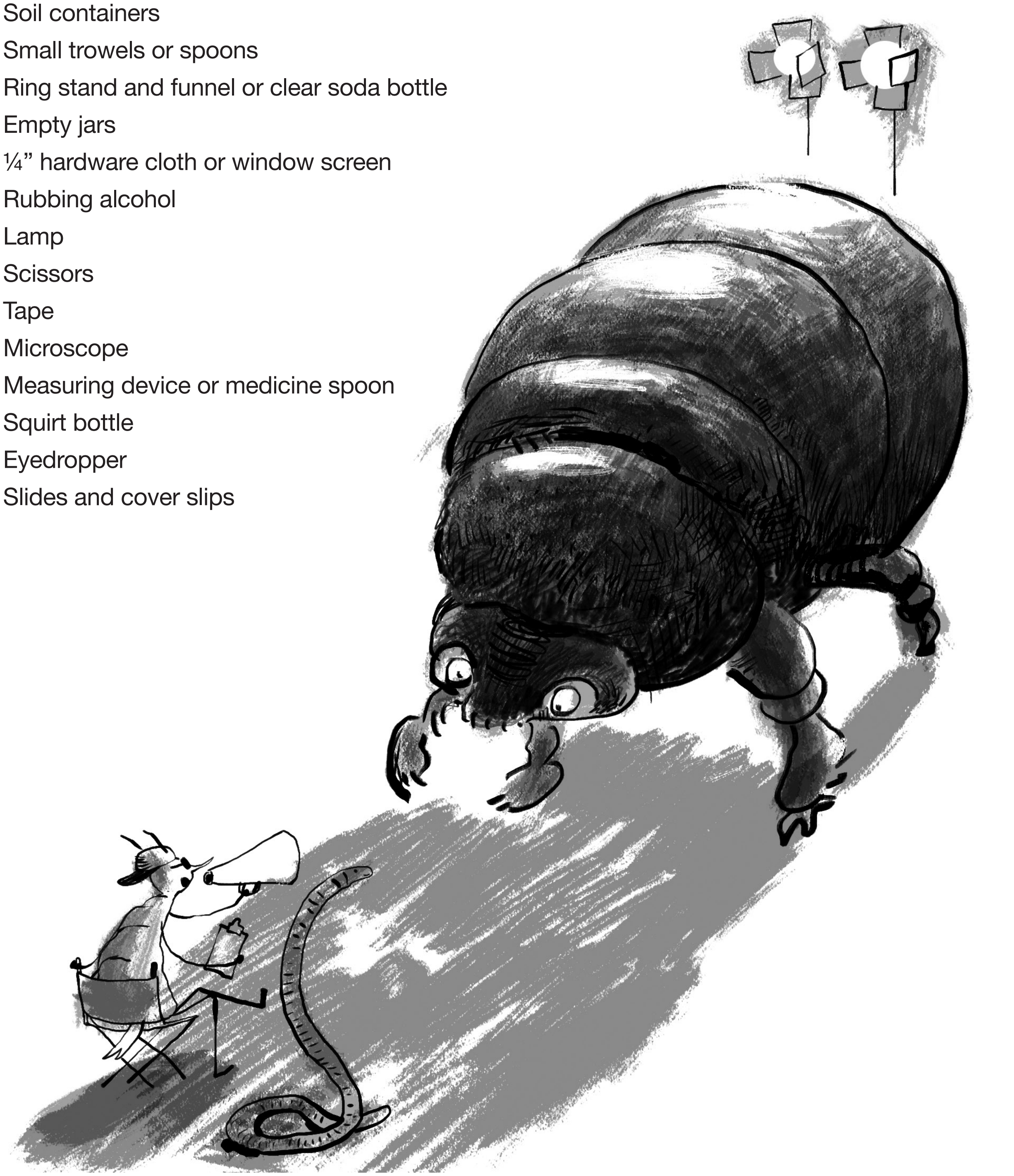
Materials:

- Chart paper
- Internet access
- Trowel or shovel
- Digital camera
- Soil samples
- Soil containers
- Small trowels or spoons
- Ring stand and funnel or clear soda bottle
- Empty jars
- ¼” hardware cloth or window screen
- Rubbing alcohol
- Lamp
- Scissors
- Tape
- Microscope
- Measuring device or medicine spoon
- Squirt bottle
- Eyedropper
- Slides and cover slips

Quote for Thought and Discussion

“Land, then, is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants, and animals.”

— Aldo Leopold
A Sand County Almanac, 1949



Background Information

Just like the living organisms above the ground, life under the ground also comprises a very intricate food web. The U.S.D.A. Natural Resources Conservation Service's *Soil Biology Primer* includes a Soil Food Web graphic; it is available at http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/.

In a simplified overview, plant roots give off exudates that consist of carbohydrates produced by the plant through the process of photosynthesis. These exudates become food for bacteria and fungi in the soil. These microscopic organisms are consumed by slightly larger life forms (although in most cases still too small to see with the naked eye), such as nematodes, protozoa, and some arthropods. These organisms are eaten in turn by larger creatures that can be seen without a microscope, such as larger arthropods (like millipedes and sow bugs) and earthworms. Finally, near the top of the web, small soil creatures become a buffet for even larger animals, such as moles.

In addition to eating each other, many of these underground dwellers also consume dead and decaying organic matter (both plant and animal) that has made its way down to the soil.

Just as they do for life above the ground, plants provide the base for the food chain in the soil. An interesting point to consider: Plants could probably survive without aboveground animals, but they are dependent on the food web below the ground to recycle the nutrients they need to live.

Plants rely on various bacteria and fungi to release nutrients from decaying plant and animal material, as well as from the breakdown of inorganic matter such as minerals. And in many cases these microorganisms also facilitate the availability of the nutrients to the plants. Nutrients as they naturally exist in the soil are not always in a form that plants can use. Plants depend on soil-dwelling microorganisms to convert certain nutrients into accessible forms that are available for uptake. Some microorganisms even play an active role in helping roots with the process of absorption. There is also evidence that plants form beneficial partnerships with organisms like mycorrhizal fungi to increase their access to water.

A lack of understanding about the complexities and importance of the soil food web results in problems for many gardeners. The application of insecticides, herbicides, and synthetic fertilizers, along with horticultural practices such as repeated soil tilling, can impact underground organisms and destroy the balance of life within the soil system. For example, a fungicide applied to a lawn will not only kill the fungus that is attacking the lawn, it may also kill off the fungus that is working beneficially with the grass's roots to make nutrients and water more available to them.

An excellent resource book for additional background information about life in soil is *Teaming with Microbes* by Jeff Lowenfels and Wayne Lewis (Timber Press, Portland, OR, 2010). Although it's filled with detailed scientific information, it appeals to practical gardeners and is written in a style that is easy to read for both educators and students.

Laying the Groundwork

Begin by asking students to list everything that lives in the soil. Record their responses on a sheet of chart paper so that you can compare it to what they learn about soil life in this lesson. Next, as an introduction to life underground, watch the video "The Science of Soil Health: Changing the Way We Think About Soil Microbes" from the U.S.D.A Natural Resources Conservation Service, available at https://www.youtube.com/watch?v=EyKfpOso8q8. This video offers amazing imagery of microscopic life in action and an overview of the importance of the soil food web. Students can complete "The Science of Soil Health" Worksheet at the end of this lesson as they watch. Ask, What do you think we would find living in our local soils?

Exploration

There is no better way to explore soil life and human impact on soil life than direct observation.

Collect five to 10 soil samples from different locations at your school or in your community. This can be a class activity, or the students and/or the instructor can collect them ahead of time. Collect samples from diverse locations where you might expect to find different soil life populations. For example, collect some samples from areas where plants are thriving (and thus you would expect to find healthy soil life populations) and some from areas where the soil is bare or has poor plant growth (where you would expect to find little to no soil life).

You may also want to get a sample from an area that is highly maintained (such as a golf course) to consider the impact of regular fertilizer and pesticide applications, as well as a sample from a natural area where there is minimal human impact on the soil. (Make sure to get permission before collecting samples.) Try to collect approximately the same amount of soil at the same depth at each location.

Collect each soil sample in a jar or other vessel with an open top, and then cover it securely with a piece of window screen to allow airflow and to keep any larger life from escaping before you can explore it. Plan to use the samples as soon as possible so the soil doesn't dry out, which may kill the organisms inside.

Label the samples and take careful notes about where each was collected, as well as the conditions of the surrounding area; for example, what type of plant life is present, is it close to water, does the area experience heavy foot traffic, etc. If possible, take photos of the sites to help with later discussions. You can use the Soil Sample Inventory Worksheet at the end of this lesson to help with the data collection.

Have students begin their investigations by digging through the samples with small trowels or spoons to look for gastropods (slugs and snails) and large arthropods (invertebrates such as insects, mites, and centipedes). Students can work individually or in small teams. Have students keep an inventory of what they find.

Next, set up a Berlese funnel to look for smaller organisms. Instructions for creating a funnel can be found at the following resources.

"The Berlese Funnel" by the Soil Science Society of America:
http://www.soils4teachers.org/files/s4t/lessons/berlese-funnel.pdf

"Constructing Berlese Funnels to Study Invertebrate Density and Biodiversity" by Carolina Biological:
https://www.carolina.com/teacher-resources/

Interactive/constructing-berlese-funnels-study-invertebrate-density-biodiversity/tr19101.tr

A magnifying glass is helpful for close observation. Have students add this information to their inventory.

Finally, if you have microscopes available, students can look for any microorganisms present in their samples. Dr. Elaine Ingram from the Soil Food Web Inc. has a series of YouTube videos that demonstrate the process of investigating soil organisms under a microscope: https://www.youtube.com/watch?v=H8CClDH7jW0&t=656s. Record the findings.

With inventories in hand, ask students to develop a way to present and compare the data they have collected, such as through graphs or charts. Discuss the results, asking students what they have discovered about the soil health at each sample's location. Based on the data, ask them, Can you draw any conclusions about how humans impact soil life? Are there any limitations of your findings? Complete the exploration by brainstorming a list of additional experiments students would like to conduct to further investigate this topic.

Making Connections in the Garden

Complete the same activities from the exploration with your garden soil. If you have funds available, you may want to look into sending your sample off to a professional laboratory for a biomass analysis to compare with your own findings. A list of labs that complete microbiological testing can be found on the Soil Foodweb, Inc. website: http://www.soilfoodweb.com/Labs.html.

From your results, ask students to determine whether or not they think the existing soil food web in their garden is acceptable for the plants you plan to grow. Through research, have them draft a plan to either sustain the soil life (if they find their existing level of soil life is acceptable) or improve the soil life (if they decide the soil biodiversity is low).

If you are not able to submit your own soil sample for testing, you can find an example of a biomass test result to use for exploration and discussion in the book *Teaming with Microbes* by Jeff Lowenfels and Wayne Lewis (Timber Press, Portland, OR, 2010).

Extension

Dig deeper into the background of the "Superstars" of the soil. Ask students to choose from a list of common soil inhabitants and write a short research paper. At minimum, they need to find a picture of their organism, a description of its life cycle, learn about what it eats and the conditions it needs to survive, and finally the role it plays in soil life/health. Have them share their reports with their classmates and, as a class, choose to do one of two things to compile this information: create a Soil Inhabitant Yearbook or create a class play with their organisms as the main characters. Then have them present their project to other students and/or community members. Possible inhabitants to choose from include (but are not limited to):

- bacteria (actinomycetes)
- archaea
- fungi
- algae and slime molds
- protozoa (amoebae, ciliates, flagellates)
- nematodes
- arthropods (mites, spiders, centipedes, millipedes, springtails, roaches, beetles, termites, ants, sow bugs)
- earthworms
- gastropods (slugs and snails)
- reptiles and mammals (snakes, moles, voles)

References

"Soil Biology Primer." U.S.D.A. Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/

Lowenfels, Jeff and Wayne Lewis. *Teaming with Microbes*. Timber Press: Portland, OR, 2010.

"Science of Soil Health: Changing the Way We Think About Soil Microbes" by United States Department of Agriculture Natural Resources Conservation Service. 26 Feb 2014. https://www.youtube.com/watch?v=EyKfpOso8q8

"The Berlese Funnel" by the Soil Science Society of America. http://www.soils4teachers.org/files/s4t/lessons/berlese-funnel.pdf

"Constructing Berlese Funnels to Study Invertebrate Density and Biodiversity" by Carolina Biological. https://www.carolina.com/teacher-resources/Interactive/constructing-berlese-funnels-study-invertebrate-density-biodiversity/tr19101.tr

"Prepare a Soil Sample — Introduction to Microbiology" by Dr. Elaine Ingham. 4 May 2011. https://www.youtube.com/watch?v=H8CClDH7jW0&t=656s

Soil Foodweb Inc. by Dr. Elaine Ingham. http://www.soilfoodweb.com/Labs.html

The Science of Soil Health

WORKSHEET

Gather answers to the following questions as you watch “The Science of Soil Health: Changing the Way We Think About Soil Microbes” from the U.S.D.A Natural Resources Conservation Service, available at https://www.youtube.com/watch?v=EyKfpOso8q8.

❶ What is an example of a beneficial task completed by microorganisms in the soil provided in this video?

❷ What makes an organism a “bad” organism?

❸ What keeps an organism population in check in the soil environment?

❹ How can we support the diversity of organism species in the soil?

Soil Sample Organism Inventory

WORKSHEET

Sample #: ____________

Sample was collected from: _____________________

Description of Collection Site:
What type of plant life was growing above the soil?

______ grass
______ shrubs/trees
______ ornamental annual or perennial plants
______ fruits or vegetables
______ none
______ other. Please list:

Is the soil in this sample treated regularly with fertilizer?

______ yes
______ no
______ unknown

Please list any details known about fertilizer treatments:

Is the soil in this sample treated regularly with pesticides, fungicides, or herbicides?

______ yes
______ no
______ unknown

Please list any details known about treatments:

Is the soil subject to regular compaction from foot or vehicle traffic?

______ yes
______ no

Is this soil from an area that is naturally wet or floods regularly?

______ yes
______ no

Is this soil from an area that is usually dry?

______ yes
______ no

Please list any additional details about the conditions present at the location where this sample was collected:

Observation Method Used	Soil Organism Found	Approximate # Present	Sketch of Organism	Additional Notes

Digging into Soil

JOURNAL PAGE

Name:________________________________

Date:_________________________________

Lesson #:______________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 3
In the Beginning

Summary

Where does soil come from? Students explore the origins of existing soil and how new soil is made.

Objectives

Students will learn:

- Soil is formed through the breakdown of bedrock and other earth materials via climate and decomposition by microbes, fungi, and plants.
- The kinds of plants and animals that contribute organic matter to the soil as they decay impact the composition and appearance of soil.

Link to *S is for Soil*

- So, Where DO Soils Come From?
- How Soils Are Made
- Myths and Legends of The Soil

Key Terms

Parent material: These are the rocks that are broken down to form the mineral components of soil.

Soil formation: This involves the weathering of inorganic materials and the decomposition of organic matter to form soil components.

Weather: Atmospheric conditions observed over a short period of time.

Climate: Weather conditions in an area over a long period of time.

Topography: Study of shape and elevation of features on the surface of the Earth.

Link to Next Generation Science Standards Performance Expectations

HS-ESS1-6: Apply scientific reasoning and evidence from ancient Earth materials, meteorites and other planetary surfaces to construct an account of Earth's formation and early history.

Time

Laying the Groundwork: 30 minutes
Exploration: 4 weeks
Making Connections in the Garden: 30 minutes

Materials:

- Internet access
- Gallon plastic bags
- Variety of organic waste
- Soil
- Thermometer

Quote for Thought and Discussion

"Be it deep or shallow, red or black, sand or clay, the soil is the link between the rock core of the earth and the living things on its surface. It is the foothold for the plants we grow. Therein lies the main reason for our interest in soils."

— Roy W. Simonson
USDA Yearbook of Agriculture, 1957

Background Information

Soil is the top layer of the Earth's surface that is comprised of both minerals and organic matter. The inorganic matter in soil is formed by the breakdown of bedrock and other earth materials into smaller particles. The organic portion is comprised of living organisms and decaying organic matter. There are a number of different factors that influence soil creation — both how it is formed and its ultimate composition. The Soil Science Society of America and U.S.D.A Natural Resources Conservation Service place these factors into five different categories:

❶ **Parent material.** There are three different groups of rocks on Earth (sedimentary, igneous, and metamorphic), but thousands of rocks comprised of different mineral combinations that fall within these groups. Soils retain some of the properties of their parent rock material, which is one reason for the variability among soils. For example, igneous rocks tend to weather into soils that are predominantly sand, while sedimentary rocks tend to form soils that are dominated by clay. Soils may or may not be derived from the bedrock located immediately below them. In fact, the U.S.D.A. Natural Resources Conservation Service estimates that over 95% of the soils on the earth are not found where they were originally formed. Over time, soil may be moved by wind, ice (glaciers), or water, relocating it away from its place of origin.

❷ **Climate.** Soil formation is highly influenced by the weather it experiences

over time. Weather breaks down the parent rock, both by physical means such as wind, rain, and snow that cause rocks to rub against each other, as well as by initiating chemical reactions that cause the rock to break down. These are known as weathering processes. Also, as mentioned above, weather can redistribute surface materials. Climate greatly influences the rate at which organic material decomposes in the soil. In general, soils will form faster in moist areas with warmer temperatures and will develop more slowly in dry areas with cooler temperatures.

❸ **Topography.** The slope of the land impacts soil formation. Differences in exposure to rain, wind, and sunlight influence the weathering of the parent rock. Additionally, gravity and water movement down slopes influence the relocation of soils. The steeper the slope, the greater the impact erosion has on soil movement.

❹ **Biological organisms.** A diverse population of living organisms contributes significantly to soil formation. They can play a role in the breakdown of inorganic minerals, but, more importantly, they are the source of the organic matter (both alive and decaying) within soils. Microorganisms such as fungi and bacteria secrete chemicals that contribute to the weathering and breakdown of rocks. Living organisms can cause physical changes, such as when plant roots grow through cracks in rock and force the rock apart. Soil organisms are also responsible for breaking down dead organic matter. Life above ground influences soil formation by providing the dead organic matter to break down. Therefore, soil formation is highly influenced by the types of plants and animals that live in a region.

❺ **Time.** The final factor that influences soil formation is time. Existing soil is constantly being influenced by many of the factors listed above. New parent material is continually undergoing weathering and organic material is decaying to create new soil.

Just how long does it take to make soil? This is a question without one right answer. It is completely dependent on the factors above.

For more information about soil formation for your specific state, check out your state's U.S.D.A. Natural Resources Conservation website. You can find a link at https://www.nrcs.usda.gov/wps/portal/nrcs/sitenav/national/states/.

Laying the Groundwork

Share the cartoon image about the importance of good soil from “Oh, Brother!” by Bob Weber Jr. and Jay Stephens, published on 4/25/2011 available at: http://www.cartoonistgroup.com/store/add.php?iid=60092
Ask students, Why is this gardener so protective of her soil? How long do you think it takes to make soil?

Ask students to research the answer to this question: How long does it take to make one inch of topsoil? Instruct them to bring in their answer along with reference information for where they found it.

Exploration

Have students share the results of their Laying the Groundwork research. Compile a list of all of the responses and compare the findings. Is there one right answer? No, there is not one right answer. Use this as an opening to discuss the five factors influencing soil formation listed in the Background Information above. Explain to students that because the formation of soil is dependent on these variable factors, the time it takes to create new soil will also vary.

When did soil first appear on Earth? Rocks were formed first as the surface of the Earth cooled. Scientists use a variety of techniques for dating rocks and meteorites, and have estimated that the Earth is approximately 4.6 billion years old. The U.S. Geological Survey has information on radiometric dating methods that you can share with advanced students at Age of the Earth, U.S.G.S., available at: https://pubs.usgs.gov/gip/geotime/age.html and https://geomaps.wr.usgs.gov/parks/gtime/ageofearth.html.

The next major step in the development of life on Earth was the formation of liquid water, which served as a home for living organisms and also sparked the weathering of rocks and the development of soil.

Have students read the article “One Amazing Substance Allowed Life to Thrive on Land” by Clair Asher, published by the BBC in 2015 and available at http://www.bbc.com/earth/story/20151205-one-amazing-substance-allowed-life-to-thrive-on-land. You can use the worksheet at the end of this lesson to guide their reading. From this article, create a timeline of the development of soil on the Earth. A sample timeline is also provided at the end of this lesson.

Demonstrating the weathering of rock may not be an easy task in the classroom — although you can certainly bring in a variety of rocks along with tools like metal nail files and hammers to try (don’t forget the safety goggles and gloves). However, allowing students to observe the decomposition of organic matter into compost is a simple way for them to observe part of the soil formation process. You can accomplish this by creating traditional outdoor compost bins or worm compost bins. Instructions for making both kinds of compost bins are available on the KidsGardening website at https://kidsgardening.org/gardening-basics-composting/ and https://kidsgardening.org/gardening-basics-worm-composting/.

Another way to show this transformation of organic matter is to have students make simple decomposition observation bags by placing pieces of plant debris, old fruit, vegetables, and moist bread in clear gallon plastic bags. (Alternatively, students can create observation chambers using clear plastic containers.) They can place the items in the bags separately, or to make the experiment more sophisticated they can create different combinations of ingredients in each bag. Include a scoop of soil in some bags but leave it out of others for comparison. Other variables to test include sunlight availability (offering a variety of light exposures), temperature (perhaps put some in a refrigerator), and moisture levels. They can also experiment with keeping the bags/containers tightly closed versus introducing air regularly, but make sure to warn students not to inhale or ingest contents while examining. Some types of mold can be harmful.

Have students make daily observations; they'll likely see some mold and other fungal growth within a week. (Timing is dependent on the materials chosen and temperature.) A sample Decomposition Bag Observation Worksheet is available at the end of this lesson. Continue the observations until the contents of some of the bags begin to resemble soil. Compile the results and discuss. Did some of the bags decompose faster than others? What factors seemed to influence the timing? What do you think was different in the bags that also contained actual soil? What does this information tell us about the formation of soil? Based on this experiment, do you think humans can help encourage soil formation?

Making Connections in the Garden

You can research the origins of your school's native garden soil without leaving your classroom. The U.S.D.A. Natural Resources Conservation Service has uploaded all of their soil survey information into an online Web Soil Survey, available at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

The basic steps for completing a search of the survey are listed on the home page. (You can also find some screen shots at the end of this lesson to help walk you through the process.) Start by clicking on the "Start WSS" button. Next, define your AOI (Area of Interest). Once you have your AOI defined, click on the tab for "Soil Map" and it will provide you with the name of your soil type (or types) on record. You will then be able to click on the soil type name for additional information; for example, under the heading of "Setting" you will find a description of the parent material of your soil.

Once you uncover this information, save it to use with additional lessons in this guide.

If you are gardening in raised beds or containers and have brought in soil from other sources, you may also want to research the origins of the soil you purchased. Call your supplier and ask for information about its history.

To expand on this activity, look up information about soils in different locations (grasslands, deserts, wetlands, etc.) to compare to your results.

Extension

Visit a local compost facility in your community for a firsthand look at how this important soil amendment is being produced on a large scale. If a field trip is not possible, you can watch a tour of Seattle's Cedar Grove Compost Facility at https://www.youtube.com/watch?v=OaiRKS6n3sQ.

References

"Soil Formation" by The Soil Science Society of America. http://soils4teachers.org/formation

"Soil Formation and Classification" by the U.S.D.A. Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054278

"Soil Formation" by U.S.D.A. Natural Resources Conservation Service – Washington State. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wa/soils/?cid=nrcs144p2_036333

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"Age of the Earth", United States Geological Survey. https://pubs.usgs.gov/gip/geotime/age.html

"The Age of the Earth", United States Geological Survey. https://geomaps.wr.usgs.gov/parks/gtime/ageofearth.html

"One Amazing Substance Allowed Life to Thrive on Land" by Clair Asher. 5 December 2015. BBC.com. http://www.bbc.com/earth/story/20151205-one-amazing-substance-allowed-life-to-thrive-on-land

Web Soil Survey by The United States Department of Agriculture Natural Resources Conservation Service. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

"Turning Seattle's Food Scraps Into Gardening Gold w/ Cedar Grove Compost" by Len Davis, 9 Feb 2010. https://www.youtube.com/watch?v=OaiRKS6n3sQ

One Amazing Substance

WORKSHEET

Answer the following questions as you read "One Amazing Substance Allowed Life to Thrive on Land" by Clair Asher, published by the BBC in 2015 and available online at http://www.bbc.com/earth/story/20151205-one-amazing-substance-allowed-life-to-thrive-on-land.

❶ What are some of the reasons the author provides to support the statement that "soil is crucial to almost every aspect of life on land?"

❷ What date does the author give for how long ago soil began to develop on Earth?

❸ What two factors allowed the conditions on Earth to stabilize and marked an important turning point for soil development?

❹ It is believed that the earliest soil did not hold water or nutrients well and thus was not a friendly host to support life. What organisms does the author give credit to for creating soil that supported life?

❺ Plants were able to move to land because of their symbiotic relationship with what organism? How were both of these organisms beneficial to the development of soil?

❻ Soil has been slowly evolving for billions of years, but the author warns that human actions are destroying soil resources at a much faster rate. What does she list as the major threat to soil in our society?

One Amazing Substance

WORKSHEET (CONTINUED)

❼ From this article, create a timeline of the development of soil on the Earth.

Date	Event

Development of Soil Timeline

This chart is based on facts provided by "One Amazing Substance Allowed Life to Thrive on Land" by Clair Asher. 5 December 2015. BBC.com. http://www.bbc.com/earth/story/20151205-one-amazing-substance-allowed-life-to-thrive-on-land

Date	Event
4.6 billion years ago	Clay-rich rocks developed on Earth as temperatures cooled. They were frequently pummeled by meteors and broken into smaller pieces.
3.8 billion years ago	Liquid water formed and began to weather the rocks. This was the first step towards soil formation.
3.5 billion years ago	Life appeared on Earth, and organic matter that built up on the shoreline mixed with the weathered rocks, forming the first true soil.
700 to 550 million years ago	Lichens appeared. The symbiotic relationship of algae (that can make food through photosynthesis) and fungi (that can collect water from the environment) gave lichens the ability to colonize soil. As they lived and died, they changed the makeup of soil by producing acids that increased the weathering of rock, contributing organic matter to soil composition.
440 million years ago	Plant life moved to land along with the mycorrhizae fungi in their root systems, adding more organic matter and nutrients to soil.
490 to 430 million years ago	Land animals emerged, further increasing the organic matter in soil. Some land animals evolved to live within the soil, greatly impacting soil structure.
360 million years ago	The structure and composition of soils present at this date were very much like those of the soils we have today.

Decomposition Bag Observation

WORKSHEET

Bag #:

Contents:

Location:

Sunlight availability:

Average temperature:

Was soil added?

Moisture level rating at beginning of experiment:

No moisture	Low moisture	Moist	High moisture

Was air added?

Decomposition Bag Observation

WORKSHEET (CONTINUED)

Use the following chart to record your observations:

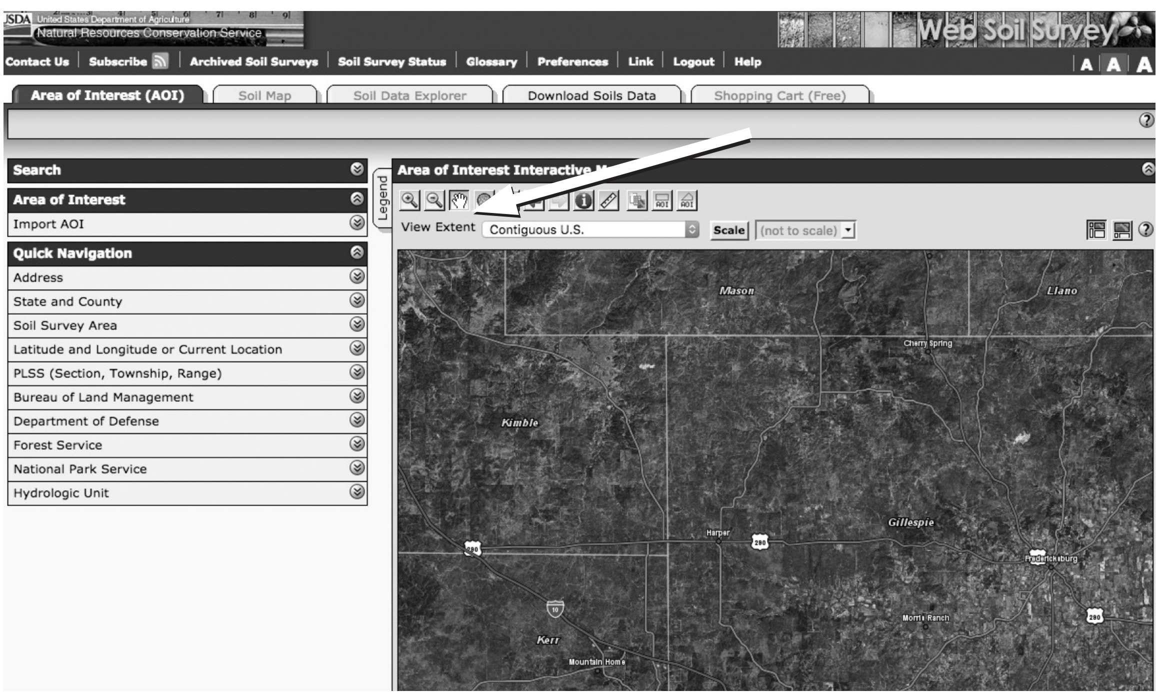
Date	Do you see mold or fungal growth?	Describe any changes in appearance of contents.

Using the Web Soil Survey

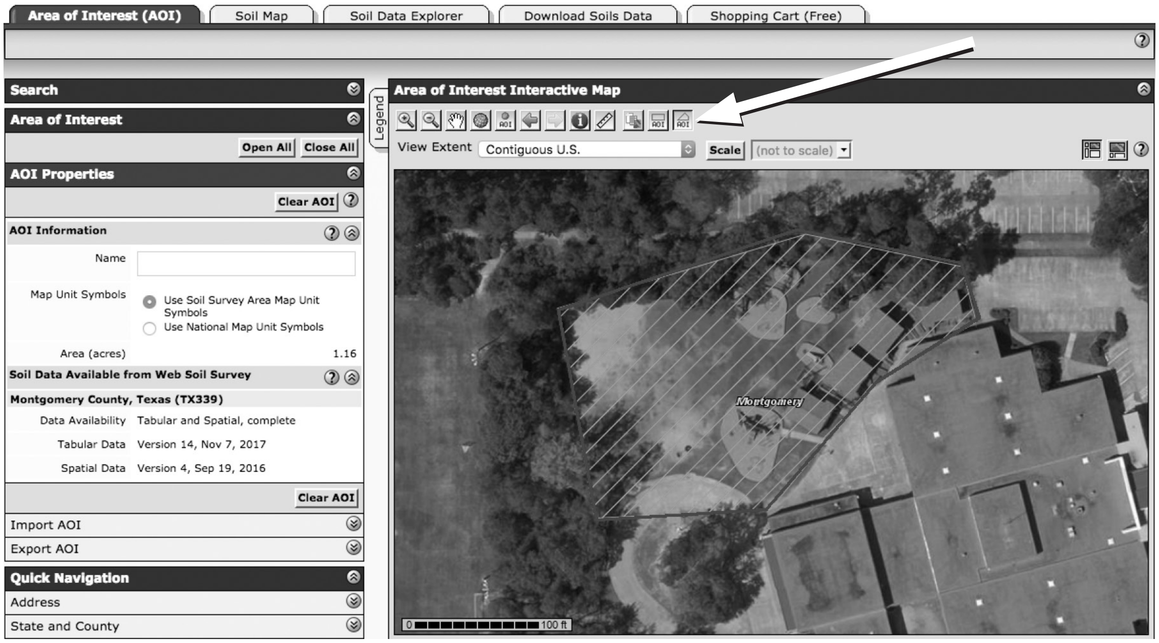
You can research the origins of your school garden soil without leaving your classroom. The U.S.D.A. Natural Resources Conservation Service has uploaded all of their soil survey information into an online Web Soil Survey available at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. From this website you can discover an amazing amount of information about soils across the U.S. Here are the basic steps to help guide your use of the Web Soil Survey:

❶ Click on the green START WSS Button.

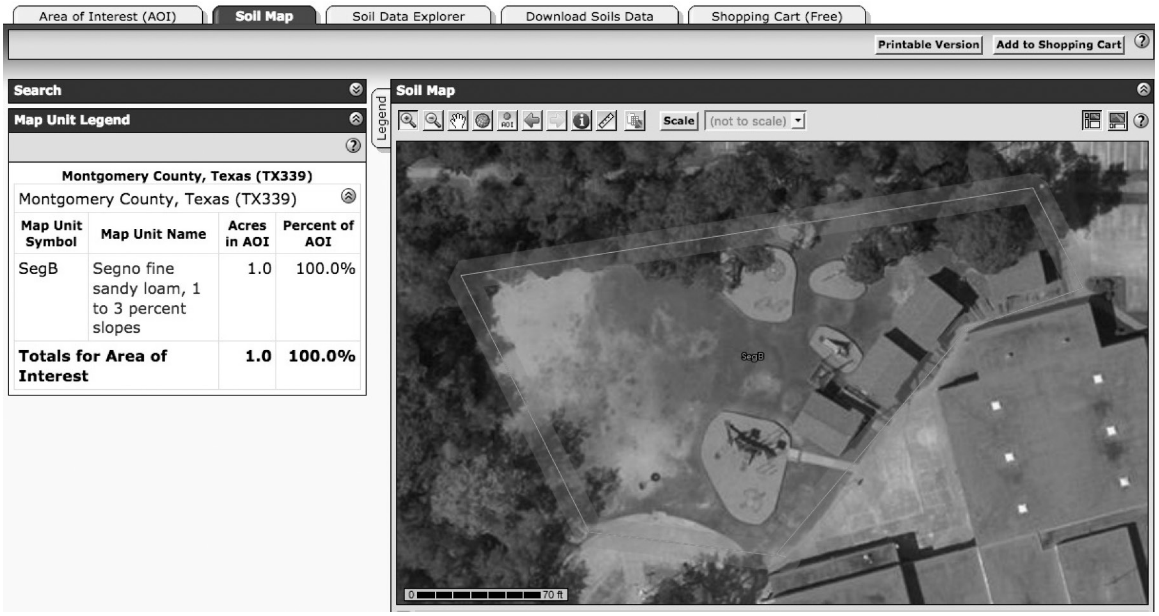
❷ Find your Area of Interest. Underneath the “Area of Interest Interactive Map” Toolbar you will find buttons to zoom in and zoom out, and a hand to move the map. Choose a button, and then click on the map to perform that function. Use a combination of these tools until the area that you want data on is clearly pictured on the screen.



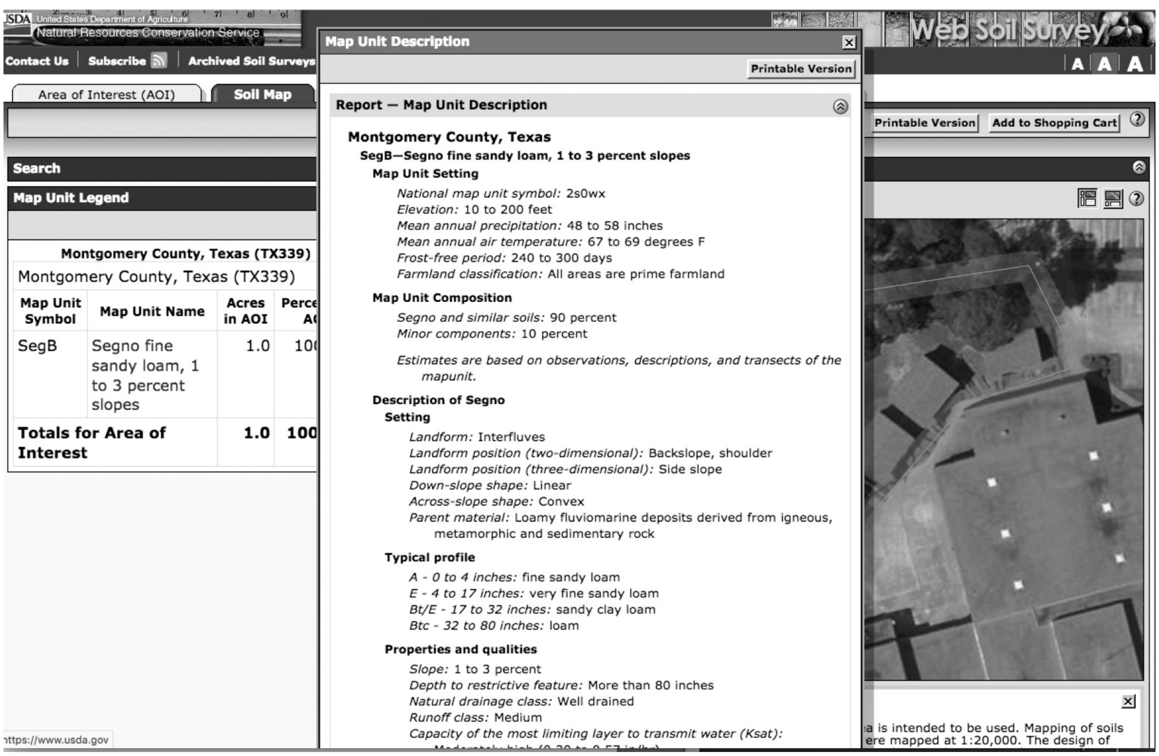
❸ Define your Area of Interest. Select the AOI button with the square or the AOI button with the polygon and then outline the specific area that you want to learn more about.



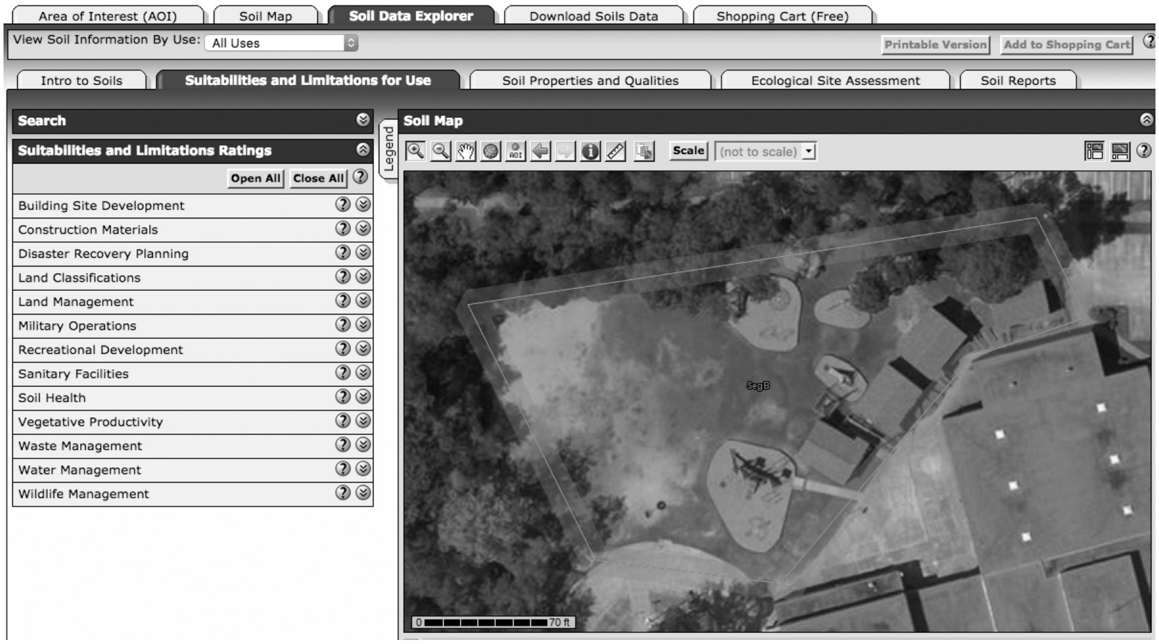
❹ Once your Area of Interest is defined, select the “Soil Map” tab at the top of the page and you will get a description of the soil type on record for this location.



❺ Click on the soil type name highlighted in blue for additional details about the soil.



❻ Select the Soil Data Explorer in the top tabs for additional information about the use of this soil.



Digging into Soil

JOURNAL PAGE

Name:________________________________

Date:_________________________________

Lesson #:_____________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 4
Texturally Speaking

Summary

Students will discover how soil texture is used to describe soils and group them into categories for practical application.

Objectives

Students will learn:

- Inorganic soil particles are defined by their size and are categorized as sand, silt, or clay.
- The proportion of sand, silt, and clay defines the soil texture and can tell us a lot about the soil.
- Different plants grow well in different types of soils.

Link to *"S" is for Soil*

- So, Where DO Soils Come From?
- How DO I Find Out About the Soils Where I Live?

Key Terms

Sand: Sand particles are the largest, coarsest mineral particles in soil; they range in size from 2.00–0.05 mm in diameter and feel gritty when rubbed between your fingers.

Silt: Silt particles are 0.05–0.002 mm and feel similar to flour when dry.

Clay: Clay particles are smaller than 0.002 mm, feel sticky in your fingers when wet, and clump to the point that you can't see an individual particle without a microscope.

Loam: Soils with specific proportions of these three mineral particles are called loams.

Link to Next Generation Science Standards Performance Expectations

HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effect on Earth materials and surface process.

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.

Time

Laying the Groundwork: 15 minutes
Exploration: 2 to 3 days
Making Connections in the Garden: 1 hour

Materials

- Sand
- Silt
- Clay
- Hand lenses
- Microscopes
- Soil samples
- Digital camera
- Water
- Clear, straight-sided bottle or jar with lid
- Landry detergent (optional)
- DIY soil nutrient test (optional)

Quote for Thought and Discussion

"To be a successful farmer one must first know the nature of the soil."

— Xenophon, Oeconomicus, 400 B.C.

Background Information

Talking about soil texture takes us back to looking at the mineral components of soil — sand, silt and clay. These mineral particles are derived from rocks broken down over thousands of years by climatic and environmental conditions (rain, glaciers, wind, rivers, animals, etc). The largest, coarsest mineral particles are sand. These particles are 2.00–0.05 mm in diameter and feel gritty when rubbed between your fingers. Silt particles are 0.05–0.002 mm and feel similar to flour when dry. Clay particles are extremely fine — smaller than 0.002 mm. They feel sticky in your fingers when wet and clump to the point that you can't see an individual particle without a microscope. The proportion of these three mineral particle sizes in a soil determines its texture.

The arrangement of these mineral particles in relation to each other leaves small openings, or pores. Pore space an important component of soil structure. In the optimal situation for most garden plants, about 50 percent of the volume of the soil is pore space, with half of that filled with water and half filled with air. The other 50 percent consists of sand, silt, clay, and organic matter.

The proportion of the different-sized mineral particles affects the amount of air, water, and nutrients available to plants, as well as how the soil "behaves." The smaller the soil particles, the more they bind together when wet. Thus, clay soils can be sticky and difficult to work. They drain poorly and have less pore space for air, so roots may suffer from a lack of oxygen. However, clay soils are often rich in plant nutrients. In contrast, sandy soils can drain water too quickly for healthy plant growth and tend to be low in nutrients, but they are easier to work. Adding organic material can offset many of the problems associated with either extreme.

The U.S.D.A Natural Resources Conservation Service has developed a Soil Textural Triangle that classifies soils based on the percentage of sand, silt, and clay they contain. You can view this triangle at https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_050242.jpg.

Although scientists use many methods to classify soil, gardeners and laypeople usually use soil texture to understand how soils perform under certain conditions. While there's no such thing as a perfect soil, different plants grow best in different types of soil. Most common garden plants prefer loam — soils with a balance of different-sized mineral particles (approximately 40 percent sand, 40 percent silt, and 20 percent clay) with ample organic matter and pore space. However, some plants grow better in sandy soils, while others are well-adapted to clay soils.

Laying the Groundwork

Bring in samples of isolated sand, silt, and clay so that students can investigate their individual properties. Have them look at the samples using both hand lenses and microscopes. Encourage students to use their senses of sight, touch, and smell to explore, and then record their observations. You can use the Soil Texture Worksheet at the end of this lesson to help guide their exploration. Sand and clay samples are widely available for purchase (sand at home improvement stores and clay at craft supply stores). To obtain a sample of isolated silt, check at online science supply stores.

Exploration

Once students have explored the properties of each of the individual components, they are ready to investigate the properties when these components are combined in soils. Gather soil samples from multiple locations, including your school garden. Students can bring in samples from home, or they can collect samples from different areas of your schoolyard or community. Record where each sample was gathered, along with information about the site, such as what was growing in the soil. Students can use the Soil Texture Exploration Worksheet at the end of this lesson to record the results of these investigations. Take photos of the samples to help with discussions after the experiments.

Begin by showing them the Soil Textural Triangle from the U.S.D.A Natural Resources Conservation Service, available at https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_050242.jpg. Explain the different classifications that have been developed based on the percentages of sand, silt, and clay found in a soil, with loam containing all three particle sizes in specific proportions. If possible, print out a copy of this triangle for each student to use during the Exploration activities.

Next, use two easy ways to explore soil texture. The first is to conduct a Ribbon Test with each of the samples.

Ribbon Test

❶ Take a small clump of soil and add water until it makes a moist ball.

❷ Roll the ball of soil between your hands. If the soil makes a nice, long ribbon, then it has a lot of clay in it (sticks together well). If it crumbles in your hand, then it contains a lot of sand. If it is somewhere in between, then the soil is probably a mix of sand, silt, and clay. (A soil with a balance of all three components is called a loam.)

❸ Ask students to estimate what percentage of each component they think is present. Explain that the ribbon test may not be exact, but that scientists often use it as a convenient tool in the field to create a general description of a soil because it is very easy to implement — all you need is a little water.

The U.S.D.A. Natural Resources Conservation Service has published a Guide to Texture by Feel flow diagram (available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311) to aid in the classification of soil using the Ribbon Test in the field. Provide access to a copy of this flow diagram while students complete this activity. Have them use the diagram and the Soil Textural Triangle pictured at the bottom of the webpage to choose a classification for their soil samples based on their Ribbon Tests. Have them record their results.

Follow up the Ribbon Tests with "Mudshake" Tests of the samples.

Mudshake Tests

❶ For each soil sample, have students fill a clear container with straight sides about two-thirds full of water; then add enough soil to nearly fill the jar. You can also add a pinch of laundry detergent to help the soil components separate well. Shake the jar vigorously and then set it in a place where it won't be disturbed. Have students observe the jar over the next couple of days as the particles settle into layers. The larger sand particles are heaviest and settle at the bottom, followed by a layer of silt, then topped by a layer of clay. The clay may stay suspended and cloud the water for a couple of days, which is why the sample needs to sit undisturbed. Organic matter will float on or just below the water surface.

❷ Once the soil in the jar has settled, measure the height of each layer, as well as the overall height of the soil (including all layers). Then translate these measurements into percentages for each component by dividing the height of each component by height of the sample. Record the results.

❸ With percentages in hand, students can then use the U.S.D.A. Natural Resources Conservation Service's Soil Texture Calculator to determine their soil's classification based on texture. The calculator is available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167. You can also use the Soil Textural Triangle to determine the classification.

If you would like to see a demonstration of the Ribbon and Mudshake Tests to help with your Exploration, check out "What is a Soil Ribbon?" from Raising Nebraska, University of Nebraska–Lincoln at https://www.youtube.com/watch?v=2FjxKnJURBI&t=16s.

Evaluate the Results

❶ Have students compare the results of the Mudshake versus Ribbon Tests. Ask, Are they a close match? Which test do you think is more accurate and why? What are the benefits and drawbacks of using each method?

❷ Finally, reconnect the results to the descriptions of the soil sample collection sites. Ask, Do you see any connections between what was growing at the collection site (and how well it was growing) and the results of the tests? How do you think soil texture impacts plant growth?

Making Connections in the Garden

What does the soil texture mean in your garden? A soil's texture greatly influences its overall structure and can impact factors such as nutrient and water availability, water drainage, and, ultimately, overall plant growth.

Clay soils can be sticky and difficult to work. With fewer air spaces, they drain poorly, so in times of significant rainfall roots may suffer from a lack of oxygen. However, in times of drought, clay soils also hold on tighter to the water molecules that are present in the soil, which means that less water is available to be absorbed by plant roots. Plants that grow in heavy clay must be able to tolerate these two extremes. Also, when clay soil dries out it creates a hard, impermeable surface that causes water to run off rather than soak in. On the bright side, clay soils contain and retain more nutrients, which may mean higher nutrient availability for your plants.

Sandy soils can handle large influxes of water and drain water quickly — sometimes too quickly. Because of the excess drainage, they can be low in nutrients, because the nutrients leach out to lower soil layers.

Silt-dominant soils generally hold more water than sand but less than clay, which makes for generally good growing conditions. On the downside, because they are lighter in weight than sand but do not stick together like clay, they are more susceptible to erosion.

Since each particle size has its strengthens and weaknesses, many common garden plants grow best in loams — soils with a balance of different-sized mineral particles (usually defined as 40 percent sand, 40 percent silt, and 20 percent clay). Adding organic matter to a soil can help overcome some of the challenges if one of the mineral sizes is present in too high a quantity. Organic matter added to sandy soils can help with water and nutrient retention. Organic matter added to clay soils can help create more pore space. Organic matter added to silty soils can help the particles stick together better and decrease erosion.

So what kind of soil and nutrients do you have to work with in your school garden? In addition to the tests in the Exploration, consider conducting a DIY nutrient test (available at most garden centers). Or send a soil sample to your state soil lab, which will provide you with an exact analysis of your soil's texture and nutrient content. These soil tests are usually reasonably priced; contact your local Extension Office for information about soil labs in your area.

Whether you use a DIY test or have testing done by a soil lab, "Soil Fertility" by Soil Science Society of America can help you interpret your results:
http://www.soils4teachers.org/fertility.
This webpage provides a description of the essential nutrients plants need for healthy growth, including macronutrients that are needed in large quantities and the micronutrients that are needed in small quantities.

The good news is that no matter what you find out about your garden soil, different plants thrive in different types of soil. If your school garden is in native soil that is not optimal for growing traditional garden plants, and efforts to add organic matter to improve the soil have not been successful, research plants that will grow well in the soil you have available. Contact your local native plant society for additional information and invite a native plant expert to your class as a guest speaker to share the benefits of growing native plants for the local ecosystem.

Extension

One way to explore the impact of soil texture on plant growth is to study and grow plants that are adapted to grow in soils that are dominant in one mineral particle size — sand, silt or clay. For example, most desert plants are adapted to growing in soils that are comprised predominantly of sand. The Arizona-Sonora Desert Museum has an excellent article on desert plant adaptations titled "How Plants Cope with a Desert Climate," available online at
https://www.desertmuseum.org/programs/succulents_adaptation.php.

Ask your students to read this article and then devise experiments to grow plants adapted for sandy soils, such as succulents and cacti, in a variety of soils that include different amounts of sand, silt, and clay. They can track growth and compare the results to explore the influence of soil texture on plant health.
Plants adapted for wetland soils are another potential experimental group. The U.S.D.A. National Resources Conservation Service

provides an informative publication titled "Wetland Plants: Their Function, Adaptation and Relationship to Water Levels" at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_010758.pdf.

References

"Soil Textural Triangle" by the U.S.D.A. National Resources Conservation Service. https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_050242.jpg

"Guide to Texture by Feel" by the U.S.D.A. National Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311

"Silt" by National Geographic. https://www.nationalgeographic.org/encyclopedia/silt/

"What is a Soil Ribbon?" by Raising Nebraska, University of Nebraska–Lincoln, 23 June 2017. https://www.youtube.com/watch?v=2FjxKnJURBI&t=16s

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Soil Texture

WORKSHEET

Use the following chart to explore sand, silt, and clay particles.

	SAND	SILT	CLAY
SIGHT			
Describe what the sample looks like.			
Describe what the sample looks like using a hand lens.			
Describe what the sample looks like using a microscope.			
Draw a picture of the sample as seen under a microscope.			
TOUCH			
Describe what the sample feels like.			
SMELL			
Describe what the sample smells like.			

Soil Texture

EXPLORATION

Sample #:

Sample Collected From:

Description of the Collection Site:

Ribbon Test Results

❶ What happened when you tried to make a ribbon with your soil sample?

❷ Use the Guide to Texture flow diagram at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311 to determine the soil classification for this sample.

Soil Sample Classification:

❸ Based on your Ribbon Test, estimate the amount of sand, silt, and clay you think might be present in your sample:

_______ Sand
_______ Silt
_______ Clay

Mudshake Test Results

❹ Measure each of the layers in your container:

______ Sand (bottom layer)
______ Silt (middle layer)
______ Clay (top layer)

❺ Translate the information above into percentages by dividing the height of each component by the total height of the settled sample and multiply times 100.

______ % Sand
______ % Silt
______ % Clay

Soil Texture

EXPLORATION (CONTINUED)

❻ Do you have an organic matter floating at the top of your container? Describe any organic matter present.

❼ Use the U.S.D.A. Natural Resources Conservation Service Soil Textural Triangle or Soil Texture Calculator to determine each soil's classification based on the texture results from these tests. The calculator is available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167.

Soil Sample Classification:

❽ How do the results of your Mudshake Test compare with your estimations of sand, silt, and clay from the Ribbon Test?

❾ Which test results do you think are more accurate and why?

❿ List benefits of using the Ribbon Test and examples of situations in which you would use it.

⓫ List benefits of using the Mudshake Test and examples of situations in which you would use it.

Digging into Soil

JOURNAL PAGE

Name:_______________________________

Date:_______________________________

Lesson #:____________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 5
Sleuthing Soil Structure

Summary

What is soil structure? This lesson will provide an in-depth look at how soil structure impacts its functionality.

Objectives

Students will learn:

- Soil structure describes how all of the components in the soil are arranged.
- Soil structure is just as important as the materials contained in the soil.
- Healthy soil must also include adequate pore space, which can be filled with air and water.
- Human activity frequently disrupts soil structure, which impacts the soil's ability to absorb water and increases problems of stormwater runoff and erosion.

Link to *"S" is for Soil*

- How Can You Tell Healthy Soils from Unhealthy Soils?

Key Terms

Soil structure: A soil's structure is the arrangement of its soil components.

Pore space: This is the open space located within the soil that can be filled with air or water.

Soil erosion: This is the process of soil being moved from its place of origin by forces such as wind and water.

Link 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-ESS2-5: Plan and conduct an investigation of the properties of water and its effect on Earth materials and surface processes.

Time

Laying the Groundwork: 1 hour
Exploration: 2 hours
Making Connections in the Garden: 1 hour

Materials

- Soil clumps
- Large, clear plastic or glass containers
- Small pieces of hardware cloth/wire mesh cloth
- Soil samples
- Large plastic jars with holes in the bottom
- Smaller plastic containers that will fit into the larger jars with holes in the bottom
- Water
- Food coloring
- Pan to catch water run off
- Flour
- Bread
- Plates
- Plastic cups

Quote for Thought and Discussion

"Soil erosion is as old as agriculture. It began when the first heavy rain struck the first furrow turned by a crude implement of tillage in the hands of prehistoric man. It has been going on ever since, wherever man's culture of the earth has bared the soil to rain and wind."

— Hugh H. Bennett and W.C. Lowdermilk
circa 1930s

Background Information

There is more to good soil then just having the right components (minerals and organic matter) present. The amount of each component and how the particles are all arranged are also important. The arrangement of the soil components defines the overall soil structure.

Soil is composed of minerals and organic matter. The minerals are classified by their size, with the largest particles called sand (2.00-0.05 mm in diameter), followed by silt (0.05-0.002 mm), and then the smallest, clay (smaller than 0.002 mm). You will also find organic matter in a wide range of sizes depending on its state of decomposition.

In addition to these components, healthy soil also needs pore space for air and water. In an optimal situation for most plants and underground organism life, about 50 percent of the volume of the soil would be pore space, with half of that filled with water and half filled with air. The other 50 percent would be composed of sand, silt, clay, and organic matter. Although it's obvious that animals need air, roots also need air as much as they need water. Unless they are adapted to wet conditions, plants can actually suffocate or drown if their roots are completely submerged in water for extended periods of time.

The proportion of these different-sized particles and how they are arranged affects pore space and thus the amount of air, water, and nutrients available to plants. It also affects how the soil "behaves." Clay particles are small and will clump tightly together. Silt particles are often arranged in sheets. Sand particles offer the most pore space between mineral components. The organic matter in soil also influences how the particles are arranged.

Like the mineral component, organic matter also comes in many different sizes and shapes. Soil structure is highly influenced by underground organisms, which excrete bodily fluids that act like a glue to help everything stick together into clumps called aggregates. The formation of aggregates creates additional pore space that is so vital for plant roots and soil organisms.

In addition to its impact on plant and animal life, soil structure also plays a key role in the capability of soil to absorb water. Many common human activities negatively impact soil structure by crushing pore space. Examples of these activities are tilling, soil compaction from foot or vehicle traffic, and removal of native vegetation. This disruption can lead to a decrease in the soil's ability to absorb water and contributes to common problems such as stormwater runoff and erosion, both of which ultimately lead to soil loss and pollution of surface water sources. Therefore, encouraging the building of good soil structure has important environmental implications.

Laying the Groundwork

As a class, watch the following videos demonstrating the Slake and Infiltration Tests from Dr. Ray Achuleta from the U.S.D.A. Natural Resources Conservation Service. A short introductory video titled “Soil Health Lessons in a Minute: Soil Stability Test” is available at https://www.youtube.com/watch?v=9_ItEhCrLoQ.

A longer version video demonstrating the same test, titled “Slake and Infiltration Test by Ray for ENHS 766 Class,” which includes more explanation, is available at https://www.youtube.com/watch?v=CEOyC_tGH64.

You can use the worksheet at the end of this lesson to help students process the information provided in these demonstrations.

As a class, discuss why it is important for soils to be able to absorb water. What happens in communities when the soil cannot adequately absorb the rainwater it encounters? Discuss recent episodes of flooding either locally or nationally. Here are a few examples:
NPR’s “3 Reasons Houston Was A Sitting Duck for Harvey Flooding”
https://www.npr.org/2017/08/31/547575113/three-reasons-houston-was-a-sitting-duck-for-harvey-flooding

The Atlantic’s “Houston’s Flood Is a Design Problem”
https://www.theatlantic.com/technology/archive/2017/08/why-cities-flood/538251/

In addition to talking about problems caused by the volume of water moving in an environment, discuss the important role soil plays as a filter that helps keep our water supply clean. If the soil does not filter water, how do we keep our lakes and rivers clean?

Finally, discuss how a soil’s ability to absorb water affects plant life, and the importance of having a balance of water- and air-filled pore space for plants.

Exploration

Ask your local U.S.D.A Natural Resources Conservation Service office (most counties in the United States have a field office) if they are available to come to your school for a Rainfall Simulator Demonstration. If you do not have a local office or if your local office does not have the resources available, you can show students the “USDA Rainfall Simulator” video from Across the Fence, a program of The University of Vermont Extension, for a virtual demonstration: https://www.youtube.com/watch?v=Ix2WljRZQ_A

To hone engineering skills, ask your students to design and build their own rainfall simulator as a group or individual activity. If you feel that they need additional design ideas, you may want to show them the Fun Science Demos’ “Erosion and Soil” video:
https://www.youtube.com/watch?v=im4HVXMGI68

Continue your exploration by learning about the stormwater runoff and erosion issues in your community. Come up with ideas for educating the public about those issues and, if possible, allow your students to participate in demonstrations of their rainfall simulators.

Making Connections in the Garden

Conduct the Slake and Infiltration tests demonstrated in Dr. Achuleta’s videos to explore the soil from your school garden or a schoolyard.
Ask students, What do these tests tell you about the soil structure in your garden? Does

the soil provide adequate pore space for your plants to thrive? Will the soil be able to absorb the rainwater your garden receives? Do you need to improve your soil structure? If so, ask students to research gardening techniques they can employ to improve the soil structure in their garden.

Extension

You can use bread and flour to further demonstrate how soil structure makes a big difference in water absorption. Didi Pershouse offers an excellent activity to help students visualize the importance of soil structure in her book Understanding Soil Health and Watershed Function: A Teacher's Manual, available online at https://www.didipershouse.com/understanding-soil-health-and-watershed-function.html.

You can find the activity "Flour Vs. Bread: How Aggregate Structure Influences Water Flows" on pp. 9-20. In the activity, the flour represents the unstructured mineral components of soil and the bread represents soil with organic matter and soil organisms. You compare what happens when both the flour and bread experience "rain" (water from a cup). Her lesson includes worksheets for data collection, talking points for class discussion, and additional activities for further exploration.

References

"Soil health lessons in a minute: soil stability test" by Dr. Ray Achuleta from the U.S.D.A. Natural Resources Conservation Service, 27 Dec 2012. https://www.youtube.com/watch?v=9_ItEhCrLoQ

"Slake and Infiltration Test by Ray for ENHS 766 Class" by Dr. Ray Achuleta, 23 Feb 2010. https://www.youtube.com/watch?v=CEOyC_tGH64

"3 Reasons Houston Was A Sitting Duck for Harvey Flooding" by David Schaper, NPR News, 31 Aug 2017. https://www.npr.org/2017/08/31/547575113/three-reasons-houston-was-a-sitting-duck-for-harvey-flooding

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Pershouse, Didi. Understanding Soil Health and Watershed Function, A Teacher's Manual. The Soil Carbon Coalition: the U.S.D.A Natural Resources Conservation Service, the U.S.D.A Southern Plains Climate Hub, The Soil Carbon Coalition, Redlands Community College, The Dixon Water Foundation, 2017. https://www.didipershouse.com/understanding-soil-health-and-watershed-function.html.

Slake and Infiltration Tests

WORKSHEET

Answer the following questions after watching "Slake and Infiltration Test by Ray for ENHS 766 Class" by Dr. Ray Achuleta: https://www.youtube.com/watch?v=CEOyC_tGH64

❶ What are the differences between the two soil aggregates being compared in this experiment?

❷ What is soil pore space? What is it filled with?

❸ How do biological cementing agents help the soil?

❹ Why is soil infiltration important for plants and our environment?

❺ What are two jobs of healthy soil systems in our environment?

Digging into Soil

JOURNAL PAGE

Name:________________________________

Date:_________________________________

Lesson #:______________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 6
Horizons Happen

Summary
The movement of water, minerals, and organic matter within soil can lead to the formation of distinct layers with common properties. What can we learn from these soil layers, also known as soil horizons?

Objectives
Students will learn:

- Soils have different layers (horizons) and the layers vary in size and composition depending on the climate and vegetation present.
- Exploring soil horizons can tell you about the environmental conditions in the area and how the soil has been treated in the past.

Link to *"S" is for Soil*

- How Soils Are Made
- Soil, As Cake
- Reading the Layers
- Vive La Difference in Soils
- How Do I Find Out About the Soils Where I Live?

Key Terms
Horizons: These are common layers with similar characteristics that form in soil over time.

Soil profile: This is a vertical cross-section of the soil that allows scientist to view all the soil horizons.

Soil series: This is a grouping of soils with similar horizons categorized by scientists to help in understanding the characteristics and behavior of different types of soil.

Link to Next Generation Science Standards Performance Expectations
HS-ESS2-1: Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Time
Laying the Groundwork: 30 minutes
Exploration: 1 hour
Making Connections in the Garden: 2 hours

Materials

- Internet access
- Soil profile cake ingredients
- Place to dig
- Shovel
- Digital camera

Quote for Thought and Discussion
"Each soil has had its own history. Like a river, a mountain, a forest, or any natural thing, its present condition is due to the influences of many things and events of the past."

— Charles Kellogg
The Soils That Support Us, 1956

Background Information

The movement of water along the soil surface and through the soil, along with the distribution of minerals and organic matter within soil, can lead to the formation of distinct layers with common properties. From years of studying soils, scientists have identified frequently found layers with similar compositions. These layers are called horizons. Not all soils have all of these common layers, and not all of the layers will be the same size, but the classification can still aid in helping to understand the characteristics of a soil.

The common horizons identified are:
O Horizon: The top layer that includes the most recent additions to the decaying organic matter. This layer is usually dark because it contains the most humus.

A Horizon: This layer is called the topsoil and consists mostly of mineral matter, but is still a bit darker in color because it also includes a fair amount of decomposed organic matter. This is where most roots can be found and also where the majority of underground organisms live.

E Horizon: This horizon is usually pale in color as it contains mostly sand and silt particles. Most of the clay, nutrients, and organic matter have been leached out by water drainage, a process called eluviation.

B Horizon: This horizon is also called the subsoil. It is lighter in color because it contains little organic matter; however, this is where many of the materials that have leached out of the E Horizon will accumulate.

C Horizon: This layer is known as the substratum and includes partially weathered parent material and minerals.

R Horizon: This lowest horizon is rarely seen and includes the bedrock.

To view these layers or horizons in the field, scientists create something called a soil profile. They dig straight down into the soil so that all of the horizons can be viewed. Scientists have grouped soils that have similar soil profiles into categories, and they call these categories soil series. Knowing the characteristics of each soil series offers clues about how a soil will behave in the environment; for example, how well it will hold nutrients or drain water. This information can help determine how best to use the land. For example, knowing the soil series may help farmers determine what plants would grow best on their land. In an urban area, construction companies and city planners might look at a series to decide if the soil is suitable to support a new building or a road.

Over 20,000 different soil series have been identified. The U.S.D.A. Natural Resources Conservation Service provides Official Soil Series Description Fact Sheets:https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/data/?cid=nrcs142p2_053586

They also offer a Soil Profile Gallery containing photos of a handful of soil profiles that show a variety of soil series:https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr7/profile/?cid=nrcs142p2_047970

Laying the Groundwork

Bring excitement to learning the different soil layers by making a Soil Profile Cake. Use different ingredients to represent each horizon and then "dig" in. Here are some suggestions for the different layers:

- **O (humus or organic matter):** chocolate icing with chocolate chips
- **A (topsoil):** chocolate cake
- **E (eluviated horizon):** white or yellow cake
- **B (subsoil):** white or yellow cake with pieces of crushed chocolate sandwich cookies baked inside
- **C (parent material):** layer of coarsely chopped or mini chocolate sandwich cookies
- **R (bedrock):** layer of regular-sized chocolate sandwich cookies

The Dr. Dirt Website offers similar ideas for making Dirt Pudding to demonstrate soil horizons, and takes it a step further by altering the ingredients to create the profiles that look like specific soil series: http://www.doctordirt.org/dirt-pudding

If you would prefer to make this a non-edible activity that would also create longer-lasting learning tools/models, you can challenge students to create their own soil profiles using craft materials. (Use natural materials if possible to be more environmentally friendly.) Provide them with a list of the layers and then let their imaginations run wild.

Exploration

Begin your exploration of soil layers by sharing the photo gallery of soil profiles available from the NRCS USDA: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr7/profile/?cid=nrcs142p2_047970

The profiles pictured are broken down into six categories: Blackland Prairie, Appalachian Plateau, Valley and Ridge, Piedmont, Caribbean Region, and Coastal Plain. Look for similarities and differences between the different profiles and categories.

Next, try to dig out your own soil profile for firsthand viewing. Find a safe location to dig a deep hole at your school garden, schoolyard, or in your community. Before you dig, be sure to locate underground utilities like electricity, sewer, and water lines. You can usually contact school maintenance staff or utility companies for assistance. The utility companies also offer a special Call Before You Dig service that you can reach by dialing 811. This free service is designed to promote safety; with one call you can have all utility lines marked within a couple of days. More information about the service is available at http://call811.com/.

Once you have dug your soil profile, challenge students to find distinct horizons in the soil and measure the height of each layer. Take pictures of your profile with a yardstick or measuring tape on the side to document your findings.

You can compare your results to the information on the typical soil series in your area provided by the U.S.D.A Natural Resource Conservation Service's Web Soil Survey, available at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

To use the Web Soil Survey, click on "Start WSS." Once on the Web Soil Survey page, begin by defining your Area of Interest (AOI). Once you have your AOI defined, click on the tab for "Soil Map" and it will give you the name of your soil type (or types) on record, highlighted in blue. Click on the soil type name for additional information. Under the description you can find information about the "Typical Profile," which offers the horizons you are likely to see, as well as their height and composition. A series of step-by-step screen shots to help you navigate through the Web Soil Survey can be found at the end of this lesson.

Compare your findings to the profile information you discover online and discuss with students. Ask, Are they different or the same? If different, do you think this has to do with your digging technique (perhaps you were not able to dig as deep as you may have liked?) or variability of location?

Take your exploration further by investigating the impact of climate and vegetation on soil layers. For example, in areas with a dry climate and little plant matter, the O and A levels are likely to be very thin because very little organic matter is being added to the surface each year. In warmer areas with heavy vegetation, these layers will be thicker.

Run additional reports on the Web Soil Survey to investigate soils in areas that you know host different types of vegetation, or have different climates than your own location. You can choose to stay local or expand to other states. Keep a chart of the information from the "Typical Profile" sections to compare the results. A sample worksheet to help you collect data can be found at the end of this lesson. Draw conclusions about the impact of climate and vegetation on soil layers based on your findings.

Making Connections in the Garden

In a previous lesson, we looked at the water absorption rate of the top levels of your garden soil, but the layers below can also impact water absorption and drainage in your garden. If you have a well-draining topsoil over a subsoil of thick clay, in periods of heavy rains your soil may hold too much water and harm your plants.

You can further explore the drainage of your soil by conducting an on-site infiltration test. The Earth Partnerships for Schools, University of Wisconsin – Madison Arboretum has developed an informative handout titled "Infiltration Test: Exploring the Flow of Water Through Soils": https://arboretum.wisc.edu/content/uploads/2015/04/RGS-2-4_Infilitration-Test.pdf. Although this handout was designed to help with planning a rain garden, it can be used to help assess any type of school garden site.

Note that if you currently garden in raised beds, you will want to conduct your infiltration test on the soil beneath the beds. One of the reasons for using raised beds for your school garden is that they allow you to bring in the best soil you can find and create a growing space with optimal drainage. However, if your raised beds are not very deep, the drainage of the soil below them can still significantly impact your garden. If you are in the initial planning stages and you find that your existing soil is very compacted and drains poorly, you may want to choose taller raised beds. If you have existing raised beds with drainage problems, you may want to consider raising their height.

Extension

Soil scientists are not the only researchers interested in studying the layers of soils. Archeologists use the term stratigraphy to describe the study of soil layers and other materials in the Earth's surface. You can use the following article to help students explore the investigations into soil and its impact on history:

"The Science of Soil" by Dr. John Wah. Time Team America.
http://www.pbs.org/time-team/experience-archaeology/soil-analysis/

References

"From the Surface Down: An Introduction to Soil Surveys for Agronomic Use, 2nd Ed." by the U.S.D.A Natural Resources Conservation Service. 2010.
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053238.pdf

"Official Soil Series Description Fact Sheets" by the U.S.D.A Natural Resources Conservation Service.
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/data/?cid=nrcs142p2_053586

"Soils Overview" by the Soil Science Society of America.
https://www.soils.org/files/about-soils/soils-overview.pdf

"Soil Profile Gallery" by the U.S.D.A Natural Resources Conservation Service.
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr7/profile/?cid=nrcs142p2_047970

"Dirt Pudding" by Dr. Dirt.
http://www.doctordirt.org/dirt-pudding

"Infiltration Test: Exploring the Flow of Water Through Soils" by the Earth Partnerships for Schools, University of Wisconsin – Madison Arboretum. https://arboretum.wisc.edu/content/uploads/2015/04/RGS-2-4_Infilitration-Test.pdf

Web Soil Survey by The United States Department of Agriculture Natural Resources Conservation Service.
https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

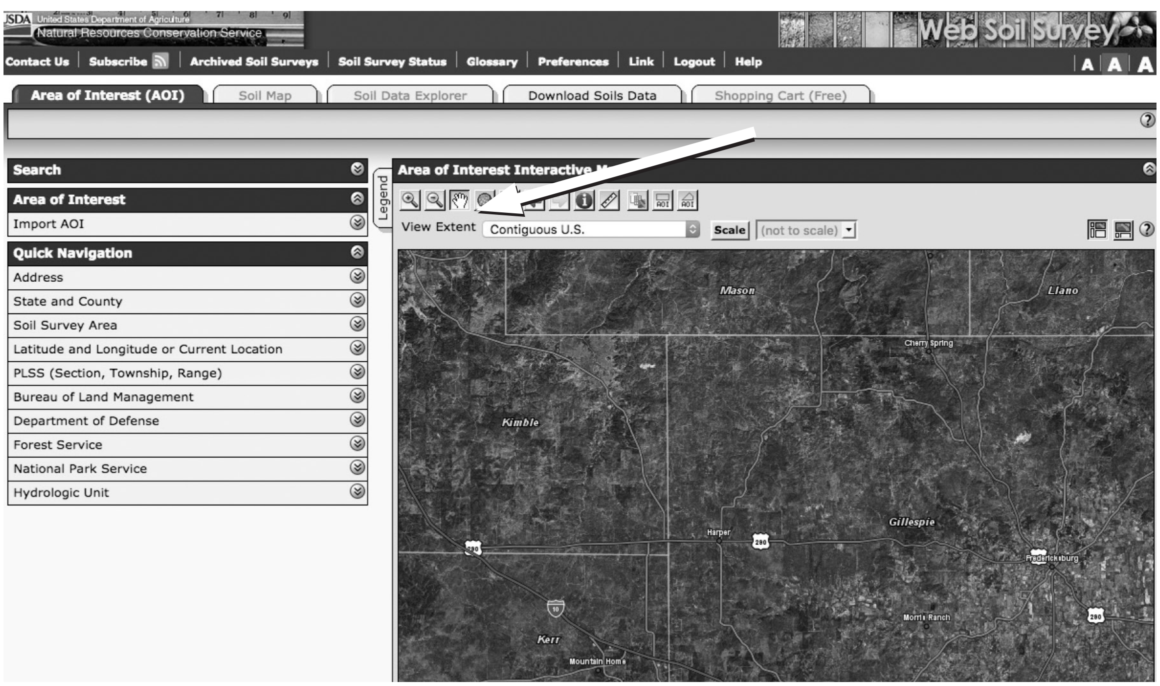
"The Science of Soil" by Dr. John Wah, Time Team America.
http://www.pbs.org/time-team/experience-archaeology/soil-analysis/

Using the Web Soil Survey

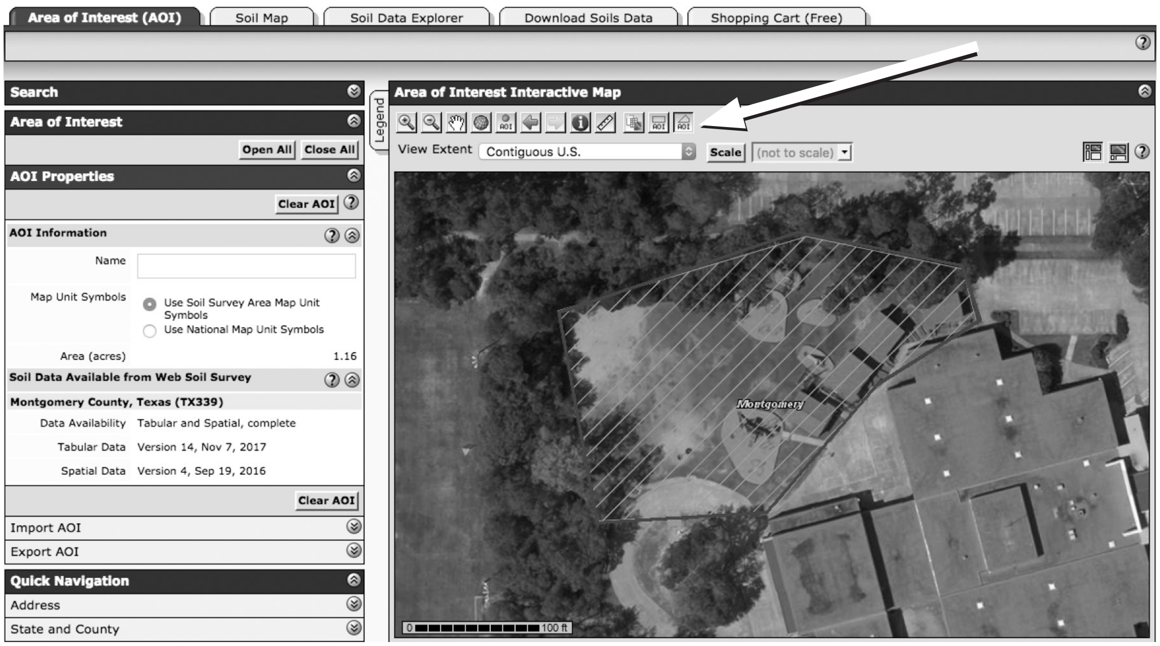
You can research the profile of your schoolyard soil without leaving your classroom. The U.S.D.A. Natural Resources Conservation Service has uploaded all of their soil survey information into an online Web Soil Survey available at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. From this website you can discover an amazing amount of information about soils across the U.S. Here are the basic steps to help guide your use of the Web Soil Survey:

❶ Click on the green START WSS Button.

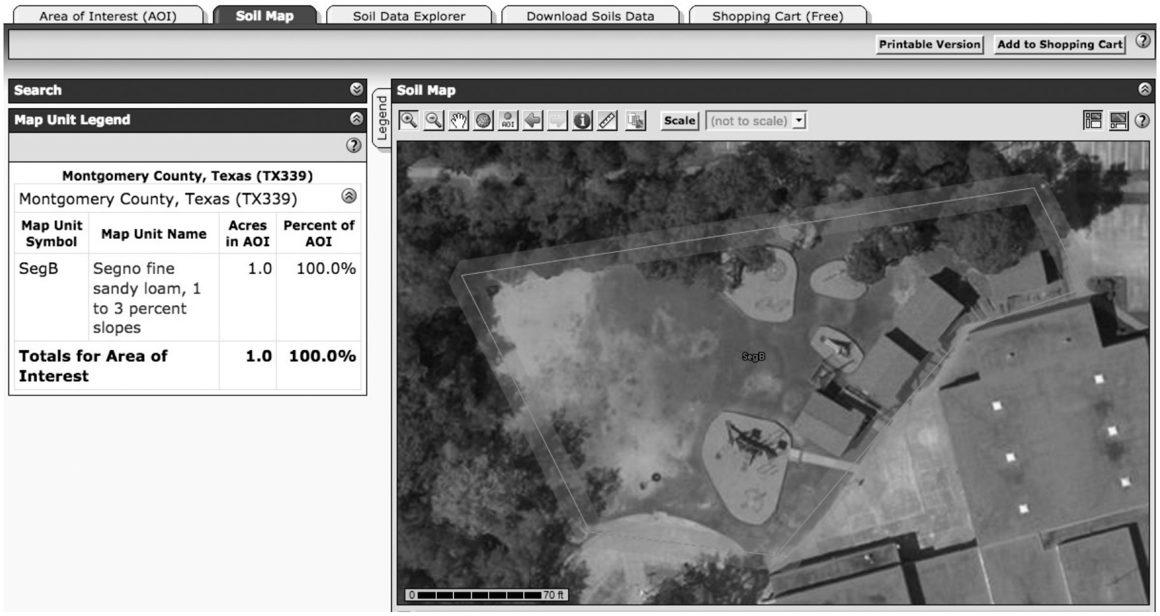
❷ Find your Area of Interest. Underneath the "Area of Interest Interactive Map" Toolbar you will find buttons to zoom in and zoom out, and a hand to move the map. Choose a button, and then click on the map to perform that function. Use a combination of these tools until the area that you want data on is clearly pictured on the screen.



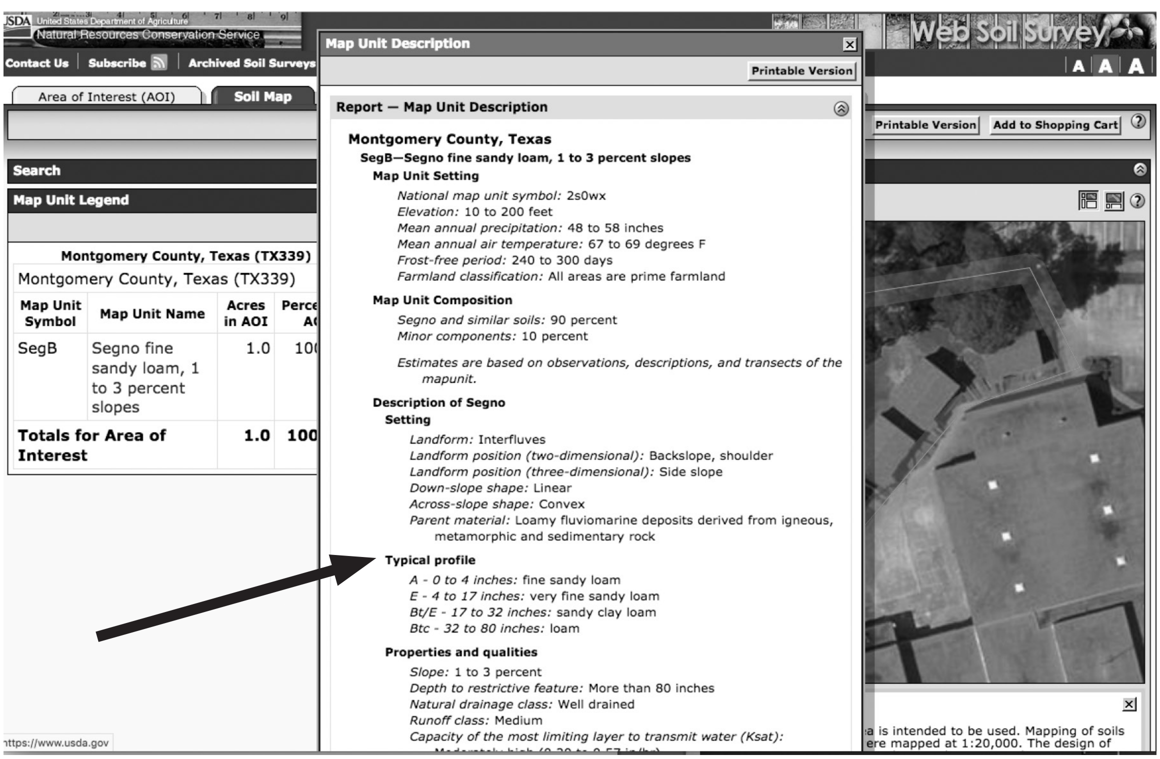
❸ Define your Area of Interest. Select the AOI button with the square or the AOI button with the polygon and then outline the specific area that you want to learn more about.



❹ Once your Area of Interest is defined, select the "Soil Map" tab at the top of the page and you will get a description of the soil type on record for this location.



❺ Click on the soil type name highlighted in blue for additional details about the soil. About halfway down the page you will see a listing for "Typical Profile" which will describe the soil layers you should expect to see and their approximate heights.



Soil Profile Investigation

Use the U.S.D.A Natural Resource Conservation Service's Web Soil Survey to compare soil profiles in areas with different climates and vegetation. Access the survey at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

Location	Description of Climate	Vegetation Present	Soil Type Identified	Layers in Typical Profile

Digging into Soil

JOURNAL PAGE

Name:______________________________

Date:_______________________________

Lesson #:___________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 7
The Soil-Air Connection

Summary

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.

Objectives

Students will learn:

- Soil stores carbon and helps regulate atmospheric carbon.
- Soil provides nutrients and habitats to all life on land.

Link to *"S" is for Soil*

- Who Really Needs Soil Anyway
- What Role Do Soils Play?
- Oceans v. Soils: Which is the Best Regulator of The Earth's Atmosphere?
- How Long Does Soil Carbon Last?
- Soil Carbon Grasslands
- Soil Carbon Distribution in Croplands

Key Terms

Carbon cycle: This is the movement of carbon throughout the environment.

Global warming: This describes an increase in the Earth's average global surfaces temperatures.

Climate change: This describes a long-term change in the Earth's climate.

Link 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.

Time

Laying the Groundwork: 30 minutes
Exploration: 2 hours
Making Connections in the Garden: 2 hour

Materials:

- Internet access
- Chart paper or dry erase board and markers

Quote for Thought and Discussion

"We are part of the earth and it is part of us ... What befalls the earth befalls all the sons of the earth."

— Chief Seattle, 1852

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.

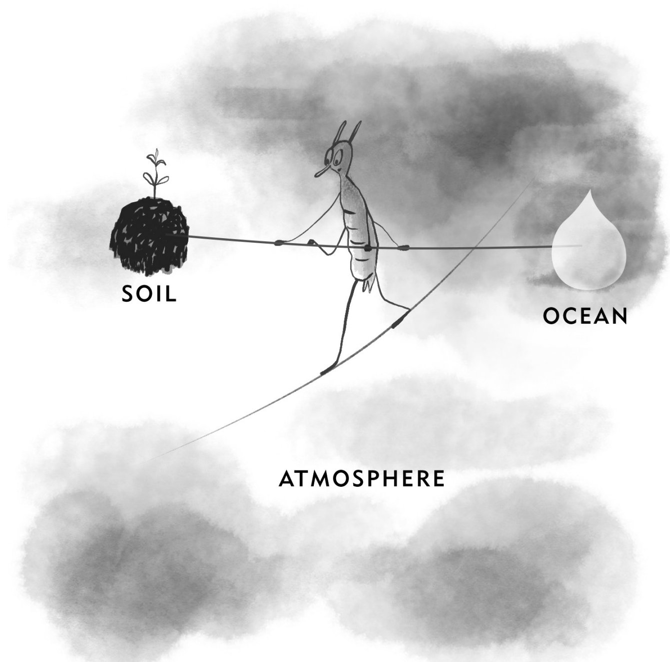
Atmospheric carbon combines with oxygen to become carbon dioxide, which is a greenhouse gas. Greenhouse gases absorb and then re-emit energy back to the Earth. Therefore, the more carbon dioxide in the air, the warmer the temperatures both on land and in the oceans. The warmer temperatures also increase 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. The worksheet at the end of this lesson will help guide your discussion.

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/originals/BioComponents_Carbon.jpg.

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 found at the end of this lesson plan.

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: http://cdiac.ess-dive.lbl.gov/pns/convert

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/video/food-forward-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 in the Garden

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 at the end of the lesson as a guide if needed. After thorough consideration, as a class decide if you will incorporate any of these practices into your garden program.

Extensions

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 at the end of this lesson plan as a guide. 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.

References

"This Carbon Cycle" by NASA's Earth Observatory. https://earthobservatory.nasa.gov/Features/CarbonCycle/

"The Soil Story" by Kiss the Ground. https://kisstheground.com/

"Carbon Cycling and Biosequestration: Integrating Biology and Climate Through Systems Science," United States Department of Energy, March 2008, DOE/SC-108. https://genomicscience.energy.gov/carboncycle/

"Global Carbon Cycle Components Diagram" by the United States Department of Energy. https://public.ornl.gov/site/gallery/originals/BioComponents_Carbon.jpg

NASA's Global Climate Change Website. https://climate.nasa.gov/

"Conversation Tables." The Carbon Dioxide Information Analysis Center from the US Department of Energy Berkeley Lab. Reproduced from: *Carbon Dioxide and Climate,* 1990. ORNL/CDIAC-39, Carbon

Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Third Edition. Edited by Fred O'Hara Jr.
http://cdiac.ess-dive.lbl.gov/pns/convert

"SOS: Save Our Soil" by PBS, 4 September 2014.http://www.pbs.org/video/food-forward-sos-save-our-soil

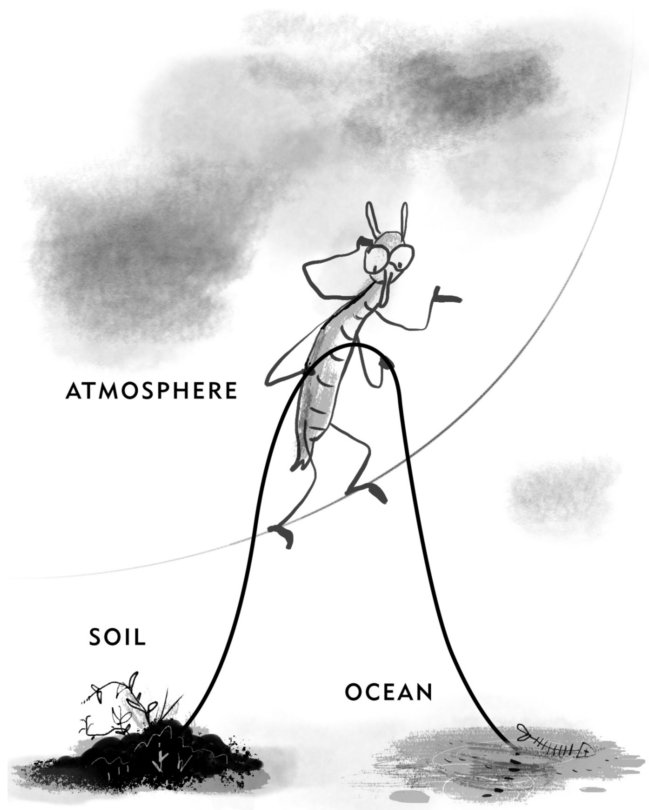
"How the World Passed a Carbon Threshold and Why It Matters" by Nicola Jones, Yale Environment 360, 26 Jan 2017. https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters

"The Carbon Cycle and Soil Organic Carbon" Agronomy Fact Sheet Series #91. Cornell Cooperative Extension
http://nmsp.cals.cornell.edu/publications/factsheets/factsheet91.pdf

"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

Barlow, Zenobia, Karen Brown, and Margo Crabtree. Understanding Food and Climate Change. The Center for Ecoliteracy, 2018.
https://www.ecoliteracy.org/download/understanding-food-and-climate-change-interactive-guide



The Soil Story

WORKSHEET

Answer the following questions as you watch "The Soil Story" from Kiss the Ground, available at https://kisstheground.com/. (To find video, scroll to the bottom of the page.)

❶ According to the video, what is causing climate change?

❷ Does the amount of carbon on our planet change?

❸ What does the video suggest is the solution for stopping and reversing the impacts of climate change?

❹ Where is carbon stored on Earth?

❺ How have humans impacted the natural balance of carbon on our planet?

❻ What are some of the solutions this video suggests for bringing carbon back into balance in soil and air?

Global Carbon Cycle

Data from the U.S. Department of Energy estimating the amount of carbon cycling through the Earth each year is available at https://public.ornl.gov/site/gallery/originals/BioComponents_Carbon.jpg

	Amount of Carbon Released into the Atmosphere (Gigatons Carbon/Year)	Amount of Carbon Removed from the Atmosphere (Gigatons Carbon/Year)
Actions Releasing Carbon into the Air		
Plant respiration	60	
Human actions (for ex. use of fossil fuels and release of carbon from soil through actions such as tilling)	9	
Air-sea gas exchange	90	
Microbial respiration and decomposition	60	
Actions Removing Carbon from the Atmosphere		
Photosynthesis by plants to produce carbohydrates		123
Air-sea gas exchange		92
Total	219	215

Result = 4 more gigatons of carbon are being released into the atmosphere each year than are being stored out of the atmosphere.

Atmospheric Carbon Dioxide Levels

Use the following chart to report the CO2 levels as measured by NASA at the Mauna Loa Observatory in Hawaii, available at https://climate.nasa.gov/vital-signs/carbon-dioxide/.

Date	Level of Carbon Dioxide Reported (ppm CO2)	Change in Level of Carbon from Previous Year (ppm CO2)	Change in Level from Previous Year converted to Gt C (Gigatons of Carbon)*
January 2008			
January 2009			
January 2010			
January 2011			
January 2012			
January 2013			
January 2014			
January 2015			
January 2016			
January 2017			
January 2018			

*1 ppm by volume of atmosphere CO2 = 2.13 Gt C
Source: The Carbon Dioxide Information Analysis Center from the US Department of Energy Berkeley Lab: http://cdiac.ess-dive.lbl.gov/pns/convert.html#3.

How the World Passed a Carbon Threshold and Why It Matters

WORKSHEET

Answer the following questions as you read "How the World Passed a Carbon Threshold and Why It Matters," by Nicola Jones published in YaleEnvironment360 and available at https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters

❶ Based at the current rate of increase, how long will it take for CO2 levels to reach 500 ppm? What other environmental changes are expected because of their correlation to increasing carbon dioxide levels?

❷ What are some of the natural sources contributing CO2 to the environment?

❸ Why do CO2 levels vary during the year?

❹ Millions of year ago, the CO2 levels in the atmosphere were much higher than they are today. What are some of the explanations for why the concentrations decreased?

How the World Passed a Carbon Threshold and Why It Matters

WORKSHEET (CONTINUED)

❺ What type of evidence is used to determine CO_2 levels in the past?

❻ What are some of the variables that make it a challenge to predict future CO_2 levels?

❼ What are the three scenarios the Intergovernmental Panel on Climate Change has predicted for carbon levels and temperature changes in the near future?

Land Management Practices to Increase Soil Carbon

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. Use the chart below to determine if any of these practices can be implemented at your school garden.

Practice	Cost to implement	Time required	Will this change the aesthetics of the garden?	Will this change how we use the garden?	Recommend adopting?
No-till management					
Return crop residue to soil					
Planting cover crops					
Amending the soil with manure and compost					
Crop selection: plant perennials and high residue annual crops					

News Article Evaluation

WORKSHEET

Title of article:
Author:
Publication:
Date published:
Website address (for online articles):

Summary of article:

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 the article quantify in some way the impact soil can have on carbon levels or climate change? If so, what is stated?

Where did the author get his/her data? Did he/she provide information about the source/sources? Are the sources reliable?

Digging into Soil

JOURNAL PAGE

Name:______________________________

Date:_______________________________

Lesson #:___________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 8
The Soil-Water Connection

Summary

What is the relationship between soil and water? Students will learn about the vital role soil plays in the water cycle and its importance in keeping our water supply clean.

Objectives

Students will learn:

- Soil is an important part of the water cycle and helps clean our water supply.

Link to *"S" is for Soil*

What Role Do Soils Play?

Key Terms

Stormwater Runoff: This is rain that falls to the Earth and enters sewers or surface waters without being absorbed into the soil.

Link to Next Generation Science Standards Performance Expectations

HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effect on Earth materials and surface processes.

Time

Laying the Groundwork: 30 minutes
Exploration: 2 hour
Making Connections in the Garden: 4 hours

Materials

- Internet access
- Clear plastic bottles
- Soil samples
- Water
- Food coloring
- Miscellaneous objects to represent pollutants
- Vinegar
- Baking soda
- pH test kit

Quote for Thought and Discussion

"While the farmer holds the title to the land, actually it belongs to all the people because civilization itself rests upon the soil."

— Thomas Jefferson

Background Information

Soil is an important part of the Water Cycle. As precipitation returns evaporated water back to ground level, how and where that precipitation hits and where it travels to next will determine whether it remains a clean resource that is vital to all life on our planet, or, conversely, if it will be exposed to chemicals or other pollutants and become a potential hazard that must be cleaned before it is used. When water hits land's surface, it follows one of two main pathways — either it infiltrates into the soil or it runs off into local streams, lakes, and rivers.

Infiltration of water into the soil provides many benefits. Healthy soil works like a sponge, soaking up water and allowing it be processed slowly into the environment. Some of this water stays in the topsoil to support plant life. Some slowly percolates down through the layers of the soil to recharge groundwater sources such as aquifers.

Soil can also act as a water filter, potentially cleaning out harmful pollutants that were present in the precipitation. Soil helps to clean water through physical, chemical, and biological means. First, pollutants may be removed by getting stuck in the pore spaces within the soil (physical). Pollutant chemicals may also be attracted to other chemicals in the soil and form new bonds that trap them in place rather than allowing them to move down into ground water (chemical). Finally, soil-dwelling microbes such as fungi and bacteria may help to break down pollutants and transform them into new, non-harmful chemicals (biological).

The U.S. Geological Survey Water Science School shares the following list of factors that impact the infiltration of water into the soil:

- **Precipitation:** The amount that falls and how quickly it falls.
- **Base Flow:** How quickly the water moves through the soil.
- **Soil Characteristics:** The components of the soil (the inorganic and organic materials) along with the structure of the soil (especially the amount of pore space) will determine how quickly water can be absorbed. Sandy soils can usually absorb water the fastest, clay the slowest.
- **Soil Saturation:** The amount of water already in the soil influences how much more it can take up.
- **Land Cover:** Vegetation can help slow down the movement of water and give the soil more time to absorb it.
- **Slope:** Water falling on steep surfaces will move faster over land, giving it less time to be absorbed, while water falling on flat surfaces will have more time to infiltrate.

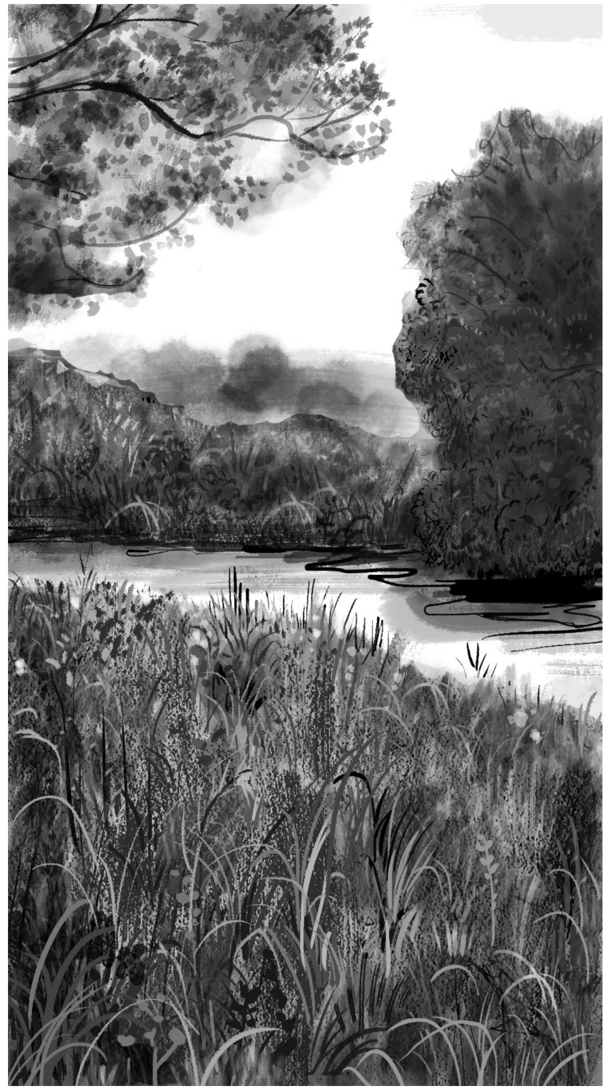
Water that is not absorbed into the soil will drain across the surface as it moves with gravity towards the lowest points and ultimately accumulates in sewers, streams, rivers, lakes, and the ocean. Although stormwater runoff is a natural part of the water cycle, human civilizations have made the journey of water across the land more treacherous.

As water travels across both soil-covered and paved land, it can pick up pollutants that will not have an opportunity to be filtered out before ending up in surface water sources. Although harmful chemicals and litter are most likely what first come to mind when considering pollutants, the soil itself can also be a pollutant. When land is cleared of its vegetation, soil erosion occurs when loose soil is picked up by water runoff and then deposited in streams and rivers. This can cause major problems.

Additionally, as we have developed the land and changed its topography, we have interrupted water's natural pathways and eliminated the areas where temporary excess water could accumulate when needed. Much to our detriment, our actions have led to flooding and the increasing prevalence of contaminated water resources.

There are many ways that we can work with soil to protect our water resources, including:

- Leave green spaces in our community that give rainwater access to soil. Rain gardens, for example, are specifically designed to capture and hold stormwater runoff, giving it time to infiltrate soil.
- Reduce areas of exposed soil by leaving a covering of crop residues, planting cover crops, or mulching.
- Avoid disturbing soil structure by reducing tilling.
- Use irrigation water wisely to decrease demands on both ground and surface water supplies.
- Choose native plants that have little or no need for supplemental irrigation.



For more background information, check out the following sources:

The USGS Water Science School.
https://water.usgs.gov/edu/

"Soils Clean and Capture Water" by Meghan Sindelar, Soil Science Society of America, April 2015.
https://www.soils.org/files/sssa/iys/april-soils-overview.pdf

"Soils Store and Filter Water," Food and Agriculture Organization of the United Nations, 2015 International Year of Soils.
http://www.fao.org/3/a-i4890e.pdf

Laying the Groundwork

Watch the video "Soils Clean and Capture Water" from The Soil Science Society of America, available at https://www.youtube.com/watch?v=ZwQeTJEeedk.

The worksheet at the end of this lesson can help students capture details as they watch. Talk about the important role soil plays in the Water Cycle. Discuss water infiltration and runoff in your schoolyard and/or community. Ask, Where does rain go after it falls? Are there areas that always flood? How clean is our water supply? Does our community have any environmental concerns about our water supply?

Exploration

To explore the role of soil in the Water Cycle, have students set up an experiment that will investigate its filtration abilities by creating models to expose soil to "polluted" water. Instruct them to compare how the soil composition (amount of sand, silt, clay, and organic matter present) impacts results by testing samples of different soil types. Explain that they will need to design a model where water can move through the soil and the runoff can be collected for testing.

Have them consider ways they can determine if "polluted" water that has moved through the soil. For example, they can add materials that they can see to the water, such as food coloring or food particles to represent organic matter. Then they can then look for these materials in the water after it has passed through the soil sample. Or they can add substances like vinegar or baking soda as "pollutants" to the water, allow the water to pass through the soil sample, and then test the water with a pH strip to see if the vinegar or baking soda are still present. There is a worksheet at the end of this lesson that can help students brainstorm experiment ideas.

Here are some resources to spark ideas for designing experiments. Or, you can have students conduct one of these activities as written if time or skill level do not allow for them to design their own:

The Cary Institute of Ecosystem Studies In New York offers a great experiment example in their Hudson River Ecology Unit that students can use for guidance: http://www.caryinstitute.org/educators/teaching-materials/changing-hudson-project/land-use-change/day-4-soil-natural-water-filter (*Make sure to click through all the tabs to see lesson overview, procedure, resources, standards, and credits.)

The U.S.D.A. Natural Resource Conservation Service also has a very simple water filtration experiment: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050949.pdf

Making Connections in the Garden

Introduce your students to the concept of a rain garden. Rain gardens provide a perfect setting to teach about soil infiltration, water quality, habitat creation, and the impact of our actions on protecting our natural resources. A rain garden is a garden planted in a depressed area to encourage water collection. This design enables rain gardens to trap stormwater before it becomes runoff and allows it to slowly be absorbed and filtered by the soil.

The plants in a rain garden must have high tolerance for excess moisture and the increased levels of nutrients often found in stormwater. Rain gardens are most useful if situated downhill from impervious surfaces, such as rooftops and roads, and are designed to collect runoff from those surfaces. They slow down the flow of stormwater by collecting it in the sunken garden area and allowing it to absorb into the soil, rather than causing erosion and carrying pollutants into nearby waterways.

As you have learned in this lesson, in suburban and urban settings much of the rain that falls hits impervious surfaces, such as roofs, parking lots, and roads, where it cannot be absorbed. It becomes runoff, moving across the ground to areas where it can be absorbed or into local waterways, either directly or via storm sewers. In urban settings as little as 15% of the water may be absorbed where it falls and up to 55% will run off. This reduces the replenishment of groundwater reserves, which endangers drinking water supplies and can ultimately cause cities to sink (subsidence). It also creates a significant amount of water to deal with above ground. To prevent urban flooding, cities install drainage systems to move stormwater to municipal water treatment facilities or to streams, lakes, and rivers.

Although rain is an important contributor for recharging local waterways, the problem with runoff from urban environments is what the runoff is carrying. As the water moves across surfaces such as streets, parking lots, and roofs, it picks up all sorts of pollutants, from nutrients like nitrogen and phosphorous that fuel algal blooms to pesticides, herbicides, oil, grease, heavy metals, and harmful bacteria. These pollutants can kill aquatic life and interfere with the delicate balance of aquatic ecosystems. Scientists estimate that 70% of the pollution in streams, rivers and lakes is from stormwater runoff.

To decrease the amount of runoff flowing directly into local waterways, some of it may be diverted into treatment facilities to remove the contaminants. It is then deposited into waterways or used for drinking supplies. However, it is not feasible for treatment facilities to catch and process all stormwater. Rain gardens are another solution.

Rain gardens help catch storm runoff and then aid in absorption and filtration of the water. Benefits of installing rain gardens include:

- decreased amounts of polluted stormwater runoff reaching local streams, rivers, and lakes.
- increased absorption of water to recharge groundwater supplies.
- filtration of pollutants by soil and plants, which helps improve water quality in groundwater supplies.
- installation that is less expensive than other drainage techniques.
- an attractive addition to your landscape and a low-maintenance alternative to lawns.
- creation of a habitat for birds and butterflies.

Investigate your school's need for a rain garden. Visit your schoolyard right after a rain and create a map showing areas of flowing and standing water. Return after an hour and document and compare your findings. Repeat after two hours. Ask, How well does our schoolyard manage rainwater? Are there any areas that need help?

In order to capture rainwater, the garden must be planted downslope from buildings and other surfaces that increase stormwater run-off, but upslope from municipal storm drains and natural waterways. The garden must also be located at least 10 feet away from a building foundation and should not be placed over a septic system. Also, avoid locations under mature trees, because the digging of the garden could cause serious damage to their root systems.

If you find a good spot, walk your students through the design process and then have them come up with their own rain garden design for the area. KidsGardening offers a planning worksheet at https://kidsgardening.org/wp-content/uploads/2016/11/Rain_Garden-9_12.pdf to help. The planning process is a valuable lesson, but if time and resources are available, continue to pursue plans to install a rain garden at your school. In addition to the environmental benefits it will provide, it can serve as a valuable learning tool for your students and for the community.

Extension

Introduce students to the concept of a watershed. A watershed is a defined area of land where all streams and rainfall accumulate in a common place. The U.S. Geological Survey offers a website called "Science in Your Watershed" at https://water.usgs.gov/wsc/. From this site, you can locate your local watershed (select "Locate Your Watershed" from menu bar on the left side of webpage) and explore links to additional information, as well as a compilation of projects and publications that are specific to your area. As a class or through group or individual projects, use this website to find your local watershed and create a map for your classroom.

If you would like to find out more about regional watershed projects, you can visit the USGS regions page and click through to your state's page: https://www.usgs.gov/science/regions.

Because water systems are so vital to the local environment, there are many local nonprofit and community organizations groups that are focused on watershed monitoring and preservation efforts. If possible, invite a member of a local watershed association to your class to share information about their watershed programs.

Another great resource to help you dig deeper into the soil–water connection is The Soil Carbon Coalition, a nonprofit organization whose efforts are focused on increasing the carbon- and water-holding capacities of soil. Their informative guide *Understanding Soil Health and Watershed Function: A Teacher's Manual* is available at https://www.didipershouse.com/understanding-soil-health-and-watershed-function.html. It offers a wide variety of lessons focused on soil's role in the water cycle.

They have also developed a companion titled *Field Methods for Monitoring Soil Health and Watershed Function*, available at https://soilcarboncoalition.org/learning/fieldmethods.pdf, that provides very specific instructions on how to collect data for soil explorations. In addition to these resources, they are also constructing an online network to help collect data from observations about soil health and watershed function from around the globe at atlasbiowork.com. If starting a watershed and soil health monitoring program is of interest to you, check out The Soil Coalition's main webpage, https://soilcarboncoalition.org/, for more details.

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"Soils Store and Filter Water," Food and Agriculture Organization of the United Nations, 2015 International Year of Soils http://www.fao.org/3/a-i4890e.pdf

"April: Soils Clean and Capture Water" from The Soil Science Society of America, 29 March 2015. https://www.youtube.com/watch?v=ZwQeTJEeedk

"Soil: The Natural Water Filter." The Cary Institute of Ecosystem Studies Hudson River Ecology Unit. http://www.caryinstitute.org/educators/teaching-materials/changing-hudson-project/land-use-change/day-4-soil-natural-water-filter

"Filtration" The U.S.D.A. Natural Resources Conservation Service, Soil Quality Fact Sheet. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050949.pdf

Rain Garden Planning Worksheet from KidsGardening.org. https://kidsgardening.org/wp-content/uploads/2016/11/Rain_Garden-9_12.pdf

"Science in Your Watershed" by the United States Geological Survey. https://water.usgs.gov/wsc/

Pershouse, Didi. *Understanding Soil Health and Watershed Function, A Teacher's Manual.* The Soil Carbon Coalition: the U.S.D.A Natural Resources Conservation Service, the U.S.D.A Southern Plains Climate Hub, The Soil Carbon Coalition, Redlands Community College, The Dixon Water Foundation, 2017. https://www.didipershouse.com/understanding-soil-health-and-watershed-function.html.

Pershouse, Didi and Peter Donovan. Field Methods for Monitoring Soil Health and Watershed Function. The Soil Carbon Coalition. May 2017. https://soilcarboncoalition.org/learning/fieldmethods.pdf

Soils Clean and Capture Water

WORKSHEET

Answer the following questions as you watch the video "Soils Clean and Capture Water" from The Soil Science Society of America: https://www.youtube.com/watch?v=ZwQeTJEeedk

❶ How clean is rainwater?

❷ What two things can happen to rain when it hits land?

❸ What can happen to water that flows over the ground?

❹ How do urban areas manage storm water drainage?

❺ What are three ways soil cleans water?

Soils Clean and Capture Water

WORKSHEET (CONTINUED)

❻ What type of soil is the best water filter?

❼ Does water have a negative or positive charge? How does that help with water filtration?

❽ Soil microorganisms such as bacteria and fungi have the ability to turn chemicals that would be harmful in our water supply into what three compounds that can be safely released into our atmosphere and water systems?

Design a Water Filtration Experiment

WORKSHEET

Use the following worksheet to help you design an experiment to test the filtration abilities of soil.

Objective of the Experiment: Through this experiment you want to determine how well soil filters water and/or whether soil composition impacts the filtering process.

❶ Make a list of the questions that you could investigate related to the filtering abilities of soil. For example, How well does soil filter out different kinds of pollutants? Does soil composition change how well soil filters out pollutants?

❷ Choose one of the questions above as the focus of your experiment and write a hypothesis of what you expect to find.

❸ Create a model using readily available supplies that allows you to move water through soil, simulating rain and/or stormwater runoff, and to collect the resulting solution.

❹ What is the independent variable in your experiment? What input or treatment are you going to change to see if you arrive at different results (for example, types of soil or types of pollutants)?

Design a Water Filtration Experiment

WORKSHEET (CONTINUED)

❺ What is the dependent variable? What are you going to collect, measure, and evaluate to see if your treatments cause different results?

❻ If you are going to test whether the type of soil makes a difference in filtration, what types of soil will you use? (Ideas: loamy soil, sand, sandy soil, clay soil.)

❼ If you are going to test how well soil filters out different types of pollutants from water, what kind of pollutants can you use so that you can determine if they are present in the water that drains from the soil? (Ideas: food coloring, raisins, vinegar, baking soda.)

❽ What inputs will you need to keep constant to make sure you are not impacting the end result?

❾ How will you measure the results? Create a chart to collect your data.

❿ Create a title for your experiment.

Digging into Soil

JOURNAL PAGE

Name:______________________________

Date:_______________________________

Lesson #:____________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 9
Leaving Our Mark on Soils

Summary

How have humans impacted soils? Students will explore how human actions alter soil and investigate some of the negative impacts of human activity. They will also learn about ways we can remediate damaged soils and rebuild new soils.

Objectives

Students will learn:

- Throughout history, humans have not always considered how their actions impact local soils, resulting in damage to soil systems.
- Human actions can have significant impacts on soil health.

Link to *"S" is for Soil*

How Have Humans Impacted Soils?

Key Terms

Soil Salinization: This is the building up of excess salts in soils to the point that plants struggle to survive.

Superfund Sites: These are locations in the United States that have been deemed environmentally hazardous and are slated for cleanup.

Phytoremediation: This is the use of plants to remove contaminants from the soil.

Link to Next Generation Science Standards Performance Expectations

HS- ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

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 cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Time

Laying the Groundwork: 30 minutes
Exploration: 3 hours
Making Connections in the Garden: 1 hour

Materials

- Internet access
- Soil test for heavy metals

Quote for Thought and Discussion

"The nation that destroys its soil, destroys itself."

— Franklin Delano Roosevelt

Background Information

As a species that is dependent on soil for our survival, our track record of taking care of this life-giving resource is more negative than positive. From the Ancient Sumerians, whose irrigation usage resulted in the salinization of the fertile lands of Mesopotamia, to the Dust Bowl of the 1930s in the American Midwest, we have continuously cultivated the land with only our most immediate needs and economic gains in mind, rather than with the long-term vision of maintaining healthy soil. In some cases, we've learned from our mistakes in time to make amends. In other cases, the soil becomes so degraded that the land enters a state of desertification, and returning it to its original state becomes a very distant dream.

The Food and Agriculture Organization of the United Nations declared 2015 the International Year of Soils to bring into focus the global challenges facing soil. As part of this effort, they published report called the "Status of the World's Soil Resources." The full document can be downloaded at http://www.fao.org/3/a-i5199e.pdf

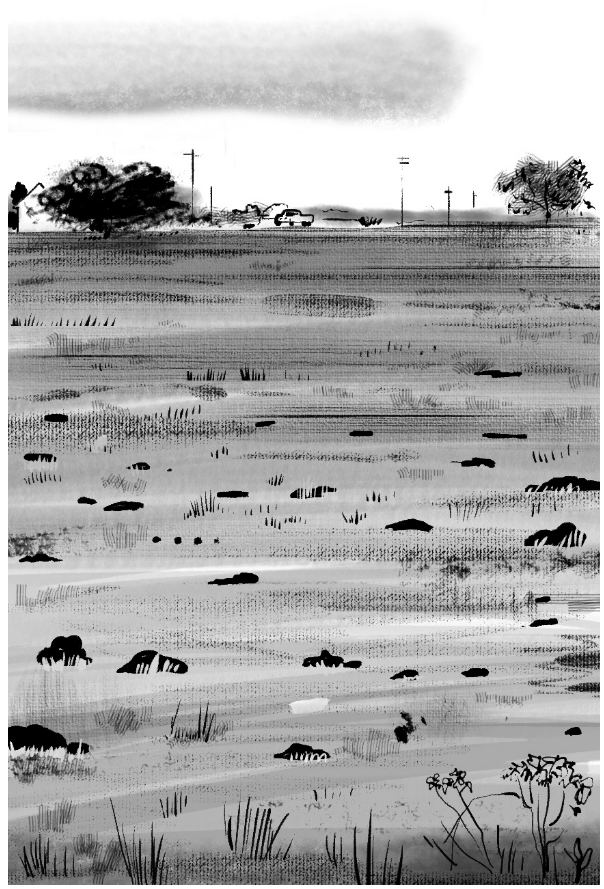
A summary of the report can be found at http://www.fao.org/3/a-i5126e.pdf

The report focuses on what they consider to be the top 10 threats to soil function on a global scale. (This list is located on pp. 2–4 in the summary of the report.) These threats are:

- Nutrient imbalance (too much or too little)
- Soil acidification (lowering of soil pH)
- Soil biodiversity loss (decrease in diversity of organisms living in the soil)
- Soil compaction
- Soil contamination
- Soil erosion
- Soil organic carbon loss
- Soil salinization
- Soil sealing (covering land with impermeable, artificial material)
- Soil waterlogging

These soil concerns are present in countries all over the world, providing opportunities for countries to act together to solve them. Unfortunately, as the world population grows, the development of land will continue to increase, as will our food and water needs. With each generation, we ask our soils to be even more productive (in terms of food production, carbon sequestering, water filtering, etc.) in a more limited space.

To continue at our current rate of growth, we will need to expand our efforts to preserve soil resources and use them wisely. In addition, we need to find ways to rehabilitate soil that has been damaged.



Laying the Groundwork

Share the following Frank and Ernest Cartoons and discuss as a class:

Frank and Ernest, 8 Aug 2008. http://www.cartoonistgroup.com/store/add.php?iid=7949

Frank and Ernest, 18 June 1994. http://www.cartoonistgroup.com/store/add.php?iid=68039

Ask students to brainstorm a list of some of the ways humans negatively impact the environment, and especially soil? Share the list of the top ten threats to soil function published by the U.N. Are these impacts out of necessity for survival or are they about convenience or desirability for a certain lifestyle? Are they the result of intentional destruction or more unintentional consequences of not understanding how our actions will impact nature? Do you think we can move towards societies that live in harmony with our environment?

Exploration

The Environmental Protection Agency's Superfund Program (https://www.epa.gov/superfund) is responsible for cleaning up the nation's most contaminated land and responding to environmental emergencies and natural disasters. With the goal of protecting public health and the environment, the program includes many sites with damaged soil.

On the main Superfund website, you can search for sites in your area (scroll down the page and under the heading "Learn About Superfund" click on "Sites Where You Live"). A map of all sites is also available at https://www.epa.gov/cleanups/cleanups-my-community. Are there any locations in your community that are targeted for clean up? How was the soil impacted? Why did the damage occur?

There is usually a complex set of factors impacting each Superfund site, both in how the problem was created and how to clean it up. For example, businesses that polluted were also sources of employment for people and provided financial resources for communities. Some of the techniques or chemicals that proved to be hazardous were developed to try and meet a need for a product in the economy. Land that was used for industrial purposes was converted to residential housing without the knowledge of its prior use being passed along to the new residents.

Cleaning up the sites can also be complex. Where do the displaced business and residents go? If you remove contaminated water and soil, what do you do with it? Will its new storage location create the same problems for new communities nearby? You can use the worksheet at the end of this lesson to encourage students to dig deeper into the background of an example Superfund site location.

If you cannot locate any local stories to help bring the issues to life, you may want to use these articles/news stories to discuss the complexity of the issues:

"It's a Superfund Site, but It's Also Their Livelihood" by Vivian Wang: https://www.nytimes.com/2017/08/04/nyregion/queens-epa-superfund-radiation-businesses.html

"Their Soil Toxic, 1,100 Indiana Residents Scramble to Find New Homes" by Abby Goodnough: https://www.nytimes.com/2016/08/31/us/lead-contamination-public-housing-east-chicago-indiana.html

This same neighborhood was featured in a video from PBS titled "In East Chicago, Fallout from Toxic Soil Runs Deep": http://www.pbs.org/video/chicago-tonight-east-chicago-fallout-toxic-soil-runs-deep/

Follow up your discussion of the issues by reviewing the process the EPA goes through to clean up each site, available at https://www.epa.gov/superfund/superfund-cleanup-process. The steps include:

- Preliminary Assessment/Site Investigation
- National Priorities List Site Listing Process
- Remedial Investigation/Feasibility Study
- Records of Decision
- Remedial Design/Remedial Action
- Construction Completion
- Post Construction Completion
- National Priorities List Deletion
- Site Reuse/Redevelopment

Ask students to evaluate the process. Does it seem reasonable? Are there any steps you would add in or take away to make it more efficient? You can use the Superfund Cleanup Process Worksheet at the end of this lesson to help with the evaluation.

Enough talk about the problems; move your discussion to the solutions. In your search of the Superfund sites you will most likely find many examples of the removal of contaminated soil. Do you think this is a good solution? Why or why not?

The EPA has more information about cleaning up contaminants on their Contaminated Site Clean-Up Information webpage: https://clu-in.org/. On this page you can learn about technologies being used and developed for remediation. So the good news is that scientists are indeed looking for ways to actually clean contaminated soil, rather than just moving it to a new location where it is likely to become a problem at a later date.

One of the solutions they are studying is the use of plants to remove contaminants from the soil. This technology is called phytoremediation. It can work in a number of different ways. In some cases, harmful chemicals are removed from the soil and "trapped" in plants, and then the plants are disposed of (still producing a waste product, but the soil is clean). In other situations, the harmful chemicals are absorbed by the plants and released in vapor form into the atmosphere (still transferring the chemicals into the environment). Sometimes, chemicals are absorbed by the plant and then transformed into new, less harmful chemicals (a much better result).

Newer studies are looking at how plants and microbial activity in the soil actually work together to transform harmful chemicals into new, benign chemicals in the root zone — a true cleaning up of the problem. The type of technology available depends on factors such as the size of the site, the location of the contaminants in the soil (shallow versus deep), and the actual chemical involved. Have students read the EPA's Citizen's Guide to Phytoremediation at https://clu-in.org/download/Citizens/a_citizens_guide_to_phytoremediation.pdf. A worksheet is available at the end of this lesson to help guide them as they read.

Create a class list of the benefits and challenges of phytoremediation technologies. Look at factors such as cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Ask students to find examples of phytoremediation being used in the field. They can fill out the Photoremediation Worksheet at the end of this lesson to compile their results. Here are a few links to get them started:
"Super Trees Clean up Superfund Sites" by Dava Sobel. 26 December 2008. Discover Magazine, http://discovermagazine.com/2009/jan/26-worker-trees-clean-contaminated-water

"Probiotics help poplar trees clean up Superfund sites," http://www.washington.edu/news/2017/08/14/probiotics-help-poplar-trees-clean-up-toxins-in-superfund-sites/ University of Washington News. 14 August 2017

The EPA also has a video on one of their phytoremediation projects "Crozet, VA Phytoremediation Project": https://www.youtube.com/watch?v=IabslL-SgqY

Conclude your investigation of phytoremediation by compiling a class list of the different types of plants ("Environmental Superstars") being used for this soil-cleaning solution.

Making Connections in the Garden

To help prepare youth for gardening at home in the future, teach them about one of the most common soil contamination problems in gardens — lead. Lead is a heavy metal that has entered the soil in a variety of ways, including through paint residues (lead-based paints for housing were banned in 1978), pesticides, and car exhaust from the days of leaded gasoline. Most recently, concerns have arisen about lead in public water supplies due to corroding pipes. Although the use of lead in common products is now restricted, once it is in the soil it can stay there for a very long time. Although this type of contamination is often associated with urban soils, it's also possible for soils in suburban and rural area to be contaminated by lead.

The main route of exposure to lead in the garden is through inadvertent direct ingestion of the contaminated soil and dust that gardeners and plants come into contact with. While plants grown on soil that is high in lead may take up some through their roots and store it in their leaves and fruits, most of the risk comes from ingesting the lead-contaminated soil or dust deposits on the plants, rather than from actual uptake of lead by the plants themselves. Similarly, contaminated soil can be ingested via dirt and dust on hands.

While it's typically considered safe to eat fruits and vegetables grown in soils with lead levels up to 300 ppm, a level found in many urban soils, this standard applies only where soil exposure to youth is not a concern. Where soil ingestion can occur, as with youth who may touch their mouths or food with dirty hands, soil with lead levels greater than 100 ppm should not be used for edible gardening.

Test your school garden soil for lead. If the soil test determines areas at your site have lead levels above 100 ppm, be sure to seek out expert advice from your local Cooperative Extension Service or Health Department on the safest strategies before beginning to garden. Do NOT grow edibles in the ground. You may still be able to garden safely by laying heavy-duty landscape fabric over the ground and pathways and mulching thickly to keep gardeners from easily coming into contact with the soil. Then construct raised beds at least 18 inches tall and fill them with fresh, uncontaminated soil.

Even if your site is technically deemed “safe” but has somewhat elevated lead levels, it’s a good idea for school gardeners to take measures to reduce exposure to soil-borne lead, including:

- Add plenty of organic matter to the soil (helps to lessen plant uptake of lead).
- Maintain soil pH around 6.5 (helps to lessen plant uptake of lead).
- Do not eat dirt or unwashed vegetables.
- Make sure everyone working in the garden washes their hands immediately after gardening and before meals.
- Grow fruiting crops, such as tomatoes, peppers, beans, and okra, rather than root crops and leafy vegetables or herbs. Studies have shown that lead does not readily accumulate in the fruiting parts of vegetable and fruit crops, but accumulates more in leafy vegetables like lettuce and root crops like carrots.
- Peel root crops and remove the outer leaves of leafy crops before eating.
- Clean produce thoroughly before eating or storing to remove as much contaminated dust and dirt as possible.

If you are not growing edibles, you may still be able to plant a garden if you take steps to limit students’ direct contact with lead contaminated soil and dust by putting down landscape fabric and topping it with mulch. Soils with lead levels that are not suitable for veggies and fruits may still grow great shade trees, flowering shrubs, and cut flowers, as long as adults taking proper precautions and do the planting and working of the soil. Risk varies with the level of contamination, so if your soil test reveals lead levels in excess of 100 ppm, be sure consult with your local Extension Service and Health Department for advice. Also make sure knowledge about the contamination is passed down to the new garden coordinators each year so that later on, your ornamentals are not replaced with edibles.

Extension

As seen by exploring the SuperFund sites, decisions made by industry to maximize profits can lead to negative impacts on natural resources. In our capitalist society, businesses run on the basic principal of supply and demand, and they strive the to reduce costs of inputs in order to maximize their overall profits. Unfortunately, the value placed on natural resources is often based only on their immediate use and assumes the supply is unlimited. This shortsighted view can lead to placing an inaccurate cost or sometimes no cost at all on the natural resource.

The following quote from David Montgomery in his book *Dirt: The Erosion of Civilizations* can serve as a good springboard for class discussion:

“There are plenty of reasons to argue for smaller, more efficient government; market efficiencies can be effective drivers for most social institutions. Agriculture is not one of them. Sustaining our collective well-being requires prioritizing society’s long-term interest in soil stewardship; it is an issue of fundamental importance to our civilization. We simply cannot afford to view agriculture as just another business because the economic benefits of soil conservation can be harvested only after decades of stewardship, and the cost of soil abuse is borne by all."

Additionally, use the following editorial cartoons to discuss the responsibilities of businesses for their negative impact on the soil:

Nick Anderson's Editorial Cartoons, 2 Feb 2002, http://www.fao.org/3/a-i5199e.pdf

Nick Anderson's Editorial Cartoons, 13 Aug 2015, http://www.fao.org/3/a-i5126e.pdf

Extend your discussion by holding class debates related to ownership of land and our natural resources. Here are a few ideas for debate topics:

"Should government be able to regulate the use of all land?"

"Who should pay to clean up contaminated soil and water resources?"

"Does property ownership include both the surface and what exists beneath the ground?"

References

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and
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"In East Chicago, Fallout from Toxic Soil Runs Deep" PBS video.
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"Phytoremediation: An Environmentally Sound Technology for Pollution Prevention, Control and Remediation: An Introductory Guide to Decision-Makers," United Nations Environment Program. http://www.unep.or.jp/Ietc/Publications/Freshwater/FMS2/1.asp

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"Citizen's Guide to Phytoremediation," The Environmental Protection Agency.
https://clu-in.org/download/Citizens/a_citizens_guide_to_phytoremediation.pdf
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26 December 2008. http://discovermagazine.com/2009/jan/26-worker-trees-clean-contaminated-water

"Probiotics help poplar trees clean up

Superfund sites" by Michelle Ma. University of Washington News, 14 August 2017. http://www.washington.edu/news/2017/08/14/probiotics-help-poplar-trees-clean-up-toxins-in-superfund-sites/

"Crozet, VA Phytoremediation Project" by the US Environmental Protection Agency, https://www.youtube.com/watch?v=IabslL-SgqY

"Plan for a Safe and Successful Edible Garden" KidsGardening.org. https://kidsgardening.org/designing-a-school-garden-plan-for-a-safe-and-successful-edible-garden/

Montgomery, David. *Dirt: The Erosion of Civilizations*. University of California Press. Berkeley: 2007.

Nick Anderson's Editorial Cartoons, 2 Feb 2002. http://www.cartoonistgroup.com/store/add.php?iid=4931

Nick Anderson's Editorial Cartoons, 13 Aug 2015 http://www.cartoonistgroup.com/store/add.php?iid=131148

Superfund Site

WORKSHEET

Use this worksheet to evaluate the complex factors surrounding the identification and cleanup of a Superfund Site. Locate a Superfund Site from the National Priorities List to investigate at https://www.epa.gov/superfund/search-superfund-sites-where-you-live. Then complete the following information using the provided background information.

Site Name:
City
State:
County:

Why was this site designated a Superfund Site:

Was this site a place of business? If so, what happened to the business?

Are there residential areas adjacent to the site?

What are the risks at this site?

Has cleanup started? If so, what was done?

If contaminants were removed, where did they go?

Continue your research by conducing an Internet search for additional media and resources related to this Superfund Site.

Evaluating the Superfund Site Clean Up Process

Answer the following questions about the Superfund Cleanup process as you read https://www.epa.gov/superfund/superfund-cleanup-process.

In your own words, provide a short summary about each step of the Cleanup process:

❶ Preliminary Assessment/Site Investigation

❷ National Priorities List Site Listing Process

❸ Remedial Investigation/Feasibility Study

❹ Records of Decision

Evaluating the Superfund Site Clean Up Process (continued)

❺ Remedial Design/Remedial Action

❻ Construction Completion

❼ Post Construction Completion

❽ National Priorities List Deletion

❾ Site Reuse/Redevelopment

Now that you understand the process, answer the following questions:

❶ What are your overall impressions of the Superfund Cleanup process?

❷ Do you think this process provides a way to quickly identify and contain hazardous conditions?

❸ Did you find any examples where it seemed like there was duplication of efforts or repetition of activities? Are there any steps that you think could be removed or combined to make it more efficient?

❹ Do you think this process provides adequate opportunities to inform and involve the local community?

❺ Does knowing this process exists make you feel safer?

❻ Do you think this is an expensive process? Where do you think the funds should come from to remediate the Superfund sites?

A Citizen's Guide to Phytoremediation

Answer the following questions as you read the EPA's A "Citizen's Guide to Phytoremediation": https://clu-in.org/download/Citizens/a_citizens_guide_to_phytoremediation.pdf

❶ What is phytoremediation?

❷ What are the 4 different ways that plants can help clean up contaminants?

❸ Can all plants be used for phytoremediation?

❹ What factors influence the time it takes for phytoremediation to work?

❺ What are some of the benefits of using phytoremediation?

Phytoremediation

WORKSHEET

Use this worksheet to compile a list of real life examples where phytoremediation is being used to clean up contaminated sites.

#	Article Title, Author and Publication Name	Date Published	Web Address	Location of Site
1				
2				
3				
4				
5				

Phytoremediation

WORKSHEET (CONTINUED)

#	Plants Used	Contaminants Impacting Site	Were Contaminants Contained, Removed, Transformed, or Other	Effectiveness of Treatment	Comments
1					
2					
3					
4					
5					

Digging into Soil

JOURNAL PAGE

Name:________________________________

Date:_________________________________

Lesson #:______________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:
Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).

LESSON 10
Save our Soil

Summary

How can humans protect existing healthy soils? How can humans improve soils? In this lesson, students will both learn about and find ways to share knowledge of how to protect this important natural resource.

Objectives

Students will learn:

- Spreading knowledge about soil is an important tool for protecting existing healthy soils.
- Soil experts are trying to improve soil throughout the world in a variety of ways.
- Think globally, but act locally, by finding ways to impact your local soil through a remediation project or educational outreach program.

Link to *"S" is for Soil*

- What is The Relationship Between Soils and The Earth's Atmosphere?
- What is Required to Keep Soils Healthy?
- Trillions of Soil Microbes Are Now Out of Work
- What Can We Do to Improve Soils? (and Address Climate Change)
- Follow the Leadership Provided by Soil Microbes and Soil Fungi
- What Can I Do to Have the Quickest Greatest Benefit to Help the Earth's Soil Again Become Healthy?
- Not All Ranching Is the Same
- Not All Farming Is the Same
- Whole System Thinking – Soils Can Recover with Simple Solutions!
- Healthy Soils Will Save Us
- Farmer and Rancher Well – Being
- Food Quality
- The Time Is Now to Recover a Healthy Planet
- How Do We Know If We Are Failing to Recover the Planet?
- How Can You Help Recover the Planet?

Key Terms

Healthy soil: Soil that is well balanced in nutrients and alive with large populations of microorganisms is considered healthy.

Biodiversity: This is defined as the presence of a large number of different types of life in an ecosystem.

Link to Next Generation Science Standards Performance Expectations

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

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.

Time

Laying the Groundwork: 15 minutes
Exploration: 2+ weeks
Making Connections in the Garden: 1 hour

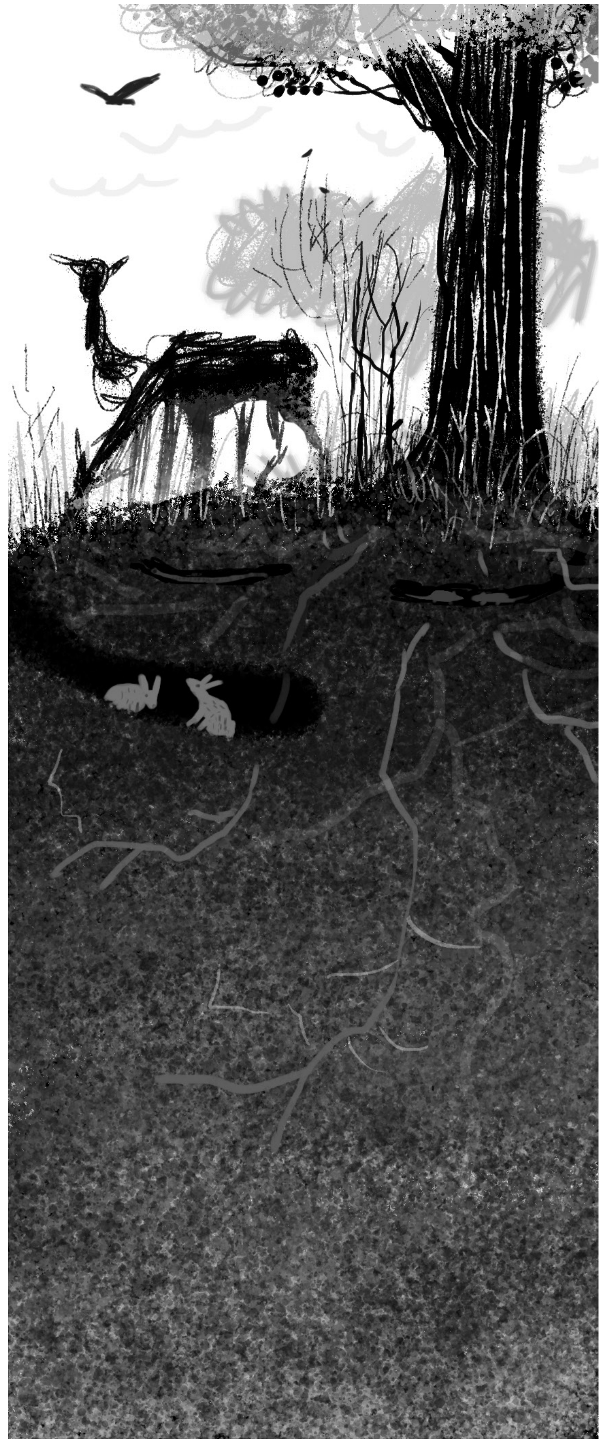
Materials

• Internet access
• Will depend based on project selected

Quote for Thought and Discussion

"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."

- Aldo Leopold
1949. A Sand County Almanac



Background Information

Healthy soils are absolutely critical for all life on Earth. Unfortunately, since humans transitioned from their original hunter/gatherer lifestyles into an agriculturally based society, we have been disrupting the natural cycles within the soil for our own gain. This has led to negative impacts that have been detrimental to the entire planet. What can we do to stop our abuse of the soil and protect the soil that remains? How can we go a step beyond that and actually improve soil health and bring back its natural balance?

First and foremost, we must understand that our actions have an impact, and we must believe that we can make a difference. This provides the motivation to make changes to our current methods and to develop and adopt new technologies focused on building healthy soil. *"S" is for Soil* offers many practical action steps for stopping the destruction of our soils and returning soil back to better health, including:

- Educate all people around the globe about their role in protecting the Earth. Every single person needs to feel a responsibility for taking care of the soil and other natural resources. We need to teach everyone to appreciate the role of soil in a healthy ecosystem.
- Encourage farmers to rebuild soils by reducing and eliminating tilling; adopting the use of biotic and organic fertilizers that encourage life in the soil; avoiding the use of chemical fertilizers, herbicides, and pesticides that kill soil organisms; decreasing compaction of soil; and using cover crops to prevent erosion.
- On non-agricultural land, minimize disruption of the soils and strive to maintain soil in its natural state. For example, avoid draining wetlands or trying to forest native grasslands. Replant eroded soils in native vegetation.
- Buy products from farmers and other companies that are using practices that protect soil resources.
- In urban areas, replace lawns with vegetable and perennial gardens. Just like farmers, avoid using chemical fertilizers, herbicides, and pesticides that negatively impact soil life. Use vegetation and mulch to prevent erosion.
- Recycle organic "wastes." These valuable resources truly do become waste when they end up in landfills.
- Encourage biodiversity above and below ground. Diverse plant and animal life is a sign of a system in balance. More diversity makes for a stronger and more resilient ecosystem.
- Clean up contaminated soils and waters and work to prevent further damage.
- Monitor soil through regular soil testing to keep track of soil health. Early detection of problems will allow communities to find solutions to remedy the problems before they become environmental disasters.
- Contact your government representatives and ask them to support policies that encourage healthy soils, water and other environmentally friendly practices

The facts are clear — if we do not work to protect our soil, we will not be able to maintain life as we know it. Our current practices are quickly reducing the amount of healthy soil available as we decrease soil life and destroy soil structure. Soil conditions are contributing to global warming, which is increasing the intensity of our weather and leading to rising sea levels that are swallowing up coastal lands. As the human population grows, it won't be long before our food and water supplies are not enough to provide for everyone, leading to the collapse of societies around the globe. The time to get moving on solutions to save our soil is now.

Laying the Groundwork

Watch "The Compost Story" video from https://kisstheground.com/. Kiss the Ground is a nonprofit organization focused on promoting the important role soil and composting can play in improving our environment and decreasing the impact of global climate change. Through educational efforts, they want to increase the use of composting to improve soil and decrease waste.

Use the worksheet at the end of this lesson to gather information from the video while viewing. Ask students to evaluate the Kiss the Ground website and videos. How well do you think their message comes across? Do you feel like you have a better understanding of soil and compost? What audience do you think they are trying to reach? Do you want to start composting after watching them? Have they won you over? Are you ready to "kiss the ground"?

Exploration

The Food and Agriculture Organization of the United Nations recognizes soil stewardship as an issue of great global importance. Their Global Soil Partnership (http://www.fao.org/global-soil-partnership/en/) has adopted five pillars of action to help direct their energies towards responsible management of this natural resource:

PILLAR 1: Soil Management – Promote sustainable management of soil resources for soil protection, conservation and sustainable productivity.

PILLAR 2: Awareness Raising – Encourage investment, technical cooperation, policy, education, awareness, and extension in soil.

PILLAR 3: Research – Promote targeted soil research and development focusing on identified gaps, priorities, and synergies with related productive, environmental, and social development actions.

PILLAR 4: Information and Data – Enhance the quantity and quality of soil data and information: data collection (generation), analysis, validation, reporting, monitoring, and integration with other disciplines.

PILLAR 5: Harmonization – Harmonization of methods, measurements, and indicators for the sustainable management and protection of soil resources.

Have students read the article "Soils Are Endangered, but the Degradation Can Be Rolled Back" published by the Food and Agriculture Organization of the United Nations in December of 2015 and available at http://www.fao.org/news/story/en/item/357059/icode/.

Use the "Soils are Endangered" Worksheet at the end of this lesson to gather the facts presented. Create a list of the evidence the U.N. provides to support their position that the state of our soil is a global problem. What are some of the solutions they propose? Analyze these solutions and talk about what some of the challenges and constraints they may face in implementation.

Tell your students that now it is their turn to come up with a solution to help save our soil. As a culminating activity of this soil exploration, ask the class to brainstorm ways that they could have an impact on the soil in your local community. Break the class into small groups (this project could also be done as individual assignment or as a full class project, if preferred) to develop a project proposal that should include:

- An overview of the problem

- A proposed solution to the problem
- Evidence supporting the use of their solution
- Action steps and supplies needed to implement (including budget)
- A list of results they hope to achieve
- Description of how they will evaluate the success of the project

You can make copies of the Digging into Soil Final Project to serve as a guide for project development.

They can consider some of the pillars of action that were developed by the U.N. as inspiration. Also, although allowing students the freedom to be innovative and creative is best, if they need some examples to get them started you can propose these ideas:

- Create an educational outreach program for youth or adults in your community to expand their knowledge about the importance of soil and promote the use of best soil management practices in home landscapes.
- Build a rain garden or work with a native plant restoration project in an area that has been damaged from development.
- Work with a local soil conservation project or with a local water quality monitoring group to collect data about your community's natural resources.
- Discover local business and farms that are working to help the environment, and help promote their work and bring them consumer support.
- Find out about pending legislation that would impact soils, and start a letter-writing campaign to the appropriate local, state, or national government leaders urging them to support environmentally friendly policies.
- Develop a citizen science project that will help collect data to monitor local soil and water conditions.

Once proposals are written, try to put one or more of them into action, giving students the knowledge that they have made a difference and the understanding that there is power in the decisions they make in the future.

Making Connections in the Garden

Evaluate all of your current school garden practices, including soil preparation, plant selection, planting techniques, watering and weeding practices, nutrient and pest management practices, and garden clean up techniques to determine if you are using the most environmentally and soil-friendly practices available.

Begin by creating a list of garden management practices that your young gardeners have discovered, either through experience or research, that promote optimum soil health. These may include:

- testing soil to understand existing nutrient content and pH. Make sure to only amend as needed to correct deficiencies.
- using organic fertilizers and compost to improve soil nutrient content and soil structure.
- conducting soil organism inventories and tests for microorganism activity, if possible, to better understand the health of your soil.
- testing for contaminants such as lead to make sure your soil is safe for your use.
- decreasing disturbance of soil by avoiding tilling. Instead of pulling dead plants from the ground at the end of the season, cut them off at the soil line and leave the roots in the ground (although make sure to remove full plants if you suspect disease problems).
- mulching or planting cover crops between gardening seasons.

- watering wisely to keep soil moisture at optimum levels.
- choosing to grow plants well adapted to your climate and soil conditions.

Ask students to brainstorm any additional practices specific to your site. Next, evaluate each practice and determine if you have already implemented it or not. If it is not a current practice, determine whether it is feasible for your school garden program to implement. You can use the checklist at the end of this lesson to help with this activity. From this information, create your own School Garden Soil Health Management Policy document to guide your future actions and to keep your garden soil healthy and in top shape.

If time and space allow, students could use their new knowledge of soil health to conduct experiments in your school garden. Some options for exploration include:

- growing the same plants in different types of soil.
- using different types of fertilizers and organic matter in garden beds.
- using cover crops in some beds but not others.
- using different types of mulch to protect soil.

Your experimental beds could be used for student learning and could also serve as demonstration plots for your community.

Extension

Just like the U.N., the U.S.D.A Natural Resources Conservation Service is also working hard to increase public awareness about the importance of soil and our role in protecting our soil resources. Check out videos from the U.S.D.A Natural Resources Conservation Service's "Unlock the Secrets in the Soil" Campaign: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=stelprdb1245890

Have students vote on their favorite. Why is it their favorite?

As a class, have student groups create their own 3- to 5-minute PSA about soil and why and how we should protect it. Let students take on the responsibility of creating the PSA from start to finish. Share the final product with the school and community.

Resources

Apfelbaum, S.I., J. Broughton, S. Lehnhardt. *"S" is for Soils!* 2018.

"The Compost Story" video by The Kiss the Ground. https://kisstheground.com/

Global Soil Partnership, The Food and Agriculture Organization of the United Nations. http://www.fao.org/global-soil-partnership/en/

"Soils are endangered, but the degradation can be rolled back," The Food and Agriculture Organization of the United Nations, 4 December 2015. http://www.fao.org/news/story/en/item/357059/icode/

"Unlock the Secrets in the Soil," The U.S.D.A Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=stelprdb1245890

The Compost Story

WORKSHEET

Answer the following questions as you watch watch "The Compost Story" video from https://kisstheground.com/.

❶ According to the video, how many pounds of food waste go to landfills each year?

❷ Instead of going to landfills, what does this video suggest we do with our green waste?

❸ What natural system does composting mimic?

❹ What are some of the benefits compost offers presented by this video?

❺ According to this video, what percentage of our waste could be composted?

❻ When organic matter like food scraps and leaves decompose in landfills, what harmful gas is produced?

❼ What are the steps involved in the proposed regenerative system?

Soils are Endangered

WORKSHEET

Fill out the following information as you read, "Soils are Endangered, but the Degradation Can Be Rolled Back," published by the Food and Agriculture Organization of the United Nations in December 2015 and available at http://www.fao.org/news/story/en/item/357059/icode/.

❶ What are some of the causes given for decreasing soil health in our world?

❷ According to this article, why is soil important?

❸ What is driving the deterioration of soil?

❹ In your own words, what are the recommended priorities for action to stop and reverse the damage to our soil?

❺ How can government policies help support the actions you have listed in #4?

❻ What are 4 of the major challenges soils are facing listed as key findings in this article?

Digging into Soil

FINAL PROJECT

It is your turn to make a difference! For your final Digging into Soil Project, your task is to come up with a solution to help save our soil. Your project can help address a local, national or even a global soil health problem.

Your project proposal needs to include:

_________ Overview of the problem you want to address through your project.

_________ Detailed description of your project and how it will solve the problem you are targeting.

_________ Support for why you think your solution will address your problem. In this section, include examples of similar projects conducted in other communities.

_________ List of steps you plan to take to implement your project.

_________ List of supplies needed, including possible donations and proposed budget for purchases.

_________ Ideas for how you will get the community involved in your project.

_________ List of the results you hope to achieve.

_________ Description of the methods you will use to measure the success of your project.

_________ Projection of how your project will impact soil health today and in the future.

Sustainable Garden Management Practices

CHECKLIST

Please complete the following checklist to inventory the sustainable management practices used in the garden:

Sustainable Garden Management Practice	Do you currently implement this practice?	Would you like to implement this practice?			Practice not Feasible or Applicable
		Do you have time to implement?	Is it affordable?	Is it allowed by school policy?	
Annual soil testing to determine nutrition needs					
Use organic fertilizers					
Add compost to soil					
Conduct soil organism inventory					
Monitor for pests					
Use mechanical pest control					
Use biological pest control					
Test soil and water for contaminants					
Use no-till practices					

Sustainable Garden Management Practices

CHECKLIST (CONTINUED)

Sustainable Garden Management Practice	Do you currently implement this practice?	Would you like to implement this practice?			Practice not Feasible or Applicable
		Do you have time to implement?	Is it affordable?	Is it allowed by school policy?	
Compost garden waste					
Compost food waste from cafeteria					
Leave plant roots and residue in soil at end of season					
Mulch between crops					
Plant cover crops					
Rotate crops on 3 year cycle					
Use native plants					
Use a diversity of plants					
Monitor rainfall					
Use drip irrigation					

Digging into Soil

JOURNAL PAGE

Name:________________________________

Date:_________________________________

Lesson #:______________________________

The theme of this lesson was:

What I learned about soil while completing this lesson:

Questions and thoughts I have after completing this lesson:

Soil Precept:

Create a precept related to how we should treat soil from the information learned in this lesson (definition of a precept - a command or principle intended as a general rule of action).