

INSIDE OREGON'S FORESTS

A high school forestry curriculum

FOREST MANAGEMENT

1: What Is Forest Management?

2: Surveying a Forest Tract

3: Analyzing Forest Soil

4: Forest Density Lab

5: Forest Thinning

6: Harvesting

7: Reforestation

8: Silviculture Tour

9: Developing a Forest
Management Plan



Oregon Forest
Resources Institute

Introduction

[Inside Oregon's Forests](#) is a high school curriculum developed by the Oregon Forest Resources Institute (OFRI) to help students build a deep understanding of Oregon's forests. The seven modules are loosely organized around topics and concepts from the [Oregon Forest Literacy Plan](#), a forest-education conceptual framework developed by OFRI and available at learnforests.org.

Curriculum Goals and Objectives

The overall goal of this curriculum is to provide engaging, standards-based lessons that help high school students understand the environmental, economic and social importance of Oregon's forests, as well as the principles behind forest management. Through the lessons, students will be able to:

- explain basic tree biology
- identify the forest types in Oregon
- describe the environmental, economic and social benefits Oregon's forests provide
- explain scientific and economic principles involved in managing Oregon's forests
- describe current issues facing Oregon's forests
- identify actions they can take to help ensure the sustainability of our forests

Curriculum Overview

Following is a description, as well as a suggested sequence and time frame, for each of the seven modules in the curriculum.

Sequence & Time Frame	Module	Description
Weeks 1-2	Oregon's Forest Heritage	Students are introduced to Oregon forests and their history, and examine some changes in our state's forestland over time.
Week 3	Forest Basics	Students gain an understanding of both tree biology and the forest types in Oregon, and practice identifying and measuring trees.
Weeks 4-5	Environmental Importance of Oregon's Forests	Students explore the environmental importance of forests: for example, how they protect our water resources, provide habitat and store carbon.
Week 6	Economic Importance of Oregon's Forests	Students examine Oregon's forest economy, including the products, energy and jobs that come from forests.

Weeks 7-9	Forest Management	Students learn about forest management and practice forest management skills, such as surveying a forest tract, analyzing forest soil and developing a management plan.
Weeks 10-11	Forest Management Issues	Students explore the impacts of fire, forest pests and climate change on Oregon's forests, and conduct an opinion survey related to a forest management issue.
Week 12-13	Our Responsibility to Oregon's Forests	Students learn about certification as a way to achieve forest sustainability, and plan and carry out a service-learning project.

How to Use the Curriculum

The curriculum is designed to be flexible. Teachers may select modules or lessons that fit their educational goals, as each lesson can either stand alone or build on prior lessons. This curriculum may be used:

- as the basis for a 13-week or semester-long course on forestry
- to teach a single unit on forestry within other high school courses, such as agricultural science and technology, or environmental science
- to help prepare students for the FFA Career Development Event (CDE) on Forestry, or for Envirothon

Curriculum Resources

The following [Resources](#) (available at learnforests.org) support teaching the curriculum:

- Glossary
- Supplies
- OFRI Publications and Videos
- Student Pages
- Field Investigations
- Oregon Standards Connections
- Oregon Forest Literacy Plan Concepts

About OFRI

The Oregon Forest Resources Institute supports and enhances Oregon's forest products industry by advancing public understanding of forests, forest management and forest products.

FOREST MANAGEMENT

1: What Is Forest Management?

Overview

Students watch a brief video exploring the concept of forest management and then consider what forest management might mean for particular management goals.

Time Considerations

Preparation: 15 minutes

Procedure: One 50-minute class period

Learning Objectives

Students will be able to:

- Develop a working definition of the concept of forest management.
- Identify activities that may be involved in forest management.
- Compare different forest management strategies for a forest, depending on management goals.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Oregon English Language Arts Standards

- Reading Science and Technical Subjects – 11-12.RST.1. Analyze what science and technical texts say explicitly as well as inferentially, citing evidence to support the analysis, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

Oregon Forest Literacy Plan Concepts

- 3.B.1. Forest management is a long-term process that can lead to changes in tree species composition, size and age, as well as in forest health and resilience.
- 3.B.2. From time immemorial, Indigenous people of Oregon have used fire and other practices such as girdling trees and land clearing to manage the forest. Their traditional ecological knowledge of Oregon’s forests informs forest management practices that sustain forests.
- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.
- 3.B.4. Forest management includes using natural processes and goal-oriented decisions and actions to achieve a variety of desired outcomes, including environmental (e.g., wildlife habitat and carbon sequestration), economic (e.g., timber production) and social (e.g., recreation) outcomes. Many of these outcomes are interrelated and can be managed for simultaneously, while others may be incompatible.

Materials

- [Forest Fact Break: Forest Management](#) video (1:53 minutes), available at learnforests.org
- “Managing Forests for Specific Goals” student page

Background Information¹

How do you ensure that a forest is sustainable for the long run? Forest management is the practice of giving forestlands the proper care so that they remain healthy and vigorous, and so that they provide the products and amenities the landowner wants.

Many people believe that the best way to protect a forest is to leave it alone. But generations of forest management and harvesting experience show that most forests do better with some form of management to ensure their health and sustainability.

This does not mean that all forests are managed the same way. Oregon’s forests generally fall into one of three management classifications:

- Reserve – managed primarily for environmental attributes, such as old-growth habitat
- Multi-resource – managed for multiple uses including recreation, water, wildlife habitat and some timber production

¹ Source: Adapted from “[Sustainable Forest Management Is Key](#).” Oregon Forest Resources Institute, oregonforests.org.

- Wood production – managed primarily for timber production, while protecting water quality and habitat

Forest management helps balance a forest’s environmental, social and economic values, providing the wood products and recreational access that society desires. It involves planning how to address the well-being of wildlife, the quality of watersheds, the health of the trees and plants, and the reduction of fires, insect infestations and diseases. It may include planting, thinning, prescribed burning, harvest and replanting.

This lesson introduces the concept of forest management as students consider what it might involve for a particular forest. In the next eight lessons, students will examine in depth specific management skills and strategies.

Key Vocabulary

carbon sequestration*

forest management*

forest reserves

management strategies

recreation

sustainability

timber production

watershed protection

**included in Glossary*

Procedure

1. Ask students what they think of when they hear the term “forest management.” Have students call out words or phrases, and write them on the board.
2. Show the brief video *Forest Fact Break: Forest Management* and discuss with students how the video’s description of forest management compared with their ideas.
3. Point out that the management of a specific forest depends on the amenities and products that the landowner wants (or that society expects) the forest to provide. Ask students what some of the goals people might have for forests are, and create a list of the goals on the board. (Possibilities include timber production, watershed protection, wildlife habitat, recreation, forest reserves and sequestering carbon.) Discuss the value of each goal.

4. Ask students for their ideas of management activities that landowners might undertake to meet their goals, and create a separate list of these on the board. (Possibilities may include planting, thinning, prescribed burning, harvest and replanting, among many others.)
5. Divide the class into small groups and give each group one of the goals on the list from step 3. Their job will be to identify how they might manage a 100-acre forest based on their goal.
6. Give each group a copy of the student page and allow time for them to work through the questions.
7. Have groups share their main management strategies based on their goal. As a class, compare and contrast the management strategies presented. Discuss:
 - a. What activities does forest management include?
 - b. In what ways do forest management strategies differ depending on the management goal?
 - c. Is there a management activity or outcome that all forest management goals share?
 - d. Are there any scenarios for which the best forest management strategy is to do nothing?
 - e. How is forest management similar to or different from farm management?
 - f. In what ways does forest management ensure the sustainability of forests?

Assessment

Ask students to write two paragraphs defining forest management and how it might differ for different goals.

Extension Ideas

- Explore the Coquille Indian Tribe's approach to forest management using a Tribe-created student lesson (see box).
- Discuss how forest management might change over time with changes in laws or values, or with environmental changes.

Coquille Indian Tribe's Approach to Forest Management

The Coquille Indian Tribe has lived in southwest Oregon for thousands of years and continues to thrive there. Generations of experience by the Coquille and other tribes has led to traditional ecological knowledge that has proved that most forests do very well with some form of human management to sustain the health of the ecosystem and the various resources that humans draw from the environment.

The Tribe's unique approach to forest management has become a model for federal, state and private forest managers, and serves as an example of how humans can act in sync with the ecosystem to meet a complex mix of economic, social and cultural needs while maintaining healthy forestlands.

Explore the Tribe's approach with your students through a Grade 10 lesson, [Forest Management](#), created by the Tribe and available at coquilletribe.org. Discuss with students:

- In what ways do the Coquille Indian Tribe's forest management methods reflect scientific practices for effectively balancing human interests with a healthy ecosystem?
- In what ways do the Coquille Indian Tribe's methods serve as a model for how to reduce the impact of human activities on the environment and promote biodiversity?

Managing Forests for Specific Goals

Imagine that your group owns and manages 100 acres of forest that consists primarily of same-age conifer trees.

1. What is your goal for this forest?
2. How would you know that your goal is being met?
3. What natural forest processes can you build on to meet your goal?
4. What things might you do in the short term to further your goal?
5. What things might you do in the long term to further your goal?
6. What management activities, assessments and strategies might you undertake to ensure that your forest remains healthy and vigorous in the long run, while also meeting your goal?

2: Surveying a Forest Tract²

Overview

Students learn some skills that forest managers use to survey forestland: pacing to measure horizontal distance, using compasses to find direction, map reading, and creating a map of a forest stand (or other site).

Time Considerations

Preparation: 30 minutes

Procedure: Two to four 50-minute class periods

Learning Objectives

Students will be able to:

- Identify ways that pacing, using a compass and mapping are useful in survival and forest management.
- Determine their average pace and measure distances between two points using pacing.
- Accurately use a compass to determine direction.
- Combine compass and pacing skills to follow an “orienteeing” course.
- Identify common symbols on a topographic map.
- Use pacing and compass skills to create a simple forest map.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Science and Engineering Practice – Using Mathematics and Computational Thinking. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

² This lesson was adapted from *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources. Chemeketa Community College.

Oregon Mathematics Standards

- Number and Quantity – HS.NQ.B.3 Use reasoning to choose and interpret measurement units consistently in formulas, graphs, and data displays, as a way to understand problems and to guide the solution of multi-step problems.

Oregon Forest Literacy Plan Concepts

- 3.A.4. Oregon’s forests are managed under private (e.g., family and industrial), public (e.g., state and federal) and tribal ownership. Each type of ownership may have different management objectives, and is subject to different protection laws and policies. Management objectives may even differ within classes of ownership.

Materials

- “Pacing” student page
- 100-foot measuring tape
- Stakes, flags or other markers for the course
- Orienteering compasses, one per pair of students
- “Compass and Pacing Instruction Cards” teacher page, copied and cut apart (two cards per student pair)
- Topographic maps of a nearby forest, available for free download from U.S. Geological Survey, store.usgs.gov (either printed, or accessible on-screen as PDFs)
- Graph paper (or gridded lab notebook)

Background Information

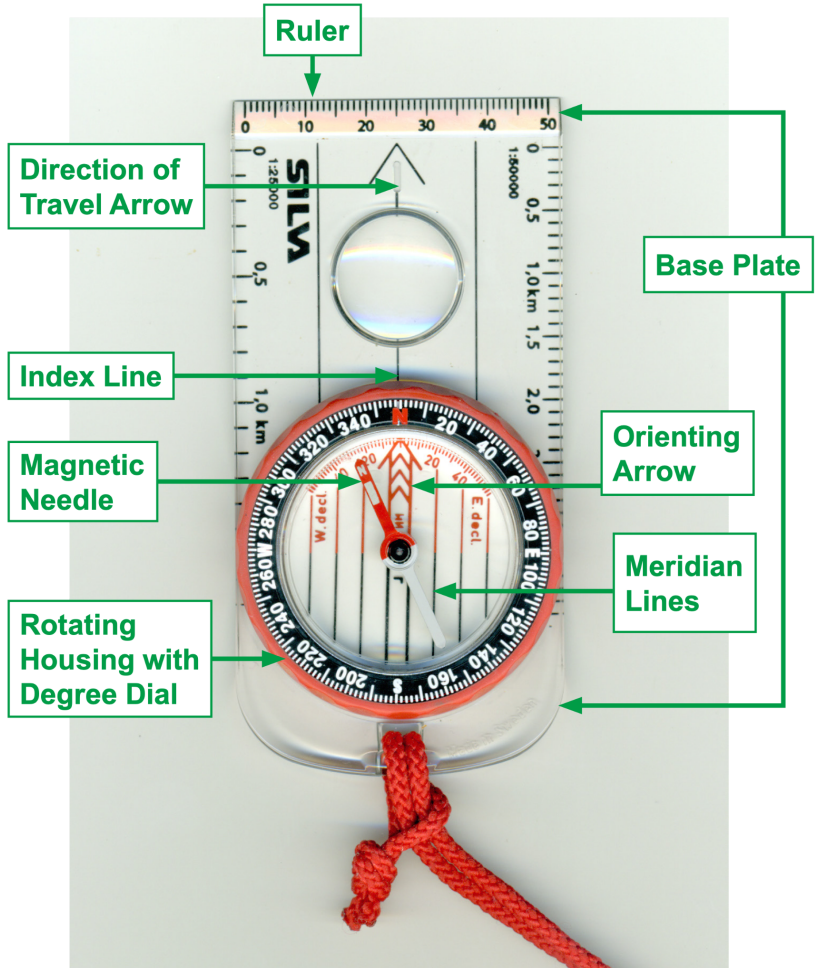
Pacing is a useful technique for measuring distance in the field, as it requires no equipment. In ancient Rome, one pace was measured as two natural steps, from the heel of one foot striking the ground to the heel of that same foot striking the ground. Today, while many people measure one-step paces (from the heel of one foot to the heel of the other), foresters and ecologists generally use two-step paces.

The average length of a pace will vary between people, and will also vary across different types of terrain. Most people have a one-step pace of about 30 inches and a two-step pace of about 60 inches.

The map symbols introduced in Part 3 of the lesson are those required for the FFA Forestry Career Development Event’s map reading. More symbols may be found in the USGS publication [Topographic Map Symbols](http://pubs.er.usgs.gov), available at pubs.er.usgs.gov.

Using a Compass to Follow a Bearing

1. Turn the dial on your compass until the degree you want matches up with the index line.
2. Hold the compass flat in your hand so the direction-of-travel arrow points directly away from you.
3. Turn your entire body until the north (red) end of the needle rests squarely in the orienting arrow.
4. You are now facing your bearing. Step forward in that direction to follow that bearing.



Key Vocabulary

bearing*

compass

contour*

pacing*

topographic map*

**included in Glossary*

Preparation

- For Part 1 of the lesson, you will need to set up four different courses. Two of the courses should be 300 feet long, or a similar, same-size length – one on an uneven or irregular surface (such as a field) and one on a smooth surface (such as pavement or sidewalk). In addition, measure and set up two “mystery” courses of different lengths (A and B) for students to measure using pacing.
- For Part 2 of the lesson, you will need to set up a compass course that consists of 20 markers placed five feet apart in a straight line running from magnetic west to magnetic east. Number the most westerly marker “1” and consecutively number the markers moving east until all 20 markers are numbered.
- Copy the student page. Copy the “Compass and Pacing Instruction Cards” teacher page, and cut apart.
- For Part 4 of the lesson, identify a suitable forest stand or other site near your school for students to map.

Procedure

Part 1 – Pacing

1. Ask students how measuring distances, using a compass and mapping might be useful for survival and for forest management.
2. Explain that students will be learning some skills that forest managers may use to survey their forestland. First, they will learn a technique for measuring horizontal distances called pacing. With this technique, individuals use their own natural pace to estimate distances.
3. Show them the two 300-foot courses, and direct them to pace the two courses – two times per course – to compute their pace length. Give them copies of the “Pacing” student page to record their results.
4. Challenge students to use their pace length to estimate the length of the two “mystery” courses, recording their estimates on the student page.
5. Discuss student findings. First, get a show of hands to find out their estimates for the two mystery courses. Then share the actual distances with them. How close were their estimates? What factors might affect the accuracy of this method? (Examples include ground cover, weather, footwear, ground surface and time of day.) In what situations might this method be useful for forest landowners?

Part 2 – Using a Compass

- Show students how to use a compass to follow a bearing (see “Using a Compass to Follow a Bearing” in the Background Information). Give them practice following various degree bearings such as 225 degrees, 120 degrees, due north, due east and so on.
- Show students the course you have set up (see Preparation). Explain that each pair of students will get one of the “Compass and Pacing Instruction Cards” that has a starting point marker number and directions to follow.
- Pairs should start at the marker number indicated on their card and follow the steps described. All routes lead back to a marker number on the starting line. After they’ve followed the instructions, students should note the number of the nearest marker.
- When students have completed the instructions on one card, give them a different instruction card to follow.

“Compass and Pacing Instruction Cards” Answer Key

Starting Point	Destination Point
1	7
2	19
3	2
4	8
5	16
6	8
7	8
8	9
9	15
10	19

Part 3 – Reading Forest Maps

- Divide the students into pairs, and give each a copy of the topographic map (or access to viewing on-screen).
- Introduce or review some or all of the map symbols identified on the “Topo Map Symbols” student page.
- Challenge students to find as many of the symbols as possible on their maps, marking them with sticky notes or highlighter (either real or virtual).

Part 4 – Creating a Forest Map

- Take students to a forest stand or other site on or near your school (see Preparation). As a class, identify the boundaries of a rectangular study area at the site and, using a steel measuring tape, measure the length and width of the area.
- Direct students to make a rough scale drawing of the perimeter on graph paper or in their lab notebooks, using as much of the space available as possible.
- Have students work in pairs and, using hand compasses and their pace, measure and draw in the important features encountered at the study site, such as paths, ridges, valleys, vegetation boundaries, and so on. Students should sketch these features and include data on pacing and compass direction.
- Back in the classroom, allow students time to create scale maps of the area, using the information they recorded in the field and some of the map symbols they explored in Part 3.

Assessment

Use students' forest maps as an assessment of their surveying skills. Based on your particular situation, develop a rubric for assessing the maps with criteria such as number and quality of important features, accuracy of location, number of map symbols and so on. You may also want to create a map transparency of the study site to use in assessing student maps.

Extension Ideas

- The FFA Forestry Career Development Event requires participants to determine the degree reading between each of a set of stakes. Practice determining compass bearings as follows.
 - Face the stake or other object.
 - Hold the compass flat in your hand with the direction-of-travel arrow pointing out toward the stake. Do not hold the compass near metal belt buckles.
 - Turn the dial until the north (red) end of the needle rests squarely in the orienting arrow.
 - Read the number at the index line. That number is the bearing for your stake.
- Practice reading the information available on maps of forested areas. For online interactive GIS maps of Oregon, see the Oregon Department of Forestry's [LocatOR](https://gisapps.odf.oregon.gov/LocatOR) application, available at gisapps.odf.oregon.gov/LocatOR. Work in small groups to design geocaching trails to share with another group.

Pacing³

Pacing is a useful skill for measuring forest stands or other distances in the field. It involves using your natural walking pace to estimate a distance. For this exercise, count two steps as one pace: that is, from the heel of one foot striking the ground to the heel of that same foot striking the ground again.

1. To determine your pace, walk a measured course, counting the number of paces you take. Then, divide the length of the course by that number. For accuracy in the field, find your average pace on both smooth and uneven surfaces.

Smooth Surface

Trial 1:

Course Length: _____

Number of Paces in Course: _____

Pace Length = Course Length ÷ Number of Paces: _____

Trial 2:

Course Length: _____

Number of Paces in Course: _____

Pace Length = Course Length ÷ Number of Paces: _____

³ Source: Adapted from *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources. Chemeketa Community College.

Uneven Surface

Trial 3:

Course Length: _____

Number of Paces in Course: _____

Pace Length = Course Length \div Number of Paces: _____

Trial 4:

Course Length: _____

Number of Paces in Course: _____

Pace Length = Course Length \div Number of Paces: _____

Average Pace Length = (Trial 1 Pace Length + Trial 2 Pace Length + Trial 3 Pace Length + Trial 4 Pace Length) \div 4 = _____

2. Use your average pace length to measure unknown distances.

Mystery Course A

Number of Paces in Course: _____

Course Length = Average Pace Length x Number of Paces in Course = _____

Mystery Course B

Number of Paces in Course: _____

Course Length = Average Pace Length x Number of Paces in Course = _____

Compass and Pacing Instruction Cards⁴

(Copy and cut cards apart)

<p>Starting Point: 1 Go 36 degrees for 122 feet Then 149 degrees for 58 feet Then 235 degrees for 86 feet Destination number: _____</p>	<p>Starting Point: 6 Go 03 degrees for 100 feet Then 132 degrees for 74 feet Then 225 degrees for 69 feet Destination number: _____</p>
<p>Starting Point: 2 Go 17 degrees for 104 feet Then 150 degrees for 52 feet Then 142 degrees for 64 feet Destination number: _____</p>	<p>Starting Point: 7 Go 34 degrees for 119 feet Then 186 degrees for 50 feet Then 228 degrees for 74 feet Destination number: _____</p>
<p>Starting Point: 3 Go 38 degrees for 125 feet Then 237 degrees for 90 feet Then 186 degrees for 50 feet Destination number: _____</p>	<p>Starting Point: 8 Go 346 degrees for 102 feet Then 129 degrees for 78 feet Then 211 degrees for 58 feet Destination number: _____</p>
<p>Starting Point: 4 Go 36 degrees for 122 feet Then 174 degrees for 50 feet Then 228 degrees for 74 feet Destination number: _____</p>	<p>Starting Point: 9 Go 346 degrees for 102 feet Then 129 degrees for 78 feet Then 186 degrees for 50 feet Destination number: _____</p>
<p>Starting Point: 5 Go 22 degrees for 107 feet Then 158 degrees for 54 feet Then 186 degrees for 50 feet Destination number: _____</p>	<p>Starting Point: 10 Go 343 degrees for 104 feet Then 141 degrees for 64 feet Then 145 degrees for 61 feet Destination number: _____</p>

⁴ Source: *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

STUDENT PAGE

LESSON 2

Topographic Map Symbols⁵

Map symbols are an important part of map reading. They can depict various features including roads, boundaries, buildings, landmarks, places of interest, water supplies and mines. Following is a list of some common symbols used in topographic maps.

Building	
Cemetery	
Quarry or open pit mine	
Gravel, sand, clay, or borrow pit	
School; house of worship	
Perennial stream	
Perennial river	
Intermittent stream	
Perennial lake/pond	
Spring or seep	
Highway or road bridge; drawbridge	

ROADS AND RELATED FEATURES

Please note: Roads on Provisional-edition maps are not classified as primary, secondary, or light duty. These roads are all classified as improved roads and are symbolized the same as light duty roads.

Primary highway	
Secondary highway	
Light duty road	
Light duty road, paved*	
Light duty road, gravel*	
Light duty road, dirt*	
Light duty road, unspecified*	
Unimproved road	
Unimproved road*	
Trail	
Power transmission line; pole; tower	
Standard gauge railroad, single track	
Standard gauge railroad, multiple track	

CONTOURS

Topographic

Index	
Approximate or indefinite	
Intermediate	
Approximate or indefinite	

⁵ Symbols adapted from "[Topographic Map Symbols](https://pubs.usgs.gov/topographic/symbols/)." US Geological Survey, pubs.usgs.gov.

3: Analyzing Forest Soil⁶

Overview

Students participate in a lab comparing soils from two or more different sites, looking at organic composition, pH, macronutrients, soil texture and the presence of soil invertebrates, to learn more about this important element in forest management.

Safety Notes

- Be sure to follow all lab safety guidelines set out by your school or district.
- Have students wear safety goggles throughout the lab.
- Be mindful of open flames for the organic component procedure.
- Be aware of the possibility of chemical contact with skin while using the soil test kit.
- Follow the test kit guidelines for disposing of spent chemicals.
- Be sure that students follow rules for the safe and ethical treatment of living things.

Time Considerations

Preparation: 30 to 60 minutes (with time enough in advance to dry soil samples)

Procedure: One to three 50-minute class periods

Learning Objectives

Students will be able to:

- Describe some chemical and physical components of soil (organic composition, pH, soil macronutrients and texture).
- Use a dichotomous key to identify soil invertebrates.
- Compare two or more different soil samples.
- Explain the importance of soils in forest management, based on evidence from their investigation.

⁶ Source: This lesson was adapted from “Soils: Physical and Biological Analysis,” in *Environmental Science II* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

Standards Connections

Oregon Science Standards

- HS.LS2.2. Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS.ESS3.1. Earth and Human Activity. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- Science and Engineering Practice – Using Mathematics and Computational Thinking. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Oregon English Language Arts Standards

- Writing History, Science, and Technical Subjects – 9-10.WHST.2 and 11-12.WHST.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Oregon Mathematics Standards

- Mathematical Practice – MP.2. Reason abstractly and quantitatively.

Oregon Forest Literacy Plan Concepts

- 1.C.7. Oregon’s regions vary in soil types, elevation, topography, temperature, wind and rainfall patterns. These variations create the different forest types and species composition that, together with disturbance histories, contribute to the region’s biodiversity.
- 4.B.5. We need a variety of professionals and skilled workers to sustain our forests, including foresters, scientists, engineers, lawyers, information technology professionals, land managers, investors, educators, communications specialists, fire fighters, loggers, tree planters, truck drivers, mechanics and wood products manufacturers. Resources are available to learn about these valuable and rewarding careers.

Materials

For the class:

- 12” soil core samples from two or more sites, dried (see Preparation)
- Leaf litter samples from the same sites (see Preparation)
- One-gallon sealable bags and garbage bags (for soil and leaf litter samples)
- Asbestos gloves
- Tongs (for lifting crucibles)
- Digital balance

For each lab group:

- Safety goggles
- Porcelain crucible with cover (for heating core samples)
- Needle probe (for stirring core sample)
- Bunsen burner
- Ring stand and clamp (for crucibles)
- Matches
- Asbestos pads
- Soil test kit (for testing pH, nitrogen, phosphorous and potassium levels)
- Large aluminum tray
- Screw-cap vial (for soil invertebrates)
- Tweezers or forceps (for soil invertebrates)
- “Soil Lab Procedures” student page
- “Soil Lab Data Sheet” student page
- “Key to Soil and Leaf Litter Invertebrates” student page

Background Information

Soils are complex systems of organic and inorganic components. Soil composition greatly influences plant and animal communities, as well as the potential human uses for a given site. Land management decisions are fundamentally tied to soil types – whether it is forestry, agriculture, building/construction or other land use. In this lesson, students examine various physical and biological characteristics of soil. For more details, see the soil lab student pages.

Key Vocabulary

clay

invertebrate*

leaf litter*

loam

macronutrient*

nutrient*

organic*

soil*

soil pH*

**included in Glossary*

Preparation

- Choose two or more sites that are likely to have different soil types for collecting soil samples – either on your school grounds or from nearby locales. Possible sites might include a grassy area, a treed area, a timber production tree farm, a wildlife refuge slough area, a pastureland or a forest with trees 50 to 70 years old or older. Wherever you collect the samples, be sure you have permission from the landowner or manager to do so.
- At each site, collect a 12-inch core sample, placed in a one-gallon sealable bag, as well as the litter layer from a 1-m² area, placed in large plastic bags. Dry the core samples in aluminum pans in a drying oven at 55 C° for four days.
- Set up soil analysis kits and other equipment for each group on lab benches. Make copies of the student pages.

Procedure

- Discuss: What is soil? Why is it important? What might forest managers want to know about the soil in the forests they manage?
- Divide the class into pairs or small groups. Give them copies of the “Soil Lab Procedures” student page, and explain the various tests students will conduct.
- Give each group a soil sample and matching leaf litter to analyze. Have them use the equipment provided to follow the lab procedures, recording their results on the “Soil Lab Data Sheet” student page. They will also need a copy of the “Key to Soil and Leaf Litter Invertebrates” page to identify the organisms they find.

- Lead a class discussion about students' findings:
 - What differences did the groups find between the sites' soil organic content, pH, macronutrient levels, soil texture and soil invertebrates? What might these differences say about each of the sites?
 - Given the findings for a particular site, would this site be suitable for the commercial production of trees? What might be major forest management concerns for this site?
 - Which sites might be suitable for recreational activities? What soil characteristics may limit the type of recreation that occurs at each site?

Assessment

Give students the following writing prompt: Assume that your sample was taken from a 100-acre plot of land that you have just inherited. Prepare a one- to two-page narrative that describes what you have learned about this land. Taking into account the characteristics of the soil, describe what you might do with this land. Include the evidence that supports your choices.

Extension Ideas

- Construct food webs representing the energy flow in the soil samples.
- Find out more about your area's soil by checking out Natural Resources Conservation Service's [Web Soil Survey](http://websoilsurvey.nrcs.usda.gov) website at <http://websoilsurvey.nrcs.usda.gov>, which includes a soil survey for every county in the United States with soil descriptions and characteristics, aerial photographs and other soil resources.
- Compare soils in Oregon with other regions of the world.

Soil Lab Procedures⁷

Safety Note: Wear goggles during this lab, and follow any other safety instructions provided by your teacher.

Organic Content

Organic material increases the water-holding ability and aeration of soil. As decaying plants decompose, they add important nutrients and influence the soil's pH. Thus, the amount of organic material in soil is an important consideration.

Organic matter burns at high temperature and decomposes to CO₂ and H₂O. In general, the inorganic components of the soil do not decompose at high temperatures. Therefore the loss in weight of a soil sample after burning can be used to estimate organic content.

Procedure

1. Weigh a glazed porcelain crucible (without the cover) to the nearest 0.01 gram:
_____.
2. Fill the crucible approximately two-thirds full with an oven-dried sample of soil.
3. Reweigh the sample plus the crucible to the nearest 0.01 gram: _____.
4. Subtract the weight of the crucible. This is the "dry sample weight": _____.
5. Place the uncovered crucible over a flame (Bunsen burner) and cook for 15 minutes. While cooking, stir with a probe, but be careful not to remove any soil in the process.
6. Ask the teacher to use tongs and asbestos gloves to remove the crucible from the flame. Cover it and allow it to cool on a heat-proof pad.
7. After about 5 minutes, when it's cool enough to weigh, remove the cover and reweigh the sample to the nearest 0.01 gram. This is the "cooked sample weight": _____.
8. Calculate the percent (%) of organic matter in the soil sample using the formula:
Percent Organic Matter = (Dry Sample Weight – Cooked Sample Weight) x 100
Dry Sample Weight
9. Record the percent of organic matter for your sample on the data sheet.

⁷ Source: Adapted from "Soils: Physical and Biological Analysis," in *Environmental Science II* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

pH

A soil's pH is a measure of its acidity. The pH scale runs from 0 to 14, with 7 being neutral. Values below 7 are progressively more and more acidic, while values above 7 are progressively more and more alkaline, or basic.

Plants often have specific soil pH requirements. Crops such as blueberries and strawberries, for example, prefer more acidic soils, while most vegetable crops require somewhat more alkaline soils. Soils closely associated with Douglas-fir and other cone-bearing trees are often acidic. That's because tannic acid accumulates as a result of decomposition of conifer needles and branches.

Interpretation of Soil pH Levels

pH 4.0 – strongly acidic

pH 5.0 – moderate to strong acidity

pH 6.0 – slight to moderate acidity

pH 7.0 – neutral (neither acidic nor alkaline)

pH 8.0 – slight to moderate alkalinity

pH 9.0 – moderate to strong alkalinity

Procedure

1. Use soil from your soil core sample.
2. Follow the instructions that come with the soil test kit to determine the soil's pH.
3. Record your measurements on the data sheet.
4. Clean and dry the soil kit components and pack them neatly back in the case.

Macronutrients

Macronutrients are chemical elements that plants need for growth and development. Three primary macronutrients in soil that plants use are nitrogen (N), phosphorus (P) and potassium (K). A measure of these three components provides a good picture of soil fertility. Most commercial fertilizers contain varying amounts of these three macronutrients, which are often shown on fertilizer labels. A label of "15-30-10," for example, indicates 15 percent by weight for N, 30 percent for P and 10 percent for K.

Procedure

1. Use soil from your soil core sample.
2. Follow the instructions that come with the soil test kit to determine the soil's nitrate-nitrogen level.
3. Follow the instructions to determine the phosphorus level.
4. Follow the instructions to determine the potassium level.
5. Record all the values for soil macronutrients on the data sheet.
6. Clean and dry the soil kit components and pack them neatly back in the case.

Soil Texture

Soil texture is a physical property determined by the size of mineral particles in the soil. Soils are generally made up of larger fragments of sand or gravel embedded in microscopic silt or clay particles. Soil texture is very important, because it affects a plant's ability to get nutrients, water and air at the root level.

Mineral Particles in Soil

Gravels – 2.0 mm in diameter or greater

Sands – 0.02 mm – 2.0 mm in diameter

Silts – 0.002 mm – 0.02 mm in diameter

Clays – less than 0.002 mm in diameter

Most soils contain a mixture of sand, silt and clay. Soils that are predominantly sand have few nutrients, don't hold water and are prone to drought. Soils that are predominantly clay contain nutrients and hold water well, but do not allow movement of air or water, and don't drain well. The best soils for most plants contain a relatively even mixture of sand, silt and clay, and are called loam.

Procedure

Conduct a simple field test using the sense of touch to approximate soil texture:

- Place a small handful of dry soil (about the size of a marble) on the palm of your hand.
- Add a few drops of water to moisten it to the point that it can be worked with the fingers.

- Knead the soil between your thumb and fingers, breaking up clumps. Remove any sticks, gravel or pebbles.
- Squeeze the soil between your thumb and fingers. Use the following chart to determine the approximate soil type.
- Record your findings on the data sheet.

Soil Type	Characteristics of Squeezed Moist Soil ⁸
Sand	Feels gritty and does not hold a ball shape.
Sandy Loam	Can be molded into a ball, but the ball breaks up easily.
Silt	Has silkiness like flour (not gritty; can be molded into a ball, but is easily deformed).
Loam	Can be molded into a ball that can be handled without breaking or deforming.
Clay Loam	Can be formed into a long thin “ribbon” that easily breaks.
Clay	Feels sticky, and can easily be formed into a long thin “ribbon.”

Soil Invertebrates

Soil invertebrates play critical roles in the long-term stability and fertility of soils. Their activities aerate the soil, speed up decomposition of organic materials and distribute important nutrients.

Procedure

1. With your leaf litter in a large tray, use tweezers to collect any invertebrates you see, placing them in a vial.
2. Use the “Key to Soil and Leaf Invertebrates” page to identify the organisms you found.
3. Record your findings on the data sheet.

⁸ Adapted from Project Learning Tree, “Monitoring Forest Health” in *Exploring Environmental Issues: Focus on Forests*.

Soil Lab Data Sheet

Soil Characteristics

	Site #1	Site #2	Site #3	Site #4
% Organic matter				
pH				
Nitrate N (lbs/acre)				
Phosphorus P (lbs/acre)				
Potassium K (lbs/acre)				
Soil texture				

Soil Invertebrates

	Site #1	Site #2	Site #3	Site #4
Springtails				
Earthworms				
Roundworms				
Beetles				
Beetle larvae				
Slugs				
Snails				
Flies				
Fly larvae				
Millipedes				
Proturans				
Pseudoscorpions				
Spiders				
Sowbugs				
Mites				
Ants				
Caterpillars				
True bugs				
Harvestmen				
Other: _____				
Other: _____				
Miscellaneous				
Total # Individuals				
Total # Species				

STUDENT PAGE

LESSON 3

Key to Soil and Leaf Litter Invertebrates⁹

For each organism you find, start with #1 and, depending on whether legs are present or not, go to the question number indicated. Continue until you determine the type of organism. Please note that some immature insects such as fly larvae, beetle larvae and moth larvae may not be accurately identified with this key.

1	Legs present	4
	Legs absent	2
2	Body spindle-shaped, smooth, unsegmented, slender, usually light-colored, minute (approx. 0.5-1.5 mm long)	Phylum Nematoda (roundworms)
	Body not spindle-shaped, or if spindle-shaped, animal is segmented, usually darker in color and 1.5 mm long	3
3	Body distinctly segmented and worm-like, shell absent	Phylum Annelida (earthworms)
	Body not segmented, soft and smooth, with or without shell	Phylum Mollusca (snails and slugs)
4	Three pairs of legs present	5
	More than three pairs of legs present	14
5	With functional wings	6
	Without functional wings	10
6	With only one pair of wings; second pair of wings replaced by a pair of short, pin-like structures (halteres)	Order Diptera (flies)
	With two pairs of wings	7
7	Front and hind wings similar in texture and thickness	8
	Front and hind wings unlike in texture; front wings may be horny or leathery	9

⁹ Source: "Soils: Physical and Biological Analysis" in *Environmental Science II* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources. Chemeketa Community College.

8	Wings usually covered with scales; sucking mouthparts	Order Lepidoptera (moths and butterflies)
	Wings transparent; chewing or sucking mouthparts	Order Hymenoptera (wasps)
9	Front wings horny or leathery and usually meeting in a straight line down the back, forming a veinless sheath over the abdomen; hind wings folded under front wings when not in use; chewing mouthparts	Order Coleoptera (beetles)
	Front wings thickened and leathery at base and membranous at tip; mouthparts, a piercing-sucking beak arising from the anterior portion of the head	Order Hemiptera (true bugs)
10	Abdomen terminating in two or three tail-like appendages (cerci); long antennae, chewing mouthparts	Order Thysanura (silverfish)
	No cerci at end of abdomen or, if cerci-like appendages are present, they are pointed in an anterior direction (i.e., the springs of springtails)	11
11	Narrow-waisted; chewing mouthparts	Order Hymenoptera (ants)
	Not narrow-waisted	12
12	Ant-like, but broad-waisted and usually light-colored	Order Isoptera (termites)
	Not ant-like	13
13	Small, delicate insects with long, usually double appendages on underside of abdomen; chewing mouthparts (very common in litter samples!)	Class Collembola (springtails)
	Small, soft-bodied, plump insects with two short tubes at end of abdomen; piercing mouthparts in a beak that arises from back of head	Order Homoptera (aphids)
14	Four pairs of walking legs present; head and thorax fused to form cephalothorax (Class Arachnida)	15
	More than four pairs of walking legs present	18
15	First pair of appendages (pedipalps) with large pincer-like claws; abdomen distinctly segmented; generally less than 10 mm long	Order Pseudoscorpionida (pseudoscorpions)
	First pair of appendages not usually highly modified; abdomen not distinctly segmented; length variable	16
16	Tiny, total length less than 2 mm; body generally oval or shield-like	Order Acari (mites)
	Larger, total length greater than 2 mm; body shape variable	17

17	Cephalothorax distinct from abdomen; leg length less than 3x body length	Order Araneae (spiders)
	Cephalothorax not distinct from abdomen; leg length greater than 3x body length	Order Opiliones (harvestmen, daddy-long-legs)
18	Two pairs of appendages per abdominal segment	Class Diplopoda (millipedes)
	One pair of appendages per abdominal segment	19
19	Thorax composed of eight overlapping segments, abdomen composed of six segments; seven pairs of legs plus one pair of maxillipeds (anterior)	Order Isopoda (sowbugs)
	Thorax and abdomen variable; more than seven pairs of legs	20
20	Antennae with three distinct prongs, nine pairs of legs	Class Pauropoda
	Antennae not as above, more than nine pairs of legs	21
21	Minute, total length less than 10 mm; 10 to 12 pairs of legs, poison claws absent on first trunk segment	Class Symphyla
	Larger, total length generally more than 10 mm; generally more than 12 pairs of legs, poison claws present on first trunk segment	Class Chilopoda (centipedes)

4: Forest Density Lab¹⁰

Overview

Students use Lego® bricks to model forest density and “build” forest stands with optimal spacing.

Time Considerations

Preparation: 30 minutes

Procedure: One to two 50-minute class periods

Learning Objectives

Students will be able to:

- Define forest stand density.
- Model different forest stands to compare their density and spacing.
- Determine the optimal spacing and size class distribution for a particular stand.

Standards Connections

Oregon Science Standards

- HS.LS2.2. Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- Disciplinary Core Idea – HS.LS2.C. Ecosystem Dynamics, Functioning, and Resilience. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.
- Science and Engineering Practice – Developing and Using Models. Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Science and Engineering Practice – Analyzing and Interpreting Data. Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution.

¹⁰ Source: Adapted from “Lego® Forest Density Lab” in *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

Oregon Forest Literacy Plan Concepts

- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.
- 3.B.4. Forest management includes using natural processes and goal-oriented decisions and actions to achieve a variety of desired outcomes, including environmental (e.g., wildlife habitat and carbon sequestration), economic (e.g., timber production) and social (e.g., recreation) outcomes. Many of these outcomes are interrelated and can be managed for simultaneously, while others may be incompatible.

Materials

- 16x16-stud Lego® baseplates, one per individual or pair
- Assortment of different-sized Lego® bricks: one-stud,¹¹ two-stud, four-stud, six-stud and eight-stud bricks (if possible, it is helpful if the bricks of each size are the same color)
- “Forest Stand Density” student page
- Camera (optional)

Background Information¹²

Stand density is an important concept in forest management. It is a measure of how many trees are growing per unit area. The density of a stand of trees affects a number of factors: tree size (and therefore tree value), tree and stand growth, branch and crown size, wood quality (such as presence of knots) and certain attributes of wildlife habitat. Land managers can directly influence stand development by manipulating stand density.

Forest managers use a variety of measures such as trees per acre (TPA), basal area per acre (BA/A), Reineke’s Stand Density Index (SDI), volume (board feet) and Relative Density (RD) to determine density. In this lesson, students calculate the trees per acre and use Stand Density Index and Relative Density to observe the spacing of trees within stands.

A stand’s SDI is equal to the number of trees averaging 10 inches in diameter (DBH) present in the stand. A site’s maximum SDI is both site- and species-specific, and describes the maximum

¹¹ The “studs” are the extensions on the bricks or platform that enable them to hold together. The number of studs denotes brick size.

¹² Source: “Lego® Forest Density Lab” in *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

number of 10-inch-diameter (DBH) trees that the stand could support before natural thinning would occur. RD is calculated by dividing the measured SDI by the maximum SDI. Thus,

$$RD = \text{Measured SDI} \div \text{Maximum SDI}$$

Each species has a different maximum Stand Density Index as well as optimal Relative Densities. Decades of research and empirical data have yielded some general rules for tree vigor and growth rates of coastal Douglas-fir in the Pacific Northwest. The tree-growth zones shown below have been established for Douglas-fir.

Note that the Coast Range is very productive, so Douglas-fir’s maximum SDI is higher than it may be in other areas. In the Willamette Valley, for instance, the maximum SDI will vary between 510 and 550, depending on site quality. Also, remember that each species has a different maximum SDI value.

Table: Growth Zones for Coastal Douglas-Fir¹³

Zone	Description	SDI (per acre)	RD
Maximum Density Zone	The biological maximum of 10-inch-diameter trees that could possibly grow in an acre in this area.	600	1.0 (100%)
Mortality Zone	Some trees will begin to die due to tree-to-tree competition.	330-600	.55-1.0
Healthy Zone	Trees are vigorously growing, optimally using site resources.	210-330 ¹⁴	.35-.55
Diversity Zone	This density allows for differentiation of crown positions in the canopy.	120-240 ¹⁵	.20-.40

¹³ Source: “[Using Lego® Blocks to Demonstrate Concepts of SDI and Relative Density](#)” by Monica Spicker. Spokane Community College. Available at ir.library.oregonstate.edu.

¹⁴ This is the well-accepted thinning zone; allowing the stand to grow to 330 SDI and then thinning back to 210 SDI optimizes site resource utilization without allowing competition-induced mortality.

¹⁵ Thinning back to these levels of SDI should promote growth of understory vegetation or regenerated trees.

In this lesson, each two-stud Lego® brick represents a 10-inch-diameter (DBH) Douglas-fir tree growing in Oregon’s Coast Range. The two-stud brick has an SDI of 1, a one-stud brick represents 0.5 SDI, a four-stud brick presents 2 SDI, and so on. A Lego® baseplate of 16x16 studs has a total SDI of 128, and represents ¼ acre of forestland. The following table shows the brick sizes, their comparable tree size and SDI, as well as the number of bricks that would be needed for even SDI distribution among the five sizes at various relative densities.

Table: Number of Bricks Needed for Even SDI Distribution at Different Relative Densities (RD) for a 16x16 Baseplate

Brick Size	Comparable Tree Size (DBH)	Stand Density Index (SDI)	Relative Density (RD)		
			RD = 0.15	RD = 0.35	RD = 0.55
1-stud	6.5 inches	0.5	8	18	28
2-stud	10.0 inches	1	4	9	14
4-stud	15.4 inches	2	2	4	7
6-stud	19.9 inches	3	1	3	5
8-stud	23.8 inches	4	1	2	4

Key Vocabulary

basal area

diameter at breast height (DBH)*

Relative Density (RD)

stand density

Stand Density Index (SDI)*

tree size class

trees per acre (TPA)

**included in Glossary*

Preparation

Gather the materials. Make copies of the student page.

Procedure

1. Ask students: What might be the consequences of forest trees growing very close together or very far apart?
2. Point out that forest density is an important measure of a forest's health. Using information from the Background Information, introduce the concepts of trees per acre (TPA), Stand Density Index (SDI) and Relative Density (RD).
3. Give each individual or pair a 16x16-stud Lego® baseplate, an assortment of different-sized Lego® bricks and a copy of the “Determining Stand Density” student page. Direct them to follow the directions on the student page to build three different forest stands with different characteristics. You also may have students take pictures of each of their stands to compare later.
4. When students have completed the lab, lead a class discussion about what they learned, asking such question as
 - a. What distribution of tree sizes enabled you to best achieve the optimal density?
 - b. How did your mixed-age stand model compare with your optimal stand density model?
 - c. What does your modeling tell you about stand densities in a real forest?

Assessment

- Have students write a paragraph describing what they observed in the modeling exercise and what they learned from it.

Extension Idea

- Use the data from the activity to determine Basal Area (BA) for each of the stands. Basal Area describes the average amount of an area (usually an acre) occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height, and expressed as per unit of land area (typically square feet per acre). For this exercise, students calculate the area of each class of trees at breast height and then add together all the areas of all the trees, multiplying by four to express square feet per acre.

Determining Stand Density

Use Lego® bricks to model a forest stand, with each brick size representing a different size Douglas-fir tree and the 16x16-stud baseplate representing a quarter acre.

Stand 1: Place “trees” on the 16x16 baseplate in any array you choose. Then determine the Trees per Acre (TPA), Stand Density Index (SDI) and Relative Density (RD) for your stand, using the table below.

Brick Size	Comparable Tree Size (DBH)	Stand Density Index (SDI) per Tree	Number of Trees in Size Class (N)	SDI for Size Class (SDI x N)
1-stud	6.5 in	0.5	i:	a:
2-stud	10.0 in	1	ii:	b:
4-stud	15.4 in	2	iii:	c:
6-stud	19.9 in	3	iv:	d:
8-stud	23.8 in	4	v:	e:
TPA (sum of i-v above) x 4:				
Stand SDI (sum of a-e above):				f:
Stand SDI per Acre (f x 4):				g:
Relative Density (RD) = Stand SDI per Acre ÷ Maximum Stand SDI (g ÷ 512)				h:

Stand 2: Place trees on the 16x16 baseplate to build a forest stand with a Stand SDI of 240 per acre, the optimal density for Douglas-fir trees growing in the Coast Range. Be careful not to crowd trees (crowding is when one brick touches another brick at more than one stud).

Brick Size	Comparable Tree Size (DBH)	Stand Density Index (SDI) per Tree	Number of Trees in Size Class (N)	SDI for Size Class (SDI x N)
1-stud	6.5 in	0.5	i:	a:
2-stud	10.0 in	1	ii:	b:
4-stud	15.4 in	2	iii:	c:
6-stud	19.9 in	3	iv:	d:
8-stud	23.8 in	4	v:	e:
TPA (sum of i-v above) x 4:				
Stand SDI (sum of a-e above):				f:
Stand SDI per Acre (f x 4):				g:
Relative Density (RD) = Stand SDI per Acre ÷ Maximum Stand SDI (g ÷ 512)				h:

Stand 3: Create a mixed-age stand with a Relative Density of .35 per acre by choosing three or more different tree sizes and placing enough of each in the stand so that the total SDIs for each size class are about the same. Be careful not to crowd trees.

Brick Size	Comparable Tree Size (DBH)	Stand Density Index (SDI) per Tree	Number of Trees in Size Class (N)	SDI for Size Class (SDI x N)
1-stud	6.5 in	0.5	i:	a:
2-stud	10.0 in	1	ii:	b:
4-stud	15.4 in	2	iii:	c:
6-stud	19.9 in	3	iv:	d:
8-stud	23.8 in	4	v:	e:

TPA (sum of i-v above) x 4:	
Stand SDI (sum of a-e above):	f:
Stand SDI per Acre (f x 4):	g:
Relative Density (RD) = Stand SDI per Acre ÷ Maximum Stand SDI (g ÷ 512)	h:

5: Forest Thinning¹⁶

Overview

In this field investigation, students determine the trees per acre of a forest plot and then make recommendations for thinning it to a given density, including which trees they would remove.

Time Considerations

Preparation: 30 minutes

Procedure: One to two 50-minute class periods

Learning Objectives

Students will be able to:

- Determine the trees per acre of a given forest plot.
- Calculate the number of trees that should be removed to reach a given optimum density.
- Recommend which trees to remove based on their location, size, live crown ratio, health and form.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Science and Engineering Practice – Constructing Explanations and Designing Solutions. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Oregon Mathematics Standards

- Mathematical Practice – MP.2. Reason abstractly and quantitatively.
- Number and Quantity - HS.NQ.B. Attend to units of measurement needed to solve problems through quantitative reasoning and mathematical modeling.

¹⁶ Source: Lesson was adapted from *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

Oregon Forest Literacy Plan Concepts

- 3.B.1. Forest management is a long-term process that can lead to changes in tree species composition, size and age, as well as in forest health and resilience.
- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.

Materials

- Flagging tape
- Stakes
- “Forest Thinning Tally Sheet” student page
- Measuring tapes
- Optional: calculators or calculator app

Background Information¹⁷

The most common tool used in silviculture is thinning, which means removing some trees so that the remaining trees have more light and other resources to grow. All plants have a predetermined size-density relationship, meaning that at a given density (trees per acre) individual plants can only grow to a certain size. To get larger, they need more space.

This relationship has been well researched by foresters, so they know the optimal spacing for tree growth. Managing tree growth with thinning requires staying above a minimum spacing and far enough above the optimal spacing to allow for growth until the next thinning.

A general rule for Douglas-fir, for example, says that minimum adequate spacing can be estimated by the number of inches of diameter measured at breast height (DBH, 4.5 feet above ground on uphill side of tree). Using this method, a 12-inch-diameter tree would need a minimum of 12 feet to

Optimal spacing for various tree species

Species	Optimal spacing (in feet) at		
	6" diameter	10" diameter	16" diameter
Douglas-fir	8	12	17
Western hemlock	6	10	14
Western redcedar	7	11	16
Grand fir	8	12	18

¹⁷ Source: “Tending Your Trees,” in *Establishing and Managing Forest Trees in Western Oregon*. Oregon Forest Resources Institute.

the nearest 12-inch-diameter tree, while a 20-inch tree would need 20 feet. If you were thinning a forest you would want to provide for future growth, so Douglas-fir forests are commonly thinned to spacings of diameter plus 4 or 5 feet. The chart below indicates the optimal spacing of various Oregon forest tree species.

In deciding which trees to remove in thinning, foresters will take into account the health of the individual trees, including whether they are alive, show any deformities (such as the top missing) or have signs of poor health (such as fungus or evidence of insect damage).

Another factor they may consider is a tree's "live crown ratio." This is the percentage that the crown represents of the total tree height. Determining live crown ratio involves measuring or estimating the vertical distance from the top of the tree to the lowest live branch and dividing that measurement by the total height of the tree. For Pacific Northwest conifers, a live crown ratio of 30 percent or more is considered healthy. Trees with less than 30 percent may be good candidates for thinning.

Key Vocabulary

live crown ratio*

plot density

target density

thinning

**included in Glossary*

Preparation

Identify a suitable forest study area. It should include space for 0.05-acre (1/20 of an acre) circle plots for each student group. At 0.05 acres, each circle plot will have a radius of 26.3 feet.

You may mark the circle plots in advance, with a stake at the center and stakes or flags around the perimeter, or have students do that as part of the lab.

Procedure

1. Ask students what happens if the trees in a forest stand grow too close together. Discuss the importance of thinning as a way to maximize tree growth.
2. Give students the following scenario: You are in charge of managing a 4-acre forest plot for maximum wood production. Foresters have determined that the optimal stand density for this forest is 200 trees per acre (for westside forests) or 100 trees per acre (for

eastside forests). Your job will be to determine how many trees you would need to reduce, and which specific trees you would cut or thin, to reach the target.

3. Point out that each team will look at a 0.05-acre sample plot within the stand – a circle plot, with a radius of 26.3 feet – and mark the trees they would thin with flagging tape. Ask students what characteristics they might consider to determine which trees to thin.
4. Hand out copies of the student page. Explain live crown ratio and answer any other questions about the task.
5. Take students to the study area, and divide them up into lab groups of two to four students. If you haven't already marked the plots, have groups measure and mark their 0.05-acre plots.
6. Direct groups to count the number of trees in their plot, calculate the trees per acre (as shown on the student page), determine how many trees they would need to thin to reach the target density, and identify (on the student page and with flagging tape) which trees they would recommend removing. Point out that every tree larger than 2" DBH should be identified and recorded on their student pages.
7. When groups finish up their task, have them share with another group their findings and which trees they recommend thinning.

Assessment

Ask students to write a few paragraphs describing their lab experience, including their method and reasoning for determining how many and which trees to thin.

Extension Ideas

- Enter the data collected from the lesson into a modeling program to estimate tree growth and visualize other forest processes. The [Landscape Management System](http://landscapemanagementsystem.org) at landscapemanagementsystem.org is a free software program developed by University of Washington, College of Forest Resources, Silviculture Laboratory; Yale University School of Forestry and Environmental Studies; The Cradle of Forestry in America; and the U.S. Forest Service.
- Watch an 8-minute OPB Oregon Field Guide segment on forest thinning: [Oregon Field Guide, Season 21, Episode 5](http://www.opb.org), available at [opb.org](http://www.opb.org).
- Explore forest thinning using resources from OSU Forestry and Natural Resources Extension, which can be found on the "[Thinning](http://www.knowyourforests.org)" webpage at [knowyourforests.org](http://www.knowyourforests.org).

3. Calculate the plot density (in trees per acre) using the following formula.

Plot Size: 0.05 acres (1/20 of an acre)

Number of Trees (larger than 2" diameter at breast height) in Plot: _____

Plot Density = Number of Trees in Plot x 20 = _____ Trees per Acre

4. Determine the thinning requirement for the plot by finding the difference between the Plot Density and the Target Density.

Target Density (trees per acre): _____

Plot Density (trees per acre): _____

Difference between Target Density and Plot Density: _____

Number of Trees to Thin = Difference in Density x Plot Size = _____

6: Harvesting

Overview

Students learn about the Oregon Forest Practices Act and its general requirements for harvesting and reforestation. They then compare six different timber forest harvest systems and choose the most appropriate system for a specific scenario.

Time Considerations

Preparation: 15 minutes

Procedure: One to two 50-minute class periods

Learning Objectives

Students will be able to:

- Describe the key features of the Oregon Forest Practices Act.
- Compare different timber harvest systems.
- Given a real-life scenario, choose the best harvest system or systems for it.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Oregon Forest Literacy Plan Concepts

- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.
- 3.B.4. Forest management includes using natural processes and goal-oriented decisions and actions to achieve a variety of desired outcomes, including environmental (e.g., wildlife habitat and carbon sequestration), economic (e.g., timber production) and social (e.g., recreation) outcomes. Many of these outcomes are interrelated and can be managed for simultaneously, while others may be incompatible.

Materials

- “Timber Harvest Systems” student pages
- “Timber Harvest Systems Compared” student page

Background Information¹⁹

In forest management, trees are harvested for a variety of reasons. They may be harvested to improve the health of the forest; to control the types of trees that grow on the site; to attract certain wildlife species; to provide a source of income for the landowner; to produce paper, lumber and numerous other forest products; or to improve access to the area for hikers, hunters and other recreational users.

Oregon has strict laws for protecting forests, some of which have been in place since 1941. Oregonians recognize that ensuring the abundance of our forest resources helps everyone, and that keeping them economically viable prevents their conversion into non-forest use. These laws have been developed and updated as an ongoing collaboration between scientists, landowners, elected officials and the general public. They help ensure that all Oregon forests operate under a unified set of guidelines and practices so that we sustain our forestlands for generations to come. These laws provide protection for soil, air, water, fish, wildlife and forest resources.

In 1941, Oregon adopted the Oregon Forest Conservation Act to address reforestation and fire protection. In 1971, Oregon became the first state to implement a comprehensive set of laws governing forest practices with the Oregon Forest Practices Act (OFPA). Leaders from the forest sector helped develop these laws to guide pre-operation planning, education for operators, and cooperative efforts among landowners and government.

Some of the requirements in the Oregon Forest Practices Act include:

- Reforestation: Landowners must complete replanting within two years after harvest. Within six years, the harvest area must be a healthy stand of trees that can outgrow competing grass and brush.

¹⁹ Sources: Information about Oregon Forest Practices Act: “[Oregon’s Forest Protection Laws](#).” Oregon Forest Resources Institute, oregonforests.org.

“[Are There Laws that Protect Our Forests?](#)” Oregon Forest Resources Institute, learnforests.org.

Information about timber harvest systems: “Common Types of Timber Harvest Systems.” [Oregon Forest Protection Laws: An Illustrated Manual](#). Oregon Forest Resources Institute, oregonforests.org.

- Protection of water sources: Timber harvesting, road building and chemical use are restricted close to streams, to protect fish and drinking water.
- Protection of wildlife habitat: Live trees, snags and fallen logs must be left after harvest to provide structure for wildlife habitat.
- Limits on clearcuts: A clearcut cannot be more than 120 acres. Clearcuts within 300 feet of each other cannot total more than 120 acres on the same ownership.

Since 1971, Oregon has adopted additional rules that help protect forests, water quality and wildlife habitat. The OFPA is periodically updated to reflect new scientific data, new operating technology and new forestry practices, to ensure our forest resources are properly protected.

Common Types of Timber Harvest Systems

Cutting trees, moving logs to a landing and loading logs for transport to a mill all are part of a timber harvest system. There are different timber harvest systems. Each one has advantages, which are described on the student pages. Modifications can make them even more versatile. The systems include conventional chainsaw and tractor skidder harvest, cable logging, shovel logging, cut-to-length harvesting, whole-tree harvesting and helicopter harvesting.

The terrain of the forest area will influence the choice of logging system. On gentle terrain, tree processors and forwarders, excavators, tractors and skidders (explained in the student pages) and even horses can be logical choices. On steep terrain, the choice shifts to cable or helicopter systems.

Key Vocabulary

cable logging

cut-to-length harvesting

helicopter harvesting

shovel logging

timber harvest*

timber harvest system

tractor/skidder harvest

whole-tree harvesting

**included in Glossary*

Preparation

Make copies of the student pages, or provide on-screen access to them.

Procedure

- Remind students of the many different products that come from Oregon forests. Ask them what might happen if forest owners were able to harvest trees on their land whenever and however they wanted.
- If students are not aware of it, provide a brief overview of the Oregon Forest Practices Act, using ideas from the Background Information. Point out that this law is designed to protect Oregon’s forests.
- Discuss how harvesting timber might compare to harvesting agricultural crops such as lettuce or pears. (For example, lettuce or pears could be harvested by hand in the field, but since trees are so massive, harvesting requires large equipment to cut, move and load the logs. In both types of harvest, care must be taken not to compact the soil or disturb the landscape.)
- Give students copies of the “Timber Harvest System” student pages. Direct them to read about each system and, using the “Timber Harvest Systems Compared” student page, make notes about which system is best for which situation.
- Ask students to work in pairs or groups and write a scenario to describe a particular forestland area. They should include in their description its size, how sloped or flat it is, how large or dense, and the forest landowner’s goal for harvesting it.
- Invite students to swap scenarios with another pair or group to determine the best harvesting method for the scenario they are given. Pairs or groups should be able to give their reasoning to defend their choice.

Assessment

- Have students use presentation software (such as PowerPoint or Prezi) to describe the Forest Practices Act and its requirements for timber harvest.

Extension Ideas

- Show students the video [Inquiry at Hinkle Creek: Doing Science in Our Forests](#) (16:59 minutes, available at learnforests.org), and discuss what the investigation revealed about management methods in the two watersheds.
- Share with students the [Find Your Path: Logging Crew](#) video (2:20 minutes, available at learnforests.org), and arrange for students to visit an active logging site in your area.

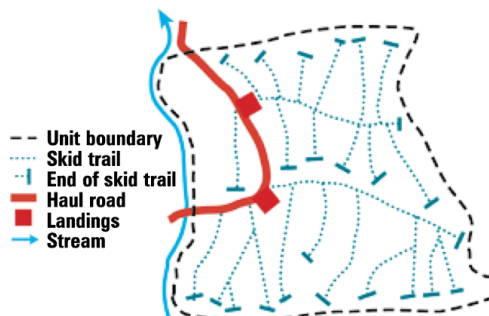
Timber Harvest System: Conventional Chainsaw and Tractor/Skidder Harvest

Hand-operated chainsaws are used to cut, delimb and buck trees into logs at the stumps. Skidders or crawler tractors (dozers) drag the logs to landings, where they are loaded onto trucks.



Tree felling, limbing and bucking are done with chainsaws.

Typical harvest layout. Skid trails should be planned and marked in advance. They often follow parallel branching patterns as shown (see Page 60). By winching logs across greater distances, skid trails can be located farther apart, reducing the area of skid trails and soil impacts from vehicle traffic.



Advantages

- adaptable to smaller harvest locations
- generally less costly equipment

Equipment used

- chainsaw
- log skidder or crawler tractor (dozer)
- log loader or self-loading log truck

Topography considerations

- normally restricted to slopes less than 35 percent
- haul roads usually located at the bottom of the logging unit

Soil considerations

- use of designated skid trails keeps machines on planned routes to help reduce soil disturbance
- on weaker soils, heavy traffic may result in trail ruts that require more water bars after logging
- soil disturbance can be reduced with widely spaced trails and pulling a winch line farther to logs – synthetic lines and other equipment features can make this task easier
- tractors and skidders should lift the front end of logs to reduce soil gouging

Forest stand considerations

- provides much flexibility with a variety of stand management goals

Slash disposal considerations

- lop and scatter possible with light accumulations of slash
- pile and burn is an option but requires additional steps and costs
- chipping and biomass energy utilization may be possible

Reforestation considerations

- yarding traffic or post-logging treatment can scarify ground and create areas for natural regeneration or hand-planting
- some advance regeneration may be lost or damaged by vehicle traffic

Economic considerations

- often more labor intensive
- generally, more roads are necessary
- least expensive method if road construction is not needed or is budgeted separately

Left: Skidders or dozers drag logs from the forest to the log landing. To reduce soil disturbance, rubber-tired skidders or crawler tractors are kept on skid trails. Winch line and chokers pull logs to the machine. **Right:** At the landing, a log loader moves logs onto trucks for delivery to the mill.



Timber Harvest System: Cable Logging

On steep terrain, this system uses a steel cable to carry either whole trees or logs to a landing after trees are felled with chainsaws.

Advantages

- allows for harvesting on steep ground and other sensitive terrain
- eliminates the need for skid trails
- can reduce construction and less favorable locations of roads

Equipment used

- chainsaw
- cable yarder
- delimber and log loader

Topography considerations

- well-suited for slopes of 35 percent and greater
- concave slopes allow more cable deflection and greater system efficiency
- intermediate supports allow for log lift in uneven terrain
- haul roads usually located at the top of the logging unit

Soil considerations

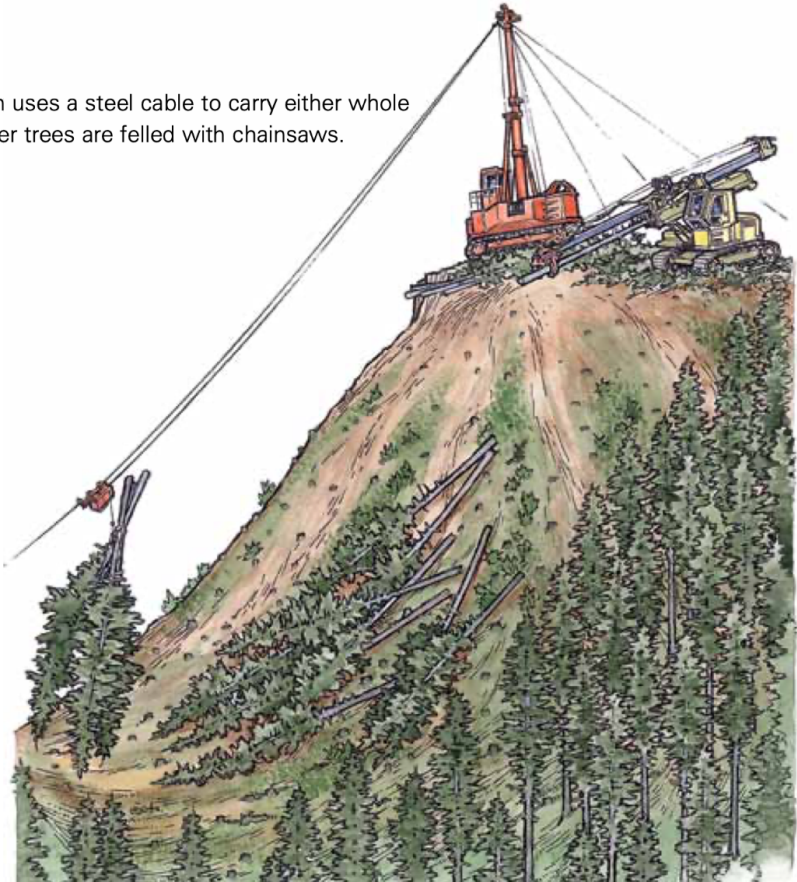
- can significantly reduce soil compaction and disturbance if logs are properly lifted
- heavy equipment is confined to roads and landings

Forest stand considerations

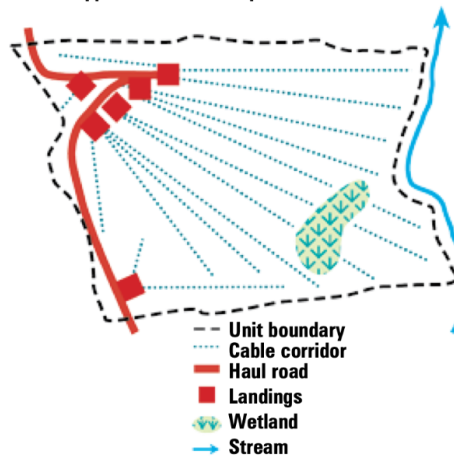
- primarily used with clearcuts and some partial cuts
- a more difficult method for thinning, with potential damage to residual stems

Slash disposal considerations

- if whole trees are brought to the landing, in-unit slash is minimized



Cable yarding systems can reach out 2,500 feet or more, especially with intermediate cable supports. This can help limit road construction needs.



Typical cable harvest layout. Generally logs are pulled uphill, but can also be moved downhill. With a strategic layout, logs can be lifted over streams, wetlands and canyons (see page 63).

- heavy slash piles at the landing must be treated or utilized
- if whole tree yarding is not used, prescribed burning of slash may be needed (see pages 69-72)

Reforestation considerations

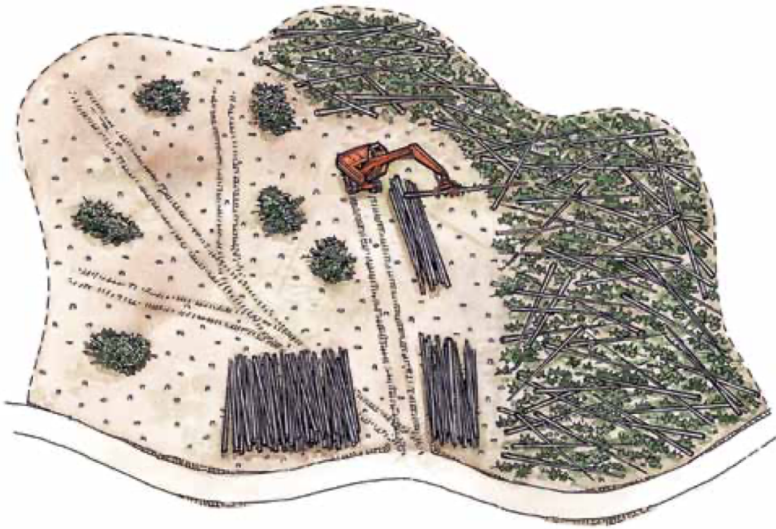
- may expose fewer spots for easier planting or natural seeding
- brush control needs also may be greater when scarification is reduced

Economic considerations

- can be more costly and specialized than ground-based systems
- small-scale systems can be competitive in some situations

Timber Harvest System: Shovel Logging

This ground-based harvest system uses a log loader (also called a shovel) to move logs rather than a skidder, tractor or forwarder. The shovel moves logs across the unit to locations near the road where they can be loaded onto log trucks. Logs are often picked up and moved ("swung") several times before reaching the road.



The shovel starts at the nearest access point and moves logs until they are within reach of the road. From there they can be loaded on trucks.

Below: Excavators equipped with grapples are common choices for handling logs and doing other useful tasks.



Advantages

- requires few people and machines
- few or no skid trails needed; existing roads may be adequate
- brush can be piled during harvest operations.

Equipment used

- chainsaw
- tracked excavator equipped with a grapple to grip and move logs

Topography considerations

- limited by slope due to machine instability on steep side hills
- may allow for harvest of some sensitive areas, with less disturbance than other systems

Soil considerations

- less compaction and disturbance if machine passes are limited

Forest stand considerations

- used primarily in clearcuts or partial cuts
- requires clearing of roadsides for log decks

Slash disposal considerations

- while moving logs, the excavator can pile heavy concentrations of slash for burning, chipping or other utilization

Reforestation considerations

- while or after moving logs or slash, the excavator can prepare the site for planting or seeding

Economic considerations

- small crew size
- one machine for multiple tasks can reduce costs
- efficiency improves with shorter yarding distances

Timber Harvest System: Cut-to-Length Harvesting

This ground-based system uses a mechanized harvester (tree processor) and a forwarder. The harvester severs, de-limbs and cuts each tree into logs and stacks them in the forest. The forwarder follows, picking up the logs and carrying loads to log trucks. It is also called a harvester-forwarder system.



A single grip processor can reach out 30 feet, cut a tree, strip the limbs, cut the stem into pre-programmed lengths and lay the logs on the ground, all in less than a minute. Ideally, they travel over the tree tops and limbs they leave.



A forwarder follows the harvester, picking up logs and delivering them to log trucks. They can travel long distances, reducing the need for log truck roads.



Logs are offloaded from the forwarder directly to log trucks.

Advantages

- leaves slash (tree branches and tops) in the forest
- reduces the need for log landings and access roads

Equipment used

- harvester/processor (tracked or wheeled)
- forwarder (often wheeled)

Topography considerations

- normally limited to slopes less than 35 percent

Soil considerations

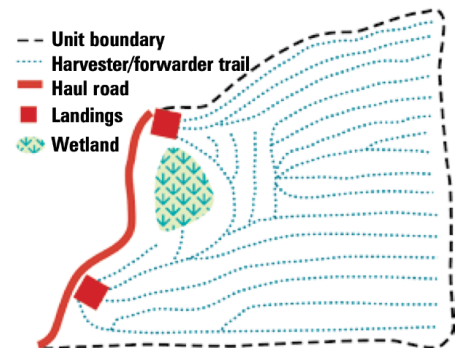
- can reduce compaction and disturbance, especially if the processor moves over duff and slash and if forwarders stay on slash-covered, designated skid trails
- slash left in the harvest unit will recycle nutrients and organic matter

Forest stand considerations

- an efficient method for commercial thinning
- typically used to move short logs out of the forest rather than long logs
- processor efficiency in dense stands is useful for forest health and fuels treatments

Slash disposal considerations

- by traveling over and compacting the slash, the system can reduce wildfire hazards and may meet slash hazard control requirements with no further treatment
- equipment can be used for slash piling for burning, chipping or other utilization



Typical harvest layout. Designated harvester/forwarder trails are about 60 feet apart and often follow parallel patterns across the harvest units.

Reforestation considerations

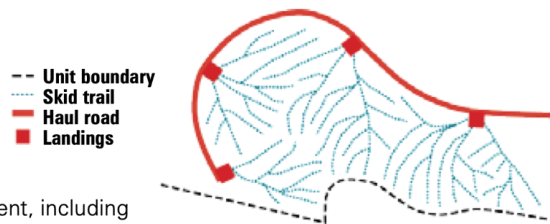
- common for thinnings where residual stocking does not trigger reforestation requirements
- if used for heavier cuts and slash loads, extra steps could create spots for planting or seeding

Economic considerations

- may not require new or improved roads
- relatively expensive and specialized machinery and operators
- may require larger volumes or higher quality timber for efficient use

Timber Harvest System: Whole-Tree Harvesting

This harvest system brings the entire tree, limbs and tops attached, to the landing or roadside. It can be used for both ground-based and cable applications. When used in ground applications, a feller-buncher often is used to cut and pile bundles of trees in the forest. Then a tractor or skidder drags the tree bundles to the landing or roadside. Finally, a delimeter converts the trees to logs.



Advantages

- can be relatively efficient, including use of smaller material
- slash is brought to the landing or roadside where it can be burned, chipped or otherwise utilized

Equipment used

- feller-buncher
- crawler tractor or skidder with grapple
- stroke-boom delimeter
- log loader

Topography considerations

- normally limited to slopes less than 35 percent
- with ground-based harvest, haul roads are usually at the bottom of the logging area

Soil considerations

- vehicles travel over a larger portion of the area as they cut, stack, gather and drag whole trees
- potential for more soil disturbance and compaction than other ground-based systems
- removal of tops and limbs does not recycle nutrients and organic matter near its source

Forest stand considerations

- efficient harvest and stand conversion when using a clearcut,
- can be used when thinning, but damage to remaining trees can be a problem.



A feller-buncher severs trees and lays them in bunches with limbs and tops attached. Bunches are oriented with tree trunks facing downhill.

Slash disposal considerations

- slash can be piled and later burned, chipped or otherwise utilized
- slash returned to the harvest area can recycle nutrients and organic matter (see pages 67-69)

Reforestation considerations

- widespread traffic and large tree bundles may damage advance regeneration
- dragging tree bundles can expose areas for planting or seeding

Economic considerations

- costs can increase on steeper ground or with longer skid distances
- bunching trees can help reduce the cost of handling small diameter trees.

Typical harvest layout. The feller-buncher and grapple skidder travel over most of the unit. Confining multiple trips to primary skid trails can reduce soil disturbance.



A crawler tractor or skidder with a grapple picks up bunched trees and drags them to a landing or roadside. Some grapples can swing 180 degrees, making it easier to operate in tight spaces.



The stroke-boom delimeter operates at the landing or roadside, removing tree limbs and top, cutting the stem into logs and stacking them.



The loader serves two needs: loading trucks and piling tops, branches and log chunks for later burning, chipping or other utilization.

Timber Harvest System: Helicopter Harvesting

This harvest system was once used exclusively for large, high-value timber. Helicopter harvest remains a higher-cost alternative, but it can be used for smaller logs when timber volumes and quality are adequate.

Advantages

- can harvest visually sensitive, inaccessible or other areas where other systems are unsuitable
- useful option for locations with high recreational use, special wildlife habitat, riparian/wetlands or geologic hazards
- may reduce or avoid new road construction, including hazardous/sensitive locations

Equipment used

- chainsaw
- logging helicopter
- helicopter maintenance and fueling equipment
- log loader

Topography considerations

- can be used on any type of terrain with suitable landing and helicopter service area locations (i.e., adequate size, safety and efficiency)

Soil considerations

- minimizes in-unit soil disturbance and compaction because logs are fully suspended
- large landings and service areas may require extra drainage or other treatment

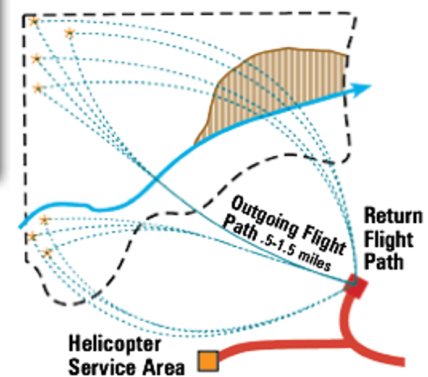
Forest stand considerations

- offers efficient, but costly method for commercial thinning
- large landings and service areas can locally impact forest stands.



This helicopter has a payload capacity of 6,000 pounds. Flight distances are kept to one-half to 1.5 miles. Longer distances are more costly. Planning to achieve optimum payloads for each trip helps make the operation economic.

Typical harvest layout



- Unit boundary
- Flight path
- Haul road
- Landings
- ▨ Cliffs/sensitive soils
- Stream
- ★ Log pick-up point

Slash disposal considerations

- lop-and-scatter methods typically are used to reduce fire hazards
- if further treatment is needed, it can be costly where road access is limited

Reforestation considerations

- slash left on-site and limited yarding disturbance result in fewer exposed spots for easy planting or natural seeding

Economic considerations

- typically the most expensive logging system
- equipment and crew needs can result in costs three to four times those of ground-based systems
- reduced road construction needs may help offset high costs
- without adequate volume of higher value logs, harvest costs may exceed timber revenues

LESSON 6

Timber Harvest Systems Compared

Good for...	Conventional Chainsaw and Tractor/Skidder Harvest	Cable Logging	Shovel Logging	Cut-to-Length Harvesting	Whole-Tree Harvesting	Helicopter Harvesting
Smaller harvest or thinning?						
Clearcuts or partial cuts?						
Level land (less than 35% slope)?						
Sloped land (35% slope or greater)?						
Minimizing the number of skid trails needed?						
Areas with special wildlife habitat?						
Minimizing soil disturbance?						
Minimizing cost?						

7: Reforestation

Overview

Students read about and answer questions on techniques for successful reforestation, and then calculate the number of seedlings that would be required to reforest a given area.

Time Considerations

Preparation: 15 minutes

Procedure: One 50-minute class period

Learning Objectives

Students will be able to:

- Describe the key features of the Oregon Forest Practices Act.
- Explain the steps involved in successful reforestation.
- Calculate the number of seedlings that would be required to reforest a given tract of land.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Science and Engineering Practice – Using Mathematics and Computational Thinking. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Oregon Mathematics Standards

- Mathematical Practice – MP.4. Model with mathematics.

Oregon Forest Literacy Plan Concepts

- 3.B.1. Forest management is a long-term process that can lead to changes in tree species composition, size and age, as well as in forest health and resilience.

- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.

Materials

- [Forest Fact Break: Reforestation](#) video (1:22 minutes), available at learnforests.org
- Technology to share video
- “Reforestation in Oregon” student page
- “Reforestation in Oregon – Questions” student page

Background Information²⁰

Reforestation is Oregon law. But even before these laws were in place, forest landowners – much like farmers – replanted after every harvest. Because of landowners, Oregon is a national reforestation leader, planting about 40 million new seedlings each year, according to the Oregon Department of Forestry.

Reforestation is an essential part of active forest management. Before harvest, foresters determine the best plan of action to ensure the regrowth of a healthy forest. Sometimes this means immediate replanting, while other times it means leaving trees as seed sources. When appropriate, seedlings of several different tree species are planted to maintain diversity in a working forest.

The land needs to be prepared to improve the growth and health of young trees. This requires clearing away post-harvest debris through a few different methods:

- Controlled and contained burning
- Using herbicides within the rules and regulations of the Environmental Protection Agency and Oregon Department of Forestry to control weeds and other vegetation that compete with young trees
- Using machines to clear excess logging debris to allow planting of seedlings

Seedlings are planted while they are dormant so they can take advantage of cool, wet weather conditions that promote good root development. This means seedlings are typically planted from winter into early spring. In Oregon, seedling survival typically surpasses 95 percent.

Through consistent and responsible reforestation, Oregon can keep its forests healthy and sustainable.

²⁰ Source: “[Reforestation Is Oregon Law](#).” Oregon Forest Resources Institute, oregonforests.org.

Key Vocabulary

artificial regeneration

bare root stock

container stock

free to grow*

reforestation*

regeneration*

**included in Glossary*

Preparation

Copy the student pages or provide on-screen access to them.

Procedure

1. Ask students to jot down what they think reforestation means. What might be the purpose of reforestation?
2. Show students the 90-second video *Forest Fact Break: Reforestation*. Discuss: How did the information in the video compare to what students wrote down?
3. Give students copies of the “Reforestation in Oregon” student page.
4. After allowing time for students to read, give them copies of the “Reforestation in Oregon – Questions” student page and have them discuss the questions in pairs or small groups.
5. Have students work in pairs to solve the following problem:

You are the manager of eight acres of forestland that have just been completely cleared and need to be reforested. After talking with foresters in your area, you have decided to plant Douglas-fir seedlings spaced 12 feet apart, as this would be the optimal spacing for your site. Your task now is to determine how many Douglas-fir seedlings you would need to reforest the entire area, with the seedlings spaced 12 feet apart.

You may choose to have students look up the area of an acre as part of their problem-solving, or tell them that an acre is equivalent to 4,840 square yards or 43,560 square feet.

- Have students share their responses, explaining how they got their answer. (The correct answer is in the following box.) Discuss how the number would change if the trees were planted 6x6 feet or 10x10 feet apart, and why someone might choose to plant the seedlings closer or farther apart.

Spacing and Number of Trees per Acre – Answer

To determine the number of trees needed to plant one acre, you must divide 43,560 square feet (the area of an acre) by the number of square feet each tree needs. For 12x12 spacing, $43,560 \text{ square feet per acre} \div 144 \text{ square feet per tree} = 302 \text{ trees per acre}$. For eight acres, multiply the trees per acre times eight ($302 \text{ trees per acre} \times \text{eight acres} = 2,416 \text{ trees}$).

Spacing (feet)	Square Feet per Tree	Trees per Acre	Trees for Eight Acres
12x12	144	302	2,416
10x10	100	436	3,488
6x6	36	1,210	9,680

Assessment

To assess student understanding, direct them to write a report describing their reforestation plan for the forestland described in the activity – including why they are reforesting the land and how they determined the number of trees required.

Extension Ideas

- Have students participate in a tree planting or reforestation effort. For information on how to plant trees, see [Establishing and Managing Forest Trees in Western Oregon](#), available at oregonforests.org. See Lesson 3: Service-Learning Project in the “Our Responsibility to Oregon’s Forests” module for ideas for developing this as a service-learning activity.
- Visit a forest seedling nursery to learn firsthand how seedlings are grown. See “[Sources of Native Forest Nursery Seedlings](#),” available at oregon.gov/odf, for a possible nursery in your area.

Possible Answers to “Reforestation in Oregon – Questions” Student Page

- Besides being the law in Oregon, reforestation provides multiple benefits, including wood products, watershed protection, fish and wildlife habitat, and recreational opportunities, as well as providing shade and absorbing greenhouse gases.

2. Planning and evaluating the site; preparing the site; selecting proper species and stock-type; planting at the optimal time for the location; maintaining the seedlings until they are “free to grow.”
3. Bare root seedlings – packaged in bags, with roots exposed. Container seedlings – come in a container, often made of Styrofoam.
4. Ponderosa pine.
5. Possible answers: western hemlock, western redcedar.
6. Planted in rich planting soil; at the proper depth; with no air pockets; with roots directed down into the soil with space between them; and with the main stem upright.

Reforestation in Oregon²¹

Replanting a forest after it has been harvested, known as reforestation, is important. For one thing, it's the law in Oregon. Beyond the law, however, reforesting makes good sense for the environment and for the economy. Since nearly half of the state's land area grows trees, forests can provide multiple benefits, including wood products, watershed protection, fish and wildlife habitat, and recreational opportunities. Our forests can even make an impact beyond our borders, since trees provide cool shade and absorb greenhouse gases that contribute to climate change.

Oregon was the first state in the nation to pass laws to ensure continuous harvest of timber on private lands while safeguarding soil, air, fish and wildlife resources. In 1971, Oregon enacted the Oregon Forest Practices Act, which regulates many activities conducted on forestland, including reforestation. Oregon law requires reforestation when timber harvesting reduces the number of trees below specific stocking levels. Landowners must complete reforestation within 24 months after harvesting. Depending on site productivity, at least 100 to 200 seedlings per acre must be established. However, most landowners plant 300 to 400 trees per acre.

Today, about 40 million trees are planted every winter and spring in Oregon. These tree seedlings are carefully planted on public, industrial and family forestlands. It takes good planning and follow-through to ensure success in this labor-intensive and expensive work.

Planting is the most common way to ensure a fully stocked young forest. This is known as artificial regeneration and is often used in heavily managed stands. Advantages to artificial reforestation include quick, uniform regeneration, less susceptibility to environmental factors (e.g., natural seed dispersal, poor seed years, etc.), a head start over brush and selecting seedlings from superior genetic stock. Natural regeneration, by comparison, may take longer and result in spotty regeneration.

²¹ Source: *Exploration of Oregon Forests: Module 4 – Forest Management 1 – Cycles and Reforestation*. Developed by Julie Woodward based on the Oregon State University Forestry Extension's *Basic Forestry Short Course*.

The Five Steps to Reforestation:

STEP 1:

Carefully plan, evaluate and prepare the site. Consider the condition of the planting site: vegetation present, soil type, aspect (direction the slope faces), wildlife and pests. Site characteristics affect critical site resources necessary for seedling survival and growth, including water, sunlight, temperature and nutrients.

STEP 2:

Choose an appropriate site preparation method or combination of methods. Several methods are available to prepare sites for planting. These methods include mechanical, manual and chemical. Costs depend on site conditions, methods used, existing vegetation and the amount of logging debris or slash.

STEP 3:

Select the proper species and seedling stock-type for the site. Different tree species are adapted to different site conditions. Choose seedlings specifically for the seed zone and elevation. Obtain tree seedlings by encouraging natural seeding, by transplanting seedlings growing in the wild or by purchasing nursery-grown seedlings.

STEP 4:

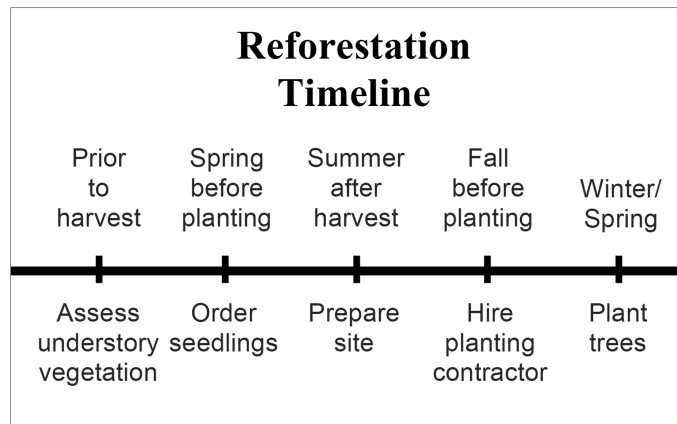
Plant conifer seedlings in western Oregon from January through March. In higher elevations or in eastern Oregon, plant as soon as possible after snow melts and the ground thaws, generally late March through April. Keep seedlings cool (34 to 40 degrees F) and moist, and handle them gently at all times. Site conditions dictate the spacing and density of trees. In western Oregon, typical spacing is 10' x 10'. In eastern Oregon, trees are generally spaced at 12' x 12'. Select good planting spots such as areas of exposed mineral soil that are free of weeds.

STEP 5:

Once seedlings are planted, additional maintenance often is needed to ensure their continued survival and growth. The first two years following planting are critical for survival. New seedlings may require protection from animals, weeds or drought. According to Oregon laws, by the sixth year, the new stand must be “free to grow” (able to out-compete surrounding grasses and brush).

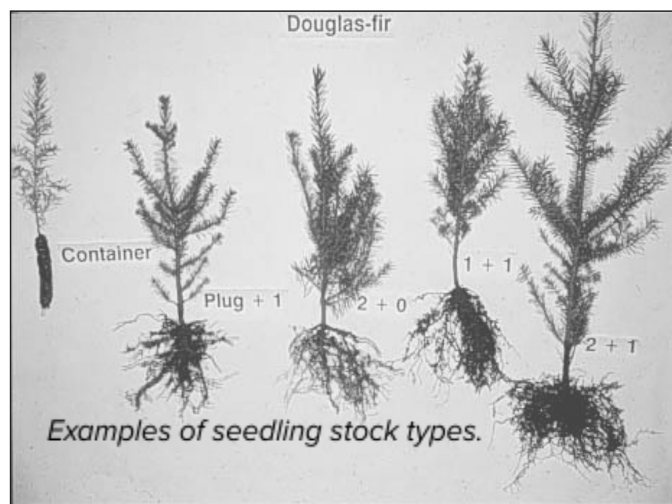
Timing

Although planting is only done in winter and early spring, reforestation is an effort that takes place year-round for most landowners. The figure to the right outlines typical reforestation timeline.



Nursery Stock

Nursery stock used for planting includes bare root and container stock. Bare root is just as it sounds: the trees are packaged, usually in bags, but their roots are exposed. Bare root seedlings are usually less expensive than container stock. Container stock comes in a container, usually made of Styrofoam. Although it is usually more expensive, this method avoids the damage associated with uprooting the trees before transport, as the seedlings are planted along with the soil from the container.



The following figure illustrates examples of seedling stock types. The names can be a bit confusing, but the numbers are associated with how many years the tree spent in a container and in the ground as a bare root. For example, “Plug + 1” means that the tree spent one year in a container, or “plug,” and one year in the ground as a bare root.

Planting Seedlings

Planting should occur when the seedlings are dormant and the soil is moist, and when subsequent rains will water the plants. This generally means mid-December to mid-March.

Matching Species to Site

Species	Shade	Wet Soil	Drought	Frost	Browse
Alder	1	4	1	2	2
P. Pine	1	4	5	5	4
Douglas-fir	2	2	2-3	4	2
Grand Fir	4	3	2	3	4
W. Hemlock	5	3	1	1	4
W. Redcedar	5	4	1	2	1

(1=not tolerant, 5=tolerant)

Species of seedlings to plant should be determined by soil type, native species and existing vegetation, and seeds must be from the correct seed zone.

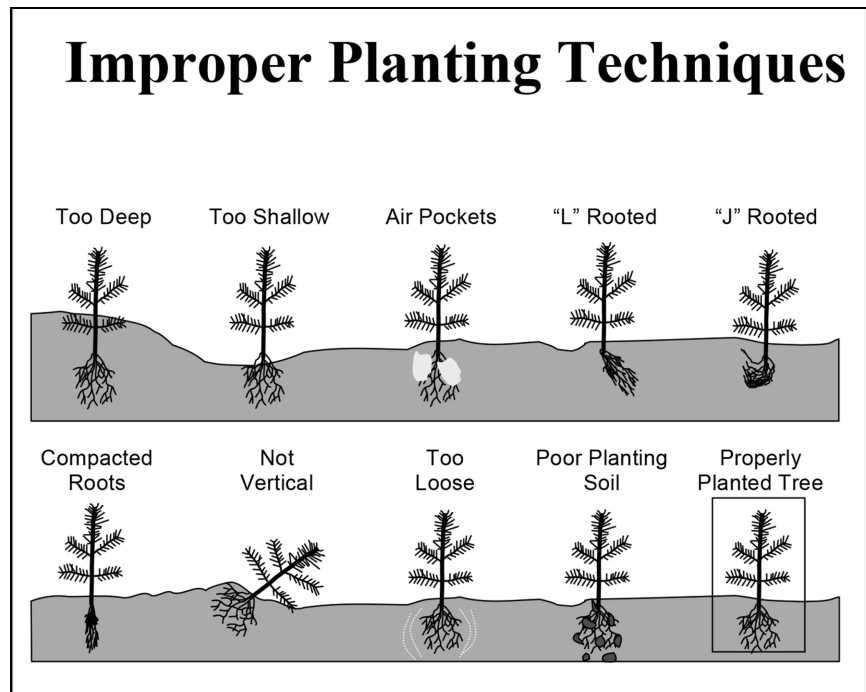
When planting seedlings, it is also important to ensure trees have enough space to grow and meet the landowner's long-term objectives. Another important component is properly matching tree species with site

conditions. The figure above briefly summarizes common Oregon tree species and their tolerance to specific site conditions.

Tree planting requires time and practice. Proper tree planting techniques are important to successful reforestation and long-term tree survival. See the diagram "Improper Planting Techniques" at right for conditions that often lead to seedlings dying.

Summary

Replanting trees after harvest, or reforestation, is required by the Oregon Forest Practices Act. Beyond the letter of the law, replanting also makes environmental and economic sense. But this labor-intensive and expensive work requires good planning and follow-through, including the choice of timing, nursery stock, tree species and planting technique. Today, about 40 million trees are planted every winter and spring in Oregon on public, industrial and family forestlands.



Reforestation in Oregon – Questions²²

1. Why is reforestation important?
2. What steps are involved in reforesting an area?
3. Explain the differences between bare root and container seedlings.
4. Name an Oregon tree species that tolerates drought conditions well.
5. Name an Oregon tree species that tolerates shade well.
6. Describe a properly planted seedling.

²² Source: *Exploration of Oregon Forests: Module 4 – Forest Management 1 – Cycles and Reforestation*. Developed by Julie Woodward based on the Oregon State University Forestry Extension's *Basic Forestry Short Course*.

8: Silviculture Tour²³

Overview

Students visit a forest site to learn about management techniques and strategies, and then create a written report or other documentation of the visit. (As an alternative to a field trip, a forest management representative may be invited to give an in-class presentation.)

Time Considerations

Preparation: 30 to 60 minutes

Procedure: One 50-minute class period

Learning Objectives

Students will be able to:

- Describe the management objectives of a particular forest site or forest owner.
- Explain the silvicultural techniques used to manage the forest to meet the objectives.
- Write a detailed report describing what they learned.

Standards Connections

Oregon Science Standards

- Disciplinary Core Idea – HS.ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Science and Engineering Practice – Obtaining, Evaluating, and Communicating Information. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

²³ This lesson was adapted from “Silviculture Tour” in *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

Oregon English Language Arts Standards

- Writing History, Science, and Technical Subjects – 9-10.WHST.4 and 11-12.WHST.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Oregon Forest Literacy Plan Concepts

- 3.B.3. Forest management ranges from active management (e.g., planting, thinning and harvesting) to passive management (e.g., reserves and wilderness areas) to grow, restore, maintain, conserve or alter forests.
- 3.B.4. Forest management includes using natural processes and goal-oriented decisions and actions to achieve a variety of desired outcomes, including environmental (e.g., wildlife habitat and carbon sequestration), economic (e.g., timber production) and social (e.g., recreation) outcomes. Many of these outcomes are interrelated and can be managed for simultaneously, while others may be incompatible.

Materials

- [*K-12 Forest Education Opportunities: A Guide to Forestry Education Programs and Materials Available to You and Your Students*](#), available at learnforests.org
- “Silviculture in Practice” student page

Background Information²⁴

Silviculture is the practice of growing and managing forests and forest stands to increase their productivity. The name comes from the Latin “silvi-“ (forest) + “culture” (as in growing). Silviculture attempts to create and maintain the composition and structure of a forest that will best meet the objectives of the landowner. These objectives vary greatly among owners, but may include:

- Controlling stand structure – A stand’s shape or structure may be modified for aesthetic reasons, to facilitate treatments and harvest, to control animal pests or improve wildlife habitat. Its structure may be modified to select for certain age classes, arrangements of canopy levels/layers of vegetation, or distribution of diameter classes.
- Controlling composition – The types and quality of various species in the forest define the forest composition. Composition is controlled to limit undesirable species or poorly

²⁴ Adapted from “Silviculture Tour” in *Forest Surveying and Silviculture* by Dr. Wynn Cudmore. Northwest Center for Sustainable Resources, Chemeketa Community College.

formed trees, and is achieved by site preparation; cutting, burning or applying herbicides to unwanted species; or introducing desired species.

- Restocking unproductive areas – Areas capable of growing trees but not fully stocked because of fire, logging, disease or animal damage may be restocked by planting seeds or seedlings.
- Protecting and reducing losses – Forest losses from fire, diseases, insects, wind or competition may be reduced by applying silvicultural methods such as thinning and salvage logging.
- Controlling rotation length – The number of years required to grow a stand to a specified condition of economic maturity (i.e., rotation length) may be modified to achieve different goals. Douglas-fir, for example, is commonly grown on a 40- to 60-year rotation to produce sawtimber in western Oregon, but landowners may carry it longer for improving wildlife habitat and having larger trees to market.
- Facilitating harvesting – Planning operations may include management activities that make harvesting efficient, economical and predictable.
- Conserving site quality – Silviculturists, like farmers, must conserve resources (particularly soils) on a site to preserve future productivity. Silvicultural practices also have a great deal of influence on site microclimate. If site quality is conserved, renewable resources such as trees can replace themselves. Soil erosion is considered the least reparable of disturbances. Nutrients and applied chemicals can be lost through surface runoff and leaching.

Note that forests are managed for different purposes and may serve very different societal needs. Research in social science and economics – as well as in the natural sciences – may be used to inform forest management decisions.

Field trips to actual silvicultural operations are valuable for seeing how things are done in the “real world.” This lesson provides an opportunity for students to ask questions of the forest manager and to gain insight into the day-to-day challenges and issues facing this type of operation.

Key Vocabulary

converting species

cost/benefit analysis

density diagram

silviculture*

**included in Glossary*

Preparation

- Arrange a visit to a forest site where silviculture is being practiced. Use [Find a Forester](#) on the www.oregon.gov/odf website to contact a stewardship forester in your area, or check with your local [Forestry and Natural Resources Extension](#) agent, listed at forestry.oregonstate.edu. For possible field-trip locations and activity ideas, see the [K-12 Forest Education Opportunities](#) guide (available at learnforests.org), which lists many of the diverse forestry education programs offered throughout Oregon. If a field trip is not possible, seek out and invite a forest manager to visit your class. In either case, students may use the student page to record their findings and form the basis of their reports.
- When arranging the field trip or class visit with the forest manager, share the student page questions so that he or she can plan a presentation that is as relevant as possible to the lesson's learning objectives.

Procedure

1. Discuss the meaning of the term “silviculture.” Talk about some of the forestland objectives that may be met through silviculture techniques. (See the Background Information for possibilities.)
2. Explain that students will have a chance to learn more about silviculture from someone in the field.
3. Either on the field trip or in the classroom with a forest manager, encourage students to use the “Silviculture in Practice” student page to ask questions and record their answers.
4. After the field trip or presentation, direct students to use their notes to develop a report on their findings. Establish criteria for the report, such as:
 - a. Write a two- to four-page report (double-spaced, 12-point font) describing the field-trip site (or class visitor).
 - b. Include a title with the name and location of the silvicultural operation and the date of the visit.
 - c. Use the headings topics from the “Silviculture in Practice” student page as a template for the body of the report, using the pertinent sections.
 - d. Describe concisely, yet thoroughly, the processes involved in the organization's silvicultural process.
 - e. Write the report in coherent paragraphs, not just bullet points.

Assessment

Use students' reports to assess both what they learned about silviculture practices and their ability to communicate scientific information.

Silviculture in Practice

While on the field trip, find out as many of the following items as you can:

Ownership and personnel

- Who is the landowner?
- Who decides what management activities will be done?
- Who actually implements the activities done to this forest?

Management objectives

- What are the main management objectives for this forest?
- What “rules of thumb” are used to determine management strategies?
- What other planning tools are used (such as density diagrams, cost/benefit analysis or other)?

Information about the forest

- What pressures or impacts does this forest face?
- What wildlife habitat does it support?
- What opportunities does this forest offer for the future?

Management activities

What methods are used for:

- Thinning?
- Pruning?
- Planting?
- Fertilizing?
- Converting species?
- What challenges do these activities present?

9: Developing a Forest Management Plan

Overview

Students use an Oregon forest management plan template to describe a tract of forestland and to consider different ecological, economic and social outcomes for it.

Time Considerations

Preparation: 30 minutes

Procedure: One 50-minute class period up to several weeks, depending on how involved students become in the plan development

Learning Objectives

Students will be able to:

- Explain the purposes of a forest management plan.
- Use a forest management plan template to describe and plan for a specific forestland.

Standards Connections

Oregon Science Standards

- HS.ESS3.3. Earth and Human Activity. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- Disciplinary Core Idea – HS-ESS3.C. Human Impacts on Earth Systems. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Science and Engineering Practice – Constructing Explanations and Designing Solutions. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Oregon English Language Arts Standards

- Writing History, Science, and Technical Subjects – 9-10.WHST.2 and 11-12.WHST.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Oregon Mathematics Standards

- Mathematical Practice – MP.2. Reason abstractly and quantitatively.

Oregon Forest Literacy Plan Concepts

- 3.C.4. Oregon foresters and forest managers prepare forest management plans based on landowner goals and objectives, capacities of the forest site, laws and available management tools (e.g., planting, harvesting and using prescribed fire). The plans guide management decisions, and are often required for funding applications or documentation for forest certification.
- 3.C.7. Sustainable forest management takes into account environmental, economic and social dimensions of sustainability. It includes maintaining forest health, productivity and diversity, and maintaining a forested land base for the needs of present and future generations.

Materials

- [“Oregon’s Forest Management Plan Template,”](#) available at oregonstate.edu
- [“Forest Management Planning System Guidelines,”](#) available at oregonstate.edu
- Optional: [Establishing and Managing Forest Trees in Western Oregon](#), available at oregonforests.org
- Optional: [Understanding Eastside Forests](#), available at oregonforests.org
- Additional materials and information needed to complete the management plan (optional; see Preparation)

Background Information²⁵

Forest management plans are overarching, long-range plans that guide the annual management of forestlands. Federal, state and private forest managers develop plans to meet regulations and guide on-the-ground operations.

Even individual forest landowners should have a written forest management plan for an increasing number of reasons, including tax and business needs, land use actions and forest certification. But perhaps the most important reason to develop a management plan is so that the landowners can learn about their forest, describe how it looks today and how they want it to look in the future, and develop or refine a course of action. A plan is also a good way to let heirs and others know the landowners' vision for the future of the forest and the steps they have taken to achieve that vision.

A management plan helps ensure that the forest will be managed so that its many resources are available for generations to come. It may incorporate social, economic and environmental considerations. Plans typically include:

- Property information, including the location, size, ownership, history and other details
- Goals and objectives
- Maps and photos
- Property resource information, with details about the wood, water, wildlife and other resources on the site
- Recommendations for future action
- Business and operations information, such as tax, management and liability matters

For this lesson, students will be using a forest management template designed specifically for individual forest landowners in Oregon.²⁶ It includes sections on the history and description of the property, landowner goals, planned actions for improving the property and where to get help.

²⁵ Source: Adapted from "[About Forest Management Planning](#)," *Oregon Forest Management Planning*. Oregon State University.

²⁶ Oregon's Forest Management Plan Template reflects the work of the Uniform Resource Planning and Endorsement System project, which is a collaboration of 10 different organizations. The template is designed to further communicate the necessary information needed to meet Oregon Forest Management Plan guidelines.

Key Vocabulary

forest management plan

Preparation

Decide what forest area students will use as the basis for their management plan. For example, they may develop a plan for a forest they have studied in the other lessons, or they may create a draft plan for a particular forest landowner in your community.

Depending on your time and student interest, determine how in-depth you want students to go in their management planning. For a brief introduction to forest management plans, groups might simply fill out the template as much as possible from what they know. For a more thorough study, or as a culminating activity, groups might develop full-blown plans by interviewing the landowners for details about the land's history and their vision for its future, researching maps and images, surveying and inventorying the forestland, and determining recommended actions.

See "[Forest Management Planning System Guidelines](#)," available at oregonstate.edu, for suggestions for completing the forest management template.

Procedure

1. Ask students what they think the value of having a forest management plan might be. What might a plan include?
2. Explain that students will gain experience developing a management plan for the selected forest area.
3. Introduce students to the "Oregon's Forest Management Plan Template," pointing out the different sections and discussing which ones students will be responsible for completing. You may want to refer students to the "Forest Management Planning System Guidelines" for more detailed directions and explanations for each section.
4. Ask students what goals they would see for this forestland and what actions would support those goals. Encourage them to consider environmental, economic and social aspects.
5. Direct students to work in pairs or small groups to fill in the details of their management plans. You might have on hand forest management resources for them to draw on, such as *Establishing and Managing Forest Trees in Western Oregon* or *Understanding Eastside Forests*.

Assessment

Ask students to present their plans to the class, pointing out their key features and recommendations.

Extension Idea

Invite a forestland manager to your class to share features of their management plan.