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# K-12 Partnership Lesson Plan

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# *Big Roots for Big Problems*

# *Exploring the ecosystem services of roots*

## Overview

Student will explore the idea of what ecosystem services are, focusing on the importance of plant’s root systems. A brief introduction to ecosystem services will be followed by an interactive demonstration illustrating a basic ecosystem service. Then students will have an opportunity to construct their own root systems and test out their designs to see how they fare in a heavy rain event. Finally, after conducting a month long experiment with different watering regimes, students will determine whether certain plants are more equipped to deal with drought and what makes them better. This is a highly interactive lesson that requires some preparation prior to implementation.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Understand how healthy ecosystems provide valuable services
* Distinguish between four different categories of ecosystem services
* Understand the specific role of roots in providing services
* Understand the differences in root systems between many native and exotic plants
* Demonstrate the role of root systems in drought resistance

**Length of Lesson**

Introductory presentation: 15 minutes

Soil erosion demo: 10 minutes

Root building competition: 20 minutes

Drought experiment: 20 minutes

**Grade Levels**

Grades 6-12

**Standards covered (NGSS)**

Disciplinary Core Ideas:

*Middle School*

* **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
* **MS-LS2-3**: develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem
* **MS-LS2-4**: construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations
* **MS-LS1-4**: use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively

*High School*

* **HS-LS2-6:** evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem

Cross Cutting Concepts:

* Patterns
* Cause and effect
* Scale, proportion, and quantity
* Systems and system models
* Structure and function

Science and Engineering Practices

* Asking questions and defining problems
* Developing and using models
* Planning and carrying out investigations
* Analyzing and interpreting data
* Constructing explanation and designing solutions
* Engaging in argument from evidence

***Previous Michigan Standards Met:***

* **S.IP.00.11**: make purposeful observations of the natural world using the appropriate senses
* **S.IP.00.12**: generate questions based on observations
* **S.IP.00.13**: plan and conduct simple investigations
* **S.IP.00.14**: manipulate simple tools (for example: hand lens, pencils, balances, non standard objects for measurement) that aid observation and data collection
* **S.IP.00.15**: make accurate measurements with appropriate (non-standard) units for the measurement tool
* **S.IP.00.16**: construct simple charts from data and observations
* **S.IA.00.12**: share ideas about science through purposeful conversation
* **S.IA.00.13**: communicate and present findings of observations
* **S.RS.00.11**: demonstrate scientific concepts through various illustrations, performances, models, exhibits, and activities
* **S.RS.02.15**: use evidence when communicating scientific ideas
* **L.OL.03.41**: classify plants on the basis of observable physical characteristics (roots, leaves, stems, and flowers)
* **L.EV.03.11**: relate characteristics and functions of observable parts in a variety of plants that allow them to live in their environment (leaf shape, thorns, odor, color)
* **E1.1A**: generate new questions that can be investigated in the laboratory or field
* **E1.1B**: evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions
* **E1.1C**: conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity- length, volume, weight, time interval, temperature- with the appropriate level of precision)
* **E1.1h**: design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables
* **E1.2g**: identify scientific tradeoffs in design decisions and choose among alternative solutions
* **E2.1B**: analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) a that make up the Earth
* **E2.1C**: explain, using specific examples, how a change in one system affects other Earth systems

**Materials**

* Two large plastic containers (for soil erosion box, see below)
* Seedling trays (to start seedlings for drought experiment)
* Small pots (for growing plants in drought experiment)
* Soil
* Native and exotic plant seeds
* Pipe cleaners
* Paint roller trays
* Saw
* Watering can

**Background**

### Ecosystem services play an essential role in our everyday life from the natural products we use to the air we breathe. Ecosystem services can be split into 4 categories: supporting, provisioning, regulating, and cultural. Supporting ecosystem services are those necessary for the production of all other ecosystem services. Examples would be soil production, seed dispersal, primary production, and oxygen production. Provisioning services are products we obtain from ecosystems, such as food, water, energy, and pharmaceuticals. Regulating services are benefits we obtain from the ecosystem through its management. Some examples of regulating services would be water purification, crop pollination, and pest and disease control. The final category is cultural services, or nonmaterial benefits people experience from the natural environment. Hiking, kayaking, religious connections to nature are all examples of cultural ecosystem services.

### The roots of a plant are responsible for many ecosystem service categories. They aid in carbon sequestration and nutrient cycling (regulating), soil production and limit erosion (supporting), and yield edible roots and tuber (provisioning). Limiting soil erosion is of utmost importance to our agricultural system. Plant cover and large root systems occupying the soil act as an anchor for topsoil and in heavy rainfall events and windy conditions root systems play a crucial role in keeping the topsoil in place. Roots are also crucial in water uptake. Deeper and more dispersed root systems are much more likely to supply adequate water to the plants during drought conditions. There are many benefits arising from promoting native biodiversity within a particular ecosystem, one of those being that native plants are more adapted to the local conditions, which may include deeper root systems to sustain growth through drought conditions. In this lesson, we will investigate if this holds true. Roots offer many ecosystem services that are crucial to our survival; this lesson simply investigates a few of those.

### Activities of the session

1. Before the lesson:
   1. Prepare the soil erosion boxes for classroom demonstration (see below)
   2. Initiate drought tolerance experiment at least one month before final data collection (see below).
2. Introduce the concept of ecosystem services, and the different categories of services the ecosystem provides (use powerpoint presentation).
3. Introduce roots as one trait of plants that provide several valuable services (list and explain several examples).
4. Explain the relationship between plant roots and soil erosion.
5. Soil erosion box demonstration (see below)
6. Build Your Own Root System activity (see below)
7. Introduce the relationship between root systems and drought
8. Drought experiment (see below)

**Resources**

* Big roots for Big Problems powerpoint, soil erosion demonstration instructions, build your own root system instructions, drought experiment instructions, and an excel data sheet to help create graphs are all available on the “Big Roots for Big Problems” lesson page on the KBS GK-12 website.
* http://en.wikipedia.org/wiki/Erosion

**Extensions and Modifications**

The drought experiment can easily be modified to change treatments or comparisons

**Assessment**

Brief written assessments can be used to show whether students understand whether or not their predictions were upheld, and why or why not.

**Big Roots for Big Problems**

**Soil Erosion Demonstration!**

**Materials:** two plastic bins (with walls less than 6 inches tall), fast growing grass seeds, growth medium (e.g., potting soil), device to cut plastic (e.g., handsaw, durable scissors, box cutter), watering can, two trays or buckets

**Background:**

This activity is designed to demonstrate how vegetation and roots stabilize soils to prevent erosion. Erosion is the process where soil is removed from one location by water or wind and deposited somewhere else. Soil erosion can result in a wide range of problems including desertification, land degradation, loss of nutrient rich topsoil, and degradation of waterways. Plant roots hold soil together in an intertwining mass that protects against wind and water erosion. Larger, more complicated root systems are more effective at holding soil together. In this activity the teacher or the class will construct soil erosion boxes in order to compare how soil erodes in a vegetated bin (i.e., soil and established grass) versus a non-vegetated bin (i.e., only soil). This demonstration is especially appropriate before doing the *Build Your Own Root System!* activity in this lesson plan.

**Procedure:**

1. Three weeks prior to the demonstration, prepare the soil erosion boxes.
   1. Fill each plastic bin with 3-5 inches of potting soil.
   2. On the narrower side of both bins, cut out a section of the plastic from the top of the bin wall down to the top of the potting soil and no wider than half the width of the side. When the opposite end of the erosion box is elevated, this missing section will be where the water and soil erode out of the box during the demonstration.
   3. In one of the bins, liberally cover the surface of the soil with grass seed and then cover the seed with a light layer of soil. Do not plant grass in the other bin.
   4. Water both bins and place them in a window or under a grow light for three weeks or until the grass and roots are well established. Water as necessary.
2. For the demonstration, situate the soil boxes in the front of the classroom with the cut side of the box facing the students.
3. Elevate the opposite end (i.e., the non-cut side) 3-5 inches to create a sloping surface. Make sure these are stable and won’t slide off the table.
4. Ask the students to make a prediction about which soil erosion box will yield more erosion during a rain event.
5. Have at least two students volunteer to help with the demonstration. One student will take a full watering can (preferably one with a spout head that makes the water exit in multiple streams simulating rainfall) and liberally water the top third of the soil erosion box without the grass to simulate a rain event. The second student will hold a tray or bucket at the bottom of the erosion box to collect the water and eroded soil.
6. Set the tray aside.
7. Repeat this procedure with the vegetated soil erosion box, using approximately the same volume of water. Use a new tray or bucket to collect the water and eroded soil.
8. Place the two trays side by side and have the students compare how much soil eroded out of each box. If it’s difficult to tell which tray holds more soil, dry the wet soil mixture and weigh the soil during a future class period.

Were the students predictions correct? Did the soil erosion box with the grass yield any soil at all? Why or why not?

Where in their environment might the students find bare soil that might be eroded away during rain events?

Inform the students that as our climate changes, models predict (and we’ve already seen) that we will experience more intense rain events, and fewer slow-soaking rain events. How might this affect the amount of erosion that might occur on the landscape?

**Big Roots for Big Problems**

**Build Your Own Root System!**

**Group size:** 1-2

**Materials:** Pipe cleaners, scissors, paint roller trays, soil, watering can

**Background:**

This activity is designed to demonstrate the relationship between roots and soil erosion. Erosion is process where soil is removed from one location by water or wind and deposited somewhere else. Soil erosion can result in a wide range of problems including desertification, land degradation, loss of nutrient rich topsoil, and degradation of waterways. Plant roots hold soil together in an intertwining mass that protects against wind and water erosion. Larger, more complicated root systems are more effective at holding soil together. In this activity students will construct their own root system using pipe cleaners and test how effective their roots are at preventing soil erosion.

**Procedure:**

1. For each group distribute 1 paint roller tray (or any other container with a sloped surface) and 5 pipe cleaners
2. Attach two “anchors” to the top of the paint roller tray near the top of the sloped portion with about 3 inches of space between them. These anchors are what the students will attach their root systems to and they can be just about anything so long as they hold the root system in place (chopsticks, knitting needles, additional pipe cleaners)
3. Students must design their own root system using the pipe cleaners as roots. Students may cut up the pipe cleaners however they would like and attach their roots to the anchors
4. Once the roots are in place carefully add soil on top of the roots, filling in the space between the two anchors
5. Use the watering can to simulate rainfall on the soil. Be sure to use the same amount of water for each group (we recommend ¼ liter)
6. Compare how well the different groups managed to prevent soil erosion based on how much soil was lost from between the two anchors

**Big Roots for Big Problems**

**Drought Experiment!**

**Group size:** 1-3

**Materials:** seeds of native and non-native plants, small pots, seedling trays, growing medium and sand, data sheets

**Background:**

This activity is designed to demonstrate the relationship between roots and drought tolerance in plants. Plants that are able to maintain growth through drought conditions are also able to continue to feed insects and mammals, provide nectar to pollinators, mediate water loss from soil, and so on. Roots that are deep, fibrous, and have a complex structure or more likely to be able to access and retain water in dry soils. Many of the exotic species that are dominant in human-modified ecosystems are adapted to these highly disturbed conditions, but do not have root systems that are suited for drought tolerance and maintaining ecosystem services long-term. The native species that are used to replace these exotic species in landscaping are selected primarily to increase native diversity and because of the native insects and other animals they support, but also typically have impressive root systems adapted to drought. In this activity students will collect data on plant growth in different species of native and exotic plants that have been subjected to different levels of simulated drought.

**Advance preparation:**

*\*Seeds must be sown well in advance of when the lesson is planned to allow time for germination (1-2 wks), root establishment (2-4 wks), and drought experiment (at least 4 weeks)*

1. Select at least 3 native and 3 exotic species. You should choose species that will germinate relatively quickly (see suggestions below). Many native species will have low or no germination without a period of ‘cold-stratification’ or exposure to temperatures under 40o F, so if you wish to use these species then be sure to make time for that.
2. Sow seeds in open seed flats in a seed-germination growing medium (these are widely available and usually labeled as such) and keep moist.
3. Prepare a large batch of a [growing medium:sand] mixture at a ratio of [10:1] to [5:1]. You want your soil to be droughty. You can use the some growing medium that you used to germinate seeds.
4. Transplant seedlings into small pots (any size but 2-4” square pots are good) when their first true leaf is fully emerged (the first ‘leaf’ in grasses and pair of ‘leaves’ in wildflowers are cotyledons or ‘seed-leaves.’ You probably already know this.)
5. To provide replication of each species across three different watering regimes, you will want at least 15 individuals of each species (e.g., 5 individuals/species/regime).
6. Allow at least one week for transplants to acclimate to their new home. Water daily.
7. OK, now you need to apply the drought treatment. For each species, divvy up the plants into three groups randomly. Start the treatments, and make sure they last at least 4 weeks. *Before you start the treatments, you may choose to collect ‘baseline data’ by counting leaves on each plant and/or measuring the length of the longest leaf. If you do you this, you will need to mark each plant uniquely so that your baseline value can be subtracted form the appropriate post-treatment value of the appropriate plant.*
   1. Treatment 1 (‘control’): water 3X/week
   2. Treatment 2 (‘stressed’): water 1X/week
   3. Treatment 3 (‘drought’): water 1X/every other week

**Procedure:**

1. Students will collect data on the plants in order to compare how each species responds to different levels of drought. Start by discussing what tolerance of drought would look like. Ask students to describe it. (*Basically, there would be very little difference in growth across the treatments.*)Now generate predictions: *Which species will better tolerate drought? Will native and exotic species respond differently?*
2. Data collection: you will need to decide on a **response variable**.
   1. If you collected baseline data (see 7, above), you can count leaves or measure the longest leaf and calculate the difference between the start of the experiment and now. You could also use this method if all plants were the same at the beginning of the experiment (e.g., all had one leaf).
   2. A more reliable measure of growth is dry biomass. You could i) clip each plant, ii) place it in a small, labeled paper bag, iii) let it dry in a sunny spot for about one month, and iv) weigh it in grams.
3. Record this data on data sheets (see attached)
4. Enter data into Excel spreadsheet (see attached). Graphs will automatically be generated showing growth relative to the ‘control’ for the ‘stressed’ and ‘drought’ treatments for i) each species individually, and ii) natives and exotics as groups; the coefficient of variation, which calculates how great differences are across the treatments for i) each species individually, and ii) natives and exotics as groups

Interpret graphs. Does the data match your predictions? Why? Why not?