Digging Deep

Draft edition

A Soil Health Lesson
Set for School Gardens
Grades K-8
Created by Tualatin SWCD and the Mudpies with support from the Gray Family Foundation
www.swcd.net
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Introduction

This lesson set was created by members of the Mudpies Curriculum Development Team, a group of Tualatin SWCD volunteers, with support from the Gray Family Foundation and guidance from the Portland State University Metro STEM Partnership.

The lesson set was designed as part of a greater effort to help connect Next Generation Science Standards to the school garden while promoting soil health education in schools and better soil health practices in school gardens.

School and community learning gardens and farms directly connect students and schools to the wider community by providing shared citizen science opportunities between school and community members while also providing valuable food and environmental services to the community. For example, our partners at Oregon Food Bank and 5 Oaks Middle School in Beaverton have successful run a school-community garden program for several years that helps feed and educate both the school and lower income people in the community. By broadening awareness of food systems and the issues related to them, these gardens and farms provide context for and deeper understanding of global food security issues too. Our work has supported development of such strong programs at schools and in communities throughout our region.

Our program demonstrates a commitment to creating comprehensive, significant and lasting change in our local and regional educational systems in several ways. This lesson set is the result of research and development of curriculum-tied plans and activities in order to provide clear, teachable soil health information to teachers that can be justifiably used throughout the academic year. Providing support for understanding how the soil in gardens/farms functions allows teachers to more efficiently and more successfully maintain soil health, translating into better performing, more sustainable school gardens/farms.

This program helps teachers and garden volunteers or managers understand the importance of soil health, its connection to the functioning of many other natural systems as well as its own functioning, and how to improve soil health through simple practices. This knowledge will empower them to create and sustain school gardens/farms to significantly influence soil health, stormwater management, nutrient
management, and other conservation issues, creating a direct and lasting impact on the environmental footprint of local schools and demonstrating best practices for the next generation of gardeners and farmers.

The design of this curriculum intentionally incorporates science, technology, education, math and the arts in the garden/farm and curriculum-tied lesson plans and activity ideas that celebrate a rich diversity of talents, expression and learning skills. By literally enabling teachers, students and community members to dig into the soil, getting their hands dirty while learning about its inhabitants and properties, then applying simple practices to keep it healthy, this program enriches both student connectedness to nature and the very soil on which their garden depends.

We hope you find the lesson ideas inspiring and useful, that they support a vibrant garden-based education program in your school, and that you in turn contribute to the growing collection of soil health resources, activities and lesson plans available to the teaching community.

**Why is this lesson set only a draft?**

As any experienced teacher knows, curriculum development takes a lot of time and testing. Volunteers for Tualatin SWCD and education partners have worked diligently for a year reviewing educational resources and developing the NGSS aligned classroom and garden activity ideas.

Due to changes in staffing and limited capacity, the future development of this curriculum at this time remains uncertain. We would welcome your feedback though, especially if you are interested in continuing development of this project as a collaborator or leader.

Please contact Lacey Townsend at Tualatin SWCD, 503-648-3174 x102, or your local workshop coordinator to learn more about providing feedback and getting involved with continuing development of this resource!
Learning Goals and Objectives

Students and teachers will improve their understanding of the following areas -

- Basics of Soil Structure
  - Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface.
  - Eroded mineral material from the Earth’s surface is one component of soil.
  - Eroded mineral material in soil can be divided into three sized particles: sand, silt, and clay.
  - Soils can be categorized by their texture and the proportion of sand, silt and clay particles within the soil. These are called soil types.
  - Plant species are adapted to specific soil types, and soil types vary all around the world.
  - Soil can be eroded and transported by the force of wind, water or human activity.
  - Sand particles alone have no binding force and are easily erodible.
  - Silt particles alone have little binding force and are easily erodible.
  - Due to their size and shape, clay particle exhibit high levels of attraction to one another, and as a result are sticky. Nonetheless, on their own, alone, they are erodible.
  - Soil also contains organic matter from living and decaying plants within and incorporated from outside of the soil.
  - Healthy soil consists of a balance of eroded mineral particles and organic matter.
  - Together, soil particles and organic matter can be formed into small and larger clumps called aggregates, which resist erosive force better than soil particles alone.
  - These particles and organic matter form a structure to soil.
  - The structure of soil consists of solid materials and the pore spaces between them.
  - These pore spaces may be filled with water or air.
  - The volume of water that can be held in the pore space of a soil is called its holding capacity.

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
- Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.
- Plant roots extract these nutrients and water from soil for use in growth and energy production.
- Plants store energy within their roots in the soil.
- Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.
- Plant exudates contribute to formation of stable soil aggregates.

- **Soil as an Ecosystem**
  - In addition to the physical structure of soils, many creatures live within the soil.
  - Students and teachers will understand the ecological role, habitat requirements and soil health benefits of: bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.
  - Students and teachers will understand the soil food web.
  - The living creatures in soil also produce exudates that bind soil aggregates together.
  - The living creatures in the soil alter soil structure, increasing pore space and allowing great water and nutrient holding capacity.
  - Organic matter and plant roots provide food and habitat for some creatures in the soil food web.

- **Soils and Nutrients**
  - Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
  - These nutrients are cycled through the Earth’s system in specific ways.
  - Students and teachers should understand the essential nutrient cycles that involve soil, including carbon, nitrogen and phosphorus cycles.
  - Within the soil, these nutrients can be dissolved from the surface of mineral and organic matter by water held within soil pore space. When dissolved in this manner, the nutrients become available for the roots of the plant to absorb.
  - Plants make particular use of nitrogen and phosphorus in the formation of proteins and the reproductive parts of the plant. Students and teachers should understand the reproductive cycle of plants and how this cycle contributes to human agriculture and food supplies.

- **Human Impact on Soil Health and the 4 Principles of Soil Health**
  - All around the world, people live on and work with the soil. Human beings depend on soil in many different ways.
As world population and food production demands rise, keeping our soil healthy and productive is important.

Soil health is a way of understanding how well soil is functioning to support plants, soil biology, and human needs.

Human activity can affect how the soil functions. These activities include farming, gardening, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.

Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.

The U.S. Department of Agriculture Natural Resource Conservation Service has identified several principles of soil health that identify how people can harm and help soils through these activities.

- **Principle 1:** The surface of the soil should be kept covered by living plants or other materials as much of the year as possible. This protects soil from the erosive force of wind and rain.
- **Principle 2:** Soil should be disturbed from human activities such as digging, plowing, diskng, tilling, etc., as little as possible. Disturbing the soil can destroy the habitat of creatures living in the soil. Disturbing the soil can also increase its vulnerability to the erosive forces of wind and water. Disturbing the soil can result in the loss of organic matter or nutrients.
- **Principle 3:** Keep plants growing in the soil year round. These plants provide protection and coverage for the soil (principle 1). They can increase the organic matter in the soil if incorporated into the soil at the end of their life cycle. Some plants fix nitrogen from the air, increasing soil fertility. The living root of plants within the soil produces exudates that increase soil aggregate formation and also provides food and habitat for creatures living in the soil ecosystem.
- **Principle 4:** Grow a diverse mix plants to provide a diverse mix of roots underground. This helps prevent erosion due to varying root depth and structure, and provides a variety of food and habitat for creatures living in the soil ecosystem.

Permaculture is a form of gardening and farming that utilizes plants that produce fruits for harvest where the plant itself is never or rarely harvested, eliminating or severely limiting all soil disturbance.
- The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
- People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.
## Activity Map

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### Elementary

1. What is biomass?
2. What is pH?
3. What is organic matter?
4. What affects how much plants grow?
5. How will the garden grow?

### Middle School

8. Perkin’ Through the Pores
9. Nitrogen and root nodules
8. Common garden weeds and their roots
9. Decay of organic matter
11. How do we change the soil?
12. How do we change the soil?

1. How do we change the soil?
2. Pore space and moisture
3. Disruption of soil aggregates
## Topic 1: The Basics of Soil

### Activity 1: What is biomass?

**Discipline:** Life Science

**Topic:** Growth, Development, and Reproduction of Organisms / Matter and Energy in Organisms and Ecosystems

**Lesson Length:** 35 minutes + 2 weeks of observation.

**Activity Description:** Students will use the garden to grow several types of grass and measure how much biomass each one produces, how the water, sunlight, nutrients, soil type, temperature and fertilizer affects their growth and their biomass development.

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<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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<tr>
<td>MS-LS1-5</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>LS1.C: Organization for Matter and Energy Flow in Organisms</td>
<td>Energy and Matter</td>
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<tr>
<td>MS-LS1-6</td>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>PS3.D: Energy in Chemical Processes and Everyday Life</td>
<td>Within a natural system, the transfer of energy drives the motion and/or cycling of matter.</td>
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<td></td>
<td></td>
<td>LS1.B: Growth and Development of Organisms</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td>
</tr>
</tbody>
</table>
## Common Core Standards Integration: ELA/ Literacy

**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts

**RST.6-8.2** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

**WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

**WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research

## Common Core Standards Integration: Mathematics

**6.EE.C.9** Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

### Materials

- Garden;
- Pot or water gallon;
- Scissor;
- Potting Soil;
- Wheat or rye seed (30 seeds of each type);
- Corn seed (30 seeds);
- Whole oats (30 seeds);
- Water;
- Paper towels;
- Scale;
- Cookie sheets;
- Oven (optional)
### Soil Health Concepts on the Farm or in the Garden

1. Basics of Soil Structure
   1. Soil also contains organic matter from living and decaying plants within and incorporated from outside of the soil.
   2. Healthy soil consists of a balance of eroded mineral particles and organic matter.

2. Soil as Habitat for Plants
   1. Terrestrial plants root themselves in soil.
   2. To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
   3. Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.
   4. Plant roots extract these nutrients and water from soil for use in growth and energy production.
   5. Plants store energy within their roots in the soil.
   6. Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.
   7. Plant exudates contribute to formation of stable soil aggregates.

3. Soils and Nutrients
   1. Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
   2. These nutrients are cycled through the Earth’s system in specific ways.
   3. Students and teachers should understand the essential nutrient cycles that involve soil, including carbon, nitrogen and phosphorus cycles.
   4. Within the soil, these nutrients can be dissolved from the surface of mineral and organic matter by water held within soil pore space. When dissolved in this manner, the nutrients become available for the roots of the plant to absorb.
   5. Plants make particular use of nitrogen and phosphorus in the formation of proteins and the reproductive parts of the plant. Students and teachers should understand the reproductive cycle of plants and how this cycle contributes to human agriculture and food supplies.

### Background

Biomass is anything that is or has once been alive. The term that refers to the amount of biological material an organism or group of organisms contains. For a plant to grow and reproduce, it uses sugar that came from the photosynthesis process. This process occurs in plants that take the energy of sunlight to transform water and carbon dioxide into sugar and starches (carbohydrates). When the sunlight energy is taken, a chemical in the leaves of plants makes the reaction possible. Therefore, we can say that biomass it is also an indicator of
photosynthesis and growth.

Nowadays, biomass has a very important role: it’s key to develop biofuel. The biomass that we use as biofuel can be considered wood, manure and sugar cane, for example. When you burn this material, heat is released and it can be used in cars, to heat places, to heat water in power plants (that will use the steam to turn on a turbine), among others.

Having a plant, with high biomass productivity and that it is not on a food chain, allows for a greater potential of generating more biofuels.

**PROCEDURE**

**Activity**

1. Count out 30 seeds of each type of grass you are using and plat it about 1 inch (2.5 cm) under the soil. Do it in every different soil treatment that you are using (more shade, more fertilizer, less water, etc.)
2. Choose one type of plant and plant it in a pot or cut the water gallon and use it as a pot.
3. Let it be in a dark place.
4. Water as needed. The soil should be moist.
5. Keep track of the date you planted, how much you watered, if you apply fertilizers, among others things that you choose to experiment.
6. Observe then every day and recorded anything that you think it is interesting. Continue the experiment with observations until each plant has sprouts.
7. Write down the day of the 1st, 10th and 20th sprout for each type of grass.
8. After the grasses sprout, measure the height of the plants every two days and write down the average.
9. After two weeks, pull all of the plants out of the pots and let then separated. Get as much of the root as you can.
10. If any of plants die, recorded as well. Remember to write down the conditions (too much sun, too much dark…)
11. Wash off the dirt and pat the plants dry with a paper towel.
12. Weigh all the plants of each type and write down the weights.
13. Lay the plants on cookie sheets and let it out in the sunshine for the plants to dry until crispy. If it is not sunny enough, use an oven at 150o F (65o C) and keep an eye for then not to burn.
14. Carefully weigh the dry plants. Write the weights in your worksheet. This is the final biomass for each type of plant.
15. Compare all the results.
**Student Reflection**

Which plants sprouted the quickest and which sprouted the slowest?

Do they were in different soil type or the same?

What happened with the plants that were in the dark?

How do you think that the difference in each boxer plant affected their growth and the results?

Which plant grew the tallest?

What are the things you think that made this plant grow tallest? Why do you think that the others were smaller? (Compare between the same type of plant)

Which plant produced more biomass?

Can you relate the sun incidence with the biomass amount?

Can you relate others components that had influenced this activity, such as water, fertilizer…?

Can you compare this to the rate at which the seeds sprouted and the height of the plants?

**Teacher Reflection/Debriefing**

After class, take time for reflection. How did this lesson go?

- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

**Adaptations**

**To Add Complexity**

You can keep a portion of the grasses growing for four weeks or more. You can also repeat the activity to compare different trials.

You can study how the amount of carbon dioxide in the air affects plant growth by sealing the plants in a clear plastic bag with a bowl of baking soda and vinegar.

You can try burning the dried grasses to see which produces the most heat energy.
References and Attribution

This lesson researched/designed by: Rebeca Tombolato Garofalo Oliveira, TSWCD volunteer

TSWCD Lesson Plan Template Consultant: Jane Wilson, MAT, TSWCD volunteer

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

Save the earth Science experiments. Harris, Elizabeth Snoke.

Others:


http://www.learnbiofuels.org/biofuels-lessons/as3-total-biomass-study

https://www.glbrc.org/education/classroom-materials/exploring-energy-transformations-plants-0
# Topic 1: The Basics of Soil

## Activity 2: What is pH?

**Grade Level - Middle School**

**Core Topic: Matter and Energy in Organisms and Ecosystems**

**Core Idea: Life Science**

**Lesson Length: 15 minutes+**

**Overview**

Students will mix vinegar and baking soda into soil samples. Both vinegar and baking soda will react with soil contents making bubbles, indicating if the soil is acidic or alkaline. The activity starts in the garden (with the soil samples) and finish in the classroom (with the test). After testing the soil pH, kids can figure out what kind of plants they can grow.

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<th>Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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<tbody>
<tr>
<td>MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem</td>
<td>Analyzing and Interpreting Data</td>
<td>LS2.A: Interdependent Relationships in Ecosystems</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>Analyze and interpret data to provide evidence for phenomena. (MS-LS2-1)</td>
<td></td>
<td></td>
<td>□ Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)</td>
</tr>
</tbody>
</table>
### Common Core Standards Integration: ELA/ Literacy

**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)

### Materials

- Marker;
- Cups to get the collect soil (as many as you want to test);
- Containers to test the soil (as many as you want to test);
- ½ cup of vinegar for each container tested (alkaline test);
- Distilled water;
- ½ cup of baking soda for each container tested (acidic test);
- Provide a sheet for students to record data

### Soil Health Concepts Covered

Students and teachers will improve their understanding of the following areas -

- **Basics of Soil Structure**
  - The structure of soil consists of solid materials and the pore spaces between them.
  - These pore spaces may be filled with water or air.
  - The volume of water that can be held in the pore space of a soil is called its holding capacity.

- **Soil as Habitat for Plants**
  - Terrestrial plants root themselves in soil.
  - Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.

- **Soil as an Ecosystem**
  - In addition to the physical structure of soils, many creatures live within the soil.

- **Soils and Nutrients**
  - The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
Background

Soil pH is a measurement of the acidity or alkalinity of a soil. On the pH scale, 7.0 is neutral. Below 7.0 is acidic, and above 7.0 is basic or alkaline. A pH range of 6.8 to 7.2 is termed near neutral.

This variation influences the root uptake availability of many elements, like nutrients to plants and the activity of soil microorganisms. Phosphorus, for example, will become less available in highly alkaline soils.

The pH is determined by the comparative concentration of H\(^+\) and OH\(^-\) ions. But, in the experiment below, some of the chemical reactions can be related to the pH state.

The vinegar reacts to some components in the soil. The presence of calcite and dolomite and the absence of calcium carbonate can contribute to make the chemical reaction happen. Usually, soil with these characteristics is an alkaline soil; that is why the vinegar is used to give you an idea of your pH soil rate. The same thing happens with the baking soda.

Procedure

Activity

1. Collect the soil sample. (You can use the remain soil from organic matter activity)
2. Label the cups for you to know which soil you are testing;
3. For each type of soil you need two containers, to test alkaline and acidic;
4. Put two spoonful of soil that you want to test in each container;
5. Label it the same way as you labeled the cup and add Vinegar in one container and baking soda on the other;
6. Add \(1/2\) cup of vinegar to the first container and observe;
7. If bubble you can write down in your worksheet, if don’t, go to next step;
8. Add distilled water to the second container until the soil is muddy;
9. Add \(1/2\) cup of baking soda;
10. Write down what happened;

Wrap-up

The presence of bubbling reflects the chemical reactions that happened in the soil when vinegar or baking soda is added. If the soil bubbles with the vinegar is told that the soil pH is alkaline;
if reacts with baking soda that the soil pH is acidic.

After testing the soil pH, the students can make a comparison between the plants, and maybe the animals, that live in each type of soil.

**Student Reflection**

Do you think that the soil pH is important? Can you see any difference in the gardens with different pH scale?

Are the plants and animals living in the soil different in each type of soil? How?

Why do you think this can happen? Do you think that plants can thrive in different pH scale?

**Teacher Reflection/Debriefing**

After class, take time for reflection.

How did this lesson go?

Celebrate what went well. What could be improved or eliminated.

What re-teaching or reinforcement of ideas is needed?

**Adaptations**

**To Add Complexity**

If you have a pH meter, you can use it or a pH strip. This will make your students just write the results on the worksheet and go for the discussion. This way you can have accurate data about the soil pH.

You can research what kind of flowers thrive in each pH scale and try to plant them in the soil that don’t have the same pH scale and wait to see what happen. Do not forget to water and plant it on the sunny/shade requirements.

You can dig a plant out from your garden to compare the root system too. Be careful when doing this to not cur the roots off.
References and Attribution

This lesson authored by: Rebeca Tombolato Garofalo Oliveira, TSWCD volunteer

TSWCD Lesson Plan Template designed by Jane Wilson, TSWCD volunteer and veteran teacher and curriculum designer.

All lesson plans in this curriculum reviewed by Stephanie Wagner, Portland State University, and the Portland Metropolitan STEM Project.

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

http://preparednessmama.com/testing-your-soil-ph-without-a-kit/

With additional reference to:

http://geology.com/minerals/acid-test.shtml

http://www.ext.colostate.edu/mg/gardennotes/222.html

http://www.ext.colostate.edu/mg/gardennotes/222.html

The nature and properties of soils (book)
Topic 1: The Basics of Soil

Activity 3: What is organic matter?

Grade Level - Middle School

Core Topic: Matter and Energy in Organisms and Ecosystems (LS2), Structure and Properties of Matter (PS1.A)

Core Idea: Interactions, Energy, and Dynamics Relationships in Ecosystems

Lesson Length: 20 minutes+

Overview

*Learners will add hydrogen peroxide to different soil samples. It will react with the carbon in the soil forming CO₂ bubbles, due the presence of organic matter. The activity starts in the garden (with the soil samples) and finish in the classroom with the test. After testing the amount of available carbon in the soil, kids can describe how levels of organic matter can affect plants.*

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<tr>
<td>MS.PS1-1.: Develop models to describe the atomic composition of simple molecules and extended structures.</td>
<td>Modeling: developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.</td>
<td>PS1.A: Structure and Properties of Matter</td>
<td>Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)</td>
</tr>
<tr>
<td>MS-PS1-2.: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.</td>
<td>PS1.B: Chemical Reactions</td>
<td>PS1.A: Structure and Properties of Matter</td>
<td>Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)</td>
</tr>
</tbody>
</table>
## Common Core Standards Integration: Mathematics

**MP.2** Reason abstractly and quantitatively.

**6.RP.A.3** Use ratio and rate reasoning to solve real-world and mathematical problems.

**6.SP.B.4** Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

**6.SP.B.5** Summarize numerical data sets in relation to their context

## Common Core Standards Integration: ELA/ Literacy

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-1)

**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)

## Materials

- glasses or plastic cups (how many you need)
- containers to get soil samples
- marker to label soil samples in cups
- 6% hydrogen peroxide (available in any drugstore)
- sticks for stirring the soil
- wrist watch or clock
- soil auger (or small trowel)
- My Soil is Better than Your Soil Standards Check data sheets
Soil Health Concepts Covered

- Basics of Soil Structure
  - Healthy soil consists of a balance of eroded mineral particles and organic matter.
  - Together, soil particles and organic matter can be formed into small and larger clumps called aggregates, which resist erosive force better than soil particles alone.
  - These particles and organic matter form a structure to soil.

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
  - Plants store energy within their roots in the soil.
  - Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.
  - Plant exudates contribute to formation of stable soil aggregates.

- Soil as an Ecosystem
  - In addition to the physical structure of soils, many creatures live within the soil.
  - Organic matter and plant roots provide food and habitat for some creatures in the soil food web.

- Human Impact on Soil Health and the 4 Principles of Soil Health
  - The U.S. Department of Agriculture Natural Resource Conservation Service has identified several principles of soil health that identify how people can harm and help soils through these activities.
    - Principle 1: The surface of the soil should be kept covered by living plants or other materials as much of the year as possible. This protects soil from the erosive force of wind and rain.
    - Principle 3: Keep plants growing in the soil year round. These plants provide protection and coverage for the soil (principle 1). They can increase the organic matter in the soil if incorporated into the soil at the end of their life cycle. Some plants fix nitrogen from the air, increasing soil fertility. The living root of plants within the soil produces exudates that increase soil aggregate formation and provides food and habitat for creatures living in the soil ecosystem.
    - Principle 4: Grow a diverse mix plants to provide a diverse mix of roots underground. This helps prevent erosion due to varying root depth and structure, and provides a variety of food and habitat for creatures living in the soil ecosystem.
  - The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
Background

Soil organic matter is a complex and varied mixture of organic substances, among others, due to its nature – the remains of living things. All organic substances, by definition, contain the element carbon, which make the soil organic matter have the largest amount of carbon present on the land.

Soil organic matter plays a significant part in a number of global cycles, like Carbon Cycle. The element carbon is the foundation of all life. Its cycle is all-inclusive because it involves the soil, higher plants of every description and all animal life, including humans.

Organic matter also improves soil productivity; plants grow better in soils with high organic content. There are many reasons for this. First, the decomposition of organic matter converts nutrients into forms that can be used by plants, like nitrogen, phosphorus, potassium, and many other micronutrients. Organic matter also improves the soil structure and keeps nutrients from being washed away by rain before the plants can use them. It also acts like a sponge, helping retain moisture in the soil.

Perhaps, the most useful approach to defining soil organic matter quality is to recognize different portions or pools of organic carbon.

In this experiment, learners will compare the amounts of organic matter in different soils on their site. A chemical reaction between soil carbon and hydrogen peroxide makes this possible.

Since the organic fraction of plant materials is made largely of carbon and hydrogen, its decomposition results in oxygen consumption and carbon dioxide (CO₂) release.

When soil is mixed with hydrogen peroxide (H₂O₂), the carbon from the organic matter in the soil bonds with the oxygen (O₂) to form carbon dioxide (CO₂) bubbles and water. The carbon dioxide (a gas) occurs as bubbles that the learners can observe. Vigorous, long-lasting bubbling indicates a large amount of organic matter. When oxygen consumption by organic matter happens, oxidation has occurred. You will notice that once the bubbling process is complete, the soil’s color with organic matter that had a dark color will be different.
### Preparation

Find sites that have different amounts of organic matter and that you can take some samples from to test and compare with your garden. A forest or wooded area, for example, would have high organic matter than a badly eroded playground. A roadside or lawn would probably be somewhere in the middle.

### Procedure

#### Warm-up

Talk about compounds and molecules.

Talk about hydrogen peroxide. Which are the atoms on it?

What kind of atom do we have in the soil?

#### Activity

Label the cups and containers so that children will know which soil came from each site.

Using a trowel have students remove a sample of soil about five cm deep from each test site and place the soil in different containers and bring them back to the classroom.

Ask then to place two tablespoons of each type of soil in a separate cup.

Students will add three to four tablespoons of hydrogen peroxide to the soil in the cups until the soil is completely covered. This should produce bubbles.

Using a watch with a second hand, learners will record the time bubbling occurs. If there is not time to record how long the soil bubbles, learners can stir their soil, watch their cups for five minutes, and then report the amount of bubbling.

Using the worksheet, full fill any information that you got from the experiment.

#### Wrap-up

The amount of bubbling reflects the amount of organic material present. Explain to learners the process that caused the bubbling in the soil cups.
**Student Reflection**

Ask them if they think organic matter is important. Why? What did the sites that had the most organic matter look like? What did the site with the least amount of organic matter look like? Where does organic matter come from? What happens to soil when organic material is removed? You can relate the organic matter in your garden with the plant growth on it with the other sites that you tested. Do you have more plants? Are your plants growing strong? What happened with the soil when they added hydrogen peroxide? Was it a chemical reaction? Why?

**Teacher Reflection/Debriefing**

After class, take time for reflection.

How did this lesson go?

Celebrate what went well. What could be improved or eliminated.

What re-teaching or reinforcement of ideas is needed?

**Adaptations**

**To Add Complexity**

You can do a compost activity and put the compost in your garden. After a while, you can test the garden that you put your compost with the one you did not.

You can write the chemical equation on the black board and ask to the kids try to explain what happened with every atom, or you can use the models built, if they made it. This can be done using legos as well.

**References and Attribution**

This lesson authored by: Rebeca Tombolato Garofalo Oliveira, TSWCD volunteer

TSWCD Lesson Plan Template designed by Jane Wilson, TSWCD volunteer and veteran teacher and curriculum designer.

All lesson plans in this curriculum reviewed by Stephanie Wagner, Portland State University, and the Portland Metropolitan STEM Project.
Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:


With additional reference to:

Building soils for better crops.

The nature and properties of soil.
## Topic 1: The Basics of Soil

### Activity 4: Perkin’ Through the Pores

**Activity Description:**
Students will determine the water holding and draining capacities of different soils and investigate how organic matter affects the amount of water soil will hold.

<table>
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<tr>
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</table>
| Students who demonstrate understanding can: 5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. | Developing and Using Models  
- (5-LS2-1) Connections to Nature of Science  
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena  
- (5-LS2-1)  
- (5-ESS2-1) | LS2.B: Cycles of Matter and Energy Transfer in Ecosystems  
- (5-LS2-1)  
ESS2.A: Earth Materials and Systems  
- (5-ESS2-1) | Systems and System Models  
- (5-LS2-1)  
Systems and System Models  
- (5-ESS2-1) |

### Common Core Standards Integration: ELA/ Literacy

RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (5-LS2-1)

SL.5.5 Include multimedia components and visual displays in presentations when appropriate to enhance the development of main ideas or themes. (5-LS2-1)
Common Core Standards Integration: Mathematics

MP.4 Model with mathematics. (5-LS2-1)

STEAM Connections- Arts Integration:

Use the following background concept as prompt for students to draw a set of three illustrations:

1-Water moves too quickly through sand, meaning that plant roots can dry out rapidly.

2-Water moves very slowly through clay, but clay can hold water so tightly that plants cannot get to it.

3-Soil that is good for plants has a mixture of sand, silt, and clay particles, as well as organic matter. It allows water to move through slowly so that some is held in the soil for plants to use.

<table>
<thead>
<tr>
<th>Standards Driven Questions</th>
<th>Vocabulary- NGSS</th>
<th>Vocabulary- Lesson related</th>
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</table>
| *Use Blooms to guide levels of questions appropriate for NGSS language* | • Model  
• Matter  
• Geosphere  
• Biosphere  
• Hydrosphere  
• Environment | • Soil structure  
• Humus  
• Organic Matter  
• Pores |

Materials

- Funnels (2-liter bottles cut in half, 1 per group)
- Coffee filters (cupcake-shaped, 4 per group)
- 2 cups each of 4–5 different dry soil samples (use a variety of textures from sandy to clayey)
- Measuring cups
- Water

Resources

Invitees to activity as appropriate for: supervision; guest experts, or related programs

Companion Resource-

Soil Samples (Soil Texture)

This is a great kit for teaching students about soil textures. The kit includes two cups of sand, two cups of silt, and two cups clay. Each
**Materials continued**
- Stopwatches or a clock with a second hand
- “Comparison Graph” activity sheet
- 4–5 cups of potting soil
- Essential Files (maps, charts, pictures, or documents)
- "Comparison Graph" activity sheet

The kit weighs eight pounds. All of the soil samples are from the state of Utah and are representative of the Intermountain Region, although the mineral content may be different, the particle sizes are true to soil texture type and can be used by other states for demonstration purposes.

**URL**
[https://utah.agclassroom.org/cart/Details.cfm?ProdID=32&category=0](https://utah.agclassroom.org/cart/Details.cfm?ProdID=32&category=0)

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**Soil Health Concepts on the Farm or in the Garden**

Students and teachers will improve their understanding of the following areas -

- **Basics of Soil Structure**
  - Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface.
  - Eroded mineral material from the Earth’s surface is one component of soil.
  - Eroded mineral material in soil can be divided into three sized particles: sand, silt, and clay.
  - Soils can be categorized by their texture and the proportion of sand, silt and clay particles within the soil. These are called soil types.
  - Sand particles alone have no binding force and are easily erodible.
  - Silt particles alone have little binding force and are easily erodible.
  - Due to their size and shape, clay particle exhibit high levels of attraction to one another, and as a result are sticky. Nonetheless, on their own, alone, they are erodible.
  - Soil also contains organic matter from living and decaying plants within and incorporated from outside of the soil.
  - Healthy soil consists of a balance of eroded mineral particles and organic matter.
  - Together, soil particles and organic matter can be formed into small and larger clumps called aggregates, which resist erosive force better than soil particles alone.
  - These particles and organic matter form a structure to soil.
  - The structure of soil consists of solid materials and the pore spaces between them.
  - These pore spaces may be filled with water or air.
  - The volume of water that can be held in the pore space of a soil is called its holding
Human Impact on Soil Health and the 4 Principles of Soil Health

- Soil health is a way of understanding how well soil is functioning to support plants, soil biology, and human needs.
- Human activity can affect how the soil functions. These activities include farming, gardening, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.
- Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.
- The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
- People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.

Background

Sand, silt, and clay particles make up the inorganic, mineral component of soil. Sand particles are the largest and can be seen with the naked eye. Sand has a coarse feel and allows water to move through very quickly. Silt particles are too small to see with the naked eye. They are often found in places that have flooded and dried out again. Clay particles are the smallest, fitting together so closely that it is difficult for water to flow through.

The best soil for plants allows water to move through slowly so that some is held in the soil for plants to use. Water moves too quickly through sand, meaning that plant roots can dry out rapidly. Water moves very slowly through clay, but clay can hold water so tightly that plants cannot get to it. Soil that is good for plants has a mixture of sand, silt, and clay particles, as well as organic matter. Organic matter, also known as humus, acts like a sponge to help the soil capture water. Organic matter is formed by the decomposition of dead plants and animals or plant and animal waste.

Organic matter helps sand, silt, and clay particles stick together, forming good soil structure. Hundreds of soil particles are glued together by organic matter into groups called aggregates. Aggregation of soil particles creates pore space, making it easier for water, air, and plant roots to move through the soil. A soil with lots of organic matter will be crumbly. The thoroughly decomposed organic matter in a crumbly soil can absorb lots of water. On a dry weight basis, humus has a water-holding capacity of several hundred percent.
While water is absorbed by organic matter and held in the small pores within aggregates, the large pores in between aggregates allow water to move quickly through the soil. Well-managed soils that are high in organic matter tend to be more porous, allowing them to rapidly absorb rain and snowmelt (if the soil is not frozen). This reduces erosion. Of course, when the soil is saturated by a long period of rainfall, any additional water then runs off. But until the soil is saturated, it will store up water and let it go gradually.

Crops use lots of water. Summers are dry in the western United States, and most crops will not grow without irrigation. Sometimes irrigation water is scarce and farmers have to take turns, irrigating only at their assigned times. In the eastern United States it rains throughout the summer, so many crops are grown without irrigation. However, farmers cannot control the rain. Sometimes it may not rain for several days, or it may rain so hard that the soil is completely saturated. Organic matter helps soil store more water, prevents erosion, and produces better crops.

**PROCEDURE**

**Warm-up**

**Entrance Slip- Quick Write**

Ask students to think about what happens when it rains. Where does the water go? Where do puddles form first?

**Activity**

**Activity 1: Mark, Get Set, Go**

1. Prepare the funnels made from 2-liter bottles as shown in the picture (make a mark 5½ inches up from the bottom of each bottle, cut each bottle in half at the mark, invert the bottle tops, and nestle the tops into the bottoms).

2. Divide the class into four or five groups, depending on how many soil samples you have. Provide each group with a funnel and bottom, 2 coffee filters, 1 cup of a soil sample, a measuring cup, and water. Make sure each group has a different type of soil sample.

3. Instruct students to place one coffee filter into the funnel and then add 1 cup of soil into the filter. Cover the sample with another filter. This will ensure even coverage and avoid
splashing.

4. Designate one person in each group as a timekeeper and another as the water pourer. When the timekeeper says “go,” the water pourer should pour 1 cup of water into the funnel.

5. Time should be kept until most of the water has gone through the soil sample. Some samples will drain quite quickly, while others could take 30 minutes or more. Proceed with Activity 3 while keeping an eye on the samples and waiting for them all to finish draining.

6. Compare the time it took for water to percolate through each sample. Add the data to the “Comparison Graph” activity sheet.

7. Pour out and measure the water that percolated through each sample. Record this on the activity sheet as well.

**Activity 2: Adding Organic Matter**

1. Instruct the students to return to their groups and empty out their funnels. Starting with new, dry soil will ensure consistent, representative results.

2. Proceed to duplicate the experiment with one change: after placing a new, dry coffee filter into the funnel, add ½ cup of dry soil into the filter and ½ cup of potting soil (to increase organic matter; most potting soils are largely made up of organic matter). One student should mix in the organic matter with his or her finger, being careful not to puncture the filter. Cover the sample with another new filter.

3. Duplicate steps 4 through 7 in Activity 1. Be sure to record the data on the “Comparison Graph” activity sheet.

4. Discuss the background material and ask students to identify which sample had the most sand and which had the most clay. Add this evaluation to the graph.

**Wrap-up**

Quick review summary of lesson key ideas/concepts.
### Student Reflection

**Exit Slip:**

What ideas do you take away from these experiences that are easily understood?

What is still a little “muddy”... unclear?

### Teacher Reflection/Debriefing

After class, take time for reflection. How did this lesson go?

- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

### Recommended Reading

- Compost by Gosh! (Book/Booklet)
- Diary of a Worm (Book/Booklet)
- Dirt: The Scoop on Soil (Book/Booklet)
- Sand and Soil: Earth's Building Blocks (Book/Booklet)
- Farming in a Glove (Kit)
- Soil Samples (Soil Texture) (Kit)
- Learn How To Compost (Website)

### References and Attribution

This lesson researched by: Jane Wilson, TSWCD volunteer

TSWCD Lesson Plan Template Consultant: Jane Wilson, MAT, TSWCD volunteer

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, OVE Program Manager, TSWCD.
This lesson adapted from:

Activities 1 and 2 adapted from USDA Soil Conservation Service publication Soil and Water Conservation Activities by Albert B. Foster and Adrian C. Fox.

Author(s)

Debra Spielmaker

Organization Affiliation

Utah Agriculture in the Classroom

With additional reference to:

http://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=147
Perkin’ Through the Pores—Comparison Graph

What was the amount of water collected after percolation in each sample?

<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
</table>

Which samples do you think had the most sand? _______________

Which sample had the most clay? _______________

Which sample had the most organic matter? _______________

(Hint: Compare the amount of water collected, the speed of percolation, and the visual evidence.)
Topic 2: Soil as Habitat

Activity 5: What affects how much plants grow?

Discipline: Life Science
Topic: Growth, Development, and Reproduction of Organisms / Matter and Energy in Organisms and Ecosystems

Activity Description:
Students will grow the same plant in different areas of the garden and measure how much above and below ground biomass each one produces. They will record observations about the available sunlight, soil texture, soil moisture, organic matter content, and soil nutrients to explore how these affect plant growth.

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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<tbody>
<tr>
<td>MS-LS1-5, MS-LS1-6</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>LS1.C: Organization for Matter and Energy Flow in Organisms</td>
<td>Energy and Matter</td>
</tr>
<tr>
<td></td>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>PS3.D: Energy in Chemical Processes and Everyday Life</td>
<td>Within a natural system, the transfer of energy drives the motion and/or cycling of matter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LS1.B: Growth and Development of Organisms</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td>
</tr>
</tbody>
</table>

Common Core Standards Integration: ELA/ Literacy
**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts

**RST.6-8.2** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

**WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

**WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research

### Common Core Standards Integration: Mathematics

**6.EE.C.9** Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

### STEAM Connections- Arts Integration:

Activity can be adapted to produce pressed plant vouchers. For more details, visit http://store.msuextension.org/publications/AgandNaturalResources/MT198359AG.pdf

### Vocabulary- Lesson related

- Biomass
- Carbon
- Fossil fuel
- Biofuel
- Food chain

### Materials | Resources
Planting/growth
- Data collection sheets for each group
- Access to a garden or outdoor area for potted plants
- A graduated measuring device for watering the plants, one per group of students
- A water source (hose or bucket)
- Scissors
- Potting soil mix: You will need a well-balanced potting soil, plus clay, sand and mulch sufficient to fill all of the garden pots. These ingredients will be combined proportionally depending on the tested variable.
- 16 one gallon pots
- Masking tape and a permanent marker, or garden stakes to label pots
- Seeds for the plant of your choice (fava beans recommended for ease and speed of growth)
- Rulers
- Rain gauge and outdoor thermometer (optional)
- Camera(s) for recording progress (optional)
- Slow release fertilizer or liquid fertilizer (see different methods for each below)

Harvest:
- Outdoor sink or buckets of water
- Paper and markers
- Paper towels
- Scale
- Cookie sheets (optional)
- Oven (optional)
- Nitrogen soil test kit (optional)

Activity adapted from:
Save the earth Science experiments. Harris, Elizabeth Snoke.

Variations of this activity:
http://www.sciencemadesimple.com/botany_plant_projects.html
http://sciencefair.math.iit.edu/projects/plantgrowth/

Soil Health Concepts on the Farm or in the Garden

4. Basics of Soil Structure
   1. Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface.
   2. Soils can be categorized by their texture and the proportion of sand, silt and clay particles within the soil. These are called soil types.
   3. Plant species are adapted to specific soil types, and soil types vary all around the
world.
4. Soil also contains organic matter from living and decaying plants within and incorporated from outside of the soil.
5. Healthy soil consists of a balance of eroded mineral particles and organic matter.
6. The structure of soil consists of solid materials and the pore spaces between them.
7. These pore spaces may be filled with water or air.
5. Soil as Habitat for Plants
1. Terrestrial plants root themselves in soil.
2. To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
6. Soils and Nutrients
1. Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
2. Plants make particular use of nitrogen and phosphorus in the formation of proteins and the reproductive parts of the plant. Students and teachers should understand the reproductive cycle of plants and how this cycle contributes to human agriculture and food supplies.

Background

Biomass is the total mass of organisms in a given area or volume. Here, we refer to all of the plant growth produced in a given area, both above and below ground. For a plant to grow and reproduce, it uses sugar produced by the photosynthesis process. This process occurs in plants that take the energy of sunlight to transform water and carbon dioxide into sugar and starches (carbohydrates). When the sunlight energy is taken, a chemical in the leaves of plants makes the reaction possible. Therefore, we can say that biomass it is also an indicator of photosynthesis and growth.

Nowadays, biomass has a very important role: it’s key to develop biofuel. The biomass that we use as biofuel can be considered wood, manure and sugar cane, for example. When you burn this material, heat is released and it can be used in cars, to heat places, to heat water in power plants (that will use the steam to turn on a turbine), among others.

Having a plant, with high biomass productivity and that it is not on a food chain, allows for a greater potential of generating more biofuels.
### Preparation

For this experiment, students will grow plants in pots. This allows you to control the relative soil texture and organic matter content.

Read the seed packet for the plant you have selected. Determine the soil requirements for the plant you have selected. This activity will guide you through using fava beans, which require a sandy loam (40% sand, 40% silt and 20% clay by weight). Most stores sell potting soil is a suitable mix of loam, peat, sand and nutrients to adequately approximate sandy loam.

### PROCEDURE

#### Warm-up

Brainstorm on paper: Provide the students with the seed packets for the seeds to be used in this experiment. Have them list the factors that will affect plant growth.

#### Activity

Day 1:

1. Have the class discuss their brainstorm warm up as a group. Divide into small groups and have each group for a guess (hypothesis) about how one factor will affect plant growth. Some hypothesis recommended for testing:
   - More/less sunlight will produce more/less plant growth.
   - Plants grown in different soil textures will grow at different rates.
   - More/less soil moisture will produce more/less plant growth.
   - Greater/less, organic matter in the soil will produce more/less plant growth.
   - More/less nitrogen will produce more/less plant growth.

   Students may also create a hypothesis about which factor will affect plant growth more. For example:
   - Restricting sunlight will affect plant growth more than reducing water.
   - Plants grown in the wrong soil texture will grow more slowly than plants grown in the right soil texture but very little organic matter.
   - Adding nitrogen will produce more plant growth than adding more organic matter will.

2. Select test locations in the garden for each of the following:
   - Very sunny
   - Very shady
3. Label the pots as follows and set them out in the sunny and shady spots according to the chart at the end of this activity. The chart also labels the daily treatment instructions for each pot. Pots should be labelled: Loam sun more water, loam sun less water, loam sun add nitrogen, loam sun add organic

4. Each group should be assigned 1-2 treatment pots. *Optional:* you may run multiple replications in each treatment. One replication will be 16 pots, two replications are 32 pots, and three replications are 48 pots.

5. Each group should start by preparing the soil for their pots based on the label. Have students thoroughly water soil when prepared, then let pots drain until they no longer drip. (*Optional:* Students may observe and record the water holding capacity of their soil at this step; for a model activity, visit http://extension.uga.edu/k12/science-behind-our-food/lesson-plans/soilwaterrel.pdf)
   - Students preparing the loam will fill the pots with just potting soil.
   - Students preparing the sandy loam will prepare pots with a mix of ½ potting soil and ½ sand, well mixed.
   - Students preparing the pots with loam and organic matter will mix ½ loam and ½ organic matter, well mixed.
   - Students preparing sandy loam with organic matter will mix 1/3 loam, 1/3 sand, and 1/3 organic matter, well mixed.
   - Students preparing add nitrogen can mix the recommended amount of slow release fertilizer into the potting soil according to the package directions. (If you are using a liquid fertilizer, have these students fertilize the plants according to the package instructions throughout the experiment.)

6. Have students plant three seeds in the pots at the recommended depth. One week after germination, have students select the strongest seedling and remove the other two.

7. Record the date you planted.

After Day 1:

8. As a class, decide how much water will be applied at a time to the plants. We recommend trying ¼ gallon per pot.

9. Have students monitor their plants daily, recording how much they watered, if they applied fertilizers (liquid method), weather conditions (sunny/cloudy, rainfall – if possible, use a rain gauge to accurately record local rain fall) and height of plant growth. Students may also record any other interesting observations.

10. If students cannot visit the garden daily, have them provide the necessary plant care and observe on days when they can visit. The teacher or garden volunteers can provide plant care per the instructions in the chart below between class visits.
11. Record dates on which any plants die. Proceed to step 11 for these plants if large enough to measure biomass.

12. Two weeks after successful germination (you may extend the experiment through the length of the growing season if desired; if beans are harvested, weigh them and record), have students use paper and markers to create a page labelled in the same way as each pot. Have students work on a prepared surface (concrete pad, tart or solid surface tables) to pull all of the plants out of the pots. They should gently loosen and shake off as much of the soil as they can. *Optional:* to completely remove soil material, students can gently wash roots in outdoor sink or buckets of water. Pat plants dry. Students should work with one plant at a time and placed the dried plant on the paper labelled with the same name.

13. Weigh all the plants of each type and record the weights.

14. Lay the plants on cookie sheets. Lay trays out in the sunshine for the plants to dry. If it is not sunny enough to do this, take the labelled plants home (you may want to use labelled gallon Ziploc bags) and use an oven at 150 degrees F to slowly dry them, keeping an eye out to prevent burning.

15. Carefully weigh the dry plants. Record the weights. This is the final biomass for each type of plant.

16. Students can calculate the difference between the wet and dry biomass if desired.

**Wrap-up**

Have students discuss how the experiment went. Which hypotheses held up? What else did they observe? How did the various components of soil (texture, organic matter, nutrients, water) affect plant growth? Have them think about what the seed packets said about growing requirements – do the results of the experiment make sense based on the packets? How might the weather or other confounding variables have affected the experiment?

**Student Reflection**

Which plants sprouted the quickest and which sprouted the slowest?

Do they were in different soil type or the same?

What happened with the plants that were in the dark?

How do you think that the difference in each boxer plant affected their growth and the results?

Which plant grew the tallest?
What are the things you think that made this plant grow tallest? Why do you think that the others were smaller? (Compare between the same type of plant)

Which plant produced more biomass?

Can you relate the sun incidence with the biomass amount?

Can you relate others components that had influenced this activity, such as water, fertilizer...?

Can you compare this to the rate at which the seeds sprouted and the height of the plants?

**Teacher Reflection/Debriefing**

After class, take time for reflection. How did this lesson go?
- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

**Adaptations**

**To Simplify**

Test fewer variables. Start from same-aged vegetable starts.

For younger students, the teacher may prepare the experiment through step 11 and have students focus on observing the relative size of the plants, which may be measured by height or weight.

**To Add Complexity**

- Have older students create a report or poster about their experiment. Ask them to use charts and graphs to help analyze their data. Ask them to make recommendations for growing beans next year based on what they learned.
- You can keep a portion of your plants growing for four weeks or more. Then you can do the activity again and compare the results.
- You can study how the amount of carbon dioxide in the air affects plant growth by sealing the plants in a clear plastic bag with a bowl of baking soda and vinegar.
- You can try burning the dried plants to see which produces the most heat energy. For more information on biomass and energy activities, visit [http://www.nrel.gov/education/pdfs/educational_resources/elementary/biomass_activities.pdf](http://www.nrel.gov/education/pdfs/educational_resources/elementary/biomass_activities.pdf)
- You can also experiment with the gases produced during seed germination or decay.
Visit [http://www.webquest.hawaii.edu/kahihi/webquests/topical/energy/SC7.3.1biomass/extras/BiomassHandsOnLearningActivity.pdf](http://www.webquest.hawaii.edu/kahihi/webquests/topical/energy/SC7.3.1biomass/extras/BiomassHandsOnLearningActivity.pdf) for an activity in this area that could be conducted before our activity. You would harvest the viable seedlings produced and plant them at step

**Recommended Reading**

- How Plants Grow, Donna Herwick Rice
- Gardening Lab for Kids, Renata Fossen Brown
- Energy from Living Things: Biomass Energy, Rachel Stuckey

**References and Attribution**

This lesson researched/ designed by: Rebeca Tombolato Garofalo Oliveira, TSWCD volunteer

TSWCD Lesson Plan Template Consultant: Jane Wilson, MAT, TSWCD volunteer

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

Save the earth Science experiments. Harris, Elizabeth Snoke.

Others:


[http://www.learnbiofuels.org/biofuels-lessons/as3-total-biomass-study](http://www.learnbiofuels.org/biofuels-lessons/as3-total-biomass-study)

[https://www.glbrc.org/education/classroom-materials/exploring-energy-transformations-plants-0](https://www.glbrc.org/education/classroom-materials/exploring-energy-transformations-plants-0)
<table>
<thead>
<tr>
<th>Test pots</th>
<th>Sun</th>
<th>Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunny Loam, More Water</td>
<td>Sunny Loam, Add fertilizer Fill pot with potting soil only. Either add slow release fertilizer to soil as directed or apply liquid fertilizer during experiment as directed. Add water every other day. You decide how much water – be consistent!</td>
<td>Shady Loam, More Water Fill pot with potting soil only. Add water every day to keep spoil moist. You decide how much water – be consistent!</td>
</tr>
<tr>
<td>Sunny Loam, Less Water</td>
<td>Sunny Loam, Add organic matter Fill pot with ½ loam and ½ organic matter, well mixed. Add water every other day. You decide how much water – be consistent!</td>
<td>Shady Loam, Less Water Fill pot with potting soil only Add water every day to keep spoil moist. You decide how much water – be consistent!</td>
</tr>
<tr>
<td>Sandy Loam More Water</td>
<td>Sunny Loam Add fertilizer Fill pot with potting soil only. Either add slow release fertilizer to soil as directed or apply liquid fertilizer during experiment as directed. Add water every other day. You decide how much water – be consistent!</td>
<td>Sunny Loam Add fertilizer Fill pot with potting soil only Add water every day to keep spoil moist. You decide how much water – be consistent!</td>
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<tr>
<td>Fill pot with ( \frac{1}{2} ) potting soil and ( \frac{1}{2} ) sand, well mixed. Add water every third day. Soil can get dry between watering. You decide how much water – be consistent!</td>
<td>Fill pot ( \frac{1}{3} ) loam, ( \frac{1}{3} ) sand, and ( \frac{1}{3} ) organic matter, well mixed. Add water every other day. You decide how much water – be consistent!</td>
<td>Fill pot with potting soil only Add water every third day. Soil can get dry between watering. You decide how much water – be consistent!</td>
</tr>
</tbody>
</table>
# DATA COLLECTION FOR PLANT GROWTH EXPERIMENT

Our group name: ________________________  Label on our pot: ________________________

Group members: _________________________________________________________________

Planting date: _______  Germination date: _______  Harvest date: _______

<table>
<thead>
<tr>
<th>Date</th>
<th>How much water added</th>
<th>How much fertilizer added</th>
<th>How much rain fell since last observation</th>
<th>Current air temperature</th>
<th>Height of the plant (after germination)</th>
<th>Other observations</th>
</tr>
</thead>
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</table>
**DATA COLLECTION FOR PLANT GROWTH EXPERIMENT**

**HARVEST DATA**

Our plant was ______________ inches from the longest root to the highest shoot/leaf.

It weighed ______________ before drying.

It weighed ______________ after drying.

We calculate that ______________ of the weight was water.

**Conclusions and Observations**

From our data and observations, we conclude:
Topic 2: Soil as Habitat

Activity 6: Decay of Organic Matter

Grade Level- 9-12

Core Topic- Ecosystems: Interactions, Energy, and Dynamics

Core Idea- Cycles of Matter and Energy Transfer in Ecosystems

Lesson Length: 60-90 minutes + wait time

Overview

Decomposition is an ongoing process in the soil. The rate of which depends on biological activity, the chemical composition of material, and environmental conditions. To better appreciate the factors that influence decomposition, this learning activity will have students measure the rate of decomposition of different types of tea, after being buried for approximately 90 days. They will be able quantitatively analyze the data and contribute to the international scientific community. This activity will expose students to ideas of soil quality, chemical cycling, and the conservation of matter. The majority of time spent on this activity will be spent in the classroom, but a portion of this activity will be spent outdoors, digging in the soils of a school garden or other soils on school grounds.
### Objectives

**Students who demonstrate understanding can:**

- Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

### Practices

- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

### Disciplinary Core Ideas

- **LS2.B:** Cycles of Matter and Energy Transfer in Ecosystems

### Crosscutting Concepts

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5)

### STEAM Connections

- This activity can incorporate art through:
  - Creating artistic representation of factors influencing decomposition
  - Creating artistic representation of the carbon cycle of the students’ tea bag and school yard/garden plants, and where decomposition occurs
<table>
<thead>
<tr>
<th>Lesson Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary- NGSS related</td>
</tr>
<tr>
<td>• Quantitative</td>
</tr>
<tr>
<td>• Data displays</td>
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<tr>
<td>• Mathematical representations</td>
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<tr>
<td>• Natural phenomena</td>
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</tbody>
</table>

Materials

<table>
<thead>
<tr>
<th>People Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each group of (2-3) students:</td>
</tr>
<tr>
<td>• An unused Lipton Rooibos and Lipton Green Tea Bag (pyramid style bags made of non-decomposable material)</td>
</tr>
<tr>
<td>• Printed data form</td>
</tr>
<tr>
<td>• Pencils</td>
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<tr>
<td>• 2 plastic plant labels or similar aboveground marking device</td>
</tr>
<tr>
<td>• A waterproof marker</td>
</tr>
<tr>
<td>• A balance</td>
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<tr>
<td>• A trowel</td>
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<tr>
<td>• A ruler</td>
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</tbody>
</table>

This activity may require assistance to supervise students outdoors.

Soil Health Concepts Covered

- Basics of Soil Structure
  - Soil also contains organic matter from living and decaying plants within and incorporated from outside of the soil.
  - Healthy soil consists of a balance of eroded mineral particles and organic matter.
- Soil as an Ecosystem
  - In addition to the physical structure of soils, many creatures live within the soil.
  - Students and teachers will understand the ecological role, habitat requirements
and soil health benefits of: bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.

- Students and teachers will understand the soil food web.
- Organic matter and plant roots provide food and habitat for some creatures in the soil food web.

- Soils and Nutrients
  - Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
  - These nutrients are cycled through the Earth’s system in specific ways.
  - Students and teachers should understand the essential nutrient cycles that involve soil, including carbon, nitrogen and phosphorus cycles.

- Human Impact on Soil Health and the 4 Principles of Soil Health
  - People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.

**Background**

“Decomposition is a part of the global carbon cycle and tells us about the biological activity in the soil. Decomposition is the decay of organic (plant) matter by soil microorganisms.” Decomposition is necessary to convert the nutrients in dead animal and plant material (organic matter) back to usable chemical forms in the soil for plants and algae, the lowest level the food web, to use. When decomposers use the chemical energy (in the form of sugars) from the organic matter they simultaneously break the matter into smaller, molecular forms that plants can use.

The basic factors that influence decomposition rates are:

- "Environmental conditions (moisture content, acidity, nutrient content).

- The chemical composition of the material that needs to be broken down (wood vs sugars).

- The presence of decomposers (organisms that are involved in the break down, like mites, worms, fungi, bacteria. Different organism groups specialize in different
In this activity, “by burying two types of tea with different decomposition rates, we obtain information on how much and how fast plant material is broken down”.

As decomposition occurs, carbon dioxide (CO₂) is released into the atmosphere, “which is an important greenhouse gas, that may accelerate global warming.” Soil is one of the largest emitters of carbon dioxide to the atmosphere, and the reason why the results of this activity are of scientific interest. This tea bag index is an effort to create an index for decomposition rates that is developed from global soil and climate conditions. The Tea Bag Index is a scientific research project that is collecting data about decay rates of tea around the world in order to better understand the ways that different soil contribute to climate change. Anyone can take part in the project by following the standardized procedure available online and laid out in this activity.

**Preparation**

Identify an area of soil large enough for the activity. The size of this area and location will vary depending on the types of environmental conditions tested for and the size of the class (see section “To Add Complexity”). Prepare group materials: divide up materials, print data sheet (with space to fill in the code name for their group, the initial weight of the bags, the vegetation in the area of the site, and the experimental conditions). Divide students into small groups of 2 or 3; each group will be responsible for testing one experimental condition, and should place their two tea bags in the same test area.

**Procedure**

**Activity**

EXPERIMENT

1) Students should label the plastic white side of the tea bag labels with their group code, using a permanent marker.
2) Have each group weigh their Rooibos and Green tea bags separately on a balance and record weight on their data sheet.

3) Bury the tea bags 8 cm deep, in separate holes, leaving the tea bag label aboveground.

4) Students should also write their group code on the plastic plant labels and mark each burial site with a plant label.

5) “Have students note the date of the burial, the geographical position (GPS coordinates or address), the vegetation/ecotype, and the experimental condition of the site on their data sheet.”

6) After approximately 90 days, remove the tea bag and bring back to the classroom, being careful to not puncture the bag during the process (as any lost tea would make the bag unusable for measurements).

7) Let the teabag dry fully in a sunny spot for at least 3 days. Remove any loose soil from the bag. Remove what remains of the tea bag label, but leave the string attached.

8) Measure the final weight of each bag and record this measurement along with the initial notes on one excel sheet for analysis.
CALCULATIONS

Calculate weight loss as percentage of the start weight. Average the weights of any tea bags that shared the same experimental conditions. Have students share their weight loss results and make a plot of their data, comparing the environmental conditions or tea types to each other. Diagram a carbon cycle and identify the decomposition stage. Use the data in the plot, and the experimental conditions tested, to talk about the rates of decomposition and to draw out the factors that influence them.

To participate in the TBI submit a data form to http://www.decolab.org/tbi/data/index.php and you can receive a calculation of your project’s Tea Bag Index.

Students should understand:

What decomposition is, why it is important, what environmental conditions affect the intensity of biological activity/decomposition, and the transformations that the carbon in the tea undergoes leave the tea bag.

Other questions to explore:

What atoms, in addition to carbon, are conserved during decomposition.
What organic matter (other than the tea bags) is in the soil?
How does decomposition relate to climate change?
What is soil health and how does it relate to decomposition?
What makes the Green Tea and the Rooibos Tea decay at different rates?
What are decomposers? Name a few.
### Student Reflection

*Designer instructions: What questions should student explore or be able to answer?*

- Soil organisms rely on organic matter in the soil for food.
- All organic matter is not created equal.
- Carbon atoms in our food and in the soil are part of a larger global carbon cycle.
- The role of photosynthesis and respiration in the carbon cycle.

### Teacher Reflection/Debriefing

After class, take time for reflection.
How did this lesson go?
Celebrate what went well. What could be improved or eliminated. What re-teaching or reinforcement of ideas is needed?

### Adaptations

**To Simplify**

Remove any additional experimental conditions and simple test the two types of tea in one area. For even simpler procedure, bury the tea yourself and only do the collection, measurements, and discussion with students.

**To Add Complexity**

Incorporate experimental conditions that let you test for effects of land use on soil health. Have groups compare compacted sites to disturbed sites? If the school has a garden, try to identify areas that have different farming techniques (i.e. watering schedule, fertilizer schedule, presence of cover crops).
Recommended Reading

The Tea Bag Index: http://www.decolab.org/tbi/index.html

NRCS Soil Food Web, Ingham

References and Attribution

This lesson authored by: Adriana Escobedo-Land, TSWCD volunteer

TSWCD Lesson Plan Template designed by Jane Wilson, TSWCD volunteer and veteran teacher and curriculum designer.

All lesson plans in this curriculum reviewed by Stephanie Wagner, Portland State University, and the Portland Metropolitan STEM Project.

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

Lehtinen et al., Soil Science Society America: Soil Lessons- Tea4Science
Topic 2: Soil as Habitat

Activity 7: Common garden weeds and their roots
Discipline: Life sciences

Topic: Environment

Lesson Length: 40 minutes +

Lesson Designer: Adriana Escobedo-Land

Activity Description:
All plant root systems serve the same basic functions: drawing nutrients and water from the soil, keeping the plant upright in the soil, and serving as storage for nutrients and photosynthesis products. Weeds in particular, regularly have roots have a specialized function, to spread the plant asexually. Provided below is information about the root systems and vegetative reproductive characteristics of common garden weeds in Oregon. By comparing these weed roots, students have the opportunity to discuss the role of roots and soil in the context of plant evolution and human impact on plant biodiversity. This activity uses the school garden as a space for observation and weeds from the garden as a model; the bulk of the activity, the discussion section, can take place in the classroom or the garden.

NGSS Aligned Standards Overview, STEAM Connections and Soil Health Concepts

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who demonstrate understanding can: HS-LS2-7 HS-LS4-2</td>
<td>1. Asking questions (for science) and defining problems (for engineering) 3. Planning and carrying out</td>
<td>Life Science Ecosystems: Interactions, Energy, and Dynamics</td>
<td>1. Patterns. 3. Scale, proportion, and quantity. 4. Systems and system models.</td>
</tr>
</tbody>
</table>
Soil Health Concepts on the Farm or in the Garden

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
  - Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.
  - Plant roots extract these nutrients and water from soil for use in growth and energy production.
  - Plants store energy within their roots in the soil.
  - Plant roots produce exudates, or chemicals released from the root into the soil for...
several purposes.

- Plant exudates contribute to formation of stable soil aggregates.

- **Soil as an Ecosystem**
  - Organic matter and plant roots provide food and habitat for some creatures in the soil food web.

- **Soils and Nutrients**
- **Human Impact on Soil Health and the 4 Principles of Soil Health**
  - All around the world, people live on and work with the soil. Human beings depend on soil in many different ways.
  - As world population and food production demands rise, keeping our soil healthy and productive is important.
  - Soil health is a way of understanding how well soil is functioning to support plants, soil biology, and human needs.
  - Human activity can affect how the soil functions. These activities include farming, gardening, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.
  - Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.
  - The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
  - People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.

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<thead>
<tr>
<th>Vocabulary- NGSS</th>
<th>Vocabulary- Lesson related</th>
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<tbody>
<tr>
<td>Feedback mechanisms</td>
<td>Cover cropping</td>
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<td>Homeostasis</td>
<td>Soil microbiology</td>
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<tr>
<td>Advantageous heritable traits</td>
<td>Soil quality</td>
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<tr>
<td>Biological evolution</td>
<td>Plant competition</td>
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<td>Weeds</td>
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<td>Reproduction</td>
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<td>Habitat</td>
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<td>Soil as habitat</td>
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</table>

**Materials**

- Shovel
- Printed observation form for each student or to be shared in groups
- Writing utensil for student/groups
• Paper towels or rags to wipe off dirt from roots if particularly moist

Classroom discussion
• Tub or bag to take the weeds into the classroom

Garden discussion
• Writing tools (e.g. mobile white board, A-frame with paper pad)

Background
The roots are a vital organ of the plant, structurally and nutritionally; they hold the plant upright and create a channel of cells that allows for nutrient and water uptake. Additionally, in many plants, particularly taproot plants, the root system is a significant storage site for photosynthesis products (i.e. proteins, sugars, and carbohydrates). In addition to being a vital organ of the plant, roots greatly enhance the soil around them. Roots create pore space and excrete organic molecules; both of these functions create a hospitable environment for beneficial soil microorganisms, which results in overall healthier soils. The root systems of many weed species are particularly useful because they serve the additional purpose of spreading the weed.

Weeds are typically identified as plants that regularly grow in areas where people do not want them to grow. Sometimes weeds are simple nuisances, other times they can cause serious damage to the ecosystem, human health, or the economy. Weeds share one or many of a variety of biological characteristics, including: the resiliency and abundance of seeds, the ability to spread quickly, and (of particular relevance to this lesson) the reproductive capabilities of vegetative parts of the plant.

In the classroom, weeds serve as a great subject for a discussion of plant evolution and advantageous heritable characteristics. A plant’s ability to reproduce and spread greatly affects the plant’s success and ability to outlive other plant species. Weeds that spread by vegetative means (i.e. reproduction other than by seed) are relatively easy
to identify in the field, and because they have this advantageous characteristic, they are common and abundant in agricultural fields, gardens, and lawns.

Specifically, these advantageous characteristics include: weeds with the ability to regrow a stem from a broken root fragment (including creeping wood sorrel and dandelion, found in the list below) and weeds that can develop a trailing stem that produces roots at the stem nodes, called a runner or stolon (example weeds are common chickweed and field bindweed).

Extensive taproot system of pigweed on the left, a creeping root/stolon of field bindweed on the right. [http://courses.missouristate.edu/pbtrewatha/field_bindweed.htm]

Weeds are often a conservation concern due to their tendency to outcompete native plants, and consequently reduce plant biodiversity. The presence of invasive weeds in altered, man-made environments is evidence of the human impact on biodiversity. Weeds are commonly found in areas where the soil is bare and empty of plants, due to natural or human caused disturbances. Humans support weed populations by creating these bare soils, which provide a sunny and competition free spot for weed seeds to germinate. Reducing the amount of bare soil in a garden is a proactive approach to weed control, and an important step in improving soil health. Cover
cropping, the practice of planting a crop to reduce soil erosion and manage soil quality, creates competition for weeds in commonly bare areas in agriculture, such as between planting rows and under larger perennial plants. Mulching is another important form of weed control that can inhibit seed germination by covering exposed soil with decomposable and durable material such as wood chips. Even with these weed control measures in place, weeds can flaunt their advantageous characteristics and grow anyway.

In a stable ecosystem, plants that we call weeds serve an important function of protecting and pioneering bare soils. Most of our natural systems are unstable, degraded by human activity, and the pioneering function of these weeds is no longer as valuable, and indeed often harmful. Weeds are a novel tool for discussing the relatedness of human activity and evolutionary advantageous traits, and conveniently, a common part of most school gardens.

What Students Need to Know / This Lesson Builds On…

The necessary requirements of plants

The basic role of plant organs (e.g. roots, stems, leaves).

Lesson Key Ideas and Concepts

Roots and soil health

The advantage of cover cropping

Advantageous plant characteristics, and their relation to plant success, plant evolution

What makes a weed a weed

Preparation
Identify weeds from the list (ideally from the top six of the list, those that exhibit vegetative reproduction) that are currently in the school garden or school yard. Know the school garden schedule and try to fit in the activity before any planned weeding events.

Create forms for students to note their observations, include, in some form, these sections and suggestions: weed population dispersal (e.g. growing in a bunch or cluster vs. dispersed growth) and habitat (shaded, undeveloped grown in area, recently broken up soil, fertile garden bed soil, on gravel or mulched pathways, etc.)

**PROCEDURE**

**Warm-up**

Entrance Slip- Quick Write: What are the functions of the root? What do we use roots for? What do plants require to live, and which of those requirements do the roots provide?

Briefly introduce the concept of weeds and the images and names of the weeds from the list, but do not discuss the root systems or vegetative reproductive characteristics. Ask the students to spend some time before they go outside thinking of where they see weeds grow (habitat), and how often and what ways they see weeds grow together (dispersal).

**Activity**

The root systems and vegetative reproductive characteristics of common pacific northwest weeds found in gardens:

<table>
<thead>
<tr>
<th>Common name (Latin name)</th>
<th>Root system; and vegetative reproductive characteristics</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Root Type</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Canada thistle <em>(Cirsium arvense)</em></td>
<td>Taproot with extensive lateral roots; deep, broken roots develop new shoots, shoots arise from root buds</td>
<td></td>
</tr>
<tr>
<td>Common chickweed <em>(Stellaria media)</em></td>
<td>Fibrous; roots from nodes on stem</td>
<td></td>
</tr>
<tr>
<td>Creeping wood sorrel <em>(Oxalis corniculata)</em></td>
<td>Taproot; roots from nodes on stem; broken roots can develop new shoots</td>
<td></td>
</tr>
<tr>
<td>Dandelion <em>(Taraxa cum officinale)</em></td>
<td>Taproot; broken roots can develop new shoots</td>
<td></td>
</tr>
<tr>
<td>Plant</td>
<td>Root Characteristics</td>
<td></td>
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<tr>
<td>---------------------------</td>
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<td></td>
</tr>
<tr>
<td>Deadnettle (Lamium purpureum)</td>
<td>Fibrous; roots from nodes on stem</td>
<td></td>
</tr>
<tr>
<td>Field bindweed (Convolvus arvensis)</td>
<td>Taproot with extensive lateral roots; extensive and deep, broken roots develop new shoots, shoots arise from root buds</td>
<td></td>
</tr>
<tr>
<td>Nipplewort (Lapsana communis)</td>
<td>Fibrous</td>
<td></td>
</tr>
<tr>
<td>Redroot pigweed (Amaranthus retroflexus)</td>
<td>Taproot with extensive lateral roots</td>
<td></td>
</tr>
</tbody>
</table>
HANDS ON

Take the students to the garden with notebooks or observation papers and give around 5 minutes for the students to find and attempt to identify weeds that were discussed with the group beforehand. Take another 5 minutes for students to gather observations about weed population dispersal and habitat.

With the class, decide on a handful of weeds to remove from the soil. Identify smaller weeds with more manageable root size, and weeds that may express particularly interesting characteristics (such as a creeping wood sorrel with a runner).

Drive a shovel into the ground a few inches from the weed of interest, and move the shovel back and forth in the soil to loosen up the soil around the root. Grab the plant as low down the stem as possible or even on the root, and gently pry the plant, with as many of the roots as possible, from the soil. If there are runners, take care to remove those gently as well.

At this point, take plants into classroom if that is where the discussion will take place.
Free the roots of loose soil, wipe and rinse off if necessary to better see the root (be aware that fine fibrous roots will clump together when wet, which may make the root system model unusable).

Before discussing the reproductive capabilities of weeds, let students share observations (from the garden or from warm up) about dispersal patterns, make list or diagram dispersal patterns.

Have students brainstorm in groups to list reproductive characteristics, other than seed dispersal, that could have led to the plant dispersal patterns (any one of the vegetative reproductive characteristics found in the table, or others that the students think of).

Come together as class to make a list of the vegetative reproductive characteristics of the garden weeds collected.

Give the groups a minute to remake their list in consideration of any new characteristics identified in the weeds at hand.

As a class, compare student group lists to known characteristics in the table above. Have students share what they guessed correctly and what was incorrect or where information in the table may be insufficient. This activity is a living document, so not only is constructive criticism important for refining this activity; it is an important skill for developing rigorous scientific procedure.
Finally, identify the most commonly shared observations about weed habitat. Talk about what human disturbances have created those environments (e.g. removed trees = no shade, gravel layer, fertilized garden plot, bare soil from bed preparation, bare soil from foot traffic).

**Wrap-up**

This is the time to relate vegetative reproductive characteristics to evolution. Ask what is the advantage of these traits, what factors may have resulted in these species evolving these traits: NGSS HS-LS4-2: (1) the potential for a species to increase in number... (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment].

While acknowledging the hardiness of these weeds root systems and the weed habitats, this is an opportunity to talk to students about ways to reduce weed habitat and prevent weeds in the garden before they develop a complex root system.

**Student Reflection**

Exit Slip:

What ideas do you take away from these experiences that are easily understood?

What is still a little “muddy”... unclear?

> what makes a plant a weed?

> what traits of plant evolution were discussed today [runners and broken taproots]

> despite being troublesome, weeds still do good things for the soil, how so? [role of roots...conclude that roots are important, if cover crops roots are present they inhibit weed growth]

> why is a healthy soil helpful for humans?
### Teacher Reflection/Debriefing

After class, take time for reflection. How did this lesson go?

- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?
### Adaptations

#### To Add Complexity

Once weeds have been identified outdoors, give students a day in the computer lab to create their own weed report. They can choose one weed they encountered in the garden. Have them compile information about the weed’s natural history, the soils and habitats they succeed in (i.e. degraded, quality soils, etc.). Have them report on the economic damage done by these weeds, typical means of eradication (pesticide control), and alternative methods of eradication.

### Recommended Reading

Green Street Stewards Weed Identification Guide:  
http://www.portlandoregon.gov/bes/article/471991

http://articles.extension.org/pages/18529/an-ecological-understanding-of-weeds

### References and Attribution

This lesson researched/designed by: Adriana Escobedo-Land, TSWCD volunteer  
TSWCD Lesson Plan Template Consultant: Jane Wilson, MAT, TSWCD volunteer  
All lesson plans in this curriculum reviewed by: Stephanie Wagner, MS, Portland State University, and the Portland Metropolitan STEM Project.  
Curriculum design funded by the Gray Family Foundation.  
Curriculum design directed and edited by: Jennifer Nelson, MS, OVE Program Manager, TSWCD.
This lesson adapted from:

http://growing-gardens.org/school-garden/weeds%20poster.png
Topic 2: Soil as Habitat

Activity 8: Nitrogen and root nodules

Discipline: Life Sciences

Topic: Cycles of matter and energy transfer in ecosystems

Lesson Length: 60 min

Lesson Designer: Adriana Escobedo-Land

This lesson was adapted in part from the following resources:
For full resources, please see Recommended Reading, References and Attributions.

Activity Description:
Nitrogen is an atom that is present throughout the world. It is a vital plant nutrient that exists in the soil as forms usable and unusable to plants. The process of biological nitrogen fixation puts directly usable nitrogen in the soil. Nitrogen-fixing bacteria are the sole organisms responsible for this process. This activity demonstrates the way that nitrogen moves through the ecosystem, and has students step out of the classroom to find sites of biological nitrogen fixation, in the root nodules of clover. By identifying nodules, nitrogen-fixing bacteria-hosting plant structures, students will learn more about the unseen life in the soil and have a tangible example of a biological symbiosis. This activity is an active way for students to approach the topic of chemical cycling in the ecosystem.
Performance Expectation | Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts
--- | --- | --- | ---
Students who demonstrate understanding can: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. | HS-LS2-4 | LS2.B: Cycles of Matter and Energy Transfer in Ecosystems | Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4)

Soil Health Concepts on the Farm or in the Garden

- **Soils and Nutrients**
  - Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
  - These nutrients are cycled through the Earth’s system in specific ways.
  - Students and teachers should understand the essential nutrient cycles that involve soil, including carbon, nitrogen and phosphorus cycles.
  - Within the soil, these nutrients can be dissolved from the surface of mineral and organic matter by water held within soil pore space. When dissolved in this manner, the nutrients become available for the roots of the plant to absorb.
  - Plants make particular use of nitrogen and phosphorus in the formation of proteins and the reproductive parts of the plant. Students and teachers should understand the reproductive cycle of plants and how this cycle contributes to human agriculture and food supplies.

- **Human Impact on Soil Health and the 4 Principles of Soil Health**
  - All around the world, people live on and work with the soil. Human beings depend on soil in many different ways.
  - As world population and food production demands rise, keeping our soil healthy and productive is important.
  - Soil health is a way of understanding how well soil is functioning to support plants, soil biology, and human needs.
  - Human activity can affect how the soil functions. These activities include farming,
growing, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.

- Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.

- The U.S. Department of Agriculture Natural Resource Conservation Service has identified several principles of soil health that identify how people can harm and help soils through these activities.

  - Principle 1: The surface of the soil should be kept covered by living plants or other materials as much of the year as possible. This protects soil from the erosive force of wind and rain.
  - Principle 2: Soil should be disturbed from human activities such as digging, plowing, disk ing, tilling, etc., as little as possible. Disturbing the soil can destroy the habitat of creatures living in the soil. Disturbing the soil can also increase its vulnerability to the erosive forces of wind and water. Disturbing the soil can result in the loss of organic matter or nutrients.
  - Principle 3: Keep plants growing in the soil year round. These plants provide protection and coverage for the soil (principle 1). They can increase the organic matter in the soil if incorporated into the soil at the end of their life cycle. Some plants fix nitrogen from the air, increasing soil fertility. The living root of plants within the soil produces exudates that increase soil aggregate formation and also provides food and habitat for creatures living in the soil ecosystem.
  - Principle 4: Grow a diverse mix plants to provide a diverse mix of roots underground. This helps prevent erosion due to varying root depth and structure, and provides a variety of food and habitat for creatures living in the soil ecosystem.

- The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.

- People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.

<table>
<thead>
<tr>
<th>Vocabulary- NGSS</th>
<th>Vocabulary- Lesson related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure and function</td>
<td>Microbiology</td>
</tr>
<tr>
<td>Cycling of matter and energy</td>
<td>Nutrients</td>
</tr>
<tr>
<td>Chemical processes</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Molecules</td>
<td>Root nodules</td>
</tr>
<tr>
<td>Ecosystem processes</td>
<td></td>
</tr>
</tbody>
</table>
Materials

- Magnifying glass
- Shovel if collecting root nodules is not a homework assignment

Background

The primary nutrients that plants require—nitrogen, phosphorus, and potassium (N, P, and K)—come from the soil. Each of these nutrients is responsible for different functions in the plant. Nitrogen is a component of many complex and essential molecules, such as chlorophyll and DNA, both of which are necessary for typical plant functions. In soils, nitrogen is naturally made available to plants by the decomposition of plant and animal matter; and by nitrogen-fixing bacteria that transform nitrogen in the air (N₂) into a biologically available form that sticks to the soil (NH₄⁺). Biological nitrogen fixation is just one of many processes in the nitrogen cycle:
The diagram above illustrates the terrestrial nitrogen cycle, which includes the different chemical forms of nitrogen (grey boxes), the name for the chemical and biological processes (grey arrows), the organisms that are responsible for the processes (white boxes), the primary nitrogen inputs into the soil (white boxes), and the movement of nitrogen out of the soil (white arrow). Other significant parts of the cycle not shown here are fossil fuel emissions that release nitrogen into the atmosphere and lightning strikes that add reactive nitrogen to the atmosphere, which can be rained out. Stores of nitrogen exist in different chemical forms and in different areas around the globe.

The processing of chemicals through these areas is called biogeochemical cycling. Humans affect the nitrogen cycle globally through agricultural practices, by changing both the amount and chemical form of nitrogen in each part of the ecosystem. In a school garden, nitrogen can be added to the soil in various ways, by adding manure or compost, or planting nitrogen-fixing cover crops. These techniques can also build up soil carbon level, which improves soil health. Adding only inorganic fertilizer to meet nutrient demands has no beneficial impact on carbon levels, and can reduce soil quality by adding excess salts to the soil. Environmentally damaging forms of nitrogen are those plant available forms (also called reactive nitrogen) in the soil that leach into waterways or volatilize into the air, when there is too much of the nutrient or the soil structure is degraded, which can be the case when soil carbon levels are low. Increasing soil carbon and nitrogen is a concern of most growers, biological nitrogen fixation, the process that the students will learn about today, is an important way to add both chemicals to the soil.

Biological nitrogen fixation relies on nitrogen-fixing bacteria, which often live in association with plants, inside of plant root structures called root nodules. Rhizobia are the particular type of bacteria that elicit and reside in root nodules. Legumes are one of a handful of plant families that makes the root nodules and provides sugars to the bacteria, in exchange for the nitrogen that they fix. “Once the legumes die and decay, the nitrogen compounds become part of the soil’s organic matter”. The nitrogenase enzyme that is responsible for the chemical conversion of dinitrogen (N₂)
to ammonium (NH$_4^+$), requires an low aerobic or anaerobic environment to function. The inside of nodule is an anaerobic space; legume nodules are a pinkish-red color when nitrogen fixation is occurring because they have an extra measure of protection from oxygen, in the form of a reddish colored molecule called leghemoglobin. Fixing nitrogen takes a lot of energy, when enough nitrogen is present in the environment, biological nitrogen fixation will not occur, and legume nodules will appear white. Any legume will work for this activity; clover, however, is easy to find and is likely fixing nitrogen in a school lawn or field.

### What Students Need to Know / This Lesson Builds On…

- Functions of plant roots
- Atoms and molecules, chemical equations

### Lesson Key Ideas and Concepts

- Soil microbiology
- What chemical forms of nitrogen in the environment, what processes cycle the nitrogen through these forms
- Symbioses in the soil (needs of the plants and bacteria)
- Nitrogen, as a cycle, and as a necessary plant nutrient
- Structure and function of root nodules (providing an anaerobic space)

- explain nitrogen fixation
- explain how clover and other legumes fix nitrogen
- demonstrate whether a legume is fixing nitrogen or not.

### Preparation

If time allows and a computer lab is available, let students explore the interactive terrestrial nitrogen cycle model.

If not, use the nitrogen cycle diagram provided to walk through the nitrogen cycle, aided by this article on the nitrogen cycle: http://sciencelearn.org.nz/Contexts/Soil-Farming-and-Science/Science-Ideas-and-Concepts/The-nitrogen-cycle.

**PROCEDURE**

**Activity**

*Find root nodules*

“The gathering of the clover could be a homework activity to give students time to find good samples with large nodules on the roots that can be easily observed. Use a shovel to unearth the roots – you are less likely to break roots off.”

If nodules are to be collected day of on school grounds see if the school garden is using clover as a cover crop, if not there is likely some clover in a school lawn. Clover can be easy to identify by finding the greenest patches in a lawn (nitrogen availability is correlated with chlorophyll production and dark green leaves).

*Examine root nodules*

*Student handout: Nitrogen fixation*

1. Rinse the soil from the roots of your clover and lay on a tray.

2. Look for nodule formations. Remove a few nodules from plant roots.
3. Cut nodules in half with a sharp knife or your fingernail.

4. Determine whether nitrogen fixation is taking place. Use a magnifying glass for close observation. Pinkish-red nodules show that nitrogen fixation is taking place. Brown nodules are mature and ready to fall off the roots. Green or white coloring shows nitrogen is not being fixed.

5. Is nitrogen fixation happening in each of the plants? Did some plants have both red and green/white nodules?" –sciencelearn

6. Make a list of the different habitats where the clover was pulled from. Note the inner nodule color found in the different habitats. Are there clear relationships between nodule color and habitat? Why might this be? What forms of nitrogen might be present in the habitats identified.

7. “Discuss in pairs or as a class how nitrogen fixation helps soil fertility, the leguminous plant and all other plants. What are some reasons why nitrogen fixation does not occur?”

Discuss BNF equation in context of soil nitrogen cycle

\[ \text{N}_2 + 8\text{e}^- + 8\text{H}^+ + \text{ATP} \rightarrow 2\text{NH}_3 + \text{H}_2 + 16\text{ADP} + 16\text{Pi} \]

- What is the initial chemical reactant, where does rhizobia source nitrogen [\text{N}_2 in the air]
- The product of nitrogen cycle is shown as both \text{NH}_3 and \text{NH}_4^+, discuss where the other hydrogen comes from [the acidic environment of the soil!].
- What other forms of nitrogen in the cycle contain protons (\text{H}^+)?
- What are the reactive and unreactive forms of nitrogen in the equation (what’s the difference between the two) [see bond strength, triple bond of N2, see nitrogen cycle article for a table]
### Student Reflection

**Exit Slip:**

What ideas do you take away from these experiences that are easily understood?

What is still a little “muddy”… unclear?

### Teacher Reflection/Debriefing

After class, take time for reflection. How did this lesson go?

- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

### Adaptations

**To Add Complexity**

If your classroom has the capacity for aseptic culturing of bacteria, the *Rhizobium* from the nodules can be easily isolated on mannitol yeast extract agar plates (this media can be purchased as a prepared dry powder from online suppliers, or made in the classroom). Resources for making the media and a basic protocol for culturing *Rhizobium* are available online, and here:


### Recommended Reading

- [http://forages.oregonstate.edu/nfgc/eo/onlineforagecurriculum/instructormaterials/availabletopics/nitrogenfixation/definition](http://forages.oregonstate.edu/nfgc/eo/onlineforagecurriculum/instructormaterials/availabletopics/nitrogenfixation/definition)

### References and Attribution

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This lesson adapted from:

# Topic 3: Human Impact

**Activity 9: How Will the Garden Grow? Think about design.**

**Activity Description:**
This lesson asks students to identify a problem caused by the location of a garden that influences soil health. Students will observe plant traits for signs that show they are stressed and not doing well. The garden cannot be moved to another more suitable location.

*This activity is designed for a school with an existing garden. Can follow up with Activity 10 with slight modification to assess how to solve the problem within the garden.*

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who demonstrate understanding can:</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>LS3.B: Variation of Traits</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.</td>
<td>Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2)</td>
<td>The environment also affects the traits that an organism develops. (3-LS3-2)</td>
<td>Cause and effect relationships are routinely identified and used to explain change. (3-LS3-2)</td>
</tr>
</tbody>
</table>
Soil composition is an important part of deciding where to place a garden. How are plant traits influenced by changes in soil composition?

- Traits
- Environment
- Characteristics
- Cause and Effect
- Change

Video:

Soil Health Concepts on the Farm or in the Garden

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
  - Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.
  - Plant roots extract these nutrients and water from soil for use in growth and energy production.
  - Plants store energy within their roots in the soil.
  - Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.

Background

It is easy to become frustrated when the garden is not doing well. Plants may appear droopy, have damaged leaves, or may not produce the fruits or vegetables we want.

Some problems in the garden related specifically to soil health. Before we tear out a garden and start over, we can assess the health of the plants and the soil in order to
determine what can be fixed.
This lesson will take students through the act of assessing plant health for clues to soil health. Here are some of the signs of plant health that are associated with soil health:

**Poor Soil Drainage:** Gardening, especially if you are growing fruits and vegetables, takes a lot of water to be productive. You may think a constantly wet soil consistency is the best condition for your plants, but soils that retain water like a sponge and do not allow it to drain steadily create an environment that encourages root rot and possible plant death. Pay close attention to your garden so you know if you have poor soil drainage. Your plants are one of the best indicators of poor soil conditions. Their growth is directly influenced by the water flow within soil pockets. The foliage may begin to look stunted compared to past growth. If you look closely at the leaf, the green may have a yellow tone along the edges and markings can stretch out across the leaf surface, affecting the plant's photosynthesis processes. Poor soil drainage that is not remedied will eventually cause leaves to fall off and the stems and limbs will die back. Unless you have planted moss purposely within the garden, its presence is a key indicator of poor soil drainage. Typical moss species enjoy wetland conditions; water is practically stagnant where they proliferate. If you find moss growing around your garden, remove it. Once you have removed it, amend the soil so it can drain better. The moss will return if you have not fixed the problem.


**Foliage color and growth:** A plant leaf can tell a lot about the health of a plant. Shriveled or pale leaves could be indicative of a problem. If the plant looks sickly, soil might need to be modified or the problem may lie inside of the plant itself. Take a clipping of a poorly growing plant and place it in a glass of water. If the water becomes cloudy or milky, there may be a bacterial problem. If the water remains clear, the plant may have a virus. The presence of fuzz or hairs growing on leaves could indicate the presence of a fungus.

Unless you are planting heirlooms, beware of unexpected colors on the leaves of your vegetables. If the lower leaves of a plant begin to yellow, it is usually a sign that the plant has exhausted the available nitrogen. By letting the lower leaves die, the plant is prioritizing which leaves are most important for photosynthesis. You do not want a plant to make that choice. Sometimes, the nutrients are in the soil, but unavailable because of the soil’s temperature. If your plants look purple, they are likely suffering from a deficiency of phosphorus. Oftentimes that does not mean the phosphorous is absent in the soil, but that the ground might be too cold for the plant to process the stuff. Try using some mulch to warm things up.


**Disease:** Even with flaky, dark soil in your garden, pests and plant ailments are still a fact of life, says Littlefield. “You could have the best soil in the world, and you’re still going to have some insects and diseases,” Littlefield says. “The Japanese Beetles are going to come and eat your roses no matter what you do.” Nothing will thwart a swarm of locusts, but if your garden gets hit hard by pests or disease, it may be a sign that your plants are stressed. Plants have immune systems, just like humans, with built-in defenses like chemicals and thick skin to stop pests and diseases. But if the plant isn’t getting what it needs, it can become thin-skinned and unable to defend itself. Littlefield cites the white birch tree as an example. In its natural forest habitat, the birch successfully fends off attacks from the Bronze Birch Borer, an insect that burrows into birches and lays eggs; the larvae eat their way into the tree. In a healthy birch, the larvae drown in the tree’s robust sap. But birches planted in the midst of a lawn are stressed and don’t produce the same flow of sap. The larvae survive and kill the tree. If your garden often gets wiped out with whatever’s going around, it’s a good indication you need to work on your soil health.


**Flowers:** Certainly there are low-maintenance plants that do not produce flowers, but relying only on these plants in your garden can prove troublesome over the long haul. Bees, birds and butterflies are attracted to sweet, flowering plants. These animals and insects are essential to pollination, and without them the garden cannot procreate. A
thriveing garden is one that has a mix of plants, including some flowering varieties that will keep birds, butterflies and bees coming back again and again.


**Minimal weeds:** If the only thing you’re growing is weeds, then there is a problem in the garden. Weeds tend to be more tolerant of poor soil conditions and can quickly take over and force other plants out. Planting ground cover and using mulch is a natural way to keep weeds at bay. You may need to do some manual work on your hands and knees and pull out weeds as well. The fewer the weeds, the more likely your plants will grow tall and full.


### Preparation

1. Provide students with a way to record and compare what they learn – a data sheet, a log book, a poster board, etc.

### PROCEDURE

**Activity**

This activity can be divided into several days or several of the tests can be combined into one or more days. Instruct students to make observations of the following tests, and allow a time in the classroom for groups to evaluate what they have learned and select a garden plot location based on it.

**Warm-Up: Assessing plant health in the garden**

In the classroom, ask students to talk about what makes a good, healthy garden. What do plants look like when they are doing well? What do they look like when they are doing poorly? What are the goals for the garden – are the plants producing enough fruits and vegetables? Are there enough blooms to feed pollinators? Does the foliage
of the plants look attractive? Are there many pests? Does the garden often need watering?

The class may benefit from watching a short video such as the one here about diagnosing problems in plants:

https://www.youtube.com/watch?v=uxCddjkg0Bc

This video is also a good way to introduce careers in soil and plant health.

Activity

Following this discussion, spend some time teaching the class about some of the signs of poor plant health (information available at http://extension.psu.edu/pests/plant-diseases/all-fact-sheets/diagnosing-poor-plant-health). See next page for handout.
<table>
<thead>
<tr>
<th>What went wrong</th>
<th>Look for</th>
<th>Why</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly planted plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeds did not emerge</td>
<td>Soil that is too compact</td>
<td>New plants cannot push out roots or break through surface</td>
</tr>
<tr>
<td></td>
<td>Rot</td>
<td>Fungus may have rotted the seed (soil too wet)</td>
</tr>
<tr>
<td></td>
<td>Very wet soil</td>
<td>Leads to rot</td>
</tr>
<tr>
<td></td>
<td>Very dry soil</td>
<td>Not enough moisture for seed to break casing</td>
</tr>
<tr>
<td>After seeds emerged, plants don’t grow</td>
<td>Soil without enough nutrients</td>
<td>New plant does not have enough nitrogen, phosphorus or potassium (N-P-K) to develop new tissues</td>
</tr>
<tr>
<td>After seeds emerged, plants were swollen, twisted, distorted</td>
<td>Herbicide in the soil (ask about past use)</td>
<td>Herbicides can affect the expression of plant genetic material and lead to deformed development</td>
</tr>
<tr>
<td>Leaf tip burn</td>
<td>Ask about high use of fertilizer</td>
<td>Too much fertilizer can prevent plants from developing efficiently</td>
</tr>
<tr>
<td></td>
<td>Ask about pesticide spray</td>
<td>Can damage plant tissues</td>
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<tr>
<td>Established plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellowing leaves/plant</td>
<td>Test soil for nutrients</td>
<td>Plant does not have sufficient nutrients, iron or manganese</td>
</tr>
<tr>
<td></td>
<td>Ask about high use of fertilizer (young leaves)</td>
<td>Too much fertilizer can prevent plants from developing efficiently because of imbalances</td>
</tr>
<tr>
<td></td>
<td>Test soil for nutrients (older leaves)</td>
<td>Not enough nitrogen, magnesium or potassium</td>
</tr>
<tr>
<td></td>
<td>Ask about watering schedule</td>
<td>Overwatering can drown roots and make it difficult for plants to uptake nutrients. Can also lead to root rot.</td>
</tr>
<tr>
<td>What went wrong</td>
<td>Look for</td>
<td>Why</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
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<tr>
<td>Dead or yellow round spots on leaves</td>
<td>Ask about pesticide spray</td>
<td>Can damage plant tissues</td>
</tr>
<tr>
<td></td>
<td>Have soil tested for fluoride</td>
<td>Can damage plant tissues</td>
</tr>
<tr>
<td>Dead or yellow irregular spots or flecks</td>
<td>Ask about pesticide spray</td>
<td>Can damage plant tissues</td>
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<tr>
<td></td>
<td>Test soil for heavy metals</td>
<td>Air pollution can also damage plant tissues</td>
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<td></td>
<td>Test temperature of irrigation</td>
<td>Cold water can damage plant tissues</td>
</tr>
<tr>
<td></td>
<td>water</td>
<td></td>
</tr>
<tr>
<td>Mosaic pattern of light and dark green</td>
<td>Test soil temperature</td>
<td>High temperatures can damage plant tissues</td>
</tr>
<tr>
<td></td>
<td>Ask about pesticide spray</td>
<td>Pesticides can damage plant tissues, even if they were applied in previous years.</td>
</tr>
<tr>
<td>Leaves with abnormal color pattern</td>
<td>Red or purple leaves</td>
<td>Can indicate a deficiency of nutrients</td>
</tr>
<tr>
<td>Leaves very dark green with water soaked, limp</td>
<td>Bacterial infection</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
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<tr>
<td>appearance</td>
<td></td>
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<tr>
<td>Leaf tips and margins dead</td>
<td>Overfertilization</td>
<td>Too much fertilizer can prevent plants from developing efficiently because of imbalances</td>
</tr>
<tr>
<td></td>
<td>Underwatering</td>
<td>Plants need water to move nutrients through vascular tissues, to grow new tissue and for respiration.</td>
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<tr>
<td></td>
<td>Pesticide damage</td>
<td>Pesticides can damage plant tissues, even if they were applied in previous years.</td>
</tr>
<tr>
<td>What went wrong</td>
<td>Look for</td>
<td>Why</td>
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<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Leaf tips and margins dead (continued)</td>
<td>Vascular wilt disease</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Leaves too small</td>
<td>Too much or too little fertilizer</td>
<td>Too much/little fertilizer can prevent plants from developing efficiently because of imbalances.</td>
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<td></td>
<td>Root rot</td>
<td>Roots that are too wet are susceptible to diseases and rotting.</td>
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<tr>
<td>Leaves very brittle</td>
<td>Minor nutrient deficiency</td>
<td>Nutrient deficiencies can prevent plants from developing efficiently because of imbalances.</td>
</tr>
<tr>
<td>Leaves falling off</td>
<td>Overfertilization</td>
<td>Too much fertilizer can prevent plants from developing efficiently because of imbalances</td>
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<tr>
<td></td>
<td>Overwatering</td>
<td>Roots that are too wet are susceptible to diseases and rotting. Too much water can damage roots, displace air in soil.</td>
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<td>Pesticide damage</td>
<td>Pesticides can damage plant tissues, even if they were applied in previous years.</td>
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<td>Root rot</td>
<td>Roots that are too wet are susceptible to diseases and rotting.</td>
</tr>
<tr>
<td></td>
<td>Natural cycle of plants</td>
<td>Sometimes leaves fall off of healthy plants!</td>
</tr>
<tr>
<td>Leaves wilted</td>
<td>Overwatered (soggy soil; algae on soil surface)</td>
<td>Roots that are too wet are susceptible to diseases and rotting. Too much water can damage roots, displace air in soil.</td>
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<tr>
<td></td>
<td>Underwatered</td>
<td>Plants need water to move nutrients through vascular tissues, to grow new tissue and for respiration.</td>
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<td>What went wrong</td>
<td>Look for</td>
<td>Why</td>
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<td>-----------------------------------------------</td>
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</tr>
<tr>
<td>Leaves wilted (continued)</td>
<td>Stem rot</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Leaves with white powdery growth on surface</td>
<td>Powdery mildew</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Leaves with black growth in patches in general over surface</td>
<td>Sooty mold</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Stem tips too small</td>
<td>Nutrient deficiency</td>
<td>Nutrient deficiencies can prevent plants from developing efficiently because of imbalances.</td>
</tr>
<tr>
<td></td>
<td>Too much herbic peace</td>
<td>Herbicides can stunt/alter plant growth. Some herbicides build up in the soil.</td>
</tr>
<tr>
<td>Too many stem tips</td>
<td>Too much herbic peace</td>
<td>Herbicides can stunt/alter plant growth. Some herbicides build up in the soil.</td>
</tr>
<tr>
<td>Stems rotted at soil line</td>
<td>Fungal or bacterial disease</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td></td>
<td>Overwatering</td>
<td>Roots that are too wet are susceptible to diseases and rotting. Too much water can damage roots, displace air in soil.</td>
</tr>
<tr>
<td>Stems rotted above soil line</td>
<td>Fungal or bacterial rot</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Stem tips dead</td>
<td>Overfertilization</td>
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<td>---------------------------------------------</td>
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<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Stem near soil line abnormally swollen and galled</td>
<td>Crown gall bacterium infection</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Stem near soil line with abnormal 'cauliflower' growth</td>
<td>Bacterial fasciation infection</td>
<td>Poor soil health can make plants more susceptible to diseases</td>
</tr>
<tr>
<td>Excessively slow growth</td>
<td>Soil too compact</td>
<td>Lack of pore space for air and water; difficult for plant roots to push through soil.</td>
</tr>
<tr>
<td>Excessively slow growth</td>
<td>Poor fertilization or watering schedule</td>
<td>Too much/little fertilizer can prevent plants from developing efficiently because of imbalances. Too much water can damage roots, displace air in soil. Too little water is a problem because plants need water to move nutrients through vascular tissues, to grow new tissue and for respiration.</td>
</tr>
<tr>
<td></td>
<td>Root rot</td>
<td>Roots that are too wet are susceptible to diseases and rotting.</td>
</tr>
</tbody>
</table>
### Wrap-up

Quick review summary of lesson key ideas/concepts.

- How can we tell is a plant has the proper requirement to survive and flourish?
- What signs of poor plant health are also signs of poor soil health?
- What can we change about the condition of the soil to improve its health?
- What can we change about how we take care of the garden to improve soil health.

### Student Reflection

Exit Slip:

What ideas do you take away from these experiences that are easily understood?

What is still a little “muddy”… unclear?

### Teacher Reflection/Debriefing

After class, take time for reflection. How did this lesson go?

- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

### Adaptations

**To Simplify**

This activity can be simplified by reducing the number of indicators of poor plant health the students are looking for. You may want to scout the garden ahead of time to determine what problem signs they are most likely to see. You can then narrow down
the list of problem signs they will learn about to fit just those that are present.

To Add Complexity

Have students prepare a report on the what signs of plant problems they saw in the garden and recommend solutions (changes to the soil or changes to gardening practices).

As a class, select which changes you will test. Set up control (do nothing) and experimental (one change) plots with the same plants. Keep all other practices the same except the one you are testing. Repeat this activity to assess plant health when seedling emerge, midway through the growing season, and at harvest. Have students assess what worked and what didn’t, and update their recommendations accordingly.

References and Attribution

This lesson researched/ authored by: Jane Wilson TSWCD volunteer; completed by Jen Nelson, TSWCD.

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

https://www.rain.org/global-garden/soil-types-and-testing.htm


http://www.rodalesorganiclife.com/garden/10-easy-soil-tests

http://extension.psu.edu/pests/plant-diseases/all-fact-sheets/diagnosing-poor-plant-health
Topic 3: Human Impact

Activity 10: How will the garden grow? Think about location!

Discipline: Life Science

Topic: Heredity: Inheritance and Variation of Traits

Lesson Length:

Activity Description:
Builds on knowledge children learned in 3-LS3-1 that flowering plants have traits inherited from parent plants through seeds. In this lesson, students will investigate how a plant’s environment, specifically the location of a garden, can also have an effect on plant traits. The focal point in this investigation is soil and how location impacts soil composition.

This lesson is designed for schools that are just starting a school garden.

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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</thead>
<tbody>
<tr>
<td>Students who demonstrate understanding can:</td>
<td>Constructing Explanations and Designing Solutions</td>
<td>LS3.B: Variation of Traits</td>
<td>Cause and Effect</td>
</tr>
<tr>
<td>3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.</td>
<td>Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2)</td>
<td>The environment also affects the traits that an organism develops. (3-LS3-2)</td>
<td>Cause and effect relationships are routinely identified and used to explain change. (3-LS3-2)</td>
</tr>
</tbody>
</table>
### Common Core Standards Integration: ELA/ Literacy

**RI.3.7** Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur). (3-LS1-1)

**SL.3.5** Create engaging audio recordings of stories or poems that demonstrate fluid reading at an understandable pace; add visual displays when appropriate to emphasize or enhance certain facts or details. (3-LS1-1)

**RI.3.1** Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-LS3-1),(3-LS3-2)

**RI.3.2** Determine the main idea of a text; recount the key details and explain how they support the main idea. (3-LS3-1),(3-LS3-2)

**RI.3.3** Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-LS3-1),(3-LS3-2)

**W.3.2** Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-LS3-1),(3-LS3-2)

**SL.3.4** Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (3-LS3-1),(3-LS3-2)

### Common Core Standards Integration: Mathematics

**MP.4** Model with mathematics. (3-LS1-1)

**3.NBT** Number and Operations in Base Ten (3-LS1-1)

**3.NF** Number and Operations—Fractions (3-LS1-1)

**MP.2** Reason abstractly and quantitatively. (3-LS3-1),(3-LS3-2)

**MP.4** Model with mathematics. (3-LS3-1),(3-LS3-2)

**3.MD.B.4** Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the
horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. (3-LS3-1),(3-LS3-2)

<table>
<thead>
<tr>
<th>Standards Driven Questions</th>
<th>Vocabulary- NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>The location of a garden impacts soil composition. How are plant traits influenced by changes in soil composition?</td>
<td>• Traits</td>
</tr>
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<td>• Environment</td>
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<td>• Characteristics</td>
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<td>• Cause and Effect</td>
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<td></td>
<td>• Change</td>
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</tbody>
</table>

**Materials**

Video:


Materials:

- A data sheet, a log book, a poster board, etc. for recording observations.
- A large, empty coffee can for each group
- Permanent marker
- Tin snips
- A length of 2x2 inch wood for each group that will fit across can
- A mallot for each group
- A gallon jug of water for each group
- Wire flags
- Hand trowels and/or shovels
Soil Health Concepts on the Farm or in the Garden

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
  - Plant health is also dependent on several micronutrients derived from soil to support plant structure and development.
  - Plant roots extract these nutrients and water from soil for use in growth and energy production.
  - Plants store energy within their roots in the soil.
  - Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.

Background

Background Essay information source:
http://opb.pbslearningmedia.org/resource/thnkgard.sci.ess.location/think-garden-location-location/

Gardening Essentials

Location

Choosing the location of the backyard garden is a critical decision for its health. Since plants cannot move, they are limited to the benefits their location naturally offers, plus whatever the gardener can do to help them thrive.

A garden is part of an active habitat. Deer, raccoons, opossums, squirrels and some pets will consume garden plants. Planting near a flower garden attracts pollinators, while planting near a doghouse may attract a digger. Successful gardeners must understand the other participants in their garden’s habitat.

Natural conditions such as soil, sun, and weather determine the quality of life in an ecosystem. Knowledge of the needs of individual plants helps drive decisions. Some
plants—like lettuce—thrive in partial shade. Others—hot peppers and tomatoes, for example—benefit from 8-10 hours of sunlight each day. Blueberries, like azaleas, prefer 50 percent shade and acidic soil. Some people prevent damage from frost, hail, or drought by planting in beds where a hoop house frame can be easily constructed. An understanding of local weather patterns, plant life cycles, and optimal growing conditions helps inform the decision regarding location.

Other considerations also should be taken into account in choosing the garden’s location. If the garden is easy to get to, that will contribute directly to its health. Sources of water, access to tools, and distance from the home or school should factor into the decision. Current and future plans for land use are also important. For example, choosing a school garden right next to the playground or future building site may literally stomp out chances for success.

A school or home garden can fit into a variety of settings, from large plots to raised beds to containers, each offering opportunities for learning and enjoyment and each demanding different levels of effort for success.

**The Importance of Water**

One of the most important considerations for garden locations is the proximity of water. To make sure water remains plentiful and unpolluted, gardeners follow sustainable practices like using rain barrels and drip irrigation; planting rain gardens; relying on rain gauges to determine if and when they need to water; and choosing native and other plants that are adapted to their region’s climate and growing conditions.

The role of water in plant health reveals much about photosynthesis, plant structure, and life cycles. The unique function of plants in making their own food depends upon regular access to water. The very structure of the plant from root to leaf allows for the entry, movement, and processing of water. Examining the importance of water to plants emphasizes the essential role of water to all life.

There are several ways that water supports life through plants. It holds up the plant
and contributes to the plant’s structure. It is essential to photosynthesis and to the transport of glucose, the food created through photosynthesis, throughout the plant. It also is essential to the transport of nutrients like phosphorus from the soil and roots to the rest of the plant. And plants participate in the water cycle by using and releasing water molecules into the environment.

**Soil Composition**

Much of the health and success of a garden depends upon the soil. The roots of a plant work like a sponge soaking in water and nutrients from the soil. If the soil does not drain well, heavy rain will drown the plants. If the soil is compacted, plants will struggle to form roots. When nutrients are deficient in the soil, there are consequences for the plant. Luckily, there are several methods of preparing and enriching a garden’s soil that improve soil quality and the chance of success.

Scientists have identified 14 key plant growth nutrients in soil, including both macronutrients (those that are required in greater quantities) and micronutrients (those that are required only in smaller amounts).

Nitrogen (N), phosphorus (P), and potassium (K) are identified as primary macronutrients because they are often depleted in soils and need to be replenished for plants to thrive. The secondary macronutrients are calcium (Ca), magnesium (Mg), and sulfur (S). These chemical nutrients usually are present in large enough quantities that gardeners don’t need to add them to soil.

The most important micronutrients are boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo), and zinc (Zn).

All soil is not the same. A soil test reveals what nutrients are present and which ones need to be added. Earthworms—which enrich and aerate soil as decomposers that break down dead or decaying matter—are another indicator of healthy soil.

One step that the gardener may take to improve soil quality is using compost. Potato peelings, coffee grounds, and eggshells are just a few of the items that can go into a compost pile. After several months of decomposition, compost turns into a rich, black
material that looks like dirt. It can be added to soil before planting or placed around the plant as mulch. Either way, the soil is enriched.

**Preparation**

1. Scout your school for potential garden locations before hand. Keep in mind safety factors such as vehicle traffic, visibility of location from school, access for emergency vehicles, suitability for walking/handicap access, etc., as well as practical concerns such as access to water for crops. Because this lesson focuses on soil, be sure to take into account access to light as well.

2. Select one or more potential garden locations that students can compare and contrast.

3. Read through full lesson and prepare soil health test kits (see sections marked with PREPARE).

4. Provide students with a way to record and compare what they learn – a data sheet, a log book, a poster board, etc.

**PROCEDURE**

**Activity**

This activity can be divided into several days or several of the tests can be combined into one or more days. Instruct students to make observations of the following tests, and allow a time in the classroom for groups to evaluate what they have learned and select a garden plot location based on it.

A good preparation for this activity would be to have students think about what plants they want to grow in the garden. Student can research those plants or the teacher can provide them information about what kind of soil conditions are best for the plants they want to grow. Later, students will use this information to assess which of location is best for the plants they want to grow.

**Test 1: Infiltration Rate and Compaction**
To be healthy, a soil needs to be able to breath and water needs to be able to move through it reasonably easily. Compacted soils don't allow much air to circulate to the root zone and water (rainfall or irrigation) tends to just run-off. This increases erosion and strips away vegetation and topsoil. A normal, loosely compacted soil helps to absorb and retain water, releasing it slowly, and allows the root zone of plants to "breath". These soils are generally more productive, since plants can grow much more readily. Dense, highly compacted soils typically have less plant growth, which increases runoff.

- Prepare students by discussing why plants need water and how water enters into the soil.
- Students should form a guess/hypothesis about the qualities of soil that allow water to reach the roots of plants.

Procedure for infiltration test:

- **PREPARE**: First, get a large, empty coffee can and cut off the bottom.
- **PREPARE**: Second, beginning about 3" up from the bottom, mark the inside of the can every ½" with a permanent marker, being careful not to cut your hand on the edges of the can.
- Drive the can about 3" into the ground until the first mark is level with the ground (placing a board on the top of the can and pounding the board with a hammer will help drive the can into the ground. Be careful not to irrigate the area first, since this will prevent you from getting an accurate measurement of the infiltration rate.)
- Fill the can with water clear to the top and begin timing the rate of infiltration. Measure the amount of water that has drained into the soil at the end of each minute for the first ten minutes. Determine the rate of infiltration in inches per minute by dividing the total number of inches of water that drained away in the can by 10 minutes. Knowing the actual water infiltration rate for your soil is critical if you want minimize the amount of water you use.
- Repeat the experiment at several areas around your school, being careful to record each location and its infiltration rate. If the infiltration rates at each location vary considerably, then draw a quick sketch of area, and plot the infiltration rate for that
area. If you install an automated sprinkler system, you can adjust the emitters in each area to only deliver the amount of water that can infiltrate in a given amount of time. This will eliminate irrigation run-off from your garden, while ensuring adequate soil moisture for plants.

**Simple Compaction Test**

Plunge a wire flag vertically into the soil at different locations. Mark the depth at which the wire bends. The sooner it bends, the more compacted the soil. A foot or more of easily penetrable soil is ideal.

**Test 2: Soil Texture and Composition**

Ask students to bring in soil samples from home or collect samples from your schoolyard. Give them a chance to investigate the soil with a plastic spoon and a hand lens. Ask: What is soil? Can you identify different components of the soil? What does it look, smell and feel like? Do all of our samples look identical? How are they the same? How are they different?

**Procedure:**

- Share information about the components of soil and how the amount of sand, silt and clay present effects growing conditions for plants.
- Use the ribbon test to estimate the amount of each component in your soil samples. First, take a small clump of soil and add water until it makes a moist ball.
- Rub the soil together between your fingers. If the soil makes a nice, long ribbon, then it has a lot of clay in it (thus sticks together well). If it crumbles in your hand, then it has a lot of sand. If it is somewhere in between, then you probably have a good mix (a soil with a good mix of all 3 components is called a loam).
- Ask students to estimate what percentage of each component they think is present. Explain that the ribbon test may not be exact, but scientist may use it in the field to create a general description of a soil since it is very easy to implement (all you need is a little water).
Students can consider what types of plants they want to grow and research the soil type requirements for those plants.

**Test 3: Structure and Tilth**

Plants benefit from soil that has ample pore space for the movement of air and water, and lots of organic matter for structure and to feed creatures living in the soil. Open, porous soils allow the free movement of water and oxygen, so plants can develop strong, healthy roots.

**Procedure**

When the soil is neither too wet nor too dry, dig a hole 6 to 10 inches deep. Separate an intact section about the size of a soup can and break it apart with your fingers. Determine whether the soil is cloddy, powdery, or granular. Ideally, your soil should be made up of different sized crumbs that will hold their shape under slight pressure. Crumbs, or aggregates, as soil scientists call them, that break apart only with difficulty mean your soil is too hard.

**Test 4: Assessing the soil food web**

A thriving population of diverse fungi, bacteria, insects, and invertebrates is one of the most visible signs of soil quality. The more that creeps and crawls under your garden, the less opportunity there is for pests and disease. Each level of soil life does its part to break down plant residue and make more nutrients available for plant growth. Not only do earthworms aerate the soil, but their casts infuse the soil with enzymes, bacteria, organic matter, and plant nutrients. They also increase water infiltration and secrete compounds that bind soil particles together for better tilth.

**Procedure:**

Measure the animal life in your soil by digging down at least 6 inches and peering intently into the hole for 4 minutes. Tick off the number and species of each organism observed, such as centipedes, ground beetles, and spiders. Because most soil organisms spurn daylight, gently probe the soil to unearth the more shy residents. If
you count less than 10, your soil does not have enough active players in the food chain.

When the soil is not too dry or wet, examine the soil surface for earthworm casts and/or burrows. Then dig out 6 inches of soil and count the number of earthworms squirming on the shovel. Three worms are good; five are better. The absence of worms means the soil does not have enough of the organic matter they feed on.

**Test 5: Seeking organic matter**

**Procedure:**

The easiest of the three tests for soil health, students should be instructed to observe the soil they have dug up for the previous tests or by digging a fresh hole.

Dig down 6 inches 1 month after turning it into the soil and then look for plant matter. The range of organic material is important to notice here. The presence of recognizable plant parts as well as plant fibers and darkly colored humus indicates an ideal rate of decomposition.

**Wrap-up**

Quick review summary of lesson key ideas/concepts.

- Why is it important to have good infiltration of water into the soil? What happens to water that does not infiltrate?
- Why do the creatures living in the soil matter for a healthy garden?
- What is the role of organic matter in healthy soil?

**Student Reflection**

Exit Slip:

What ideas do you take away from these experiences that are easily understood?

What is still a little “muddy”… unclear?
### Teacher Reflection/Debriefing

After class, take time for reflection. How did this lesson go?
- Celebrate what went well.
- What could be improved or eliminated?
- What re-teaching or reinforcement of ideas is needed?

### Adaptations

#### To Simplify

*Infiltration*: This activity can be simplified by making it less quantitative. Students can be instructed to dig shallow holes of roughly 6 inches in diameter and 6 inches in depth. They can proceed by pouring equal amounts of water into the holes and timing how long infiltration takes. To keep it simple, students can skip calculating the infiltration rate and simply compare their observation of how long infiltration took.

#### To Add Complexity

PBS offers additional resources in the Think Garden series that can be developed into excellent lessons of this type:

**Soil Composition**


**The Importance of Water**


**Plant Structure**

[http://opb.pbslearningmedia.org/resource/5dea21b4-6c92-46ff-982c-8650f9429c01/think-garden-plant-structure/](http://opb.pbslearningmedia.org/resource/5dea21b4-6c92-46ff-982c-8650f9429c01/think-garden-plant-structure/)
Cool Crops


What’s a Food Chain?


Garden Health and Maintenance


Sustainable Gardening


References and Attribution

This lesson researched/ authored by: Jane Wilson TSWCD volunteer; completed by Jen Nelson, TSWCD.

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, OVE Program Manager, TSWCD.

This lesson adapted from:

https://www.rain.org/global-garden/soil-types-and-testing.htm


http://www.rodalesorganiclife.com/garden/10-easy-soil-tests
Topic 3: Human Impact

Activity 11: Human impact on soil pore space and moisture content

Discipline: Physical science
Topic: Structure of matter
Lesson Length: 90 minutes
Lesson Designer: Adriana Escobedo-Land

Activity Description:
One of the most important functions of soil is to hold air and water. The area where air and water is held in soils is called the pore space. Pore space is a function of soil structure, which is dependent on soil texture and soil organism activity. Students can quantify pore space by calculating the soil moisture content of samples from the school garden. The students can use these tests as a way to compare water-holding capacity of the soils of their school garden to the soils of degraded areas. If results are reproducible, these tests could be used to inform school garden practices, related to soil and water conservation.

NGSS Aligned Standards Overview, STEAM Connections and Soil Health Concepts

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
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<tbody>
<tr>
<td>Students who demonstrate understanding can:</td>
<td>HS-PS1-3 (structure and interaction of bulk matter, electrical forces - ionic forces)</td>
<td>HS-ESS3-4</td>
<td></td>
</tr>
</tbody>
</table>
STEAM Connections - Arts Integration:

Use the parameters and scale provided to design a model soil aggregate.

http://docs.rwu.edu/cgi/viewcontent.cgi?article=1073&context=fcas_fp

Learning Goals and Objectives

- Basics of Soil Structure
  - Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface.
  - Eroded mineral material from the Earth’s surface is one component of soil.
  - Eroded mineral material in soil can be divided into three sized particles: sand, silt, and clay.
  - Healthy soil consists of a balance of eroded mineral particles and organic matter.
  - Together, soil particles and organic matter can be formed into small and larger clumps called aggregates, which resist erosive force better than soil particles alone.
  - These particles and organic matter form a structure to soil.
  - The structure of soil consists of solid materials and the pore spaces between them.
  - These pore spaces may be filled with water or air.
  - The volume of water that can be held in the pore space of a soil is called its holding capacity.

- Soil as Habitat for Plants
  - Terrestrial plants root themselves in soil.
  - To survive, terrestrial plants create their own source of energy (sugars) using inputs of sunlight, atmospheric carbon, and water derived from the soil.
  - Plant roots extract these nutrients and water from soil for use in growth and energy production.
  - Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.
  - Plant exudates contribute to formation of stable soil aggregates.

- Soils and Nutrients
  - Plants require nitrogen, phosphorus and other nutrients available in solution for support of their growth.
  - Within the soil, these nutrients can be dissolved from the surface of mineral and organic matter by water held within soil pore space. When dissolved in this manner, the nutrient become available for the roots of the plant to absorb.

- Human Impact on Soil Health and the 4 Principles of Soil Health
  - All around the world, people live on and work with the soil. Human beings depend on
soil in many different ways.

- Human activity can affect how the soil functions. These activities include farming, gardening, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.
- Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.
- The U.S. Department of Agriculture Natural Resource Conservation Service has identified several principles of soil health that identify how people can harm and help soils through these activities.
  - Principle 2: Soil should be disturbed from human activities such as digging, plowing, diskng, tilling, etc., as little as possible. Disturbing the soil can destroy the habitat of creatures living in the soil. Disturbing the soil can also increase its vulnerability to the erosive forces of wind and water. Disturbing the soil can result in the loss of organic matter or nutrients.
  - Principle 3: Keep plants growing in the soil year round. These plants provide protection and coverage for the soil (principle 1). They can increase the organic matter in the soil if incorporated into the soil at the end of their life cycle. Some plants fix nitrogen from the air, increasing soil fertility. The living root of plants within the soil produces exudates that increase soil aggregate formation and also provides food and habitat for creatures living in the soil ecosystem.
  - Principle 4: Grow a diverse mix plants to provide a diverse mix of roots underground. This helps prevent erosion due to varying root depth and structure, and provides a variety of food and habitat for creatures living in the soil ecosystem.
- Permaculture is a form of gardening and farming that utilizes plants which produce fruits for harvest where the plant itself is never or rarely harvested, eliminating or severely limiting all soil disturbance.
- People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and diverse rotations.

<table>
<thead>
<tr>
<th>Vocabulary- NGSS</th>
<th>Vocabulary- Lesson related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Porosity</td>
</tr>
<tr>
<td>Electrical forces</td>
<td>Soil moisture</td>
</tr>
<tr>
<td>Human activity</td>
<td>Keep it covered</td>
</tr>
<tr>
<td></td>
<td>Water conservation</td>
</tr>
<tr>
<td></td>
<td>Soil particles</td>
</tr>
</tbody>
</table>
Materials

For each 3-4 person group:

- Trowel
- Sealable, microwave safe, plastic food storage containers; glass containers can be used but they must be light enough to be measured on a balance
- Scale or balance, ultimately to obtain a mass
- Data sheet and pencil

Background

Soil is composed of organic matter, mineral particles (the product of rock/parent material), living organisms, and pore spaces (that are filled with liquids and gases). Soil structure refers to the clustering of soil particles into discrete units called aggregates and the consequent pore space left within and between these aggregates. Pore spaces provide room and habitat for soil microorganisms and roots. Pore space is also an important area for gas and liquid storage.
Soil texture is a physical characteristic of the soil that describes the size and proportion of the particles that make up the soil (i.e. the amount of sand, clay, and silt). For instance, Portland area soils are commonly silty-clay, which results in a tighter soil structure and higher water retention capabilities. “Soil texture affects water content through its influence on binding sites and storage volume. Water binds to the soil particle surfaces, so those soils with the largest surface area per unit volume have the greatest potential for storing water. Surface area is directly proportional to clay or organic matter content (colloids). Adding residues that raise organic matter content can increase the water-holding ability of sandy soils…. Loss of aggregation and compaction can diminish a soil's pore volume, and as a consequence, reduce infiltration, volumetric water storage capacity, water movement and alter patterns of water distribution.”

-Soil Water Content Lab from Professor Farrell from University of Minnesota Duluth.
Soil texture, soil organic compounds, and soil microorganisms all contribute to the stability of soil aggregates, which determine overall soil structure. Aggregates are bound together by different chemical and biological forces, depending on the size of the aggregate. Aggregation of gumball size macroaggregates is the result of roots and fungal hyphae. Smaller aggregate formation is caused by microorganisms’ secretion of organic molecules (i.e. polysaccharides). As aggregates decrease in size, the chemical properties of the soil particles (sand, clay, silt, and humus) play an increasingly important role in aggregate formation. Soil particles like clay are complex molecules, whose overall chemical structure results in a charged surface that then influences important soil traits such as water-holding capacity (due to the polarity of water) and nutrient holding capacity (due to the positive charge of most nutrients).
Pore space is a complex soil feature, which is affected by soil health, texture, and the activity of soil organisms. Improving soil health in a school garden is a guaranteed way of increasing aggregate stability and pore space. The total amount of pore space in the soil is called porosity. When soils are saturated, porosity is quantified by soil moisture content, the amount water in the soil. This activity provides the procedure for measuring the moisture content of school garden soils easily in the classroom in order to compare the porosity of areas of the school garden that are exposed to different environmental conditions.

See NRCS Soil Health Management Principles (linked below), for a more detailed background on soil health and agricultural practices.

What Students Need to Know / This Lesson Builds On…

Ionic bonds
Familiarity with the components of soil
SI system
Microorganisms

Lesson Key Ideas and Concepts

Pore space exists between aggregates and within aggregates
How the interactions between soil molecules result in overall soil stability/structure
Necessity of pore space for soil biome and plants
What human activities reduce pore space in soils?
What garden practices lead to greater pore space and water content?

**Preparation**

Gather containers, trowels, and balances. Print data collection sheets, one for each student.

Determine the mass of containers with lids beforehand, and record the mass on the containers or label the containers and note the masses on a separate tracking sheet. Either way, make sure all containers are massed before they become wet or have soil added to them.

Soak the test areas (for a consistent amount of time) in place beforehand to replicate baseline moisture exposure, or plan to remove samples after a recent rainfall.

Find out, if you don’t already know, what soil and water conservation management techniques are currently practiced in the school garden.

**PROCEDURE Please consult Warm Up and Wrap Up document for how to begin and end any activity.**

*Identify soils*

Find soils around school grounds that are exposed to different environmental conditions to compare in this activity. For example, the soil under a schoolyard lawn could be compared to a garden bed section that had a successful cover crop, to a garden bed section that was covered with straw, to a compacted school garden path. Either with the class or beforehand (see To Simplify) identify which areas the students will focus on for this activity.
Decide as a class which area they expect to have the highest water content, based on principals of soil health and soil structure. Similarly, discuss which area they expect to have the lowest water content.

**Collect soils**

Once the class has identified the areas of the garden they would like to test, it’s time to collect the soils for testing. You will need a representative soil sample from each area that the class is testing; ideally each student group would be assigned one test area. But student groups could also double up in test areas for reproducibility.

A representative sample is the combination of multiple small samples from one test area. To collect, have each group:

- Dig a trowel-wide hole to a consistent soil depth for all samples (3-4 inches should be deep enough to include the A horizon from natural soils, but not so deep that watering or a rainstorm wouldn’t easily reach this level)
- From the bottom of this hole use the trowel to remove roughly 2-3 tbsp of soil and place in the container
- Repeat sample collection two more times within their test area
- Aim for all three individual samples to make one complete representative sample of roughly 1/2 cup volume
- Seal containers and head back to the classroom. Remind the students to fill in their holes when they’re finished!

**Measure moisture content and data analysis**

*Refer to data collection sheet for data collection steps.*

Drying the soils: Break up larger soil aggregates for faster drying. If they fit, place all samples—in their respective containers—in the microwave on high for 15-20 minutes, with lids removed. At this point, if necessary, dry samples can be stored away, for another test day to finish activity. Note: Typically soil samples are dried inside of drying ovens, microwave ovens, however, have been shown to quickly, conveniently,
and satisfactorily dry soils in preparation for soil moisture tests.

[https://www.crops.org/files/publications/jnlse/pdfs/jnr005/005-01-0025.pdf]

Discussion

What does moisture content measure exactly (in units and spatially in the soil sample)

Did the test areas perform as predicted?

What soil characteristics could have led to any unexpected results?

What biological factors influence soil structure? Physical factors?

List some ways that soil conservation and water conservation are connected?

What practices in the garden lead to improved soil quality?

Adaptations

To Simplify

Collect soil samples beforehand from two different test sites start the activity by describing the collection areas and jump right into measuring moisture content.

To Add Complexity

Follow up on any unexpected results

Create more test trials for each area or begin to test another soil property that could have influenced results, soil texture.

The LEAF program’s Soil Lab [https://www.uwsp.edu/cnr-ap/leaf/SiteAssets/Pages/School-Forest-Chemistry/Soil%20Lab.pdf] or

The Soil Water Content Lab [http://www.d.umn.edu/~pfarrell/Soils/SOIL%20WATER%20CONTENT%20LAB.htm]
Recommended Reading

Soil sampling

http://soiltesting.tamu.edu/publications/E-534.pdf

NRCS Soil Health Management Principals


References and Attribution

This lesson researched/ designed by Adriana Escobedo-Land, TSWCD volunteer

TSWCD Lesson Plan Template Consultant: Jane Wilson, MAT, TSWCD volunteer

All lesson plans in this curriculum reviewed by: Stephanie Wagner, MS, Portland State University, and the Portland Metropolitan STEM Project.

Curriculum design funded by the Gray Family Foundation.

Curriculum design directed and edited by: Jennifer Nelson, MS, OVE Program Manager, TSWCD.

This lesson adapted from:

http://www.uic.edu/classes/cemm/cemmlab/Experiment%201-Water%20Content.pdf

TSWCD High School Soil Moisture Data Collection Sheet

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Mass in g</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructions on when measurements are taken</strong></td>
<td></td>
</tr>
<tr>
<td>Mass of container +lid: $\text{M}_{c}$</td>
<td></td>
</tr>
<tr>
<td>Written on container or provided by teacher</td>
<td></td>
</tr>
<tr>
<td>Mass of wet soil and container + lid: $\text{M}_{\text{WSC}}$</td>
<td></td>
</tr>
<tr>
<td>Initial measurement of wet representative sample</td>
<td></td>
</tr>
<tr>
<td>Mass of dry soil and container + lid: $\text{M}_{\text{DSC}}$</td>
<td></td>
</tr>
<tr>
<td>After drying fully in oven</td>
<td></td>
</tr>
<tr>
<td>Determine the mass of soil solids:</td>
<td></td>
</tr>
<tr>
<td>$\text{M}<em>s = \text{M}</em>{\text{DSC}} - \text{M}_{c}$</td>
<td></td>
</tr>
<tr>
<td>Determine the mass of pore water:</td>
<td></td>
</tr>
<tr>
<td>$\text{M}<em>w = \text{M}</em>{\text{WSC}} - \text{M}_{\text{DSC}}$</td>
<td></td>
</tr>
<tr>
<td>Determine the water content as a percent:</td>
<td></td>
</tr>
<tr>
<td>$w = (\text{M}_w/\text{M}_s) \times 100$</td>
<td></td>
</tr>
</tbody>
</table>

*Adapted from UIC Laboratory Testing Experiment from Prof. Krishna Reddy’s lab: [http://www.uic.edu/classes/cemm/cemmlab/Experiment%201-Water%20Content.pdf]*

**Calculation space:**
Topic 3: Human Impact

Activity 12: Disruption of soil aggregates

 Discipline: Natural sciences, conservation sciences

 Topic: Land surfaces

 Lesson Length: 90 minutes

 Lesson Designer: Adriana Escobedo-Land

Activity Description:
Soil erosion is a natural process that is caused by water, wind, and glacial activity, which can be exacerbated by human activity. In this activity, students will informally survey the soils of their school garden and then compare their results to Natural Resources Conservation Service (NRCS) web-based soil survey information. At the end of this activity, students will have covered the topics of soil erosion, the effects of water on land surface, human land use and its effects on erosion, and the soil health management practices in the garden. This activity is two-part, with time spent in the garden and time spent in the computer lab using an online soil survey site.

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| Students who demonstrate understanding can: HS-ESS3-1. Construct an explanation based on evidence for how | 1. Asking questions (for science) and defining problems (for engineering) | Earth and Space Sciences  
Earth's Place in the Universe  
Earth's Systems | 1. Patterns.  
2. Cause and effect.  
3. Scale, proportion, and quantity.  
4. Systems and |
| | 2. Developing and | | |
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the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

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

<table>
<thead>
<tr>
<th>Soil Health Concepts on the Farm or in the Garden</th>
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<td>- Eroded mineral material from the Earth’s surface is one component of soil.</td>
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<td>- Eroded mineral material in soil can be divided into three sized particles: sand, silt, and clay.</td>
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<td>- Healthy soil consists of a balance of eroded mineral particles and organic matter.</td>
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<td>- Together, soil particles and organic matter can be formed into small and larger clumps called aggregates, which resist erosive force better than soil particles alone.</td>
</tr>
<tr>
<td><strong>Soil as Habitat for Plants</strong></td>
</tr>
<tr>
<td>- Plant roots produce exudates, or chemicals released from the root into the soil for several purposes.</td>
</tr>
<tr>
<td>- Plant exudates contribute to formation of stable soil aggregates.</td>
</tr>
<tr>
<td><strong>Soil as an Ecosystem</strong></td>
</tr>
<tr>
<td>- The living creatures in soil also produce exudates that bind soil aggregates together.</td>
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</tbody>
</table>
Human Impact on Soil Health and the 4 Principles of Soil Health

- All around the world, people live on and work with the soil. Human beings depend on soil in many different ways.
- As world population and food production demands rise, keeping our soil healthy and productive is important.
- Soil health is a way of understanding how well soil is functioning to support plants, soil biology, and human needs.
- Human activity can affect how the soil functions. These activities include farming, gardening, developing roads and other infrastructure for transportation, changing the course of rivers, developing buildings for living and commercial activity, and so forth.
- Human activity affects soil function by cutting into or digging into the soil, compressing or compacting the soil, removing the plants that live in the soil, contaminating the soil with chemicals, etc.
- The U.S. Department of Agriculture Natural Resource Conservation Service has identified several principles of soil health that identify how people can harm and help soils through these activities.
  - **Principle 1**: The surface of the soil should be kept covered by living plants or other materials as much of the year as possible. This protects soil from the erosive force of wind and rain.
  - **Principle 2**: Soil should be disturbed from human activities such as digging, plowing, disk ing, tilling, etc., as little as possible. Disturbing the soil can destroy the habitat of creatures living in the soil. Disturbing the soil can also increase its vulnerability to the erosive forces of wind and water. Disturbing the soil can result in the loss of organic matter or nutrients.
  - **Principle 3**: Keep plants growing in the soil year round. These plants provide protection and coverage for the soil (principle 1). They can increase the organic matter in the soil if incorporated into the soil at the end of their life cycle. Some plants fix nitrogen from the air, increasing soil fertility. The living root of plants within the soil produces exudates that increase soil aggregate formation and also provides food and habitat for creatures living in the soil ecosystem.
  - **Principle 4**: Grow a diverse mix plants to provide a diverse mix of roots underground. This helps prevent erosion due to varying root depth and structure, and provides a variety of food and habitat for creatures living in the soil ecosystem.
- Permaculture is a form of gardening and farming that utilizes plants which produce fruits for harvest where the plant itself is never or rarely harvested, eliminating or severely limiting all soil disturbance.
- The long-term impacts of soil disturbance include loss of soil fertility, loss of soil organic matter, salination of soils, desertification, etc.
- People can improve the health of soil in many ways, including by farming or gardening using the soil health principles and systems that include no-till, cover cropping and
diverse rotations.

<table>
<thead>
<tr>
<th>Vocabulary- NGSS</th>
<th>Vocabulary- Lesson related</th>
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<tbody>
<tr>
<td>• Natural systems</td>
<td>• Soil erosion, erodibility</td>
</tr>
<tr>
<td>• Human impact</td>
<td>• Soil infiltration</td>
</tr>
<tr>
<td>• Geosciences</td>
<td>• Soil texture</td>
</tr>
<tr>
<td>• Earth surface processes</td>
<td>• Soil particles</td>
</tr>
<tr>
<td></td>
<td>• Soil structure</td>
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<table>
<thead>
<tr>
<th>Materials</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printed handouts</td>
<td>Access to hand washing area</td>
</tr>
<tr>
<td>Trowels (# depends on group size)</td>
<td></td>
</tr>
<tr>
<td>Ruler or meter stick</td>
<td></td>
</tr>
<tr>
<td>Spray bottles or containers for water (even encouraging students to bring their own water bottles for use would be sufficient)</td>
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</tbody>
</table>

**Background**

Erosion is the wearing away of the surface of the land. Soil erosion is a process, where
soil particles are detached from aggregates of the original soil, then transported and deposited in a new location. It is a natural process that is caused by water, wind, and glacial activity. Rates of erosion are frequently accelerated by human activity by way of deforestation, livestock grazing, and improper agricultural practices. Topsoil is the upper layer of soil that contains a large amount of plant nutrients, organic matter, and soil organisms, and it is the primary victim of erosion. Soil erosion worldwide impacts the productivity of agricultural lands by removing precious topsoil from cropland and by damaging soil structure, thereby reducing the water-holding capacity of soils, leaving soils more prone to drought. Surface runoff, the flow of water moving over soils instead of through them, leads to additional soil degradation and erosion. See FAO Restoring The Land site (top link on recommended reading) to learn more about the severity and impacts of erosion.

Soil texture is a physical characteristic, an inherent property of the soil, which describes the size and proportion of the particles that make up the soil (i.e. the amount of sand, clay, and silt). These particles are dependent on the type of original parent material and weathering. Soil texture is the principle factor in determining a soil’s susceptibility to erosion (erodibility). Soil structure, soil biology, and soil organic matter content also predict erodibility, but to a lesser degree. When considering erosion in your own garden, it is these other factors—soil structure, soil biology, and soil organic matter content—that you can act on and improve, through soil health management practices. These practices establish stable soil aggregates and abundant soil organism populations with garden practices such as cover cropping, covering beds with straw in the winter, and using compost.
Fig. Classic soil texture triangle that identifies the soil types based on soil particle percentages

Soil texture influences the infiltration of water into the soil and the ease of soil particle detachment, two predictors of erosion and runoff. When water is slow draining (in the case of compact, or heavy clay soils) waterlogging occurs and runoff risk increases, which damages the structure of the soil. However, aggregates tend to be more stable in these soils so detachment is less common. In soils where water infiltrates quickly, the soil particles are often larger (sand), and less likely to aggregate, which leads to easier detachment, but lower risk of runoff. For instance, the soils underneath the Tualatin Soil and Water Conservation District offices are loam, which falls in the middle of the soil texture triangle; if the loam tended towards the sandy corner, the soil would have a moderately loose soil structure and low runoff rates, but be susceptible to wind erosion, and in need of organic matter inputs for soil aggregate stability to reduce detachment rates.

The tools used to measure soil texture vary in complexity and accuracy. A simple feel-by-touch activity is a common method for determining texture on site. This tool is
convenient, but the results can be inaccurate if the tester is not familiar with the nuances of the local soil. Another tool for determining local soil texture is a mapping tool called “Web Soil Survey”, available from the Natural Resources Conservation Services, which pulls from a database of expert-collected soil surveys that include information on climate, water tables, and land use. This tool matches the soil texture data to different erosive agents (climactic events, intense winds and rain) to predict area-specific erosion rates, the Erosion Index. This activity provides an introduction to both of the tools described here.

N.B. In practice, many schools use raised beds that can contain nonnative soils, whose characteristics will differ from those of the native soil. If this is the case in your garden, this activity can be an opportunity for students to compare textures of two different soil types, and to consider the responsible use of their local soils in spots in the garden other than the raised beds.

**What Students Need to Know / This Lesson Builds On…**

The components of soil and the difference between physical and biological properties of the soil; soil aggregates

Land use practices, agricultural around the world

The water cycle, pertaining to runoff and groundwater

**Lesson Key Ideas and Concepts**

- Soil erosion degrades the soil and reduces the quality of farmland.
- Soils are unique with a variety of classes that informs how the soil stores and moves water.
At any scale of agriculture, there are simple soil-building steps that can reduce the risk of erosion and run off.

### Preparation

Print Texture By Feel handouts for each group (available as module link or here: [http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311)).

Print Getting Started handouts, enough for half the class (available as module link or here: [http://websoilsurvey.sc.egov.usda.gov/App/GettingStarted.htm](http://websoilsurvey.sc.egov.usda.gov/App/GettingStarted.htm))

Reserve the computer lab for the class period.

Fill and have a spray bottle and ruler on hand. Gather trowels and a container to collect them in.

### PROCEDURE

*Go out in the Garden*

Have students group up (since there are few supplies needed for this part of the activity, group size can be determined by the teacher, whatever size seems manageable for groups to work through a single handout together, 4 or 5?).

Provide a handout to each group and warn them that their hands and handout will get dirty. Give each group a trowel (or dig some holes beforehand). Bring your spray bottle along.
With the class as a whole, find spots in the garden that can be dug up and likely contain the original soil (a good distance from crops and roots of large perennials, outside of the garden bed). If the garden uses raised beds, this is a good time to discuss why this might be different than the soil outside of the bed (it may have been transported there, from an area with different parent material), and display what the students are to do for the activity.

Dig a small hole a few inches deep (a couple inches deeper in the garden beds to accommodate extra compost and amendment material that may have been added to the top). Remove 25 grams or a medium sized handful.

Follow the steps on the NRCS diagrammed flow chart with the students; apply water from spray bottle when necessary. Remind students to remember what soil texture class was decided on and to do the same when they do it on their own. Have a meter stick or ruler on hand to diagram what “2 cm” looks like.

Assign groups to the previously determined garden testing spots. Let them walk through the activity on their own. Each student in the group can have their own sample so that they can talk through it together. Be available to offer guidance in wetting samples and determining ribbon breakage length. Encourage them to settle on a single answer, but if they can’t have them remember what they were stuck between so that they can discuss that with the class.

Have everyone wash up and return to class.
Have students share their results, make a tally on the board. Ideally, with the same soil in the garden area, they should have settled on the similar answers. But it could be that the soil in the parts of the garden was fill or different soil than the original site, or that some students weren’t able to detect subtle differences in the soil.

In front of a computer

By walking the students through the process of pulling data reports from a map interface, this activity offers a unique experience to use real world datasets and mapping software, which often have missing information. It may be good to run through this site ahead of time to check that WSS has all the needed information about the area of your specific school garden.

Introduce the key information that the students will be using the Web Soil Survey to find: K erosion factor, and the percent of clay, silt, and sand.

WSS: Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

“Erosion factor Kf (rock free)” indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Have students split groups and reorganize into pairs for working at the computer.

Give each group a Getting Started printout or let them navigate to the web link once
they’re on the computers. This printout will help students identify their area of interest (the school garden) on the map and the steps to print. The steps in between are provided below:

Have students follow the directions on Getting Started to select the area around their school as an Area of Interest.

In the soil data explorer tab, students can read about soils if they haven’t been sufficiently introduced to the subject, by selecting “Introduction to Soils” from the left hand Table of Contents, and selecting “View Selected Topics”.

From the Soil Data Explorer tab, select Soil Properties and Qualities, then the K Factor, Rock Free from underneath the Soil Erosion Factors subheading (click small icon on right), and finally “View Rating” to see the number factor listed in the table and
shown in the map (the legend to the map on the upper left hand tab on the corner of
the map).

Under the Soil Physical Properties subheading, similar steps can be taken to identify
the percent of soil, sand, and silt. The one difference is that depth needs to be noted, so
use an estimate of the depth that was used by the students out in the garden.

Check students’ results once they find the for the school garden. Have them identify
another AOI (their home, a favorite park, a berry farm they go to in the summer, etc.)
and print out or write down the K factor and the Percent of clay, sand, and silt for the
new area. For a final assignment have students spend time at home identifying where the soil texture of their school garden falls in the soil texture triangle and what that means for the erosion risk. Specifically have them identify, based on their soil if they should be most concerned about water or wind risk and why, and then identify one way they can improve soil health in the garden to mitigate this risk. Offer them web sources to get started. Some sources offered in recommended reading: Think Soils is a great resource for this.


Adaptations

To Simplify

Remove the Web Soil Survey part of this lesson. Focus on in the garden soil texture testing (see commonly available online “soil texture jar test” for more details). Create small trials where the students compare their individual results from different tests to see if they reached the same conclusion about what the texture was. Have the group critique the methods used in their different tests and discuss the idea of reproducibility in science.

To Add Complexity

Have the students explore other tools and offerings of the NRCS’ Web Soil Survey, including adding a layer that includes ecology and land use. Ask the students to analyze the area around their own home or other areas of interest.

http://websoilsurvey.sc.egov.usda.gov/App/Help/WSS_HomePage_HowTo_3_0.pdf

Recommended Reading

http://www.fao.org/docrep/u8480e/u8480e0d.htm
Think Soils- UK Environment Agency; Factors that Influence Erosion and Runoff

http://adlib.everysite.co.uk/resources/000/263/234/chapter2.pdf

OSU- Human Impacts on Ecosystems: Erosion; Muir, P.S.

http://people.oregonstate.edu/~muirp/erosion.htm

Soil Biology and soil management, University of Minnesota Extension


References and Attribution

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This lesson adapted from:
http://websoilsurvey.sc.egov.usda.gov/App/Help/WSS_HomePage_HowTo_3_0.pdf