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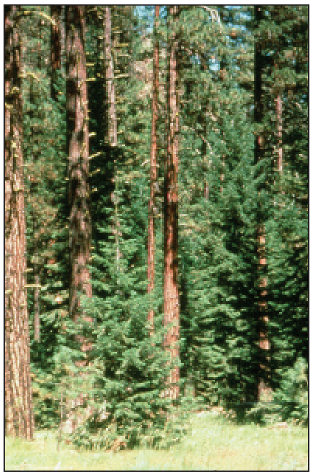

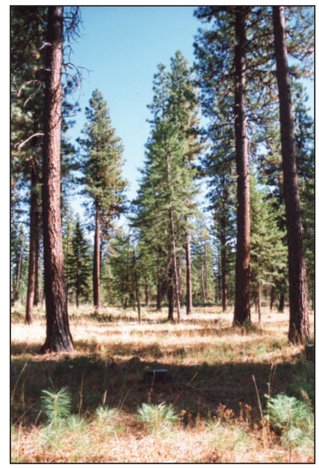

Ecology and Management of Eastern Oregon Forests

A COMPREHENSIVE MANUAL FOR FOREST MANAGERS

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Getting Started: Establishing management goals for my property

Determining goals for your property is an important first step and is often the hardest task if you haven't managed forestland before. Establishing clear goals for your property will help guide and prioritize management actions you might take. To help you determine and refine your management goals, make your way through the following worksheet. You may also get ideas by visiting with other landowners or attending forest landowner tours to see what they are doing and how they approach the management of their land. Once you have your goals set, create an action plan and a suite of treatments to nudge or move your forest toward those goals. Remember that managing your woodlands is a long-term venture, often taking several years or decades to achieve some of your goals.

1. How much of your land (acres) is in the following categories? (Note: It might be helpful to draw a map of your property and identify key places that are important to you.)

   ❏ Forest
   ❏ Range
   ❏ Pasture
   ❏ Farm/Orchard
   ❏ Buildings
   ❏ Homes
   ❏ Rivers and streams
   ❏ Ponds
   ❏ Special or unique places (historic, etc.)

2. How long have you owned you land? _______ years

3. Why did you acquire the land?

4. What do you want your land to provide today?

5. What do you want your land to provide in 20-50 years?

6. What do you most enjoy about your land?

7. What do you enjoy the least about your land?

8. On a scale of 1 (for least important) to 5 (very important) how important are the following potential land-management goals to you?

___ Derive income from timber products.
___ Derive income from farming/livestock.
___ Derive income from nontimber forest products:
___ Improve wildlife habitat.
___ Reduce risk of catastrophic wildfire.
___ Increase resilience to drought, insects and disease, and other disturbances.
___ Learn more about what kind of land-management projects are possible.
___ Pass land on to future generations.
___ Have a quiet place to enjoy.
Other________________________________

9. On a scale of 1 (for least important) to 5 (very important) how important are the following potential land-management barriers to you?

___ Land-management projects are too much to handle now.
___ I am worried about how land-management projects will affect our time for other family and/or personal activities.
___ I am concerned that other family members do not understand what I value most about our property.
___ I am concerned about the financial cost of carrying out some land-management activities.
___ I do not know what the best steps to take are.
___ I do not know how or where to market my timber.
___ Current regulations don't allow me to do what I envision for my property.
___ I don't know the rules about what I can do on my property.

10. Based on your responses from #8, list the three most important reasons for managing your land.

____

____

____

11. Based on your responses from #9, what is the major barrier preventing you from managing your land?

____

12. Based on your responses to all the questions above, what are three important questions for which you might look for answers as you read this publication?

____

____

____

A ponderosa pine stand in Central Oregon

Introduction

The forests of eastern Oregon are diverse—varying from pure stands of ponderosa or lodgepole pines to mixtures of the pines with Douglas-fir, larch, and grand and subalpine firs—and they have many values, including providing important ecosystem services, such as clean water and air, places to enjoy wildlife and to recreate, range for livestock, and timber production. You'll find this manual to be a valuable reference providing the background, information, and tools needed for managing your forest and rangeland according to your values.

Due to the forests' complexity and the great diversity of owner objectives, these forests are managed with a variety of strategies. Determining the potential of any particular forest area is not easy, and choosing management options to accomplish your objectives may be difficult. If you are interested in solving this puzzle of complexity and successfully managing your forestland, this manual is for you.

Determining your goals for your property is an important first step. If you are unsure how to go about developing goals, refer to "Identifying Your Woodland Resources and Management Goals" on the facing page to help you get started.

Chapter 1 is an overview of the ecology and management of eastern Oregon forest types. It will help you understand which forest type(s) you have and give you some ideas about their management. Chapter 2 is about the long-term strategies and tools you need to plan and carry out the management of your forest. Chapters 3 through 5 focus on the ecology and management of four major forest types: ponderosa pine, lodgepole pine, and warm and cool mixed-conifer. Chapter 6 covers reforestation and vegetation control. Chapter 7 focuses on important insects, diseases, and parasites that affect forests and landscapes. Chapters 8 and 9 deal with management for range and wildlife values. If you are thinking of conducting a timber harvest, Chapter 10 discusses what you need to know in carrying out a successful harvest operation. Given the threat of wildfire, Chapter 11 provides ideas on how to make your forests more fire resistant. A glossary, Appendix 1, defines many of the specialized terms used throughout the publication.

CHAPTER 1

Understanding eastside forest types

Stephen A. Fitzgerald and William H. Emmingham

This chapter will help you understand the general ecology and management of central and eastern Oregon forests and help you decide which forest type(s) you have on your property. We explain some basic ecological relationships and tree characteristics, define the major forest types, and discuss common management problems and techniques to keep trees healthy and to ensure your forest has the stand conditions, wildlife habitat, forest products, and other values you desire.

Geology and ecology of eastern Oregon forests

A basic understanding of the geology, soils, and climate of eastern Oregon and of the way the forests have developed over time will help you determine which tree species to manage and which management strategy is likely to work best. The forests discussed here include those on the eastern slopes of the Cascade Range and in the Ochoco, Strawberry, and Blue mountains (Figure 1.1).

The mountains of eastern Oregon originated in a variety of geological processes. They contain a rich variety of ancient to recent rock types formed at great depths and either uplifted into mountains, extruded in lava flows, or ejected aerially from volcanos. Some of these formations contain rich fossil records. Other portions were formed when lava periodically spilled across the surface of eastern Oregon, leaving basalt layers thousands of feet thick. Erosion processes such as river down-cutting and several glaciation periods subsequently shaped the mountains. In the Wallowa and Steens mountains, glaciation during the past few ice ages left long, deeply carved valleys through layer upon layer of basalt. The east flanks of the Cascades were formed as active volcanos erupted violently and covered the surface with various forms of volcanic pumice and ash or molten lava.

Figure 1.1. The topography, climate, and geology of eastern Oregon create a diverse mosaic of forest types.

About 7,700 years ago, the violent eruption of Mount Mazama formed Crater Lake. Coarse pumice deposits covered hundreds of thousands of acres near the mountain, and fine ash layers were deposited across northeastern Oregon and beyond (Figure 1.2, page 8). Posteruption winds sometimes blew fine ash from south slopes and deposited it on north slopes, or ash washed or sloughed off steep slopes and was deposited in ravines and river bottoms. All these geologic processes created variation in landforms and soils which, combined with slope,

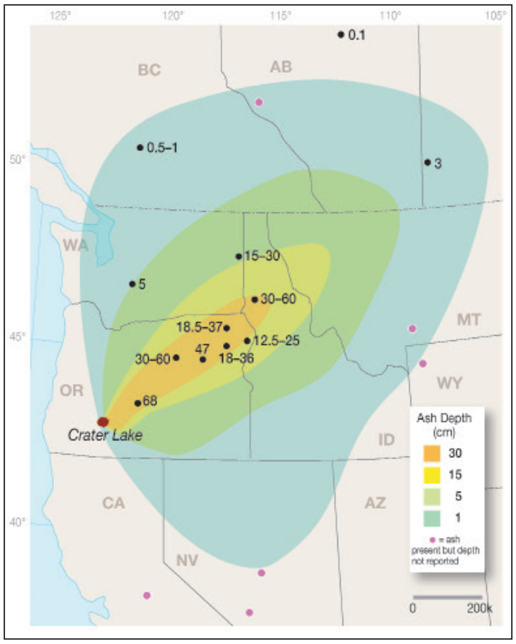


Figure 1.2. When Mount Mazama erupted 7,700 years ago, coarse pumice deposits covered hundreds of thousands of acres near the mountain, and fine ash layers were deposited across northeastern Oregon.

aspect, and elevation, created large differences in plant growth and forest potential on sites only short distances from one another.

Plant distribution and growth in the Pacific Northwest are most strongly influenced by temperature and drought. The eastern Oregon climate is hot and dry in summer and cold and moist in winter, when much of the annual precipitation (8 to 100 inches) comes as snow. Rainfall increases with elevation, but temperatures drop. The high Cascades form a "rain shadow." As moist air from the Pacific rises over the Cascades and the air mass cools, it is less able to hold moisture, forcing moisture from clouds in the form of rain or snow before the air mass arrives east of the mountains depleted of moisture.

During summer, three to five months pass with insignificant amounts of rain, creating very stressful drought conditions for trees and other plants as soil water is depleted. The severity of drought on a particular site depends on:

- Annual rainfall
- Elevation (which is related to temperature)
- Soil moisture-holding capacity (which is related to soil type and depth)
- Evaporative demand (which is related to site aspect, such as a north versus a south slope)

Figure 1.3. A ponderosa pine forest type with pine in both overstory and understory.

Deep, ash-filled soils at moderate elevations on north slopes can store winter precipitation and create conditions that support very productive forests. Coarse, gravelly deposits on hot, south slopes can create droughty sites with low moisture-holding capacity that are far less productive. The net effect on the landscape is a complex pattern of forest types and growing conditions. All this variation means that management actions must be tailored to the changing site and forest conditions on a small scale.

Major forest types of eastern Oregon

Most private forestland of eastern Oregon is one of four forest types: lodgepole pine, ponderosa pine, warm-dry mixed-conifer, or cool-moist mixed-conifer. A "forest type" indicates the potential for that soil and site to produce certain kinds of forest stands (see Figure 1.3). Before you make management decisions, it is important to know which forest type you have and, therefore, the most suitable trees species to promote or manage for; with a little practice, it is possible to determine forest type (Table 1.1, page 9).

Ponderosa pine forest type

This type supports nearly pure ponderosa pine forests (Figure 1.3). The ponderosa pine forest type is so dry that no other commercial tree species can grow there; however, western juniper can often be found in the understory as seedlings and saplings or occasionally as a medium-sized tree in the forest canopy. Historically, fire visited this type at short intervals (every 5 to 25 years), keeping stocking levels low and the stands open and park-like. This is the climax pine type because ponderosa pine is able to regenerate beneath itself. Pine regeneration is often poor or nonexistent due to long periods between cone crops, long summer droughts, and low site productivity. The presence of Douglas-fir or grand fir

Table 1.1. How to recognize eastern Oregon forest types and which species to manage.

Tree species present	Forest type	Manage for these species
Only ponderosa pine	Ponderosa pine	Ponderosa pine
Mostly lodgepole pine	Lodgepole pine	Lodgepole pine
Douglas-fir, grand fir or incense-cedar and ponderosa pine, or larch	Warm-dry mixed-conifer	Ponderosa pine, larch, Douglas-fir, or species mixture
Subalpine or grand fir, lodgepole, Engelmann spruce, Douglas-fir, and larch, with or without other species	Cool-moist mixed-conifer	Lodgepole pine, larch, Douglas-fir, grand fir (on best sites), or species mixture

seedlings and saplings in the understory indicates more moisture meaning the site is a warm-dry mixed-conifer forest type.

Lodgepole pine forest type

This type is more than 90 percent lodgepole pine. Lodgepole pine dominates the forest on three major site types: on pumice flats, in frost pockets (slight depression where cool air collects), and on high-elevation plateaus. A primary climate factor for the lodgepole pine type is the potential for heavy frost during spring and summer, when seedlings are actively growing. Of the common tree species, lodgepole pine is the most tolerant of frost. Its ability to tolerate frost damage allows it to germinate, survive, and grow in the most frost-prone areas. Historically, a common pattern in lodgepole pine stand development was mountain pine beetle attacks that killed most of the existing stand, followed by an intense, stand-replacement fire. Lodgepole pine also is within many mixed-conifer forest types, either as part of the mixture or as the dominant pioneer species; if the latter, it might be replaced by more shade-tolerant species, such as grand or subalpine firs (Figure 1.4).

Figure 1.4. Lodgepole pine stand with a pine overstory and an understory of mostly grand fir and some subalpine fir, indicating that this is a cool-moist, mixed-conifer forest type.

Both lodgepole and ponderosa pine forest types are managed for those pine species because they are the only trees that do well on those sites. Both pines can, however, be managed in nearly pure stands on some mixed-conifer sites.

Mixed-conifer types

A mixture of conifer species occupies many forest sites across central and eastern Oregon that are not limited by drought or spring or summer frosts. Historically, fire visited frequently on the drier end of the mixed-conifer type (similar frequency as in the climax ponderosa pine type) and at longer intervals on the cool-moist end of the mixed-conifer type. Fire intensity varied from light to intense depending on fuel accumulation since the last fire. The mixed-conifer forests can be divided into two subtypes based on temperature and moisture conditions.

The warm-dry mixed-conifer type occupies the warmer and drier end of the spectrum.

Figure 1.5. A warm-dry mixed-conifer forest type, with a ponderosa pine overstory and an under- and mid-story of grand fir and Douglas-fir.

Typically, ponderosa pine dominates in young stands, but where soils are deep, larch may also play the role of a pioneer species. Douglas-fir and grand fir most commonly regenerate in the understory (Figure 1.5), but incense-cedar joins them on the east flank of the Cascades along with sugar pine. Ponderosa pine also can regenerate vigorously beneath open stands, often in even-aged patches. Site productivity is higher than on the ponderosa pine type.

The cool-moist mixed-conifer type is indicated by the addition of more moisture-demanding and cold-tolerant species, such as subalpine fir, western white pine, or Engelmann spruce (Figure 1.4, page 9, and Figure 1.7, page 12). Typically, lodgepole pine or larch dominates the early successional stages and grows well, but ponderosa pine, Douglas-fir, and grand fir also can be present. Engelmann spruce may be part of a mixture or be in almost pure stands at upper elevations or along streams and small rivers where cold air drainage and deep frost eliminate the other species. Western white pine and sugar pine (both five-needle pines) can also be found in the cool-moist mixed-conifer type on the eastern flank of the Cascades.

Figure 1.6. A cool-moist, mixed-conifer forest type, as indicated by the presence of larch and grand fir, with some Douglas-fir and ponderosa pine in the mix.

On mixed-conifer sites that have been thinned or selectively logged, a wide variety of species mixes can grow. Remember, even if you have mostly pine in the overstory but seedlings of Douglas-fir, grand fir, or incense-cedar are scattered about in the understory, the site should be classed as warm-dry mixed-conifer type. Engelmann spruce and subalpine fir are key indicators of the cool-moist mixed-conifer type. The pines, larch, and Douglas-fir can be found in either type.

Exceptions to the simple rules for determining forest type occur where fire or logging and reforestation have modified species distribution and may mask the true forest type. For example, you may find mostly pine instead of a mix of pine and Douglas-fir or grand fir where a young lodgepole pine stand has seeded in after an intense wildfire. The fire may have eliminated the fir species that can grow on the site. Therefore, instead of a lodgepole pine type, it should be regarded as a mixed-conifer type. It is sometimes necessary to depend on shrubs, herbs, or grasses as indicators of forest type. In such cases, referring to the local plant-association guides (available from the U.S. Forest Service ecologist or silviculturist) can be very helpful.

The productive potential of the different forest types ranges from very low in lodgepole pine on pumice to quite high in warm-dry mixed-conifer. Productive potential drops again at the cold end of the cool-moist mixed-conifer type, mainly because of the short, cool growing seasons. Site index is a measure of site potential or productivity based on how fast trees grow to a certain height for a given age (100 years); see Chapter 2 for ways to determine site index for your forest stands.

You can manage mixed-conifer types for any one of the species present—pure ponderosa or lodgepole pine, for example. Often, however, there are advantages to managing a mixture of species. In the warm-dry mixed-conifer types, it is especially desirable to keep a substantial component of ponderosa pine or western larch because they resist defoliation by spruce budworm or Douglas-fir tussock moth. On cool-moist mixed-conifer sites, manage for ponderosa pine, western larch, Douglas-fir, grand fir (on better sites), Englemann spruce, western white pine, sugar pine, and lodgepole pine.

Maintaining a diversity of species is appropriate whenever it fits the owner's objective. Just keep in mind that management options are greater for a mixture of species.

Tree tolerance to environmental stresses

Each tree species has unique capabilities to tolerate stresses such as shade, drought, heat, flooding, wind, frost, fire, and attack by insects or disease. Trees that can live through long summer droughts are said to be drought tolerant. Trees that can live in shade are known as shade tolerant. Trees with thick bark are fire tolerant because the bark insulates the tree from heat damage. Tolerances determine where trees survive and grow, how they compete with other trees, and what we can expect them to do under management.

How to Use Tree Tolerances in Your Management

You need to know the relative tolerances of the species in your forest because you need to match each species' abilities with the role you want it to play. The key is to match the species to the site and to your objectives. What combination of tree species will do the job for you? For example, on warm-dry mixed-conifer sites you can manage for ponderosa pine, Douglas-fir, and grand fir. Relative shade tolerances indicate that, for regeneration, Douglas-fir and grand fir will regenerate naturally under a pine overstory as long as a good seed source is available.

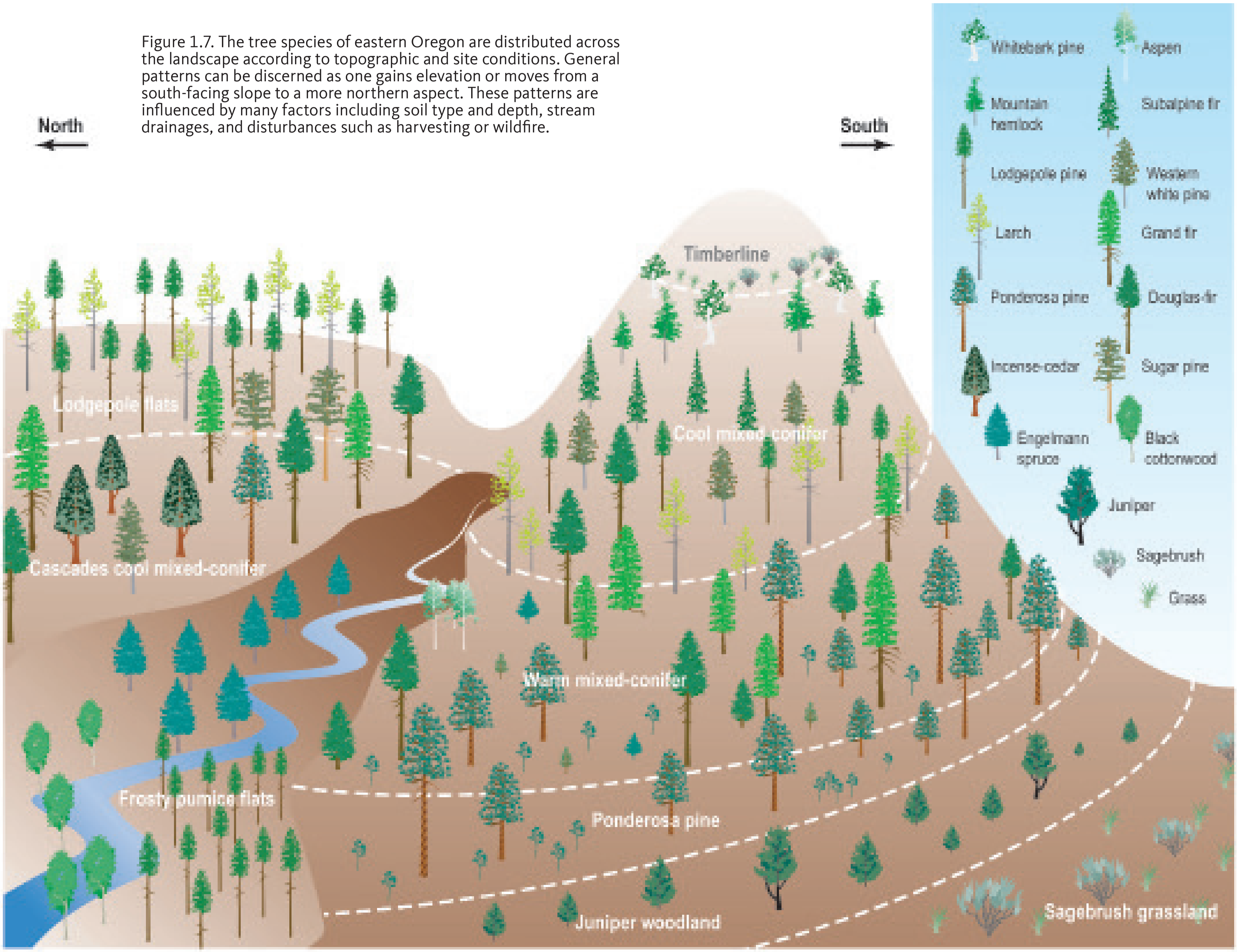


Figure 1.7. The tree species of eastern Oregon are distributed across the landscape according to topographic and site conditions. General patterns can be discerned as one gains elevation or moves from a south-facing slope to a more northern aspect. These patterns are influenced by many factors including soil type and depth, stream drainages, and disturbances such as harvesting or wildfire.

Figure 1.8, page 14, and Table 1.2 show relative tolerances of each tree species. The numbers in Table 1.2 are not exact measures, but they show how each species performs relative to the other species. The relative tolerances of different trees help explain the current condition of many forest stands and are extremely important in making management decisions (see "How to Use Tree Tolerances in Your Management," page 11). For example, the shade tolerance of Douglas-fir and grand fir have allowed them to replace less-shade-tolerant lodgepole and ponderosa pines over much of eastern Oregon during the last century. The frost tolerance of lodgepole pine explains its distribution and makes it a candidate for planting in frosty locations, but its low tolerance for bark beetle attack means that careful attention to thinning and harvest is a must. One final point to remember is that trees that are tolerant of a particular environmental stress, like shade, don't necessarily like it and grow well in it. They are, however, able to tolerate it better than other species. For example, many trees classed as shade tolerant prefer to grow in full sunlight.

Table 1.2. Relative tolerances of trees to environmental stress factors in eastern Oregon.*

	Tolerance to[a]								Characteristics		
Species	Shade	Drought	Flooding	Wind[b]	Frost	Fire[c]	Snow load	Pest damage[d]	Lifspan (yr)[e]	Mature ht. (ft) Normal/max.[f]	Knowledge of silvics[g]
Conifers											
Whitebark pine	5	5	2	1	1	3	1	4	500	40/75	little
Mountain hemlock	1	5	3	2	1	4	1	5	400	100/200	little
Subalpine fir	1	5	2	4	2	5	1	5	125	80/200	little
Engelmann spruce	1	5	1	5	1	5	1	4	225	120/165	some
Grand fir	1	3	2	3	3	4	1	5	175	120/210	well
Sugar pine	3	3	3	2	3	3	3	4	500	180/245	some
White pine	3	3	2	3	1	3	3	4	250	170/205	well
Western larch	5	3	2	1	2	1	2	2	250	160/190	well
Douglas-fir	2	2	5	2	3	2	2	4	250	130/180	excellent
Incense-cedar	3	2	3	2	3	3	3	2	300	100/180	little
Lodgepole pine	4	2	1	3	1	5	3	3	100	80/120	well
Ponderosa pine	5	1	2	1	2	1	4	3	300	165/200	excellent
Western juniper	5	1	4	1	2	4	3	1	500	40/60	little
Broadleafs											
Cottonwood	5	4	1	4	4	5	5	4	150	80/120	little
Quaking aspen	5	4	2	2	2	5	5	4	70	55/100	well

* The numbers are not exact measures but instead show how each species performs relative to other species.

[a] 1 = high tolerance; 5 = low tolerance

[b] Index combines wind firmness (rooting) and trunk resistance to breakage.

[c] Index based on bark thickness and on experience with which species survive after a fire.

[d] Index combines damage from insects, disease, and animals.

[e] Typical longevity.

[f] First number is the common height on good forest sites; second number is maximum height recorded.

[g] Degree to which management of the species is understood.

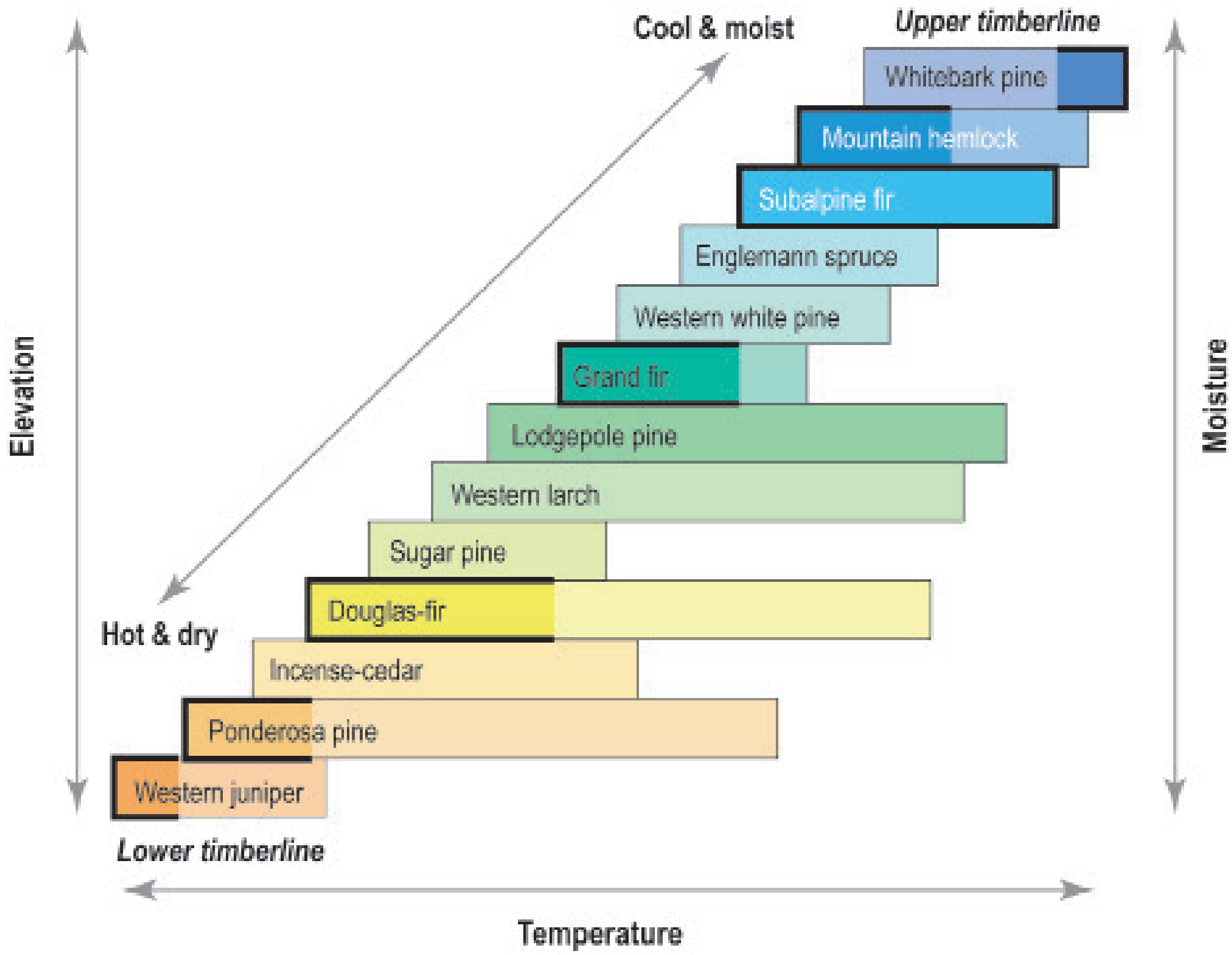


Figure 1.8. This diagram shows where each tree species is found in relation to other tree species in a general gradient of moisture and temperature from low to high elevation. It shows the distribution of coniferous trees in eastern Oregon from lower timberline (lower left) to upper timberline (upper right) in order of their normal appearance. Heavier lines in the boxes around species' names show where the given species is more shade-tolerant than any other species on the same site. For example, Douglas-fir growing with ponderosa pine and western larch will regenerate in the understory (Diagram modified from Franklin and Dyrness 1973).

Characteristics of selected eastern Oregon trees

Let's review some of the important species for their special tolerances. Conifer species are listed in the general order in which they grow, from warm, dry, low-elevation sites to cool-moist, high-elevation sites (see Figure 1.8, page 14). Deciduous trees are listed separately. For help with tree identification, see *Trees to Know in Oregon*, EC 1450, https://catalog.extension.oregonstate.edu/ec1450.

Conifer species

Western juniper is intolerant of shade and grows in open stands called juniper woodlands. It is quite tolerant of drought and typically grows where it is too dry for any other tree species. Juniper grows slowly and has varying form, from short wide-spreading trees with large branches to trees with good tree form on more-productive sites. Western juniper has had limited commercial value as lumber, fuel for co-generation, or fence posts. Over the last century, juniper has expanded its cover six-fold, often dominating many sites and causing subsequent declines in the abundance and cover of grass, herbs, and shrubs important to some wildlife and grazing animals. Loss of herbaceous and shrub layers beneath juniper often leads to increased soil erosion and long-term site degradation. Juniper is resistant to pest damage but is sensitive to fire and can be killed by prescribed fire with the goal of improving rangeland values (see *Biology, Ecology and Management of Western Juniper* (*Juniperus occidentalis*), TB 152, https://catalog.extension.oregonstate.edu/tb152).

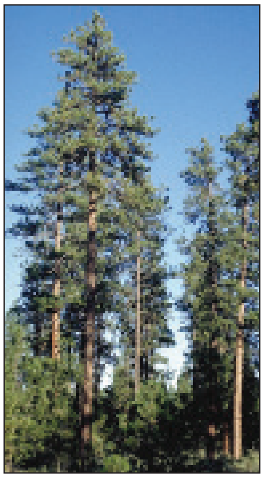


Photo: Ed Jensen

Ponderosa pine

Ponderosa pine tolerates drought but not shade. It is second only to juniper in its ability to grow on the driest forested sites, where productivity is low; however, it grows better on mixed-conifer sites. It develops thick bark at a relatively young age, so it readily withstands low-intensity surface fires. It is resistant to defoliation and root disease. Ponderosa pine grows to large sizes, and its high-quality wood has made it the most valued and managed species in the dry interior West. It is susceptible to bark beetle attack when stands become overstocked, and in some areas it is badly infected by parasitic dwarf mistletoe.

Photo: Ed Jensen

Douglas-fir

Incense-cedar, where it grows on the east flank of the Cascades, is more shade tolerant than ponderosa pine. It has low market value because of a fungus that causes pockets of rot to form in the wood. It is not favored in management except as a species for diversity. It is highly susceptible to fire due to its thin bark.

Douglas-fir is more shade tolerant than the pines but not quite as drought tolerant as ponderosa pine. When young, it is susceptible to fire but eventually develops a thick, fire-resistant bark that allows older trees to survive light surface fires. Because of decades of fire control, Douglas-fir is much more widespread now than it was a century ago. Its high-value wood makes it a welcome addition for those interested in timber management. It is, however, susceptible to defoliating insects, dwarf mistletoe, and some root diseases, especially in dense, nearly pure stands. It is resistant to rot from stem damage and less susceptible to bark beetle attack than associated pine species.

Photo: Ed Jensen

Western larch (the yellow trees)

Sugar pine is less drought tolerant and more shade tolerant than lodgepole and ponderosa pines. In eastern Oregon, it is limited to the east flank of the Cascades, increasing its distribution from north to south. Although it is vulnerable to blister rust, a non-native disease, it grows well in warm and moist mixed-conifer forests and has moderate wood value.

Western larch is less drought tolerant than the pines and Douglas-fir. It is less shade tolerant than Douglas- and grand firs. Where it comes in after fire or clearcutting, it grows rapidly in height the first decade of life but can become suppressed in overstocked stands. Dwarf mistletoe can be a serious problem. Western larch resists defoliation by spruce budworm and Douglas-fir tussock moth and is resistant to root diseases, but it can be severely defoliated by needle diseases and by the larch casebearer (an insect). However, the impact of the casebearer has been greatly reduced since the introduction of natural parasites as biological controls. Because western larch is resistant to defoliation and root rots, it is advisable to promote mixed stands of pine, larch, and Douglas-fir on deeper soils and north aspects. Western larch is highly resistant to fire due to its thick bark and other characteristics.

Photo: Walter Seigmund

Lodgepole pine

Lodgepole pine is only slightly less drought tolerant than ponderosa pine. It is especially frost tolerant, and it has a special ability to grow on soils composed mostly of pumice, a coarse volcanic ash. In central Oregon, it forms pure stands over thousands of acres on deep deposits of pumice from what is now Crater Lake. It also forms pure stands in frost pockets, in or on the margins of wet meadows, and on high plateaus where summer frosts can be severe. It easily becomes suppressed in overstocked conditions and should be released by thinning. Like ponderosa pine, at high densities it is susceptible to bark beetle attack and suffers from dwarf mistletoe. Also, it is locally heavily infected by western gall rust, which can cause loss of volume and wood quality. Its bark is relatively thin, and therefore it is easily killed by fire, but it regenerates readily from abundant and frequent seed crops. Lodgepole pine grows well in youth but cannot grow as tall or as big in diameter as ponderosa pine. However, its wood is valued for both lumber and paper.

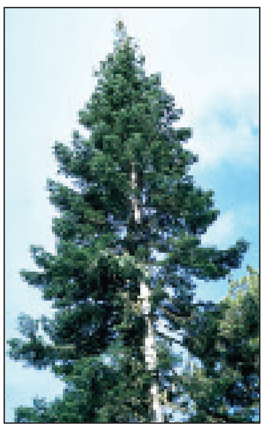


Photo: Ed Jensen

Grand fir

Grand fir is more shade tolerant than Douglas-fir or the pines but less drought tolerant. It is a good grower, and in most mixtures it grows faster than any of its neighbors (pine, larch, Douglas-fir). It is, however, quite susceptible to drought, root disease, and stem decay; it is killed by bark beetles and fire; and, like Douglas-fir, it is periodically defoliated. Defective trees are quite important for cavity-nesting wildlife species. Historically, its white wood was less valuable than ponderosa pine or Douglas-fir. By keeping grand fir at less than a third of the stand's potential stocking level, you can avoid many problems with insects and disease.

In Oregon forests, trees commonly referred to as "white" or "grand" fir are really hybrids between *Abies grandis* and *A. concolor*; others are more purely *A. grandis*. All are referred to as grand fir in this publication.

Photo: Ed Jensen

Engelmann spruce

Western white pine's natural distribution is confined to small areas of the Wallowa and Cascade mountains. It is, however, a regular member of the cool-moist mixed-conifer forests in northern Idaho and western Montana. It may be a valuable addition to the relatively moist end of the warm-dry mixed-conifer type because it grows fast and has high wood value. It is less drought tolerant than Douglas-fir and moderately shade tolerant where it grows. It is susceptible to bark beetle attack at high stocking. Although it is extremely susceptible to white pine blister rust (an introduced fungus), there has been considerable progress in finding, breeding, and planting rust-resistant strains of white pine.

Engelmann spruce is a frost-tolerant species found along streams, where frost is common in summer, and at higher elevations or north slopes where moisture levels are adequate. Thus, it is most common in the cool-moist mixed-conifer type. It can grow on periodically flooded or high-water-table sites; however, it is subject to windthrow in such areas. It has low susceptibility to spruce budworm, a defoliating insect. Spruce is shade tolerant relative to the pines. Its wood is valued for its light weight, light color, and strength. It is susceptible to spruce bark beetle attack in overstocked stands or near areas where spruce windfall has occurred. Engelmann spruce can be managed (thinned) to maintain tree health and vigor, but due to its shallow root system, opening up the stand can lead to blowdown.

Subalpine fir is a short-lived species (70 to 125 years) found at higher elevations in cool-moist mixed-conifer types. It is sensitive to fire. It can be attacked by balsam wooly adelgid and can be damaged severely by root and stem decay. It grows in closed forest stands or in subalpine parklands. As a shade-tolerant species, it often seeds in under lodgepole pine or larch in the cool-moist mixed-conifer forest type. It has marginal wood value.

Photo: Ed Jensen

Subalpine fir

Mountain hemlock is found above or mixed with subalpine fir in the cool-moist mixed-conifer type or near timberline in subalpine parklands. It is quite susceptible to root disease, stem decay, and dwarf mistletoe. It is found primarily along the crest of the Cascade Range and in the Wallowa Mountains, where its values for wildlife and watershed are greater than its commercial timber value.

Whitebark pine is the conifer found at timberline, usually in subalpine parklands. Like other five-needle pines, it is highly susceptible to white pine blister rust. Its seeds are an important source of wildlife food, such as for the Clark's nutcracker. Like mountain hemlock and subalpine fir, it is found mostly in national forests and has no commercial timber value.

Deciduous broadleaf species

Black cottonwood grows in riparian areas along streams or lakes. It is important for shading streams and for diversity. The wood is soft and brittle and decays easily, but it is good for pulp and veneer. Deer, elk, and cattle frequently browse its leaves and twigs.

Quaking aspen grows in a variety of locations associated with moist meadows or rocky slopes and adds important diversity to eastern Oregon forests. It is valued for its beauty because of its white bark and bright fall foliage (Figure 1.9). This species forms large clonal patches through a process called suckering: roots spreading away from the main stem send up sprouts (called suckers) that grow into trees. The patches may be small or cover tens of acres. Cattle, deer, and elk readily browse the high-protein leaves and twigs. Aspen is prone to stem decay and provides high-quality cavity-nesting habitat thanks to cavities that woodpeckers excavate in decayed aspen.

Aspen stands have declined in acreage and health over the last century and have been the focus of restoration activities in recent years. More information on the management and restoration of aspen can be found in *Land Manager's Guide to Aspen Management in Oregon*, EM 9005, https://catalog.extension.oregonstate.edu/em9005.

Figure 1.9. Deciduous species such as quaking aspen provide important diversity values including habit for cavity-nesting birds and forage for big game animals. They also provide a visual treat with their varied fall colors.

Disturbance and change in eastside forests

Forests are dynamic, changing either slowly or rapidly. We refer to most kinds of rapid change as “disturbance” because it is so noticeable, such as that caused by fire or large wind events that topple trees and forests. Gradual changes in forests occur through tree growth and competition among species. Changes in tree size and form and in stand canopy structure over a few decades are referred to as “stand development.” In a longer timeframe (several to many decades), changes in forest species composition, tree understory development, and stand structure involve a process of change called “succession.”

Stand development

Stages of stand development are (1) regeneration, (2) stand closure, and (3) stem exclusion and/or stagnation. During the regeneration phase, trees become established and grow without competition among neighboring trees. During stand closure, trees grow taller and crowns expand, closing the canopy until the taller trees use most of the water, nutrients, and light, leaving little for understory vegetation. During the stem-exclusion phase, less-vigorous trees die while more-dominant trees survive and continue to grow. Stand stocking, a measure of how completely the trees use site resources, is important in stand development. In fully stocked stands, dominant trees receive enough resources to grow well (10 rings or fewer per inch of radial growth). In overstocked stands, all trees grow slowly (more than 15 to 20 rings per inch radial growth) and trees lack the vigor to resist bark beetle attack and some diseases.

In a condition called “stagnation,” most trees remain in a slow growth mode, and a few die. This generally occurs in young stands with very high stocking. This condition is considered poor because the stand development process becomes “stuck” for long periods during which tree growth is extremely slow. A stand’s tendency to stagnate depends on the tree species, stand density, and site productivity. Single-species stands on low-productivity sites (e.g., lodgepole pine) are especially prone to stagnation.

Succession: In the process known as succession, tree, plant, and animal species gradually change over periods of several decades or centuries as stands grow dense and modify the microclimate within the forest. A group of early seral species gradually is replaced by species referred to as “late successional.” A common example is when Douglas-fir or grand fir seed in and grow in the understory of a ponderosa pine stand on a dry mixed-conifer site. Over several decades, the firs grow up, the stand becomes overstocked, and the pines decline in vigor. Eventually, beetles attack and kill the pine, leaving forests increasingly dominated by firs. Fir-dominated stands are susceptible to severe insect defoliation and mortality, which in turn can leave stands susceptible to high-intensity fire.

Disturbance: Disturbance can result from fire, timber harvest, grazing, insect attack, or disease. Since humans migrated to the Pacific Northwest more than 10,000 years ago, they have considerably influenced the disturbance pattern in the forests of eastern Oregon. The kind and frequency of disturbance in eastern Oregon forests have changed over the last century. Since about the year 2000, wildfires have increased in size and intensity in Oregon and across the West, creating rapid and great change in our forests.

From fire promotion to fire exclusion: Before European settlement, fires set by Native Americans or by lightning burned through the forests at regular intervals. The intensity and frequency of burning varied with the degree to which forests dried out on a seasonal or climatic-cycle basis. Fire intensity also was strongly related to the amount (tons), type (size), and distribution of wood and fuel on the site. At low elevations, dry forests (e.g., those on ponderosa pine and warm-dry mixed-conifer types) had low-intensity fires at frequent intervals (5 to 25 years), resulting in low stocking levels of fire-resistant ponderosa pine and/or larch. At low stocking, these trees grew well and became larger and more fire resistant as their bark grew thicker. Most often, the low-intensity fires killed mostly smaller pine trees or thin-bark species and consumed understory shrubs and grasses. Fuel loads remained low. At upper elevations, more-moist forests did not burn as frequently, thin-bark species gradually seeded in, shrubs grew large, and fuels accumulated.

Typically, the longer the interval between fires, the greater the fuel load and the more intense the subsequent fire. Therefore, in the cool-moist mixed-conifer type, intense, stand-replacement fires occurred at long intervals, ranging up to 100 years or more. After fire, seral species including lodgepole pine and larch seeded in, forming pure or mixed stands that were gradually invaded by shade-tolerant subalpine fir after many decades of stand development.

Fire exclusion and suppression: Soon after European settlers arrived, they cleared land and began to suppress fire by restricting ignitions and fighting wildfire. Fires were less likely to burn across areas after grazing had removed grasses and herbs (fuel). Since about 1910, efforts to control fire have been increasingly effective. Thus, for over a century, fire exclusion has allowed stands to become dense to the point of overstocking or stagnation. Fire-sensitive, shade-tolerant species like Douglas-fir and grand fir seeded in and spread across the landscape (Figures 1.10a–h, pages 20–21).

Insects, diseases, and other pathogens, such as dwarf mistletoe, were historically a natural part of the disturbance pattern and often interacted with wildfire to influence the distribution of successional stages across the landscape. Stands that had large numbers of trees killed by beetles or root disease became especially prone to intense, stand-replacement fires. Decades of fire exclusion have created dense stands, changed forest composition, and facilitated the movement of bark beetles, defoliators, and root diseases through stands and landscapes. Stands are more vulnerable, and landscapes contain higher percentages of fire-susceptible trees or stands.

Because the changes in forests due to fire exclusion were gradual, they went unnoticed until recently. Gradually, large areas became susceptible to burning at uncharacteristically high intensities. Forest stands in this unstable condition are prone to loss of both financial and wildlife values when most trees succumb to either insect attack or wildfire, although other wildlife habitat is created (snags, for example). Recent intense and widespread wildfires can be attributed to these successional trends. Such fire can severely impact watersheds, reducing their capacity to absorb and filter water during heavy rain or rapid snowmelt. Millions of acres of federal and private forests in eastern Oregon are in need of forest restoration treatments to improve forest health and increase resiliency to insects, disease, and wildfire.

Grazing: As European settlers moved into the region over the Oregon Trail during the nineteenth century, cattle and sheep grazing and timber harvesting joined the list of disturbance factors. Intensive grazing by large herds of sheep and cattle spread across the landscape, often concentrating in riparian areas. Watershed conditions often were heavily impacted (Figures 8.6a–c, page 172).

Grazing intensified as ranching became common over much of eastern Oregon. Grazing removed understory vegetation, and ranchers seeded many introduced grasses to “improve” grazing. Also, domestic grazing animals spread introduced weeds.

Overgrazing by sheep or cattle was recognized as a problem around the turn of the twentieth century and has come under increasing regulation on federal forestland. Ranchers also have modified their forest and range management practices to improve forage production and to limit damage to watersheds. Still, problems remain. For example, the spread of noxious weeds has degraded range conditions and threatens forest range values over large areas. Livestock also tend to congregate around streams and water sources where damage may occur and thus need to be constantly managed to reduce impacts.

Timber harvesting: Timber harvest early in the last century often removed the more valuable ponderosa pine, larch, and white pine in a way that was criticized as "high grading." The removal of large pine trees created openings and increased the water and light available for

Figure 1.10a. 1909. The stand receives its first selection cut. The original stand was dominated by ponderosa pine and had approximately 50 trees per acre. Loggers used horses to harvest about half of the trees on the site. They left the other half as "reserve" timber for a second future cut and to provide seed for a new generation of trees. Most of the Douglas-firs were harvested, even though they were of lower economic value, to keep a native parasitic plant, western dwarf mistletoe (*Arceuthobium campylopodum*), from spreading through the stand.

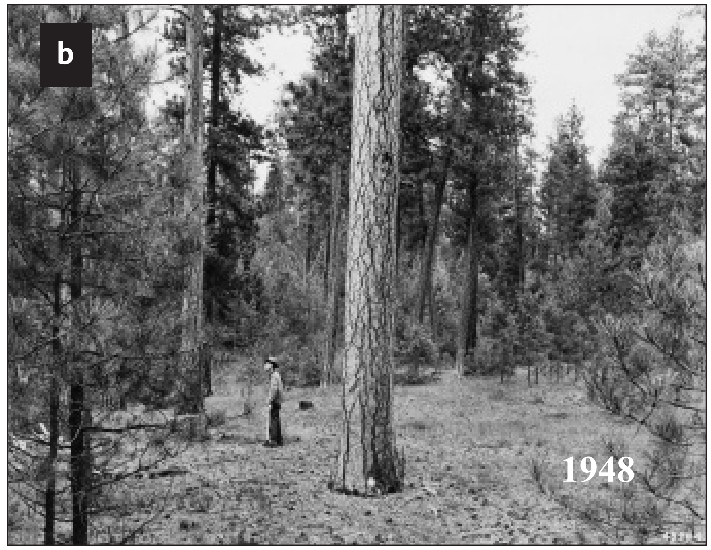


Figure 1.10b. 1948. The reserve trees grew quite well for 40 years, especially during the first decade after logging and during a period of high rainfall about 30 years later. Some trees were blown down shortly after logging, but few others died. Abundant young ponderosa pine and Douglas-fir became established. These young trees grew about one inch in diameter every three to four years. The large tree in the center has been marked to be cut (see paint/blaze at stump height).

Figure 1.10c. 1958. To make room for the young trees to grow well, most of the undamaged Douglas-firs over 14 inches in diameter were harvested in a second selection cut in the 1950s. Loggers also cut dead-topped and lightning-damaged trees, slow-growing old trees, trees with decay near the base, and trees leaning more than 20 degrees.

Figure 1.10d. 1968. In 1962, some large trees were cut (third selection cut) and patches of smaller trees were thinned. The most striking result captured in this photo is the proliferation of ponderosa pine seedlings. Ponderosa pine seedlings originate sporadically, in years after the trees produce abundant cones. They establish well in open spaces and on bare soil.

Figure 1.10e. 1979. Lots of young Douglas-fir seedlings are growing among the pines. Douglas-fir tolerates shade and dense forest conditions better than pine, so its seedlings can grow even when the site is partly occupied by taller trees and is shady.

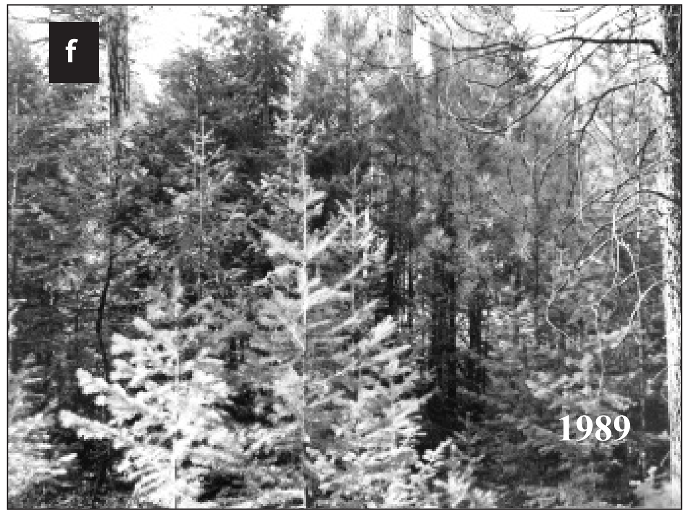


Figure 1.10f. 1989. Ponderosa pine and Douglas-fir seedlings have developed into a dense understory. Tree branches are almost continuous from the ground into the tops of the tallest trees, making this stand prone to wildfire. Eighty years ago, wildfires changed the forest very little. Now they are likely to kill even the oldest, tallest trees on the site.

Figure 1.10g. One hundred years later. Some overstory trees were removed in a 1992 selection cut (fourth). Small trees killed by a 1993 underburning treatment have mostly fallen to the ground. Douglas-fir tree regeneration noted in 1979 continues to grow in patchy thickets.

Figure 1.10h. One hundred and six years later. Shrub species in the understory have become more prominent. Douglas-fir regeneration evident in foreground and background.

Adapted from "A Century of Change in a Ponderosa Pine Forest," Rocky Mt. Research Station, USDA Forest Service. Online at: https://firelab.org/project/century-change-ponderosa-pine-forest

the more-shade-tolerant Douglas- and grand firs to seed in and grow in the understory, which accelerated their development (Figure 1.10a–h) and oftentimes allowed them to replace the fire-tolerant pines and western larch.

All these disturbances had three major effects on forest health:

1. The trend toward higher stand densities in pine and fir stands reduced the vigor of individual trees and increased the tendency for forests to be attacked by bark beetles.

2. The increased abundance of fire-sensitive species (e.g., Douglas-fir when young and

Figure 1.11. Mortality in this stand of ponderosa pine is due to both root rots and bark beetles. It is also susceptible to severe, stand-replacement fire due to the heavy fuel load of dead trees.

grand and subalpine firs) in mixed-conifer types led to stands with much higher susceptibility to serious insect defoliation by spruce budworm and Douglas-fir tussock moth. Overstocking and stagnation foster attack by bark beetles, root diseases, and mistletoe (Figure 1.11). Fir species are also much more susceptible to drought.

3. The trend to higher stocking and multiple canopy layers (Figures 1.5, page 10, and 1.10e-f, page 21) led to stands that are prone to uncharacteristically destructive fires, and, because of large fuel accumulations, to fires that are extremely difficult to control. Even large pine and larch with thick bark are susceptible as the fires climb high into tree crowns on a fuel ladder of grasses, herbs, shrubs, and mid-canopy trees. See Chapter 11 on fire and reducing fire risk.

Historic and current conditions

Forest condition varies according to the forest's history of management; its history of fire, insect, and disease attack; and the prevalence of mistletoe. On the negative side, many federal and private forests are overstocked and vulnerable to bark beetle attack (Figure 1.11). Fire suppression and lack of thinning have allowed stands to grow to high stocking levels, in some cases to the point of stagnation. An even-greater area is poorly stocked or stocked with poor-quality trees that will provide few wildlife or timber benefits in the future. High-grade timber harvesting of the past tended to remove only the valuable, well-formed pine or larch, and it left stands dominated by Douglas-fir, grand fir, or subalpine fir trees of poor form and vigor. Such species composition made them susceptible to defoliation by insects. In other cases, bark beetles killed many of the well-formed larger pine and left poor, understocked forests that have little timber value or opportunity for management.

On the positive side, fire or logging disturbance sometimes created soil surface conditions quite favorable for regeneration. Young stands became established and represent good opportunities for future management. In other cases, properly carried out selection management has resulted in mixed-species and mixed-age stands that have potential to grow high-quality timber and provide good wildlife habitat. Also, where naturally regenerated understories existed, logging the overstory sometimes released seedlings to grow into high-value stands. Thinning or harvest has in many cases promoted growth of valuable forage and browse for big game.

Riparian conditions also vary widely. A large proportion of streams have been negatively impacted because of the tendency of livestock to concentrate near water. Fencing off riparian areas and distributing water tanks have been used to improve the situation; however, many areas need further attention on managing livestock.

Your forest may have been degraded by events in the past or may have benefited from them. Either way, try to understand the current forest condition in relation to its potential, and determine what you need to do to put your forest on track to satisfy your long-term objectives.

Management of eastern Oregon forests

Opportunities for beneficial management abound. Until recently, low timber values and low productivity of eastern Oregon forestlands made intensive management for timber production uncommon. Although many private forest owners have tended their stands and have healthy, productive forests, many other forest areas would benefit from more proactive management. Thinning forest stands, managing fuels, and better managing riparian areas are needed to correct current conditions. Such management would help prevent adverse impacts by insects, disease, or fire and would make the yield of values (e.g., wildlife habitat, timber, or grazing) more predictable.

In recent decades the loss of sawmills across central and eastern Oregon has made the profitability of timber management more difficult because of reduced markets and longer distances to transport logs. This has made it increasingly more difficult for landowners to economically treat stands to reduce stocking levels and promote more-healthy forest conditions.

Even where stands are in good condition, normal patterns of forest development and succession ensure that the forest will be different in the future. Because eastern Oregon forests are susceptible to a variety of health problems, the consequences of any management strategy, including “no touch” management approaches, must be carefully considered.

Clearly, proactive management to control species composition, stand stocking levels, and fuel loading will create stands that are more resistant to wildfire, bark beetles, defoliators, dwarf mistletoe, and root disease. If commercial timber production is an important objective, these controls allow you to grow and sell timber at a time of your choosing, rather than after fire or insect damage when log values are low and management options have been lost.

Managing forest stands and landscapes often can ensure that a variety of forest values—including timber, habitat for wildlife, livestock production, and recreation—are available simultaneously. Each owner should decide what combination of values to promote and should determine the land’s potential to produce those values.

Management implications of landscape patterns

Over a landscape of hundreds to thousands of acres, forest types form a varied pattern, and any one type may cover only a few to thousands of acres (Figure 1.13, page 25). To get the most from your land, or to simply avoid problems, you need to recognize where forest types change and what the changes mean for management.

Figure 1.12. Prescribed fire may be used to help control overstocking and reduce the danger that wildfire will destroy the stand.

Highlights of Important Management Benefits

Three basic management tools—stocking level control, species composition control, and fuel load control—are key to growing healthy, productive forests.

Stocking level control

Overstocking reduces tree vigor and sets up a stand for bark beetle attack. The most basic tool for keeping trees vigorous is thinning to manage stocking level at all stages of stand development. Proper thinning has been shown to give the best protection against bark beetles for Douglas-fir, true firs, and pine species. Each species has its own stocking guide, and fine-tuning to each site may be necessary (see Chapters 3, 4, and 5).

Species composition control

Keeping a mix of species and age classes is a good way to cushion stands against a variety of problems. Below are three examples of how managing for a variety of species can avoid risks from pathogens or insects.

1. Bark beetles and defoliators can attack mixed species stands in mixed-conifer types. Properly thinned stands are resistant to beetle attack, but they are still susceptible to defoliator attack if the stands contain a high proportion of Douglas-fir, grand fir, or subalpine fir. It is possible, however, to avoid this threat by maintaining a high proportion (more than 70 percent of the basal area) of ponderosa pine or larch, or, on more moist sites, of both pine and larch. This strategy is effective in minimizing damage even during outbreaks of Douglas-fir tussock moth and spruce budworm.

2. Dwarf mistletoes are common parasites on many tree species in eastern Oregon. Dwarf mistletoe infection reduces tree vigor and growth and can in some cases kill the tree. Dwarf mistletoe seeds are windborne, but they can infect only trees of the same species from which they grew initially. So, if ponderosa pine mistletoe has become a severe problem, switching to Douglas-fir and larch as the main species will help because ponderosa pine mistletoe cannot spread to Douglas-fir or larch. Maintaining a variety of species and a diverse stand structure, and selectively thinning to remove mistletoe-infected trees, often can help solve mistletoe problems.

3. Root diseases affect all tree species in eastern Oregon, slowing growth and sometimes killing the tree. However, each species has a different susceptibility to each disease. Knowing the differences between species and how to identify root diseases in the field will help you manage species composition to avoid root-disease problems (see Chapter 7).

Fuels management

Clearly, sustainable management of eastside forests requires careful planning and judicious use of available tools such as thinning, prescribed burning, or other methods of fuel reduction. Thinning reduces the amount of fuel on site and helps structure the stand to prevent spread of wildfire. Treating residual fuels by piling and burning or by prescribed broadcast burning (Figure 1.12, page 23) is critical in keeping the next fire on the ground and out of the forest canopy. See Chapter 11.

Many management objectives, including control of wildfires or insect outbreaks, can be achieved only by thinking at the landscape scale. Overstocking and species composition problems on many ownerships make the region susceptible to large-scale insect outbreaks or wildfires. Many wildlife species depend on having a mixture of habitats; for example, open grassy areas for feeding and dense young stands for shelter (see Chapter 9). Finally, the landscape perspective reminds us that planning and cooperation with neighboring landowners can help attain a more fire- and insect-resilient forest landscape and region.

It is important to keep *all* your forest acres in good health because insect infestations, wildfires, and even root diseases move across the landscape from one forest type to another. For example, a bark beetle infestation that starts in an overdense stand may spread into a recently thinned, adjacent stand. Stands that have been properly thinned contain healthy, vigorous trees that will resist most attacks. Likewise, a wildfire that kills all trees in a dense, mixed-conifer stand where beetles have previously killed a lot of trees also might destroy a nearby thinned stand if thinning slash remains untreated. Your stands are more likely to survive fire if you've treated the thinning slash. Reducing fuels lowers fire intensity, even during a wildfire.

Figure 1.13. Managing a landscape with many forest types and ownerships takes careful planning and good coordination to ensure safety from fire, insects, and disease.

Figure 1.14. Well planned and executed selection management can create healthy mixed species and mixed-age stands that have potential to grow timber as well as provide good wildlife habitat.

Summary

This chapter is intended only to get you started on matching or aligning the land's capabilities and your objectives. Management practices are discussed in greater detail in the following chapters.

Managing the variety of eastern Oregon forest types is a big challenge. Much of the area is dominated by the ponderosa pine forest type with one tree species; thus, you cannot choose which tree species to manage because only ponderosa pine will grow there. In such cases, thinning is your main tool for maintaining a healthy forest.

In mixed-conifer types, you can choose both the species and stocking level. Long experience has shown the value of managing a mixture of a few species. This provides you more management options and helps avoid wildfire, insect, and disease problems. Combining control of species composition, stocking levels, and fuel loading gives you the greatest opportunity to maintain healthy trees and fire-resistant stands. Passive, no-touch approaches do not protect your stands from fire or insect attack in the long run.

CHAPTER 2

Silvicultural systems for eastside forests

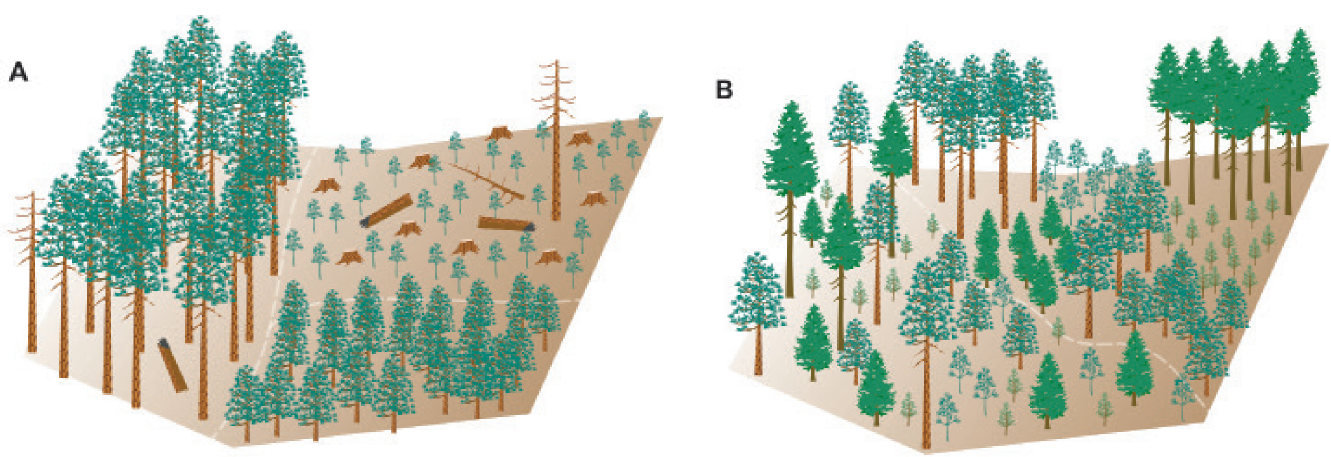
Stephen A. Fitzgerald and Paul T. Oester

You have many choices for “designing” your forest—how it looks and what it produces—using a variety of long-term management strategies called silvicultural systems. You’ll carry out your long-term strategies in operations such as planting and vegetation management, thinning, pruning, fertilizing, and prescribed burning.

It is critically important to choose your long-term strategy before you begin any management in your forest. If you act without a strategy, you run the risk that what you do today will make it difficult or impossible at some later time to achieve your long-term goals.

Lack of timely management action over thousands of acres and many decades has significantly reduced both the commercial and amenity value of eastern Oregon forests. Active management can restore many of those values. Passive “management” is risky because natural trends in stand development and succession often lead to forests at high risk of insect attack or wildfire.

In choosing a management strategy, you first need to decide whether you want relatively simple even-aged, single-story stands or more complex two-aged or uneven-aged, multistory stands (Figures 2.1a–b). A critical element of the plan is how you will bring young trees into the forest; i.e., how you will regenerate the forest. The three methods of regenerating



Figures 2.1a–b. Even-aged stands (a) are composed of trees that regenerated within a decade or so, but they vary in height and diameter, depending on their competitive position. Still, the tree crowns form a single overstory canopy. Dominant trees grow larger than suppressed trees. Uneven-aged stands (b) are composed of trees of a few or many sizes and ages (lower left). Tree crowns form an open, multilayer canopy. Or, they may be composed of small groups of trees that are more or less even-aged (upper right).

even-aged stands are clearcutting, shelterwood cutting, and seed tree cutting. Two-aged stands can be created by planting trees under a shelterwood and retaining the overstory trees for an extended period of time. Regenerating uneven-aged stands uses individual tree selection (ITS) and group selection harvest methods. All of these approaches require active monitoring and management to guide stand structure, stand density, and forest health.

Which silvicultural system you choose depends on these factors:

- Your long- and short-term objectives
- Current stand conditions; e.g., is the stand already even-, two-, or uneven-aged?
- Site factors, e.g., is it a dry, ponderosa pine type of site or a cool-moist mixed-conifer type of site?
- Insect and disease problems
- Competing vegetation
- Slope and terrain
- Timing of harvest and access for harvesting equipment

This chapter describes some of the long-term strategies (silvicultural systems) and how site and stand conditions influence the management operations needed to achieve your objectives.

Even-aged regeneration methods

Clearcutting

Clearcutting has been used successfully to produce young, even-aged stands on mixed-conifer, lodgepole, and some ponderosa pine sites. A typical reason to clearcut is to convert lodgepole or ponderosa pine stands that have been heavily damaged by insects, disease, mistletoe, or wind or that have had all the good or high-value trees removed in past high-grade harvests. The value of remaining trees may be marginal, and the dead and dying trees will continue to deteriorate and lose value. Clearcutting captures as much value as possible and helps make the operation economically feasible. In these situations, your main goal is to start over and establish a young, productive stand that is relatively resistant to forest pests. Clearcutting also is used to harvest forest stands that are mature; i.e., they have reached their highest long-term growth rate and top commercial value.

Once you clearcut, you are required by law to reforest the site within six years. Reforestation (see Chapter 6) can be by planting seedlings or by allowing seed from surrounding stands to naturally regenerate the site. Because natural regeneration is often uncertain or slow, planting helps you meet the six-year requirement. If you want to use natural regeneration, you need a special plan approved by the Oregon Department of Forestry. Be forewarned that establishing a plantation after natural regeneration has failed is much more expensive than planting in the first place, because competing vegetation (grasses, shrubs, etc.) will have reestablished.

Avoid clearcutting on dry, climax ponderosa pine or lodgepole sites or on hot, south-facing slopes with shallow soils. These are areas where soil surface temperatures are high and soil moisture is low. Planted seedlings are likely to die under these harsh conditions. In contrast, on more-moist clearcut sites, planted seedlings of site-adapted species work well if competing vegetation is initially kept in check.

You can soften the unnatural look of a clearcut by using irregular boundaries (no straight lines, if possible) and, as required by the Oregon Forest Practices Act, by leaving snags and a few green trees in the interior of the clearcut for future snags (Figure 2.2). The idea is to break up the opening in a more natural-looking way and to provide important feeding areas for deer, elk, and other wildlife. Snags and large, down logs within a clearcut provide valuable habitat for cavity-nesting birds and mammals long into the future.

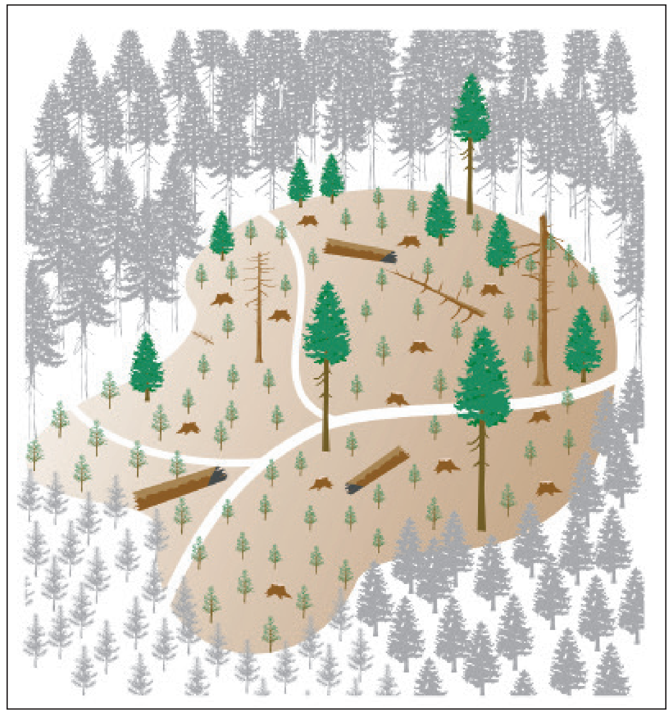


Figure 2.2. A clearcut with irregular boundaries, snags, and scattered green trees

Shelterwood and seed tree cuttings

A shelterwood cutting leaves enough trees per acre to provide shelter and/or a seed source to regenerate the site. Shelterwoods leave 10 to 25 trees per acre of the larger trees present. Be aware that reducing a stand below 40 to 50 square feet of basal area per acre triggers the legal requirement to reforest the area. Shelterwood cutting is used to encourage regeneration on harsh, south-facing slopes and in frost pockets. Residual overstory trees provide shade, helping seedlings survive summer drought. In frost pockets, an overstory canopy reduces the severity of frosts that can kill germinating or planted seedlings. Summer frost also can severely restrict growth or kill most of the new needles each year. If the shelterwood is on a harsh site, planting vigorous seedlings of a drought- or frost-tolerant species is a good idea.

A seed tree cutting provides a source for natural seeding where sheltering is not important. Seed tree cuts leave two to nine trees per acre, which can satisfactorily regenerate relatively moist sites where shade is not needed. However, seed tree cutting is rarely used in eastern Oregon because site conditions and lack of regular cone crops are likely to keep regeneration below legal requirements.

Figure 2.3. Shelterwood in a mixed-conifer stand. Note that healthy, well-formed trees with long live crowns are left to provide the best possible seed source. This photo was taken just after most of the stand was cut to leave shelter/seed trees.

Since part or all of a new stand may come from natural regeneration, it is very important to leave healthy, well-formed trees of the species you want to manage on the site. Leave trees should be large, dominant and co-dominant trees that are vigorous and have full, dense crowns (Figure 2.3). Also, they should be free of mistletoe and other health problems. The tree species left as shelter and seed trees should be appropriate for the site (refer to Table 1.1, page 9), that is, species that will do well on that particular forest type for the long term. Typically, trees with these attributes are windfirm, resistant to insects, and capable of producing shade and abundant seed for natural regeneration.

Overstory shelter or seed trees may be harvested later to release the understory seedlings or may be left to create a two-story stand (see section on two-aged stands, page 30). If you harvest the overstory, do so after planted or natural regeneration is well established (5 to 10 years) but before seedlings are 2 to 4 feet high. This timing will minimize damage to regeneration. Remove any overstory trees of the regenerated species that are infected with mistletoe to prevent infecting understory trees. Leaving some overstory trees can provide the following:

- Vertical stand structure (i.e., layers of vegetation in the understory, midstory, and overstory) and wildlife habitat

- Increase in leave-tree value for harvest later
- Opportunity to convert to an uneven-aged stand over time

During overstory removal, protect seedlings and saplings from damage by using directional felling—felling trees toward skid trails—and using designated skid trails for harvesting equipment. Or, harvest during winter when a snow pack can protect seedlings.

Windthrow of leave trees can be a problem (Figure 2.5, page 31). In areas that get high winds (e.g., ridge tops and saddle gaps) or have shallow or wet soils, seed trees are more likely to blow over. Avoid shelterwood and seed tree cutting in these areas. Massive blowdown is likely in stands that had been growing densely and then were opened up in one harvest operation. The better approach is first to thin dense stands to improve windfirmness and cone production, then make a shelterwood cut a decade or more later. A systematic thinning program throughout the life of a stand helps grow good windfirm trees.

Two-aged regeneration methods

Two-aged stands can be created by first conducting a shelterwood cut as previously described. The understory is then planted with desirable species or regenerated naturally from seeding from overstory trees (Figure 2.4). The overstory and understory grow simultaneously. During this time, significant high-value wood is grown on the large-diameter overstory trees. Over time some of large overstory trees may be removed to release the younger understory trees because as the large trees continue to grow, they increasingly shade the understory and consume a lot of the below-ground growing space. In addition, understory trees may require precommercial thinning at some point to maintain their growth and health. Over time, the understory trees grow and replace the overstory cohort. Two-aged stand management can be the precursor to converting the stand to an uneven-aged stand in the long run.

Figure 2.4. In two-aged stands, the overstory and understory grow simultaneously.

Uneven-aged regeneration methods

Individual tree selection

The individual tree selection (ITS) harvesting method is used to create and maintain uneven-aged stands having trees of three or more age classes mixed together, with more small and medium-sized trees and fewer large trees (Figure 2.6). The mix of tree ages and sizes includes both merchantable and non-merchantable trees. It's important to inventory uneven-aged stands so that periodic thinning can be used to adjust the balance between large and small trees (Figures 2.7a and 2.7b, page 32). Using ITS may help you avoid the costs of tree planting by maintaining a continuous forest canopy on the site and relying on natural regeneration. ITS is considered an intensive approach because you need to selectively remove trees in the stand every decade or two, and you have to be careful to protect understory trees.

Figure 2.5. Windthrow in a shelterwood.

Stands that already have three or more size/age classes as a result of past harvesting, windthrow, insects, or other disturbances are good candidates for ITS. Stands that have two age/size classes (two-aged stands) can be converted to uneven-aged stands with additional thinning and reforestation over time (e.g., 10 to 30 years).

ITS is applied by conducting a selection cut every decade or two, removing trees across the various size classes across each acre (see "Managing stocking in ITS," page 32). With each selection entry, growing space for residual trees or new regeneration is created. The upper diameter limit for ITS typically is 18 to 25 inches. When individual trees grow to this limit, they are harvested. Trees or groups of trees less than this diameter are selectively removed to a specified spacing based on species, site productivity, and time until the next selection harvest (Figure 2.6) to keep overall stand densities, including those of small trees, relatively low. For example, densities of uneven-aged stands are managed at only 50 to 75 percent of the full stocking level targets for even-aged stands (see page 35) in order to promote the growth of mid- and understory trees. These lower densities reduce the risk of bark beetle attack and encourage good growth on all trees in all size classes. It is equally important to have new seedlings establish after most selection harvests to ensure continued recruitment of trees into larger age classes over time.

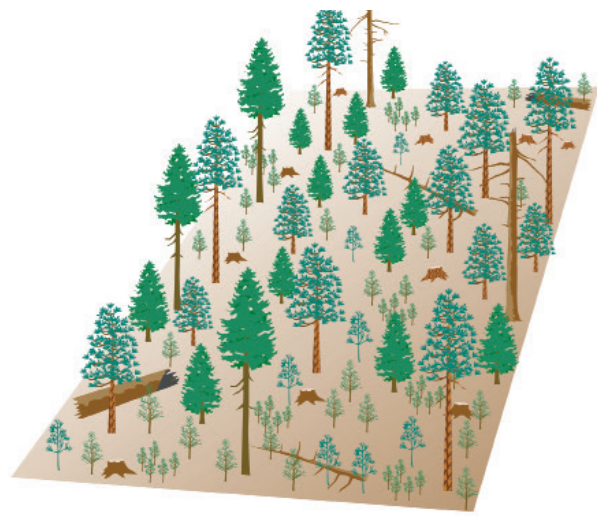


Figure 2.6. A hypothetical stand maintained by the ITS method, in which trees in all size/age classes are thinned periodically.

A common mistake is to maintain uneven-aged stands at too high a density or to delay needed selection harvests. Overstocked stands especially suppress the growth of smaller trees. Often, an overstocked stand has too many large trees. For example, a 30-inch dbh tree has almost 5 square feet of basal area, so four 30-inch trees will occupy 50 percent of the lower stocking limit for ITS on many sites. The goal here is to find a good balance between overstory stocking and under- and mid-story tree growth.

It is important to remember that ITS is not "take the best trees and leave the rest" or what is referred to as high-grading. All size/age classes should be selectively thinned, even trees not of commercial size, leaving the best-formed and most-vigorous trees to grow. Thus, during each cutting entry, the selection cut may involve cutting commercial and smaller

Managing Stocking in ITS

Management of ITS stands involves periodic cutting in all age/size classes to achieve a balance between smaller understory trees and bigger overstory trees. Inventory of stands is necessary before partial cutting to estimate the number of trees per acre (tpa) in each size class. Figure 2.7a depicts an uneven-aged stand with more tpa in the 4- and 8-inch diameter classes than in the 12- to 24-inch classes. Figure 2.7b superimposes a logical target number of trees for each diameter class (dotted lines on the estimates of current stocking (bars). This simple tool illustrates the need to thin in the 8- and 16-inch classes while leaving trees in the 4- and 12-inch classes.

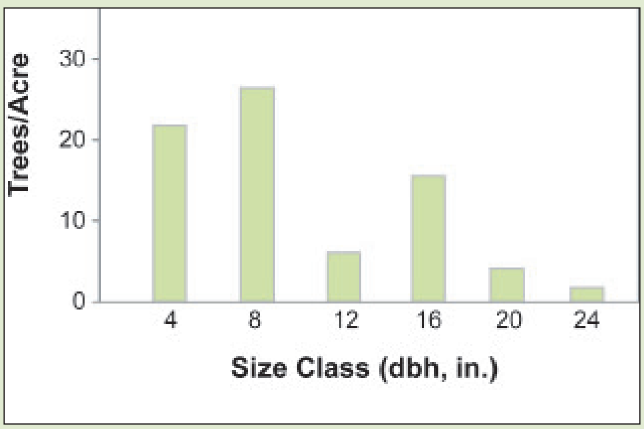


Figure 2.7a

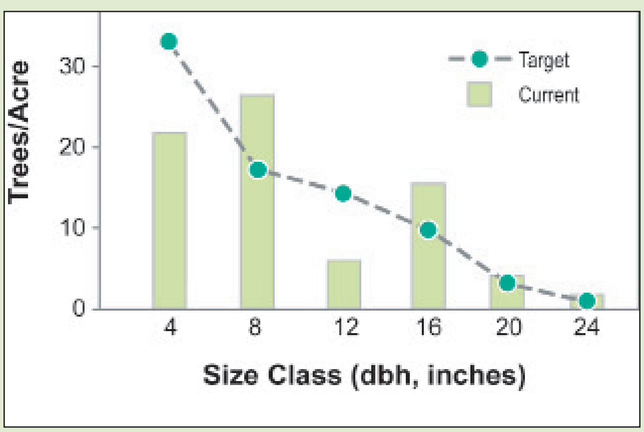


Figure 2.7b

non-commercial trees. Usually the cutting of non-commercial trees is done as a separate operation for work efficiency or contract reasons.

Most tree species regenerate well from seed on mineral soil. However, if cone and seed production are poor (typical of larch) or competition from herbs, grasses, and shrubs is a significant problem, vegetation control and hand-planting may be needed to establish a new size/age class or to secure the desired mix of species.

To prevent injuring seedlings, saplings, and commercial-size trees during harvest, carefully design the logging system (Figure 2.8, page 33). It is important to plan and establish a permanent skid trail system that reuses skid trails, limits soil disturbance, and reduces soil compaction and damage to trees. Use directional tree felling to minimize damage to residual trees, which in turn reduces risk of certain insects, disease, and decay.

Group selection

Group selection harvests remove trees in small groups, from about 0.5 to 4 acres. Group selection creates many small, even-aged stands of several different age or size classes within the larger stand of 30 to 100 acres or more (see Figure 2.1b, page 27). Group selection cuts are made so that 10 to 25 percent of the stand area is harvested and regenerated in small openings every decade or two until the entire area has been harvested and regenerated over a period of many decades. Natural seeding or planting can regenerate group selection cuts. A permanent skid trail system is important in managing stands with the group selection method.

The forests of central and eastern Oregon, particularly ponderosa pine forests, are often “clumpy” or “groupy” by nature and so are ideal for the group selection method. These forests often are a mosaic of even-aged pockets of various ages and sizes as a result of regeneration in areas disturbed by fire, wind, insects, disease, livestock grazing, and past timber harvest. Many pine forests, for example, have patches of extremely dense, small-diameter trees where tree growth has stagnated (Figure 2.9, page 33). Such patches urgently need thinning to improve tree growth, vigor, and resistance to bark beetles. If trees within these groups have mistletoe infections, these trees should be removed to prevent spread of mistletoe.

On moist sites, it might be necessary to help the less-shade-tolerant ponderosa pine and larch by reducing the amount of shade-tolerant Douglas-fir and grand fir. Older, mature patches can be thinned to maintain an age/size class, or an entire mature group can be harvested to establish a new age class. On moist sites, it is important to make the group openings large enough (1 to 4 acres) to allow ponderosa pine and larch to establish and grow without competition from other species. Because they are shade intolerant, ponderosa pine and western larch need larger group openings.

Free selection

In many areas, forests vary in density, species composition, and tree age. Free selection combines ITS and group selection methods in such an area. Current stand conditions dictate what to do on any particular acre. For example, ITS methods are suited to the part of the stand that contains a mixture of three age/size classes. In other parts of the stand, trees may be clumpy. Some of the clumps can be thinned to promote tree growth, while some trees in mature groups can be harvested to create a new opening and age class of trees. Group selection openings also can be created by making an opening in parts of the stand with poorly formed, insect- or disease-infected trees. Poorly stocked areas can be planted. Free selection is flexible and takes advantage of existing stand conditions to produce a diverse forest over time.

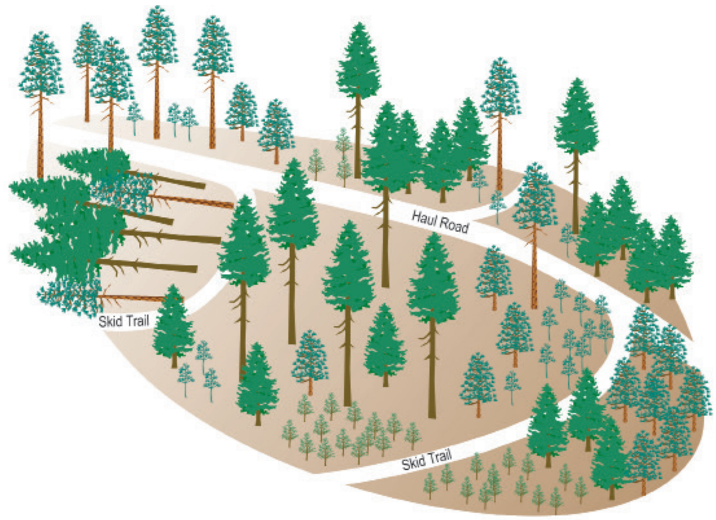


Figure 2.8. Harvesting a mature group of trees in the group-selection harvest method (as in other methods) depends on having a well-designed skid trail and haul road layout.

Tree health and stand stability depend on stand stocking

Maintaining proper stand density and stocking are the keys to maintaining healthy, stable forests that reliably produce the forest values you set in your objectives.

As mentioned in Chapter 1, stands change over time, developing from open to closed as trees grow. As trees grow, they consume more and more site resources such as sunlight, water, nutrients, and space. Each site has limited resources. As trees grow larger, the site eventually reaches its carrying capacity and some trees lose out, becoming less vigorous. Eventually all the trees in a stand may become less vigorous and therefore less healthy. Removing some trees is necessary to maintain stable, healthy stand conditions.

Research has shown that fast-growing trees can resist bark beetle attack, some diseases, and mistletoe infection. Therefore, maintaining forest health boils down to keeping individual trees growing well. How many trees per acre you can keep vigorous depends on the site's basic ability to support trees (i.e., site productivity) and on tree size.

Site productivity varies from place to place, often over short distances in central and eastern Oregon. For any given level of site productivity, there are stocking or density limits, which can be defined in terms of trees per acre and tree size or by basal area per acre. Above the upper stocking limit, the stand is said to be overstocked, and many trees in the stand will become vulnerable to attack by beetles or root disease (Figure 2.10). It is important to keep stands below that level so that most individual trees remain healthy and vigorous.

Figure 2.9. In a stagnated stand, pole-size lodgepole pines grow slowly or not at all. Thinning should release the trees with the best crown ratios for healthy growth.

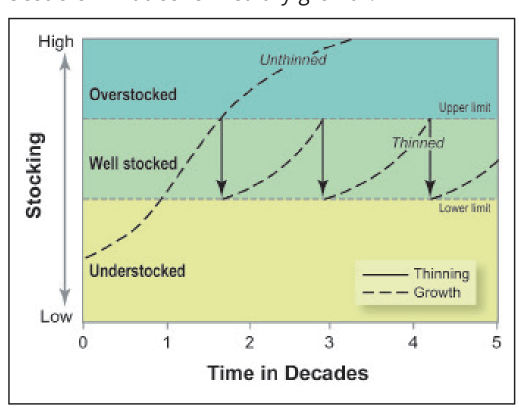


Figure 2.10. The stocking levels (dashed lines) of forest stands change over time. As trees grow, stocking levels progress from low, or understocked, to well stocked and, eventually, to overstocked. Through periodic thinning, stocking levels can be maintained within the "well stocked" zone, where the trees and stands are resistant to beetle attack and are wind-firm.

Measuring Site Index

A site's productive potential is expressed as a site index. Site index is based on how tall certain dominant trees will grow over a given time—50 years for lodgepole pine and 100 years for ponderosa pine and other eastern Oregon tree species. A site index of 70 means dominant trees grow, on average, to 70 feet in 100 years; a site index of 140 means dominant trees grow to 140 feet in 100 years.

To determine the site index of a stand for each species, you need to systematically measure trees whose height growth has not been significantly suppressed from excessive stand density or top breakage during their development. Typically, these are dominant trees. Measure total height and age at breast height. Age is determined by boring to the center of the tree at breast height with an increment borer and counting the number of annual rings from the center to the outermost ring. Height is measured using a clinometer or other instrument *See Tools for Measuring Your Forest*, EC 1129, for more details on measuring tree heights.

As an example, you measure six dominant trees in a 10-acre stand of ponderosa pine:

Tree	Height	Age	Tree	Height	Age
1	75	98	4	63	70
2	82	95	5	63	65
3	70	80	6	60	60

Next, plot the height and age data points on the ponderosa pine site index curves in Figure 2.11. Because site productivity can vary in a stand, you might get a "shotgun" pattern of data points. Use your judgment as to which site index curve best represents your tree sample points. In Figure 2.11, site index curve 80 best fits the data points. Now, you can use 80 to find the maximum and minimum trees per acre in thinning operations (see example in Chapter 3, pages 62–66). Note: If your data points fall across several site index classes on the graph, you may need to measure more trees throughout the stand and divide the stand into areas of similar height growth or site index.

We establish a lower stocking limit based on how often we wish to thin or on the volume needed to make a thinning profitable. If stands are thinned below the lower stocking limit, volume growth per acre over time will be diminished.

The period between thinnings depends on site productivity, how many trees are removed, and the target stocking level. For best results, you will need to determine the site productivity of your stands *before* you begin thinning; see "Measuring site index," left.

Establishing stocking level targets

Site index is the most common way to quantify the capacity of the site to grow trees. More-productive sites can support more trees of a given diameter or basal area than sites of lower productivity because more resources are available to trees. Therefore, you need to determine the site index for each stand (see "Measuring site index," at left).

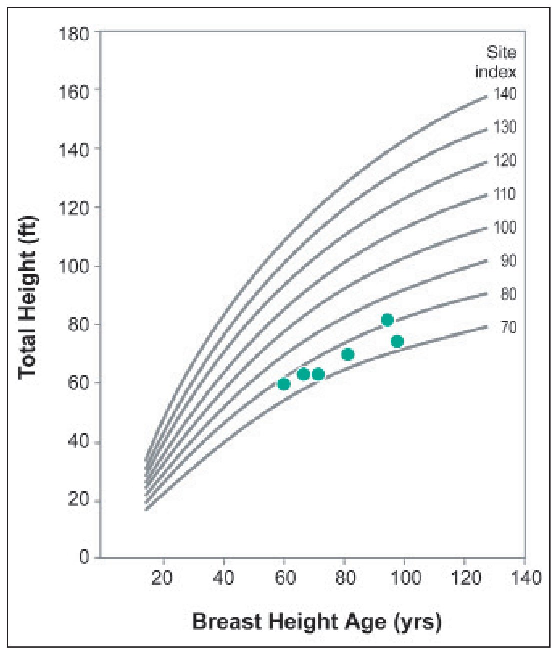


Figure 2.11. Site index curves (100-year basis) for managed, even-aged ponderosa pine stands in central and eastern Oregon. Heights are for the tallest trees in the stand (from Barrett 1978).

Stocking level control for even-aged stands

In relatively pure even-aged stands, each species has its own stocking limits, which depend on tree size, spacing, and site index. For example, Table 3.3 or 3.4 (page 58–59), provides stocking guidelines for ponderosa pine stands with an average diameter of 4 to 30 inches. Each diameter class (e.g., 6, 8, and 10 inches) has a minimum and maximum number of trees per acre recommended for each site index. Basal area guidelines also are provided.

The guidelines consider efficient use of site resources, susceptibility to bark beetle attack, and tree vigor and growth. The tables apply only to even-aged stands or even-aged groups within uneven-aged stands.

For each species, density management tables are provided in the appropriate chapter. Keeping your stand within stocking limits for a given diameter and site index maintains good growth and tree vigor. See the thinning example in Chapter 3.

If you manage your stand close to the upper stocking level, residual (“leave”) trees grow more slowly and take longer to reach a given size because there is more competition. The advantage is that you come closer to capturing the full potential of the site to grow wood (that is, volume/acre/year). If you manage your stand close to the lower stocking level, there is less competition and individual trees grow faster in diameter, taking less time to grow to a target size. This approach leaves more site resources to grow understory trees or other vegetation.

Stocking level control in uneven-aged stands

Achieving proper stocking levels is more complex in uneven-aged stands than in even-aged stands. In group-selection management, within the even-aged groups you can follow the guidelines above for even-aged stands. However, you might want to maintain slightly higher stocking at the edges, where older groups adjoin younger groups, to foster windfirm edges.

Radial Growth and Basal Area

In many Eastern Oregon sites, site quality and tree height growth are not well correlated; therefore, site index is not always a useful measure of productivity. Stands may be overstocked even if they are thinned to levels specified in tables based on site index. In such cases, you can better judge site quality by comparing radial growth with stand basal area. First, some background.

Basal area, expressed in square feet per acre, is a good measure of stand stocking, and it is easy to measure with a basal area angle gauge. The gauge measures the cross sectional area of living trees at breast height. See *Measuring Your Trees*, EM 9058, to learn how to measure basal area. Each species has different basic rules for stocking based on basal area.

Radial growth is a good way to judge stand vigor and site quality in order to set stocking levels. Measure radial growth at breast height by taking an increment core and counting the rings in the outermost inch. A tree with good vigor will grow five to ten rings per inch. Trees with poor vigor will have 20, 30, or more rings per inch.

Three factors are important in determining current radial growth rates: site quality, current stocking, and historic stocking. Poorer sites may not support good rates of radial growth at the basal areas specified in the tables. You should suspect poor site conditions if the most vigorous trees (trees with more than 40 percent live crown ratio) on your site are very widely spaced and their rate of radial growth is far less than expected for the stocking level. If the radial growth of residual trees remains at 15 to 20 or more rings per inch when your stand is at or below the upper stocking level (as in the basal area table), you need to thin to lower residual basal areas. In stands where high grading has removed the vigorous dominant and co-dominant trees and left poorly growing trees, the radial growth rates on residual trees can remain low for a decade or more, even if properly spaced. To learn more about the Growth Basal Area System that was designed to handle this situation, see Hall (1987).

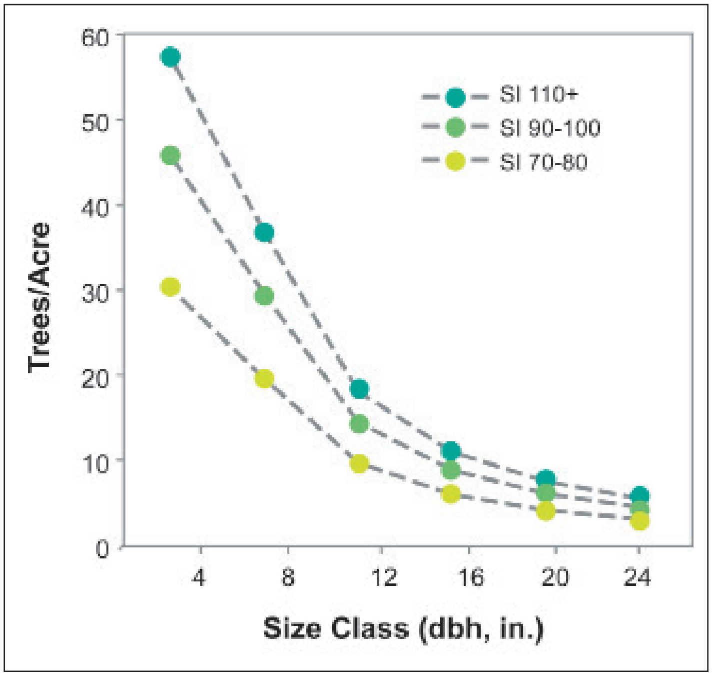


Figure 2.12. Stocking level targets in trees per acre (tpa) by diameter class for ponderosa pine stands on sites of low (SI 70–80), medium (SI 90–100), and high (SI 110 and above) productive potential.

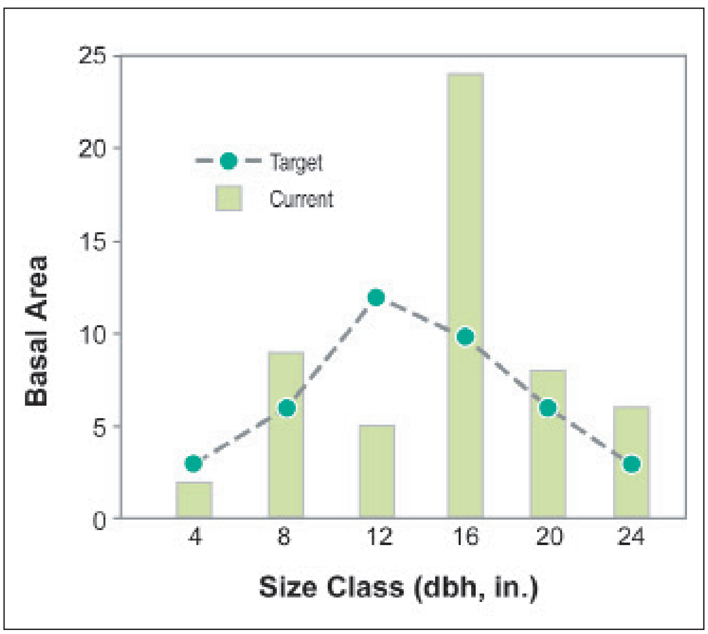


Figure 2.13. Stocking levels in basal area (bars) and target basal area by diameter class (dotted line) for an ITS stand. Thinning should remove trees in diameter classes whose basal area exceeds target levels.

In individual tree selection (ITS) thinning, where trees of many sizes are thoroughly mixed within the stand, stocking control is essential but more complex. The goal of selection harvests is to maintain a balance among larger, older trees and younger, smaller trees so that all sizes are growing well. Target stocking levels vary by site productivity: more productive sites can support higher stocking levels. Figure 2.12 shows the theoretical stocking levels by diameter class for ponderosa pine sites of low, medium, and high productive potential. A good rule of thumb is to maintain the overall stocking level—measured in basal area —at 50 to 75 percent of the full stocking target level for the stand's site quality. In practice, this means you will need to measure basal area in many places to determine how much to cut during periodic thinnings.

For example, Figure 2.13 shows the amount of basal area (bars) in an ITS stand. Also shown is a target basal area (BA) level (dots) for each diameter class. The site index and stocking level tables (or radial growth measurements) for this stand indicate full stocking is 80 square feet of BA. Upper stocking level for ITS would be 70 percent of 80, or 56 square feet —which is the approximate current stocking. The target lower stocking level is 50 percent of 80, or 40 square feet.

Growing stock can be distributed in the different age/size classes in a variety of ways, but we chose to put about 85 percent of the growing stock in the 8- to 20-inch size classes (see Figure 2.13). This distribution provides ample numbers of trees to grow into each larger age/size class. We decided to leave the 8-inch diameter class as is to fill in the 12-inch class in the future, and we decided to remove 14 square feet in the 16-inch class, 2 square feet in the 20-inch class, and 3 square feet in the 24-inch class, bringing overall stocking down to the desired level. Note that the 12-inch-diameter class did not have enough stocking to warrant thinning any trees in that size class. Also, over time it is important to keep young trees growing into the 4-inch diameter class; 50 to 100 seedlings and saplings less than 2 inches in diameter would be adequate.

How often you harvest in the ITS system depends on stand density, tree vigor, the current number of age classes in the stand and, most important, the site's productive capacity. For example, on ponderosa pine sites capable of growing 250 board feet or more per acre per year, you could thin the stand every 10 to 15 years and remove on average 2,500 to 3,750 board feet per acre. The entry cycle for harvest on less-productive sites might be as long as 25 years.

Techniques for stand tending

In describing the silvicultural approaches, we focused on management that would help shape the stand and secure regeneration. That is why we often refer to the silvicultural approaches by their final harvest method (e.g., clearcut or group selection). After regeneration is established, management must ensure the forest remains healthy and at low risk of fire, beetle attack, or mistletoe infection. Active management—including thinning, slash reduction, and possibly pruning—is necessary to tend and manage stands toward a desired stand condition.

Figure 2.14. Prescribed burning on private land. The woodland road has been strategically used in this case as a fire line.

Prescribed fire and slash treatment

Prescribed (controlled) fire, slash burning, and chipping or “slash busting” are increasingly important tools for managing eastern Oregon forests. These techniques are used with other management operations such as thinning and pruning. Although fire is used primarily to reduce accumulated fuels, it also can accomplish other management objectives, such as ridding stands of invading tree species like western juniper, incense-cedar, and grand fir or stimulating forage production. Historically, fire was a very dominant disturbance in eastern Oregon forests. Frequent fires reduced fuels and tree density, maintaining the dominance of ponderosa pine in many mixed-conifer stands. Slash burning and prescribed fire can be a cost-effective way to achieve the same tree health and stand stability. Smart managers plan fuels reduction as an integral part of any harvest operation because it’s efficient to use harvesting equipment to concentrate fuels for winter burning.

Burning slash and fuel concentrations is the most common fuels treatment after thinning or final harvest. Reducing accumulated slash is required by Oregon law if slash exceeds certain levels determined by the state forester. The advantage of burning slash piles, particularly if covered with plastic or concentrated fuels, is that it can be done during wet weather to avoid danger of wildfire.

A prescribed or broadcast burn is controlled by igniting the fire under specific fuel and weather conditions and with specific ignition patterns that use roads and other fuel breaks to control the fire’s intensity (Figure 2.14). The objective of broadcast burning is to reduce fuels to the point that any wildfire has such low intensity that it stays on the ground and does not kill all the trees. Some eastern Oregon ranchers use fire regularly as a range management tool to stimulate the growth of grasses and forbs and to kill invading western juniper. However, many private forest landowners do not use prescribed fire because they may lack the knowledge, experience, and equipment needed to use fire effectively, and they fear the financial liability if the fire escapes. Contact your local Oregon Department of Forestry office for more information on prescribed burning and liability laws.

Thinning even-aged stands or small groups

Thinning is the most commonly used and most important stand-tending tool. It removes some trees from the stand and concentrates the growing potential of the site into fewer, more vigorous trees. Thinning improves trees' growth and their resistance to fire and some insects and diseases, and improves wind firmness. Thinning also can increase average tree size, market value, and overall stand value, and it can shape the stand for the benefit of wildlife or livestock.

Precommercial thinning

Precommercial thinning (PCT) removes trees that are too small to have commercial value. The purpose of precommercial thinning is to remove enough trees in overstocked young stands so that remaining trees can grow quickly to commercial size. PCT improves species composition and stand vigor and therefore reduces the risk of bark beetle damage. The key to successful PCT is reducing stand density to a target spacing or number of trees per acre. The most common mistake in PCT is leaving too many trees.

When precommercial thinning creates slash—a major fire hazard—Oregon law requires you to reduce the hazard. Typically, this is done by hand or by mechanically piling slash. Piles are later burned during the wetter months. Contact your local Oregon Department of Forestry (ODF) stewardship forester for information on slash treatments (abatement) and fire laws in Oregon. When operating a chain saw and other equipment in your forest, you will need an operations notification from your local ODF office. See Chapters 3, 4, and 7 for ways to avoid problems with pine engraver beetles, which breed in the slash; the new generation of beetles emerges and attacks standing green trees.

Precommercial thinning is an investment in the stand. Costs for contracting precommercial thinning and slash reduction range from $150 to $500+ per acre. However, you can reduce out-of-pocket expense by doing the work yourself. Generally, you recover the cost of PCT through improved tree growth and a shorter time to the first commercial thinning. It is important to understand that failure to do precommercial thinning can be a serious error, leading to high mortality rates and a poor stand for future management. Beetle kill and competition-induced mortality can ruin a young stand because often the best trees are killed. Cost-share assistance may be available to help defray a significant amount of PCT costs. For information and details, contact your ODF stewardship forester.

Be aware that commercial markets for small trees are continually changing. Trees once considered too small for commercial harvest now sometimes can be sold for pulpwood. However, pulpwood markets fluctuate, so consult with local mills, log buyers, or consulting foresters frequently for current prices and minimum log sizes. Take advantage when market prices are high to accomplish much-needed management in your stand.

Commercial thinning

Commercial thinning is by far the most important and frequently used management tool for eastside forests. Current logging costs and prices for logs or pulpwood will influence the diameter at which stands can be thinned profitably. When average dbh reaches 10 inches, the stand could be ready for commercial thinning. Eastside stands often are commercially thinned between ages 40 and 80, depending on site productivity and whether stand density was reduced earlier with precommercial thinning.

Commercial thinning is the primary way to shape forest stands once they have regenerated. Thinning is used primarily to control stocking levels, to stimulate growth, and to prevent beetle attacks. Thinning combined with improvement cutting (discussed below) is also a way to control stand species composition and improve stand health by, for example, removing larger diseased or mistletoe-infected Douglas-fir trees while leaving better-formed, mistletoe-free ponderosa pine trees.

Carefully planned commercial thinning operations can accomplish the following:

- Maintain and improve diameter growth to shorten the time to the next commercial entry
- Reduce the stand's susceptibility to bark beetles, Armillaria root disease, and destructive crown fires
- Reduce risk of wildfire when combined with slash disposal or prescribed burning
- Enhance forage production for browsing deer and grazing for elk and livestock

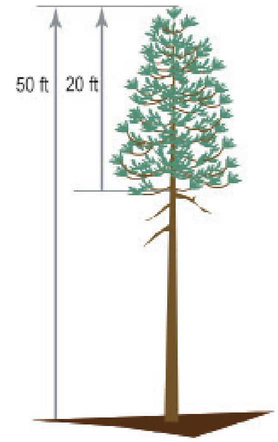


Figure 2.15. The live crown ratio compares the amount of tree bole with live branches to the total height of the tree. A 100-foot tree with live branches on its top 40 feet has a live crown ratio of 40 percent. Likewise, a tree that is 50 feet tall and has 20 feet of live crown, as shown here, has a live crown ratio of 40 percent. Although live crown ratio can be measured, usually it is estimated visually.

Selecting Trees for Healthy Forests

Healthy forests can reliably perform a variety of functions from producing timber to providing food and shelter for wildlife and livestock. It is important to select and leave trees for good growth, stand stability, and diversity. Most managers wish to provide a variety of functions, so they leave a variety of tree types.

Live crown ratio Live crown ratio is one of the best indicators of health and vigor (Figure 2.15). In even-aged stands, trees with a 40 to 50 percent live crown ratio will provide the best future growth and longevity. In even-aged stands that have differentiated into crown classes, these will be dominant and co-dominant trees. In repeatedly thinned stands, live crown ratio is also a good indicator of tree vigor. In uneven-aged, ITS stands, live crown ratios of 40 to 70 percent are desirable, and young trees may have crown ratios up to 100 percent.

Height-to-diameter ratio (H:D ratio) Another indicator of tree stability and growth potential is the ratio of total tree height to tree diameter (measured in the same units). A tree that is 100 feet tall and 1 foot in diameter has a ratio of 100. The higher the ratio, the less stable the tree. Trees with a ratio of more than 80 are rather unstable. Ratios in the 50 to 80 range are satisfactory and should be selected as leave trees. Note that trees with a high H:D ratio are likely to be exceptionally old for their size since they grew in height but not in diameter for a long time.

Selecting trees for diversity Some of the more difficult decisions to make are the amount, kind, and distribution of diversity elements to leave. Most elements of diversity are provided by deformed, diseased, or infected trees or by snags. Leaving diseased or infected trees in a stand adds risk. For example, trees that are heavily infected by mistletoe to the point of deformation provide excellent wildlife values but can also be the source of infection of other trees. Where possible, leave relatively healthy trees that have been deformed by breakage rather than by disease.

It is important to understand the differences in tree species' susceptibility to diseases, insects, or mistletoe and the means and rate of spread of each pest. It is also important to think of the forests as a mosaic of different stand types and conditions rather than as a uniform entity. A Douglas-fir heavily infested by mistletoe could be left safely if it is surrounded by young ponderosa pine but not if it is surrounded by Douglas-fir. Large snags are extremely important for many cavity-nesting birds and animals; however, they also are infamous for spreading embers once ignited by a wildfire. Therefore, snags can be retained where they are surrounded by relatively fire-resistant conditions. For more about enhancing wildlife habitat, see Chapter 9.

- Promote stand growth and succession to provide future wildlife habitat
- Provide periodic income, which increases over time as tree size and value increase

Stands of merchantable size offer many thinning options for landowners. Stands can be thinned either lightly and frequently (e.g., every 10 years) or more heavily but less often (e.g., every 20 years or longer). The choice depends on your income needs and other objectives and on whether the terrain is gentle enough to allow less-expensive ground-based harvesting equipment. On steeper terrain, more-expensive cable logging systems require higher cut volumes to pay for the operation and still provide profit to the landowner (see Chapter 10).

Thinning methods

Commercial thinning in a given stand usually involves complex decision-making. Trees can be removed for any of several reasons. Tree crown class is the best way to assess a tree's potential in a thinned stand. The thinning methods are low, high or crown, and free thinning for even- and uneven-aged management (Figures 2.16–20, pages 41–43).

Stands with little prior management often become overstocked. Overstocked stands have suppressed- and intermediate-crown-class trees that show very little height growth, very slow diameter growth (narrow annual rings), relatively short live crown ratios, and height to diameter ratios over 100. The stands have far more trees per acre than recommended (see stocking tables in Chapters 3, 4, and 5).

If your stand has been overstocked a long time, even dominant and co-dominant trees may have crown ratios less than 40 percent. If the stand is older, strongly consider a final harvest (clearcut). If it is a young stand with little commercial value, it is a good idea to thin and leave dominant and co-dominant trees, but their response to thinning may be delayed by a few or many years (e.g., 10 years) until they have had time to add live (green) crown as they grow in height.

Crowns on trees growing in dense stands might be lopsided. Snow or ice can pile up on the long side of the crown, causing the tree to bend or break under the weight. Leave trees with symmetrical crowns (as much as possible) will be far more stable.

When thinning an overstocked stand for the first time, be aware that the stand may be unstable and subject to windthrow if it is thinned too heavily. The first thinning in a dense unmanaged stand should be light, to allow residual trees time to develop windfirmness. After a few years, thinning can open up the stand progressively with fewer problems.

Leave trees should have the following characteristics:

- Crown class: dominant and co-dominant
- Crowns: full, healthy, symmetrical, 40 percent live crown ratio or greater
- Boles: free of sweep, crook, double tops, and logging damage or wounds
- Health: free of damaging insects, disease, conks, root rot, and mistletoe

When thinning, make sure trees to be cut—or to be left—are marked clearly with paint.

Thinning and harvesting details should be specified in a logging contract to make sure expectations are clear; see *Contracts for Woodland Owners*, EC1192, https://catalog.extension.oregonstate.edu/ec1192.

Continued on page 44

Low thinning

Figure 2.16. A typical unthinned (natural) tree stand with trees of varying size and vigor.

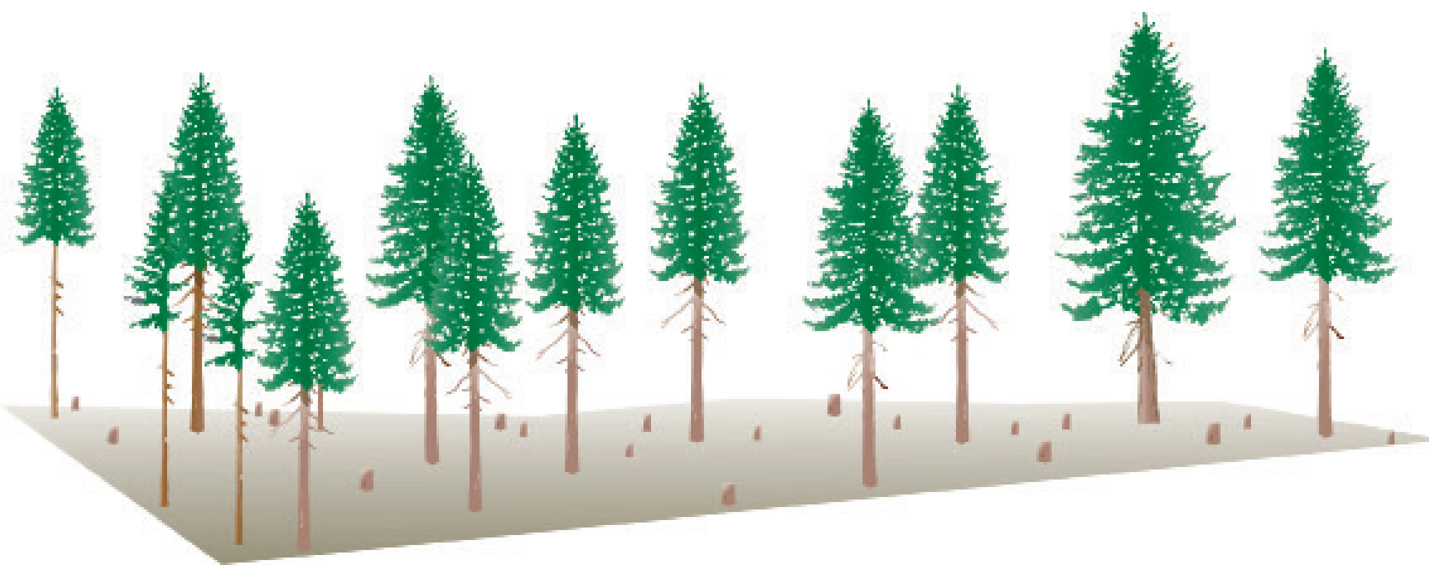


Figure 2.17. Low thinning, also called thinning from below, removes mostly smaller trees in the suppressed and intermediate crown classes, some in the co-dominant, and very few in the dominant crown classes. Low thinning releases better formed and faster growing dominant and co-dominant trees by removing trees that otherwise would die from competition. Because smaller trees are removed, logging costs tend to be higher and the operation less profitable. A good place to use low thinning is in well-stocked, uniform stands. Low thinning is a relatively simple method and is the most commonly recommended approach.

High thinning

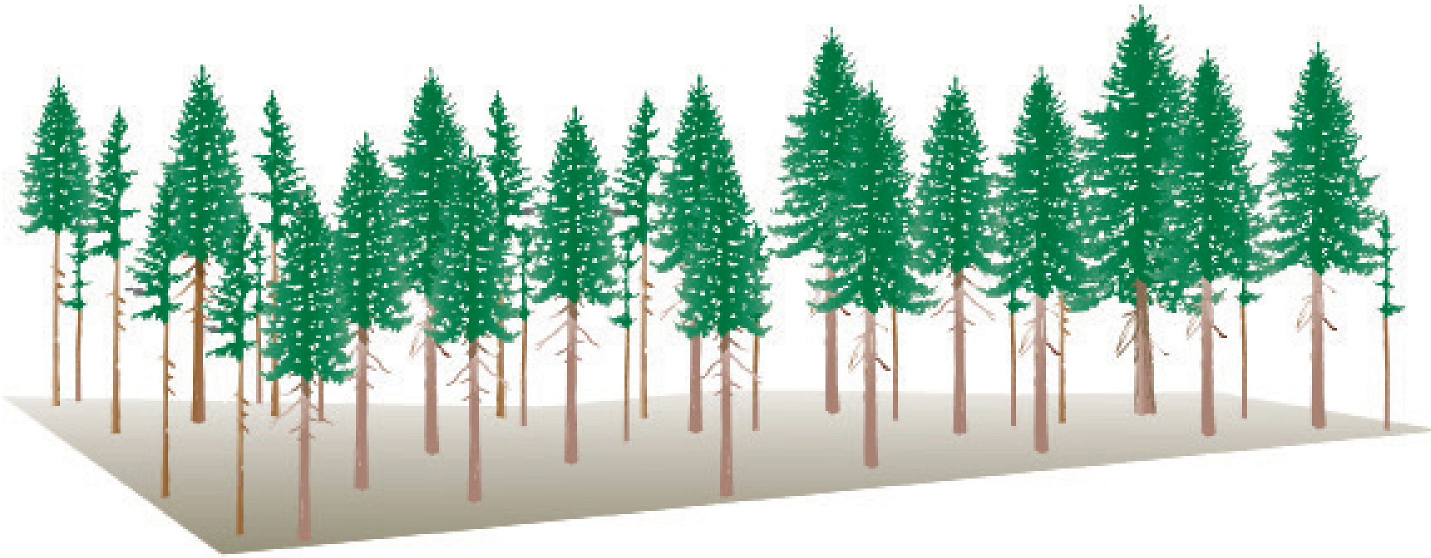


Figure 2.16 (repeated). A typical unthinned stand.

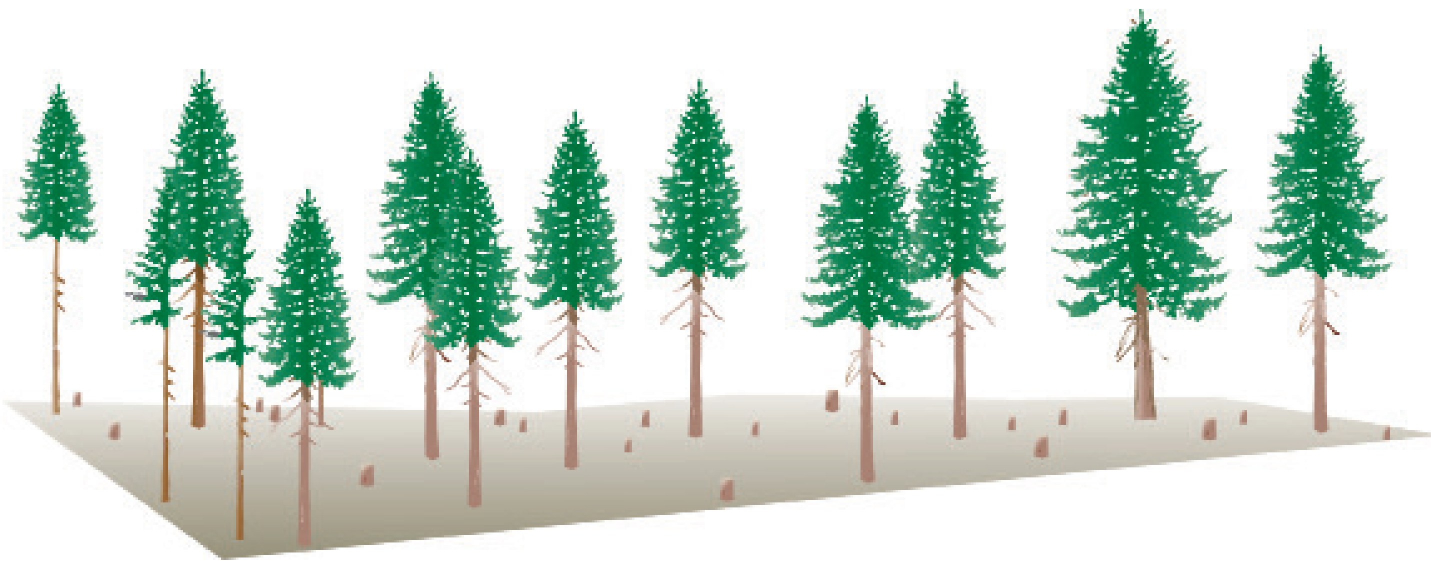


Figure 2.18. High or crown thinning removes some dominant and co-dominant trees in a stand to free up growing space for other vigorous co-dominant and dominant trees. Because larger trees are removed, logging costs are lower and profits higher. A good time to use high thinning is early in the life of an irregular, naturally regenerated stand to remove rough (i.e., large limbed), dominant trees that take excessive growing space to produce low-quality logs. Avoid removing too many of the large trees, a practice known as high-grading, because that reduces the value and future growth of the stand. A good way to avoid high-grading is to be sure that the stocking level target is filled with high-quality, well-formed, dominant and co-dominant trees.

Free thinning

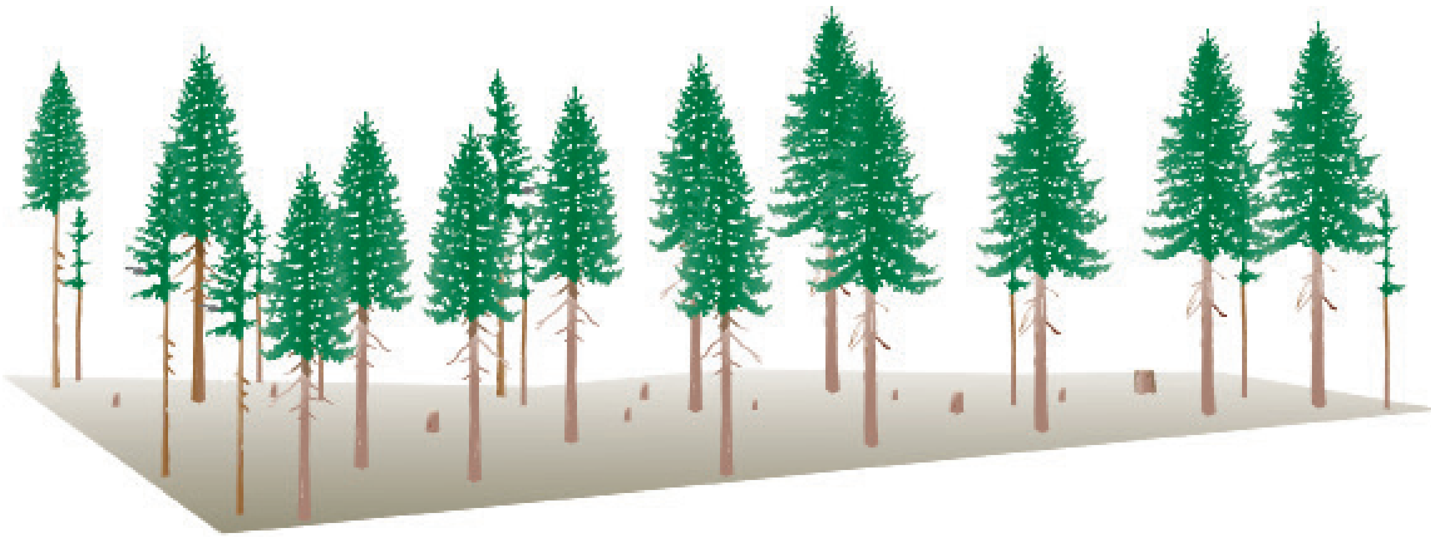


Figure 2.19. Free thinning is a combination of both high and low thinning. In many cases, free thinning works best in eastern Oregon stands because of the variability in stand and site conditions; however, this method requires more knowledge and skill.

High grading

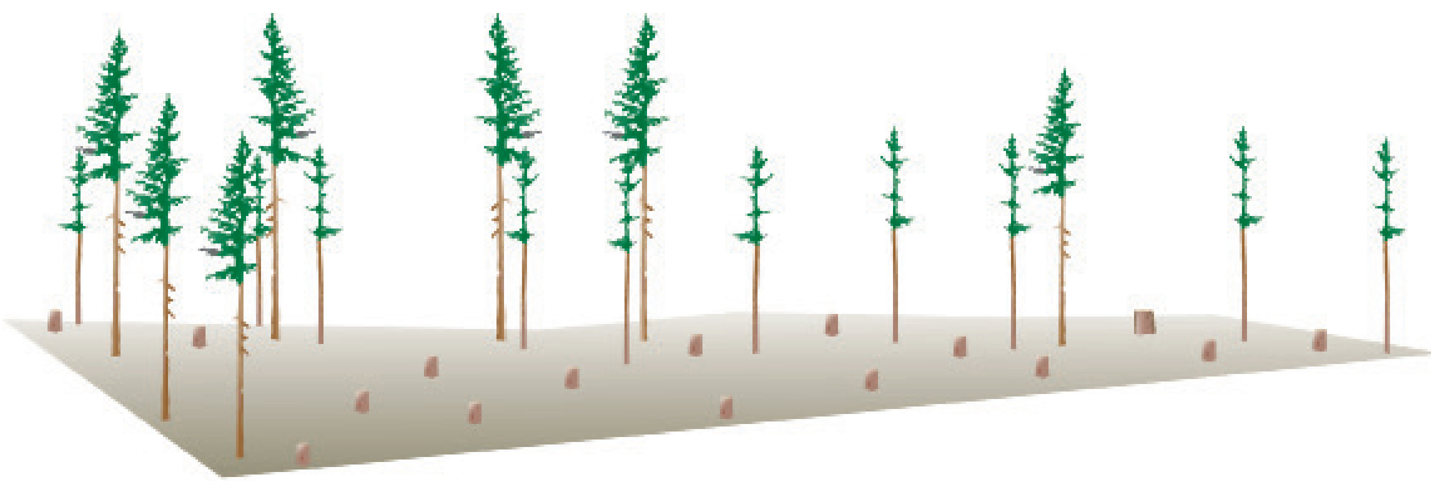


Figure 2.20. Sometimes a technique called diameter-limit cutting (high grading) is used instead of proper thinning methods. **This is not recommended.** Diameter-limit cutting often degrades genetic quality, reduces diversity and future growth, and lowers future harvest tree quality and value. Because it removes all trees over a certain diameter (often the smallest merchantable diameter, such as 10 to 12 inches), it almost always results in leaving suppressed, poorly formed, or diseased trees that will not grow well—and are subject to windthrow and bark beetles. To reach defined goals for your stands, be sure to clearly mark the trees to be removed according to the thinning methods described in this chapter.

Figure 2.21. Wind damage to a stand of ponderosa pine. Salvage cutting is needed to capture the value of the damaged trees and reduce habitat for bark beetles.

Improvement cutting

As mentioned in Chapter 1, stands with certain species compositions can create management problems in the long run. The main purpose of improvement cutting is to improve/alter species composition, tree form, and tree vigor. Improvement cutting removes trees to release pole-sized and larger trees. Improvement cuttings are usually commercial and are often the first planned operation in previously unmanaged or mismanaged stands. Remove trees with broken tops, basal scars from fire or mechanical damage, crooks, sweep, and porcupine damage. In mixed-conifer forests, improvement cuttings may be used to remove grand fir and Douglas-fir to create pine-dominated or pine- and larch-dominated stands that are less susceptible to insects and disease in the long run. Improvement cutting also can be used to promote the growth of trees that could be seed trees for natural regeneration in the future. In stands with several age classes, species, and stand conditions, thinning and improvement cutting often are combined in one operation.

Sanitation and salvage cuttings

Sanitation and salvage cuttings are used to correct problems or to salvage value after a damaging event such as wind, snow and ice, fire, lightning, insects, and disease (Figure 2.21). Damage can be more frequent during drought years when trees are stressed and wildfire threat increases. Damaged trees can harbor insects or disease that can spread to other trees.

Sanitation cutting removes individual trees infested by insects or disease. Done in a timely fashion, this reduces the potential for insect populations to increase and spread to other trees. Examples include removing beetle-infested trees or trees damaged by wind or fire that are likely to become infested. Prevent beetle spread from trees left on site by burning or chipping them. Considered alone, sanitation cutting might not pay for itself right away, because the value of the trees might not offset the cost of removing them. However, it's generally a good investment because the sanitation cutting removes infested trees before insect or disease infestations increase and spread, thereby preventing greater losses in the future.

Salvage cutting removes recently dead, dying, or damaged trees to capture their economic value. Prompt action is essential to ensure that you capture the trees' value before decay brings further loss. Also, timely salvage operations can reduce future fire hazard and the buildup of insects so they are less likely to attack nearby healthy trees.

In most salvage situations where insects and disease have caused considerable mortality and threaten remaining healthy trees, sanitation and salvage cuttings are often combined and used effectively to maintain or enhance stand health. A typical sanitation/salvage operation removes trees that are either dead or dying and, in addition, might remove trees of low vigor that are susceptible to insect attack or disease. This reduces fuel levels, and promptly treating residual fuels will help make the residual stand even more resistant to wildfire. Sanitation/salvage cutting also should leave the stand at a stocking level that promotes vigor in the residual trees; however, it may be advisable or required to plant areas with low residual stocking, particularly if the operation reduces stocking below the minimum stock level specified by FPA.

Sanitation/salvage operations often become necessary in stands that weren't managed well in the past. Be aware, however, that sanitation/salvage cutting may increase the spread of Armillaria and Heterobasidion root diseases, so stands heavily invested with these root rots should be left alone or clearcut and managed for alternative species (see Table 7.4, page 149, for a hierarchy of tree species' vulnerability). If stands are properly managed with timely thinnings, little sanitation or salvage cutting is needed generally because stands remain healthy.

Large dead and dying trees provide valuable habitat for wildlife, particularly woodpeckers, songbirds, bats, and squirrels (see Chapter 9). To retain specific trees for wildlife during sanitation/salvage operations, mark them with a large W on all sides with orange or red tree-marking paint. Specify in your logging contract that you want those trees left for wildlife.

Stand fertilization

Fertilizing eastern Oregon forests sometimes can increase stand growth significantly. Studies show that most forest species in the Pacific Northwest respond best (i.e., add wood volume) with about 200 pounds of nitrogen per acre. The response lasts approximately four to eight years. However, growth response on coarse soils in central Oregon is best when nitrogen is applied with phosphorus and sulfur. Less-productive sites respond relatively more to fertilization than more-productive sites; however, the actual wood volume increase is greater on the more-productive sites. The growth increase on poor sites usually does not justify the expense.

Fertilization is most commonly used in stands of merchantable size on highly productive sites. Since the fertilizer response lasts less than 10 years, it makes sense to fertilize about 10 years before a commercial thinning so your investment is repaid early. Although both thinned and unthinned pole and small sawtimber stands respond to fertilization, thinned stands respond more consistently and show a greater individual tree response than unthinned stands.

Douglas-fir or ponderosa pine on above-average sites might respond to nitrogen fertilization depending on soil type, amount of fertilizer, and stand conditions. Trees on basalt-derived soils are more likely to respond than those on granitic soils.

Unlike in western Oregon, little fertilization has occurred on eastern Oregon commercial forest land.

Stand pruning with intensive management

Pruning is cutting off the lower limbs of young trees to increase the amount of clear wood grown on the tree's bole (Figure 2.22). Pruning can increase tree and stand value when it is combined with intensive management that includes proper thinning and stocking-level control. Pruning also can help achieve other objectives:

- Increase light to the understory for improved forage production
- Reduce mistletoe infections if mistletoe infestations are light and confined to lower branches
- Reduce "fuel ladders" and the potential for surface fires to move up into the canopy
- Improve aesthetic values

Most conifers can be pruned, and procedures are similar for different species. Although the economics of pruning have been studied, future markets for clear wood are unknown and currently mills have not been paying higher prices for pruned trees. Therefore, approach pruning cautiously.

Figure 2.22. A stand of ponderosa pine recently pruned and thinned. Note that the thinning and pruning slash has been piled for burning at a later date to prevent beetle invasion.

Summary

You have an opportunity to manage or design your forest using the silvicultural methods discussed in this chapter. In managing your forest, keep in mind that it can take several years to move or nudge your forest in the direction you want and it may take several treatments to get it there. It is important to take into account the species composition, site productivity, and potential insect and disease issues in managing your forest whether you are managing it in an even-aged, two-aged, or multi-aged fashion. To keep your forest healthy, timely intermediate stand treatments, such as thinning or improvement cutting, are often necessary.

CHAPTER 3

Managing ponderosa pine

Stephen A. Fitzgerald

The "western yellow pine," or ponderosa pine, is the most valuable tree species in eastern Oregon, and in the Pacific Northwest it is second in value and use to Douglas-fir. The vast and accessible ponderosa pine forest helped open up the West by providing raw materials for a budding, but even then important, forest industry. Ponderosa pine forests produce some of the most valuable forest products, including small and large saw timber, clear logs for veneer for high-end uses such as window moldings and doors, and chips for paper. Increasingly, special products are being harvested from ponderosa pine forests including cones, seeds, and mushrooms. Ponderosa pine forests also provide forage for livestock grazing, habitat for deer and elk, fish and clean water, and recreation. Actively managing your forests can enhance these values to meet your objectives. This chapter discusses the ecology and management of ponderosa pine, including tools and options for achieving management objectives for ponderosa pine forests in all phases of stand development (Figure 3.1a-c).

Figures 3.1a–c. (At left) Mature ponderosa pine stand.

(Below, left) Thinned, pole-size ponderosa pine stand. Note forage production beneath.

(Below, right) Vigorous ponderosa pine seedlings 5 years after planting. As these seedlings grow, they will need to be thinned.

Ponderosa pine grows on a variety of sites and is a flexible species that can be managed with both even- or uneven-aged silvicultural systems (see Chapter 2). Even ponderosa pine stands that are overstocked or have been high-graded often respond well to good management. Although ponderosa pine can be managed in mixtures with other species on more-moist sites, this chapter focuses on only pure ponderosa pine stands on both dry and moist sites in central and eastern Oregon. Managing ponderosa pine in mixtures is discussed in Chapter 5.

Ecology

Distribution and range

Ponderosa pine is found throughout Oregon on well-drained soils and dry sites. In central and eastern Oregon, the dry, climax, ponderosa pine low-elevation forest type lies between the nonforest rangeland and western juniper woodlands and the more-moist mixed-conifer forest of the mid-elevations of the Cascade, Blue, and Wallowa mountains. Typically, ponderosa pine forests grow between 2,000 and 5,000 feet in elevation. In southwestern Oregon, ponderosa pine is also extensive in the hot, dry, interior valleys. Typically, ponderosa pine is the first conifer species you encounter as you move up from the interior valleys, but it also is found in mixtures with oaks and other hardwoods and with Douglas-fir.

In western Oregon, a genetically distinct “Willamette Valley” variant of ponderosa pine up until recently has been confined to small, isolated stands and scattered individual trees across the valley; now, however, it is being planted actively on many sites within the Willamette Valley.

Tolerance of environmental factors

Ponderosa pine can tolerate many environmental stresses, allowing it to survive and grow in harsh environments. Ponderosa pine has a high tolerance for drought, flooding, frost, wind, and surface fires (see Table 1.2, page 13). Although it can tolerate some shade, it grows best in full sun. On more-moist sites where ponderosa pine grows in mixtures with Douglas-fir, grand fir, western larch, and incense-cedar, ponderosa pine must be in the upper canopy level, getting full sunlight, in order to compete successfully and maintain its dominance in the stand. Ponderosa pine is quite tolerant of frost, but in the pumice region of central Oregon, lodgepole pine occupies the cold topographic depressions known as severe frost pockets.

Climate, soils, topography, and associated tree species

Moisture is the most important climatic variable affecting the distribution of ponderosa pine. Ponderosa pine grows where moisture ranges from about 14 to 30 inches annually, typically coming as rain and snow between October and June. Summer has high temperatures with little precipitation other than isolated thunderstorms. Therefore, moisture stored in the soil profile must sustain all tree and plant growth during the summer drought period.

Soils of eastern Oregon are highly variable. Central Oregon soils are deep pumice from volcanic eruptions. Their coarseness allows moisture to drain rapidly. Ponderosa and lodgepole pines grow well on coarse soils because they can quickly extend roots deep to reach available moisture. In the mountainous north, on the Warm Springs Indian Reservation and the eastern flank of Mount Hood, soils and terrain also are quite variable due to the combined effects of glaciation, volcanic eruptions, floods, and wind.

In the Blue Mountains, ponderosa pine grows on both ash and residual-type soils of basaltic origin. Ponderosa pine seems to grow better on residual soils than other tree species because it’s drought hardy. On more-productive, moist sites, where the soil contains fine windblown loess or ash layers, ponderosa pine commonly grows in mixtures with either Douglas-fir alone or with Douglas-fir, grand fir, lodgepole pine, and western larch and less often with incense-cedar. On these sites ponderosa is considered a seral species. On warm, dry sites where ponderosa pine reproduces naturally in its own shade and endures over time as the dominant tree, it commonly is associated with western juniper and lodgepole pine and less often with quaking aspen and Oregon white oak.

Cascades region

The climate and soils of eastern Oregon combine in many ways to influence the distribution of vegetation. Ecologists recognize many different plant associations where ponderosa pine is the climax or co-climax species.

On the dry end of ponderosa's range, where site productivity is low, it often forms a savannah of large, widely spaced trees. Here, ponderosa grows with understory shrubs such as antelope bitterbrush, big sagebrush, gray rabbitbrush, and squaw currant. Grasses and forbs include Idaho fescue, western needlegrass, bottlebrush squirreltail, and Ross sedge. Pine regeneration is minimal due to harsh site conditions.

As productivity increases, bunchgrasses such as Idaho fescue and bluebunch wheatgrass appear with the antelope bitterbrush. In some places, mountain-mahogany, an important large shrub-like tree for wildlife, may grow. Cheatgrass, an invasive annual grass, is common if disturbance has been severe. Other understory plants such as balsamroot, western yarrow, tailcup lupine, strawberry, and other forbs are common.

As site productivity improves further, greenleaf manzanita appears in the shrub layer with bitterbrush. Snowbrush ceanothus can be present but often is subordinate to greenleaf manzanita and antelope bitterbrush. Major grasses include Idaho fescue, bottlebrush squirreltail, western needlegrass, pinegrass, and Ross and elk sedges. Grass and shrub competition impedes ponderosa pine regeneration. On other sites, snowbrush often dominates the shrub layer and white fir is in the understory. Periodic fire can maintain ponderosa pine as the dominant species in the overstory.

On the upper of end of the productivity range for climax ponderosa pine, the shrub layer is sparse with occasional snowberry, greenleaf manzanita, and prince's-pine. The understory is often dominated by long-stolon sedge, thickleaf peavine, and brackenfern. Other species present can include pinegrass, tailcup lupine, Idaho fescue, bottlebrush squirreltail, and western needlegrass. Pinegrass increases after disturbance. These sites often support high populations of pocket gophers (see Chapter 6).

Blue Mountains

The Blue Mountains region has about six climax ponderosa pine plant associations or community types.

On the less-productive range of ponderosa pine, the understory is dominated by bluebunch wheatgrass or combinations of bluebunch wheatgrass and antelope bitterbrush. Other grasses include bottlebrush squirreltail and western needlegrass. On more-coarse soils in the southern Blue Mountains, Ross sedge may dominate the herbaceous layer. These ponderosa pine communities form the transition between pine forest and shrub-steppe.

On more-productive sites, the ponderosa pine understory is dominated by Idaho fescue with many other grasses and sedges including bluebunch wheatgrass, bottlebrush squirreltail, pinegrass, and Ross and elk sedges.

On the most productive ponderosa pine sites, ponderosa pine is often a co-climax species with Douglas-fir. The understory can be dominated by elk sedge with few shrubs, or the shrub layer can be quite prominent with species such as snowberry, oceanspray, and mallow ninebark. If elk sedge dominates the understory, there may be little ponderosa pine or Douglas-fir regeneration.

Stand initiation and development

Seed production and germination

Ponderosa pine can begin producing cones at age seven to 10 years. However, good cone crops are not produced until trees are 80 years or older. Ponderosa pine cones take two years to mature, and cone crops are irregular, with heavy crops every six to eight years. In any given year, cone production can be highly variable among trees. If you want natural regeneration, leave seed trees that are good cone producers (i.e., have lots of old cones scattered on the ground beneath them).

Seedfall begins in early autumn and usually ends by late autumn. Ponderosa pine seed is heavy compared to seed of other Northwest conifers. About 75 to 80 percent of the seed disseminates within 200 feet of the parent tree, although seed has been found 400 feet or more away.

Seed crops are irregular when cold damages developing conelets and insects destroy seed inside the cones. In any given year, rodents such as squirrels and chipmunks consume a tremendous amount of seed and can severely reduce the seed crop. On the other hand, rodents store pine seed in caches which they often then forget; that seed can germinate and grow into seedlings.

Seedling development

Ponderosa pine seeds germinate best in full sun and on mineral soil or disturbed duff. Germinants' fast-growing taproot enables them to reach moisture deep in the soil, so they can establish on harsh sites and coarse soils where other tree species fail. One study found that roots from germinating ponderosa pine seedlings grew 18 inches in about two months in soil that was loosened and watered.

Natural regeneration is most successful when fall seed crops are followed with abundant spring and early summer rains. Other factors in natural regeneration success include how much seed rodents eat and the degree of competition from forbs, grasses, shrubs, and other trees.

Stand development

How fast ponderosa pine stands grow depends on initial seedling density and on the degree to which disturbances—fire, insects, wind, logging—affect the availability of water, nutrients, and light for young seedlings. The level of competition from grasses, shrubs, and overstory trees also affects how quickly seedlings colonize openings and occupy the site. For example, in many places in the Oregon Cascades, tree colonization and stand development have been slow after timber harvest or wildfire because of poor ponderosa pine cone crops and severe competition from shrubs that quickly invaded the site and excluded tree regeneration. If disturbances are light (e.g., such as from an understory fire) and many overstory trees survive, site resources available to potential understory pine seedlings are limited. In this case, overstory trees still will fully occupy the site, suppressing the establishment and development of young trees even though cone crops may be good. This is particularly true on very dry climax ponderosa pine sites.

Once seedlings grow above competing herbs, grasses, and shrubs, they begin to capture most

Figure 3.2. Stagnated clump of 60-year-old pole-size ponderosa pine. The largest trees in this clump are only 4 to 6 inches dbh. Trees in the middle of the clump grow slowly or not at all. Thinning this clump will release the best trees for healthy growth.

of the available water, nutrients, and light, so diameter and height growth accelerate. As they continue to grow, they begin to compete with one another for site resources. This causes diameter growth to slow. Without thinning, a surface fire, or other disturbances to kill some trees, competition among trees becomes intense, and both diameter and height growth slow. On very dry sites, dense sapling and pole-sized stands tend to stagnate, drastically reducing potential for cubic- and board-foot yields. When stagnated ponderosa pine stands reach 8 inches in diameter, they become susceptible to bark beetles.

On dry, climax ponderosa pine sites of low productivity, the dominant and co-dominant trees within dense, even-aged groups of trees tend to stagnate and grow very slowly, if at all (Figure 3.2). On moist (mixed-conifer) productive sites, pure ponderosa pine stands may self-thin; i.e., dominant and co-dominant trees outcompete the weaker intermediate and suppressed trees. Where ponderosa pine is mixed with faster-growing species such as western larch, Douglas-fir, and grand fir, ponderosa pine can be outcompeted and become suppressed or die. Stands allowed to remain dense are more susceptible to some insects (e.g., bark beetles) and to diseases, windthrow, and snow damage (see Chapter 7). Ponderosa pine can respond well to thinning even if suppressed for several decades. However, selecting quality leave trees is critical to good response (see discussions in Chapter 2 of precommercial and commercial thinning starting on page 40).

Height growth of ponderosa pine is most rapid in pole- and small-saw-timber size classes up to about 60 years old. In older stands, height growth slows and the tree's top becomes more rounded or flat, which is typical in old-growth ponderosa pine trees. Height growth is sensitive to stand density. In very dense stands or groups of trees, for example, height growth can be severely suppressed, resulting in trees that are short for their age.

Growth and yield

Ponderosa's productivity and growth vary greatly across its range due to soils (depth, structure, and fertility), moisture, and climate (Figure 3.3, page 52). Height growth increases with site productivity. Differences in site productivity affect volume growth per acre, usually

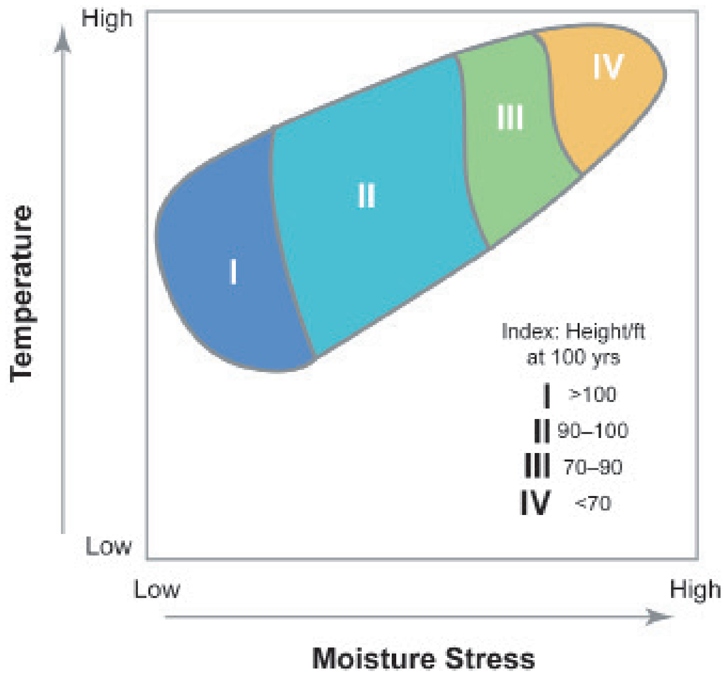


Figure 3.3. Effects of moisture and temperature on ponderosa pine productivity (adapted from Waring 1970).

measured in cubic feet or board feet per acre. Knowing your site's productivity not only gives you insight into growth and yield potential but also, because of its effects on competing vegetation levels, affects decisions such as the timing and intensity of thinning.

Site productivity for ponderosa pine varies from a site index of 70 to 140 (see Chapter 2 for an explanation of how to determine your site index). Correspondingly, board-foot and cubic-foot yields of ponderosa pine vary considerably across this range of site indices. Even for a given site index, timber yield can vary considerably due to site factors that don't affect height growth (and the determination of site index) but do affect how many trees the site can support (e.g., its stockability). Unfortunately, accurate yield tables for ponderosa pine are lacking. The primary yield tables in use today were developed by Meyer (1961) and were constructed from fully stocked stands, which overestimate timber volumes for most sites in central and eastern Oregon and are of little use to woodland managers.

In addition to site quality, timber yield also depends on stand density and past management. For example, very dense stands may have much less volume per acre at a given age because tree growth stagnated. On the other hand, good stand management and thinning promotes good diameter and height growth and will increase board-foot merchantable volumes over those in unmanaged stands.

Silvicultural systems

Ponderosa pine can be managed using either an even-aged (Figure 3.4a, page 53) or an uneven-aged (Figure 3.4b, page 53) silvicultural system. Which system you choose depends on your objectives and stand and site conditions, including these:

- Species composition
- Number of age classes
- Presence of insects, disease, or dwarf mistletoe
- Site productivity
- Soils
- Roads
- Slope and topography

This section will help clarify how to use different silvicultural approaches (see Chapter 2) and management tools such as thinning and prescribed burning.

Even-aged management methods

Clearcutting

Although typically not the first option of forest owners in central and eastern Oregon, clearcutting can be useful in converting heavily damaged, poor-quality ponderosa pine stands to young, even-aged stands. Clearcutting is best used on sites where regeneration has become established or on mixed-conifer sites with adequate moisture. Avoid clearcutting on dry, climax ponderosa pine sites or on hot, south-facing slopes with shallow soils. Planting ponderosa pine seedlings into clearcuts under these harsh site conditions is likely to fail. Obtaining high-quality seedlings and shading (shade cards) may be necessary where soil surface temperatures are high and soil moisture is low. Under these conditions, using a shelterwood approach or uneven-aged management may help avoid planting failures and high reforestation costs. On more-moist mixed-conifer sites, clearcutting followed by planting ponderosa pine seedlings often works very well.

Figure 3.4a. An even-aged ponderosa pine forest, thinned twice.

Figure 3.4b. An uneven-aged ponderosa pine forest showing stocking, tree quality, and natural regeneration after five harvest entries over 40 years.

Shelterwood and seed tree cuttings

The shelterwood and seed tree systems are good ways to encourage natural ponderosa pine regeneration. See Chapter 2 for descriptions of these methods and for recommendations for leave tree numbers and basal area. Use shelterwoods on harsh sites or frost pockets to moderate the microclimate. Use seed tree methods on more-moist mixed-conifer sites where sheltering is less important.

Because ponderosa pine is deeply rooted, it generally is more windfirm than other tree species, and shelter trees therefore are less likely to blow down. If you plan to use a shelterwood or seed tree approach for pine regeneration, it is a good idea to thin your stand five to 10 years prior to promote development of trees that will be vigorous, windfirm, and better able to produce cones once the shelterwood or seed tree cut is conducted.

Ponderosa pine seed is heavy, so shelter trees should be evenly distributed across the area to ensure even seed dispersal. As with other species, dominant and co-dominant ponderosa pine trees are preferred leave trees. Select trees that are free of mistletoe and other pests and that show recent evidence of producing cones (i.e., cones are on the ground).

Regeneration can be achieved from hand-planting seedlings, natural regeneration, or a combination of both. Creating a mineral seedbed with mechanical site preparation or broadcast burning in combination with a good seed year is critical for natural regeneration (see Chapter 6). However, because ponderosa pine cone crops are irregular, plan on under-planting pine seedlings to meet minimum reforestation standards.

Uneven-aged management methods

Ponderosa pine forests often have uneven-aged structure with up to several size/age classes of trees, lending themselves to uneven-aged management methods (i.e., individual tree selection and group selection methods). Careful management can take advantage of such naturally occurring structure, yielding both profitable and aesthetically pleasing forests.

Stocking level control in uneven-aged stands

Maintaining overdense pine stands retards regeneration and tree growth into larger size classes, and it increases risk of beetle attack. Unfortunately, overstocking is a common problem. Therefore, on climax ponderosa pine sites, uneven-aged stands need to be maintained in a more open condition. Unless selection cutting is regular and reduces stocking to appropriate levels, uneven-aged stand structure will be lost.

Stocking-level tables for uneven-aged ponderosa pine stands for sites with site indices of 70 to 110 are provided in Tables 3.3 and 3.4, pages 58–59, which need to be adjusted for uneven-aged stands. For uneven-aged management, strive for 50 percent of the recommended maximum stocking levels for even-aged stands, representing the stocking you should have after selection cutting (see Figure 2.12, page 36, for suggested stocking level curves for uneven-aged ponderosa pine by site index). These stocking levels should promote good growth in the smaller diameter classes. To use these tables, first determine your stand's site index (see Chapter 2). Then, remove trees in a selection cut to the recommended number of trees per acre (tpa) in each of your size classes. If you have a deficit in a particular size class, no cutting is necessary within that size/age class (see "Using Uneven-aged Stocking Curves" on page 55).

Table 3.1. Suggested harvest entry cycle for uneven-aged ponderosa pine stands, by site productivity.

Harvest entry cycle	Site index
15–20	70–80
10–15	90–100
10	110+

Individual tree selection

Ponderosa pine stands that already have three or more size/age classes are ideal for individual tree selection (ITS) (see Chapter 2). Often, a series of light selection cuttings can promote growth of smaller trees while maintaining adequate stocking in the commercial size classes. As trees grow to a maximum or upper-diameter limit (typically 18 to 26 inches), they are harvested. Thinning (both precommercial and commercial) often is necessary in smaller size classes to maintain good tree growth in each size class and to lower the risk of bark beetle attack. Unlike high-grading or diameter-limit cutting (see Figure 2.20, page 43), selection cutting leaves well-formed and vigorous trees in all size classes. It is equally important to have new pine seedlings establish after each harvest entry to ensure a new age class becomes established and to allow for the continued growth of smaller trees into commercial size classes. Refer to the sidebar, "Using Uneven-aged Stocking Curves," as an example of how to manage tree densities in the various tree size classes.

Each selection harvest needs to remove enough trees to create growing space for new pine regeneration. On some sites ponderosa pine is slow to regenerate naturally, and planting may be needed to ensure a new age class becomes established. In most cases, however, ponderosa pine regenerates well from seed if a mineral seedbed is created and light in the understory is adequate. Excess regeneration (Figure 3.6a, page 56) should be thinned promptly, especially on low-productivity sites, to avoid stagnation and reduce fire risk.

Using Uneven-aged Stocking Curves

Let's say you have a ponderosa pine stand on a productive site (SI 110) that has several size classes, and you want to manage it as an uneven-aged stand. You have inventoried current trees per acre (tpa) for several diameter classes (Figure 3.5, bars).

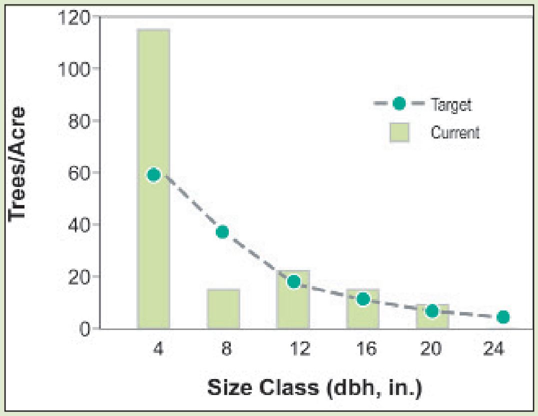


Figure 3.5. Stocking level curves for uneven-aged pondersosa pine.

You have excess trees in the 4-, 12-, 16-, and 20-inch size classes and deficits in the 8- and 24-inch classes (see Table 3.2). You want to remove the excess trees and, over time, recruit trees into the size classes that currently have deficits. Here is a summary of what needs to be done for each diameter class.

4 inch: Too many trees are in this class. Thin down to the target of 58 trees. If the distribution of these small trees is rather clumpy, you could thin them to a spacing of 16 to 18 feet, which is the same as a precommercial thinning of an even-aged stand. This may put the number of residual trees off target for this size class; however, it is more important to get good growth on the small trees.

8 inch: A deficit of trees in this class. No thinning is necessary.

12 inch: An excess of four tpa in this class. Remove four tpa, leaving the most vigorous trees that are of commercial size.

16 inch An excess of four tpa in this class. Remove four tpa, leaving the most vigorous trees, which are of commercial size.

20 inch An excess of two tpa. Because of the deficit in the 24-inch class, you decide to remove one 20-inch tree and keep the other, even though this leaves you slightly above your target of seven tpa. Your reason is that since no trees are in the 24-inch class, there is still plenty of growing space, which allows you to carry more trees in this size class. The tree removed is of commercial size.

24 inch: No action is required. Wait until trees from the 20-inch class grow into this class.

Overall, this stand is in good shape, with adequate numbers of trees in most size classes. The thinning, overall, is commercial due to trees removed in the 12-, 16-, and 20-inch classes. The value captured in these trees will help offset the cost of thinning the precommercial trees in the 4-inch class. Over time, trees from the 20-inch class will grow into the 24-inch class to balance out the stand.

Table 3.2. Sample inventory of ponderosa pine stand.

Diameter class	Current tpa	Target tpa*	Potential tpa to cut	Actual tpa cut
4 inch	115	58	57	78
8 inch	15	37	0 (deficit)	0
12 inch	22	18	4	4
16 inch	15	11	4	4
20 inch	9	7	2	1
24 inch	0	5	0 (deficit)	0

*from SI 110 curve

The time between selection harvests depends on tree vigor, which in turn depends on stand density and the site's productive capacity. For example, on sites capable of growing 200 board feet or more per acre per year, you could conduct a selection cutting the stand every 10 to 15 years and remove, on average, 2,000 to 3,000 board feet per acre. Removing less than 1,500 board feet per acre might not be economically feasible, depending on logging costs and local log prices. Given these factors, the entry cycle for harvest on less-productive sites might be as long as 20 years (see Table 3.1, page 54).

Group selection

Ponderosa pine forests in central and eastern Oregon are often "clumpy" or "groupy" because of natural seeding after small-scale disturbance, such as from wind, insects, disease, grazing, and timber harvest. These even-aged groups can range from less than 0.5 acre to 4 acres—ideal for using the group selection method. These small groups are managed as even-aged patches that together form an uneven-aged stand.

Active management to enhance the groupy nature of the stand (Figures 3.6a–b) can promote periodic income and range and wildlife values. However, groups are often too dense and need either precommercial or commercial thinning to improve their growth, vigor, and resistance to bark beetles (see stocking level guidelines for even-aged pine stands, Table 3.4, page 59). Remove most, if not all, mistletoe-infected trees within the groups.

Figure 3.6a. Group selection cutting with recent regeneration of ponderosa pine. The regeneration in this group is ready for a precommercial thinning

Figure 3.6b. Commercial thinning enhanced tree growth in this pole-size group of ponderosa pine.

On more-moist mixed-conifer sites, management of more or less pure, uneven-aged pine stands is often desirable. Here, Douglas-fir or grand fir may regenerate naturally and outcompete ponderosa pine within a group; if so, removing some of the firs may be necessary. Older, mature groups of pure ponderosa pine may be thinned if needed to maintain the age or size class, or the entire group may be harvested to establish a new age class. In harvest planning it is important to make the group openings 1 acre or larger to allow enough light so ponderosa pine can establish and not be shaded or outcompeted by other species. Consider planting ponderosa pine seedlings in group openings on mixed-conifer sites to give them a head start.

Free selection

Ponderosa pine forests often contain a complex mixture of stocking and stand conditions. The flexibility of the free-selection approach (see Chapter 2) can be used to create a diverse, uneven-aged ponderosa pine forest over time.

Stand management

A variety of intermediate stand treatments are used to create a future forest condition (whether even- or uneven-aged), improve tree and stand health, change composition or structure, and/or provide periodic income. Not all produce income. Some stand treatments require an investment now (in labor or money) for a payoff in the future. Delaying certain stand treatments might mean foregoing or delaying income, wildlife habitat, and other benefits.

The two most common management situations are (1) reforestation after harvest, fire, or major insect outbreaks and (2) managing young, dense ponderosa pine stands. Reforestation is discussed briefly in Chapter 2 and in more detail in Chapter 6.

Thinning and improvement cuttings

Thinning and improvement cuttings remove defective, diseased, or deformed trees and concentrate the site's growing potential into fewer, more-vigorous trees. These operations are especially important in initiating management of neglected stands.

Precommercial thinning

Proper spacing of 4- to 8-inch ponderosa depends on tree size and site productivity. On most sites, 16 to 18 feet between trees allows growth to commercial size. Most precommercial thinning is conducted within 20 years of establishment. When precommercially thinning ponderosa pine, keep trees that have full, symmetrical crowns; display good height growth; and are free of insects, disease, mistletoe, and other damage and deformities (e.g., forked tops, excessive bole sweep). See Chapter 5 for a discussion of precommercially thinning young ponderosa pine in mixtures with other conifer species.

Precommercial thinning in ponderosa pine often produces a lot of green slash, which is perfect habitat for the pine engraver beetle, also known as *Ips*, especially in spring and early summer when the beetle is emerging from the duff (see Chapter 7). The beetle breeds in green slash; emerging broods can attack and kill nearby healthy trees. To avoid creating a local epidemic, precommercially thin from mid-August through early fall, after beetles have flown and completed their life cycle and are at low population levels. To further reduce the risk of pine engraver attack, chip or pile the slash in the open and later burn it.

Commercial thinning

Ponderosa pine stands can be commercially thinned starting at age 40 to 80, depending on site productivity and whether the stand was precommercially thinned. Typically, ponderosa stands are ready for commercial thinning when they reach an average of 10 inches dbh. Log and pulpwood prices and logging costs also influence the diameter at which stands can be thinned profitably.

Ponderosa pine stands can be commercially thinned using low-, high-, and free-thinning methods (see Chapter 2). Low thinning works well in dense stands with a lot of trees in the co-dominant and intermediate size classes. Removing many of these trees increases the growing spacing for the better co-dominant and dominant ones.

High thinning works well in stands without much variation in tree size and in previously thinned stands. High thinning removes 10 to 15 percent of co-dominant and dominant trees, leaving the better ones. It also works well in some unthinned stands to remove rough dominant trees to promote better-formed and healthier co-dominant and dominant trees.

Because of the variation in tree sizes and site conditions within stands, free thinning—a

Table 3.3. Stocking level guidelines for even-aged ponderosa pine stands, in trees per acre (tpa) for sites with a site index (SI) ranging from 70 to 110 for ponderosa pine in eastern Oregon. For a given SI, managing the stand between the recommended minimum and maximum tpa reduces the threat of bark beetle attack, maintains full site occupancy, and provides for optimum stand growth.

Avg dbh (in)	**Recommended minimum tpa by site index (SI)**						**Recommended maximum tpa by site index (SI)**				
	70	80	90	100	110+		70	80	90	100	110+
4	420 (10.2)*	547 (8.9)	668 (8.1)	795 (7.4)	916 (6.9)		627 (8.5)	815 (7.3)	997 (6.6)	1185 (6.1)	1367 (5.6)
6	205 (14.6)	267 (12.8)	326 (11.6)	388 (10.6)	447 (9.9)		306 (11.9)	398 (10.5)	487 (9.5)	578 (8.9)	667 (8.1)
8	123 (18.8)	160 (16.5)	196 (14.9)	233 (13.7)	267 (12.8)		184 (15.4)	239 (13.5)	292 (12.2)	347 (11.2)	401 (10.4)
10	83 (22.9)	108 (20.1)	132 (18.2)	157 (16.7)	181 (15.5)		124 (18.7)	161 (16.4)	197 (14.9)	234 (13.6)	270 (12.7)
12	60 (26.9)	78 (23.6)	96 (21.3)	114 (19.5)	131 (18.2)		90 (22.0)	117 (19.3)	143 (17.5)	169 (16.1)	196 (14.9)
14	46 (30.8)	60 (26.9)	73 (24.4)	87 (22.4)	100 (20.9)		68 (25.3)	89 (22.2)	109 (20.0)	129 (18.4)	149 (17.1)
16	36 (34.8)	47 (30.4)	57 (27.6)	68 (25.3)	79 (23.5)		54 (28.4)	70 (24.9)	86 (22.5)	102 (20.7)	118 (19.2)
18	29 (38.8)	38 (33.9)	47 (30.4)	55 (28.1)	64 (26.1)		44 (31.5)	57 (27.6)	70 (24.9)	83 (22.9)	95 (21.4)
20	24 (42.6)	32 (36.9)	39 (33.4)	46 (30.8)	53 (28.7)		36 (34.8)	47 (30.4)	58 (27.4)	69 (25.1)	79 (23.5)
22	21 (45.5)	27 (40.2)	33 (36.4)	39 (33.4)	45 (31.1)		31 (37.5)	40 (33.0)	49 (29.8)	58 (27.4)	67 (25.5)
24	18 (49.2)	23 (43.5)	28 (39.4)	33 (36.4)	38 (33.9)		26 (40.9)	34 (35.8)	42 (32.2)	50 (29.5)	57 (27.6)
26	15 (53.9)	20 (46.7)	24 (42.6)	29 (38.8)	33 (36.3)		23 (43.5)	30 (38.1)	36 (34.8)	43 (31.8)	50 (29.5)
28	13 (57.9)	17 (50.6)	21 (45.5)	25 (41.7)	29 (38.8)		20 (46.7)	26 (40.9)	32 (36.9)	38 (33.9)	44 (31.5)
30	12 (60.2)	15 (53.9)	19 (47.9)	23 (43.5)	26 (40.9)		18 (49.2)	23 (43.5)	28 (39.4)	34 (35.9)	39 (33.4)

* The number in parentheses is the distance in feet between trees for a given number of trees per acre. Typically stands are not thinned to such an exact spacing.

combination of low and high thinning—often works well in many eastern Oregon ponderosa stands. Free thinning is flexible and allows you to remove some larger trees along with smaller trees that are marginally commercial so that the overall thinning operation is profitable and improves the stand by leaving the best trees, large and small.

Table 3.4. Stocking level guidelines for even-aged ponderosa pine stands, in terms of basal area per acre for sites with a site index (SI) ranging from 70 to 110 for ponderosa pine in eastern Oregon. For a given SI, managing the stand between the recommended minimum and maximum basal area per acre reduces the threat of bark beetle attack, maintains full site occupancy, and provides for optimum stand growth.

Avg. dbh (in)	**Recommended minimum basal area per acre by site index**						**Recommended maximum basal area per acre by site index**				
	70	80	90	100	110+		70	80	90	100	110+
4	37 (10.2)*	48 (8.9)	58 (8.1)	69 (7.4)	80 (6.9)		55 (8.5)	71 (7.3)	87 (6.6)	103 (6.1)	119 (5.6)
6	40 (14.6)	52 (12.8)	64 (11.6)	76 (10.6)	88 (9.9)		60 (11.9)	78 (10.5)	96 (9.5)	114 (8.9)	131 (8.1)
8	43 (18.8)	56 (16.5)	68 (14.9)	81 (13.7)	93 (12.8)		64 (15.4)	83 (13.5)	102 (12.2)	121 (11.2)	140 (10.4)
10	45 (22.9)	59 (20.1)	72 (18.2)	86 (16.7)	99 (15.5)		68 (18.7)	88 (16.4)	107 (14.9)	128 (13.6)	147 (12.7)
12	47 (26.9)	61 (23.6)	75 (21.3)	89 (19.5)	103 (18.2)		71 (22.0)	92 (19.3)	112 (17.5)	133 (16.1)	154 (14.9)
14	49 (30.8)	64 (26.9)	73 (24.4)	93 (22.4)	107 (20.9)		73 (25.3)	95 (22.2)	117 (20.0)	138 (18.4)	159 (17.1)
16	50 (34.8)	66 (30.4)	80 (27.6)	95 (25.3)	110 (23.5)		75 (28.4)	98 (24.9)	120 (22.5)	142 (20.7)	165 (19.2)
18	51 (38.8)	67 (33.9)	83 (30.4)	97 (28.1)	113 (26.1)		78 (31.5)	101 (27.6)	124 (24.9)	147 (22.9)	168 (21.4)
20	52 (42.6)	70 (36.9)	85 (33.4)	100 (30.8)	116 (28.7)		79 (34.8)	103 (30.4)	127 (27.4)	151 (25.1)	172 (23.5)
22	55 (45.5)	71 (40.2)	87 (36.4)	103 (33.4)	119 (31.1)		82 (37.5)	106 (33.0)	129 (29.8)	153 (27.4)	177 (25.5)
24	57 (49.2)	72 (43.5)	88 (39.4)	104 (36.4)	119 (33.9)		82 (40.9)	107 (35.8)	132 (32.2)	157 (29.5)	179 (27.6)
26	55 (53.9)	74 (46.7)	88 (42.6)	107 (38.8)	122 (36.3)		85 (43.5)	111 (38.1)	133 (34.8)	159 (31.8)	184 (29.5)
28	56 (57.9)	73 (50.6)	90 (45.5)	107 (41.7)	124 (38.8)		86 (46.7)	111 (40.9)	137 (36.9)	163 (33.9)	188 (31.5)
30	59 (60.2)	74 (53.9)	93 (47.9)	113 (43.5)	128 (40.9)		88 (49.2)	113 (43.5)	137 (39.4)	167 (35.9)	191 (33.4)

* The number in parentheses is the distance in feet between trees for a given basal area. Typically, stands are not thinned to such an exact spacing.

Tree spacing

Optimum tree spacing depends primarily on tree size, as measured by average dbh, and on-site productivity as measured by site index (see Figure 2.11, page 34). Tables 3.3 (page 58) and 3.4 (page 59) provide density and spacing guidelines for ponderosa pine stands in terms of trees per acre and dbh (Table 3.3) and basal area and dbh (Table 3.4). Guidelines apply only to even-aged stands or to even-aged groups within uneven-aged stands. Keeping your stand between the appropriate minimum and maximum tpa or basal area for a given average dbh maintains good stand growth and reduces risk from bark beetles.

Leave tree selection

Ponderosa pine is notorious for stand stagnation, so it is important to select the best trees to leave for future growth. Leave dominant and co-dominant trees with at least a 40 percent live crown ratio (see Chapter 2). However, in stagnated stands or clumps, even the best trees may have crown ratios of less than 40 percent. Also, crowns on leave trees in a dense stand may be lopsided, making them susceptible to breaking under snow loads. In these cases, choose leave trees that have the most crown and the most symmetrical crowns and that are free of dwarf mistletoe or other disease. Be aware that their response to thinning may be delayed a few years until they have had time to add crown volume as they grow in height. The first thinning in a dense stand should be light to allow residual trees time to develop windfirmness. Given time and enough space, suppressed young ponderosa pine respond well to thinning.

Be cautious about diameter-limit cutting (see Chapter 2) in ponderosa pine stands. If you purchased a stand that had a severe diameter-limit cut, leaving few viable trees, it may be better to clearcut and start over.

Sanitation and salvage cuttings

Sanitation or salvage cutting often becomes necessary when stands have not been managed. It is often possible to realize the value of recently dead ponderosa pine if trees can be salvaged promptly. Within six months, they lose little value. However, after a year ponderosa pine sapwood often gets blue stained and weather checked (cracked) as the tree dries out. Blue stain reduces tree value by approximately a third. By the end of the second year, the sapwood can have significant decay and deep weather checking with substantial volume and value loss, although the heartwood may be intact. At the end of the third season, the entire tree may be worthless (cull).

If wildlife is important to you, save some large dead and dying trees by clearly marking them as wildlife leave trees. Be sure the logging operator knows you want those trees to remain.

Fertilization

Fertilizing ponderosa pine forests is not common because it has not been proved profitable, even though studies show ponderosa pine sometimes responds well to 200 pounds of nitrogen (N) per acre. The growth response lasts approximately four to eight years and can result in a 30 percent increase in wood volume. However, the value of the added volume may not be enough to cover fertilization costs. On pumice soils in central Oregon, ponderosa pine responds best when this 200 pounds per acre N is applied with 100 pounds per acre of phosphorus (P) and 33 pounds per acre of sulfur (S). Stands that have been thinned respond more, and more consistently, than unthinned stands.

Pruning

Pruning ponderosa pine to produce clear lumber is not a common practice (Figure 3.7). That said, to produce the most clear wood, it's important to prune when trees are 4 to 6 inches in diameter. Avoid removing too much crown (and reducing tree growth) by pruning your pine trees in lifts, always leaving a crown ratio of 40 to 50 percent (see Chapter 2).

Pruning can be used to remove mistletoe and western gall rust infections on lower branches (less than 16 feet above the ground). Pruning and thinning can significantly increase the fire resistance of your ponderosa pine forest. Pruning the lower branches raises the tree canopy and eliminates fuel ladders which would enable a surface fire to move into tree crowns.

Prescribed underburning

Historically, fire played an important role in developing and maintaining ponderosa pine ecosystems by reducing fuels, thinning stands, and maintaining the dominance of ponderosa in mixed species stands. Prescribed fire is becoming an increasingly important tool to reduce accumulated fuels and to get rid of invading tree species such as western juniper, incense-cedar, and grand fir (Figure 3.8). Prescribed fire also can stimulate forage production for domestic livestock, deer, and elk. However, conducting a prescribed underburn requires skill and equipment that most private owners don't have, and there is landowner liability if the fire escapes and damages adjacent property. If you are interested in prescribed burning, you may need to hire a private contractor that has the equipment, know-how, and insurance to do the burn safely. Contact the Oregon Department of Forestry for an evaluation of whether your property would benefit from a prescribed underburn.

Figure 3.7. Pruning and thinning (above) have eliminated fuel ladders in this stand.

Figure 3.8. Prescribed burning in ponderosa pine (left photo) reduces accumulated fuels.

Ponderosa pine stand management options: some examples

This section provides management options for three different stand conditions and landowner objectives. These examples do not represent all possible options, and your stand conditions and objectives may differ.

Scenario 1. Young, overdense stand

Stand conditions (Figure 3.9a) and landowner objectives

1. Area was high-graded 40 years ago. The few remaining large trees are in poor shape but have provided the seed necessary for this young, dense stand to develop.

2. The young stand is rather clumpy; clumps range up to 500 tpa. Most clumps have stagnated trees with an average diameter of 6 inches, although some trees in some clumps are over 8 inches dbh. The stand site index is 70.

3. Pine engraver beetle is killing the tops of larger trees and entire smaller-diameter trees within the dense clumps. In addition, mountain pine beetles have attacked and killed some trees over 8 inches.

4. The chip market is gone, and chip prices will not likely increase any time soon, so removing the small-diameter trees commercially is not possible at this time.

5. Given that tree and stand growth is poor and insect activity is increasing, the landowner cannot afford to wait and may suffer further loss or place the entire stand in jeopardy if action is not taken now.

6. Landowner objectives are to improve the health of the stand and to produce commercial-sized trees in the near future.

Solution (Figure 3.9b)

1. In the clumps, precommercially thin from 500 tpa down to 125 tpa (19-foot spacing between leave trees) during late summer through early fall. This will allow trees to grow from the current 6 inches to 10 inches (see Table 3.3, page 58), when commercial thinning will be feasible, in about 15 years.

2. Pile slash by machine or hand to reduce insect habitat and fire hazard. Burn slash piles in late fall and winter. Some piles can be left for wildlife habitat.

3. Some clumps can be left unthinned for wildlife cover.

4. The large, poorer-quality trees can be removed commercially and a few left for snags.

5. In 15 years, or after the stand has grown to 10 inches dbh, remove 35 tpa in a commercial thinning, leaving 90 tpa. This will allow the stand to grow to 12 inches dbh, when another commercial thinning can be planned (see Table 3.3, page 58).

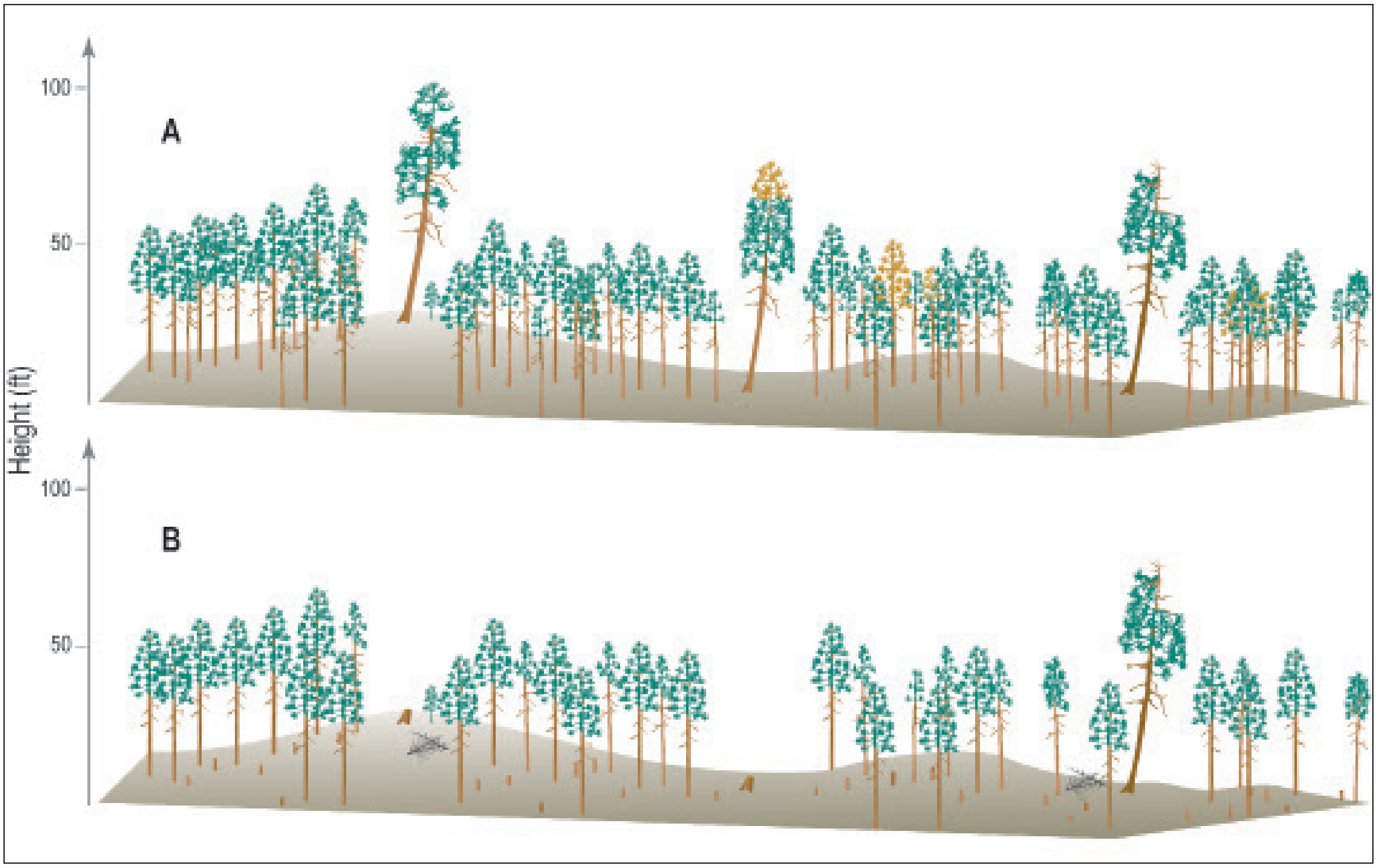


Figure 3.9A-B

Scenario 2. Pole-sized ponderosa pine stand

Stand conditions (Figure 3.10a) and landowner objective

1. The stand has an average diameter of 10 inches, 210 tpa, and a site index of 90.
2. The landowner's main objective is long-term timber production and income.
3. Tree growth and vigor are declining, and the landowner is concerned about bark beetle attack.
4. The topography is relatively flat.

Solution (Figure 3.10b)

1. Using Table 3.3, page 58, you determine the maximum and minimum tpa recommended for this stand are 197 and 132, respectively. Thus, the stand is overdense.
2. Because you want to come back and thin in the near future, you decide to thin down to 145 tpa (removing 65 tpa). This will allow the stand to grow to an average diameter of 12 inches before the next thinning is needed. When the stand grows to an average

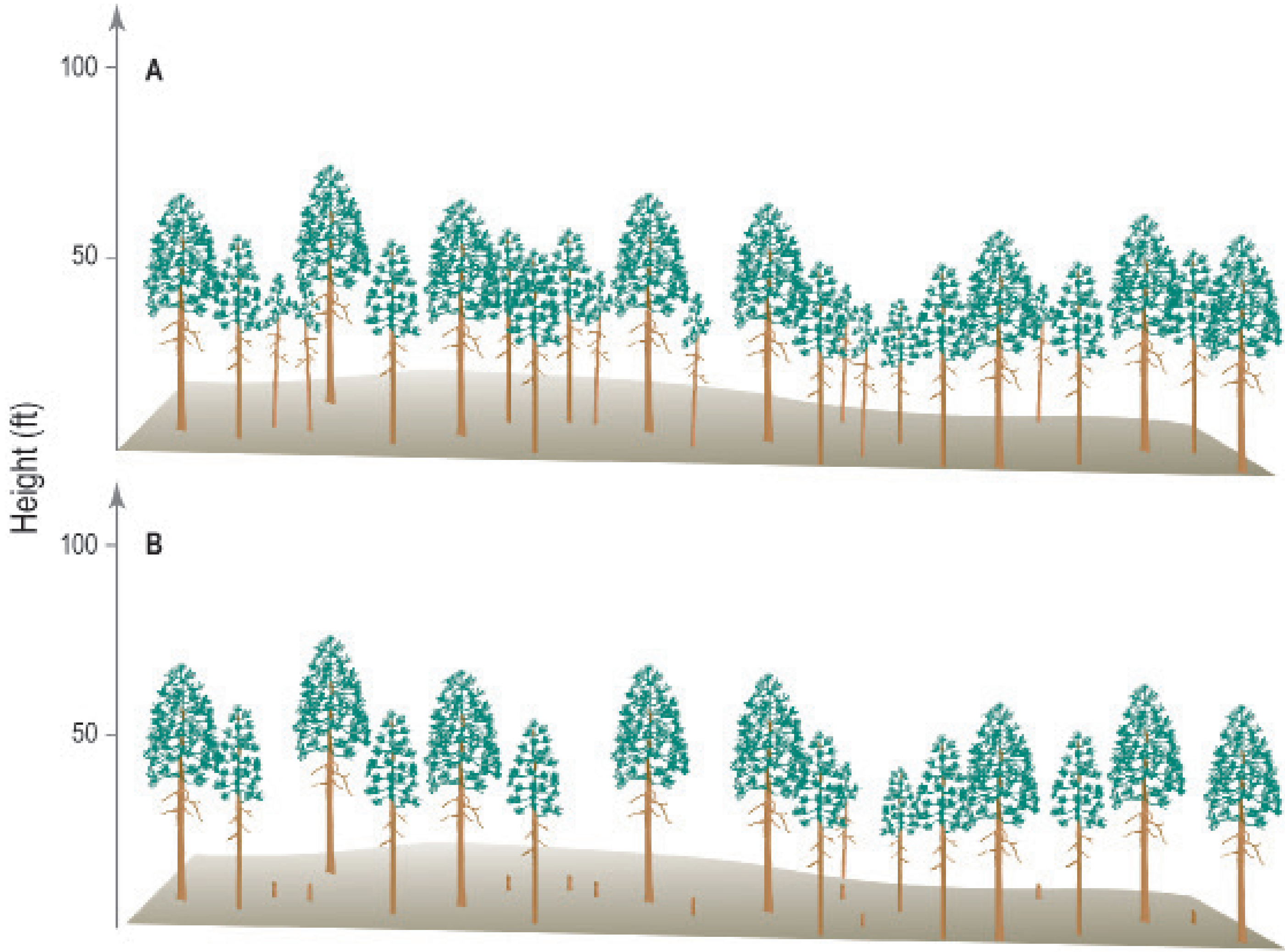


Figure 3.10 A-B

of 12 inches dbh (in about 10 years), thin again to 110 tpa. This allows the stand to grow to 14 inches for another commercial thinning. Thinning the stand again at that time, from 110 to 85 tpa, will allow the stand to grow to 16 inches dbh. The goal of all future thinnings is to maintain tree vigor, guard against bark beetle attack, and provide income. All future thinnings will produce trees that are larger and more valuable.

Scenario 3. Multistory, multiage stand

Stand conditions (Figure 3.11a) and landowner objectives

1. The stand has three distinct size or age classes—20, 60, and 100 years, with average diameters of 4, 8, and 14 inches, respectively. A few scattered 20-inch-plus old-growth pine trees are on the property but are generally in poor health. The age classes are scattered and tend to be clumpy, although there is some regeneration under the 100-year age class where the overstory is less dense. At right is a summary of current stand conditions.

Clump age (years)	Avg. tree diameter (inches)	Trees per acre (tpa)
20	4	450
60	8	255
100	14	85–125
150+	20+	Scattered

2. The landowners live on the property and consider aesthetics and wildlife important; therefore, they want to maintain the uneven-aged structure. They are not interested in harvesting the old trees, but if thinning smaller trees will improve their vigor, they are interested in doing so.

3. The stand has a site index of 80.

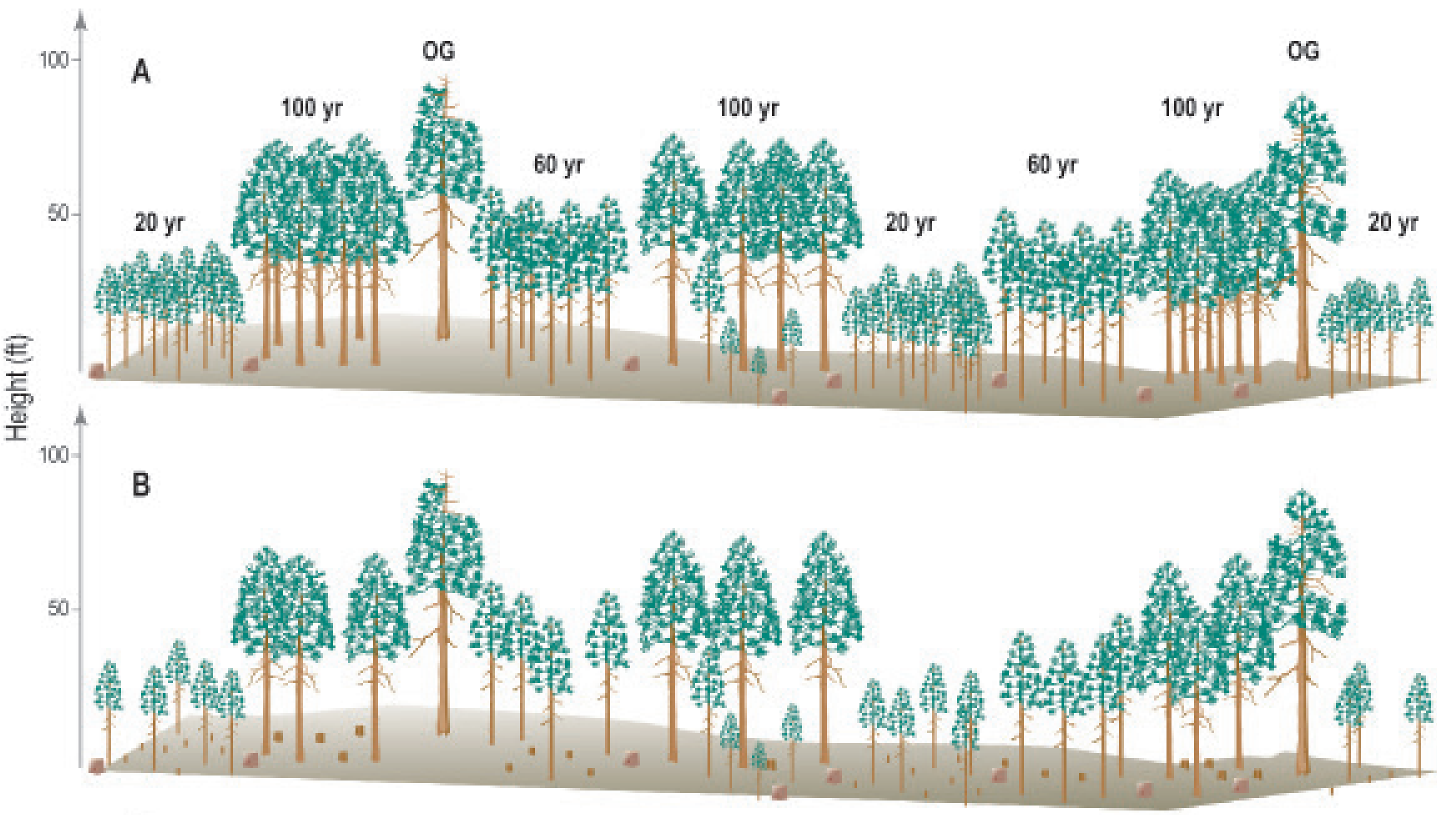


Figure 3.11 A-B

Solution (Figure 3.11b)

1. First, consider the clumps as individual stands with average stand diameters of 4, 8, and 14 inches.

2. Look at Table 3.3, page 58, to find the recommended tpa for stands with average diameters of 4, 8, and 14 inches and a site index of 80.

The 4- and 8-inch clumps Thinning here will be precommercial. Thin the 4-inch dbh clumps from 450 to 160 tpa (removing 290 tpa), or to about 16 feet between leave trees. Thin the 8-inch dbh clumps from 255 to 160 tpa (removing 95 tpa). This spacing allows residual trees to grow to a 10-inch diameter, at which time commercial thinning will be feasible. Reduce fire hazard by piling slash mechanically or manually and burning it in late fall or winter. Some piles can be left for wildlife cover.

The 14-inch clumps Trees removed here will be of merchantable size. Whether the thinning is commercial or not depends on logging costs and the amount of merchantable volume removed in the trees 10 inches and larger. Because stand density varies considerably within the 14-inch clumps (85 to 125 tpa), thinning intensity will vary as well. Where the overstory density is light and regeneration is beneath, reduce stand density from 85 to 70 tpa. This will promote the growth of understory regeneration. Where stand density is higher, thin from 125

Summary of activity for thinning example.

Timeline	Trees per acre (tpa)	Avg. stand diameter	Activity
Current stand	167	12”	Some mortality from bark beetles. Remove 82 tpa.
Future stand A	85	Grow to 16”	Remove 15 to 38 tpa.
Future stand B	47 – 70	Grow to 18”	Thin again, keeping the stand below the maximum density for each diameter class.

to 70 tpa (removing 55 tpa). This will reduce the threat of bark beetles and allow the stand to grow to 16 inches before another commercial thinning is needed (see Table 3.5).

Scattered large trees Thin around only the most vigorous of the large trees to promote their longevity. Trees over 20 inches in diameter would need a cleared radius of about 30 feet. Some of the less vigorous large-diameter trees could be harvested or left for wildlife habitat.

1. Return in 15 years and conduct a light commercial thinning in each size or age class to maintain tree growth and to release any regeneration, particularly in the larger-diameter classes.

2. If any openings in the stand are greater than 0.50 acre, plant with ponderosa pine seedlings on a 12- by 12-foot spacing to establish a fourth age class to further promote the uneven-aged character.

Summary

Ponderosa pine represents the dry end of the commercial forest zone of eastern Oregon, although it often is found on more moist mixed-conifer sites. Historically and even today, ponderosa pine forests are important ecologically and economically to the region. Ponderosa pine is quite flexible with respect to management approaches you might choose. It can be grown using even-aged, two-aged, or multi-aged strategies. Historically, ponderosa pine forests were multi-aged. It is important to prevent overstocking in ponderosa pine stands, especially on drier sites, as this can lead to moisture stress and predisposes them to insect attack, such as from bark beetles. Follow the stand density guides (Tables 3.3 and 3.4, pages 54 and 55) for maintaining proper stand stocking levels based on site productivity.

Table 3.5 (excerpted from Table 3.3). Stocking level guidelines for even-aged ponderosa pine stands, in terms of trees per acre (tpa). Recommended minimum and maximum tpa for sites with a site index (SI) ranging from 70 to 110 for ponderosa pine in eastern Oregon.

Avg. dbh (in)	Recommended minimum tpa by site index (SI)					Recommended maximum tpa by site index (SI)				
	70	80	90	100	110+	70	80	90	100	110+
12	60 (26.9)	78 (23.6)	96 (21.3)	114 (19.5)	131 (18.2)	90 (22.0)	117 (19.3)	143 (17.5)	169 (16.1)	196 (14.9)
14	46 (30.8)	60 (26.9)	73 (24.4)	87 (22.4)	100 (20.9)	68 (25.3)	89 (22.2)	109 (20.0)	129 (18.4)	149 (17.1)
16	36 (34.8)	47 (30.4)	57 (27.6)	68 (25.3)	79 (23.5)	54 (28.4)	70 (24.9)	86 (22.5)	102 (20.7)	118 (19.2)
18	29 (38.8)	38 (33.9)	47 (30.4)	55 (28.1)	64 (26.1)	44 (31.5)	57 (27.6)	70 (24.9)	83 (22.9)	95 (21.4)

* The number in parenthesis is the distance in feet between trees for a given number of trees per acre.

CHAPTER 4

Managing lodgepole pine

Stephen A. Fitzgerald and Gregory M. Filip

Lodgepole pine is widely distributed in eastern Oregon where it grows in dense stands in many areas or in mixtures with other tree species (Figure 4.1).

In the Pacific Northwest, lodgepole pine sometimes has had a bad reputation for low values at the mill and problems in management (or lack of management), including very slow growth due to overstocking, dwarf mistletoe, and bark beetles (Figure 4.2, page 68; see also Chapter 7). Also, it is found most commonly on relatively poor sites, where it grows slowly. It is, however, a fast-starting and versatile conifer and promises to be a valuable species to consider on certain sites under proper management and your objectives. In fact, there are hundreds of thousands of acres that would not be forested if it weren't for lodgepole pine's ability to grow in environments other tree species can't tolerate.

There are several other reasons for growing lodgepole pine:

- It grows in a variety of habitats often too harsh for other tree species, such as frost pockets or droughty pumice soils.
- It grows rapidly early in life and produces commercially valuable products in a relatively short time.
- Its wood is valued for a variety of products including pulp, lumber, poles, house logs, and firewood.
- Lodgepole pine forests are primary habitat for several species of birds and mammals, including the rare peregrine falcon, wolverine, snowshoe hare, and lynx. Because lodgepole forms extensive pure stands, it is the only habitat for many species.
- The commercially valuable matsutake mushroom grows especially well in lodgepole pine forests.
- Lodgepole pine often grows in riparian zones or near bogs, where it is valuable for wildlife habitat and stream shading and, when it dies, for woody debris that improves aquatic habitat.

Photo: James Hadfield

Figure 4.1. True fir grow in the understory, beneath an overstory of lodgepole pine.

This chapter covers the ecology of lodgepole pine, options for managing pure stands, and silvicultural systems that can work for you in lodgepole forests. See Chapter 5 for information about managing lodgepole pine in mixtures with other tree species.

Photo: Oregon Department of Forestry

Figure 4.2. Pitch tubes on a lodgepole pine that has been attacked by mountain pine beetle.

Shore pine is closely related to lodgepole pine, but shore pine grows along the Oregon Coast. It has different management requirements and is not discussed in this manual.

Ecology

Distribution and range

Lodgepole pine is found in the Cascade and Blue mountains of eastern Oregon, growing under a wide variety of climatic conditions and at elevations from 3,000 to 7,000 feet. Lodgepole pine grows both in extensive, pure stands and in association with many other conifers. In central Oregon, lodgepole grows on level sites and in broad depressions, with and without high water tables, where frost tolerance during germination allows it to establish and exclude other conifers. In northeastern Oregon, lodgepole pine grows in a variety of topographic situations and grows well on gentle slopes and basins at high elevations—areas where cold air collects.

Tolerance of environmental factors

Lodgepole pine is very tolerant of drought and flooding—an unusual mix of talents (see Table 1.2, page 13). Lodgepole is also very tolerant of frost, and on many frost-prone sites it is the only conifer that grows. The species has a low tolerance of shade and is very susceptible to damage from fire. It is relatively short lived mainly because it is highly susceptible to the mountain pine beetle (see Chapter 7). Lodgepole pine does not grow as large as ponderosa pine, Douglas-fir, or western larch.

Climate, soils, topography, and disturbance

The ability to tolerate poorly drained soils, droughty pumice soils, and frost pockets allows lodgepole pine to grow where other conifers cannot. In central and southern Oregon, lodgepole pine grows on wet flats and poorly drained soils that often are too wet for other tree species. As such, it is an important conifer species for riparian zones (see Chapter 9). Lodgepole also grows well on level, frost-prone sites with deep, coarse pumice deposits from Mount Mazama. Along the east flank of the Cascades, extensive stands grow above 4,000 feet in patterns attributed to fire, frost, and beetle outbreaks. In northeastern Oregon, lodgepole almost always is found on volcanic ash or alluvial material over residual basaltic soils. Depending on depth, soils with a hardpan can support lodgepole pine but not ponderosa pine or Douglas-fir.

Historically, eastern Oregon lodgepole pine forests had wildfires every 60 to 80 years. Wildfire was related to attack by the mountain pine beetle (see Chapter 7). Beetles prefer to attack larger (greater than 8 inches dbh), weakened trees including trees with previous fire scars. In mature stands, beetles often kill 70 to 80 percent of the largest trees, making them susceptible to hot surface or mixed-severity fires. Stand replacement fires that burn through existing mature stands result in the even-aged lodgepole forests we have today. Catastrophic fires burn the existing lodgepole stands completely and in the process create a mineral seedbed. This seedbed is an excellent medium for the thousands of lodgepole seeds produced each year, which germinate and grow into dense, even-aged stands. In the absence of a catastrophic fire, beetle-killed trees eventually fall to the ground, and the logs provide fuel for future fires and nutrients for future tree growth. Residual stands that escape fire mostly contain poor-quality timber, probably because beetles kill larger trees preferentially or because the trees are on poor, rocky sites.

Association with other trees and understory plants

Lodgepole pine's associations with other tree and understory plant species differ depending on whether forests are in the Cascades or the Blue Mountains.

Cascades region

In the central and northern Cascades, lodgepole pine frequently grows in pure stands with several shrubs and herbs. The most common are westernbog blueberry; bearberry; big sagebrush; Idaho fescue; western needlegrass; long-stolon, slender bog, Ross, and Nebraska sedges; tailcup and silvery lupines; beargrass; wax currant; snowbrush ceanothus; greenleaf and pinemat manzanitas; antelope bitterbrush; and big, dwarf, and grouse huckleberries. The understory plant species often indicate the productivity of the lodgepole pine stand. Lodgepole pine stands produce the most wood when they grow with sedge-lupine, beargrass, and blueberry; stands that are the least productive have sedge-needlegrass, manzanita, and bitterbrush. Lodgepole can grow in mixed stands with ponderosa pine or grand fir at mid-elevations and with mountain hemlock at high elevations.

In the southern Cascades, lodgepole forms pure stands with understories of broadpetal strawberry; Idaho fescue; bottlebrush squirreltail; lupine; grouse and big huckleberries; pinemat manzanita; and long-stolon sedge. Lodgepole stands with strawberry-fescue are more productive. Lodgepole often forms mixed stands with grand fir or ponderosa pine at the lower to mid-elevations and with quaking aspen, mountain hemlock, or whitebark pine at the higher elevations.

Blue Mountains

In the Blue Mountains, lodgepole forms pure stands only at the higher elevations, often with big huckleberry, grouse huckleberry, or pinegrass in the understory. Many of these forests are in areas where cold air drains and pools. Mixed stands are more common in northeastern Oregon than in central or southern Oregon. In mixed stands, lodgepole pine grows with subalpine fir, grand fir, larch, spruce, and Douglas-fir.

Lodgepole's Choicest Companion

Several types of edible mushrooms grow in lodgepole pine forests, but none so choice as the matsutake or pine mushroom *(Tricholoma magnivelare)*. Matsutake is one of the more commercially valuable mushrooms in Oregon; the value of the mushroom crop often exceeds the value of the timber crop under which it grows! Matsutake grows into the roots of lodgepole pine. This association of mushroom and pine roots, called myco-rrhizae, benefits both the mushroom and the pine. The extensive growth of the matsutake on the pine roots allows the pine to receive more moisture and nutrients than it could from roots alone. In turn, the pine provides food for the mushroom. The effects of forest practices on mushroom production are being investigated.

Photo: Dave Pilz

Figure 4.3. Matsutake mushrooms.

Stand initiation and development

Seed production and germination

Lodgepole pine begins producing seed at age 5 to 10 years. Good cone crops can be expected at one- to three-year intervals. Cones can withstand subfreezing temperatures, and seed and cone pests are few. Seeds can remain viable in the cone for years.

In Oregon, where most cones are nonserotinous (that is, do not require fire to open), seedfall ranges from 14,000 to 500,000 seeds per acre each year. The relatively plentiful seedfall often provides for abundant natural regeneration of lodgepole in mixed stands and in disturbed areas such as openings created by road cuts, power lines, fires, timber harvest, or beetle attack.

The percentage of viable seeds that normally germinate is one of the highest for western conifers. Seeds germinate best in full sun and on bare soil or disturbed duff. Adequate soil moisture is necessary for germination and survival. In areas with severe frost, seed germinates and survives best with some protection from a partial overstory, slash and woody debris on left on the soil surface, or nearby shrubs.

Seedling development

Seedlings are poor competitors, especially against grass. Survival is best on disturbed mineral-soil seedbeds. Seedlings expend a lot of their energy in putting down a taproot to access moisture, especially in the pumice soils of central Oregon. Because of prolific seed production, overstocking is a common problem on some sites and can lead to stagnation at early ages. Drought is a common cause of seedling mortality. Most damage occurs on soils with low water-holding capacity. Seedlings also are killed directly by freezing or frost heaving, which varies by location and soil type as well as by how cold it gets during the year. Grazing animals, especially concentrations of cattle, also damage and kill seedlings (see Chapter 8).

Stand development

Early height growth of young lodgepole pine often exceeds that of most associated tree species except larch. Diameter growth rates of lodgepole pine are severely affected by stand density. For example, unmanaged stands in northeastern Oregon may have 2,000 trees per acre (tpa), with trees only about 4 inches dbh at age 100 (i.e., stand stagnation). On a good growing site, 100-year-old trees previously thinned to 150 tpa average about 12 inches dbh.

Stands with 100 to 300 saplings per acre between 5 and 20 years old do not stagnate until about age 50. Tree volume growth can reach its maximum as early as 40 years of age in severely stagnated stands. Precommercial thinning is often needed to avoid stagnation in many stands; however, thinning before age 10 can allow new seedlings to establish (ingrowth) and thus result in repeated stagnation. Stagnation also can be caused by pests such as dwarf mistletoe and rust fungi (see Chapter 7).

Overstocked stands can shade the forest floor and limit water availability to understory plants. Little or no understory plant development or forage production results in poorer foraging habitat for elk, deer, and cattle. On the other hand, dense stands may provide good hiding cover for elk and deer (see Chapter 9).

Growth and yield

Net yield is all the wood that can be produced excluding defect and mortality. Net yields of lodgepole pine vary by site index and stand density. Site index for lodgepole pine, measured on a 50-year basis, varies from 30 to 70 (Figure 4.4, page 72). Net yields for lodgepole pine by site index in Tables 4.1 and 4.2 are for pumice soils in central and southern Oregon.

Silvicultural systems

Three silvicultural methods produce even-aged stands of lodgepole pine: clearcutting, seed tree, and shelterwood (see Chapter 2). Managing for uneven-aged stands includes individual tree selection and group-selection methods. For information about reforestation, see Chapter 6.

Methods for even-aged stands

Clearcutting

On most lodgepole pine sites, clearcutting is meant to resemble natural disturbances such as wildfire, windthrow, or beetle epidemics. Clearcutting is a good way to regenerate lodgepole pine on slopes where frost is not a problem. In some areas, however, especially in central and southern Oregon, frost pockets created by clearcutting can result in relatively poor survival of regeneration. In such cases, a shelterwood harvesting system should be used because it moderates temperature extremes. In northeastern Oregon, clearcutting works well for regenerating lodgepole, whether in frost pockets or not.

Another method that works well on industrial land in central Oregon is to use strip cuts oriented north and south with a maximum width of about two times mature tree height. This technique lessens the problems of frost and of windthrow at the edges.

Table 4.1. Net yield (board feet) **per acre for lodgepole pine in central Oregon. Volumes are for stands that were periodically thinned to maintain maximum height growth and reasonable diameter growth. Under intensive management, yields may approach these levels (adapted from Dahms 1964).**

	Site index (height at age 50)				
Age (years)	30	40	50	60	70
	Board feet				
30	880	1,510	2,160	2,790	3,440
40	1,700	2,710	3,700	4,680	5,690
50	2,690	4,100	5,520	6,960	8,380
60	3,780	5,700	7,610	9,530	11,480
70	4,980	7,330	9,930	12,420	14,910
80	6,200	9,310	12,440	15,580	18,710
90	7,420	11,230	15,080	18,940	22,750
100	8,540	13,180	17,780	22,430	27,030
110	9,350	14,720	20,050	25,380	30,750
120	10,440	16,830	23,220	29,660	36,000

Table 4.2. Net yield (cubic feet) **per acre for lodgepole pine in central Oregon. Volumes are for stands that were periodically thinned to maintain maximum height growth and reasonable diameter growth. Under intensive management, yields may approach these levels (Dahms 1964).**

	Site index (height at age 50)				
Age (years)	30	40	50	60	70
	Cubic feet				
30	490	840	1,200	1,550	1,910
40	810	1,290	1,760	2,230	2,710
50	1,120	1,710	2,300	2,900	3,490
60	1,400	2,110	2,820	3,530	4,250
70	1,660	2,480	3,310	4,140	4,970
80	1,880	2,820	3,770	4,720	5,670
90	2,060	3,120	4,190	5,260	6,320
100	2,190	3,380	4,560	5,750	6,930
110	2,280	3,590	4,890	6,190	7,500
120	2,320	3,740	5,160	6,590	8,000

Clearcuts can be regenerated by planting or by natural seeding. Good examples of clearcutting to regenerate lodgepole followed the mountain pine beetle outbreak and salvage of the late 1970s and early 1980s in northeastern and central Oregon.

Seed tree and shelterwood cuttings

Seed tree and shelterwood systems are quite effective in regenerating a young lodgepole pine stand. On slopes where frost damage is not a problem, leave 10 to 20 well-spaced trees with live crown ratios of 30 percent or more (see Figure 2.15, page 39) and little or no dwarf mistletoe or rust infections to ensure good survival and seed production and to minimize disease spread to regenerated trees. Because the volume of lodgepole seed trees or shelterwood trees is relatively small, leaving some or all of them after successful seeding or sheltering is a common practice to increase stand structure and diversity for wildlife. If you use mistletoe-infected trees as seed trees or shelterwood trees, however, remove them before regeneration is 3 feet tall or 10 years old (whichever comes first) to prevent mistletoe's spread to new trees.

In severe frost pockets, leave 20 to 30 shelterwood trees to provide more protection for developing seedlings. In this case, remove most shelterwood trees later to avoid severe competition between the overstory and the seedlings.

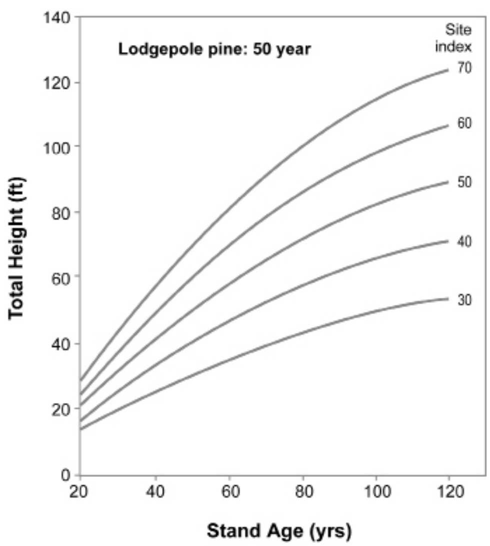


Figure 4.4. Site index curves for lodgepole pine growing in central Oregon (from Dahms 1964).

Trees should have no gall rust infections in the stem (hip cankers) that could lead to tree breakage. Some leave trees may be windthrown, but experience shows that regeneration is very successful, especially if dominant trees are selected for leave trees.

Methods for uneven-aged stands

Uneven-aged management has not been practiced in lodgepole pine forests, but it may have some potential if done properly. Climax lodgepole pine sites have many examples of natural uneven-aged stands from fire, bark beetles, and other disturbances. Group selection creates openings large enough for seed dispersal, site preparation, and enough sunlight for seed germination and seedling survival. However, this practice would not work in areas with severe frost.

Table 4.3. Silvicultural operations for managing lodgepole pine.

Age	Stage	Method	Density (tpa)	Spacing (feet)
0	Regneration	Natural	0–5,000+	n/a
		Planted	150–430	17 x 17 to 10 x 10
10-20	Young stand thinning (precommercial)	Thin, removing damaged, diseased and low vigor trees	200–350	15 x 15 to 11 x 11
70-90	Commericial thinning	Thin from below	100	21 x 21
91+	Harvest/regeneration	Clearcut/plant	350	11.5 x 11.5
		Seed tree or shelterwood/natural	10–40	66 x 66 to 33 x 33

Single-tree selection is unlikely to succeed because lodgepole pine is not shade tolerant, and it would be difficult to regenerate with this method without heavily thinning the residual stand. Stands with dwarf mistletoe should not be managed as uneven-aged because of mistletoe spread from overstory trees to smaller trees (see Chapter 7).

Stand management

Thinning and improvement cuttings

Thinning and improvement cutting often are needed to manage lodgepole stands for timber or habitat values (Figure 4.5). Trees with damage or under pest attack also can be removed with thinning and improvement cuttings. Other benefits of thinning are summarized in Chapter 2. Slash may need to be piled and burned to reduce fuel loading and fire hazard.

Precommercial thinning

Because lodgepole pine stands typically are overstocked, precommercial thinning is necessary. Consider thinning stands that are 2 to 6 inches dbh with at least 30 to 40 percent live crown ratios. Thinning can significantly enhance individual tree growth and value, improve wind firmness, help protect against bark beetles, and increase forage production by opening stands to light. In fact, many lodgepole stands may never become merchantable unless they are thinned.

Thinning also can reduce shading, in turn reducing the number of dead trees and dead branches and therefore reducing the potential spread and severity of wildfire. Thin to 15 by 15 feet, and remove small trees and continuous slash (overlapping logs and branches across the forest floor) to help reduce fire spread and severity.

If densities are greater than 350 trees per acre (11 by 11 feet), do early thinning when stands are 10 to 20 years old (after the lowest whorl of branches is dead, but before trees are 15 feet tall). Make sure no live branches are left on the stump. Densities of less than 350 trees per acre have sufficient spacing if a commercial thinning can occur when trees are 6 inches in diameter (Table 4.3, page 72).

Figure 4.5. A lodgepole stand commercially thinned to increase vigor and pevent beetle attack.

Commercial thinning

One strategy for commercial thinning is to keep stands dense (more than 350 tpa) to maintain good stem form and small branches until the they reach an average diameter of 6–8 inches and then commercially thin to 170 tpa (16–by–16–foot spacing; see Table 4.4) removing pulp and some sawlogs. Whether the operation is truly commercial will depend on log markets and logging costs. Thin again when the average stand diameter reaches 10 inches leaving 75 to 90 tpa (24–22 foot spacing), which allows the stand to grow to an average diameter of 14–16 inches when a final harvest would be conducted. The goal is to keep stands at or, preferably, below the recommended maximum tpa for any given average diameter (dbh). This significantly improves diameter growth and vigor, reduces the likelihood of mortality from bark beetles, improves windfirmness, and at wide spacing prevents tree-to-tree spread of dwarf mistletoe. The best growth response from thinning is in stands on highly productive sites, in trees less than 90 years old, and in trees with good (more than 30 percent) live crown ratios.

If timber is your objective, remove trees with dwarf mistletoe or other diseases first. However, trees with light to moderate amounts of mistletoe respond well if they are adequately spaced and have good live crown ratios. Keeping lightly infected trees also helps to maintain adequate tree stocking. Some stands may not respond to thinning because they're too old (more than 125 years), on very poor sites, or have live crown ratios less than 20 percent; in such cases, it may be better to clearcut the stand and start over.

Tree spacing

Thinning intensity is based on stocking-level guidelines such as those in Table 4.4. Guidelines are set relatively low to reduce risk of mortality caused by mountain pine beetle. We're not sure whether these guidelines should differ with site index (Cochran et al. 1994), but, in general, thinning to recommended minimum densities will stimulate good growth on the higher site indices (SI 60 to 70) and lower growth rates on poorer sites (SI 30 to 40). Although these guidelines were developed for northeastern Oregon, they probably can be used in central and southern Oregon as well, based on mortality surveys in thinned and unthinned stands in central Oregon.

If you leave fewer trees than the recommended minimum density, the stand is too open, site resources are wasted, and growth per acre declines. If you grow more trees than the recommended maximum density, competition among trees intensifies, diameter growth

Table 4.4. Trees per acre, spacing, and basal-area guidelines for lodgepole pine stands in northeast Oregon, given average tree diameters of 6 to 18 inches, in even-aged, pure stands of all site classes (adapted from Cochran et al. 1994).

	Recommended minimum			Recommended maximum		
dbh (in)	Trees/ acre (tpa)	Basal area (sq ft/acre)	Spacing (ft)	Trees/ acre (tpa)	Basal area (sq ft/acre)	Spacing (ft)
6	200	39	15	350	69	11
8	170	59	16	250	87	14
10	115	63	20	170	93	16
12	80	65	23	120	97	19
14	65	68	26	90	100	22
16	60	70	27	75	103	24
18	40	73	34	60	107	27

slows, and trees die from bark beetles. Keeping your stands between low- and high-density ranges for each diameter class maintains good site occupancy and optimum stand growth and reduces tree mortality.

Thinning example

Your 50-acre stand of lodgepole pine is about 70 years old. It's overstocked, with some mortality due to mountain pine beetles. Your forestry consultant recommends you thin the stand to reduce future mortality. The stand has about 500 trees per acre with an average diameter of 8 inches. How many trees should you remove?

Use Table 4.4 (page 74) to determine the recommended minimum and maximum number of trees when average diameter is 8 inches. The recommended number is 170 to 250 trees per acre. You have 500 trees, 250 trees more than the maximum recommended. The stand is too dense and will benefit from thinning.

If you thin to 250 trees per acre, the stand is still at the recommended maximum density and still susceptible to mortality. You decide to thin to 170 trees per acre, removing 330 trees per acre by free thinning (see Chapter 2). A sample marking of trees to remove shows that the average diameter of the residual stand will still be about 8 inches.

When will you need to thin again? With 170 tpa, thin again when the average diameter is about 10 inches. Allowing the stand to grow larger than 10 inches dbh with 170 tpa may result in mortality due to excessive competition and potential beetle attack. In this case, you would remove 75 mostly smaller-diameter trees in a thinning from below. A sample marking shows that removing mostly small trees will increase the average diameter of residual trees to almost 12 inches. Thinning the stand to 75 from 170 tpa would allow the stand to grow to 16 inches dbh before another thinning is necessary (Table 4.5).

Please note that once the average diameter of a lodgepole pine stand is greater than 8 inches, it is important to maintain thrifty stands because trees 8 inches and larger are preferred by the mountain pine beetle.

Sanitation and salvage cuttings

Lodgepole pine trees are often harvested with sanitation or salvage cuttings because of infestation by mountain pine beetle or dwarf mistletoe. Periodically thinning stands prevents the need to do sanitation or salvage cuttings.

Sanitation cutting removes living trees that have mistletoe, thus reducing spread of mistletoe

Table 4.5. Summary of activity for thinning example.

Timeline	Trees/acre (tpa)	Avg. tree diameter	Activity
Current stand	500	8”	Some mortality from bark beetles. Remove 330 tpa.
Future stand A	170	Grow to 10”	Remove 95 tpa
Future stand B	75	Grow to 16”	Thin again, keeping stand below the maximum density for each diameter class (Table 4.4).

seeds to adjacent trees. Sanitation cutting also can remove trees recently attacked by mountain pine beetle while the beetles are still under the bark. Sanitation cutting removes the beetles that would have flown and attacked other trees. Harvested trees probably would have died within the year. Sanitation cutting may or may not pay for itself as the purpose is removal of infested trees here and there to prevent buildup and spread of insects or pathogens to the remaining stand.

Salvage cutting occurs when it is too late to do a sanitation cutting and substantial tree mortality has occurred. Salvage cutting removes trees that are dead or dying on account of mountain pine beetle, mistletoe, windthrow, or wildfire in order to capture wood value before it deteriorates further.

Pruning

Few foresters prune lodgepole pine on less-productive sites because it usually does not pay. If you are on a good site, you can consider pruning lodgepole pine stands but first check local markets for clear wood demand. You can prune to remove branch infections of mistletoe or rust fungi.

If you choose to prune, do it in stages, or "lifts." Start pruning when trees are small (10 to 15 feet tall and less than 4 inches dbh). Remove branches on the lower 6 to 8 feet of stem, leaving at least 50 percent live crown. Prune only about 50 tpa, the trees that you will keep longest in the stand (Table 4.3, page 72). The second pruning should be when trees are 25 to 30 feet tall. At this time, prune branches up to 12 feet from the ground. The third pruning can be when trees are 35 to 40 feet tall; prune branches up to 18 feet. Pruning trees larger than 8 inches dbh probably is not profitable but may reduce ladder fuels or improve aesthetics. To prevent attack from insects and decay fungi, leave branch collars intact (no flush cuts) and no long stubs. Also, prune in the fall and winter to prevent attack from pitch moths.

Fertilizing

In some areas, studies have shown that lodgepole pine is responsive to additions of three key nutrients: nitrogen, phosphorus, and sulfur. As with all tree species in eastern Oregon, forest fertilization is complex (see Chapter 2). Unless you are on a good site, it is a risky investment; that is, the increase in wood production may not pay for the cost of the fertilizer application. Consult with your OSU Extension forester, a consulting forester, or an Oregon Department of Forestry stewardship forester about fertilization in your area.

Lodgepole pine stand management options: Some examples

Working with the basic principles and guidelines discussed in this chapter, here are three examples of ways to manage lodgepole pine stands in eastern Oregon.

Scenario 1: Timber stand on pumice soils

Pumice soils are common in central and southern Oregon. Managing lodgepole pine on these soils presents certain problems associated with frost pockets that can prevent regeneration.

Stand conditions (Figure 4.6a) and landowner objectives

1. This 150-acre stand is even-aged and about 50 years old, with a mean dbh of 4 inches and density of 1,500 tpa.

2. It is on a poor site (site index of 40, base age 50 years) at 3,000 feet elevation, with flat topography and a lodgepole-bitterbrush plant association.

3. Some trees have heavy mistletoe infections. The stand has stagnated.

4. The main management objective is to improve tree growth and produce wood for a local chip and lumber mill. A second objective is to create forage for wildlife and an aesthetically pleasant scene.

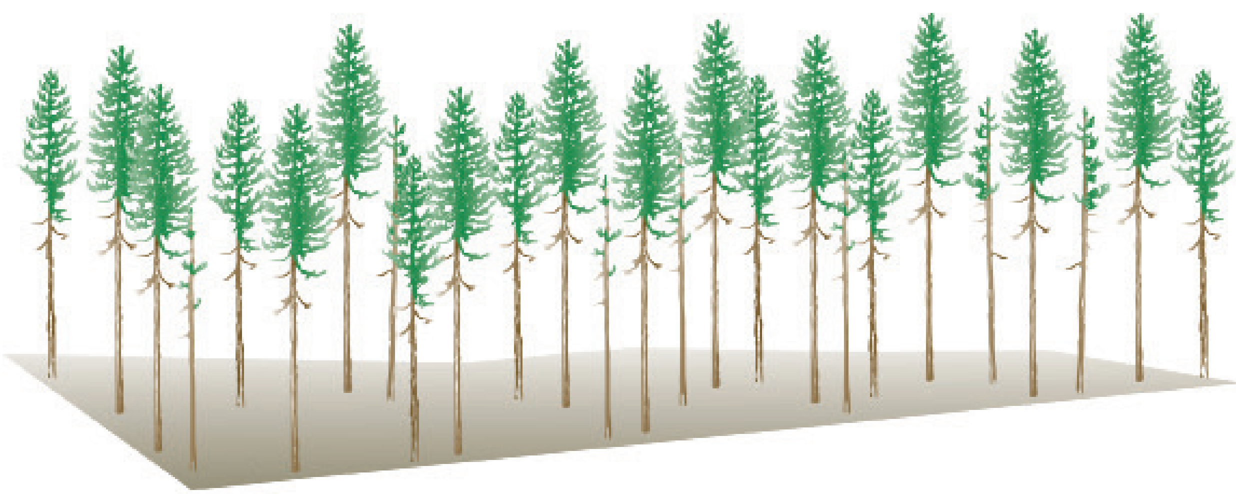


Figure 4.6a. Initial overstocked stand.

Solution (Figures 4.6b–c)

1. Commercially thin now to about 200 tpa (11 by 11 feet) to increase growth rates, reduce beetle and fire risk, eliminate mistletoe infections, and increase forage production (Figure 4.6b). Sell the trees to the local market for poles and chips. Pile and burn slash.

2. In another 15 years, harvest the stand when it has a mean dbh of about 6 to 8 inches and trees can be sold for chips or some sawlogs. Leave a light shelterwood of 10 trees per acre (65 by 65 feet) to naturally regenerate the site and reduce damage from frost (Figure 4.6c). Select residual trees with live crown ratios over 30 percent that are free of mistletoe. During the skidding operation, scarify the ground to remove competing vegetation and create a good seedbed. Don't damage the seed trees.

3. Retain shelterwood trees for aesthetic and wildlife benefits. Natural regeneration should be good: about 1,000 tpa should become established. When regeneration is 15 to 20 years old, thin to 300 tpa and pile the saplings to burn during wet weather. There won't be sawlogs or chips because the trees will still be too small.

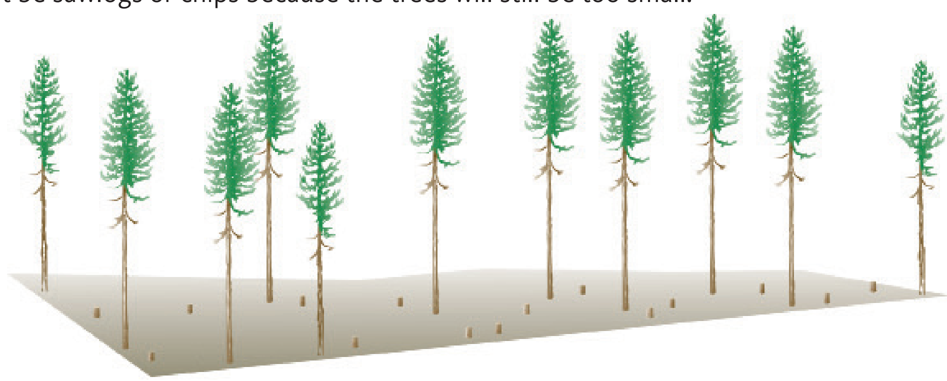


Figure 4.6b. After first commercial thinning

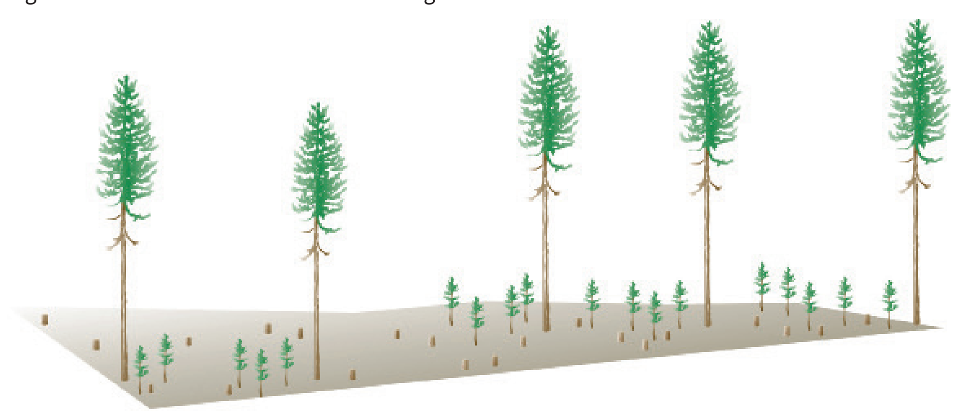


Figure 4.6c. Shelterwood stand with regeneration following second heavy thinning

Summary of Scenario 1 activity

Timeline	Trees/acre	Avg. dbh	Activities
Current stand, age 50 years	1,500	4"	Thin to 200 tpa; treat slash
15 years later, age 65 years	200	6"	Harvest the stand; leave seed trees at 10 tpa
New stand	1,000	seedlings	Thin to 300 tpa after 20 years; prune 50 tpa

Scenario 2: Cabin site in central Oregon

Lodgepole pine on a cabin, home, or recreation site needs special consideration. Aesthetic values need to be preserved while maintaining stand vigor and decreasing the risk of wildfire loss.

Stand conditions and landowner objectives

1. The stand, which surrounds a cabin on 10 acres, is 80 years old with an average dbh of 6 inches and 700 tpa.
2. The stand is on a moderately productive site (site index of 60, base age 50 years) at 4,500 feet elevation with a lodgepole-beargrass association.
3. Bark beetles already have killed some trees. Wildfire risk is high because of dead branches and many small trees down in some areas.
4. The objective is to manage mainly for recreation and wildlife, with some income from timber.

Solution

1. Thin most of the stand to 200 tpa (15 by 15 feet) to reduce beetle-related mortality and wildfire risk. Sell thinnings to a local chip mill; also sell some poles and sawlogs.
2. Leave—i.e., don't thin—some clumps of trees (about 0.5 acre) at the corners of the property to provide some diversity for wildlife and screening. Leave some snags and logs for cavity-nesting birds and other wildlife (see Chapter 9).
3. Thin in late summer or early fall. Cut stumps low, and pile, cover, and burn most of the slash that winter.
4. In 20 years, at stand age 100, thin again to about 115 tpa and sell the cut trees for lumber and poles. Grasses and shrubs will increase and provide forage for wildlife.
5. Thin again in another 20 years, at stand age 120, to 65 tpa. This reduces beetle and fire risk, provides some income, encourages natural regeneration, and at the same time retains the aesthetic character of the lodgepole pine stand around the cabin.
6. Plant some wildlife-friendly shrubs.

Summary of Scenario 2 activity

Timeline	Trees/acre	Avg. dbh	Activities
Current stand, age 80 years	700	6"	Thin to 200 tpa. Leave some clumps for wildlife
20 years later, age 100 years	200	10"	Thin to 115 tpa
20 years later, age 120 years	115	14"	Thin to 65 tpa. Plant some wildlife-friendly shrubs

Scenario 3: Timber stand in a mixed-conifer forest

Lodgepole pine often grows in mixed-species stands in northeastern Oregon. Management opportunities often are greater than in pure-species stands.

Stand conditions (Figure 4.7a) and landowner objectives

1. This 100-acre stand is about 75 percent pine and 25 percent larch. Together, density is about 5,000 tpa.
2. The stand developed on an old burn and is 15 years old. The pines are about 10 feet high and 1 inch dbh.
3. The larches are taller—2 to 3 inches dbh—and still vigorous.
4. The site is moderately productive (site index of 60, base age 50 years) at 5,000 feet elevation and has a 10 percent slope and a lodgepole pine-big huckleberry-pinegrass association.
5. No pests are detected, but the stand is extremely dense and growing slowly.
6. The main objective is future revenue from timber. Wildlife is secondary.

Solution (Figures 4.7b–c)

1. First, thin to 250 tpa, leaving a 1-to-1 mix of pine to larch to maintain diversity (Figure 4.7b), page 81. This thinning increases tree growth but still prevents invasion of new lodgepole seedlings at this age.
2. In 30 years (45 years old), the stand averages 8 inches dbh. Thin to 170 tpa (retaining the 1-to-1 species mix) and sell the thinnings as poles or sawlogs.
3. In another 20 years (65 years old), the stand averages 14 inches dbh. Thin to 65 tpa (retaining the 1-to-1 species mix) and sell the thinnings as sawlogs.
4. In another 20 years (65 years old), the stand averages 17 inches dbh. Because the sawlog market is good, clearcut half the stand (50 acres). Because lodgepole natural regeneration is good, plant 50 larch tpa to ensure a good larch-pine mix for the future (Figure 4.7c, page 81). Harvest the other half of the stand, retaining 20 overstory trees tpa for seed and wildlife shelter.

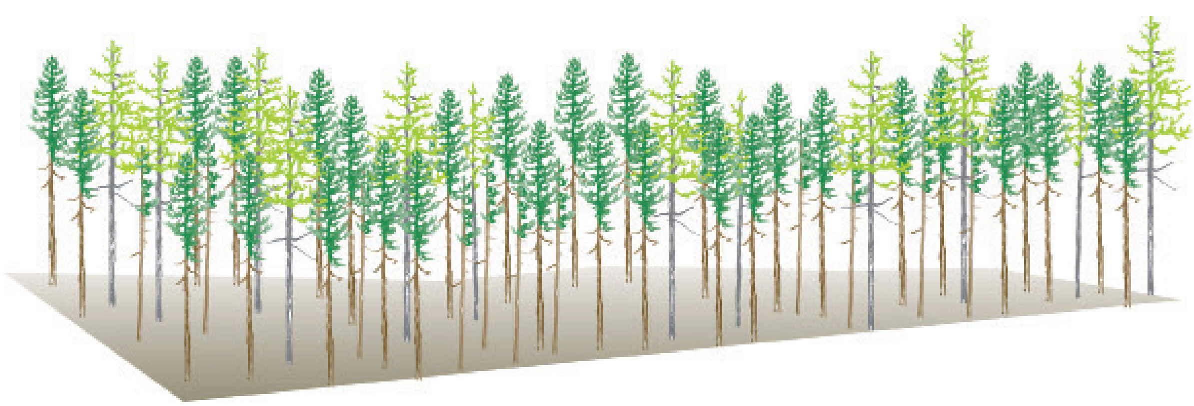


Figure 4.7a. Initial stand.

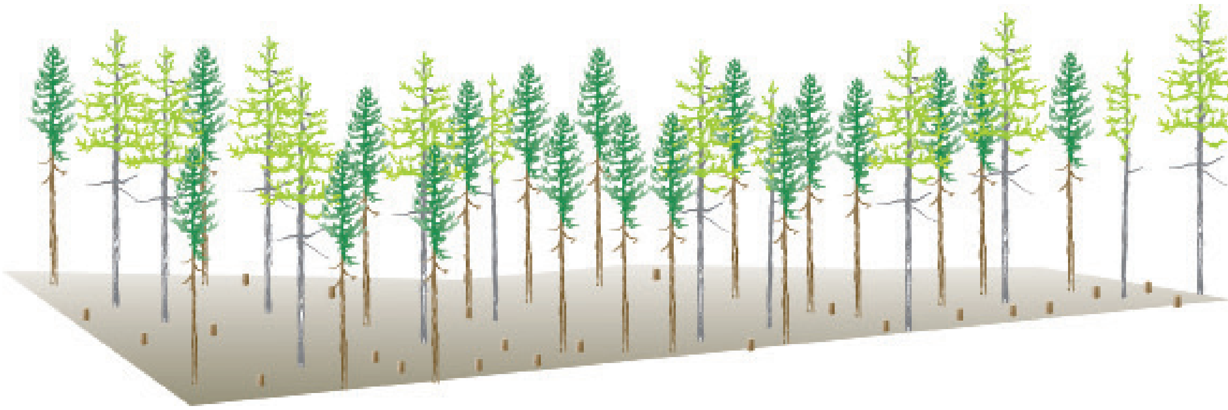


Figure 4.7b. After first thinning.

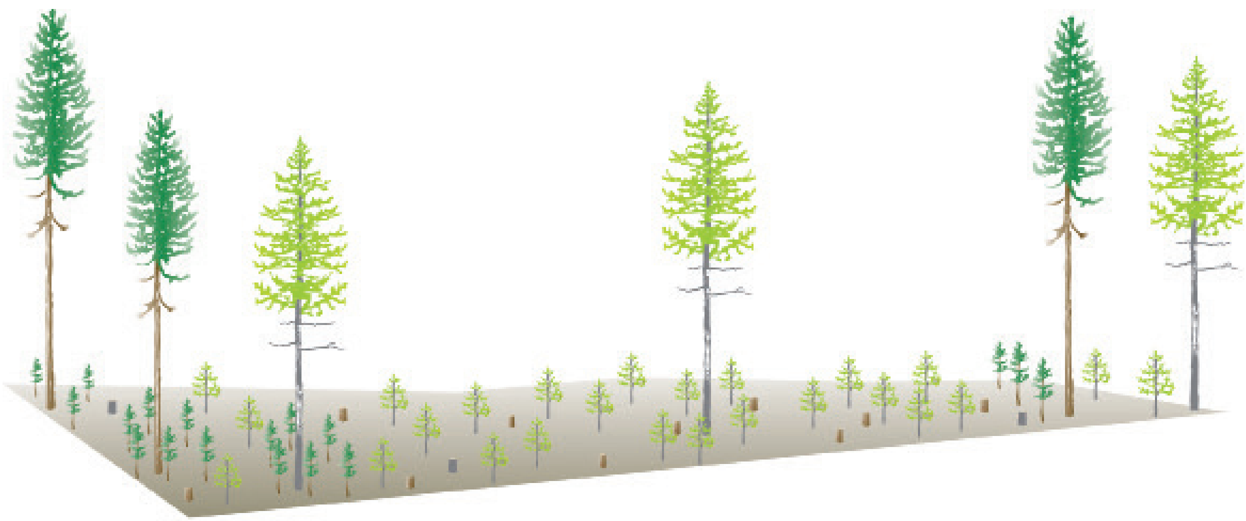


Figure 4.7c. Shelterwood with natural lodgepole and planted larch seedlings.

Summary of Scenario 3 activity.

Timeline	Trees/acre	Avg. dbh	Activities
Current stand, age 15 years	5,000	1 to 3”	Thin to 250 tpa with a 1-to-1 mixture of larch to pine
30 years later, age 45 years	250	8”	Thin to 170 tpa
20 years later, age 65 years	170	14”	Thin to 65 tpa
20 years later, age 85 years	65	17”	Clearcut half the stand; retain 20 tpa in the other half

Summary

Why grow and manage lodgepole pine? There are several potential benefits:

- A lodgepole pine forest provides products such as lumber, pulp, composition board, firewood, and mushrooms.
- It provides hiding cover for several important species of wildlife.
- It can grow on some sites where other tree species cannot (e.g., frost pockets, where ponderosa pine cannot grow).
- Abundant seed production allows lodgepole to reproduce naturally in disturbed areas and thus reduces reforestation costs.

Some potential constraints require special management:

- Frost pockets on some pumice soils can prevent lodgepole regeneration.
- Overstocking can lead to stagnation, poor tree growth, dead trees, and high fire risk.
- Several important pests, such as mountain pine beetle, dwarf mistletoe, and stem rusts and cankers, are particularly damaging in stands that are too dense.
- Overdense stands provide poor forage for wild and domestic ungulates.

These constraints can be overcome:

- Use shelterwood systems on pumice soils to protect natural regeneration and thus reduce or avoid regeneration costs. Leave some slash and woody debris to further protect seedlings from severe frost.
- Thin overstocked stands to prevent stagnation, reduce fire risk, improve habitat, and increase value.
- Properly thin stands with average dbh at or above 8 inches to avoid beetle attacks and other pests.

Reducing stand density through thinning is the key to successfully managing lodgepole pine for maximum tree growth, minimum pest and fire damage, and optimum wildlife forage.

CHAPTER 5

Managing mixed-conifer forests

Paul T. Oester

Mixed-conifer forests of ponderosa pine, Douglas-fir, true firs (primarily grand fir or white fir), western larch, and lodgepole pine weave a species tapestry across mountainous landscapes in eastern Oregon. Sometimes these species appear as pure stands, but most often they are in mixtures. Incense-cedar, western white pine, sugar pine, and Engelmann spruce can be in the mix.

Mixed-conifer is the most extensive forest type east of the Cascade crest in Oregon. With proper management, these forests can provide wood, forage, wildlife, fish, clean water and air, recreation, and beautiful vistas. Good management can improve forest health and ensure that the benefits of mixed-conifer forests are available well into the future.

Ecology

Distribution and range

Mixed-species forests are more widely distributed than either ponderosa pine or lodgepole pine forests in eastern Oregon. They are common in a north-south ribbon along the east slope of the Cascades, in south-central Oregon in Klamath and Lake counties, and throughout the mid to upper elevations in the Ochoco and Blue mountains of northeast Oregon. Generally, these forests abut ponderosa pine forests at their lower elevation limit and mountain hemlock or subalpine fir forests at the upper limit (Figures 5.1a–d, below and on page 84).

Because mixed-species forests span such a wide range of environments and to simplify management recommendations, we divide them into two types based on temperature and moisture conditions: warm and dry and cool and moist (see definitions in Chapter 1). The warm-dry mixed-conifer forest type is found on warmer and drier sites. As elevation increases, moisture improves, temperatures drop, and conditions become favorable for

Photo (left): Ed Barton

Figures 5.1a–b. Warm, dry mixed-conifer forests. At left, a mature ponderosa pine overstory with an understory mixture of Douglas-fir and ponderosa. At right, a mixture of western larch, ponderosa pine, and Douglas-fir in the overstory, with a Douglas-fir and grand fir combination in the understory.

Figures 5.1c-d. Cool-moist mixed-conifer forests. At left, lodgepole pine and/or western larch typically seed in when light conditions are favorable. At right, cool-moist mixed-conifer forests support more grand fir and cold-tolerant species such as subalpine fir and Engelmann spruce, but also include Douglas-fir and western larch.

the cool-moist mixed-conifer forest type. While elevation is a major factor in how these forest types are distributed, other factors, such as soils, aspect, topographic features, and climate patterns, also play a role. As an example, shallow soils and south slopes at moderate elevations may be too warm and dry for Douglas-fir and instead favor pure ponderosa pine forests. Low temperatures, not moisture, limit regeneration of species mixtures at the upper elevation limits of this forest type, where single-species forests of subalpine fir, whitebark pine, or mountain hemlock take over.

Climate, soils, and topography

Climate varies widely depending on storm patterns and elevation. Most mixed-conifer sites receive about 20 to over 40 inches of moisture per year. The amount of moisture doesn't tell the whole story though: 20 inches per year deposited on north slopes is more effective for growth than the same amount on south slopes. Lightning is a frequent visitor in mixed-species stands; fire frequency and intensity vary widely. The climate is typically a mixture of maritime and continental, with most of the precipitation coming as snow in winter and with long periods of warm temperatures and little precipitation in summer.

Mixed stands grow under warm, dry conditions where ponderosa pine usually seeds in after a disturbance (see Chapter 1). These drier mixed forests were historically characterized by more-open stands of shade-intolerant ponderosa pine because the species is well adapted (e.g., thick bark) to survive frequent fire-return intervals (see Chapters 1 and 2) of every 5 to 25 years. Over a hundred years of fire suppression, livestock grazing, and logging have changed the species composition and structure of these forests. Now, shade-tolerant Douglas-fir or grand fir have regenerated in the understory and dominate the warm-dry mixed-conifer type. Grand fir's ability to produce seed consistently and in abundance creates an inertia that dictates species composition in its favor across the landscape. Incense-cedar and sugar pine can join this group on the east flank of the Cascades. Larch may also be present and play the role of a pioneer species where soils are deep and enough moisture is available.

The mixed-conifer forest type can be characterized as cool and moist where more moisture-demanding and cold-tolerant species such as subalpine fir, western white pine, and Engelmann spruce can grow (see Chapter 1). Shade-intolerant species such as western larch, especially in the Blue Mountains, and lodgepole pine are common as pioneer species in mixtures on these sites. Douglas-fir and grand or white fir are common, and ponderosa pine can also be present. Subalpine fir also grows at timberline, often in conjunction with whitebark pine. Although these cool-moist forests have experienced similar fire suppression, grazing, and logging impacts as the warm-dry mixed-conifer forests, their fire regime has probably not changed as much. Historically, fire occurred here at longer intervals with mixed- to high-severity patches common.

Where you have mostly pine in the overstory but Douglas-fir or grand fir in the understory, the site should be classified as a warm-dry mixed-conifer type. Engelmann spruce or subalpine fir are key indicators of the cool-moist mixed-conifer type. The pines, larch, and Douglas-fir can be found in either type.

Site capabilities, species potentials, erosion hazards, regeneration possibilities, and other aspects of management are linked to soils. Soils under mixed-conifer forests are highly variable. In much of the warm-dry mixed-conifer type in the Blue Mountains, for example, soils are primarily residual, developed from basalts and granites. Ash-capped soils from the Mount Mazama eruption are common in both the warm-dry and the cool-moist forest types in the Blue Mountains. These vary in depth, are located mostly on north- and east-facing slopes and benches, and are some of the most productive soils in the Blues because of their high water-holding capacity. Soils on the eastern slope of the Cascades in central Oregon were formed largely in pumice with loamy subsoils or were derived from basalt or tuff with stony loam textures.

Within the mixed-conifer zone there are sites with soils or topographic features that limit species mixtures. Shallow, rocky soils on ridge tops, for instance, limit available moisture so that only drought-tolerant ponderosa pine can grow, despite precipitation amounts that would normally allow species such as Douglas-fir to grow. Aspect affects tree distribution in steep canyons, where stands of Douglas-fir grow on north slopes. Just a few feet away, on the south exposure, only ponderosa pine or only grass and shrubs grow. Pure stands of lodgepole pine grow in frost pockets or wetter soils within mixed stands.

Available soil moisture is extremely important in influencing site productivity and species distribution. Nutrient availability and cold in some areas may limit productivity, but the amount of moisture available for plant growth appears to overshadow these factors over much of the area.

Association with other trees and understory plants

For more information about the tree species found in mixed-conifer forests, see Chapter 1; note the summary of species' tolerances of environmental factors in Table 1.2, page 13.

Cascades region

Warm-dry mixed-conifer forests: On the east slopes of the Cascades, the common tree species are Douglas-fir, ponderosa pine, grand fir or white fir, incense-cedar, and sugar pine. Western larch is occasionally part of this mixture from central Oregon north. In the understory, snowberry or golden chinquapin indicate better sites. Understories on drier sites are generally snowbrush ceanothus and manzanita.

In south-central Oregon, mixed-conifer types sometimes have only ponderosa pine and white fir, often with snowbrush ceanothus, manzanita, western needlegrass, and Ross sedge in the understory. Farther to the east and northeast, mixed-conifer forests tend to have more grand fir and less Douglas-fir.

Cool-moist mixed-conifer forests: On the east slope of the Cascades, Douglas-fir, grand fir or white fir, subalpine fir, mountain hemlock, and Shasta red fir are common tree species growing at mid to upper elevations. Ponderosa pine, western larch, Pacific silver fir, mountain

Figures 5.2a–b. At left, a mixed-conifer stand shows a dominance of regenerating and midstory Douglas-fir and grand fir and a few overtopping pines. Typical shrubs growing here are common snowberry, oceanspray, and ninebark. Grasses, sedges, and forbs such as Columbia brome, pinegrass, elk sedge, and heartleaf arnica also can be found. In the right photo, succession in a warm-dry mixed-conifer forest, with grand fir and Douglas-fir regenerating under and growing up through a canopy of ponderosa pine.

hemlock, and western hemlock can also be present. In general, the understory includes baldhip rose, gooseberry, big huckleberry, willow, twinflower, sedges, heartleaf arnica, lupine, and western hawkweed.

Blue Mountains region

Warm-dry mixed-conifer forests: Ponderosa pine, Douglas-fir, grand fir, and larch grow between the drier, lower-elevation ponderosa pine forests and the higher-elevation cool-moist mixed-conifer forests (Figures 5.2a–b). Elevations normally range from 2,200 to 4,500 feet, where precipitation is about 20 to 30 inches annually. In northeast Oregon, western larch is common on better sites and lodgepole pine can be present on wetter sites but plays a minor role. These forests are typically patchy with lots of variation in density, species composition, and tree size. What appear to be pure stands of shade-intolerant ponderosa pine, western larch, or lodgepole pine can be found; however, small numbers of the more shade-tolerant species generally grow there also, indicating that without further disturbance the stands eventually will become dominated by the more shade-tolerant species, Douglas-fir and/or grand fir.

In the understory, mallow ninebark, snowberry, spiraea, oceanspray, heartleaf arnica, baldhip rose, Columbia brome, Kentucky bluegrass, elk sedge, and pinegrass are widespread.

Cool-moist mixed-conifer forests: This forest type is generally found where moisture levels are 30 inches or more, temperatures are cooler, and species such as subalpine fir and Englemann spruce can grow. Larch and lodgepole pine are common pioneer species after a disturbance, and Douglas-fir and grand fir can be present.

Ponderosa pine may be found, too, but usually is limited to elevations below about 4,500 feet; above that, heavy snow loads can cause extensive breakage. Engelmann spruce and lodgepole pine are found more commonly on frosty flats, along streams, and on wet soils. Understory plants vary by site, but typically you'll find grouse huckleberry, white trillium, Oregon boxwood, big huckleberry, twinflower, prince's-pine, Rocky Mountain maple (along streams), pinegrass, and elk sedge.

It is important to note that there are intrusions and variations of these two mixed-conifer types as well as other forest types in the landscape. Within the mixed-conifer type are sites with less or more available moisture because of elevation, aspect, or soils, so species mixtures and productivity vary widely.

Quaking aspen and black cottonwood: Quaking aspen stands in patches and cottonwoods along streams are two unique habitats in the mixed-conifer type. Managing them is important for scenic vistas, wildlife, fish, and water-quality benefits.

Groups of aspen trees that have reproduced from a single clone are common. Although quaking aspen regenerates from seed, root suckering is more common. Suckering is stimulated by disturbance, and plenty of light is essential for growth of new shoots. Without disturbance from fire or other means, quaking aspen stands may decline as older trees die from insects and disease and the stand is invaded by conifers such as shade-tolerant grand fir and/or Douglas-fir and sometimes shade-intolerant ponderosa pine on drier sites.

Many quaking aspen stands are in decline across eastern Oregon as a result of fire suppression, livestock and elk, and lack of management. Yet they play a vital role by providing important diversity across the landscape and important habitat for such species as ruffed grouse and northern goshawks. One obstacle to converting older stands to young, vigorous stands is that big game and livestock like to browse new sprouts. Fencing may be the only choice for controlling damage (see *Land Manager's Guide to Aspen Management in Oregon*, EM 9005, https://catalog.extension.oregonstate.edu/em9005).

Black cottonwood is the largest hardwood tree in the Pacific Northwest and is found in abundance along streams and oftentimes in the upland in eastern Oregon. This species provides shade along streams, cavities and structural diversity for wildlife, food for aquatic organisms, and bank stability. Associated species include Scouler's willow, redosier dogwood, and Lewis' mock orange.

Stand initiation and development

Seed production and germination

Adequate seed production and germination are important in establishing natural regeneration after disturbances in mixed-conifer forests. Good seed production depends on healthy, vigorous, mature seed trees. Trees should have long, full crowns; healthy foliage; favorable genetic characteristics (e.g., small-diameter limbs, little taper); and little or no evidence of insects, disease, or mechanical damage. Pine and Douglas-fir tend to have large seed crops about every 2 to 5 and 2 to 11 years, respectively (see Table 6.4, page 132). Larch seed is lighter than that of pine and Douglas-fir, and cone production is less frequent. Grand fir, subalpine fir, and Engelmann spruce produce large amounts of seed almost every year. Incense-cedar produces good seed crops every 3 to 6 years. Good seed production on individual grand fir trees and their abundance on the landscape create an inertia of seed and seedlings that can rapidly capture a site.

Seed falls from September to November. Generally, if collecting cones for seed, collect cones in late summer when seed is mature but cones are still closed. Timing of cone maturity and seed fall varies by species, elevation, aspect, and annual weather patterns. Check with your local OSU Extension forester, Oregon Department of Forestry stewardship forester, or consultant for local guidance.

Seed weight, wind patterns, tree height, and topography affect seed distribution. For example, western larch yields 136,000 seeds per pound. Given the same tree height, larch seed will travel farther than ponderosa pine seed, which is relatively heavy, averaging 12,000 seeds per pound. Douglas-fir seed is somewhat lighter than the pine's, at 49,000 seeds per pound. Incense-cedar seed has a large wing (about an inch long), which allows it to fall slowly and disperse long distances. If during harvest you leave trees to distribute seed, consider prevailing wind patterns and slope position; for example, trees on higher slope positions (ridge tops) do a better job of distributing seed. Leave trees with potential for good cone production—those with full crowns and with plenty of old cones on the ground. Seed fall distance for Douglas-fir is about two times tree height, the lighter larch seed goes farther, and, because true fir cones disintegrate on the branch, seed falls relatively close to cone-producing trees.

For stand establishment, good seed production and dispersal must be coupled with favorable seedbeds. Generally, mixed-conifer species germinate best when their seed falls on exposed mineral soil. Most seeds that germinate in duff will desiccate quickly unless conditions are cool and wet for extended periods of time. True firs, however, also can survive in light litter and duff up to about 0.5 inch thick, giving these species a germination advantage where soil is not exposed. Grass competition can limit seedling establishment and growth of all mixed-conifer species, particularly on warm, dry sites. For more-detailed information on differences in natural regeneration and seed production among species, see Chapters 1, 2, and 6.

Seedling and stand development

Germinated seedlings are exposed to heat, cold, wind, drought, animals, and other factors that affect their survival and growth. Organic seedbeds get hotter than mineral soil. Temperatures over 150°F can be lethal to germinating seedlings at the soil surface. Seedlings, especially during early growth, are susceptible to frost damage. Overstory conifers can moderate temperature extremes; on some mixed-conifer sites, this is critical to establishing some species (e.g., Douglas-fir on more-exposed hot, dry sites and in frost pockets). Seedlings are especially vulnerable to moisture stress; thus, competition from grasses and sedges can limit seedling survival and growth (see Chapter 6). Wildlife also take their toll on young seedlings. Look for browsing of the laterals and top (deer, elk), horn rubbing of the main stem (deer, elk), girdling at the base (voles), and root loss (gophers); see Chapter 6. Off-color foliage is often an early indicator of stem and root damage.

Early growth characteristics or juvenile height growth helps predict how trees in mixtures will compete with one another and how forests will develop. Lodgepole pine, western white pine, and western larch have rapid juvenile height growth rates; Douglas-fir and ponderosa pine have moderate rates; and grand fir, subalpine fir, and Engelmann spruce typically have slower rates. Even though species with slower juvenile height growth can't keep up initially,

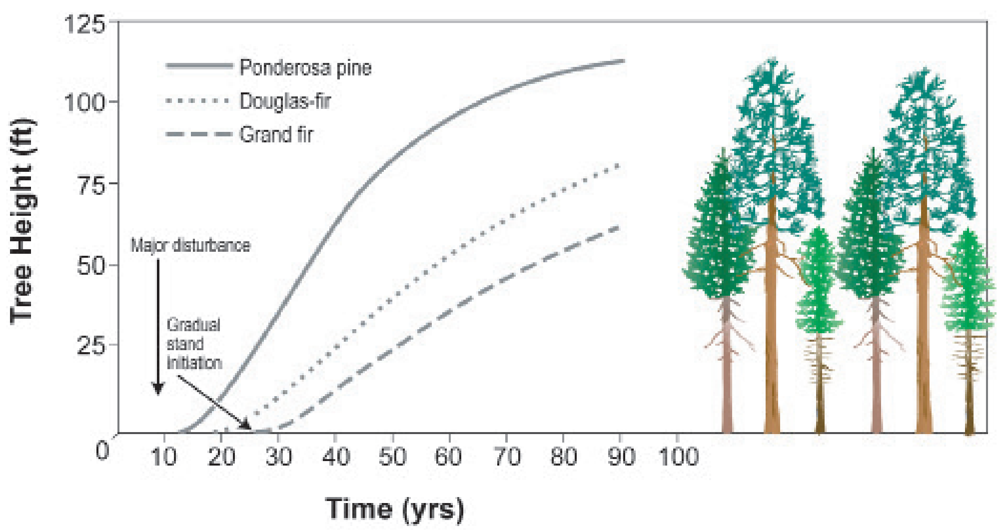


Figure 5.3. How mixed-conifer stands develop. In one model, a pioneer species such as ponderosa pine captures a site after a major disturbance. Over time, shade-tolerant species such as Douglas-fir and grand fir seed in under the pine, eventually growing up into the pine canopy and dominating the site (adapted from Oliver and Larson 1996).

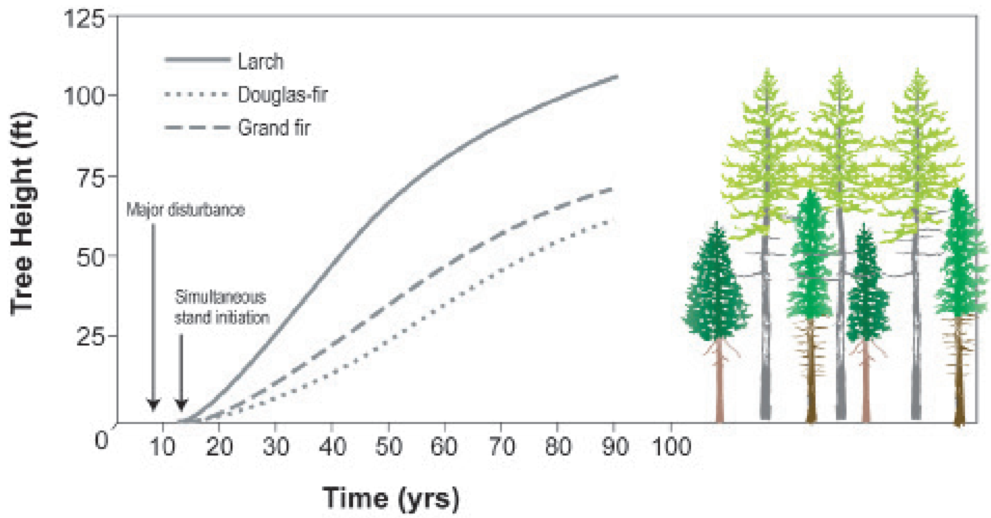


Figure 5.4. Simultaneous stand initiation. Here, several species get started at about the same time after a disturbance. Faster growing species such as larch surpass the more shade-tolerant species in the understory, which eventually grow up through the canopy to dominate the site (adapted from Oliver and Larson 1996).

some have higher shade tolerance (e.g., grand/white fir and Douglas-fir) and/or stiff, strong branches (grand fir) and eventually may move up through the canopy. In other cases, these shade-tolerant species can stay suppressed in the understory for decades.

If shade-intolerant species are overtopped by faster-growing species, they may be trapped in the understory, become suppressed, and eventually die. Watch your species mixtures; use early thinnings to adjust species composition as well as spacing to keep shade-intolerant species growing rapidly.

Shade tolerance directs stand development and species composition of mixed-conifer forests. Ponderosa pine, western larch, and lodgepole pine are least tolerant to shade; grand fir, Engelmann spruce, western hemlock, and subalpine fir are most tolerant. Douglas-fir, incense-cedar, and western white pine are in between (see Chapter 1).

Competition between species is played out through two successional models. In one, a shade-intolerant species such as ponderosa pine is the pioneer, capturing a site after a disturbance (Figure 5.3, page 88). Over time, shade-tolerant species such as grand fir and Douglas-fir seed in and begin growing in the shade of the pioneer species, eventually growing up through the canopy and dominating the site until a disturbance restarts the successional cycle. This model is fairly common in the warm-dry mixed-conifer type.

In the second model, several species get started about the same time after a disturbance. Dominance on the site depends on the different species' growth rates and development patterns, not on which species got there first. Fast-growing shade-intolerant species jump ahead, leaving the tolerant species in the understory. Even-aged mixed stands of western larch, pine, grand fir, and Douglas-fir are a good example (Figure 5.4). Because those trees grow and develop at different rates, the stand gradually develops a multistoried structure with western larch and pines in the upper reaches of the canopy and the slower-growing Douglas-fir and grand fir capturing the lower layers. All trees are approximately the same age although some are large and others smaller.

Growth and yield

Mixed-conifer forests have so many species and age combinations that it's difficult to build models or conduct scientific studies that account for this variation. Predicting how mixed-conifer forests will grow and what they will yield is more complicated than predicting for pure stands. The Forest Vegetation Simulator is a U.S. Forest Service simulation model that estimates growth of mixed stands. A detailed discussion of the model is beyond the scope of this manual; contact a U.S. Forest Service silviculturist or an OSU Extension forester for more information.

The tools described here for estimating site productivity and stand growth in even-aged stands should be used conservatively. They are best for comparing options, not for calculating exact growth and yield information for a specific stand.

Site index

Soils, aspect, elevation, climate, and other factors influence productivity of mixed-conifer forests. Site index (SI) is a good way to measure site productivity. It is based on dominant and co-dominant tree height at a particular age in even-aged stands. (See Chapter 2 for how to measure and use site index.) Site index curves for managed stands of Douglas-fir and grand fir and natural, even-aged stands of western larch are shown in Figures 5.5 through 5.7. The curves are useful also for comparing heights of dominant trees of the same age among species. Site index curves for ponderosa and lodgepole pines are in Chapters 3 and 4, respectively.

On moderate sites (site index 70 to 80), expect Douglas-fir in even-aged stands to reach 100 to 118 feet in height and 22 to 24 inches in diameter at 100 years. Grand fir will be slightly taller (105 to 120 feet) and will have diameters of 26 to 28 inches. Western larch heights and diameters are similar to Douglas-fir's for comparable sites and ages, but ponderosa pine will be shorter and thinner at the same age. On moderate sites, in 100 years subalpine fir grows to 60 feet with a diameter of 10 inches. Engelmann spruce on good sites will be 90 feet tall and 20 inches after 100 years, while incense-cedar reaches 80 feet in height with a 16-inch diameter.

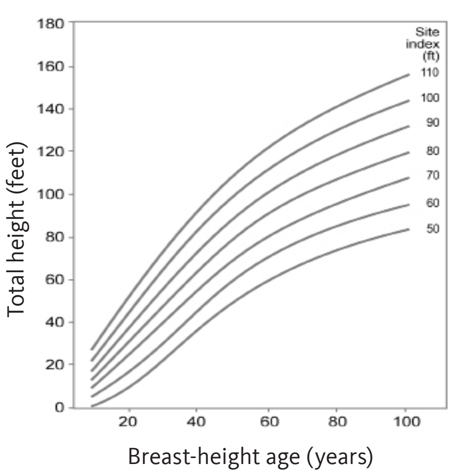


Figure 5.5. Site index curves for managed, even-aged stands of white or grand fir east of the Cascades in Oregon and Washington on a 50-year basis (Cochran 1979c).

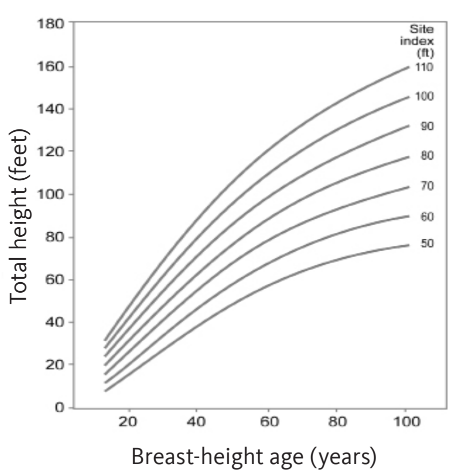


Figure 5.6. Site index curves for western larch on a 50-year basis (Cochran 1985).

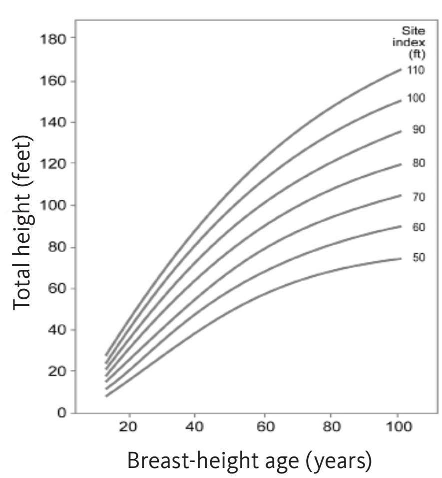


Figure 5.7. Site index curves for managed, even-aged stands of Douglas-fir east of the Cascades in Oregon and Washington on a 50-year basis (Cochran 1979b).

Cubic-foot and board-foot production

Tables 5.1 through 5.3 (below and on page 92) estimate net cubic-foot productivity (that is, gross volume minus mortality) by age and site index for Douglas-fir and grand fir and gross volumes for western larch. Yields in the tables are based on the limited published information available for eastside species; intensive management theoretically may increase net volumes over those in the tables. Net volumes at age 100 at these site indexes range from 3,378 to 16,605 cubic feet per acre for Douglas-fir, from 6,839 to 18,940 cubic feet for white or grand fir, and from 2,948 to 11,608 cubic feet per acre for western larch. Most sites in eastern Oregon will have site indexes of 50 to 100. The net volumes in these tables are 76 percent of the gross volumes for Douglas-fir and 59 to 71 percent of gross volumes for grand or white fir.

To get a *rough* estimate of board-foot volume, multiply cubic volume by 3.2. In precise calculations, conversion factors vary, increasing with tree diameter. The factor of 3.2 is suggested as a way to simplify; however, the result will be "ballpark" only.

On a moderately good site (SI 80), pure stands of even-aged Douglas-fir can reach net yields of about 29,000 board feet of wood fiber per acre after 100 years, and grand fir can

Table 5.1. Net cubic-foot volume of Douglas-fir east of the Cascades in Oregon and Washington (from Cochran 1979a). Site index based on 50 years at 4.5 feet.

Breast-height age (years)	Site index (feet)						
	50	60	70	80	90	100	110
20	481	717	1,014	1,371	1,787	2,262	2,793
30	865	1,311	1,860	2,507	3,248	4,081	5,001
40	1,263	1,914	2,701	3,619	4,660	5,817	7,085
50	1,654	2,496	3,505	4,670	5,981	7,428	9,004
60	2,030	3,051	4,264	5,654	7,208	8,916	10,767
70	2,391	3,578	4,978	6,574	8,350	10,294	12,392
80	2,735	4,076	5,650	74,36	9,415	11,573	13,897
90	3,065	4,550	6,285	8,285	10,412	12,767	15,296
100	3,378	5,000	6,885	9,009	11,349	13,886	16,605

Table 5.2. Net cubic-foot volume of grand fir or white fir east of the Cascades in Oregon and Washington (from Cochran 1979a). Site index based on 50 years at 4.5 feet.

Breast-height age (years)	Site index (feet)						
	50	60	70	80	90	100	110
20	446	736	1,073	1,444	1,838	2,249	2,671
30	1,244	1,879	2,567	3,285	4,018	4,757	5,495
40	2,142	3,095	4,019	5,104	6,118	7,122	8,111
50	3,036	42,68	5,527	6,787	8,031	9,250	10,440
60	3,892	5,366	6,851	8,320	9,757	11,155	12,511
70	4,699	6,387	8,068	9,716	11,318	12,867	14,363
80	5,458	7,335	9,188	10,993	12,737	14,417	16,033
90	6170	8,217	10,223	12,166	14,035	15,830	17,,551
100	6839	9,039	11,183	13,249	15,230	17,126	18940

reach 42,000 board feet. On an annual basis, this is about 300 to 400 board feet per acre for the 100-year period. Western larch yields 25,000 board feet for similar sites and ages. It is interesting to note that, on these moderate sites, pure, even-aged stands of grand fir theoretically could support about 45 percent more volume at 100 years than comparable Douglas-fir or larch stands. One explanation for grand fir's ability to produce more volume is that its higher shade tolerance allows trees to grow more efficiently when packed together; thus, they can grow more wood than other, more shade-intolerant species. Because Douglas-fir is more shade tolerant, we would expect somewhat higher yields from this species compared to larch as well.

These theoretical yields of pure stands must be considered, however, in light of what you find in the forest. Few mixed-conifer sites support pure stands, so the tables provide generalizations only. And, although theoretically the highest yields will be where grand fir grows in pure stands, there are serious risks to growing grand fir this way. Defoliators and root disease can cause large losses, and grand fir is susceptible to fir engraver attacks, especially in unmanaged stands, in root-disease areas, and during drought cycles (see Chapter 7). Where you have good grand fir sites (those with deep soils and adequate moisture, at higher elevations and on north slopes), grand fir can provide more-predictable high-volume yields. Add the fact that market values for grand fir have been lower and more variable than for ponderosa pine, western larch, and Douglas-fir. Just remember, there are tradeoffs.

The availability and applicability of site-index curves or yield tables for Shasta red fir, western white pine, Engelmann spruce, and mountain hemlock are discussed in Seidel and Cochran (1981). Research on these species that is applicable to eastern Oregon is either not available or sketchy; thus, growth and yield information is not provided in this manual.

How can management influence timber yield? As a general rule of thumb, on average, reasonably stocked stands of sawtimber in mixed-conifer forests in eastern Oregon grow between 150 and 300 board feet per acre per year; this is volume growth at 2 to 4 percent per year. Practices that improve tree growth and capture value in dead or dying stands through timely salvage harvests will increase usable board-foot yields significantly—as much as 20 to 50 percent over unmanaged stands.

Growth and yield information for uneven-aged stands is not readily available; however, we do know it would be different from even-aged stands in the short term. Uneven-aged stands are maintained at lower stocking than even-aged stands.

Table 5.3. Total cubic-foot volume for western larch for Oregon and Washington (adapted from Schmidt et al. 1976). Site index based on 50 years at 4.5 feet. Yield tables were validated for Oregon and Washington, and the site index values used here were revised by using a formula in Cochran 1985.

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
20	165	246	336	434	538	648
30	548	819	1,118	1,443	1,790	2,157
40	999	1,494	2,040	2,632	3,265	3,934
50	1,433	2,142	2,926	3775	4,682	5,643
60	1,823	2,724	3,721	4,801	5,955	7,176
70	2,164	3,235	4,419	5,701	7,071	8,521
80	2,462	3,680	5,026	6,484	8,043	9,692
90	2,721	4,067	5,555	7167	8,890	10,714
100	2,948	4,407	6,019	7,765	9,632	11,608
110	3,148	4,705	6,427	8,292	10,285	12,394
120	3,325	4,970	6,788	8,757	10,862	13,090
130	3,482	5,205	7,109	9,172	11,376	13,710
140	3623	5415	7397	9543	11,836	14,264

Silvicultural systems

One of the first decisions to make about managing your mixed-conifer forest, after determining your objectives and assessing stand conditions, is which silvicultural system to select. Even-aged and uneven-aged systems are two basic approaches (see Chapter 2). As a result of past harvesting and fire suppression practices, many mixed-conifer forests have two to three age classes, making uneven-aged management an understandable choice. However, many stands have been high-graded (e.g., repeated diameter-limit cutting) and consist of too many shade-tolerant species such as grand fir and Douglas-fir that are more susceptible to aggressive defoliators as well as bark beetles (Figures 5.8a–c) and root disease. These stands also carry a high proportion of poor-quality trees. The key to a healthy forest is assessing your forest situation and applying the appropriate silvicultural tool for your objectives.

Figures 5.8a–c. Failure to manage mixed-species stands can result in a higher proportion of Douglas-fir and grand fir and a higher susceptibility to western spruce budworm, one of the more aggressive defoliating insects. Damage from that pest can vary, from loss of new growth (at left), to top kill (below left) to heavy mortality in the stand from defoliation and bark beetles (below right).

Even-aged regeneration methods

Clearcutting

For most woodland owner situations, clearcutting (Figure 5.9) generally is reserved for converting damaged or at-risk stands of both mixed-conifer types to create healthy, more-pest-resistant forests. It's a method well suited for regenerating shade-intolerant species, such as larch and pine. Clearcuts have an economic advantage because fixed costs are spread over a larger harvested volume. Most clearcuts on woodland properties are used to deal with pest issues, such as converting a root disease area to resistant species or heavy infestations of dwarf mistletoe to a mistletoe free, newly regenerated forest (see Chapter 2). Avoid clearcutting on exposed south slopes in the warm-dry mixed-conifer zone or in cold-pocket areas in the cool-moist mixed-conifer type; temperature extremes can limit survival and growth of regeneration. Instead use shelterwood systems to moderate site temperatures.

Be prepared to replant all clearcut areas unless local knowledge indicates natural regeneration will be successful. The middle of larger clearcuts will not regenerate naturally very well because the seed in edge trees will only regenerate the edges. The Oregon Forest Practices rules set regeneration standards and regulate reforestation after harvest by requiring restocking within a certain time after stands are clearcut. As a general rule, treat natural regeneration as a supplement to planting. If advanced regeneration is present, you could consider using it for your future stand, but you need to determine whether it is the best species for the site and healthy enough for your new crop. If you are planning on natural regeneration to meet your reforestation goals, design clearcuts so seed reaches all parts of the area and falls on receptive ground. Natural regeneration has its best success on north and east slopes at distances up to 350 feet from the seed source (see Chapter 6).

Ponderosa pine and Douglas-fir are good choices to plant on sites below 5,300 feet in the mixed-conifer zone. On east and north slopes in the warm-dry mixed-conifer zone, ponderosa pine and Douglas-fir grow well; however, Douglas-fir does better with some shade on these sites. On south slopes plant ponderosa pine unless local knowledge shows Douglas-fir does well.

Figure 5.9. Small clearcuts or patch cuts in mixed-conifer forests can meet a variety of goals including converting a stand infested with dwarf mistletoe or root disease to a more healthy condition.

Western larch grows well in larger openings and clearcut areas on north and east aspects in both the warm, dry and the cool-moist types, but use caution on south and southwest aspects where moisture stress and sun exposure are high. Larch can grow on a variety of sites but does best on cooler aspects with more moisture and ash soils. Larch can grow on drier sites, but its growth is reduced.

In the cool-moist mixed-conifer zone where soils are wetter, or in frosty areas, lodgepole pine and Engelmann spruce are good candidates for planting.

Plan to plant and favor a variety of species to decrease the chance that all trees will be lost if disease or insects move in. Keep clearcuts small (20 acres or less) and blend them into the landscape by using irregular edges and adjusting for the natural topographic features to create a shape

Photo: Boyd Wickman

Figure 5.10. Shelterwood harvests provide seed and shelter from temperature extremes. It's important that the shelterwood system be open enough to allow for the sunlight needs of pine and larch, which are greater than fir species' need for sun. Reforestation goals can be met with natural seeding, hand-planting, or a combination of both.

like that from a natural disturbance. Leaving some snags and green trees for future snags can add a more appealing view as well as wildlife habitat (see Chapter 9). Planting with site-adapted species increases the probability of successfully regenerating the site and shortens establishment time. Planting with "off-site" species can increase mortality and risk of damage from ice and snow (e.g., to ponderosa pine at higher elevations), increase the long-term risk of damage by insects and disease, and slow growth. Competing herbs, grasses, and shrubs on any mixed-conifer site can reduce survival and growth of regeneration. Especially watch warm, dry exposures where grass is extensive, and, if necessary, use site-preparation or release treatments to reduce competition (see Chapter 6).

Shelterwood and seed tree cuttings

When considering shelterwood or seed tree cuts, remember Oregon Forest Practices reforestation requirements are triggered if stocking is reduced below minimum standards set in the OFP rules.

Shelterwood cuttings: Natural regeneration across most mixed-conifer sites has been good with shelterwood cuts, although it can take a number of years. In warm and dry or cool and moist mixed-conifer forests, consider shelterwood cuttings where warm, dry south or southwest slopes or frost pockets may limit regeneration success (Figure 5.10). Retain 10 to 20 well-distributed, large, cone-bearing trees (30 to 50 square feet of basal area) per acre to provide seed and cover for regeneration (see Chapter 2). Adjust shelterwood stocking depending on site and stand conditions. For instance, south slopes in the warm, dry type need more cover (shade) than similar exposures in the cool-moist type.

Natural regeneration success can be improved by creating a favorable seedbed. Shade-intolerant species germinate better on mineral soils. Logging disturbance, mechanical scarification with a brush blade, or prescribed burning are three ways to create that seedbed.

Shelterwoods are a good way to convert stands dominated by true fir and Douglas-fir into stands with more western larch, ponderosa pine, or lodgepole pine if these species are in the overstory. Leave larch and pine to get these species regenerated on the site, and plant when in doubt or if the preferred species do not regenerate. In fact, larch has such infrequent seed crops that you should plan on planting it. Shelterwoods are also a good technique for creating two-aged stands to jump start an uneven-aged stand structure in the future (see Chapter 2).

On warm-dry mixed-conifer sites, favor ponderosa pine in the drier areas and larch where there's more moisture. On better sites, one option might be 50 percent ponderosa, 20 percent western larch, and 30 percent Douglas-fir.

In cool-moist forest types, focus on larch and lodgepole pine. Plan for 40 percent western larch, 20 percent lodgepole pine and/or ponderosa pine (if not too high in elevation for the ponderosa), and 40 percent grand fir, Douglas-fir, subalpine fir, and Engelmann spruce. Try to keep Douglas-fir and grand/white fir to less than 40 percent to lesson impacts from western spruce budworm and Douglas-fir tussock moth outbreaks. Generally, grow grand/white fir where it grows best, on sites with over 40 inches of precipitation as a rule of thumb. Grand fir grows almost anywhere there is enough moisture and produces abundant seed so lots of trees germinate; unfortunately, this includes drier mixed-conifer sites with high moisture stress. This species has low drought tolerance, so during droughts and times of higher than normal temperatures, it is very susceptible to fir engraver bark beetle attacks and mortality. Grow grand fir only on cool-moist sites to get good growth and healthy trees and to protect your investment.

Dense stands are vulnerable to windthrow after a shelterwood harvest. If stands are very dense, thin trees 5 to 10 years before the shelterwood cut to build windfirmness. Also, avoid creating shelterwoods on ridge tops, shallow or wet soils, and areas where winds funnel. Keep as much healthy ponderosa pine, larch, and Douglas-fir as you can because of their deep root systems.

Seed tree cuttings: Seed tree cuts are not as common as shelterwood cuttings in mixed-species forests because of their high windthrow potential and lack of consistent success. On cool-moist mixed-conifer sites, seed tree cuts might be an option where windthrow risk is low. Western larch and ponderosa pine are species with high sunlight requirements and deep roots, making them good candidates for seed trees. Leave two to nine trees per acre. Monitoring natural regeneration is critical. If the stand is not regenerating in two to four years, plant seedlings. Local success can be a good way to guide whether to rely on natural regeneration. In warm-dry mixed-conifer stands, leave the thicker-barked, fire-resistant larch, ponderosa pine, and large Douglas-fir for increased protection from wild and prescribed fires.

Leave trees: Leave trees should be good seed producers and the right species for the

Regeneration: A Summary

Here's a summary of the guidelines for getting good pine and larch regeneration on warm-dry mixed-conifer sites or larch and lodgepole pine on cool-moist sites with even-aged silviculture.

Clearcutting

- *Clearcutting is a good way to convert insect- or disease-damaged areas to healthy stands.*
- *Smaller is better, 5 to 20 acres if possible.*
- *Plant seedlings to accelerate the development of forest cover and improve species mixes.*
- *Carefully select species to plant; for example, Douglas-fir and western larch are harder to grow on harsh sites due to soil moisture limitations.*
- *Watch for competing vegetation and control if necessary.*

Shelterwood and seed tree cuts

- *Good for warm and dry, frosty, and high-water-table sites.*
- *Leave healthy, vigorous seed trees.*
- *Adjust for windthrow risk.*
- *Favor pine seed trees on warm, dry sites and larch and lodgepole on frosty or moist sites.*
- *Plant pine and larch if naturals are few or regeneration is low.*
- *Watch for dwarf mistletoe; if present, remove overstory once regeneration is established.*
- *If overstory is removed, protect regeneration during harvest.*
- *Remember the high sunlight needs of pine and larch. If there's not enough light, trees can become tall, thin "whips" (see Chapter 2).*

site conditions, harbor little or no dwarf mistletoe or other diseases, have a history of cone production (cones on the ground), and have long, full crowns (see Chapter 2). Seed trees with favorable genetic characteristics (small-diameter limbs, no forks, and good taper) improve stand quality.

Once regeneration is established, the overstory can be harvested in one or two stages or left in place to provide structure for wildlife and promote a two-aged stand, setting the stage for uneven-aged management. Take care when removing the overstory to protect regeneration. Work with the operator during the planning phase so that they understand that retaining advance regeneration is a priority. Designated skid trails and directional felling are two methods that help lower regeneration damage and soil impacts (see Chapter 2). If overstory trees are infected with dwarf mistletoe and if the understory is the same species as the overstory, remove the overstory before regeneration is 4 to 6 feet high or 10 years old, whichever is first (see Chapter 7).

Uneven-aged regeneration methods

Uneven-aged management in mixed-species stands requires considering three major factors: (1) the different shade tolerances of the various species (Table 1.2, page 13), (2) differences in growth among species on the same site, and (3) pest issues on the site, especially root disease and dwarf mistletoe. For example, if pole-sized and larger ponderosa pine and grand fir are growing side by side, healthy grand fir will grow faster in both height and diameter than the pine. Because grand fir is more shade tolerant than pine, it will tend to grow up past the pine and suppress it. Increasing tree spacing to a density that encourages good pine growth will tend to enhance growth and development of high crown ratios in grand fir. As a result, over time grand fir will produce larger trees sooner and will need to be harvested so that it does not dominate the site. Root disease susceptibility of grand fir is high, so shifts to more-resistant species will be paramount for uneven-aged management to be successful. If dwarf mistletoe is present, implementing uneven-aged management will be challenging without managing for the mistletoe. Because of the complexity of implementing uneven-aged silviculture and the potential for high-grading, we suggest you also consult professionals before using these systems. General guidelines follow.

Figures 5.11a–b. Individual tree selection (ITS) in mixed-species stands focuses on leaving healthy trees in a variety of age and size classes, as in these photos. ITS promotes development of shade-tolerant species. It also is more expensive than other sytems to carry out and has potential to aggravate some pests including root disease and dwarf mistletoe. However, if carefully planned and carried out, ITS can meet many forest health and other objectives, including a more consistent income flow.

Individual tree selection

Stands in the warm, dry and the cool-moist mixed-conifer zones with two or more age classes—especially mature stands without dwarf mistletoe and root disease—are well suited to individual tree selection (ITS) methods (see *Individual Tree Selection (ITS) in a Northeast Oregon Mixed Conifer Forest*, EM9083, https://catalog.extension.oregonstate.edu/em9083 and Chapter 2). You can avoid predisposing these stands to insect or disease pests by managing species composition, density, and tree vigor.

Plucking out a tree here and there in a mixed-conifer forest causes small disturbances that favor regeneration of shade-tolerant species. Consequently, Douglas-fir and grand fir in warm-dry mixed-conifer stands and grand fir, Douglas-fir, subalpine fir, and Engelmann spruce in cool-moist forests will tend to dominate these sites. Planting ponderosa pine and/or larch in larger openings or small group cuts in warm-dry mixed-conifer sites or planting lodgepole and/or larch on cool-moist sites can improve the species mix. However, openings must be 1 to 3 acres to provide enough light for good survival and growth for the shade-intolerant species. In 1-acre openings you can expect larch and pines to do well only in the middle of the openings because of their great need for light; on north slopes, openings larger than 1 acre are necessary.

Many people think the ITS management system is aesthetically appealing. Applied over large areas, it produces vistas of more continuous forest cover. In the stand, there is good vertical structure (i.e., layering of multiple age-class crowns) and a mixture of species, which is visually pleasing (Figures 5.11a–b, page 97).

Many mixed-conifer stands in eastern Oregon have been high-graded. What is high-grading? It's when the best trees have been removed (sometimes repeatedly) during a diameter-limit logging removing just the bigger trees with no control over quality or species selection. Most high-grading has taken the early pioneer species out of the overstory and left the shade-tolerant species. How do you know whether your stand has been high-graded? Look for these signs:

- Mostly grand fir and Douglas-fir in the overstory and big, old pine stumps
- A prevalence of root diseases
- A preponderance of Douglas-fir, grand fir, subalpine fir, and Engelmann spruce reproduction
- A disproportionate number of crooked stems, poor live-crown ratios, dead or damaged tops, small crowns, damaged boles, etc.

In a warm-dry mixed-conifer forest, improve productivity by taking out poor-quality trees first; harvest Douglas-fir and grand fir primarily, and attempt to create openings of at least 1 acre to get the light-loving species to grow. One option is to expand openings where they exist. Encourage ponderosa pine and western larch where they occur and protect them. Options will depend on stand condition. For example, if the stand is heavily dominated by grand fir, it may be very difficult to create enough light to plant pine and larch without patch cutting or using some sort of group selection strategy. On the other hand, if there are some desirable species that can be left, don't risk doing too much too fast. Windthrow may be a problem after an intensive thinning, and smaller grand fir can be left until the next entry to get a merchantable log. Remember, you usually can't do it all in one entry.

The approach is the same for a cool-moist forest type, except the species to keep and promote are western larch and lodgepole pine; however, Douglas-fir and grand fir should grow well too. Promote shade intolerants by creating openings and retaining them during thinning, grow Douglas-fir in the mix, and feature more grand fir where it grows best, on the best sites. Watch for root disease. Where you find it, plant resistant species (see Chapter 7). Where mostly subalpine fir grows at higher elevations, forests are primarily valued for aesthetics as part of a recreational site or for wildlife. Less management is necessary here except for perhaps thinning to keep stands thrifty and healthy.

As shade-tolerant species become more prominent in the stand, risk from insects and disease increases. Defoliator damage (e.g., Douglas-fir tussock moth) and bark beetle attacks are risks especially in warmer, dry forest types; root diseases are a greater risk on cool-moist mixed-conifer sites. Multiple selection harvests in stands dominated by true firs can magnify root- and stem-disease problems as diseased roots are moved about, healthy roots are broken off, and soil is compacted.

Wounding trees during harvest can activate dormant stem decay fungi, such as Indian paint fungus, or provide entry points for other fungi. Keeping true fir at ages below 100 years helps lower defects from heart rot. Promoting good tree vigor through selecting healthy leave trees, maintaining good, deep crowns, and controlling stocking are ways to lower susceptibility to insects and disease. Combining these practices with proper species control will protect stands even more.

Determine a cutting cycle for commercial selection harvests. In mixed-conifer forests, the cutting cycle depends on factors such as the site's productivity, timber type, and stocking (see Chapter 2). Generally, plan on a 10- to 20-year cutting cycle. In both mixed-conifer types, better sites with plenty of larger trees allow frequent, light harvest entries, which can meet periodic-income objectives. Also, larger, more valuable trees such as yellow-bark (older) ponderosa pine allow you to take fewer at a time because each tree is worth more.

Cutting frequency also depends on your objectives, insect and disease problems, and the timber market. If you need more income now, you will cut more heavily and extend the time to the next entry. Likewise, insect problems or a good timber market favor taking more now.

You also need to establish a target maximum tree size (see Chapter 2)—in most cases, 20 to 25 inches dbh for mixed-conifer stands. Harvest trees that reach this diameter. This limit can vary depending on marketing and mill diameter limits; for instance, ponderosa pine generally increases in value with increased diameter up to about 20 inches. Other species such as Douglas-fir are purchased at the same price independent of log diameter. Some mills have an upper diameter limit above which they will reduce the purchase price, usually because their debarker can process logs only up to a given size. Check local markets.

Beware, however, of harvesting just the larger trees. If you do, eventually the stand will change from uneven-aged to even-aged. Smaller trees must be thinned to get big trees! Individual tree selection systems manage densities at 50 to 75 percent of the maximum (upper) stocking level targets (see Tables 5.6 to 5.14, pages 119–124). This guideline is based on uneven-aged management in other parts of the world and has the goal of getting regeneration fast.

Evaluate your mixed-conifer stands first before you decide to use this system, as it has limitations. For instance, gentle topography allows frequent, economical entries. Steep terrain can lengthen timing because each entry costs more; steep slopes require more-expensive cable logging systems.

Stands with extensive root disease are poor candidates for individual tree selection because the cumulative effect of regular entries is more damaging to trees and roots. Individual tree selection promotes regeneration of fir, instead of root-disease-resistant pine and larch, and it contributes also to higher disease potential. Stands with dwarf mistletoe are poor candidates for individual tree selection because the mistletoe spreads from overstory to understory trees of the same species. These stands tend to have more ladder fuels, making them more susceptible to crown fires.

In mixed-species stands, manage slash by using one or a combination of these practices (see Chapter 10):

- Whole-tree yarding (bole, limbs, and top skidded to the landing for processing)
- Lop and scatter (tops bucked into pieces and left in the woods, unpiled)
- Piling and burning
- Chipping

Whole-tree yarding requires larger landings and, unless you use special precautions such as designated skid trails and rub trees, this system can cause unacceptable damage to residual trees. Lop and scatter works well with species such as ponderosa pine and lodgepole pine if done between August and December to keep *Ips* (pine engraver) populations low; you can use this method with western larch and Douglas-fir any time of year. Fir engraver beetles also build up on grand fir slash; however, beetles moving from slash to standing trees is not as common. Grand fir and subalpine fir have more limbs and thus may require piling and burning. Except for whole-tree yarding, keep piles small (about 10 feet wide by 15 feet long by 6 feet high) and place them well away from your leave trees.

Use a brush blade to keep topsoil in place. Large openings are needed to pile slash produced from whole-tree yarding systems. Where trees are denser, slash-pile size needs to be small to prevent scorching leave trees. Consider keeping a few unburned piles in mixed-species forests as habitat for wild turkeys, quail, squirrels, rabbits, and other wildlife (see Chapter 9).

In mixed-conifer forests with high proportions of true fir and spruce, it's especially important to minimize stand damage, which in turn prevents needless stem decay, root disease spread, and breakage (see Chapter 7). Developing a designated skid trail system, which can be used repeatedly, and using directional felling are essential to minimizing stand damage.

Figure 5.12. Group cuts in mixed-conifer stands are a good way to create enough openings for light to reach to the forest floor to regenerate pine and larch. Group cuts also work well to convert insect- and disease-damaged patches into healthy stands. Keep the cut areas between 0.5 acre and 4 acres, designate skid trails and landings to minimize site damage, and plan well ahead to prepare the site and replant if natural seeding does not occur within a year or two.

Group selection

Many mixed-conifer sites are naturally clumpy. Group-selection harvesting allows you to mimic what's already on the land, especially where natural groups are smaller than 3 to 4 acres (see Chapter 2). Group cuts are 0.5 to 4 acres, or an area with an approximate width of two times the height of mature trees in that group. For example, if bigger trees are 100 feet tall, the opening should be at least 200 feet wide, or about 0.75 acre. Smaller openings provide microenvironments for shade-tolerant regeneration (Douglas-fir and true firs), and larger openings are suitable for more shade-intolerant regeneration (pines and larch). The group cut size also should consider the area needed to safely fell and yard harvested trees. Ideally, 10 to 25 percent of the whole forest area is cut in groups to regenerate a new age class every 10 years or so until the area is covered (see Chapter 2).

Group selection works best on mixed-conifer sites with gentle topography and skid trails in place. The system works especially well to convert small diseased areas to healthy stands (for example, root rot pockets or areas of heavy mistletoe) and to convert areas occupied by fir to pine and larch; see Figure 5.12 (page 100). An early thinning in the matrix (forest area between the group cuts) will increase light and encourage regeneration of species such as larch in the opening.

Group-cutting areas are regenerated naturally or by planting and can be managed as even-aged patches by subsequent precommercial and commercial thinnings. It's important to work closely with your local Oregon Department of Forestry office, as group-selection harvests can trigger reforestation requirements under the Oregon Forest Practices rules, and the harvested area may need to be planted if natural regeneration fails to meet standards.

Free selection

The use of free selection (see Chapter 2) can take advantage of the variation that exists across the forest. For example, if one part of a warm, dry forest stand has a good mixture of pine, fir, and larch, you can use the individual tree selection technique to maintain the uneven-aged structure and species composition. In the same forest, you also might have an area dominated by true firs and Douglas-fir and damaged by, or at high risk of, defoliators or root disease. In that area, use a group selection harvest with planting to encourage pine and larch.

Promoting diverse stands across the landscape enhances forest resiliency to large disturbances. That diversity can be uneven- and even-aged stands with mixed species or one species in different age classes scattered across a variety of topographic features.

Stand management

Strategies for managing mixed-conifer stands depend on site and stand conditions, tree species growth, shade tolerances, markets for different species and sizes, and your management objectives. Sample management strategies for three primary objectives—timber, wildlife, and timber with grazing—on warm and cool-moist mixed-conifer sites are in Tables 5.4 and 5.5 (pages 102–103). We emphasize that there is no single solution to management.

Developing a practical, effective strategy hinges on collecting the right information about your mixed-conifer forest. This should include insect and disease presence or potential problems, tree condition, slope, soils, aspect, species, and age-class distributions. Knowing tree density, size, growth rate, and age also is helpful. Steep areas have limited management options because costs for activities such as thinning are higher; gentle terrain keeps costs low. Dense grass competes with seedlings for water and nutrients and may need to be controlled for good seedling survival and growth. Importantly, if profits from timber production are an

Table 5.4. Some management strategies for three management objectives in warm-dry mixed-conifer stands.

Management strategies	Objectives*		
	Primary: Timber *Secondary:* Wildlife and aesthetics plus timber and forage	*Primary:* Wildlife and aesthetics *Secondary:* Timber plus timber and forage	*Primary:* Timber and forage *Secondary:* Timber and wildlife plus aesthetics
Reforestation	Plant PP at 270–300 tpa on drier sites; plant PP, WL, and DF on moist sites. Control competing vegetation if necessary. Avoid CC on harsh sites. Plant DF only with some shade.	Plant 80% PP first, then 20% DF later for a total of 300-350 tpa. Control competing vegetation if necessary. Allow maximum density (for SI and species) of regeneration where screening is desired. Encourage/create clumps of trees (create patchy conditions).	Plant PP at 150–200 tpa. Control competing vegetation if necessary. Seed less competitive grasses (non-sod-forming) at low rates a couple of years after planting. Avoid, reduce, or manage grazing for 3–4 years until trees establish.
Young forests *Precommercial thinning*	At age 10–15 yr or height 10–15 ft, thin to 260 tpa. Favor PP. Lop and leave, pile and burn, or chip slash. First commercial thin when average stand dbh = 10 in.	Thin at age 10–15 yr or height 15–20 ft. For stands over 10 acres, thin to 300 tpa in two stages, half the stand at each time. Promote diversity of tree species. Leave some slash piles. Create snags or promote retention of declining green trees for future snags and leave more DWD. First commercial thinning when average stand dbh = 10 in. Create patchy conditions.	Thin to 200 tpa at age 15–20 yr or height 10–15 ft. First commercial thinning at 10 in dbh. Favor PP. Pilke and burn slash or underburn and seed grasses.
Commercial thinning and harvesting *Even-aged management*	Thin periodically to “beetle proof” stands. Thin from below, low thinning. Retain most vigorous trees (CR above 30%–40%). Leave stocking at maximum density for SI and species. Regenerate with shelterwood, 80% PP and WL and 20% DF. Don’t CC on south slopes.	Same as timber, but thin in stages, leaving clumps of unthinned trees (more bark beetle risk, however). Favor PP and DF. Manage for maximum density for SI and species. Create snags or leave declining green trees and DWD. Seed, plant, or promote native shrubs, grasses, forbs. Develop ponds and enhance riparian areas. Prescribe burn if possible to stimulate browse. Provide bird houses and platforms. Create patchy conditions.	Thin but leave trees at minimum density for SI and species. After harvest, seed grasses on skid trails and landings.
Uneven-aged management	Promote PP on drier sites; PP, WL, and DF on moist sites. Make group cuts at 1–4 acres. Use natural regeneration or plant PP and WL. Thin all age classes, retaining most vigorous trees (CR above 40%). Manage for 80% PP and WL, 20% DF and GF.	Promote PP on drier sites; PP, WL, and DF on moist sites. Make group cuts at 1–4 acres for natural regeneration or plant PP and WL. Thin all age classes. Create snags or leave declining green trees and DWD. Plant or promote native shrubs. Seed native grasses and forbs. Enhance riparian areas. Provide birdhouses and platforms.	Same as for timber, but thin stand to wider spacing. After harvest, seed grasses on skid trails and landings.

*The objectives emphasize one primary theme for management, but other values are not ignored. Instead, they are integrated into the overall management program.

Abbreviations: CC=clearcut; CR=crown ratio; dbh=diameter at breast height; DF=Douglas-fir; DWD=down woody debris; GF=grand fir; LPP=lodgepole pine; PP=ponderosa pine; SI=site index; tpa=trees per acre; WL=western larch; WWP=western white pine.

Table 5.5. Some management strategies for three management objectives in cool-moist, mixed-conifer stands.

Management strategies	Objectives		
	Primary: Timber *Secondary:* Wildlife and aesthetics plus timber and forage	*Primary:* Wildlife and aesthetics *Secondary:* Timber plus timber and forage	*Primary:* Timber and forage *Secondary:* Timber and wildlife plus aesthetics
Reforestation	Plant equal numbers of PP (at lower elevations and south slopes), WL and DF for a total of 310 tpa. On north slopes, add WWP and LPP. Control competing vegetation if necessary.	Plant a mixture of PP, LPP, WL, DF, and WWP at 350 tpa. Control competing vegetation if necessary. Allow/maintain more tpa where visual screening desired. Encourage natural regeneration of all species. Encourage clumps of trees (create patchy conditions).	Plant PP (lower elevations and south slopes) and WL and DF at 200–250 tpa. Control competing vegetation if necessary. After a couple of years seed less competitive grasses (e.g., bunch grasses) at low rates. Avoid or restrict grazing for 2–3 yr or until trees establish.
Young forests *Precommercial thinning*	At age 10–15 yr or height 10–15 ft, thin to 258 tpa. Favor PP, WL, DF and LPP. First commercial thinning when average stand dbh = 10 in. Lop and leave or pile and burn slash.	At age 10–15 yr or height 10–15 ft, thin to 280–300 tpa. Thin in two stages for stands over 10 acres. Create snags or retain declining green trees for future snags and leave more DWD if large trees are in overstory. Favor species mixes. First commercial thinning when average stand dbh = 10 in. Pile slash for burning, leaving some for habitat.	At age 10–15 yr or height 10–15 ft, thin to 220 tpa. Favor PP, WL, DF and LPP. First commercial thinning when average stand dbh = 10 in. Pile and burn slash. Remove natural fir regeneration with thinning or prescribed fire.
Pruning	Select a total of 80 PP, DF, and WL tpa. Select vigorous, dominant, well-spaced trees. Begin pruning when tree dbh = 4 in.	Select a total of 30 DF, PP, and WL tpa. Begin pruning when tree dbh = 4 in.	Select a total of 60 DF, PP, and WL tpa. Begin pruning when tree dbh = 4 in.
Commercial thinning and harvesting			
Even-aged management	Favor retaining PP, WL, and DF in periodic commercial thinnings. Retain vigorous trees (CR above 30%). Thin from below, low thinning. Leave trees at maximum density for SI and species. Use shelterwood for establishing regeneration. Manage for 60–70% PP, WL, and LPP, 30–40% GF, DF, and SAF.	Favor retaining WL, LPP, PP, and DF. Use light thinnings from below. Retain vigorous trees. Leave trees at maximum density for SI and species. Create maximum snags and DWD. Seed or plant native vegetation. Enhance riparian areas. Provide bird platforms and houses.	Same as timber but manage for minimum leave-tree density for SI and species. Seed grass on skid trails and landings. Use light, managed grazing during seedling establishment.
Uneven-aged management	Individual tree selection will move stand to fir. Root disease a risk. Thin all age classes. Retain most vigorous trees (CR above 40%). Plant LPP, PP, and WL in openings. Entries at 5–10 yr intervals.	Same as timber but create more snags or leave more declining trees and leave more DWD. Favor diversity by planting LPP, PP, and WL in openings. Plant or promote native shrubs, seed native grasses and forbs. Enhance riparian areas. Provide bird platforms and houses.	Same as timber but manage for minimum leave-tree density for SI and species. Seed grass on skid trails and landings. Use light, managed grazing during seedling establishment.

*The objectives emphasize one primary theme for management, but other values are not ignored. Instead they are integrated into the overall management program.

Abbreviations: CC=clearcut; CR=crown ratio; dbh=diameter at breast height; DF=Douglas-fir; DWD=down woody debris; GF=grand fir;

LPP=lodgepole pine; PP=ponderosa pine; SAF=subalpine fir; SI=site index; tpa=trees per acre; WL=western larch; WWP=western white pine objective, consider markets and species values. In the past couple of decades, the number of mills has declined, leaving landowners with fewer options and with the cost of log transportation high and increasing. All this makes the profitability of growing timber more challenging. Know what you have and clearly identify your objectives before developing a management strategy!

Characteristics of mixed-conifer forest soils and tree species make it especially important to plan your harvesting operation carefully to maintain stand productivity and forest health (see Chapter 10). If thinning with mechanical equipment, do so in late summer and early fall or winter to minimize damage to tree stems and roots. Bark is tighter on the trunk, and roots are dormant or under frozen soil during these times, thus more resistant to damage. Soils are less easily compacted during dry or freezing weather. Use designated skid trails to restrict soil compaction to less than 20 percent of the site and to minimize mechanical damage to trees. This is especially important for mixed-conifer sites that have species prone to stem decay and root disease, such as true firs and spruce.

Thinning and improvement cuttings

Precommercial thinning

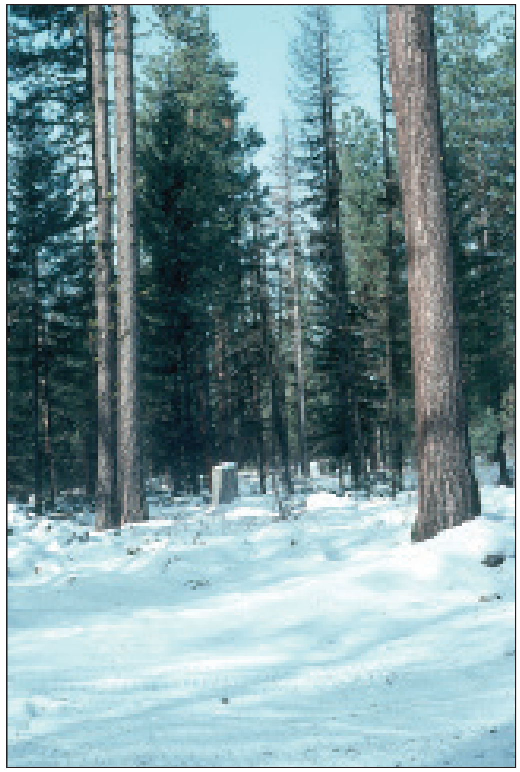
Precommercial thinning (PCT) (young stand thinning) in mixed-conifer forests is an investment in the stand's future growth, quality, and vigor. It kills/removes small-diameter trees with no commercial value (see Chapter 2 and Figures 5.13a–c, page 105).

Using PCT in young mixed-conifer stands has these benefits:

- Prevents stagnation
- Maintains optimal growth rates
- Reduces the time to a first commercial thinning
- Provides an opportunity to remove poorly formed and diseased trees
- Reduces stand susceptibility to insects and diseases
- Improves the species mix
- Improves forage yields

One rule of thumb is to thin young stands when you have over 130 percent of target stocking (tpa) that would grow to commercial size. As an example, if your goal for a ponderosa pine stand in the warm-dry mixed-conifer zone is a commercial thinning when trees average 8 inch diameter (note: under current markets a commercial thinning in this size timber would be at best marginally feasible for sawlogs), then thin when densities are greater than 300 trees per acre (tpa) to 152 to 225 tpa (Table 5.6, page 119). To keep costs low, thin early, when trees are 10 to 20 years old. For larch on good sites, thin when densities exceed 450 tpa and thin down to 300 tpa (12 feet by 12 feet). Grow this stand to 8 to 10 inches in diameter, when you can do a commercial thinning.

A good rule of thumb is to thin young stands soon after crown closure, when trees have expressed their dominance and before the live crown ratio is reduced below 40 percent. Western larch needs to be thinned early, preferably when trees are 10 years old and 10 to 15


Figures 5.13a–c. Thinning examples. Precommercially thin young, mixed-species stands to establish early species composition and density control. The stand above left is being thinned in stages and will be at a wider spacing when commercially thinned. Stocking level and species composition are important decisions when considering a commercial thinning; use Tables 5.6–5.14, pages 119-123, to determine minimum and maximum stocking levels for mixed-conifer sites.

feet tall. Larch experiences suppression early and does not respond to late thinning as well as other species. Use stocking guidelines as averages across the thinning site; leave-tree spacing does not have to be equal across the site. Leave-tree health is also important. Leave trees should be well formed, free of disease and insects, in dominant or co-dominant positions, and of the appropriate species for the site.

Stocking levels for thinning young stands depend on the species, site productivity, markets, your goals, and the target diameter for the first commercial thinning. For instance, in the warm-dry forest type, keep trees close (say, 12 by 12 feet) if your goal is to enter the stand early for a pulp harvest, but space trees farther apart (about 14 by 14 feet or more) if your first entry is going to be a small-sawlog harvest. Space even farther apart (17 by 17 feet) if livestock grazing is an important objective (Table 5.6, page 119). Wider spacing also means a longer time to the next thinning and larger trees to harvest. On cool-moist mixed-conifer sites, space species such as western larch at

12 by 12 feet if your goal is a 10-inch dbh for the first commercial thinning, which is also 308 tpa (Table 5.8, page 120). Drier and warmer climate conditions require wider spacing to keep trees vigorous.

If PCT is delayed or omitted, tree growth will slow and crop trees will reach commercial size very slowly. Deciding whether to do a late PCT is difficult. You must consider cost, biological or growth benefits, and potential damage from sunscald, bark beetles, and other problems.

Studies show that a wide range of thinning regimes will yield the same amount of wood if you allow the stand to grow for many years. Over time, wide spacing between trees will provide for fewer, larger trees than a narrower spacing with more, but smaller, trees, both with similar wood production yields. Widely spaced trees will yield less volume production in the short term, but over several decades yields will be the same as where more trees are growing on a site.

Commercial thinning tips

Use commercial thinning in mixed-conifer stands to:

- *Shift or change species composition*
- *Maintain or improve diameter-growth rates and tree vigor*
- *Remove some of the value in the stand*
- *Lower susceptibility to insects, disease, and catastrophic crown fires*
- *Enhance leave-tree quality*
- *Encourage forage production for livestock and big game*

Retain thick-bark species such as ponderosa pine, western larch, and Douglas-fir to help reduce fire damage risks. Select leave trees that:

- *Have long, A-shape crowns (evidence of good height growth)*
- *Have live-crown ratios of 30 percent or higher*
- *Are the right species for the site*
- *Are free of mechanical damage, insects, or disease*
- *Have good genetic characteristics (e.g., good form)*

In mixed-conifer forests, PCT offers you an early opportunity to shift species composition, improve long-term forest health through spacing and species selection, and encourage better quality trees. If a stand has a mixture of grand fir and Douglas-fir with ponderosa pine and western larch, you can favor the pine and larch to establish a better balance among the species, for example (Figure 5.13a, page 105). A general guideline is to keep stands at 60 to 70 percent pine and larch (shade intolerant) and 30 to 40 percent Douglas-fir and grand fir (shade tolerant). On warm, dry sites, grow mostly ponderosa pine; on cooler, moist sites, grow more larch and lodgepole pine. Favor Douglas-fir over grand fir on warmer, drier sites. Grow grand fir where there is more moisture only.

Tree diseases such as dwarf mistletoe can be reduced in young stands with PCT. Dwarf mistletoe is species specific, so in mixed stands discriminate against those trees with mistletoe and keep nonhost species (see Chapter 7).

Commercial thinning

If mixed-conifer stands are precommercially thinned, as a general rule the trees should average about 10 to 12 inches dbh by 60 years on warm, dry sites and by 40 years on good sites with more moisture. At this stage they're ready for a commercial thinning (Figures 5.13b–c, page 105). Controlling the number of trees on the site is essential to good tree growth and vigor. As with other forest types, high densities in commercial stands of mixed species can lead to slow or stagnant tree and stand growth and create excessive tree stress.

This increases susceptibility to insect attack (especially bark beetles), diseases, and natural mortality from competition.

Use low thinning (see Chapter 2) for mixed-conifer stands when you intend to leave dominant and co-dominant shade-intolerant trees and to remove the more shade-tolerant species. Also use low thinning in stands that have a good distribution of crown classes and merchantable intermediate and suppressed trees. Thinning from below will promote even-aged forest structure and retain the largest and thrifty trees in the stand.

High thinning is an option when you want to release vigorous and desirable smaller trees—for instance, when shade-intolerant trees are being outcompeted by tolerant species. Removing rough, dominant grand fir can release subordinate Douglas-fir or larch, for example. Not all dominants and co-dominants are removed in these harvests; enough are left to meet the stocking level target. Removing most of the dominant and co-dominant trees would be considered high-grading and detrimental to the stand.

Stocking guides

Stocking guides for even-aged stands (Tables 5.6–5.14, pages 119–124) are an essential tool for maintaining healthy stocking levels in managed stands. The maximum stocking level (sometimes referred to as the upper management zone) is defined as 75 percent of full stocking. The lower limit—or "thin to" stocking—is defined as 50 percent of full stocking. For each average tree diameter, you'll want to keep stands between the upper and lower stocking levels. Managing within these stocking levels is a compromise between maximizing timber production and minimizing forest health risks. Stocking below the lower level will sacrifice some timber production, but it will stimulate understory plants and/or tree regeneration. Stocking above the upper limit causes intense competition, slows tree growth, and increases mortality risk (see Chapter 2).

Table 5.6 is a stocking guideline for warm-dry mixed-conifer forests. Tables 5.7 through 5.13 are for selected species in cool-moist mixed-conifer forests. Use Table 5.14 as an alternative to Tables 5.6 to 5.13. This table reflects stocking levels as an average for each species and size class across many site conditions found within the warm-dry and the cool-moist forest types.

Although the tables were developed for sites in northeast Oregon, we suggest you use them as a general guide for mixed-conifer sites throughout eastern Oregon because they are the best available information. The guides are based on the most common plant associations in both forest types. If your stands respond poorly, see Chapter 2 for stocking guides based on radial growth.

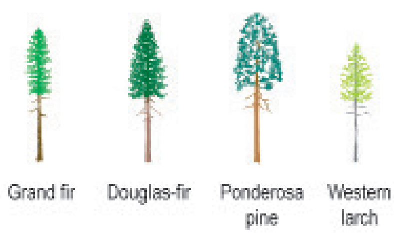
Stocking Guide Example

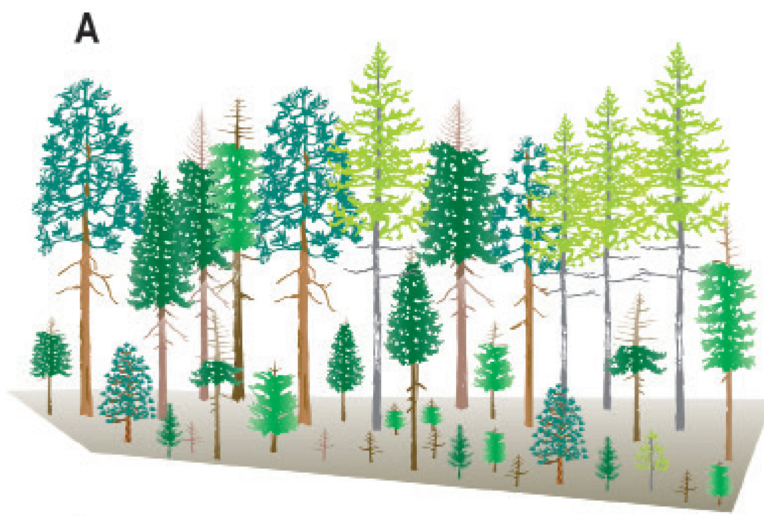
A warm-dry mixed-conifer stand of ponderosa pine and Douglas-fir has an average stand diameter of 10 inches dbh and 300 tpa. We want to thin now, then let the stand grow to 14 inches dbh. Referring to Table 5.6 (page 119), the initial thinning reduces the density from 300 trees to 84 tpa (removing 216 tpa), leaving a 23-foot spacing between trees. Eighty-four is the maximum tpa when average dbh is 14 inches. When the stand reaches 14 inches dbh, another harvest removes 30 tpa and leaves 54 tpa. This stand can grow to 18 inches dbh before the next harvest.

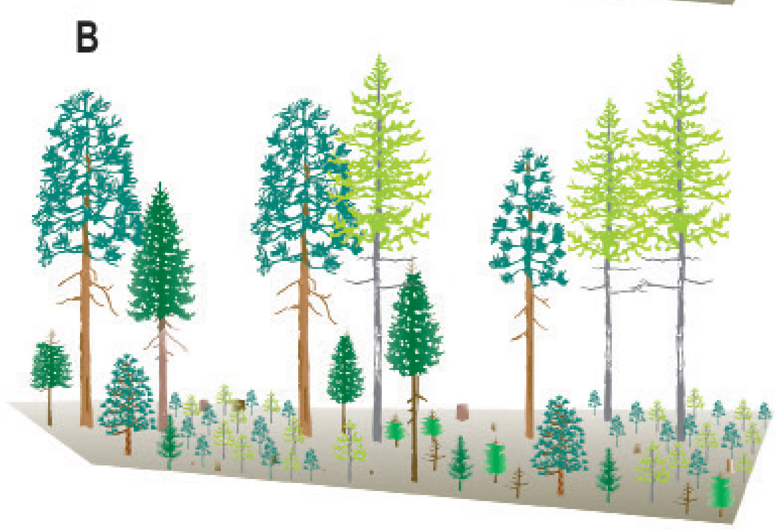
Sanitation, salvage, and improvement cuttings

A sanitation cutting removes high-risk trees, and a salvage cutting tries to recover timber value after a wildfire or insect epidemic. An improvement cutting seeks to improve the composition, structure, condition, health, and growth of the forest (see Chapter 2). Combine these types of cuttings to maintain or restore the health of mixed-conifer forests now and in the future (Figures 5.14a–b and 5.15a–b, page 109). Remove the following:

- Dead and dying trees, possibly leaving some for wildlife (salvage)
- Beetle-infested pine or fir trees (sanitation)
- Poor-vigor trees (improvement)
- Diseased trees (sanitation)
- Damaged, poor-quality trees (improvement)
- True firs (improvement, i.e., increasing resistance to defoliators and diseases by changing or balancing species composition)







Figures 5.14a–b. Due to damage by insects, disease, weather, or other disturbance, a mixed-species forest may have some tree species that are dead, dying, or injured and others that are healthy. There may also be trees of poor vigor that are not likely to live until the next harvest (A). Given time, a sanitation/salvage/improvement operation will leave the forest with healthier trees, proper spacing between trees, a good balance of species, and the potential to regenerate the best species for the site (B). The wildlife value of stand B could be improved by leaving or creating snags and down logs.

Photos: W.T. Adams

Figures 5.15a–b. An example of a sanitation/salvage/improvement treatment shows (above left) a warm-dry, mixed-conifer stand that is overstocked, insect infested, and disease damaged. Retaining healthy trees and the lower risk pine and larch (above right) improves vigor and species composition for a healthier long-term outlook.

Be sure to properly diagnose causes of poor forest health before you decide on an approach. Some disease problems, such as Armillaria and Heterobasidion root rots, can get worse after an improperly planned cutting (see Chapters 2 and 7). Ask yourself:

- What effect will these activities have on wildlife and fish habitat?
- Will the operation compact the soil excessively or boost soil erosion?
- Will some woody debris be left for long-term soil productivity and wildlife habitat?

Restoration and prescribed fire

Most warm-dry mixed-conifer forests in eastern Oregon have missed several fire cycles and been logged several times. In many cases, they are now overstocked and dominated by grand/white fir and Douglas-fir; few pines or larch are present. To restore these forests to a healthier condition with a more resilient species mix, thinning and fuels reduction practices that space trees out, manage species composition, and reduce fuel loads on the ground are needed. This can improve tree vigor and reduce the risk of wildfire killing most, if not all, of the trees. There are a number of ways to accomplish this, including using harvesting, mechanical fuels reduction, prescribed fire, or a combination.

Sanitation, Salvage, and Improvement Cuttings

Objectives

- *Sanitize stands by removing infested and high-risk trees.*
- *Reduce fire hazard (lower the fuel levels) by removing dead and dying trees.*
- *Bring a stand to better health by improving residual trees' vigor, which increases resistance to insects and disease.*
- *Increase the forest's component of insect- and disease-resistant tree species, using thinning and natural and artificial reforestation.*
- *Preserve economic value of trees that may die in the near future.*

Considerations

- *Some pest problems, such as root diseases and dwarf mistletoe, may remain in treated stands.*
- *Conversion (removing the existing stand and starting over) is often one of the best long-term solutions for heavily damaged stands.*
- *In badly damaged stands, regeneration may be hampered by competing shrubs, grasses, and herbs, which can flourish as the overstory dies and more site resources become available.*

Because these forests have been accumulating forest debris on the ground for so many years, we typically have to conduct thinning and mechanical fuels reduction before introducing prescribed fire. Prescribed fire reintroduces fire in a controlled way and is one of the best ways to control encroaching trees and shrubs. However, using prescribed fire can be difficult for private landowners because of liability issues and the lack of expertise and equipment. Stringent smoke management rules also hinder implementation. Possibilities for using prescribed fire exist; contact your local Oregon Department of Forestry stewardship forester for advice and information about cost-share programs to help reduce your restoration costs.

Pruning

Pruning as way to increase the amount of clear wood and gain higher prices at the mill is not a common practice in eastern Oregon. Part of the reason is market driven: the milling infrastructure in the region has been at low levels since the early 1990s and there is little financial incentive to prune. However, some landowners may want to prune for personal reasons and perhaps betting that things will change. The decision to prune your mixed-conifer forest for wood-production purposes should consider site productivity, tree species, tree size, and management programs. Pruning is an attractive idea on mixed-conifer sites because of their generally good tree-growth potentials.

If you decide to prune, target only the better sites. Give priority to Douglas-fir and ponderosa pine, but western larch and western white pine are also good candidates. Pruning western white pine branches about halfway up the tree can reduce white pine blister rust mortality by half. Optimum tree size for pruning is 4 to 6 inches dbh; at this size, the knotty core is small. Prune only healthy, vigorous trees and stands that have been thinned because you want the fastest diameter growth possible. Leave at least 40 to 50 percent live crown ratios in pruned trees (see Chapter 2). Prune only those trees you will retain the longest into the rotation, say, 40 to 60 tpa. You don't want to invest in pruning only to harvest pruned trees before they have plenty of clear wood.

Consider pruning for benefits other than just enhancing wood quality or reducing disease. Pruning can increase forage production by increasing light to the forest floor, increase sight distances in the stand, create a more parklike appearance, and improve access. Pruning also can reduce ladder fuels. True firs and Douglas-fir have branches near the ground that tend to stay alive longer than on species such as ponderosa pine, making them more likely to carry fire to the upper crowns. Pruning these species can be part of a larger fuels-reduction effort that includes thinning and slash disposal.

Proper pruning technique and timing are paramount to maintaining healthy pruned trees. Improperly pruned trees are more susceptible to pitch moths (if a problem locally), stem defect, and heart rot.

Fertilization

Fertilizing mixed-conifer forests of eastern Oregon is not a common practice. Studies have shown it can increase wood fiber production and stimulate understory plant growth to benefit livestock and wildlife. But before you decide to fertilize, get professional advice. See Chapter 2 for details on fertilization.

In general, fertilize mixed-conifer stands where moisture capacity is adequate and site quality is good. Trees on better sites show less response as a percentage of total wood volume than on poorer sites, but the volume increase is greater than on poorer sites. Trees growing on volcanic ash cap and basalt-derived soils seem to respond better than those that grow on granitic soils. Target thinned stands for fertilization because the extra, more-available nutrients go to fewer trees, which then produce larger diameters. If your objective is to improve financial returns, fertilize 8 to 10 years before your next commercial thinning so your investment is held only during the fertilizer-response period.

Mixed-conifer management options: Some examples

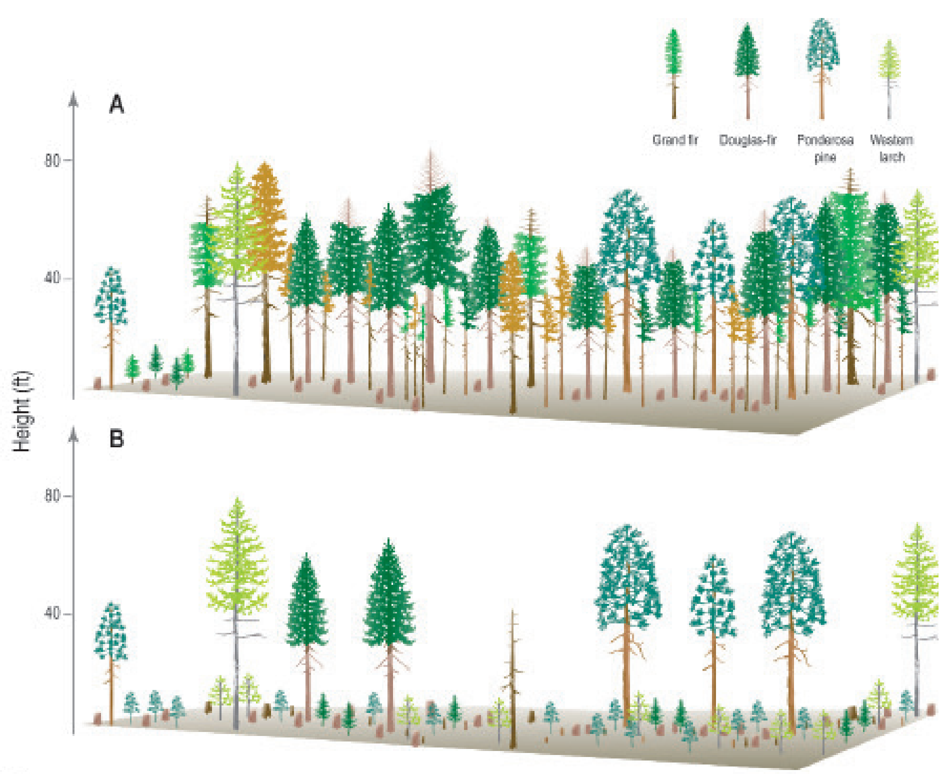
Scenario 1. Restoring a warm-dry mixed-conifer forest damaged by defoliators and bark beetles

Stand conditions (Figure 5.16a) and landowner objectives

This stand has experienced several years of repeated western spruce budworm damage. Trees are 70 to 90 years old. The stand overstory is 80 percent grand fir and Douglas-fir, 10 percent ponderosa pine, and 10 percent western larch. Most of the 4-to-7-inch-dbh grand fir and Douglas-fir (150 tpa, combined species) are dead or top-killed from budworm and bark beetles. Grass and shrubs dominate the ground cover. Cattle graze annually. The goal is to manage for multiple use: to create a healthy, productive forest compatible with a cattle operation. Modest investments in forest management are acceptable.

Solution (Figure 5.16b)

Leaving the stand as it is means it would be occupied by defective Douglas-fir and grand fir, so inaction is not acceptable based on our objectives. To reduce the fire hazard and make the stand more productive, the dead and top-killed trees should be removed as part of the treatment.



Figures 5.16a–b.

If possible, sell the small and defective trees for pulp. Historically, good pulp prices are short lived, so it's important to plan well ahead and pay close attention to the market. A pulp sale would accomplish three things: (1) provide income to fund activities such as planting; (2) reduce fuel loads, thus lowering the fire hazard; and (3) remove trees that eventually would fall down, thus reducing potential damage to regeneration, although leaving a few declining trees may moderate temperature extremes and provide snags for wildlife. Even if pulpwood is sold at a loss, removing the dead and top-killed trees may still be a good option because it prepares the site for regeneration, reduces fire danger, and could be cheaper than other alternatives (for example, felling, piling, and burning).

If selling the small dead and top-killed trees for pulp is not an option, sell them as firewood if they're not too rotten. By hand or machine, pile and burn or chip most of what is left to reduce fire risk and prepare the site for reforestation.

Put a high priority on retaining residual pine and larch as seed sources. If the stand is left to natural regeneration, the new forest is likely to mirror the old, and grand fir and Douglas-fir will occupy the site. Relying on natural regeneration here carries a higher risk of future fire and insect damage than in stands with more pine and larch.

To improve species mix, plant 1-1 bareroot or plug-1 ponderosa pine on south and southwest aspects and equal amounts of 2-0 ponderosa pine and plug-1 western larch on the east-facing slopes. Planting 2-0 ponderosa pine is an option for the south slopes, but the added cost of 1-1 trees is usually worth the investment because they survive and grow better on drier sites. Interplant a minimum of 50 to 100 tpa. Where natural seedlings are few, plant enough trees to bring the site to about 300 tpa. With proper handling, storage, and planting methods and with grass control, seedling survival should be good (see Chapter 6).

Some options for control of competing ground vegetation as part of planting:

- Apply herbicide with a backpack sprayer or ATV the fall before planting or over dormant trees immediately after planting; apply to a 4-by-4-foot area centered on each tree. Use hexazinone for ponderosa pine; use sulfometuron (Oust) or glyphosate for the larch. Do not apply hexazinone near larch! Before applying glyphosate, protect seedlings with a stovepipe or similar technique. Be aware that sulfometuron can restrict Douglas-fir growth. Read the label and follow directions for rate and timing carefully.

- Use a 4-by-4-foot mulch mat or hand scalp around trees.

- If the process of mechanical removal of woody debris doesn't disturb enough ground, then you could scarify the area with a small crawler tractor with brush blade or disk. Strive to treat 40 to 50 percent of the area and keep the disturbance well distributed. Be careful not to move topsoil or compact the soil.

Because livestock graze the area, manage them carefully to minimize damage to new plantings. Light grazing can occur once trees are established, but watch carefully for browsing and trampling damage. If livestock trample or browse seedlings, promptly remove the animals. Once trees are established, carefully manage grazing to benefit trees by removing grass competition. Seed landings and skid trails in the fall or spring with grasses (see Chapter 8).

Watch for wildlife damage. If you see big-game browsing, gopher damage, or girdling by voles, use proper control techniques.

The fir will seed in, thereby increasing stocking levels, so plan for a precommercial thinning at age 10 to 15. Thin to 200 to 300 tpa, leaving 70 percent pine and 30 percent fir.

Summary of Scenario 1 activity

1. Sell the small-diameter timber for pulp. Other options are:

   ❏ Sell the wood as firewood
   ❏ Cut the dead trees, then pile and burn or chip

2. Burn residual slash or dead trees (leave two to four snags per acre, for wildlife).

3. Plant 1-1 ponderosa pine on more exposed sites and 2-0 ponderosa pine and plug-1 larch on better sites. If interplanting is appropriate, plant 50–100 tpa; in unstocked areas, plant 300 tpa (12- by 12-foot spacing).

4. Use appropriate vegetation management methods.

5. Precommercially thin at age 10–15 to adjust species composition, leaving 70 percent pine and larch and 30 percent fir.

Scenario 2. Promoting the health and productivity of a warm-dry mixed-conifer stand

Stand conditions (Figure 5.17a) and landowner objectives

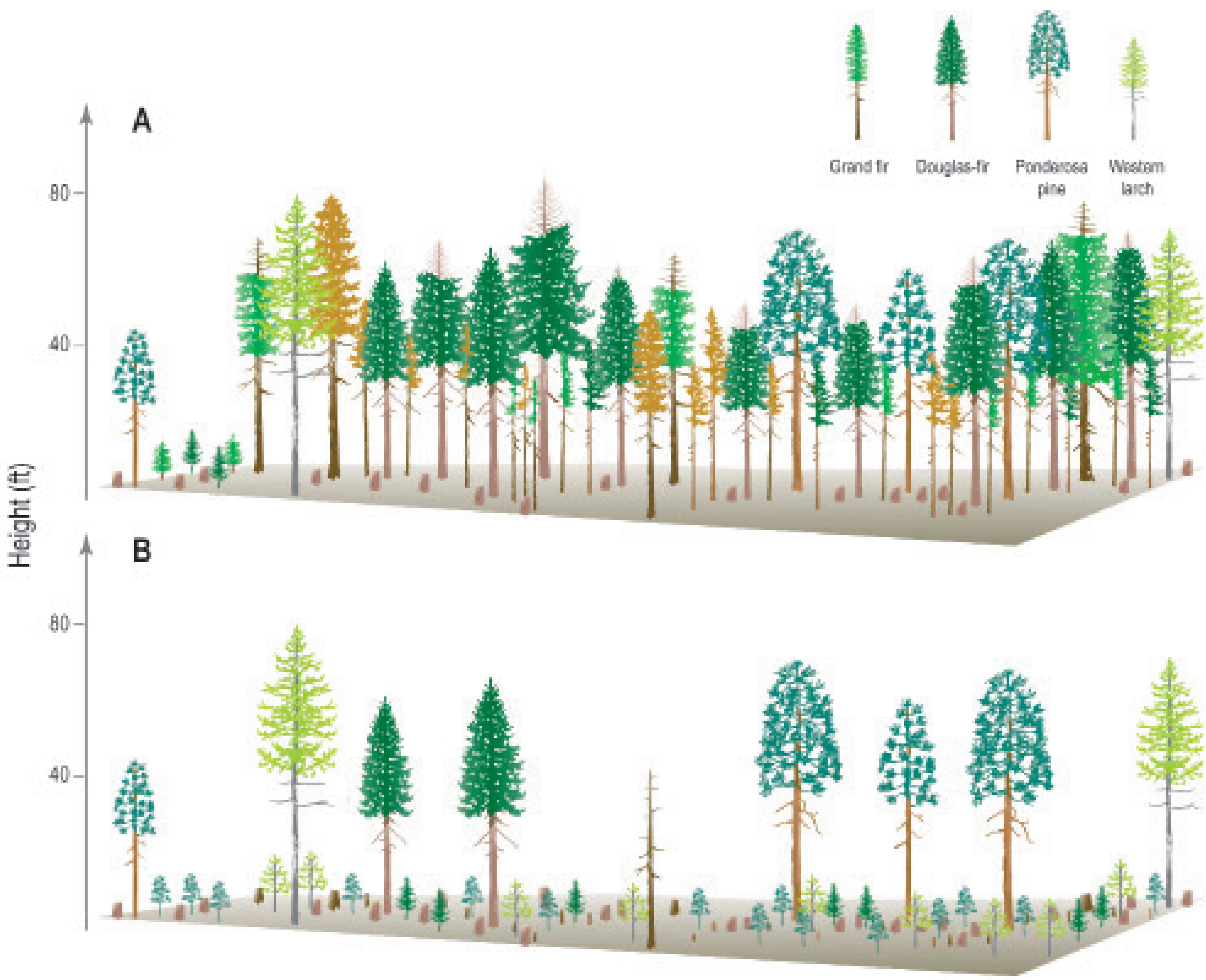
This stand is on an east-facing slope at 3,000 feet elevation. Old stumps indicate that large, widely spaced ponderosa pine and a few western larch and Douglas-fir grew here before logging in the early 1900s. This stand has been high-graded using diameter-limit cuts. Average tree diameter of sawtimber (trees 8 inches dbh and larger) is 14 inches; volume is 10,000 board feet per acre (about 80 tpa). Overstory species distribution is about 35 percent grand fir, 40 percent Douglas-fir, 15 percent pine, and 10 percent larch. Seedlings, saplings, and poles (trees 7 inches dbh or less) total more than 300 stems per acre. These trees are 90 percent fir and 10 percent pine and larch. Mistletoe is scattered in the larch and Douglas-fir. Bark beetles have killed some ponderosa pine, Douglas-fir, and grand fir, indicating trees are stressed from excess tree stocking. There's a high proportion of double-topped, crooked, spike-topped, damaged, and limby trees.

The landowners want to improve long-term forest health and maintain or enhance wildlife values. They're willing to make minor investments in management.

Solution (Figure 5.17b)

Convert this stand to a pine, larch, and Douglas-fir-dominated forest by using a shelterwood regeneration system based on the adequate numbers of pine and larch. Thin the stand from below (a low thinning) in a sawlog/pulp operation. Leave 20 to 30 tpa (totaling about 30 to 40 square feet of basal area per acre stay within the Oregon Forest Practices Act guidelines for stocking) for shelter and seed; select mostly pine, larch, and Douglas-fir. These should be dominant trees with good form and long crowns.

Remove most of the seedling and sapling Douglas-fir and grand fir less than 4 inches dbh to get pine and larch to regenerate. If healthy, leave some Douglas-fir, but the site is probably too warm and dry for good grand fir growth and risky. If pulp prices are good, remove the smaller and defective trees at a profit. Without this market, options are limited (e.g., firewood or posts and poles). Felling, piling, and burning or chipping the unmerchantable trees is a more expensive option.



Figures 5.17a–b

Seed native or domestic grasses and forbs on skid trails and landings to reduce erosion and enhance forage for wildlife and domestic livestock. Do not seed where you want seedlings to grow. See Chapter 8 for seed mixtures, rates, and timing for domestic-grass seedlings.

Regeneration can be natural or from planting. Disturbing 40 to 50 percent of the area during logging and/or mechanical site preparation will expose mineral soil for good natural regeneration. Planting 100 ponderosa pine (1-1) and 100 larch (styro 8 or larger or plug-1) per acre will hasten stand establishment and improve species composition. The Douglas-fir should regenerate naturally. Control competing vegetation as in Scenario 1, if necessary.

Once regeneration is 4 to 6 feet tall, remove overstory shelterwood trees if you want to convert to a single-aged stand and control the mistletoe. Because wildlife habitat is an objective, the overstory might be left to enhance vertical structure. However, leaving dwarf-mistletoe-infected overstory trees will increase the risk of infecting susceptible understory trees (larch and Douglas-fir, if they are left or regenerate). Leave only those infected trees with a nonhost understory (e.g., pine), or kill the trees to create snags. Minimize damage to regeneration by using directional felling and designated skid trails and by removing overstory trees when regeneration is small.

Leave a minimum of two snags per acre for cavity-nesting wildlife, or three to four per acre if wildlife is a high priority. Favor western larch and ponderosa pine snags or any green trees 12 inches dbh or larger that have poor vigor and likely will die in a few years. Leave at least one or two large downed logs per acre for wildlife and soil benefits.

Precommercially thin the understory in stages after harvesting overstory trees, leaving clumps of unthinned areas to increase edge effects and provide diversity. Space trees at about 14 feet (227 tpa) so they can grow well until they are about 10 to 12 inches in diameter. Shoot for 60 to 70 percent pine and larch and 30 to 40 percent Douglas-fir.

Summary of Scenario 2 activity

1. Thin stand to shelterwood spacing of 20 to 30 tpa or 40 to 60 square feet of basal area.

2. Sell the small-diameter trees for pulp if a market exists; if not, slash and burn or chip it or sell it for firewood.

3. Scarify or otherwise disturb 40 to 50 percent of the area and plant 100 1-1 ponderosa pine and 100 container larch (e.g., styro-8's) per acre.

4. When regeneration is 4–6 feet tall, remove shelterwood trees. Leaving the overstory would improve diversity for wildlife, but dwarf-mistletoe-infected species (Douglas-fir and larch) will infect the same species in the understory. Thus, remove or kill the overstory or cut most of the overstory and leave a few trees per acre in isolated clumps where nonhost species are in the understory.

5. Precommercially thin regeneration when it's 10–15 feet tall. This could be done in stages, leaving patches of unthinned trees to improve edge effects and diversity for wildlife. Select against poor quality and more heavily diseased trees.

Scenario 3. Uneven-aged management of a mature cool-moist mixed-conifer stand

Stand conditions (Figure 5.18a) and landowner objectives

This stand is on a cool-moist north slope at 4,500 feet elevation. It is stocked at 16,000 board feet per acre with an average stand diameter of 14 inches for sawlogs (trees over 8 inches). The overstory species mixture is 40 percent grand fir, 30 percent Douglas-fir, 10 percent lodgepole pine, and 20 percent larch (totaling 160 square feet of basal area and 150 tpa). Seedlings, saplings, and pole-sized trees up to 7 inches dbh number 200 per acre (20 square feet of basal area); many of the grand fir are suppressed. New regeneration is sparse. Pest problems include scattered true firs and Douglas-fir killed by bark beetles, a few root-disease pockets with dead and dying grand fir, and Indian paint fungus in the grand fir. The stand has some poorly formed and less vigorous trees.

The landowner is interested in periodic income and would like to increase the variety of songbirds and small mammals. The property also is used for family recreation, so maintaining aesthetic quality is important.

Solution (Figure 5.18b)

This stand is a candidate for uneven-aged management. Free-selection (see Chapter 2) harvests on a 10- to 15-year cycle will improve tree vigor, encourage regeneration, enhance stand quality, provide periodic income, and adjust species composition.

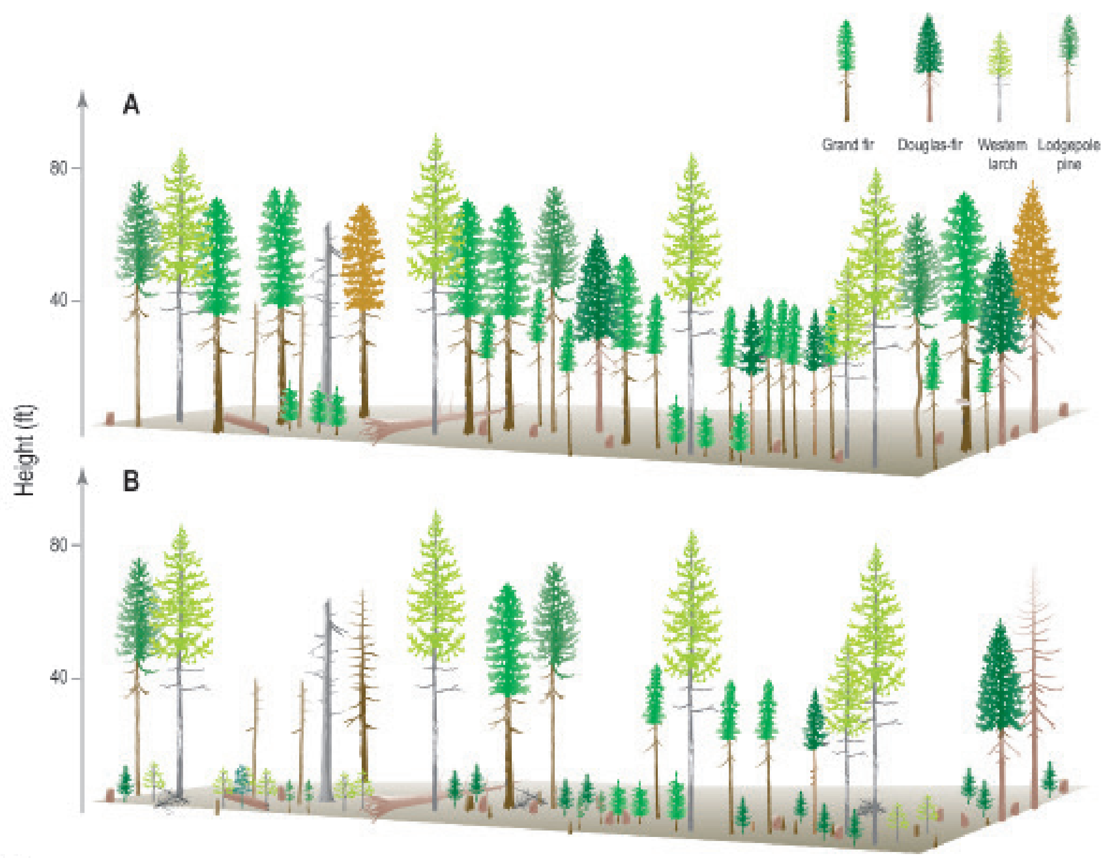


Figure 5.18 a-b

Remove trees within clumps of commercial-sized trees using individual tree selection (ITS) down to 50 to 75 percent of the maximum stocking guide (111 tpa) for even-aged stands. This is 56 to 83 tpa using the western larch stocking guide (Table 5.8, page 120; see also Chapter 2) and assuming an average 18-inch grow-to target diameter. After commercial selection harvest, thin dense pockets of smaller understory trees to 100 to 150 tpa. Retain the most vigorous and best-formed trees in all size classes during both cuts. Also, keep as much healthy larch as possible. Make group selections where there is root disease. Cut and pile the true firs in these pockets and plant larch (and maybe some western white pine) at about 200 tpa. To improve species mix outside the group cuts, plant these same species in the middle of larger openings (at least 0.5 acre). Plan for a mix of larch, lodgepole pine, Douglas-fir, and grand fir (only in areas of better soils and cool-moist conditions) outside of root-disease areas.

Reduce Indian paint fungus problems in true firs (grand or white fir) by removing the damaged and infected true fir trees, but remember to save a few for wildlife. If trees are decayed from the fungus but still merchantable for pulp, then plan to harvest when the pulp market is favorable. Keep future infections and losses low by harvesting true firs before age 100 and minimizing bole damage during logging.

During harvest, use techniques discussed earlier to minimize damage to residual trees. Limiting tree damage and soil compaction helps hold root disease in check and maintains tree vigor and good aesthetics. Stumps may be cut low (1 foot or shorter) for aesthetic reasons.

Meet wildlife priorities with these practices:

- Allowing two or three snags per acre and leaving a few declining green trees
- Leaving two or three large down logs per acre
- Encouraging multiple age classes to promote more canopy layers
- Providing bird boxes and platforms
- Seeding forbs and palatable grasses in skid trails and landings
- Leaving several small slash piles per acre

Summary of Scenario 3 activity

1. Use a free selection, uneven-aged silviculture system on a 10–15 year entry cycle. Use the stocking guides provided in Table 5.8, page 120. Thin clumps of commercial timber to 56–83 tpa or 40–60 square feet of basal area.
2. Healthy, vigorous larch, Douglas-fir, lodgepole pine, and some grand fir on the moist sites are a priority for retention.
3. Harvest trees in small groups (0.5–4 acres) where root disease is present. Cut the remaining small true firs and follow up by planting equal amounts of 2-0, plug-1, 1-1 or containerized (styro 8's or larger) seedlings of western white pine (rust resistant), and larch for a total of 300 tpa.
4. Outside the group cuts, plant larch in openings at 50 tpa each to improve species mixes.
5. Precommercially thin young sapling trees to 100–150 tpa after commercial harvest.
6. Remove diseased grand fir, but retain two to three per acre for wildlife.
7. Minimize damage to the stand by using designated skid trails and rub trees.
8. Leave two to three snags (larger is better) and two to three downed logs per acre.
9. For wildlife objectives, encourage multiple canopy layers, provide bird boxes and platforms, seed forbs and grasses, and leave small slash piles. Retain some declining trees for future snags.

Summary

Mixed-conifer forests of eastern Oregon are the most extensive timber type in the region and provide wood products, hiding and thermal cover and food for wildlife, riparian habitat for healthy streams, forage for livestock, and beautiful vistas. Because they grow a variety of species, they offer many options for management. They also are prone to a wide variety of pests, including bark beetles, root diseases, and dwarf mistletoes.

These are keys to effective management:

- Matching species to the site
- Striving for optimal species mixes
- Increasing stocking of shade-intolerant species
- Addressing pest problems
- Managing stand density/stocking

In general, favor ponderosa pine on warm-dry mixed-conifer sites and western larch, lodgepole pine, western white pine, and Douglas-fir on cool-moist mixed-conifer sites. Overstocked stands grow slowly and are more susceptible to pests and fire. Keep your stands healthy and vigorous with well-planned thinning regimes.

Table 5.6. Multi-species minimum and maximum stocking guidelines for warm-dry mixed-conifer forests in trees per acre, basal area, and spacing (Powell 1999). This guide is based on stocking levels for grand fir-pinegrass habitat type, the most common warm, dry mixed-conifer plant association in the Blue Mountains. Use these stocking guidelines when growing healthy ponderosa pine is the objective; however, if growing more Douglas-fir, larch, and grand fir is the objective, increase tpa by 20-40% (Fred Hall, personal communication).

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	253	50	13	378	74	11
8	152	53	17	227	79	14
10	103	56	20	153	83	17
12	74	58	24	111	87	20
14	57	60	28	84	90	23
16	45	62	31	67	93	25
18	36	64	35	54	96	28
20	30	66	38	45	98	31
22	25	67	42	38	100	34
24	22	68	45	33	102	36
26	19	70	48	28	104	39
28	17	71	51	25	106	42
30	15	72	54	22	107	45

Table 5.7. Minimum and maximum stocking guidelines for ponderosa pine **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir–big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.*

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	229	45	14	341	67	11
8	137	48	18	205	72	15
10	129	57	18	138	75	18
12	67	53	25	100	79	21
14	51	55	29	76	81	24
16	40	56	33	60	84	27
18	33	58	36	49	86	30
20	27	59	40	41	88	33
22	23	61	44	34	90	36
24	20	62	47	29	92	39
26	17	63	51	25	94	42
28	15	64	54	22	96	45
30	13	65	58	20	97	47

*The stocking level guides in this table are slightly lower than stocking guides for ponderosa pine in Table 5.9 because of the complex way that stocking level equations are applied. Your site might support higher stocking levels than shown in Table 5.10; consult with a professional forestry adviser if your objective is to grow ponderosa pine on cool-moist forest sites.

Table 5.8. Minimum and maximum stocking guidelines for western larch **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir-big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	496	97	9	744	146	8
8	302	105	12	453	158	10
10	205	112	15	308	168	12
12	150	117	17	224	178	14
14	115	122	19	172	184	16
16	91	127	22	136	190	18
18	74	131	24	111	197	20
20	62	135	27	93	202	22
22	52	138	29	79	208	23
24	45	142	31	68	213	25
26	39	145	33	59	217	27
28	35	148	35	52	222	29
30	31	150	37	46	226	31

Table 5.9. Minimum and maximum stocking guidelines for Douglas-fir **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir–big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	412	81	10	618	121	8
8	277	93	13	400	140	10
10	191	104	15	286	156	12
12	145	114	17	217	170	14
14	115	123	20	172	184	16
16	94	131	22	141	196	18
18	78	139	24	118	208	19
20	67	146	25	100	219	21
22	58	153	27	87	229	22
24	51	160	29	76	239	24
26	48	166	30	68	249	25
28	40	172	33	60	258	27
30	36	178	35	54	267	28

Table 5.10. Minimum and maximum stocking guidelines for grand fir **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir–big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			Maximum		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	550	108	9	825	162	7
8	334	117	11	501	175	9
10	227	124	14	341	186	11
12	166	130	16	249	195	13
14	127	136	19	190	204	15
16	101	141	21	151	211	17
18	82	145	23	123	218	19
20	68	149	25	103	224	22
22	58	153	27	87	230	22
24	50	157	30	75	235	24
26	43	160	32	65	241	26
28	38	164	34	57	245	28
30	34	167	36	51	250	29

Table 5.11. Minimum and maximum stocking guidelines for Engelmann spruce **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir–big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			Maximum		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/acre	Basal area/ acre (square feet)	Spacing (feet)
6	411	81	10	616	121	8
8	250	87	13	375	131	11
10	170	93	16	255	139	13
12	124	97	19	186	146	15
14	95	101	21	142	152	18
16	75	105	24	113	158	20
18	61	109	27	92	163	22
20	51	112	29	77	168	24
22	43	115	32	65	172	26
24	37	117	34	56	176	28
26	33	120	36	49	180	30
28	29	122	39	43	183	32
30	25	125	42	38	187	34

Table 5.12. Minimum and maximum stocking guidelines for lodgepole pine **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing (Powell 1999).** This stocking guide is based on a grand fir-big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
6	227	54	14	413	81	10
8	168	59	16	251	87	13
10	105	63	20	156	94	17
12	83	65	23	124	97	19
14	63	68	26	95	101	21
16	50	70	30	75	105	24
18	41	72	33	61	108	27
20	34	74	36	51	111	29
22	29	76	39	43	114	32
24	25	78	42	37	116	34
26	22	80	45	32	119	37
28	19	81	48	28	121	39
30	17	83	51	25	123	42

Table 5.13. Minimum and maximum stocking guidelines for subalpine fir **in the** cool-moist mixed-conifer **forest type in trees per acre, basal area, and spacing. (Powell 1999).** This stocking guide is based on a grand fir-big huckleberry habitat type, the most common cool-moist mixed-conifer plant association in the Blue Mountains.

	Minimum			**Maximum**		
Avg. tree dbh (inches)	Trees/ acre	Basal area/acre (square feet)	Spacing (feet)	Trees/acre	Basal area/ acre (square feet)	Spacing (feet)
6	496	97	9	745	146	8
8	302	105	12	453	158	10
10	205	112	15	308	168	12
12	150	118	17	224	176	14
14	115	123	19	172	184	16
16	91	127	22	136	191	18
18	74	131	24	111	197	20
20	62	135	27	93	202	22
22	52	138	29	79	208	23
24	45	142	31	68	213	25
26	39	145	33	59	217	27
28	35	148	35	52	222	29
30	31	151	37	46	226	31

Table 5.14. Average minimum and maximum stocking guidelines for warm- dry and cool-moist mixed-conifer forests in trees per acre, basal area, and spacing (Powell, personal communication). Use this table when you wish to establish stocking guidelines for target species on either warm-dry or cool-moist forest types. These stocking levels are general guides and reflect an average for each species and size class across many site conditions found within the warm, dry and cool-moist forest types. Your site conditions may warrant or require adjusting the guidelines; consult your professional forestry adviser.

	Minimum			**Maximum**		
SPECIES Forest type Avg. dbh (inches)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
PONDEROSA PINE Warm-dry						
7	156	42	17	232	62	14
12	60	47	27	89	70	22
18	29	52	39	44	77	31
25	16	56	52	24	83	43
Cool-moist						
7	176	47	16	262	70	13
12	68	53	25	101	79	21
18	33	57	36	49	87	30
25	19	63	48	28	94	39
DOUGLAS-FIR Warm, dry						
7	218	58	14	327	87	12
12	97	76	21	145	114	17
18	52	93	29	79	139	24
25	32	109	37	48	163	30
Cool-moist						
7	301	80	12	451	121	10
12	133	104	18	200	157	15
18	72	128	25	109	192	20
25	44	150	32	66	224	26
WESTERN LARCH Warm-dry						
7	223	60	14	335	90	11
12	88	69	22	132	104	18
18	44	77	32	65	115	26
25	25	85	42	37	126	34
Cool-moist						
7	330	88	12	495	132	9
12	130	102	18	195	153	15
18	64	114	26	97	171	21
25	37	125	34	55	186	28

(continued)

Table 5.14 (continued). Averaged minimum and maximum stocking guidelines for warm, dry and cool-moist mixed-conifer forests in trees per acre, basal area, and spacing.

	Minimum			Maximum		
SPECIES Forest type Avg. dbh (inches)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)	Trees/ acre	Basal area/ acre (square feet)	Spacing (feet)
GRAND FIR Warm-dry						
7	394	105	11	592	158	9
12	155	122	17	233	183	14
18	77	136	24	115	204	20
25	44	149	32	65	223	26
Cool-moist						
7	441	118	10	662	177	8
12	174	136	16	260	204	13
18	86	152	23	129	228	18
25	49	167	30	73	250	24
LODGEPOLE PINE Cool-moist						
7	212	57	14	316	84	12
12	83	65	23	124	97	19
18	41	72	33	61	108	27
25	23	78	44	34	116	36
ENGELMANN SPRUCE Cool-moist						
7	340	91	11	510	136	9
12	134	105	18	201	158	15
18	67	118	25	100	176	21
25	38	128	34	57	193	28
SUBALPINE FIR Cool-moist						
7	294	78	12	441	118	10
12	116	91	19	173	136	16
18	57	101	28	86	152	23
25	33	111	36	49	166	30

CHAPTER 6

Reforestation methods and vegetation control

Stephen A. Fitzgerald and Paul T. Oester

Regeneration and vegetation control were discussed briefly in other chapters. This chapter provides more detail on how to reforest your ponderosa pine, mixed-conifer, and lodgepole pine forests after harvest: how to obtain seedlings, when and how to plant them, and techniques for controlling competing vegetation. It's important to plan well ahead because successful reforestation requires several steps and attention to detail. In the long run, good planning reduces frustration and reforestation costs because it prevents mistakes and having to replant or take other remedial actions. Reforestation decisions should consider ownership objectives, site conditions, costs, and an assessment of what's best for creating a healthy, productive forest in the long run.

Reforestation options

Reforestation after harvest can be done by three methods, which will be discussed in more detail later in the chapter:

- Planting nursery-grown seedlings by hand (artificial regeneration; see Figure 6.1)
- Relying on retained seed trees to seed the area naturally and in a timely manner (natural regeneration)
- Taking advantage of seedlings and saplings that already are established in openings and beneath overstory trees (advance regeneration)

Figure 6.1. Planting vigorous, nursery-grown seedlings can ensure prompt reforestation.

Hand-planting nursery-grown seedlings

Reforesting by hand-planting seedlings is preferred over natural regeneration in many cases because hand-planting has these benefits:

- Ensures prompt reforestation
- Promotes vigorous seedlings, which can better withstand harsh site conditions, competition, and browsing
- Provides an opportunity to increase species diversity
- Allows introduction of genetically superior trees
- Ensures an even distribution of seedlings across the site

Other times to consider hand-planting include these:

- You want root-rot-resistant species in certain areas to decrease mortality and improve timber yields.
- A certain mixture of tree species will improve overall forest resiliency to insect and disease problems and enhance diversity for wildlife.
- You want to restore a specific tree species that was removed in past harvests or lost to fire or insects.
- You aim to improve long-term tree quality by planting beneath and within stands where existing seed trees are genetically inferior (i.e., have poor growth and form or are limby).
- You need to restore tree cover immediately after a salvage harvest, and the area lacks enough seed trees to adequately restock by natural seeding.

Successful planting involves several important steps and requires good planning. Lack of attention to detail and quality in any one step can result in poor seedling survival or total reforestation failure. For example, an attempt to save money by not protecting seedlings in areas where wildlife browse can significantly reduce seedling survival and require expensive replanting. The old adage "pay now or pay later" certainly is true of reforestation activities.

Reforestation Laws

Oregon's Forest Practices Rules require reforestation if timber harvesting reduces stocking below certain minimum levels. Usually, you must plant trees by the second year after harvest, and by year six the number of *free-to-grow* seedlings per acre must meet certain minimums. In eastern Oregon 100 to 125 free-to-grow seedlings are required depending on site productivity. Healthy residual saplings and pole-size trees (1 to 10 inches dbh) or trees greater than 11 inches dbh on the site may count toward your reforestation requirement, thus requiring fewer seedlings to plant after harvest.

If you are relying on natural regeneration to reforest an area, you must have a written plan that tells how you will encourage naturally regenerated seedlings to establish. Because natural regeneration is unpredictable, it's wise to consider making a backup strategy—for example, hand-planting seedlings in areas where few are growing naturally. Contact your local Oregon Department of Forestry stewardship forester to find out the requirements for your situation.

Plan your reforestation project well ahead of time. In recent years, demand for seedlings, particularly ponderosa pine, has been high because of wildfires and salvage logging on private and public lands. To ensure you will have enough seedlings to plant, be sure to reserve seedlings in the summer or fall before planting or contract with a nursery up to 2 years in advance.

One important step in successful reforestation is preparing the site for planting. It's important to reduce the amount of competing vegetation from the outset and to provide access and planting sites for the tree planters. Evaluate your site beforehand to determine the right site-preparation treatments. You may need a professional forester's help to evaluate your particular situation.

Generally, priorities for increasing seedling survival and growth include (in order of decreasing importance):

- Controlling competing vegetation
- Protecting seedlings from animal damage
- Planting genetically superior trees
- Fertilizing seedlings

Matching seedlings to the site

It is important to properly match tree seedlings to the site. That means both matching the seedling to the environment in which it will be planted, using seed zones as a guide, and choosing the right stock-type. Stock-types describe how a given class of seedlings was produced—bareroot, container, transplant, or a combination of these—during a specific period of time (Table 6.1). You can get seed zone maps for each tree species from the Oregon Department of Forestry field office nearest you.

It's important to buy seedlings grown from seed that came from the same seed zone and same elevation as the site you are reforesting; those seedlings are genetically adapted to that area. Seed zones are divided into elevation bands, usually at 1,000-foot intervals, to account for elevation's effect on climate. Sometimes, nurseries and agencies have off-site seedlings (i.e., those from other seed zones and elevations) and offer them at bargain prices. Do not buy

Table 6.1. Common seedling stock-type descriptions.*

Seedling stock-type description	Normal designation	Total age
1-year-old bareroot	1+0	1 year
2-year-old bareroot	2+0	2 years
1-year-old bareroot transplanted to a wider spacing in a transplant bed for another year	1+1	2 years
2-year-old bareroot transplanted to a wider spacing in a transplant bed for another year	2+1	3 years
1-year-old container-grown (also called a plug); sometimes the "P" is followed by a number, such as P7 or P15, which refers to the number of cubic inches in the plug	P+0	1 year
1-year-old plug transplanted to a wider spacing in a transplant bed for another year	P+1	2 years

* Adapted from Owyston et al. (1992).

these seedlings. Off-site seedlings have a high potential for poor growth and form and are more prone to insect-, disease-, and weather-related damage.

If you have difficulty finding seedlings matched to your area, you can contract with a nursery to have them grow the seedlings. A nursery can obtain the appropriate seed and grow seedlings for landowners typically in lots as small as 2,000 seedlings. Because it takes two years to grow seedlings (1 year for plug seedlings), you will need to plan well ahead. You'll want to plant seedlings as soon after harvest as possible so they get a head start on competing vegetation. For a list of contract seedling nurseries, contact your local OSU Extension forester or Oregon Department of Forestry stewardship forester.

There are many seedling stock-types, each with characteristics that make it suitable for planting under certain site conditions (Tables 6.2 and 6.3). Historically, for most situations in eastern Oregon, the standard stock-type has been the 2-0 (2 years old, both years growing in the field) bareroot seedling. This stock-type produces seedlings that are 8 to 10 inches tall with 10-inch roots. 2+0 seedlings are a good, economical choice and readily available for most seed zones and elevations in eastern Oregon. However, during the past decade or so, larger seedlings with better root development have been the norm, including 1-1 or plug-1 ponderosa pine, 1-1 Douglas-fir, and large plugs (8 to 12 cubic inches or more) and plug-1 (plug plus 1 year in transplant bed) for western larch. These seedlings tend to do better on eastside sites because of their larger root systems, good balance between root and shoot, and caliper (stem diameter).

Table 6.2. Suggested stock-types for various site conditions.

Seedling stock-type	Brushy sites	Droughty sites	Sites with heat damage potential	Deer and elk damage potential
1+0, P+0	Least suitable	OK, but smaller stock types may do poorly if soils very droughty.	Shade seedlings' stem bases in first year	Will need protection
2+0	OK	OK	May need first year shade	Will need protection
2+1	Best	High failure risk because of poor shoot-to-root ratio	May succumb to drought	OK
Plug +1, 1+1	OK	Best	OK	Depends on the degree of browsing pressure

Table 6.3. Seedling stock-type planting considerations in various soil types.

	Shallow, rocky, or clay soils		Deep loam or sandy soils	
Seedling stock-type	**Planting difficulty**	**Recommended planting tool**	**Planting difficulty**	**Recommended planting tool**
P+0 (plug), 1+0	Moderately difficult	Hoedad or shovel	Easy	Hoedad, auger, shovel
2+0	Moderately difficult	Hoedad or shovel	Easy	Hoedad, auger, shovel
2+1	Difficult *(not recommended)*	Shovel	Moderately difficult	Shovel or auger
Plug+1, 1+1	Moderately difficult	Hoedad or shovel	Easy	Hoedad, auger, shovel

Stock-types being used with success on some sites include 1+0 and P+0 (plug) seedlings. Although physically smaller than a 2+0, 1+0 seedlings have had good success and are cheaper to produce. Plug seedlings are grown in a plastic container, or plug, and can be grown in one year or less. They are available in a variety of sizes; styro 5, 8, 10, 15, and 20 are the most common. The number refers to the plug volume in cubic inches. Larger plugs produce bigger seedlings but at higher cost. Plug seedlings are easier to plant because of their compact size. Plug seedlings have become more available in eastern Oregon with common sizes of 8- to 12-cubic-inch containers, which do well in drier environments.

Plug ponderosa pine seedlings, particularly plugs greater than 8 cubic inches, are a good choice for tougher sites, such as harsh, south-facing slopes. That is because plug seedlings have a large root mass and comparatively small upper stem; i.e., good balance between shoots and roots. Having a good balance between shoots and roots is important for seedling survival. Seedlings that have a small root volume compared to the top (shoot) have a difficult time supplying needed water to the needles during summer. A seedling shoot-to-root ratio of 2:1 is considered good.

Avoid using plug seedlings in severe frost pockets because plugs can be pushed out of the ground by frost heaving, exposing seedling roots and causing mortality. Bareroot seedlings are a better choice for planting in frosty areas.

On cool and moist mixed-conifer sites, plant 2+0 or 1-1 bareroot or plug ponderosa pine, 8- to 12-cubic-inch plug western larch, or 1-1 bareroot Douglas-fir seedlings with a good balance between the roots and shoot. On warm-dry mixed-conifer sites (e.g. south and southwest aspects), plant 1+1 or P+1 ponderosa pine seedlings. Because of their fibrous root system and favorable root-shoot ratios, these seedlings survive and grow better under warm, dry conditions. On better warm-dry mixed-conifer sites use 1-1 or plug-1 ponderosa pine, 1-1 Douglas-fir, and either 8- to 12-cubic-inch containers for western larch or plug-1 larch.

Where deer and elk browse, plant bareroot seedlings. Avoid planting plugs; the succulent plug seedlings often are heavily browsed.

Seedling handling and care

Handle seedling bags or boxes carefully and do not drop them. Keep seedlings cool and moist from the time you pick them up at the nursery until you plant them. If you need to store seedlings temporarily, use a cooler. You may be able to rent cooler space from a timber company, the U.S. Forest Service, or a cool-storage facility in your community.

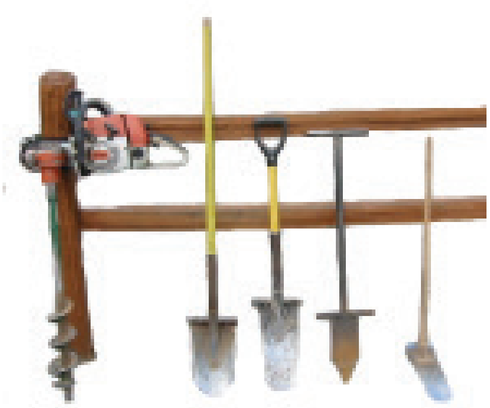


Figure 6.2. Planting tools include the power auger (at left), various types of shovels, and the hoedad (at right).

Take to the planting site only the number of seedlings you expect to plant that day. Transport seedlings in a pickup truck with an insulated canopy. If that is not possible, use a reflective ("space" type) tarp over the seedling bags or boxes. Once at the planting site, keep seedlings in a cooler or in a shaded, cool area. During planting, do not allow seedling roots to dry out; protect them from heat and wind. Dipping seedling roots in water for a few seconds before placing them in a planting bag helps keep roots cool and moist. Planting when weather is cool and cloudy also helps reduce seedling stress. Do not plant on warm, sunny days.

When to plant

Plant seedlings in early spring after soil 8 inches deep reaches 39° to 40°F. This is the temperature at which significant root growth begins. You can buy an inexpensive soil thermometer from a forestry supply catalog. This soil temperature may be reached anywhere from mid-March to early or mid-April depending on elevation, aspect (north vs. south slope), and winter and spring weather conditions. Planting when soils are too cold means roots cannot transport water on warm days, causing desiccation and death. Conversely, planting too late in the spring when air and soil temperatures are warmer prompts the shoot to begin growing before new roots have fully developed and when the upper soil strata already may have begun to dry out. This reduces survival and growth of newly planted seedlings.

Fall planting has had little success in central and eastern Oregon, except at high elevations that are difficult to access early enough in the spring. Most soils in the mixed-conifer zone are too dry in the fall, and by the time moisture is sufficient to support seedlings (late October or November), soil is too cool to allow adequate fall root growth.

Planting tools and technique

The tree spade (shovel), hoedad, and power auger are the most common planting tools (Figure 6.2, page 129). All work well in deep soils. Hoedads can scalp vegetation away before planting and are the preferred planting tool in rocky soils and on steep slopes. On sandy, pumice, or loamy soils or where grass is a problem, power augers work well, increasing planting production and reducing fatigue. Don't use power augers in heavy clay soils, however, because the auger tends to compact the sides of the planting hole, which restricts seedling root growth. Also avoid using power augers in rocky areas because of potential damage to the auger bit.

Typical tree planting problems to avoid include planting seedlings too deep or too shallow, improperly placing roots within the planting hole (e.g., J- or L-rooting), leaving air pockets around roots, and planting seedlings so that they lean (Figure 6.3, page 131).

Selecting planting microsites

Improve planting success by selecting good microsites. Especially on dry, harsh ponderosa pine sites, but even on cool-moist mixed-conifer sites, this technique can improve survival. Good microsites protect seedlings from wind, intense sun, frost, and deer and elk browsing. For example, planting seedlings on the north or northeast side of stumps and logs or within dead brush provides protection (Figure 6.4, page 131) from mid- to late-afternoon sun. Microsite planting may result in an uneven spacing, but it improves seedling survival.

Planting spacing

Proper spacing of planted seedlings ranges from 150 to 540 seedlings per acre. For most ponderosa pine sites, plant 150 (17 by 17 feet) to 300 (12 by 12 feet) trees per acre for adequate coverage. This range provides enough trees to adequately stock the site but avoids overplanting and possibly the need and expense of precommercial thinning later. For lodgepole pine sites, plant 150 to 430 (10 by 10 feet) seedlings per acre. Precommercial thinning by age 15 may be necessary at the denser planting. On mixed-conifer sites, plant 300 to 430 seedlings per acre.

In general, plant 10 to 20 percent more seedlings than needed to meet requirements to allow for mortality from competition, wildlife damage, and other factors. Refer to Chapters 3 through 5 for more details on stocking guidelines. If you expect better survival or abundant

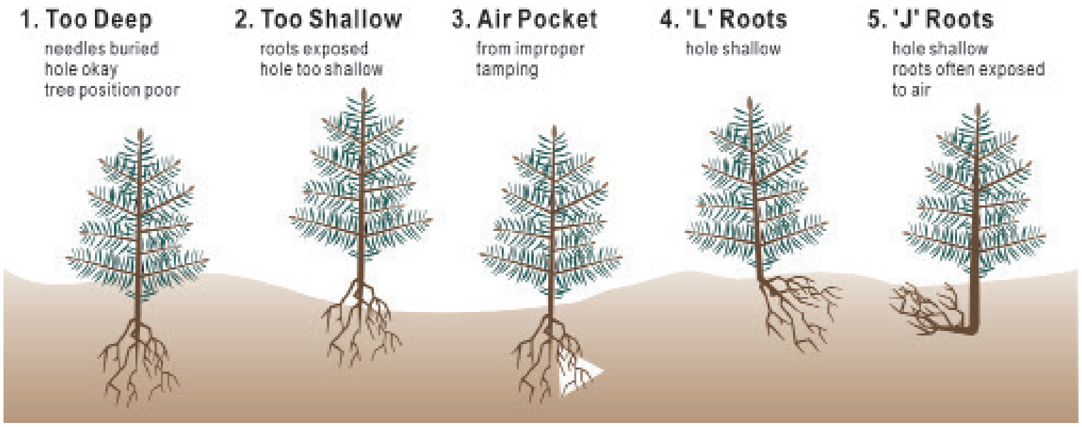


Figure 6.3. Proper and improper tree planting (adapted from Rose 1992).

natural regeneration, consider planting fewer trees depending on the desirability of the naturally seeded trees.

Fertilizing seedlings during planting

Typically, tree seedlings are not fertilized at planting, although recently interest has increased in doing so to improve seedling performance. Adding fertilizer into or immediately next to the planting hole has shown mixed results. Providing slow-release fertilizer in container (plug) seedlings at the nursery before planting them out has shown promise in western Oregon. However, many questions remain. Part of the reason is that container-grown seedlings already have an abundant supply of nutrients that they can draw from when planted; additional nutrients are not needed. Also, on dry sites, fertilizer can cause a buildup of salts that are toxic to seedlings. Studies show that if fertilizer is applied along with good weed control, bareroot seedlings are able to respond to the

Figure 6.4. Microsite planting behind a stump.

Figure 6.5. Vexar tubing protects seedlings from deer and elk browsing.

added nutrients; without good weed control, most of the nutrients are taken up by other vegetation, which then competes with seedlings and increases seedling moisture stress and mortality.

Figure 6.6. This photo shows how pocket gophers can damage pine roots.

Protecting planted seedlings from wildlife

Wildlife can severely reduce seedling growth and cause heavy mortality. Also, browsing by deer, elk, and domestic livestock puts surviving seedlings at a disadvantage to surrounding, competing vegetation. Various protective devices such as Vexar tubing (Figure 6.5, page 131) are effective but expensive and require follow-up maintenance the second year. Other deterrents include repellents such as Deer Away, Deer Off, and Plantskydd applied on the terminal leader, having an odor and taste that deters browsing. Although effective, these products may require retreatment within two months or so because they eventually wash off.

Pocket gophers that clip seedling roots are also a major problem on some sites and can cause complete reforestation failure in local areas (Figure 6.6). Gopher control methods include trapping, baiting, seedling protectors, and manipulating gopher habitat; e.g., using herbicides to reduce gophers' preferred foods such as grasses and forbs. To be effective, take gopher control measures **before** you plant seedlings.

Follow-up inspections

Plan follow-up inspections the first few years after planting to identify potential problems with your seedlings. These are signs to look for:

- Dead seedlings in groups might indicate a rodent problem.
- Seedling mortality across a broad area might indicate poor planting or excessive weed competition.
- Clipping of the terminal or lateral branches may be from big-game browsing.

Inspecting your plantation regularly will help identify problems so you can take corrective action quickly to prevent further loss or damage to seedlings. In addition, conducting a regeneration survey will help you to determine whether you have met your reforestation stocking goals and, more important, the state's minimum reforestation requirements.

Table 6.4. Minimum seed-bearing ages and intervals between large seed crops for major conifer species.*

Species	Minimum seed-bearing age (years)	Years between large seed crops
Douglas-fir	10	2–11
Grand fir	20	2–3
White fir	40	2–4
Noble fir	35–40	2–3
Shasta red fir	30–40	2–3
Ponderosa pine	16–20	2–5
Sugar pine	40–80	3–5
Western white pine	7–20	3–7
Lodgepole pine	4–8	1
Incense-cedar	—	3–6
Western redcedar	15–25	3–4
Western hemlock	20–30	2–8
Western larch	8	1–12
Mountain hemlock	20–30	1–5

*Adapted from Minore and Laacke (1992).

Natural regeneration

Many landowners in eastern Oregon have relied on natural regeneration to reforest cutover lands. Natural regeneration can save money because you don't have to buy and plant nursery stock. In addition, seedlings established from seed of nearby trees are locally adapted to your land. Although natural regeneration can be successful, relying on natural regeneration to restock your land after harvest is risky. Conifer cone crops are irregular and hard to predict. For example, good cone crops for ponderosa pine occur only every two to five years, and western larch can have intervals of one to 12 years between good cone crops (Table 6.4, page 132).

Most trees disseminate seed between September and November. Seed disperses within an area one to three times the height of the tree, depending on seed weight, topography, and wind patterns.

Several factors influence the success of natural regeneration, including these:

- The type of seedbed on which seeds germinate
- Temperature and moisture patterns during and after seed germination
- How much of the seed crop is lost to rodents, insects, and disease
- Competing vegetation

Most conifer seed germinates and establishes best on bare mineral soil. Create bare soil from logging disturbance during harvest operations and from site preparation treatments such as with machinery or prescribed fire. A crawler tractor outfitted with a brushblade (a blade with 8- to 10-inch teeth) will disturb, or scarify, the soil. Use soil scarification to evenly distribute mineral soil on about 40 percent of the harvest area. This ensures more uniform seedbed conditions for conifer seedling establishment. Prescribed fire also has been used very successfully to create mineral soil and to control competing vegetation. Prescribed fire works well on ground too steep for equipment.

When possible, time your timber harvest to coincide with moderate to heavy cone crops. To get an idea of the cone crop, inspect trees with binoculars. Pine cones take two years to ripen, but western larch, grand fir, and Douglas-fir cones mature in one year. If you need to harvest in a year when cone crops are poor, you should plan on planting tree seedlings to meet the reforestation minimum and allowing natural seeding to augment the number of seedlings in subsequent years.

Natural regeneration can be achieved with clearcutting (in some cases), seed tree and shelterwood cuttings (Figures 6.7, below,and 6.8, page 134), and the uneven-aged system using individual tree selection and group selection cuttings (see Chapter 2 for detailed

Figure 6.7. Abundant natural regeneration beneath a shelterwood. The regeneration likely will require a precommercial thinning at age 20.

Figure 6.8. Excessive advance regeneration in a mixed-conifer stand.

descriptions). Clearcutting with the goal of securing natural regeneration is not appropriate for ponderosa pine on climax ponderosa pine sites for two reasons. First, ponderosa pine seed is heavy and, depending on clearcut size, often does not disperse to the center of the clearcut. Second, clearcutting on hot, dry climax ponderosa pine sites makes it difficult for seedlings to establish from windblown seed. However, small openings of up to 2 acres created by group selection cutting regenerate well if adequate mineral soil is exposed.

Lodgepole pine regenerates extremely well after clearcutting. Lodgepole pine is a prolific cone producer, and its light seed disperses easily across clearcut openings. When cones are present, Douglas-fir and western larch also regenerate well in small clearcuts.

Seed tree and shelterwood cuttings provide large, mature seed trees evenly distributed across the site. Seed trees should be of cone-producing age, have full crowns, be vigorous, have a history of producing cones (as evidenced by cones on the ground from past crops), and be free of insects, disease, and damage.

On climax ponderosa pine sites, approximately 8 to 12 seed trees per acre, or about 15 to 25 square feet of basal area per acre, is adequate for natural regeneration. Lodgepole pine also regenerates well with seed tree and shelterwood systems, and residual trees help protect developing seedlings from frost. Because lodgepole pine has shallow roots, blowdown of seed trees can be a serious problem. Leave the largest and most windfirm trees as seed trees.

On mixed-conifer sites, it is a good idea to manage for ponderosa pine and western larch by leaving 10 to 20 seed trees per acre of these species, or about 20 to 40 square feet of basal area per acre. However, good western larch cone crops are so unreliable that you should consider planting larch as a supplement to natural regeneration. This helps promote a diversity of tree species on your site. Otherwise, you may end up with a predominance of Douglas-fir and grand fir, which seed in on their own quite readily and are less resistant to pests in the long run.

If using a crawler tractor outfitted with a brushblade to create mineral soil, be sure the bole and roots of seed trees are not damaged in the process. Prevent damage by keeping heavy equipment one to two crown-widths away from seed trees.

After 3 to 10 years, if natural regeneration has been successful, you will need to decide whether to remove some or all seed trees. To protect the regeneration beneath, use directional felling, toward skid trails. Also, designate and clearly mark skid trails ahead of time. Keep all logging equipment on skid trails to prevent damaging regeneration.

Finally, no matter which silvicultural system you decide to use for natural regeneration, the key to success is to time the timber harvest to coincide with a good cone crop, when possible, and to provide good site preparation to expose mineral soil and reduce competing vegetation.

Figure 6.9. Advance fir sapling with a good live crown ratio and an ability to respond to release.

Advance regeneration

Seedlings often establish and grow in openings and under tree canopies (Figure 6.9). In openings, seedlings become established as a result of disturbances such as past logging, wind, fire, and insects that create mineral soil and/or increased light. Natural recruitment under undisturbed tree canopies occurs slowly over a longer period as seeds fall to the forest floor and some germinate and grow. Over time, significant numbers of young trees become established in the understory. Advance regeneration has the advantage of low cost because the trees are already there and growing. However, advance regeneration can be spotty, requiring additional hand-planting where no trees have established naturally. In addition, the species that regenerate may not be appropriate for some sites; e.g., grand fir on a warm-dry mixed-conifer site. Also, advance regeneration might be infested with mistletoe and diseases (see Chapter 7). Thus, evaluate any advance regeneration to be sure it's the right species for the site and that it's healthy and vigorous.

On dry ponderosa pine and colder lodgepole pine sites, advance regeneration of these pines is quite common. Advance ponderosa and lodgepole pine regeneration releases well if surrounding overstory trees are removed and the remaining dense pine thickets are precommercially thinned.

Advance fir (e.g., Douglas-fir and true firs) regeneration on appropriate fir sites can also be considered for reforestation purposes. It can be abundant under mixed-conifer canopies and usually responds well when overstory competition is removed. Where fir grows well (on cool and moist sites), advance fir regeneration is a viable reforestation option. However, on drier fir sites, rely on and plant species that are more pest resistant, such as ponderosa pine, and mixtures of other species.

Site productivity and competition from the over- and understory are two factors that affect advance regeneration's ability to respond to release. Other factors include live crown ratio, height growth, and species. Seedlings and saplings with long live crowns—greater than 50 percent of the seedling's or sapling's height—are the most desirable. **With respect to height growth,** consider the trees' growth during the five years before release. Seedlings and saplings growing moderately well in height and with good live-crown ratios before release are likely to perform well after overstory removal (Figure 6.9).

Advance fir regeneration on cool-moist sites is a good candidate for release because adequate moisture allows seedlings and saplings to respond well to overstory removal. Be aware that shaded fir seedling and saplings in the understory develop shade needles, and trees can lose these needles after the overstory is removed because of the sudden exposure to full sunlight. Sunscald also can be a problem for understory fir species suddenly opened up to full sun. Direct sunlight on the fir's thin bark can kill the bark, creating a long wound on the south side of the tree. It's best to remove overstory trees between bud set and budbreak (i.e., fall through spring) and in two to three stages over several years to more-gradually expose understory fir regeneration to sunlight to minimize shock and sunscald. After advance seedlings are 2 to 3 feet tall, remove the overstory; waiting too much longer when seedlings are taller may result in more damage and mortality to seedlings from logging. Species with lower tolerance for shade, such as pines and larch, may not be good possibilities for release if they have been suppressed in the understory.

Reforestation Costs

The cost of reforestation after clearcutting, at the time of this printing, varies from $200 to $400 per acre. Costs should be considered long-term investments. They include site preparation, buying and planting seedlings, wildlife protection measures, and releasing seedlings from competing vegetation. Proceeds from timber harvests eventually can help offset these costs. In addition, at the time you reforest you may be able to take advantage of one or more cost-share programs through the Natural Resource Conservation Service (NRCS), the USDA Farm Service Agency, carbon sequestration programs, or the Oregon Forest Resource Trust, as well as the federal reforestation tax credit. It should be noted that programs and opportunities may vary. Contact your local OSU Extension or Oregon Department of Forestry field offices for more information on these assistance programs.

Controlling competing vegetation

Controlling competing vegetation is one of the keys to successful reforestation in dry forested ecosystems of eastern Oregon. Forbs, grasses, sedges, and shrubs compete with tree seedlings for site resources—light, water, nutrients, space—and therefore limit regeneration success, particularly natural regeneration. Even on dry eastern Oregon sites where grass and other vegetation appear to be minimal, competition below ground, particularly for moisture, can be intense. See *Enhancing Reforestation Success in the Inland Northwest*, PNW 520, https://catalog.extension.oregonstate.edu/pnw520, for more information.

Before planting, reduce competing vegetation with site preparation treatments. Tree seedlings may require an additional (release) treatment if competing vegetation reinvades quickly.

Site preparation treatments

To ensure good seedling survival, site preparation usually is needed **before** seedlings are planted. Site preparation not only removes or reduces competing vegetation, it exposes mineral soil to create plantable spots, enhances natural regeneration establishment, or removes habitat for tree-feeding wildlife. Controlling competing vegetation early on helps ensure seedlings survive and win out over their competitors. Failure to control competing vegetation from the outset may mean added expense later if seedling survival is poor and replanting becomes necessary. Even if seedlings survive, early growth is very slow without proper site preparation.

Methods used to prepare the site for either natural regeneration or hand-planted seedlings include hand-scalping, mechanical scarification, herbicides, and prescribed fire. In addition, paper or woven-plastic mulch mats can be placed around seedlings to control vegetation. For best results, it's important to use the method, or combinations of methods, that best control the target vegetation at a reasonable cost. Each alternative needs to be evaluated based on site conditions, landowner preferences, and cost. You may need to seek the advice of an OSU Extension forester, Oregon Department of Forestry stewardship forester, or forestry consultant.

Use Pesticides Safely!

Wear protective clothing and safety devices as recommended on the label. **Bathe or shower** after each use.

Read the pesticide label—even if you've used the pesticide before.

Follow closely the instructions on the label (and any other directions you have).

Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. **You may be liable** for injury or damage resulting from pesticide use.

Herbicides

To prepare sites with heavy grass and forb competition, options include using spot or broadcast applications of herbicides such as hexazinone or sulfometuron, depending on tree species to be planted, in the fall before spring planting or in the spring after planting but before budbreak (i.e., while seedlings are dormant). These are soil-active herbicides, so rain must move the chemical into the root zone of the target vegetation. Because containerized seedlings can be sensitive to soil-active herbicides, don't spray these herbicides over newly planted plugs.

Glyphosate also can be used in the fall or spring for grass control when the target plants are green and actively growing; however, it has less residual effect than the herbicide options mentioned above. When spraying glyphosate around newly planted seedlings in the spring, you will need to protect seedlings from spray drift and nozzle drip. If Ross or elk sedges are dominant competitors, a mixture of hexazinone and glyphosate works well. Do not apply hexazinone around larch or western white pine.

See Table 6.5 (page 139) for herbicide names and descriptions. For up-to-date weed control recommendations consult the *Pacific Northwest Weed Management Handbook*, https://catalog.extension.oregonstate.edu/weed.

Hand-scalping

Hand-scalping uses a hoedad or hazel hoe to scrape away competing vegetation around planting holes. To be effective, scalps must be a **minimum** of 4 feet square (Figure 6.10, page 139). Scalping is labor intensive and expensive, especially in sod, and generally is much less effective for controlling vegetation than other site-preparation methods. Scalping works best on sandy loam or pumice soils and in herbaceous vegetation when competing vegetation levels are low. Under these conditions, vegetation is more easily pulled or cut away from the planting spot. Scalped areas expose mineral soil that is quickly recolonized by grass, forbs, and noxious weeds like cheatgrass. Thus, retreatment often is necessary. Scalping is not effective on shrubs. Scalping is more expensive and less effective than either herbicides or mats.

Mulch mats

Mulch mats are an effective alternative to either scalping or spot application of herbicide, but mats can be more expensive than herbicide options. Mats are made of kraft paper, plastic, or a variety of woven-plastic fabrics (Figure 6.11, page 140). Costs vary, but generally kraft paper mats are least expensive. However, they deteriorate within one season and do not control competing vegetation long enough to ensure good seedling survival. Experience in eastern Oregon shows that woven-plastic mats provide good control of competing vegetation for a longer period than either herbicides or scalping. To be effective, mats should be at least 3 to 4 feet square. They must be pinned to the ground with staples and slash or soil placed on top to prevent them from blowing away in windy areas. Some plastic mats biodegrade within three to five seasons. Others do *not* break down and may need to be removed, adding time and expense.

Shrubby and hardwood tree sites

Sites occupied primarily by shrub and hardwood tree species such as snowbrush ceanothus, mallow ninebark, black hawthorn, oceanspray, snowberry, bitterbrush, greenleaf manzanita, maple, and alder can be treated using herbicides, mechanical scarification, prescribed fire, or combinations of these methods. Some of the more common herbicide options are glyphosate in late summer for ninebark, oceanspray, and snowberry; 2,4-D in spring and early summer for ceanothus and manzanita; triclopyr in the fall for maple and alder; and imazapyr for a wide variety of woody shrubs and grasses (see Table 6.5, page 139). Mechanical scarification should be done when soil is dry; a brushblade does a good job of clearing sites of competing vegetation, including roots. Mechanical scarification is a good way to gain access for planting and reduce competition on sites overtaken by this competing vegetation, but a follow-up herbicide treatment may be needed to kill resprouting species. Prescribed fire can also be used to reduce and kill competing shrubs and hardwood trees. However, some species can quickly resprout, and fire can stimulate dormant seeds of other species (e.g., snowbrush ceanothus) to germinate and outcompete seedlings.

Release treatments

Grass, shrubs, and other vegetation may grow faster than newly established seedlings, reducing tree growth and increasing mortality (Figure 6.12, page 140). To ensure their survival, seedlings may need to be released from this competition by using appropriate herbicides and/or by manually cutting or scalping shrubs and grass. Even with good site preparation, some vegetation can be so aggressive that release treatments are necessary.

One common mistake is to wait too long before doing release treatments, often in the hope that the seedlings will prevail. Release treatments work best if they are done early (year 1 or 2 after planting) while seedlings are still vigorous and healthy and **before** competing vegetation has overtaken and suppressed their growth. Seedlings that have been overtopped by shrubs or have been competing with grass for several years seldom respond to release or do so very slowly, wasting time and money.

Herbicides

To release certain species' seedlings from grass or elk sedge, use hexazinone or atrazine in either a spot or broadcast application in early spring or fall when seedlings are dormant. However, western larch, western white pine, and western redcedar are sensitive to

Table 6.5. Common herbicides for controlling competing grasses, forbs, and shrubs in the inland Northwest.

Herbicide				
Trade name (s)	**Common name**	**Vegetation controlled**	**Application time**	**Mode of action**
Atrazine 4L Atrazine 90	atrazine	Grasses	Early spring or late summer to early fall (August–September)	Root uptake
Accord XRT Rodeo	glyphosate	Grasses, forbs, and deciduous shrubs	Spring, summer, or fall	Absorbed through foliage
Arsenal AC Chopper Gen 2 Polaris AC or SP	imazapyr	Grasses, forbs, and selected shrubs	Spring or late summer	Foliar absorption and root uptake
Garlon 3A, Garlon 4	triclopyr	Selected shrubs	Spring or late summer to early fall	Foliar and bark absorption
Oust XP	sulfometuron	Grasses, some forbs	Spring or fall (fall better)	Root uptake and some absorption through foliage
Transline	clopyralid	Broadleaf weeds: thistles, knapweed, and hawkweed	Spring to early summer, when weeds are actively growing	Foliar absorption
Velpar L Velpar DF Velossa	hexazinone	Grasses, forbs, and selected small, young shrubs	Spring or fall	Root uptake; with Velpar, some absorption through foliage
Weedone LV-6	2,4-D	Selected shrubs	Early spring (before conifers begin growing) or late summer to early fall	Foliar absorption

Figure 6.10. Competing vegetation scalped away from a pine seedling.

Figure 6.11. A 3-foot vegetation mat around a pine seedling

Photo: Bruce Alber

Figure 6.12. On this productive site in eastern Oregon, grasses have rebounded following a harvest to the point that this ponderosa pine seedling is now under intense competition for limited water and nutrients, warranting a release treatment.

hexazinone; instead, use sulfometuron (Table 6.5, page 139). Another alternative is to use glyphosate as a spot application around seedlings in the spring; however, seedlings should be protected from the spray using a stovepipe or similar device.

If shrubs are the main competitor, apply broadcast applications from the ground or air using herbicides such as imazapyr, glyphosate, or triclopyr; herbicide selection, timing, and rates are critical to minimizing conifer damage. Herbicide combinations can be used if target vegetation is not controlled by a single herbicide. Remember, removing shrubs may release grasses, so consider combining shrub-controlling herbicides with those that control grasses, such as hexazinone and atrazine. Consult the *Pacific Northwest Weed Management Handbook* for current recommendations (https://catalog.extension.oregonstate.edu/weed).

Individual clumps of competing hardwood trees and shrubs can be treated with a directed spray, tree injection, or basal bark application using glyphosate, imazapyr, triclopyr, or 2,4-D. Your choice will depend on the target vegetation, method of application (directed spray versus basal bark application), and herbicide costs. Get advice from professional foresters before deciding which herbicide options to use and follow label directions carefully. Timing and proper application rates are not only critical for good vegetation control but also for minimizing herbicide damage to conifer seedlings.

Cutting and scalping

Although more-expensive and less-effective than herbicides, manually cutting with a chain saw or scalping vegetation offers an alternative to landowners who do not want to use herbicides. However, species that resprout or regrow quickly (within one growing season) may need repeated cutting or scalping. The cut or scalped areas should be a minimum of 4 feet square.

Summary

Reforestation is critical for achieving sustained benefits from your forests, and it is required by Oregon law following harvests that reduce stocking below a minimum level. The reforestation process requires careful planning and timely action; miss one critical step and the whole process may fail. Success is most often gained by those who develop a good plan, carefully carry out each step, anticipate and check for problems, take timely corrective action, and enjoy seeing young and healthy forests take root.

CHAPTER 7

Eastside conifer pests and their management

Paul T. Oester and Greg M. Filip

Eastside conifer forests are home to a variety of native pests (both insects and diseases) and a few introduced pests. For a discussion of animal pests, see Chapter 9. Forest pests cause a tremendous economic loss and create dead fuels for wildfires, but they also play beneficial roles in several ecological processes such as decomposition and nutrient recycling and they provide habitat for wildlife (see Chapter 9). Fortunately, the adverse effects of most pest problems can be managed with good silviculture (Figure 7.1a-b). This chapter briefly summarizes the major pests and management strategies for reducing damage; refer to *Managing Insects and Diseases of Oregon Conifers*, https://catalog.extension.oregonstate.edu/em8980, for more information.

Figures 7.1a–b. A laminated root rot center (above left) and an Armillaria root disease center (above right). Most of the dead trees are firs, and the openings are filling with shrubs. Such openings tend to persist for decades unless managers use brush control and regenerate the site with nonsusceptible species.

Bark beetles

Biology

Figure 7.2. Lodgepole pine killed by mountain pine beetle in northeastern Oregon, 1975.

Mountain pine beetle, western pine beetle, pine engraver, and red turpentine beetle are pests of pine. Douglas-fir is host to the Douglas-fir beetle, which also can attack severely weakened western larch. The fir engraver attacks true firs, and the spruce beetle infests Engelmann spruce. The western balsam bark beetle attacks primarily subalpine fir. Most species of bark beetle attack trees that are relatively large (larger than 8 inches dbh) and old (more than 80 years), especially in dense stands. Engravers, however, such as the pine engraver or *Ips* beetle, can successfully breed in stems as small as 3 inches in diameter.

Mountain pine beetle is probably one of the most aggressive bark beetles in eastern Oregon and can kill entire landscapes of susceptible trees in only a few years. Some examples include northeastern Oregon in the early 1970s where more than 1.5 million acres of lodgepole and ponderosa pines were killed (Figure 7.2); central and southern Oregon in the 1980s where more than 1 million acres were affected; and, more recently, in Klamath and Lake Counties where 370,000 acres were damaged over several years in the 2010s. These episodes represent the loss of millions of dollars in revenue to forest owners.

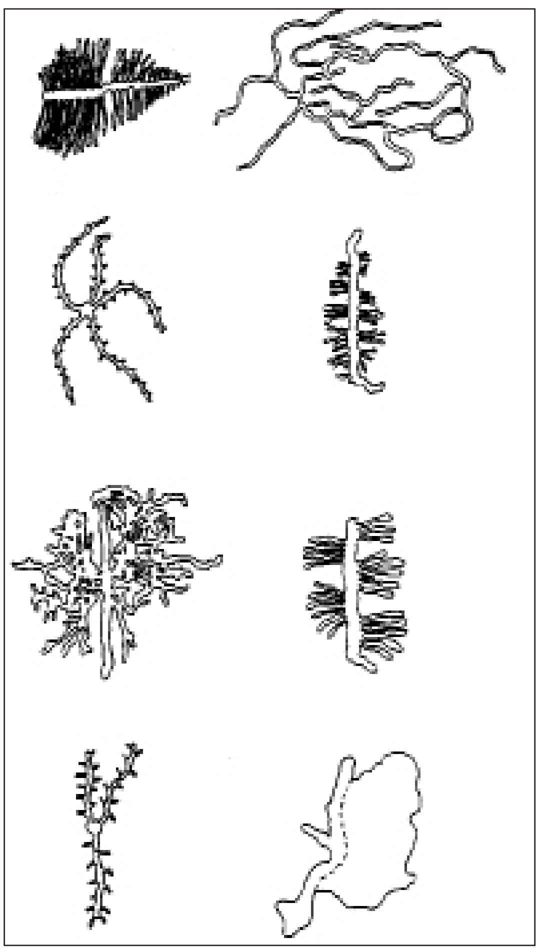


Illustration: Susan Hagle, US Forest Service

Figure 7.3. Typical patterns of galleries created under tree bark by bark beetles in eastern Oregon forests.

Mountain pine beetle attacks are easily identified. Beetles leave thumb-sized pitch globs or tubes on the trunks of living trees (see Figure 4.2, page 68). Pitch tubes, which appear in midsummer, mark where a female beetle has entered the tree. She makes distinctive tunnels or galleries under the bark (Figure 7.3). Microscopic fungi carried by the beetles help kill the tree and stain the sapwood blue or brown after a few months (Figure 7.4, page 143), reducing sawlog value significantly. Dry boring dust (like fine sawdust) also might appear in bark crevices below the pitch tubes and at the base of the tree.

Each bark beetle species creates a unique gallery under the bark, which can be used to help identify the species (Table 7.3). Galleries and external bark indicators, such as boring dust, provide clues identifying bark-beetle-attacked trees.

Beetles also have a beneficial role in forest ecosystems. They provide food for wildlife, especially birds. In fact, an obvious sign of beetle attack is tree bark partially removed by birds as they forage for larvae; this is an especially good indicator of western pine beetle on ponderosa pine. Another important role of bark beetles, especially in overstocked stands, is as recyclers of nutrients from entire trees back to the forest floor. Surviving trees benefit from the newly created growing space and from nutrients from dead needles, branches, trunks, and roots. Bark-beetle-killed trees become snags for cavity-nesting birds and other wildlife (see Chapter 9). When the snags fall, they provide habitat for a different set of wildlife. Gaps in the forest canopy as a result of tree mortality allow more light into the forest, which benefits some plants and animals and leads to greater biodiversity.

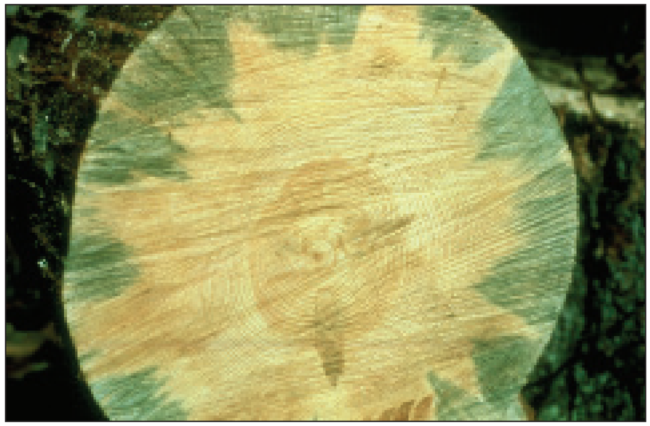


Figure 7.4. Blue stain caused by fungi carried by mountain pine beetle.

Although there are several natural controls of bark beetle populations—food supply, tree resistance, cold temperatures, birds, nematodes, and other insects—occasionally beetle populations become so large that an epidemic results. This is especially common in large areas of mature trees in overdense stands. For most species, controlling tree density and increasing tree vigor will lower susceptibility of trees and stands to beetle attack.

Management

Bark beetles prefer to attack and can kill trees that have been weakened by other causes, such as drought, overstocking, defoliation, or root disease. There are differences, however. For example mountain pine beetle in lodgepole pine stands is a more aggressive tree killer. The management strategy most universally used to prevent bark beetle attack is to maintain individual trees and stands in a vigorous condition through thinning (Figure 7.5).

Figure 7.5. Ponderosa pine stand precommercially thinned to reduce bark beetle damage and Armillaria root disease.

Pitch tubes

I can see pitch tubes on my trees! What should I do?

- *Pitch tubes are caused by bark beetles that attack weakened trees and kill them.*
- *Remove infested trees, and thin the stand to improve growing space and vigor of the remaining trees.*
- *Vigorous trees are more resistant to bark beetle attack.*

Slash created from harvesting or precommercial thinning creates habitat (food source) for pine and fir engraver beetles that can result in beetle population increases and local tree mortality, especially in ponderosa and lodgepole pines. Cull logs and tops should be limbed, cut into short (3-foot) lengths, and left exposed to sunlight. This facilitates rapid drying and makes the material unsuitable for beetle reproduction. Timing when slash is created is probably the most economical approach: limiting harvests or thinnings to late summer and fall will make the slash too dry for good beetle development. Chipping thinned material to keep engraver beetles in check works well and is an option when slash is created during the winter and spring; however, it is used very little because of the expense. Normally, trees less than 3 inches dbh can be thinned any time because small branches and stems are not sufficient habitat to produce large beetle populations.

Bark beetles are mostly species specific for host trees. Therefore, maintaining a diversity of tree species in your stands provides a “damage buffer”—if an insect becomes epidemic, nonhost trees will still be left in the stand after the outbreak. For example, Douglas-fir beetle will attack and kill Douglas-fir but not pine or spruce (Table 7.1).

When mixing pine with other conifer species, follow the stand density guidelines for pine (see Chapters 3, 4, and 5). In overstocked stands with a pine component, pines often are attacked before the other species. The relationship between thinning and “beetle proofing” is not as clear in mixed stands as in pure pine stands; however, it’s widely accepted that high vigor decreases trees’ susceptibility.

Remove windthrown Douglas-fir and spruce within one year to prevent buildups of Douglas-fir or spruce beetles, respectively, on down trees and subsequent attacks on standing green trees. If you cut firewood in May and June from pines with yellow crowns, adult beetles in the logs might leave the logs to attack standing green trees. Store firewood away from green trees, and cover firewood with clear plastic to kill beetle larvae and adults under the bark.

Table 7.1. Bark beetle pests of eastside conifer forests, their host species, and common management strategies.

Pest	Host species	Strategies
		Basic strategies: Thin to keep stands thrifty, and cut and remove infested trees. Also:
Douglas-fir beetle	Douglas-fir	Promptly salvage windthrown timber.
Mountain pine beetle	Ponderosa, lodgepole, sugar, white, and whitebark pine	Emphasize timely thinning.
Pine engraver	Ponderosa and lodgepole pine	Time production of slash and slash disposal.
Western pine beetle	Ponderosa pine	Remove trees of declining vigor.
Red turpentine beetle	Ponderosa and lodgepole pine	Emphasize timely thinning.
Fir engraver	Grand, white, Shasta red, and occasionally subalpine fir	Time production of slash and slash disposal. Manage root disease. Shift species to more pine and larch. Consider local information regarding the necessity of managing slash timing and disposal.
Spruce beetle	Engelmann spruce	Promptly remove blowdown. Keep stands in younger age classes.

Defoliating insects

Biology

Defoliating insects damage tree foliage (needles). Some species feed on new growth, others on old needles, and some on both. Some species feed within the needles, some feed from the outside of the needle, and some feed within the fascicle (base of needle). Two of the most damaging defoliators are the western spruce budworm and Douglas-fir tussock moth, whose primary hosts are true firs and Douglas-fir. Larch casebearer is an introduced pest of larch, but outbreaks have quieted since exotic parasites were introduced. Pandora moth is a defoliator of ponderosa, lodgepole, and sugar pines. Pine butterfly defoliates ponderosa pine and sometimes lodgepole pine east of the Cascade Crest but can occur on Douglas-fir west of the crest.

Figure 7.6. Grand fir lightly defoliated by western spruce budworm in northeastern Oregon.

Outbreaks occur periodically and can cause heavy defoliation and sometimes mortality; however, outbreaks are relatively short lived, about three to four years, and larvae feed on the older needles so trees have a little foliage to use for photosynthesis during the outbreak. Most defoliated trees should recover, especially if they were healthy prior to the outbreak. Mortality is tied to how much tree foliage is consumed, how long the outbreak lasts, tree health prior to the outbreak, and other factors such as whether drought occurs following the outbreak. Defoliated trees are weakened and thus more susceptible to attack by bark beetles, especially if the outbreak is followed by drought.

Western spruce budworm larvae chew on and consume new foliage of true firs, Engelmann spruce, and Douglas-fir, causing growth loss, top kill, and mortality (Figure 7.6). Historical evidence shows that epidemics seem to occur every 12 to 20 years and usually persist for 5 to 10 years. The outbreak in the 1980s and early 1990s in eastern Oregon lasted about 12 years and covered wide expanses of the Blue Mountains and the east slope of the Cascades.

Table 7.2. Defoliating insect pests of eastside conifer forests, their host species, and common management strategies.

Pest	Host species	Strategies
		Basic strategy: Maintain mixed-species stands.
Western spruce budworm	Douglas-fir; grand, white, and subalpine fir; spruce, sometimes larch	Emphasize pines and larch in species mix.
Pine butterfly	Ponderosa pine (primary) and lodgepole	Maintain high vigor.
Douglas-fir tussock moth	Douglas-fir; grand, white, and subalpine fir	Emphasize pines and larch in species mix.
Pandora moth	Ponderosa, lodgepole, and sugar pine	Maintain high vigor.
Larch casebearer	Western larch	Allow introduced and natural predators and parasites to control population.
Black pineleaf scale	Ponderosa and lodgepole pine	Maintain high vigor.

Photo: Oregon Department of Forestry

Figure 7.7. Ponderosa pine showing a shortened infested terminal caused by the western pineshoot borer.

Intensity of damage varies across the landscape, from light to heavy. The most heavily damaged stands have multiple canopy layers of fir; most defoliation is in understory trees.

Douglas-fir and true firs are hosts of the Douglas-fir tussock moth. Larvae feed first on new foliage, but larvae also consume older foliage as they develop during the growing season. This insect's epidemic cycle is short, about three years, but damage can be severe. Outbreaks recur about every 20 to 30 years.

Scale insects are defoliator pests of eastside conifers. Damage is from the insects piercing through the needle to suck out water and nutrients. The black pineleaf scale attacks primarily pines and sometimes Douglas-fir. Affected foliage is stunted at the tips, where individual needles appear yellowish and encrusted with scales. In some cases, tree crowns become faded and thin, and trees might be attacked subsequently by bark beetles. Currently, in some areas in southern and eastern Oregon, serious outbreaks of black pineleaf scale occur. Some of the more-severely affected areas are tied to pesticide drift from orchards or mosquito spray projects. The insecticides kill many of the natural predators and parasites of the scale, allowing their populations to expand.

Causes of defoliator outbreaks are complex and largely unknown, but outbreaks do require high stocking levels of host-tree species. Research in the Blue Mountains showed ants and birds play a significant role as predators and help regulate background or endemic populations of defoliating insects, possibly extending the length of time between epidemics. Providing snags for cavity-nesting birds and mammals, providing down woody debris (logs and slash) for ants and wildlife, and protecting ant colonies can enhance populations of these important predators.

Management

Direct control measures for foliage-feeding insects traditionally relied on aerial spraying with insecticides such as DDT and carbaryl. More recently, the use of these chemicals has been restricted. Now, the preferred treatment is aerial applications of biological insecticides such as Btk (short for *Bacillus thuringiensis* var. *kurstaki*), a natural bacterium that occurs in caterpillar populations and leads to their natural decline. Insecticide applications, however, cannot address the real cause of the epidemic: overstocking of the susceptible host and multiple age classes and proliferation of fir on sites too droughty for healthy growth.

The most effective management strategy to reduce the adverse impacts of defoliators in stands of mixed fir and pine is to maintain a high ratio of pine and larch; i.e., 50 to 70 percent of total stocking. In stands with fewer host fir trees, populations of the most serious defoliators (i.e., western spruce budworm or Douglas-fir tussock moth) will remain lower and damage will be less. Although some trees may be killed from pest attacks, adjacent surviving trees will occupy the growing space quickly. Pine and larch defoliators usually do not cause serious damage and disappear in a few years. Keeping trees vigorous before an outbreak with good density management will help them maintain resilience and recover better after the outbreak collapses (Table 7.2, page 145).

Shoot- and twig-feeding insects

Biology

Shoot- and twig-feeding insects affect tree growth by infesting terminal and lateral branches. One example of a shoot- and twig-feeding insect is the western pine shoot borer, which attacks young stands of ponderosa pine. This moth lays eggs under bud scales on lateral or

Table 7.3. Shoot- and twig-feeding insect pests of eastside conifer forests, their host species, and common management strategies.

Pest	Host species	Strategies
		Basic strategy: Encourage more- resistant species and mixed species. Also:
Balsam woolly adelgid	True firs	—
Western pineshoot borer	Ponderosa and lodgepole pine	Use pheromones or insecticides on high-value trees.

terminal branches early in the spring before budbreak. As eggs hatch, immediately the larvae bore into either lateral branches or the terminal leader, where they mine the central pith area. In most cases, the terminal is stunted but not killed and only the laterals are killed. Damage from this pest can be identified from the shortened infected terminal and short "bottle brush" needles or the dead current year's growth (Figure 7.7, page 146). Studies indicate each attack reduces tree height growth by about 25 percent. Frequently, the largest and most vigorous trees are affected.

Another damaging shoot- and twig-feeding insect is the balsam woolly adelgid, which periodically attacks but only occasionally kills true firs. The insect causes gouting on twigs and attacks stems and boles. Infestation results in deformed crowns, growth loss, and sometimes death. Bole infestations are more damaging than twig gouting.

Management

Insecticidal control is difficult for shoot- and twig-feeding insects because of the very narrow time window for application and the need for multiple applications. Favoring resistant tree species is a good option in mixed-species stands. Cultural options for the western pine shoot borer include removing and burning the infected leaders or branches before the insect emerges to overwinter in the fall. A disruptive pheromone for this insect is available for small treatment areas, probably less than 10 acres, but it is expensive and must be repeated annually. Recently, an "attract-and-kill" treatment (pheromone plus insecticide) became available and shows promise. Also, some shading of young pine, such as in a shelterwood system, seems to lower the risk of attack by this species (Table 7.3).

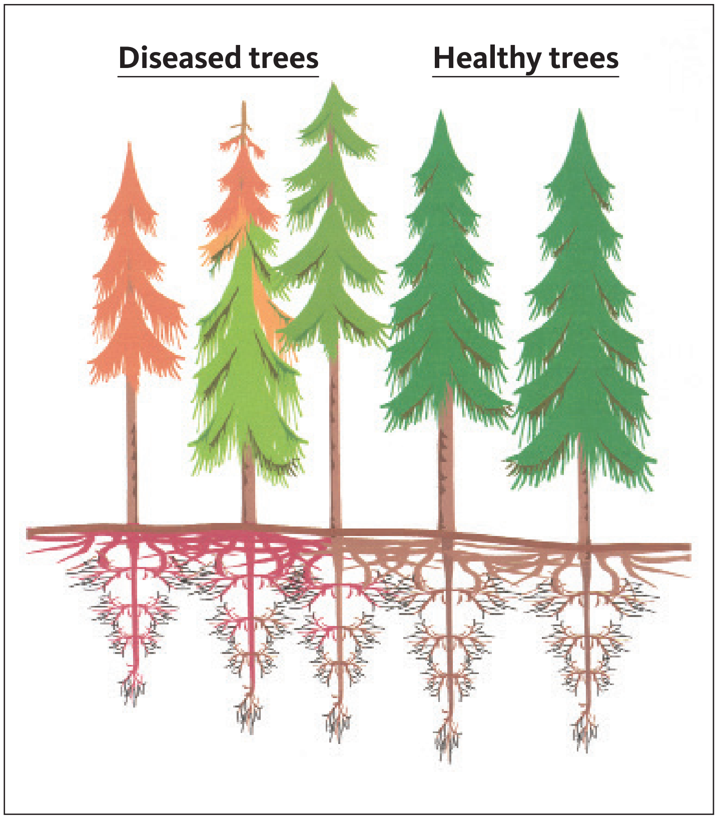


Illustration: Nancy Boriak

Figure 7.8. Root diseases spread from diseased trees to healthy trees via root contact.

Root diseases

Biology

Root diseases are the most difficult group of pests to identify and manage in eastside conifer forests. Root-disease fungi infect root tissues and restrict water and nutrient movement from the soil to the tree. Infected trees slowly decline in vigor and eventually die. The more aggressive root diseases in eastside conifer forests are Armillaria root disease and Heterobasidion root disease. Laminated root rot and black stain root disease also occur. Most infection is through root contact from infected to noninfected trees (Figure 7.8, page 147). Heterobasidion root disease and black stain root disease also spread by spores. Except for black stain, root-disease fungi remain viable in cut stumps and large roots for many decades.

Figure 7.9. Several stages of tree decline and death, usually in close proximity, are typical of root disease pockets.

Trees in root disease patches show a progression of symptoms: stunted growth, yellow to red foliage, tree death, and stem breakage. They do not die at the same time, nor will they be in the same stage of decline (Figure 7.9). Root disease often predisposes trees to attack from other pests, especially bark beetles.

Susceptibility to infection and damage by root pathogens varies with tree species. In general, true fir species are more susceptible to root disease than larch or pine.

Heterobasidion root disease in western North America consists of two biological species, *H. occidentale*, the old S group, and *H. irregular*, the old P group. These two biological species have distinct differences in host specificity. Pines are generally infected by the P group, and true fir, Douglas-fir, hemlocks, and giant sequoia by the S group. Thus, if you have this root disease in pine, it will not infect fir and vice versa.

Figure 7.10. Mixed-conifer stand thinned to reduce mortality and growth impacts from armillaria root disease. Use this practice cautiously and consult local experts for advice.

Table 7.4. Major root diseases of eastside conifer forests, their host species, and common management strategies.

Diseases	Host species	Strategies
		Basic strategy: Encourage species that are more resistant. Also:
Laminated root rot	Susceptible—Douglas-fir, larch, true fir, spruce, hemlock Resistant—pine, incense-cedar, juniper Immune—hardwoods	Emphasize pine in mix.
Armillaria root disease	Susceptible—Douglas-fir, true fir, spruce, juniper, pine, hemlock Tolerant—larch, incense-cedar	Promote tree vigor. Emphasize larch in mix.
Black stain root disease	Douglas-fir and ponderosa pine	Avoid tree wounding, keep trees vigorous, time thinning to avoid beetle flights if appropriate
Heterobasidiom root disease	True firs and ponderosa pine	Preventive: avoid tree wounding. Treatment: apply boron to cut stumps if appropriate.

Management

Many root-disease fungi can survive in roots for decades after infected trees die. If a diseased stand is harvested and replanted without considering the disease, susceptible seedlings eventually will be infected. Damage in the new stand may be worse than in the preceding stand.

Based on our understanding of how root-disease fungi spread and survive in roots, the preferred management approach is to take advantage of the differences in tree species' susceptibility to root diseases. Encourage species more resistant to disease (Table 7.4). For instance, pine and larch can be planted in root-disease areas within mixed-conifer forests. Favor disease-resistant species during a variety of silvicultural operations including planting, precommercial thinning, and commercial thinning and in clearcut, seed-tree, shelterwood, individual-tree, and group-selection systems (Figure 7.10, page 148; also Chapter 2).

Photo: Paul Aho

Figure 7.11. Conk of the Indian paint fungus on an infected true fir.

Figure 7.12. Tree wounds activate dormant decay fungi or provide entry courts for spores.

Minimize black stain root disease by reducing site disturbance and tree injury and by favoring mixed-species stands. Also, thin Douglas-fir with black stain root disease after bark-beetle vectors have dispersed in the spring, usually about early June. Thin before September 1 so thinned material can dry before winter and be unsuitable for insect vectors in spring. However, in some cases it may be best to forgo thinning altogether if disease is widespread in the plantation.

Prevent Heterobasidion root disease in pine and true firs by treating freshly cut stump surfaces with boron-containing materials (e.g., Sporax or Timbor) to prevent infection by spores. Boron treatment is effective only if applied within 48 hours of cutting and if the stumps are not already infected as evidenced by stain or decay at the stump surface. Untreated stumps, especially of true firs, probably will become infected and will spread infection to adjacent, residual trees. Use this boron treatment only in stands not previously harvested or where treatment has been carried out in the past (see Table 7.4, page 149).

Stem decays

Biology

The most common stem decay or "heart rot" in eastside conifer forests is rust-red stringy rot. It is caused by the Indian paint fungus, which infects primarily grand, white, and subalpine firs. The fungus rots away the tree's central stem. It can be identified by the large, horseshoe-shaped fruiting bodies, or conks, on the outside of the trunk (Figure 7.11, page 149). Four or more conks indicate that the tree is a complete cull. Trees younger than 100 years tend to have less defect, but by age 150 decay is common, and many of these trees are totally defective, or culls. Although cull trees have no value as sawlogs, they sometimes can be chipped for pulp. Large, hollow grand firs are important habitat for cavity-dwelling birds and small mammals and for bears as hibernation sites.

Trees become infected when Indian paint fungus spores are released into the air, drift through the forest, and infect dead branchlet stubs; there, they remain dormant until activated by physical damage. Once activated, the fungus begins to grow in the tree bole. Tree wounding activates dormant decay fungi or provides entry points for other fungi (Figure 7.12, page 149).

Heterobasidion root disease causes butt rot or stem decay in true firs that have been wounded. Red ring rot, also called white speck, is an important decayer of Douglas-fir, larch, and pines.

In general, resinous species such as the pines and Douglas-fir are more resistant to decay than species such as true firs and hardwoods. Stem wounds, often caused by logging, and especially those deep into the wood or close to the ground are important entry points for decay fungi spores.

Management

Management to avoid stem decays includes growing conifers on shorter rotations (Table 7.5, page 151). Trees less than 75 years old usually have very little decay even if wounded, whereas older trees can have considerable decay. Do not avoid or delay thinning because of concern about potential decay losses from wounding. Growth increases due to thinning will outweigh decay losses in most cases. Increased vigor will prevent infection by some decay fungi. Thin early so that decay columns, if they do form, will be small. Select crop trees that are vigorous and undamaged. When pruning, be sure to make cuts properly.

Table 7.5. Major stem decays of eastside conifer forests, their host species, and common management strategies.

Stem decays	Host species	Strategies
		Basic strategy: Manage on short rotations and prevent stem wounding. Also:
Annosus stem decay	True fir, spruce, and hemlock	—
	True fir	Promote tree vigor.
Red-ring rot	Douglas-fir, true fir, hemlock, larch, spruce, and pines	—

Photo: Beth Wilhite, US Forest Service

Figure 7.13. Indian paint fungus causes decayed heartwood and hollow stems in living small-size and larger true fir and hemlock trees.

No wound dressing can prevent decay in living trees. The following steps will keep wounding to a minimum during harvest and greatly reduce the incidence of stem decay:

- Avoid spring and early summer logging, when sap is rising and bark is not as tightly attached.
- Learn how to use different types of operating equipment properly under various circumstances of terrain, tree size, and soil type and conditions.
- When thinning or harvesting, mark leave trees rather than trees to be cut.
- Plainly flag skid trails and skyline corridors before marking and logging.
- Make trails and corridors straight.
- Protect trees near skid trails or corridors with plastic culverts or similar protective devices around trees, especially near trail corners.
- Use rub (bump) trees or high stumps at corners in skid trails and corridors.
- Cut low stumps (less than 3 inches high) in skid trails or use old skid trails where high stumps are not common.
- Use directional felling and fell to openings.
- Remove slash and debris from within 10 feet of leave trees to reduce damage from natural or prescribed fire.

Rust diseases

Biology

Important rust diseases of eastern Oregon conifers are western gall rust and comandra blister rust on lodgepole and ponderosa pines, white pine blister rust on five-needle pines, and broom rusts on true firs and spruce. Stem rusts get their name from the yellow to brown color they cause on stems or branches. Stem rusts often cause abnormal stem or branch swellings called galls (Figure 7.14).

Western gall rust, caused by a fungus, is probably the most common disease of lodgepole pine in Oregon. It also is common on ponderosa pine in some locations. Severe infection causes round to pear-shaped galls to form on stems and branches. This can lead to stem malformation, breakage, branch flagging (dead branch from gall to branch tip), and tree death, especially in seedlings. The greatest damage occurs when the rust establishes itself on the main stem and over time causes a sunken area on the stem, called a hip canker. Trees with this damage are more prone to break at the point of infection.

Comandra rust is caused by a fungus that results in top kill and breakage and sometimes kills the tree, especially seedlings and saplings. White pine blister rust is an introduced disease that continues to be a widespread killer of five-needle pines, such as western white pine, sugar pine, and whitebark pine (Figure 7.15). Broom rusts form in true firs and spruce and create ideal habitat for many wildlife species.

Photo: Alan Kanaskie

Figure 7.14. Gall caused by western gall rust on lodgepole pine.

Figure 7.15. Branch mortality caused by white pine blister rust.

Management

Manage stem rusts by removing infected trees during thinning. Prune to remove rust infections from branches. Except for white pine blister rust, all rust diseases are native, so there is a high amount of natural resistance to these diseases in most stands. Faster-growing, more-vigorous young trees, however, appear to be most susceptible. For white pine blister rust, pruning lower branches will reduce infections and using rust-resistant seedlings for planting will provide enhanced resistance (Table 7.6, page 153).

Some trees are more genetically predisposed to attack than others. Because broom rusts rarely spread to other trees and rarely cause significant losses, infected trees can be left for wildlife habitat. For future seed production, retain trees that appear most resistant.

Gall Rust

My stand has gall rust! What should I do?

- *Gall rust usually will not kill trees but in some locations can cause growth loss if damage is severe.*
- *When thinning, remove trees with stem galls or numerous branch galls.*
- *Plant resistant seedlings by collecting local seed from trees without gall rust.*
- *Prune branches if infected.*

Table 7.6. Major rust diseases of eastside conifer forests, their host species, and common management strategies.		
Disease	**Host species**	**Strategies**
		Basic strategy: Remove infected trees while thinning, prune infected branches, and favor resistant trees. Also:
Western gall rust	Ponderosa and lodgepole pine	Plant genetically resistant trees.
Comandra rust	Ponderosa pine	—
White pine blister rust	White, sugar, and whitebark pine	Plant genetically resistant trees; prune lower crowns.
Broom rust	True firs and spruce	Leave for wildlife.

Needle and shoot diseases

Biology

Several fungi attack conifer foliage. Infected needles have reduced photosynthetic efficiency and drop from the tree prematurely. The net effect is reduced tree growth and vigor as well as an unappealing appearance. Needle diseases are often most severe in off-site plantings (see Chapter 6) or following years when wet weather continues into summer.

Rhabdocline needle cast affects Douglas-fir. Fruiting bodies on the undersurfaces of infected needles release windborne spores in May to June. Only the current year's needles are susceptible, and they are not cast until the following year.

Elytroderma needle blight affects ponderosa and, rarely, lodgepole pine. It causes the 1-year-old needles to turn red in spring. The disease also affects the twigs and causes a witches' broom with upward-turning branchlets. This disease is often confused with dwarf mistletoe, but Elytroderma-broomed branches do not have mistletoe plants.

Red band needle blight affects ponderosa and lodgepole pines in Oregon. The disease is recognized by yellow to tan spots and bands that appear on needles in July. Infected needles drop in late summer or fall, or, in some cases, in spring of the following year.

Larch needle blight and larch needle cast are two common needle diseases of western larch. Needle cast affects just the tips of the needles, whereas needle blight affects the whole needle, as if scorched by fire, and all needles on a spur are affected. Needles affected by larch needle cast drop early; needles affected by larch needle blight are retained one year or more. Infected crowns usually refoliate, but repeated infection may cause growth loss.

Diplodia tip blight is a fungal disease that initially infects the needles of ponderosa and other pines then moves to the shoot, causing a canker. Look for dead branch tips (needles dead on tip of branch) and sunken, resin-filled shoots at the base of needles. This disease can be found on trees of any size or age; trees under stress are more susceptible.

Management

It is often very difficult to predict the extent of damage caused by needle diseases, but there are ways to minimize the likelihood of an outbreak and the level of damage once an epidemic occurs (Table 7.7, page 154):

- Do not manage for a single tree species. Because needle fungi are usually host specific and attack only a single tree genus (e.g., pine or fir or larch), a good strategy is to plant several species on a site, thereby limiting spread and loss if one species is affected.

- Do not import seed or non-native trees from outside your area. Bringing non-native species or seed sources onto your site may not only result in damage to these trees but may allow an increase in spores that may harm the locally adapted trees.

- In some instances, thinning will increase air circulation and reduce damage by needle disease.

- Maintain good forest health. Activities such as thinning might reduce the impact of some needle diseases by improving tree vigor and air drainage and by favoring resistant trees or nonhost tree species.

- Treating forest stands with fungicides to control needle diseases has not been cost effective. A thorough spray is required, and repeated applications could be necessary if it rains. In general, fungicides are limited to Christmas tree plantations or to single trees planted in urban settings where appearance is important.

Table 7.7. Major needle diseases of eastside conifer forests, their host species, and common management strategies.

Disease	Host species	Strategies
		Basic strategy: Plant or favor mixtures of tree species; use only local seed and native trees. Also:
Rhabdocline needle cast	Douglas-fir	—
Elytroderma needle blight	Ponderosa and, rarely, lodgepole pine	Prune infected branches.
Red-band needle blight	Ponderosa and lodgepole pine	—
Larch needle diseases	Larch	Promote good air circulation.
Diplodia tip blight	Pines	Keep trees vigorous.

Mistletoe

Mistletoe is in my stand! What should I do?

- *Dwarf mistletoe can severely retard growth and lead to tree death.*

- *Make sure that it is mistletoe: Elytroderma needle blight looks very similar.*

- *Remove infected trees with mistletoe in the mid and upper crown.*

Photo: John Thompson

Figure 7.16. Dwarf mistletoe plants on an infected ponderosa pine.

- *Prune lower branches with infections in trees with healthy upper crowns.*

- *Save a few infected trees for the wildlife; use a buffer.*

Dwarf mistletoes

Biology

Dwarf mistletoe is, in economic terms, one of the most important diseases of eastside conifers. Dwarf mistletoes are parasitic, flowering, seed-bearing plants that have stems, roots, and foliage (Figure 7.16, page 154). They rely totally on their hosts for nutrients and water. Dwarf mistletoes spread by seeds that move by gravity and wind to infect adjacent trees. The most important dwarf mistletoes in eastern Oregon are on Douglas-fir, larch, true firs, ponderosa pine, and lodgepole pine.

Although several species of conifers can be infected, dwarf mistletoes rarely cross from one species to another; the major exception is larch dwarf mistletoe, which can severely infect lodgepole pine and mountain hemlock (Table 7.8, page 156). One variety of fir dwarf mistletoe infects only white and grand firs; another variety infects only Shasta red fir. Fir dwarf mistletoe is on true firs only in the Cascades; it is not in the Blue Mountains of northeast Oregon.

Stand density and vigor affect the rate of mistletoe spread and tree susceptibility to mistletoe-caused mortality. Infestations result in witches' brooms that slow tree growth, lower wood quality, and eventually result in tree death (Figure 7.17, page 156).

The abnormal growth that dwarf mistletoes cause in their host, known as "witches' brooms," provides habitat for owls, other birds, and mammals. The dense foliage and large branches provide hiding cover and nesting platforms, and the plants themselves are a food source.

Juniper and incense-cedar are infected by true mistletoes, which unlike dwarf mistletoes have leaves and can make some of their own food. Heavily infected trees experience some growth loss.

Management

When timber production is your objective, selectively removing or girdling severely infected trees is effective in controlling stand damage from dwarf mistletoes. Because the parasite spreads most rapidly from large trees to smaller ones, the key is to remove infected overstory trees to prevent further infection and then space the understory trees to improve growth and vigor. Also, dwarf mistletoe requires a living host to survive; once the host tree dies, the mistletoe dies. Branch pruning is another mistletoe-control option for high-value trees when infections are confined to the lower crown (Table 7.8, page 156).

The best strategies include:

- Removing the infected overstory once regeneration is established
- Removing the more severely infected trees during thinning
- Shifting the stand's species composition to favor nonhosts
- Clearcutting heavily infected stands or groups and starting over

Thinning increases growth of Douglas-fir, ponderosa pine, and western larch that are lightly to moderately infected with dwarf mistletoe. Essentially, the leave trees in the thinning can outgrow the dwarf mistletoe in the lower crown. Do not thin crop or leave trees for at least five years after removing an overstory to allow enough time for latent infections to appear. After five years, thin out any trees that show infections.

Figure 7.17. Witches' brooms caused by Douglas-fir dwarf mistletoe.

In some places, you may want to keep mistletoe-infected trees for wildlife habitat. Maintain clumps of infected trees and leave a 50-foot buffer around the clump to prevent spread to healthy trees. This buffer can be of nonsusceptible trees. For instance, if you have a clump of Douglas-fir that has several witches' brooms, remove a 50-foot buffer of Douglas-fir around the clump and plant ponderosa pine or larch in that space.

Table 7.8. Dwarf mistletoe pests of eastside conifer forests, their host species, and common management strategies.

Dwarf mistletoes	Principal host species	Strategies
		Basic strategy: Switch to nonhost species. Remove the more heavily infected trees and branches during thinning and pruning, maintain vigorous growth in moderately infected stands, remove heavily infected overstory trees.
Larch	Larch, mountain hemlock, and lodgepole pine	—
Western	Ponderosa pine	—
Lodgepole pine	Lodgepole pine	—
Fir	White, grand, and Shasta red fir	—
Douglas-fir	Douglas-fir	—
True mistletoe	Juniper and incense-cedar	—

Summary

There is potential for many problems from insects and diseases in the forests of eastern Oregon, so management can be complex. Keys to success include maintaining vigorous stands of a mixture of tree species. If a stand of pure pine is the only option, it is especially important to maintain proper tree spacing. Active forest management will manipulate forest insects and diseases to reduce their impacts and to improve and maintain the quality of your forest.

CHAPTER 8

Managing forest forage values

Paul T. Oester, Leticia V. Henderson, and Tim Deboodt

Forests in eastern Oregon offer a diverse set of opportunities that range from timber production to forage production to the development of aesthetic views. Depending on the goals set for your property, you may have a need to integrate rangeland considerations into forest management planning. Rangelands are types of lands which provide habitats and forage for grazing livestock and wildlife. These lands are also sometimes referred to as grasslands, shrub-steppe, deserts, and woodlands/forests.

There are many reasons to consider forage values in your management plan for your eastern Oregon forest. First, many ranchers who own woodland say forage is their highest priority. Second, through their management, forest owners can positively or negatively influence range quality and quantity. With the right information and with careful planning, owners can improve their range resource for livestock production or wildlife forage (Figures 8.1a–c) while meeting timber production objectives. Finally, finding strategies that best integrate all resources (timber, range, wildlife, and water) can improve economic returns. This chapter has four main purposes:

- Show how forest cover influences understory vegetation
- Discuss basic grazing management principles
- Provide seeding recommendations for different objectives
- Discuss economic tradeoffs between timber and forage

Figures 8.1a–c. Thinning dense thickets (at top, far left) can increase understory production threefold in many eastside forests for several years (at bottom, far left, and at left) until crowns close in. Disturbing the soil and then seeding domestic forages after thinning can provide even greater advantages.

Integrating forage and timber production

Forage production (the growth of grasses, forbs, and shrubs) and utilization through effective grazing management strategies in eastern Oregon forests can go hand in hand with timber production and the management of wildlife habitats. In many cases, implementing a responsible grazing management plan at an appropriate utilization level will not affect timber production.

Livestock graze on most forest types and ownerships in eastern Oregon, and there are abundant opportunities to enhance forage productivity. For example, thinning dense thickets usually can provide a two- to threefold increase in forage yields. Seeding grasses, whether introduced or native, provides even greater opportunities to increase forage production.

Combining livestock grazing with good silviculture gives owners a way to integrate management plans. In fact, combining grazing and timber production might be more profitable than emphasizing one resource over the other. For ranchers, grazing timber areas is essential to making the operation profitable. Promoting abundant, high-quality forage also can attract deer and elk. Forestry practices and forage enhancement are complementary and can be compatible; however, it's essential that they be carefully coordinated and managed. Here are two examples:

- Seeding grasses without considering the impact on tree seedling survival and growth may defeat seedling establishment objectives. Seeding grasses should be coordinated carefully with tree establishment objectives. Some approaches are to delay seeding until trees are established (usually two years), seed less competitive bunchgrasses, and seed at lower rates.
- From a livestock management perspective, leaving extensive concentrations of slash after harvest limits access to forage.

Consider several factors—all discussed in this chapter—as you develop forage potential on your forest property:

- Relationships between tree cover and forage
- Blending tree and forage production
- Grazing management
- Wildlife
- Seeding guidelines
- The economics of thinning and seeding forage

Tree cover and forage relationships

It is generally understood that understory production decreases as the overstory increases. For example, in a mixed-conifer forest in the Blue Mountains, forage production decreased from 310 pounds per acre under open stands to 85 pounds per acre under closed stands. Forage was 210 pounds per acre at intermediate densities. Another study indicated that the greatest amount of understory growth is produced under crown covers of less than 40 percent.

A third study evaluated thinnings over eight growing seasons in north-central Washington on a 48-year-old ponderosa pine site. Thinning was at several spacings (13 by 13 feet, 19 by 19 feet, and 26 by 26 feet) and included a control plot. Understory production ranged from 75 pounds per acre in the control to 417 pounds per acre under the 26-foot spacing. For each percent change in the canopy, understory growth was similarly affected. Finally, in the Blue Mountains of Oregon on a warm-dry mixed-conifer site, the amount of pinegrass plus elk sedge declined by almost 50 percent once tree canopy cover exceeded 70 percent (Table 8.1).

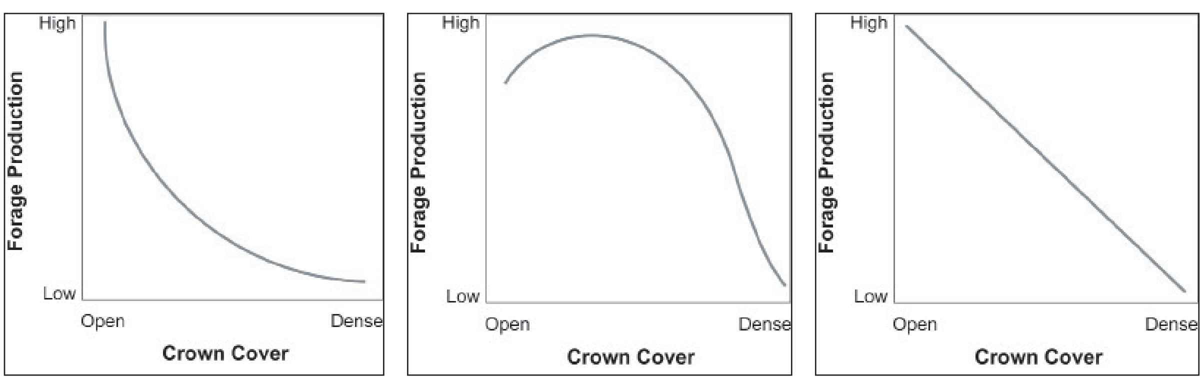
Table 8.1. The effect of tree canopy cover on pinegrass and elk sedge composition (from Hall 1988).

Tree canopy cover (percent)	Pinegrass plus elk sedge composition (% of total cover)
Under 40	75
41–70	60
71–90	40+
91+	15

The relationship between understory production and canopy closure is influenced by light and nitrogen availability and by forage species, geographic location, litter accumulation, weather and climate, soil type, past management practices, moisture competition, and other factors. In fact, the most important feature of overstory-understory relationships is that there is no set response to all conditions. However, some general patterns are seen (Figures 8.2a–c).

On drier pine sites with mostly grasses, forbs, and sedges, forage production is highest where tree canopy cover is low. As tree cover increases, forage production declines quickly at first and then levels off between moderate and high tree-canopy coverage (Figure 8.2a). For more-moist sites, such as mixed-conifer with a high shrub component, some research has shown that light to moderate forest stocking levels tend to yield as much or more understory shrub cover as forest openings (Figure 8.2b). This suggests that if you are interested in forage production on these sites, you can have all the forage the site will produce with moderate levels of tree canopy and that very wide tree spacing is not necessary for maximum forage levels.

In stands that have not been logged for 15 years or more in the Blue Mountains, the relationship between canopy cover and forage yield is not direct. Most forage yield reduction comes when canopy cover reaches 20 to 30 percent, as in Figure 8.2a. However, a recently thinned stand has a more direct relationship between canopy cover and understory yield, as in Figure 8.2c. As canopy cover increases, forage yield declines in step. As tree roots



Figures 8.2a–c. Canopy cover can affect forage yield in a variety of ways. Some of the most likely possibilities are shown here (from Clary 1988).

recolonize the site, the overstory-understory relationship returns to that of the original stand. Preliminary findings from a study in the Blue Mountains show the following:

- Elk sedge represents more than 30 percent of available forage on ponderosa pine and warm-dry mixed-conifer forests.
- Forage production (lbs/acre) appears high in ponderosa pine and warm-dry mixed-conifer forests; these sites have large amounts of marginally palatable forages such as pinegrass and elk sedge.
- Cool-moist mixed-conifer forests have a higher proportion of forbs and shrubs than drier habitats.
- Variability in understory production is influenced by stand-development stage (sapling, pole, small sawlog, and sawlog), forest type, and year.
- In ponderosa pine forests, forage production remains high up to the small sawlog stage; however, moist sites show a forage production decline after the sapling stage.
- In stands with more moisture and a high proportion of grand fir, forage production is higher in middle-aged stands than younger or older stands.

Principles for blending tree and forage production

Managing eastern Oregon forests for trees and forage production requires understanding how to blend forestry and range management principles for the benefit of both. Incorporating forage production into your forest management plan can provide an extra source of revenue by promoting livestock grazing. Forage management considerations can also enhance wildlife habitat. Here are some general principles to combine tree and forage production on a single site.

Forest Types and Forage Potentials

In ponderosa pine and lodgepole pine stands, optimum timber management maintains rather low stocking levels and thus low canopy cover, often less than 60 percent. These forest types should provide high amounts of forage for wildlife and livestock. Warm-dry mixed-conifer stands will provide excellent grazing opportunities while you are managing ponderosa pine for good diameter growth. Longer harvest cycles will cause declines in forage production as native grasses will replace domestic seedings.

In cool-moist mixed-conifer forests, invasion of grand and white firs has decreased forage production. Optimum stocking levels for timber production should provide moderate forage production. Seeding after stand treatments may double forage production compared to relying on the existing plant population to respond on its own.

Expect low forage production as shrub canopies hinder livestock from accessing forage and compete for limited resources (light, water, and nutrients) with the grasses and forbs. Shrubs such as oceanspray, ninebark, snowberry, and spirea dominate in mixed-conifer forests and limit grazing. Native shrubs provide important forage at certain times.

Thinning

Thinning dense, stagnant stands can increase forage and individual tree growth. Thinning trees can help reduce competition, which will release nutrients and other resources to promote healthy growth of the remaining vegetation. However, site conditions will have a big impact on the time required for tree growth responses to occur. Expect faster response on better sites.

Grazing

When managed correctly, grazing provides benefits to both tree and forage production. Typically, grazing in forested areas in eastern Oregon occurs during the summer and will last between two and four months. Livestock grazing the understory of a forested area will reduce plant competition for essential nutrients and resources, giving young seedlings a better chance at survival. Grazing can also help reduce wildfire intensity and spread by removing fine fuels, particularly on more productive soils.

Seeding grasses, forbs, and legumes

Seeding a mixture of introduced or selected cultivars of native grass species can improve forage production and use. Species such as orchardgrass, Sherman big bluegrass, timothy, and intermediate wheatgrass potentially can increase carrying capacity. These species of grass produce more pounds of forage per acre than native vegetation and they're often more palatable and nutritious. Because some domestic grasses mature later in the season, their crude protein levels stay high longer.

Adding forbs and legumes such as small burnet, yellow blossom sweet clover, and birdsfoot trefoil will benefit wildlife. If you're seeding legumes, the seed should be properly inoculated (inoculum is a bacterium or fungus added to the legume seed) before seeding so the plants acquire nitrogen-fixing bacteria and can better compete. Use inoculants labeled for the specific legume you are seeding. Use only fresh, age-dated inoculants purchased from dealers who store their supplies in cool, dark places to minimize deterioration. Consult with your local office of the OSU Extension Service or USDA Natural Resources Conservation Service (NRCS) or a seed company to find out how to inoculate the seed.

Seeding rates and varieties depend on site productivity and conditions and your objectives (see Table 8.2, page 162). Seeding a mixture of grasses can help manage weed problems. Any time a disturbance leaves mineral soil bare, weeds can gain a foothold. Seeded grasses can occupy the space quickly, create a competitive environment, and help keep weeds out.

Using native forages

Don't rule out the use of native grasses, sedges, and shrubs in seeding mixes. Pinegrass, Idaho fescue, bottlebrush squirreltail, and elk sedge are important to the foraging needs of ungulates (livestock and wildlife) and help stabilize soil on millions of acres in eastern Oregon. Pinegrass in its vegetative state has good protein content, similar to that of some non-native, improved grasses. Elk sedge stays green throughout the year, providing important fall and winter forage for ungulates.

Oceanspray, ninebark, ceanothus, bitterbrush, and snowberry are shrubs that livestock, deer, and elk switch to later in the season as the nutrient content of grasses declines. Wintering deer rely heavily on bitterbrush for food in central Oregon. During certain times of the year, grazing animals readily browse young shoots of willow, black cottonwood, and quaking aspen hardwood trees. Assess your situation and get professional advice before seeding grasses or conducting other forage management activity in your forestland. (For plant association information, see http://www.treesearch.fs.fed.us/pubs/20801.)

Reducing competition

Grasses compete with tree seedlings for water and nutrients. If your goal includes regenerating trees on a site, delay seeding for a few years or until trees are established. Restrict seeding to skid trails and log landings (Figures 8.3a–b, page 163). Seed grasses that will not form sod, such as orchardgrass, timothy, and Sherman big bluegrass. Seed grass mixtures at reduced rates: 4 to 6 pounds per acre. However, if noxious weeds are a threat, seed domestic grasses that can compete with weeds. In this situation, you could plant trees and grasses at the same time and then follow up by reducing competing vegetation around seedlings using herbicides, mats, or mechanical removal.

Table 8.2. Broadcast seeding recommendations for ponderosa pine, lodgepole pine, and mixed-conifer forest types.*

		Seeding rate (lb/acre)[1]	
Forest type	**Component of seeded grass mixture**	**Component mix**	**Total**
Ponderosa pine	Intermediate wheatgrass[2]	5	
	Sherman big bluegrass	1	
	Hard fescue	2	
	Alfalfa	2	
	Small burnet	1	
			11
Lodgepole pine	‘Potomac’ or ‘Latar’ orchardgrass	3	
	Hard fescue or smooth brome	Hard fescue-1 Smooth brome-2	
	Yellow blossom sweet clover	1	
	Small burnet	2	
	Timothy	1	
			8–9
Mixed-conifer	‘Paiute’, ‘Potomac’, or ‘Latar’ orchardgrass	3	
	Hard fescue	2	
	Smooth brome or timothy	Smooth brome-2 Timothy-1	
	Blue wildrye	1–2	
	Yellow blossom sweet clover	0.5–1	
	Small burnet	0.5–1	
			8–11

*Normally, drill-seeding rates are designed to achieve 20 to 30 pure live seed per square foot for the grasses you wish to dominate the stand. This is about half the broadcast rates shown in this table.

[1]In mixed-conifer forests, the lower seeding rate in the range is for warm-dry types and the higher rate is for cool-moist types.

[2]Substitute pubescent wheatgrass for intermediate wheatgrass on drier sites.

Selecting tree species

If your objective is to find the best ways to blend the production of trees and forage, then consider the effect of tree species on forage and fiber yields. For example, say you're deciding whether to grow mostly pine or more Douglas-fir and grand fir on a warm-dry mixed-conifer site (Chapter 1). On one hand, you could expect a managed pine forest to yield about 600 pounds of forage per acre per year. On the other hand, growing more Douglas-fir and grand fir could increase fiber yields over pine (pines are about 50 to 80 percent as productive as the firs), but forage production would be significantly less. Also, having more Douglas-fir and grand fir increases the risk of defoliator damage and, if root disease is in the stand, lowers yields.

Photos: Fred Hall

Figures 8.3a–b. Seeding skid trails and landings with non-sod-forming grasses stabilizes the soil and provides additional forage. It also focuses seeding to only part of the site, which frees up space for conifer regeneration.

Grazing management

Managed cattle and sheep grazing has been shown to help tree seedling survival and growth during plantation establishment. Grazing can physiologically stress the understory, resulting in smaller and shallower root systems that are less competitive with tree seedlings. Some requirements:

- Palatable forage must be available to minimize conifer damage. Nearly all introduced seeded grasses are more palatable than elk sedge and pinegrass.
- In areas where moisture is limited during the growing season (e.g., pine forests and warm-dry mixed-conifer forests), vegetation should be grazed before stored soil moisture is depleted.
- Livestock numbers, grazing duration, and grazing distribution must be controlled.
- Cost of the grazing program must be minimized to make it pay.
- Conifers are most palatable to deer, elk, and livestock during periods of rapid growth after bud burst. Areas where deer and elk concentrate during winter can also create intense browsing pressure.

When developing a grazing management plan on your forested property, consider the five basic range management principles: (1) season of use, (2) type of animal, (3) stocking rate, (4) length of grazing, and (5) distribution of animals. In some cases, grazing managers may not have the ability to alter all of these principles, but being aware of how they influence forage and tree production will help you develop a comprehensive grazing management plan. For example, if establishing young seedlings is a priority and fully managed grazing is not possible, then reduce grazing intensity and delay grazing until later in the season or restrict grazing from the site until seedlings are several years old.

Season of use: grazing rotations

Plants grazed in the early summer months will be of higher forage quality than the same plants grazed in late summer or early fall. Plants grazed during the active growing season will need longer rest periods before being grazed again when compared to plants grazed that are mature or dormant. Grazing of various plant communities for optimum animal performance is scheduled to coincide with the occurrence of green forage and maximum plant nutrient content. For most eastern Oregon forests, this generally means grazing lower-elevation meadows first, about early June. In mid-June, move to the upland ponderosa pine and warm-dry mixed-conifer forests. Move livestock to higher-elevation, cool-moist mixed-conifer and lodgepole pine forests in late summer or September. Recently thinned stands will lose forage quality earlier in the summer due to their more-open canopies and should be used first. As a general rule, grazing should leave stubble 3 inches high, and rarely graze the current year's regrowth. It is a best management practice to not graze the same pasture the same time of the year, year after year.

Type of animal

Type of animal refers both to grazing animal species and to animal age and class. In Oregon, the two most common species of livestock used in grazing operations are sheep and cattle. If animal production is not the primary purpose of livestock grazing, knowing the grazing behaviors of each species can help you decide whether to use sheep or cattle to graze available forage. Each species has strengths and weaknesses that will help you meet your management goals. Animal and gender also will influence the grazing behavior of your herd. Cattle are primarily grazers (mostly eat grass) while sheep and goats are both grazers and browsers (prefer both grass and shrubs). Younger animals (yearlings or young cows) will generally travel more than older animals.

Stocking rate

Stocking rate or animal density is defined as the amount of land allocated to a grazing animal for a specified amount of time. Pasture grazing leases on both public and private lands in eastern Oregon are determined using Animal Unit Month (AUM), which is the amount of forage required to maintain a 1,000-pound cow and her calf for 1 month. On private land, the landowner can determine the appropriate stocking rate for a piece of property. Stocking rate can influence forage, timber, and animal performance. Management objectives and specific site characteristics will dictate the appropriate stocking rate for a given site.

Length of grazing

Land managers must also decide the appropriate length or duration of grazing in a forested pasture. Stocking rate, season of use, and site productivity will have the greatest influence on the grazing duration. As an example, a pasture that has 100 AUM's of available forage can be grazed by 20 cows for five months, 50 cows for two months or 100 cows for one month. Each of these examples harvests 100 AUMs (20 x 5; 50 x 2; or 100 x 1).

Wildlife

Wildlife conservation and livestock grazing are compatible goals. Thinned stands with good grass understories are excellent forage areas for deer and elk (Figure 8.4, page 165). Where forage production is a priority, encourage cavity-nesting birds, small mammals, songbirds, deer, and elk by leaving extra snags, retaining a few slash piles, and seeding grasses and forbs that attract wildlife (e.g., orchardgrass and small burnet). Allow brush and trees to grow together in thinnings and promote a diversity of tree species and multiple layers of canopies. For more information regarding wildlife management, refer to Chapter 9.

Seeding guidelines

In developing a seeding prescription, refer to your management plan and overall goals for your property. When buying seed, always buy certified seed and read the label. When stabilizing roads on moderately productive forest sites, plant about 20 pounds of pure live seed per acre of a mixture of pubescent wheatgrass, hard fescue, intermediate wheatgrass, orchardgrass, and timothy. Roads can be managed for different grazing scenarios. If you want to limit grazing on roads, then seed grasses like pubescent wheatgrass (quick starting) and hard fescue (slow starting). These grasses are less palatable. If the objective is to attract animals to the road or lead them away from riparian areas, then orchardgrass, smooth brome, and timothy are good choices because they are productive and more palatable.

Variation in palatability among species can affect how seeding combinations are grazed. Grazing animals will most often select for the most palatable species. For example, combinations of hard fescue and pubescent wheatgrass (two of the less palatable domestic species) with orchardgrass, timothy, and smooth brome (the most palatable) can cause the more palatable species to be grazed out, leaving the less palatable to dominate. Palatability not only varies between species but will also vary for the same species during different times of the growing/grazing period.

Seeding is recommended to be done in the fall or early spring. A common practice is to seed just before or at the beginning of winter snow accumulation. The action of the snow as it melts the following spring helps move the seed into the soil. Broadcast seed on mineral soil, or, for best results, use a rangeland drill. If you're planting trees and want to seed forage as well, delay seeding until the trees are established. If delaying is not an option, reduce the seeding rates in Table 8.2 (page 162) by half so forage competition with young trees is kept manageable.

Figure 8.4. Thinning ponderosa pine forests improves tree vigor, increases resistance to insects and disease, accelerates bole growth, and, as an added benefit, provides increased forage for wildlife as well as livestock. Deer and elk are attracted to thinnings with abundant, high-quality forage.

Usually, skid trails and landings should be seeded at higher rates to reduce soil erosion and prevent weed invasion. On mixed-conifer or lodgepole pine sites, use orchardgrass, timothy, and smooth brome on landings, skid trails, and access roads. This combination is more palatable and productive as well as less competitive with tree seedlings than many native grasses.

Timothy is a good species, and palatable, but it has a bulb at the base that is readily sought by small rodents such as gophers and might result in larger rodent populations. Finally, domestic legumes need to be properly inoculated to compete on the site.

Blue wildrye

Selected grasses, sedges, forbs, and legumes

Bird's-foot trefoil (*Lotus corniculatus*)

This moderately long-lived, deep-rooted legume is suited for erosion control, big game food, and waterfowl. It can grow under dryland conditions where the effective precipitation is 20 inches or more.

Very winter hardy and useful at high elevations, it is tolerant of poor drainage and quite vigorous. This plant may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed.

Blue wildrye (*Elymus glaucus*)

This short-lived, perennial bunchgrass grows to 3 to 5 feet tall in the 15- to 23-inch precipitation zone. Shade tolerant and widely adapted to favorable sites in timbered or brushy areas, it is good for reseeding burned or disturbed areas in oak woodland or forest. It is very tolerant of fire, burning quickly with little downward transfer of heat. Blue wildrye can also provide excellent wildlife habitat for mammals, birds, and waterfowl. It provides good forage early in the season, but later it may be too coarse and stemmy. It will not survive if grazed too heavily.

Elk sedge (*Carex geyeri*)

A long-lived perennial 6 to 20 inches tall, this evergreen sedge usually keeps its semigreen leaves through the second growing season. It grows chiefly in the ponderosa pine, lodgepole pine, and mixed-conifer forests of eastern Oregon where precipitation is 12 to 20 inches annually. It prefers well-drained loamy soils. Its triangular stem has leaves branching off on all three sides (three ranked).

It is one of the earliest forage plants available at lower elevations in spring and remains green long into fall. It is moderately palatable to elk and cattle, but deer tend to avoid it. Elk sedge spreads primarily by rhizomes; it has low seed production and poor seed viability.

Hard fescue (*Festuca brevipila*)

Hard fescue is more drought resistant than chewings fescue (*Festuca rubra* ssp. *fallax*) but not as drought resistant as sheep (*Festuca ovina*) or Idaho fescues (*Festuca idahoensis*). It is adapted to the 16- to 30-inch rainfall areas of Washington State, Oregon, and Idaho. Hard fescue is used for stabilizing roadsides and ditch banks, farm tree plantings, cover in orchards, weed suppression, campsites and recreational areas, golf course fairways, farm landing strips, runway shoulders, logging roads, skid trails, ski slopes, dryland lawns, and cover for retired cropland. While it has been planted for grazing, more palatable grasses are recommended.

Idaho fescue (*Festuca idahoensis*)

This native species is well distributed in eastern Oregon and grows on all exposures and under a variety of soil conditions. Cool north slopes, heavier-textured soils, and shade are all characteristics of the type of site conditions common to Idaho fescue. It tends to occupy the drier forest sites, especially in the Blue Mountains, and is one of the more important native forages. A perennial bunchgrass, it is about 2 feet tall at maturity and spreads entirely by seed. It is a good spring or early summer forage. If heavily grazed, Idaho fescue may be replaced by invasive species, such as cheatgrass.

Intermediate wheatgrass (*Thinopyrum intermedium*)

This late-maturing, long-lived, mild sod-former is suited for hay and pasture, alone or with alfalfa. It can be grown under irrigation or on dryland where effective precipitation is 15 inches or more. It requires good drainage and moderate to high fertility. Generally, it is recommended for erosion control on ponderosa pine and mixed-conifer sites.

Kentucky bluegrass (*Poa pratensis*)

A sod-forming grass with fibrous and strongly rhizomatous roots, Kentucky bluegrass is common in moist, well-drained areas. It is often found on spring sites, riparian areas, and meadows. It is highly palatable to both livestock and wildlife, tolerates grazing, and increases under heavy use and fire.

Orchardgrass 'Hallmark', 'Potomac', and 'Latar' (*Dactylis glomerata*)

These long-lived, high-producing bunchgrasses are adapted to well-drained soils and grow under irrigation or on dryland where effective precipitation is 16 inches or more with summer rains. Orchardgrass is shade tolerant.

Orchardgrass is highly palatable and preferred over native species such as pinegrass. In reforestation, it is more easily controlled because its bunching form allows easier removal with a hoedad or Pulaski during scalping. It is suited for pasture and erosion control.

There are different varieties of orchardgrass which allow selecting for early, mid-, and late-season maturity, such as Hallmark, Potomac and Latar. Late-season varieties are preferred in mixtures with alfalfa, especially in eastern Oregon. 'Latar' is preferred in mountainous areas. Orchardgrass either increases or remains stable after burning.

Orchardgrass 'Paiute' (*Dactylis glomerata*)

Throughout the intermountain West, 'Paiute' has done well on well-drained basic and acidic soils. It performs well on soil textures ranging from clay to gravelly loams and on shallow to deep soils. It does not grow well in saline soils or in areas with high water tables.

It was selected for its ability to establish and persist in areas that receive as little as 11 inches of annual precipitation as long as summer precipitation occurs. 'Paiute' has been shown to be more drought tolerant than other orchardgrass varieties.

Elk sedge

Livestock, big game, and rabbits have shown a preference for 'Paiute'. 'Paiute' greens up 7 to 10 days earlier in the spring than 'Fairway' or standard crested wheatgrass, remains green longer, and has better fall growth.

Pinegrass (*Calamagrostis rubescens*)

Found as a carpet under ponderosa pine and lodgepole pine and in warm-dry mixed-conifer forests, this native grass likes warm, well-drained soil and is not common on wet meadows or cold, north slopes at higher elevations. It can tolerate moist to dry sites and can grow on all aspects. It is a shade-tolerant species even under heavy cover. Pinegrass greens early in the spring and remains green late into the fall. Pinegrass primarily reproduces by lateral expansion of the rhizomes.

It may be grazed during the summer. It is utilized by wildlife across its range and can provide forage for livestock throughout the year, although it is less palatable as the season goes along and under shaded conditions. It is resistant to fire, and growth generally improves following burning.

Pubescent wheatgrass (*Agropyron trichophorum*)

Slightly more drought tolerant than intermediate wheatgrass (*Thinopyrum intermedium*), pubescent wheatgrass is a long-lived, rhizomatous grass adapted to low-fertility sites and fine-textured soils where effective precipitation is at least 12 inches annually. It tolerates more alkaline and drier conditions than intermediate wheatgrass. Its ability to remain green during summer, when soil moisture is limited, is a significant characteristic. One of the least-palatable domesticated species, it can be used to discourage livestock use, such as along busy roads.

Sherman big bluegrass (*Poa secunda* ssp. *ampla*)

Sherman big bluegrass

A long-lived native bunchgrass, Sherman big bluegrass begins growth in late summer to early fall and stays green later than other species. It resumes growth in very early spring, as much as 4 weeks ahead of crested wheatgrass, and it ripens in early to late summer depending on available moisture. It has excellent palatability for livestock and wildlife year-round.

Sherman big bluegrass naturally occurs on upland sites and in open ponderosa pine and lodgepole pine forests. It is best adapted to areas that receive 9 to 20 inches of annual rainfall. Cheatgrass is the most troublesome weed during establishment of Sherman big bluegrass. Once established, it competes well with cheatgrass.

Small burnet 'Delar' (*Sanguisorba minor*)

This cultivar needs 12 inches or more of precipitation and well-drained soils. It can grow up to 2 feet tall and will establish and grow on soils with pH as high as 8.0. It is very palatable to livestock and game animals, particularly in late winter and early spring, and provides excellent bee forage. Small burnet establishes easily and should not be grazed until the second season following planting. Small burnet should be allowed to set seed 1 out of every 3 years to ensure stand regeneration.

Smooth brome (*Bromus inermis*)

Well suited to 15 to 18 inches of precipitation, smooth brome is a leafy, sod-forming, perennial, cool-season grass. It is best adapted to cooler climates and is generally hardier than tall fescue or orchardgrass. It grows best on slightly acid to slightly alkaline (pH 6.0 to 7.5) well-drained clay loam soils. Smooth brome performs best in grassed waterways, field borders, and other conservation uses where the forage can be cut and removed while in early bloom.

Tall fescue (*Schedonorus arundinaceus*)

This long-lived, high-producing bunchgrass is suited to a wide range of soils and climates. The leaves of forage types are broad, while turf types have been selected for narrow leaves. It is tolerant of strongly acid to slightly alkaline conditions (pH 5.5 to 7.0). Tall fescue is suited to irrigation, subirrigation, or moderately wet conditions as well as to dryland areas where effective precipitation is more than 12 inches. 'Fawn' and 'Alta' are the varieties of tall fescue most commonly used in the Pacific Northwest.

Timothy (*Phleum pratense*)

This perennial grass is adapted to high elevations and areas where effective precipitation is 18 inches or more. Suited for forage and erosion control, it is especially valued in revegetating forested lands in eastern Oregon. Timothy is highly palatable to livestock and wildlife from early spring through mid summer and is extremely sensitive to close or early grazing and trampling during moist conditions. Its late maturity may be an advantage under certain conditions, such as in poorly drained soils. It is highly attractive to gophers and should not be seeded where regeneration is a goal.

Yellow blossom sweetclover (*Melilotus officinalis*)

A tall, stemmy, annual or biennial legume, yellow blossom sweetclover is suited to dryland where the effective precipitation is 15 inches or more. Only biennial forms are commonly used. Sweetclover flowers are attractive to bees and butterflies.

'Madrid' has yellow flowers. It matures earlier and is more suited to sandy soils and drier conditions than white-flowered sweetclovers, though it is less productive under optimum growing conditions.

Sweetclover can be used for hay, silage, or pasture. It is, however, less palatable than many other legumes because of its bitter taste caused by the chemical coumarin in the plant tissues. Coumarin is the cause of sweetclover bleeding disease, which affects cattle after prolonged grazing on moldy or damaged sweetclover hay.

Riparian areas and grazing

Livestock or big game can co-exist with riparian systems or they can damage them. These responses are highly site-specific; no template for a grazing strategy can guarantee success. This section discusses how grazing management systems can be applied in different riparian situations. For information on plant associations in eastern Oregon riparian areas, see *Deep Canyon and Subalpine Riparian and Wetland Plant Associations of the Malheur, Umatilla, and Wallowa-Whitman National Forests*, http://www.treesearch.fs.fed.us/pubs/24936.

Decisions about specific grazing practices for riparian areas on your property should be made in consultation with professional grazing specialists. Overgrazing upland and riparian vegetation can reduce plant vigor, encourage less-desirable species, cut down and erode stream banks, and increase water temperatures and sediment loads. Improvements can be made through managed grazing techniques that allow the riparian area vegetation to rest, thus restoring the area, enhancing water quality, and increasing production. Strategies that manage grazing to protect, rehabilitate, and maintain riparian areas include these:

- Using alternative grazing strategies

- Excluding livestock
- Managing riparian zones as special-use pastures
- Implementing one or more grazing distribution systems

Figure 8.5. Riparian areas and streams can be enhanced and protected with proper grazing management. The key is to regulate the timing and intensity of animal use so that riparian vegetation can thrive and streambanks remain stable.

Using alternative grazing strategies

If grazing is having a small or moderate impact on riparian zones (Figure 8.5), attracting livestock away from the zone or using barriers might suffice. Attract livestock away from riparian areas by providing shade, salt, drinking water, or supplemental feed to reduce the time livestock spend in riparian zones. Seeding palatable forages (see Table 8.2, page 162) in the uplands might draw livestock to those areas and reduce use of riparian areas. Developing clean, high-quality water sources away from the stream is also a good tool for improving distribution of livestock. Using barriers such as large rocks or boulders, shrub thickets, and logs can protect sensitive streambanks.

Excluding livestock

More steps are necessary to protect riparian areas where livestock graze heavily. Herding and fencing are two ways of dealing with heavy use. Improved handling methods have reduced the labor-intensive and costly herding option (see George 1996). Fencing is used to segregate riparian pastures, implement grazing systems, and exclude cattle.

Managing riparian areas as special-use pastures

A riparian system is based on the premise that riparian areas can be managed independently. Advantages include better control of animal distribution and grazing intensity and timing as well as an increase in forage production. This system seems to work well when separate, fenced pastures are grazed late in the season, after riparian vegetation has finished growing and has stored adequate energy for regrowth.

Implementing a grazing distribution system

Oftentimes, issues with overgrazing are a result of poor grazing distribution rather than overstocking. Rarely are forested pastures homogenous in forage composition, water availability, and slope. This results in an uneven grazing distribution pattern.

Several grazing management systems can control grazing intensity and/or timing. Compared to season-long use, which usually degrades streamside vegetation and streambanks, these systems can improve range productivity and use. In seasonal grazing, the objective is to avoid grazing when vegetation and streambanks are most vulnerable to damage. Seasonality also plays a role when considering forage palatability. Grazing pastures with riparian areas early in the growing season when upland vegetation is more palatable will naturally encourage cattle to graze the uplands rather than riparian areas. Rest-rotation grazing rotates seasons of use and one-year rest periods among three, four, or more pastures. Land managers can easily incorporate this strategy into a grazing management plan

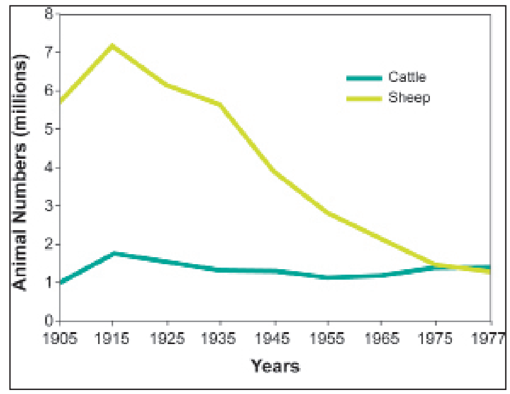
Economics of thinning and seeding forage

Seeding forages in conjunction with thinning or partial cutting can increase usable tree volume and livestock weight gains. Although livestock numbers historically were high and in some cases poorly managed, ranchers' more recent efforts to manage forage and timber have improved both grass and trees (Figures 8.6a–e, on page 172). Seeding after thinning overstocked, stagnated, small-diameter stands can be thought of as purchasing new acres and potentially can improve profitability. After thinning and seeding, an annual income from grazing becomes possible, and the time to a commercial timber harvest is shortened. In most cases, the highest profit from your property will result from management practices that focus on producing a combination of both timber and forage.

As a general rule, forage increases steadily as wood production declines (Figures 8.7a–b, page 172). However, because of the biological relationship between forage and timber growth, the tradeoff between the two products is not always constant. As a result, the combination of timber and forage results in greater economic gains than the production of either product individually. Where this point lies on the curve depends on the mixture of timber products (e.g., sawlogs and pulp), site characteristics, input costs, and the values of forage and timber.

For example, assume the value of forage is 1.5 cents per pound dry weight and timber is going for $200 per 1,000 board feet stumpage (the mill-delivered price minus costs of harvest, hauling, and taxes). If a landowner chooses to produce only timber, then he can expect a return of $50 per acre per year (0.250 thousand board feet per acre × $200 per thousand board feet). On the other hand, If the landowner chooses to manage only for forage production, then he can expect a return of $24 per acre per year (1,600 lb forage × $0.015 per lb). (Refer to Figure 8.7a.) Forage and wood production are optimum when timber is growing 230 board feet per acre per year ($46), which corresponds with 400 pounds of forage per year ($6), for a combined total of $52 per acre per year.

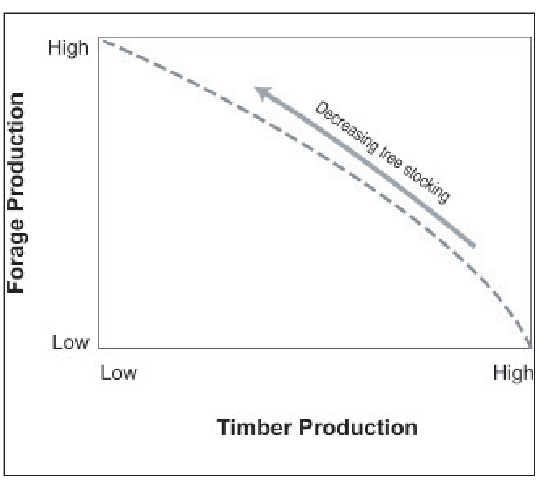
Keep in mind that these figures are relative. As prices change, the optimum combination of timber and forage will be different. If forage prices increase, we can expect to see the optimal combination to shift and favor more forage production. Similarly, as the price of timber increases, then more timber production is favorable.

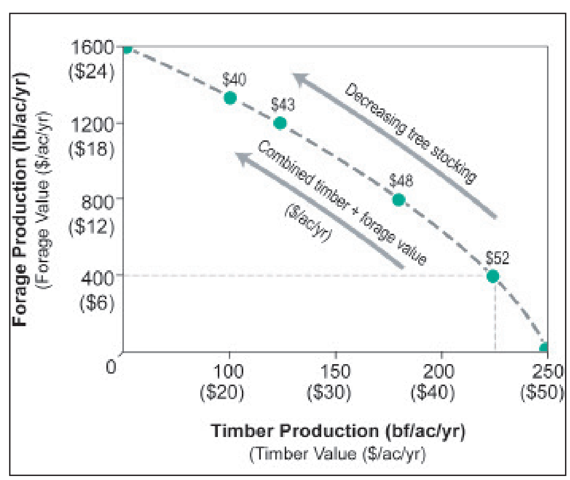


Figures 8.6a–c. Historically, livestock were heavily grazed throughout much of the inland West, damaging vegetation and soils in some areas (above left and right; Skovlin et al. 2001). However, sheep numbers have dropped dramatically from the early 1900s, and cattle numbers are generally lower (graph at right; Kosco and Bartolome 1981).

One important consideration not included in Figures 8.7a–b is changes in cost structure. For simplicity, these graphs assume there are no changes in management practices. In other words, site characteristics and management are the same

Figures 8.6d–e. Ranchers are using improved management practices with increasing success. For example, managing trees and forage by thinning and seeding potentially can enhance ranch income more than managing for either timber or forage alone (see Kosco and Bartolome 1981).





Figures 8.7a–b. Production possibilities for combining wood fiber and forage production (left, adapted from Clary et al. 1975). On the right, an example using specific forage and timber values.

at all points along the curve, and changing the amount of either timber or forage you produce will not result in any change to management costs. In reality, if you choose to implement a plan that favors more forage production, you will incur additional costs. Additional costs of forage production might include slash treatments to provide access for livestock and forage resources, seeding, fencing, and water development.

The other limitation to the graphs in Figures 8.7a–b is that there are no time considerations. These graphs represent the combination of forage and timber production at a single point in time. In reality, most capital investments for forage and timber production will last for multiple years. For example, forage seedings normally reach maximum production three years after sowing, then steadily decline over about a 20-year period as the tree canopy closes and native vegetation reestablishes. It is important to discount the cost of these projects over the course of their lifetime. Consult with OSU Extension Service specialists or the USDA Natural Resources Conservation Service for specific information and recommendations.

Noxious weeds

Noxious weeds in eastern Oregon forests are on the rise and spreading rapidly. They represent a significant threat to forest productivity by competing for growing space with both trees and forages, altering nutrient and water cycling, changing historic wildfire behavior, decreasing wildlife habitat and food, and increasing soil erosion and stream sedimentation. Invasive weeds can alter hydrologic cycles in riparian areas, lower water tables in some cases, and reduce surface water. They also adversely affect biodiversity. The outdoor experience for many hunters and recreationists is jeopardized by the loss of habitat due to noxious weeds.

Introduced, invasive plants are increasing their foothold acreage an estimated 8 to 12 percent per year. Here are some examples of invasive plant impacts:

- Diffuse knapweed (*Centaurea diffusa*) is thought to have been in the United States for more than 80 years and is increasingly spreading into forest areas.

- Spotted knapweed (*Centaurea stoebe*) and leafy spurge (*Euphorbia esula*) can reduce grazing capacities as much as 65 percent.

- Plots dominated by spotted knapweed had 50 percent higher runoff and produced 300 percent more sediment in one study.

- Dense spotted knapweed can reduce available winter forage for elk by 50 to 90 percent.

- Medusahead (*Taeniatherum caput-medusae*) and downy brome (*Bromus tectorum*), also called cheatgrass, have reduced native shrub communities important for wildlife winter habitat.

- Houndstongue (*Cynoglossum officinale*) is very invasive and can significantly reduce forage for wildlife and livestock. It is toxic to both cattle and horses. Fruits attach to the hair coats of animals and are easily transported.

- Economic losses from invasive plants have been estimated at $129.5 million per year in Montana, North Dakota, South Dakota, and Wyoming.

Forestland owners have a responsibility to recognize a noxious-weed problem if it exists and take action where needed. Following are some strategies for managing noxious weeds on forestland (adapted from the 2005 edition of the *Pacific Northwest Weed Management Handbook*).

Prevent: Eliminate individual invaders, wash vehicles and equipment, block road access to weed patches, catch weeds early, check pets and livestock for weed seed in coats, and use weed-free seed.

Identify and map: Use reference materials to help identify annual and perennial invasive plants. Map and record infestations and keep yearly records.

Prioritize weeds: For highly competitive plants, use aggressive control; for moderately competitive weeds, suppress; and for noncompetitive weeds, don't worry as much.

List controls: Using your experience, local experts, and published information, learn strengths and weaknesses of each control method.

Use biological control: Use other organisms against weeds. Some animals, insects, and diseases are possibilities. Ask a weed control expert in your area for advice on what works.

Design a weed management program: Develop year-round weed management strategies that use combinations of practices, such as watching disturbed areas for invasive species.

Seed desirable cover species to preempt weed invasion: Avoid overgrazing range and pastures.

Evaluate results: Evaluate management programs, continue mapping for future reference, and modify practices as weeds shift due to repeated practices.

Summary

Many owners of forestland in eastern Oregon value forage as their highest priority. Enhancing good-quality forage on forestland has many benefits. By integrating range values into timber management operations, ranch enterprise profitability can be improved.

Forage yields are closely tied to tree cover. Manipulating tree cover can provide an opportunity for good tree growth and forage production. The key is to find the best balance, both biologically and economically. Growing trees and livestock requires paying close attention to the needs of both. For example, seeding grasses can provide needed extra forage for livestock, but if your goals also include establishing regeneration, then some compromise will be needed to keep grass competition from slowing or preventing tree seedling establishment. Wildlife and grazing can be mutually beneficial. Thinning improves grazing opportunities for wildlife and is especially important where forage is limited and on winter ranges.

Riparian areas are sensitive to overgrazing. Be alert to damage and work to maintain or restore healthy riparian systems. Finally, noxious plants have a negative effect on forest and associated rangelands. Be prepared to identify any alien invaders, prevent their spread, and manage for good forestland conditions to minimize their impacts.

The advantages of forage seeding and associated livestock grazing include these:

- Greater usable forage in a shorter time
- Reduced fire hazard
- Improved aesthetics
- Enhanced watershed values because erosion is reduced
- Increased wildlife forage areas

CHAPTER 9

Wildlife habitat enhancement

Nicole A. Strong, Paul T. Oester, and W. Daniel Edge

Much of this manual has focused on managing trees for optimal vigor and growth. We acknowledge that managing trees, also known as silviculture, is a tool meant to meet many objectives, including producing timber and forage; providing recreation; increasing forest resilience to insects, disease, and fire; and enhancing habitat for desired wildlife.

This chapter provides tools and techniques for enhancing habitat for wildlife species, which will likely also enhance other values, which are often defined as "ecosystem services." These might include the following:

- Biodiversity
- Pollination
- Soil health
- Water quality, quantity, and temperature
- Carbon sequestration
- Cultural, spiritual, or creative needs

Many wildlife species, management goals

Central and eastern Oregon woodlands offer tremendous opportunities to manage for many wildlife species. For example, 159 species of amphibians, reptiles, birds, and mammals use mixed-conifer or ponderosa pine forests as primary habitat for feeding and/or reproduction. Pure lodgepole pine forests have about 97 species. Wildlife species use all stages of forest development—from recent openings caused by fire, storm damage, or harvest to young forests to mature forests. Frequency of use, however, will vary by stage and type of forest.

What do we mean by wildlife? Wildlife is broadly defined as animals that live on their own without taming or cultivation by people. Traditional wildlife management focused on managing game species (birds and mammals that are hunted or trapped). Gradually, the field has broadened to include nongame animals: songbirds, raptors, bats, amphibians, mammals, reptiles, and invertebrates. Fish are usually described separately because their needs are so different from those of terrestrial wildlife. We will have a limited focus on fish management in this chapter.

Whether wildlife is a management priority for you or not, there can be direct and indirect benefits to the existence of wildlife on your property. For example, some species help lower populations of forest insects and thus increase forest health. For example, thirty-five species of birds, including 24 neotropical migrants (birds that breed in Canada and the United States but spend (our) winter in Mexico, Central America, South America, or the Caribbean islands), feed on the western spruce budworm and the Douglas-fir tussock moth, two of the most destructive defoliating insects in eastern Oregon. Wildlife can also provide viewing pleasure, promote nutrient cycling, support food chains, and might even provide income to owners who offer fee hunting or wildlife-viewing opportunities.

Photo: M. Penninger

Figure 9.1 Cooper's hawk perched on a complex snag.

Wildlife habitat

Wildlife habitat has different meaning for different species. In general, when we refer to habitat, we are referring to the physical and biological resources any one species, or suite of species, needs to sustain a population. Within that habitat are provided unique food, cover, water, and space or territory needs. Later in this chapter we will describe general habitat types that will meet the needs of several species in the same forest types.

What Wildlife Live Here?

A good place to start in your wildlife management planning is to figure out which wildlife species are likely to travel through or reside on your property. The following tools are recommended for finding this information.

Oregon Biodiversity Map Viewer: This interactive mapping tool will help you obtain meaningful information about important, sensitive, rare, and listed forest species and habitats that could be found, or restored, on your property. You can explore species and ecological systems data aggregated to the sixth-field watershed and gain easy access to species status with respect to distribution or rareness as well as a measure of the watershed's importance to maintaining populations of that species or habitat. Find it at http://oregonexplorer.info/content/biodiversity-map-viewer. *Tip: If you are not tech savvy, ask your local OSU Extension forester or Oregon Department of Forestry stewardship forester to help you download and interpret this data.*

Oregon Department of Fish and Wildlife Conservation Strategy: This tool can help you prioritize species in need of conservation or habitat conservation areas. This document is available in hard copy or on the web at http://www.oregonconservationstrategy.org/. *Tip: Contact your local Oregon Department of Fish and Wildlife for assistance with using this tool.*

Food

Food needs depend on the wildlife species. Predators prey on other animals, which makes them quantity-limited. We think about prey abundance when we are managing for predators.

And while your woodland property might be full of plant material, very little of that will be digestible or provide sufficient protein and carbohydrates for herbivores. That makes food or forage quality of utmost importance when managing for herbivores. That quality varies by plant species, season, and the plants' availability to wildlife (e.g., plants may be unavailable to wildlife if access is restricted by barriers, such as fences or snow, or if lack of hiding cover makes wildlife feel too unsafe).

Birds that feed on insects and grubs, such as the Lewis's woodpecker, need sufficient prey, which means they need sufficient snags, or standing dead trees, to provide that food source. Mule deer can often be limited by access and availability of winter browse. Deer often have to travel long distances through towns and across busy roads to get to winter range, and then heavy snowpack or ice can make digging down to forage difficult. If fire suppression has led to old decadent shrubs, or too many trees that shade out that forage and browse, then the quantity and quality of forage can be reduced.

Photo: J. Ward

Figure 9.2. Ungulates like elk and deer are limited by food quality and access.

Cover

Cover is provided by vegetation (live and dead), topography, land features like rocky outcrops, and isolation. Different types of cover are used for different purposes. Thermal cover protects species from wind and extreme heat and cold. Thermal cover might be a tight patch of trees or shrubs for species such as deer or elk, or slash piles or clumps of shrubs or trees with branches that go all the way to the ground for small mammals. Hiding cover enables animals to elude predators, and nesting or denning cover is used to hide and rear young.

Photo: M. Penninger

Figure 9.3. Cover can be as simple as an unmowed field or tall grasses and a large rock, as evidenced by these fox pups.

Water

Sources of water for wildlife include metabolic water (a product of fat metabolism), preformed water (from foods high in water content), and free water. Landowners can manipulate, protect, or enhance preformed water by encouraging palatable food sources and providing free water with puddles, ponds, streams, and wetlands. Though we don't go into a lot of detail regarding fish in this chapter, it is important to think about maintaining the quality of water sources (clean, cold, and clear water) and the quality of vegetation around any water source.

Safe access to and egress from water to other habitat types is also important. For example, many landowners who have water rights and can develop ponds for fire protection and wildlife will immediately see an increase in wildlife sightings. Waterfowl, mammals, and amphibians will all take advantage of a safely accessible water source.

Space

Territory, or home range, refers to the space an animal needs in which to meet its basic needs and to reproduce. Home range is the area that a species uses in its lifetime to find food, cover, water, and mates. Territories are areas of exclusive use that are defended against other members of the same species. The two basic rules of space use are, first, that carnivores require more space than herbivores, and, second, that home range or territory size increases with body size.

Your ability to manage for a certain wildlife species has a few built-in constraints. For example, because larger species require a larger home range or territory, your opportunity to attract large animals as residents is limited by the size of your property and what is directly surrounding you. Larger properties have more opportunities for a greater variety of wildlife species. Forests also have diversity limitations. The number of tree species you can grow on your property, the range of stocking densities the land can maintain, and topography all affect the diversity of wildlife you can expect to attract to your land.

Enhancing wildlife habitat

In developing your wildlife goals, you will need to decide what wildlife you want and what your land can sustain. For example, if you want more cavity-nesting birds (birds that nest in holes in trees and down logs), then you would retain snags or create snags. In many cases, you can provide green trees for future snags at minimum cost by using poor-quality, cull trees. The goal is to determine what wildlife habitat is needed, then manipulate the vegetation to create those conditions for selected species. See the box for ideas for enhancing wildlife habitat for some species groups.

Figure 9.4. Taking an Extension class and learning to take stock of what you have on your woodlands is a great way to start planning for wildlife on your property.

A good way to start your planning is to look at the habitat you have and see what wildlife can be attracted to it. Sketch a map to identify streams, forest stands, openings, and special habitat areas like talus slopes, rock outcroppings, bogs, seeps, and riparian (forests along water) areas. Also take some time to research what species might be found in your forest type and watershed. This will help orient you to your possibilities. It doesn't mean you can't change the vegetation to encourage a particular species of wildlife, but it will give you valuable insight into what wildlife species are likely to be found.

> **More Help**
>
> *Family Forests and Wildlife: What You Need to Know* from the Woodland Fish and Wildlife Group is a great publication to get you started on your wildlife plan. It includes a worksheet at the end that will help you identify priorities and set actionable goals.

Important habitat components and structure

Woodland properties meet wildlife needs by providing specific habitat components, i.e., quality places to feed (graze and browse, hunt, or cache food), hide, breed, rear young, or hibernate. Although the specifics vary by species, several habitat components appear to be universally important for meeting the needs of diverse wildlife communities and are currently in short supply due to past management activities and a century of fire suppression. Spatial pattern, structural diversity, and dead wood (snags and down logs) are three components of habitat that you can directly affect through your forest management.

Spatial pattern: horizontal heterogeneity

Imagine what the lower-elevation forests east of the Cascades might have looked like prior to European settlement. Forest and fire ecology scientists describe a forest that experienced regular fire. This would have created a variable-density landscape, with patches that had recently burned lightly (favoring grasses and fresh palatable shrubs, forage for ungulates), clumps of trees that had not burned in some time (hiding cover for elk), and more fire-resistant tree sizes and species overall. There would have been some large snags (habitat for cavity nesting birds, denning mammals, and bats), smaller foraging snags (food for insectivores), as well as down logs (denning habitat and food via insects and fungi). Areas that had burned hot would have resulted in openings with regenerating clumps of shrubs and perhaps some hardwood trees, providing nesting and foraging habitat for several songbirds and small mammals and places for fawns to hide during the day.

If we think about all of that variety in patterns across the landscape and compare it with what we see sometimes today, it becomes clear that using silvicultural tools such as thinning and prescribed burning can provide powerful wildlife-habitat enhancement. Planning your thinning projects to promote a diversity of densities benefits many wildlife species. Here are some guidelines:

- Evenly thinning about 70 to 80 percent of your stand will encourage tree growth, vigor, and drought resistance and improve forage availability.
- Leaving 10 to 15 percent of your stand unthinned in strategic clumps (ranging in size from 0.25 acre to 1 acre) will provide hiding cover as well as foraging habitat for species such as white-headed woodpeckers.
- Creating regeneration patches throughout 10 to 15 percent of your stand will create hiding cover for ungulates, small mammals, and birds as well as create feeding habitat. Small canopy openings (0.25 to 2 acres in size) help retain snowpack and recharge ground water, thus improving soil moisture and water availability to plants and trees. Try to make these an irregular shape.
- Creating openings that promote riparian vegetation and hardwood stands such as aspen create important variety in habitat on the landscape.

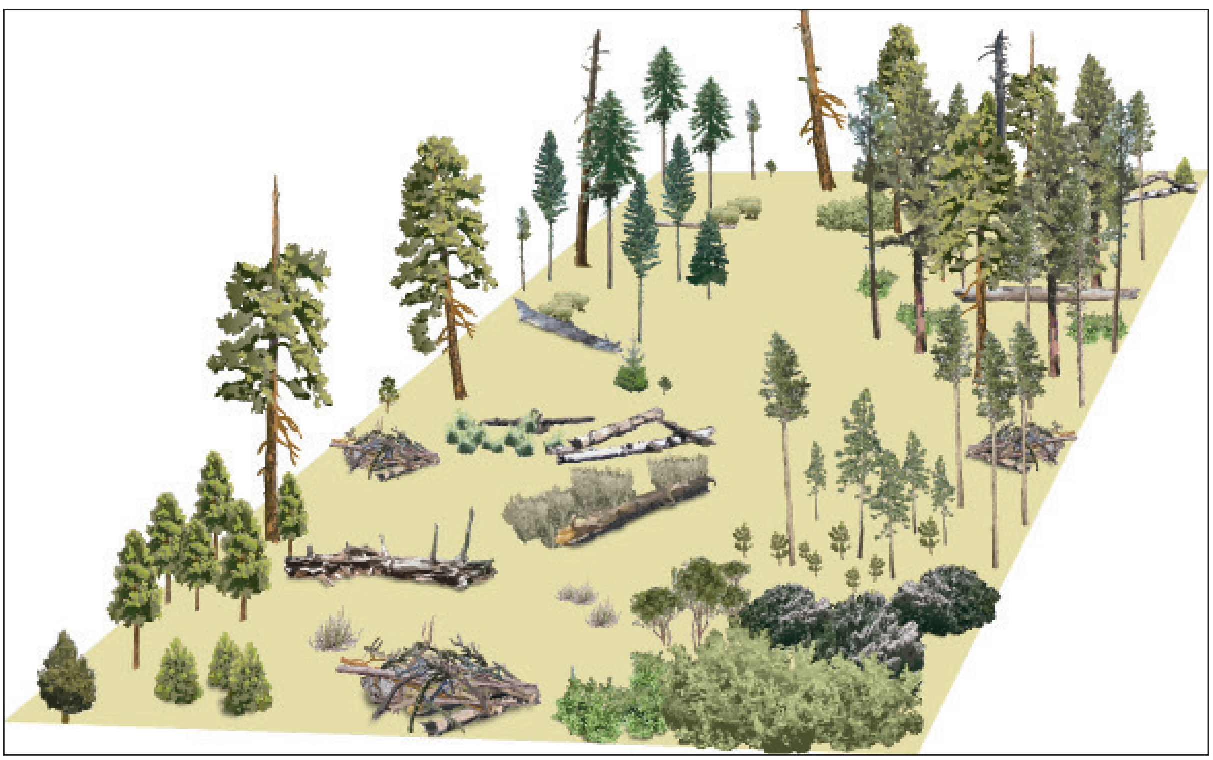


Figure 9.5. The image above represents a forest treated to reduce fire risk, be more resilient to insects and disease, and enhance wildlife habitat. Components retained in the treated stand include snags and down logs, legacy trees, openings, and patches.

Structural diversity: vertical heterogeneity

Structural diversity is another important component of wildlife habitats in woodlands. Structural diversity refers to the number of layers and complexity of vegetation in a stand. In general, wildlife diversity increases with structural diversity. You can increase structural diversity by retaining logs and snags, but it's also important to manage for multiple tree species, enhance understory development, and develop multiple age classes of trees within and between stands.

Patch cuts provide multiple age classes between stands, and individual tree selection (see Chapter 2) provides several age classes of trees within a stand. Leaving uncut patches of trees within thinned stands also creates diversity. For example, when planning to thin or harvest, you might identify small "islands" of trees (each one-tenth to one-fifth of an acre) to leave alone. You have the option of thinning these islands later. Enhance understory development and add to stand structure by using wide spacing in your thinnings (see Chapter 2).

Developing multiple age classes in a stand can increase the risk of crown fires, as layering of tree crowns through the canopy creates a "ladder" for fire to move up from the ground to tree crown levels. Isolating such clumps with fuel breaks can moderate this risk. More layers also can lead to greater damage from defoliators in fir stands, as larvae from the western spruce budworm fall down on trees lower in the canopy and build up high densities. Thus, a trade-off exists between providing greater structural diversity in the stand for wildlife and increasing the risk of crown fires and defoliator damage.

Photo: K. Bevis

Figure 9.6. Openings help retain snowpack and recharge groundwater, promote native plants, and create space for trees to grow.

Snags

Many species of plants, invertebrates, birds, and mammals use snags, or standing dead trees (Figure 9.7, page 184). Snag types are: dead, partly dead, sound wood or decayed wood, and short or tall (Figure 9.8, page 185). Different wildlife species have adapted to optimize each type of snag. Snags in the open are home to one group of cavity users; snags in cover support

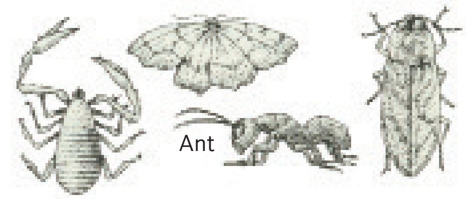
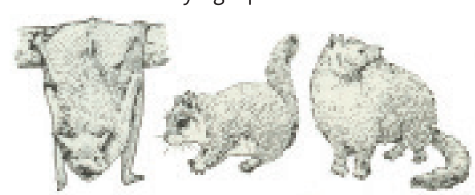
Life form	Use of snags	Examples
Fungi, mosses, and lichens	Decayed wood serves as a growth substrate.	Fungus Moss Lichen 
Invertebrates	Spaces under bark serve as cover and as places for feeding	Pseudoscorpion Moth Beetle 
Birds	Cavities are used for nesting or roosting. Snags are used as perches and to support nests.	Flicker Nuthatch Pileated woodpecker 
Mammals	Cavities serve as dens or as resting or escape cover. Areas under loose bark are used by bats for roosting.	Bat Flying squirrel Marten 

Figure 9.7. Snags are used by many species of plants, invertebrates, birds and mammals (Thomas 1979).

another mix of species. For example, snags in the open attract flickers, bluebirds, and kestrels. Snags in a cover patch, on the other hand, are important to pileated woodpeckers, sapsuckers, chickadees, and nuthatches.

Consider the following snag recommendations from the US Forest Service for high levels of cavity-nesting wildlife:

- For dry-site ponderosa pine forests, leave at least two snags per acre.
- In cool-moist mixed-conifer forests, retain at least four to six snags per acre.
- Leave six to eight snags per acre in lodgepole forests and in other colder forest environments.

Fifty percent should be hard (not yet very soft and decayed) snags over 12 inches dbh. If you have tree species options, preferences for snags are (in descending order) ponderosa pine, western larch, lodgepole pine, grand fir, and Douglas-fir. Height of snags is less important

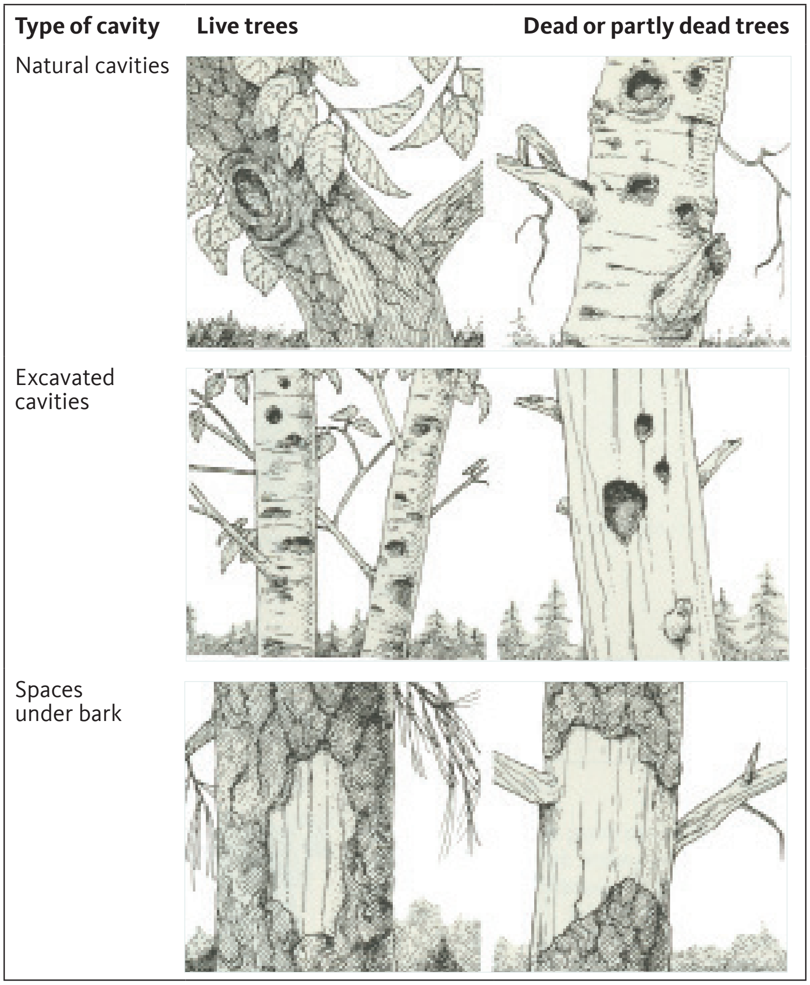


Figure 9.8. Wildlife habitat is provided by live trees and snags (Thomas 1979).

than diameter. Height can depend on safety considerations and the likelihood that the snag would blow over. Typically, 30 feet is adequate for most wildlife species.

*Key Facts About Snags**

Ponderosa pine, western larch, quaking aspen, and paper birch are favored tree species for nest sites.

- *Large-diameter snags provide nest habitat for the greatest variety of cavity nesters and remain standing longer than smaller snags.*
- *Snags should be provided in clumps, if available, on all slope aspects and positions of the slope, and adjacent to green trees.*
- *Populations of cavity nesters such as pileated woodpeckers seem to thrive in stands of ponderosa pine and in mixed-conifer forests that contain about four snags per acre, a large component of large-diameter trees, and abundant logs.*
- *Snag longevity depends on cause of death, tree species, diameter, height, amount of heartwood, geographic area, and site conditions.*
- *Compared with creating snags and wildlife structures, retaining existing snags and wildlife structures is the most cost effective and ecologically sound way to provide habitat.*

*Adapted from Bull, Parks, and Torgersen 1997.

As a general rule, the larger the snag the better. Large-diameter snags can meet the needs of all cavity-nesting species, whereas small-diameter snags will be used by only some species. Large-diameter snags also have the advantage of standing longer. Plan to leave enough snags so that, in combination with other natural tree mortality, you can meet future down-log needs.

Wildlife trees are required on “harvest type 2” and “harvest type 3” operations of 25 acres and larger. Harvest type 2 is a partial-cut harvest that does not trigger a reforestation requirement but leaves fewer trees 11 inches dbh or larger than Oregon’s Forest Practices Act (FPA) stocking standard for wildlife trees on the site. Harvest type 3 is a heavy partial cut or clearcut that requires reforestation and requires wildlife leave trees.

For clearcut or partially cut areas 25 acres and larger on private lands where wildlife trees are required, the FPA requires two snags or two green trees at least 30 feet tall and 11 inches dbh, at least 50 percent of which are conifers. These snags and/or green trees may be clumped along streams or in patches in the harvest unit, or they may be scattered across the unit. If the harvest is near a Type F or Type D stream (a stream with fish or a stream used as a

Key Facts About Decaying Logs*

- *Logs 15 inches or greater in large-end diameter are particularly important for species such as pileated woodpeckers.*
- *In mixed-conifer stands, pileated woodpeckers prefer to forage on logs of western larch, Douglas-fir, and grand fir.*
- *Logs should be as long as possible to offer the greatest range in diameters.*
- *Hollow logs of any species and size class are important structural components to favor.*
- **Adapted from Bull, Parks, and Torgersen 1997.*

domestic water source), the Oregon Department of Forestry (ODF) may require you to leave up to 25 percent of the wildlife trees near the stream (Adams and Storm 2011). Remember that these retention levels are minimums for maintaining wildlife on private woodlands; if you wish to enhance your property specifically for cavity-nesting species, you will want to retain more snags.

Topping trees to create wildlife habitat is best done 30 feet up with a chain saw or explosives. Trees treated in this way produced snags that stood the longest and received the greatest nest use by woodpeckers. Trees killed by girdling near the ground fall over too quickly to provide wildlife nest trees. Observations indicate trees killed by bark beetles are used more by cavity-nesting birds and stand longer than artificially created snags. Purposefully infecting trees with decay fungi is a new method that shows promise; it creates decayed sections on living trees for cavity-using wildlife. Preliminary results indicate western larch can be inoculated (drill holes and insert fungi-infected pegs) and will produce desirable wildlife trees at less cost than killing trees to create snags.

Down logs

Down logs (fallen dead tree trunks and roots) are another important wildlife resource (Figure 9.9). For example, in the Blue Mountains, 5 amphibian species, 9 reptile species, 116 bird species, 49 mammal species, and countless invertebrate (insect) species use logs. Down logs provide cool-moist hiding cover and a source for insects and larvae, and they slowly release nutrients and water back into soil. Logs can help retain soil on steep slopes. The bigger the down log, the longer it will remain on the landscape and the less concern there is for its acting like a flashy fuel source.

How many logs depends on who you ask. According to federal land-manager guidelines:

- Ponderosa pine forests should have at least three to six logs per acre, greater than 12 inches in diameter and at least 6 feet long.
- Mixed-conifer and lodgepole pine forests should have at least 15 to 20 logs per acre, at least 8 inches in diameter and longer than 8 feet.

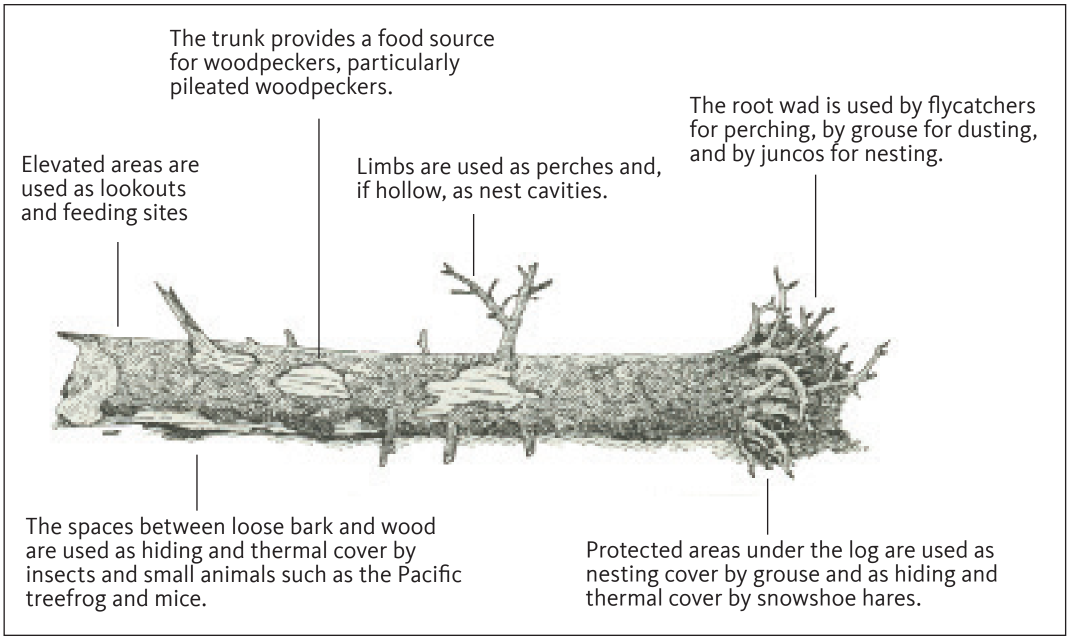


Figure 9.9. Down logs provide many kinds of habitat for wildlife (Thomas 1979).

The Oregon Forest Practices Act requires a minimum of two down logs or trees per acre after a clearcut harvest. At least 50 percent of these logs are to be conifers, and each should be at least 10 cubic feet in gross volume and no less than 6 feet long. One down conifer or suitable hardwood log of at least 20 cubic feet in gross volume and no less than 6 feet long can count as two logs. As in the case with snags, these are minimums; the more logs you retain, the better wildlife habitat you will create.

The above guidelines for snags and logs are general estimates and not related to differences in biological potential or landowner objectives. For more information on promoting down logs for specific species, consult your local Oregon Department of Fish and Wildlife biologist. Generally, when deciding how many snags and down logs to leave, more and bigger is probably better. The trade-off, however, is potentially higher fuel accumulations and, therefore, fire risk. Make this decision based on your objectives and comfort level.

Riparian areas

Because water can be a limiting resource in our landscape, wildlife use available streamside, or riparian, areas more than any other type of habitat. Of the 378 terrestrial species known to live in the Blue Mountains, 285 either exclusively depend on riparian areas or use them more than other habitats. Riparian areas are the transition zones between aquatic and terrestrial environments. They are important for wildlife because they provide water, abundant food and cover, and favorable microclimates. Also, they provide edges and corridors for animals moving among stands and different habitats. Furthermore, because riparian areas typically have more-diverse vegetation than surrounding uplands, they often provide some of the most diverse habitats on your property. For example, although riparian areas make up only 7 percent of the area in northeast Oregon, elk spend 40 percent of their time in these habitats.

Riparian management considerations include these:

- Road construction in riparian areas will make this zone undesirable for many wildlife species and increases the potential for sedimentation in streams.
- The narrower the riparian area, the more easily it is altered by management action; thus, a light touch and careful planning are needed.
- Proper grazing management should include particular attention to ensuring the welfare of riparian areas.
- Widen riparian areas where possible to ensure contiguous habitat.
- Plant appropriate hardwood trees, shrubs, herbs, grasses, and sedges adapted to riparian site conditions. Best choices will vary depending on elevation, soils, aspect, and other factors. Consult with local wildlife biologists for site-specific recommendations.
- The Oregon Forest Practices Act (FPA) regulates harvesting, road building, stream crossings, and pesticide applications in and near riparian areas.

Oregon's FPA requires you to protect streamside vegetation (by identifying a riparian management area) when you harvest along fish-bearing streams and streams that provide water for domestic needs. Other streams where harvesting occurs may need protection as well. Riparian management area requirements designate what trees, snags, and understory vegetation will be left after a harvest. Stream protection rules, including the width of the riparian management area, will vary depending on such factors as the type of harvest (clearcut or partial cut), the site's geographic region (e.g., eastern Cascades or Blue Mountains), type of stream (fish-bearing or not), and stream flow (i.e., size). You may wish to exceed these standards if you want to further increase wildlife diversity and abundance on your property. For more information, talk to a stewardship forester in your local Oregon Department of Forestry office. For a discussion of grazing and riparian areas, see Chapter 8.

Special and unique habitats

You might have special or unique habitats on your property, such as hardwood groves, caves, or meadows. If so, it's important to inventory and include them in your management plan.

Quaking aspen and black cottonwood are two species that create unique habitats in eastern Oregon and require special management to realize their potential. Quaking aspen is a preferred habitat for species such as ruffed grouse and northern goshawks, yet many quaking aspen stands are in decline across eastern Oregon as a result of fire suppression and overgrazing by ungulates and cattle. Two ways to help restore aspen are to promote regeneration and to remove invading conifers. Browse pressure on regenerating sprouts might be such that fencing may be the only feasible choice for controlling damage.

Black cottonwood abounds along stream courses in eastern Oregon, providing shade, cavities, structural diversity for wildlife, food for aquatic organisms, and bank stability. Wildlife will benefit if you retain these trees either in mixtures or pure stands, promote healthy regeneration through periodic ground disturbance, and leave some snags and logs.

Special habitats are important features on the landscape; some, such as cliffs, talus, and caves, are rare and fragile. Cliffs are steep, vertical, or overhanging rock faces. Talus is the accumulation of broken rocks at the base of cliffs or other steep slopes, and a cave is a natural underground chamber that is open to the surface. Talus is an ideal nesting site for the common raven. The great horned owl nests in cliffs or trees. Bats use caves for roosting, reproduction, and hibernation. If you have these areas on your property, carefully evaluate forest management activities and seek advice from wildlife professionals.

Habitat Needs for Key Wildlife Species of Interest

Songbirds

- *Encourage native plant species (trees, shrubs, vines, and forbs) that produce fruit and seeds.*
- *Allow for some patches with multiple canopy layers (0.10 acre or larger). If fire is a concern, you can create a fuel break by thinning more heavily around those dense patches.*
- *Install nest boxes. Make sure to have an annual cleaning and maintenance plan.*

Raptors

- *Provide nesting opportunities by maintaining or creating cavities, snags, and large trees. Remember that some raptors nest in snags that are out in openings, and some nest in snags that are part of a dense clump of trees.*
- *Create or maintain soft edges (some layering such as shrubs) between the forest and openings for feeding and a diversity of habitats.*
- *Protect cliffs, talus, caves, and rimrocks for nesting and hunting opportunities.*
- *Provide down logs to promote prey habitat.*
- *Create or maintain ponds, marshes, bogs, and streams for habitat for feeding opportunities.*

Small mammals

- *Create habitat piles and leave some slash piles to create habitat for species such as squirrels and the mountain cottontail.*
- *Seed native grasses and forbs for food.*

Upland birds

- *Leave or create brush or slash piles as protective cover for California quail and turkeys.*
- *Plant, seed, or protect breeding sites and food sources (berries and leaves).*
- *Seed grasses, forbs, and legumes for quail and ruffed grouse.*
- *Leave larger trees for turkey roosting.*

Ungulates (e.g., deer and elk)

- *Promote healthy native grasses and shrubs through thinning and controlled burning.*
- *Seed grasses and legumes on disturbed areas such as skid trails.*
- *Leave some areas unthinned for hiding cover.*
- *Thin conifer thickets to allow more forage to grow.*

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- *Restrict access to roads.*
- *Be careful with fence construction and animal movement trails. You might want to strategically install fences that can be opened during seasonal migrations.*

Overall species richness

- *Make sure fuels reduction focuses on reducing continuity of fuels, not eradication.*
- *Encourage a mixture of herbs, shrubs, and trees to provide more niches for wildlife species.*
- *Create or leave snags and large down wood.*
- *Maintain a variety of successional stages (age classes).*

Figure 9.10. This ponderosa pine stand is providing timber, hiding cover, and browse for wildlife. It was thinned and then broadcast burned.

Combining wildlife and other management objectives

Timber production, fuels reduction, and wildlife habitat enhancement can be integrated easily and are compatible in many important ways. Any time you change the number of tree species, stand structure, or the stand's successional stage, you affect food, cover, and space for wildlife. This has a big influence on the type of wildlife you will have.

Managing forests for wildlife has many variables. The following sections provide examples of ways to enhance the diversity of birds and animals in common forest types: ponderosa pine, mixed-conifer, and lodgepole.

Ponderosa pine

- During harvest operations, leave at least two large snags per acre and four to six foraging snags per acre.
- Enhance forage by conducting variable-density thinning, creating small openings (0.25 to 2 acres in size), and conducting prescribed burning.
- Leave occasional habitat brush piles.
- Leave a few down logs per acre, at least 8 inches dbh.
- Enhance the health of aspen and cottonwood habitats.
- Leave occasional islands (groups of unthinned trees, 0.25 to 1 acre in size) for cover and snag habitat.
- Look for opportunities to create, protect, or enhance water habitats, including constructing ponds.
- Protect special or unique wildlife habitats.
- Leave a few mistletoe-broomed trees where they don't endanger regeneration.
- Avoid or limit management activity during nesting, calving, and fawning.
- Create a few openings that will encourage native grasses, forbs, wildflowers, and berry-producing shrubs.

Mixed-conifer

- Leave four to six ponderosa pine, western larch, or other species snags per acre during harvest.
- Leave occasional islands for cover and snag habitat.
- Retain grand fir culls (more than 12 inches dbh) for swifts, bears, martens, and pileated woodpeckers.
- Leave four to six down logs per acre, at least 8 inches in diameter.
- Enhance the health of aspen and cottonwood habitats.

- Look for opportunities to create, protect, or enhance water habitats, including ponds.
- Protect special or unique wildlife habitats.
- Leave a few mistletoe-broomed trees where they don't endanger regeneration.
- Avoid or limit management activity during nesting, calving, and fawning.
- Create a few openings that will encourage native grasses, forbs, wildflowers, and berry-producing shrubs.

Lodgepole pine

- During thinning or other harvest operations, leave at least two large snags per acre and four to six foraging snags per acre.
- Leave occasional habitat brush piles.
- Leave a few down logs per acre, at least 8 inches dbh.
- Leave occasional islands (groups of unthinned trees, 0.25 to 1 acre in size) for hiding cover for ungulates and nesting structure for species like northern goshawk.
- Leave a few mistletoe-broomed trees where they don't endanger regeneration.
- Avoid or limit management activity during nesting, calving, and fawning.
- Create a few openings that will encourage native grasses, forbs, wildflowers, and berry-producing shrubs.

Potential conflicts

Also consider how wildlife-enhancement programs will affect your other forest management objectives. Mule deer, white-tailed deer, and elk can damage conifer seedlings, but managing to attract a higher population of these animals should not result in increased damage in most situations. Habitat enhancement can, however, increase populations of some animals such as rabbits, pocket gophers, porcupines, and voles to damaging levels. For example, planting forage crops can increase the number of meadow voles and potentially lead to root damage and girdling of seedlings. Slash piles offer food and cover for quail and rabbits, but too many rabbits without enough forage available in winter may result in damaged seedlings.

Managing woodlands for wildlife sometimes can conflict with timber goals. For instance, changing vegetation to gain wildlife diversity could lower production of high-value timber products. However, this depends somewhat on the size of the ownership. Attempting to maximize diversity on smaller ownerships could reduce timber yields, while a larger ownership might need the variability to ensure a continuous harvest.

Keeping areas more open for wildlife forage can lower timber yields if stocking is greatly reduced. Extending rotations for wildlife objectives decreases potential economic returns from timber because financial investments in timber management are held longer. Multistoried stands typically require uneven-aged management, which might result in reduced timber yields. Leaving a lot of trees with dwarf mistletoe brooms for nesting platforms, food, and hiding cover for flying squirrels and certain bird species can lower timber yields and promote expansion of the dwarf mistletoe infestation if susceptible regeneration is growing beneath infected trees. Also, retaining numerous defective or poorly formed trees for wildlife use can decrease timber quality in the stand, lowering timber values. Ultimately, forestland owners will make the management decisions by balancing these trade-offs with their ownership objectives.

One way to enhance wildlife habitat and retain high levels of timber output is to focus your wildlife habitat enhancement on those areas where it is not cost-effective to maximize timber production. Capitalize on the potential of small, unused areas, areas with poor soil for timber, riparian zones, steep slopes, disease-prone areas, and similar places to provide wildlife habitats.

Looking beyond your property

Diversity occurs on several scales in forest ecosystems, and wildlife can be expected to respond differently at each scale. At a microscale, differences in size, height, and species of trees and shrubs will attract different wildlife species. At the stand scale, differences in tree species composition, stocking density, and age structure make forest stands attractive to different species. For example, an uneven-aged, multispecies stand is likely to contain many more wildlife species than a single-aged, single-species stand of the same size.

Diversity among stands, or landscape-level diversity, is important, too. Consider how your property relates to wildlife habitat conditions on a landscape level. On large acreages, if you want to enhance the variety of wildlife (species richness), then you'll want to produce a landscape with stands of trees in several successional stages and favor both pure and mixed-species stands.

Properties adjacent to yours, as well as those beyond, can offer habitats that add to or take away from what's on your property. For example, you may not need to do any enhancement work if surrounding properties provide food, cover, water, and/or space for the wildlife you are interested in. Or, if one of your neighbors is providing abundant forage or early-successional-stage habitats adjacent to your property, you might want to emphasize the production of cover next to these forage areas. As another example, your riparian areas might be especially important for connecting special habitats on your neighbors' properties above and below you in a watershed. Knowing forest conditions and distribution of habitats on your immediate neighbors' land and at the landscape level will allow you to adjust your management accordingly. This may be especially important for larger animals, such as big game, which have large home ranges.

Incentive and cost-share programs

A number of state and federal programs offer financial and other incentives to landowners who want to enhance habitat for fish and wildlife. Incentive programs change priority locations and requirements on an annual basis. For information on current incentive programs, contact the Oregon Department Forestry, Oregon Department of Fish and Wildlife, Oregon Watershed Enhancement Board, and the federal Farm Services Agency and Natural Resources Conservation Service. Your OSU Extension forester can also help you navigate incentive program availability and requirements.

Legal status

All wildlife species in Oregon have some protection under state or federal statutes. About 85 percent of the species are protected as "nongame," or watchable, wildlife and cannot be harmed unless they are doing damage (for example, destroying nursery stock in new plantations). The remaining species are classified as "game animals" or "furbearers" and

Photo: M. Penninger

Figure 9.11. Birds, including chickadees (pictured) cause few problems on woodland properties in Oregon.

may be harvested under permit within specific seasons and limits. See your local Oregon Department of Fish and Wildlife office or a sporting goods store for hunting regulations.

Oregon wildlife codes allow a property owner or his or her agent to control animals without special permission if they are damaging property. Exceptions include big game animals, most birds, and species that are state or federally listed as threatened or endangered. See a local Oregon Department of Fish and Wildlife biologist if you are having damage problems with big game animals.

All birds except the European starling, rock dove, and house sparrow are protected under the federal Migratory Bird Treaty Act and may not be killed. A permit may be obtained from the U.S. Fish and Wildlife Service to trap or shoot protected birds if other forms of damage control have not been effective. Fortunately, birds cause few problems on woodland properties in Oregon, although they can damage structures and fruit and berry crops.

Some wildlife species in Oregon also have federal protection under the Endangered Species Act (ESA). The ESA classifies animals as “threatened” (species likely to become endangered in the near future over all or a significant portion of their range) and “endangered” (species likely to become extinct in the near future over all or a significant portion of their range).

Oregon has an ESA with definitions very similar to the federal act’s. However, the state ESA allows listing of species that are rare within the state but that might be common in other states. The state ESA affects management only on state lands, except that killing or harassing listed species is prohibited. In eastern Oregon, the American and Arctic peregrine falcons, kit fox, wolverine, and Washington ground squirrel are additional species listed under the state ESA.

Management strategies for Overall Diversity

Diversity among stands

- *Retain integrity of riparian areas versus upland areas*
- *Restore, promote, and protect non-conifer habitat types (e.g., quaking aspen)*
- *Create ponds and other water sources, and maintain/enhance wetlands*
- *Use lay-down fences to control grazing and allow wildlife access*
- *Provide different species in different stands*
- *Vary levels of vegetation control*
- *Leave unmanaged areas*
- *Consider management from a landscape perspective*
- *Maintain a variety of successional stages*
- *Use even- and uneven-aged silviculture*

Diversity within a stand

- *Leave a variety of tree species where appropriate*
- *Seed forages on skid trails and landings*
- *Retain or create snags and logs, and leave green trees for recruitment to snags*
- *Create new forage areas*
- *Leave unthinned patches*
- *Leave hollow trees*
- *Leave living trees with decay*
- *Leave some large trees*

Microhabitats

- *Protect rock outcroppings, cliffs, caves, bogs, seeps, and travel ways*
- *Leave a few high stumps*
- *Install artificial nest structures*
- *Leave a few mistletoe-broomed trees*

Summary

Many forestland owners place a high priority on seeing wildlife on their property. Eastern Oregon forests abound with many species of wildlife and offer tremendous opportunities for wildlife enhancement. Wildlife need food, cover, water, and space. You'll need to decide what wildlife you want to attract, learn their particular needs, then find out whether your land can meet those needs. Your management plan should include your wildlife goals and objectives, a wildlife inventory, and specific wildlife management activities you will undertake to meet those goals.

Snags and down logs are important wildlife habitat components. There are different types of snags and down logs, and guides are available to help you choose the best type based on your objectives.

Riparian areas are only a small part of the forest ecosystem, but, compared to uplands, they play a disproportionately important ecological role for wildlife. These areas are rich in wildlife diversity, are corridors for wildlife travel, and provide food well into the growing season when uplands dry out. Treat these areas with care by managing grazing animals and closely following the Oregon Forest Practices rules for harvesting, road building, and pesticide spraying. Developing ponds and protecting wetlands can add wildlife value to forest properties as well.

When considering wildlife, think beyond your property. What is the habitat condition of properties around you? What you do on your property can influence other properties and vice versa. Be aware of how changes on a landscape level might affect wildlife, and factor this into your decisions.

Combining wildlife and other forestry objectives is normally easy to do. Changes you make to your forest have an influence on wildlife species. Forest management practices can attract some species to your property. Be aware of potential conflicts and manage accordingly. Usually, conflicts are temporary, but they can be costly if not managed. Overall, objectives like timber production, forest health, fuels reduction, and wildlife enhancement are highly compatible, and forestland owners can enjoy a healthy forest and abundant wildlife.

CHAPTER 10

Harvesting and access

Bob Parker

This manual is designed to help you understand your forestland's potential and develop a management plan for making your woodland property become all you want it to be. A good management plan is essential, because as the French writer Antoine de Saint-Exupéry once said, "A goal without a plan is just a wish." Forests are dynamic, constantly growing and changing, so the challenge is how do you guide that change in the direction you want? One of the most powerful tools you can use is harvesting. Through harvesting, you can directly control major characteristics of a forest, such as tree species, stand density, and structure. Many woodland owners identify aesthetic beauty, wildlife, or forest health as higher priorities than harvesting, but the importance, even necessity, of harvesting as a stand management tool cannot be overlooked. Harvesting should be an integral part of the management-planning process from the very beginning in order for you to enjoy overall management success.

This chapter will introduce you to the various aspects of selecting a harvesting system that will help accomplish all your management goals. We start with a discussion of how to evaluate what you have to work with, such as site and timber characteristics. Then we'll look at the various types of harvesting systems and how you can match your unique goals and forestland with the most appropriate harvesting system.

Safety

Before we begin our discussion about harvesting systems, let's talk about safety in the woods. Whether you're pruning limbs (Figure 10.1, page 198), thinning trees with a chain saw, or skidding logs, you must always be thoughtful and careful. It is fun and rewarding to practice good stewardship on your property, but a moment of carelessness with even the simplest of tasks can result in disaster. Accordingly, here are a few things to keep in mind when working in the woods:

- Safety ALWAYS comes first.
- There is NO PLACE in a harvesting operation that is absolutely SAFE.
- EVERY cut with a chain saw is DANGEROUS. ALWAYS wear a hard hat, eye and ear protection, chaps, boots, and gloves!
- You must ALWAYS be on the alert for danger.
- You must always EXPECT THE UNEXPECTED.
- Take your TIME, don't be in a hurry.
- DON'T work ALONE.

Figure 10.1. Always wear appropriate safety equipment when using a chain saw to avoid serious injury.

Defining goals and creating a plan

The first harvesting considerations are your short-term and long-term management goals. One way to think about your goals is, What do you want your forest to look like when it grows up? Do you prefer an even-aged or uneven-aged system? Do you want to maximize both grazing and timber production? Or, do you simply want to enjoy a healthy, beautiful forest?

There's a lot to think about when defining your goals, and assistance from a forestry professional, such as a consultant forester, Oregon Department of Forestry stewardship forester, or OSU Extension forester, can be very helpful. If you would like to learn more about management planning on your own, there are some excellent online resources such as the forest management planning section at the Know Your Forest website (www.knowyourforest.org) created by the Partnership for Forestry Education.

Once you have your goals in mind, begin creating a sensible timber harvesting plan by putting in writing a thorough understanding of what you have to work with. This includes the intrinsic characteristics of the site, such as climate, topography, aspect, soils, streams, and road access. It also includes the timber selected for harvest. How big are the trees? (Figure 10.2, page 199). How much total volume will be harvested? How much volume per acre? How fast does it need to be removed? Are there potential environmental restrictions, such as protecting streams, wetlands, or sensitive wildlife species (Figure 10.3, page 199)? Your answers will allow you to analyze the various harvesting options available and develop a harvesting plan that makes sense for the site and timber, which will facilitate the successful achievement of your goals and objectives.

Photo: David Moorhead, © University of Georgia

Figure 10.2. A bobcat harvester with a hydraulic shear is often used in dense, smaller timber stands because of its ability to maneuver efficiently during the harvest.

Photo: Joy Viola, © Northeastern University

Figure 10.3. A sandhill crane take flight. Before harvesting your timber check with local officials to see if your harvest site might have any environmental restrictions that need to be addressed during a harvest.

Selecting a harvesting system

The site and timber characteristics of family forestland properties in eastern Oregon can vary widely, even within a single ownership. Table 10.1 on page 200 matches the performance capacity of the various types of harvesting systems with the site and timber characteristics for which they are best suited. It is very important to consider all the variables listed in the chart when selecting a system because if a particular system cannot adequately handle all of them, then it may not be a workable choice.

Horses or farm tractors, for example, work fine on gentle ground but are impractical on steep terrain. An additional factor to consider is the availability of harvest systems. Mechanized systems may be a good fit for your site and timber characteristics, but there are far fewer contractors with mechanized equipment than traditional crawler tractors and skidders, making it potentially difficult to find a contractor in your area.

Figure 10.4. Small-scale skidding machines like this one are a cost-effective and low-impact alternative for owners of small woodlands.

The following section contains short descriptions of where to use different types of harvest systems. The suggestions are generalized, and keep in mind that even within a single system, the equipment choices can vary greatly in size, capacity, and cost.

Gentle ground, short skidding distances

When harvesting small to medium-sized timber on gentle ground (slopes less than 5 to 10 percent), where skidding distances are less than 300 to 500 feet, consider using either horses or a farm tractor set up for harvesting timber (Figure 10.4). Their small size requires only narrow skid trails and tends to create minimal environmental disturbance such as soil displacement or compaction. However, their rate of production is slow, so if you need to harvest timber quickly because of log markets or weather constraints, then another system may be better. Even though horses and tractors are inexpensive on a per-day basis, they may actually be much more expensive than crawler tractors or rubber-tired skidders on a dollar-per-board-foot-removed basis. Horses can pull heavy loads, but they work best when constrained to smaller-sized timber and shorter skid

Table 10.1. Harvesting systems and the site and timber characteristics they are best suited for.

Performance category	Horse	Farm tractor	Crawler	Wheeled	Excavators	Mechanized systems	Small cable	Large cable	Helicopter
Timber size	< 16 in. dbh	< 20 in. dbh	All within range of machine	All within range of machine	Small–large within range of machine	< 30 in. dbh	Small–medium within range of machine	Small–large within range of machine	All; limited by weight of timber
Topography	< 5% slope	< 5% slope	45-55% slope	35-45% slope	35-45% slope	Up to 45% slope	Steep slopes; Deflection needed	Steep slopes; Deflection needed	No limit
Production potential	Low	Low	Low–high	Low–high	Medium–very high	Medium–high	Low–medium	Medium–high	Very high; Weather restricts operation
Production costs	Per-day low, per-MBF med–high	Per-day low, per-MBF medi- um–high	Low–medium	Low–medium	Low–medium	Low–medium	Low–high	Medium–high	High hourly costs; per-MBF rates acceptable depending on yarding
Road access requirements	300-500 feet maximum skidding distance	300-500 maximum skidding distance	1,000 ft possible; < 700 ft preferred	1,000 ft possible; < 700 ft preferred	300-500 ft plus	3,000 ft possible; < 1,500 ft pre-ferred	1,500 ft possible	1,000–5,000 ft possible	Distance limited only by costs per MBF, as determined by production rate
Stream protection	Excellent	Excellent	Very good depend- ing on proximity to stream	Very good depending on proximity to stream	Very good depending on proximity to stream	Good; stream crossing needs ODF notification	Excellent; cables can lift logs across streams	Excellent; cables can lift logs across streams	Excellent protection
Site disturbance	Minimal; may need additional equipment Small landing (<50 ft diam)	Minimal; may need additional equipment Small landing (<50 ft diam.)	Medium–high; soil compaction Damage to residual stand Can treat slash Medium landings (~ 75 ft diam)	Medium–high Soil compaction Damage to residual stand Can treat slash Medium landings (~ 75 ft diam)	Low–medium slash handling May damage residual stand in partial cuts Serves dual role as a log loader	Medium small–large landings Damage to residual stand possible	Minimum–me- dium May damage residual stand in partial cuts Small–medium landings	Minimum–medium Slash handling possible May damage residual stand in partial cuts Small–medium landings	Minimal Slash handling a problem Large (100 ft) landings, 50 ft set-down, and maintenance area
Availability	Few	Common	Commonly used	Commonly used	More becoming avail-able	More becoming available	Generally available: scheduling may be necessary	Common use in western Oregon; infrequent east of the Cascades	Few available
Additional capabilities		Traditional multi-purpose capability	Building roads, landings, installing culverts, and treating slash	Slash treatment	Building roads, landings, installing culverts, treating slash, and various excavating operations	Suitable for yarding only	Suitable for yarding only	Suitable for yarding only	High costs an obstacle for use beyond harvesting

Figure 10.5. Rubber-tired skidders can skid logs at longer distances quickly, work on slopes up to 35%, and are one of the most common skidding methods in eastern Oregon.

distances. Skidding on ground that is flat or slopes gently downhill is essential as pulling uphill will quickly exhaust the animals.

Farm tractors, when set up properly for logging, can be effective on flat or gently sloped ground but were not designed for the rough conditions in the woods and are extremely unstable on steeper ground. However, they can be particularly attractive for landowners who want to do their own logging because the machines can be used for multiple land management tasks, making them a cost-effective alternative.

Steeper ground, longer skidding distances

If the slopes are greater than 10 percent or if you're faced with longer and/or uphill skidding situations, then other options need to be considered. Crawler tractors and rubber-tired skidders will work well (Figure 10.5). Mechanized systems, such as cut-to-length harvesters and feller bunchers, may be appropriate if the harvested timber volume is large enough to justify their expense.

If slopes become steeper, from 30 to 35 percent, then ground-based machines such as crawler tractors or wheeled skidders will be needed. These machines are the most commonly used harvesting equipment throughout eastern Oregon because they are extremely versatile, adaptable to a wide range of topography, timber size, and weather-related conditions. They are readily available, reliable, and useful for other jobs such as building roads or piling slash. When a harvesting job is planned carefully and when using skilled and conscientious equipment operators, the site impacts, such as soil disturbance and soil compaction, are minimal. Mechanized systems are also well-adapted for these conditions but tend to be less available and more expensive.

Very steep ground, difficult skidding

When the topography becomes steep and rough with long and difficult skidding requirements, then more-specialized harvesting systems may be necessary (Figure 10.6, page 202). Equipment such as cable-assisted mechanized systems, cable yarders, and helicopters can handle even the most difficult situations, but they can be expensive and thus only economically practical when harvesting large volumes of high-quality timber. These special mechanized and cable systems can cost thousands of dollars per day, and helicopters hundreds or even thousands of dollars *per hour*. Fortunately, there is a wide range of machine sizes and capabilities, and some of the smaller mechanized and cable systems offer adequate operating capacity and reasonable costs, making them an attractive alternative for family forestland owners.

These systems may also have very low environmental impacts. For example, the cut-to-length mechanical harvesters often place the slash created by delimbing trees on the skid trails and then travel over the mat of slash, thereby protecting the soil. Small yarders such as the

Figure 10.6. Specialized harvesting systems may be necessary on steep terrain.

Koller tower can reach long distances (up to 2,000 feet), need very narrow skid corridors (approximately 12 feet), and partially suspend the logs off the ground, which greatly reduces soil disturbance.

Small scale harvesting equipment—special considerations

Many small-woodland owners are interested in doing their own harvesting, and there is an increasing number of small-scale equipment choices available that are relatively inexpensive, offer sufficient capacity to get the work done, and can be used for a variety of land-management tasks. The farm tractors discussed above and all-terrain vehicles (ATVs) are good examples, and there are other machines available, such as very-small wheeled skidders and mechanical harvesters. It is beyond the scope of this publication to discuss small-scale equipment thoroughly, but some words of caution are relevant.

Photo: Chris Schnepf, © UIniversity of Idaho

Figure 10.7. Small-scale harvesting equipment can carry surprising payloads when operated correctly and used with attachments, such as an arch or winch.

The biggest concern is safety. Popular machines such as farm tractors and ATVs were not designed for timber harvesting and don't have adequate rollover protection. Even when set up to handle the rigors of woods work, they can be unstable. These machines were also not designed with the sophisticated ergonomics built into modern harvesters, and studies indicate that small-machine operators are at risk of severe repetitive-stress-related injuries to the neck, shoulders, back, wrists, knees, etc., especially with prolonged use.

In terms of capacity, small-scale harvesting equipment (Figure 10.7) can be surprisingly effective when used correctly and paired with specialized attachments, such as an arch that carries much of the weight or a winch.

Preharvest planning

Before initiating a harvest there are a number of factors that should be considered and planned for in order for the operation to be cost effective, efficient, and able to meet all of your land-management objectives.

Evaluating economic feasibility

One of the first things to evaluate is economic feasibility. Many landowners in eastern Oregon are faced with challenges that can make harvesting impractical or even infeasible:

- Declining infrastructure: Few purchasers means little competition, resulting in low log prices.
- Low harvest volumes: Moving equipment in and out of a job is expensive, so removing only small amounts of timber results in high fixed costs, making the harvesting costs higher than the revenues.

- Haul costs: With few mills remaining, landowners often have to truck their logs long distances, which adds to the overall costs.

- Related expenses: Timber severance taxes and both federal and state income taxes must be considered as well as road building and maintenance costs and postharvest management work such as slash disposal and site regeneration.

Even if making money isn't a high priority, economics still need to be carefully analyzed or the project could become uneconomical. There are situations in which the management need may justify losing money on the harvest, such as cleaning up after a wildfire or severe disease event, but these are the exception.

Preparing for the logging operation

If your analysis shows that the proposed harvest is economical, the next step is to carefully consider how the harvest will be conducted. Taking the time to plan and prepare for the logging operation will increase the likelihood of success, increase efficiency, and decrease adverse impacts. It's important to remember that you'll have to live with the results of the harvest for many years, so make sure it's something that you'll be happy with in the long run.

Hiring a consultant

One of the first considerations is whether you'll do the harvest planning yourself or hire a consultant. If you are confident that you have the knowledge, experience, skills, and time to do all required field work, then that's great. However, most people don't have a sufficient background to handle all the required tasks, so it makes more sense to hire a consultant. Marketing the forest products for highest value can also benefit from hiring a professional who knows the industry and knows how to realize the highest returns.

Figure 10.8. It's important to ensure you have good access to the project area.

Laying out the harvest unit

Laying out the harvest unit is extremely important. Not all properties have clearly defined boundaries, and the importance of staying on your own property cannot be overstated—trespassing and cutting a neighbor's trees can lead to unpleasant legal problems.

Accessing the site is an important, but overlooked, factor. Can you physically access the project area with the required harvesting and hauling equipment during the time you need to harvest? Do you have the legal authority to use all the required roads? (Figure 10.8, page 204)

Photo: Chris Schnepf, © University of Idaho

Figure 10.9. Marking trees selectively for removal in a harvest such as a commercial thinning is an excellent way to communicate to the logger and timber buyer which trees will be taken and which left for the future. Blue-marked trees are trees to remove.

Marking trees

One of the most important forest harvest management tasks sounds simple but in fact is quite complex. When doing a partial cut, designating which trees remain and which ones to remove requires many key forest management considerations, such as these: What tree species do you want to emphasize? Do you want an even-aged or an uneven-aged system? What are the insect and disease implications? How do you successfully regenerate the site? How will the harvested trees be removed without damaging the residual trees?

Tree marking is also an effective communication tool that tells the logging contractor precisely which trees to remove and which ones to leave (Figure 10.9). Some systems such as a diameter-limit cutting are open to interpretation and miscommunication. Once a tree is cut, you can't put it back on the stump! Those decisions, for better or worse, have to be lived with.

Contracts

Many woodland owners, if not most, will hire a contract logger to harvest their timber. We won't cover the subject in depth here, but a good contract is strongly recommended. A properly written contract is an excellent communication tool that defines what is to be done and provides a remedy if contract terms are not met. It's in your best interests to avoid these unnecessary complications, so take the time to learn and understand the basic requirements

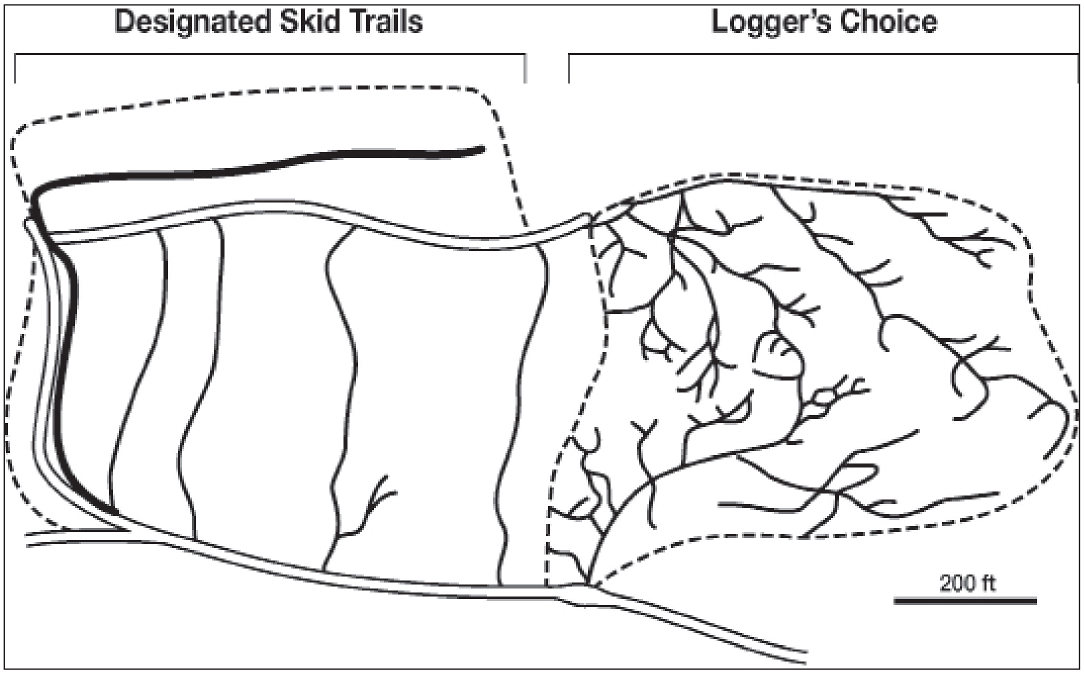

Figure 10.10. Using designated skid trails can greatly reduce site impacts from harvesting as well as improve logging efficiency and reduce logging costs.

of a well-written contract. (See *Contracts for Woodland Owners*, EC 1192, https://catalog.extension.oregonstate.edu/ec1192.)

Designating skid trails

No matter what type of harvesting system is selected, in almost all cases it is imperative to constrain the movement of harvesters and skidders within the harvest unit. Unregulated machine travel (Figure 10.10) has been shown to impact over 70 percent of a site with skid trails and landings, resulting in unacceptably high levels of damage to residual trees, soil disturbance, and soil compaction (Figure 10.11, page 207). Requiring designated skid trails not only greatly reduces these impacts but can actually increase harvesting efficiency and reduce operating costs.

Complying with the Oregon Forest Practices Act

Other preharvest planning work may be required to protect environmentally sensitive areas such as streams and riparian areas, wetlands, and wildlife habitats. Every landowner should be familiar with the Oregon Forest Practices Act (FPA) regulations. It's also a good idea to get to know your Oregon Department of Forestry stewardship foresters who are in charge of enforcing the FPA regulations. Oregon's FPA rules are designed to enable high-quality harvesting practices while protecting our natural resources by ensuring that forested sites remain forested, that streams are protected, and that wildfire prevention practices are met. One way to make sure your logging contractor is aware of these rules is to hire an Oregon Professional Logger-certified contractor; these contractors need continuing education to stay certified and can be found at the Associated Oregon Loggers website (www.oregonloggers.org).

All forest operations require obtaining a forest practices permit, typically two weeks in advance of commencing operations. This permit can be submitted through the ODF website (FERNS) or your closest ODF office.

Photo: US Forest Service

Figure 10.11. Tree damage during a selection harvest can be minimized by using skilled and conscientious loggers who use careful logging methods, as well as designated the skid trails, and matching logging equipment to the timber and site conditions.

Pre- and postharvest checklist

The following checklist summarizes the many pre- and postharvest activities you need to consider and can be a helpful tool for enjoying a successful harvest operation.

- Establish objectives.
- Conduct an economic feasibility study.
- Analyze the site and timber characteristics.
- Select a harvest system.
- Write a contract. Define expectations, timelines, liability, penalties.
- Hire a consulting forester.
- Confirm legal and physical access.
- Establish property boundaries.
- Lay out designated skid trails and designate landing areas.
- Mark trees.
- Market the timber; secure a purchaser(s).

Photo: US Forest Service

Figure 10.12. A ponderosa pine forest in eastern Oregon

- Hire a logging contractor.
- Monitor the logging operation (utilization, skid trails, slash, road maintenance) and prepare for regeneration (natural or planted).
- Perform postharvest inspection for compliance.
- Treat logging slash.
- Grass seed skid trails and landings (see Chapter 8).
- Monitor and maintain road drainage systems as needed. Close roads if necessary.
- Plant trees if necessary.

Summary

So, what do you want your forest to look like when it grows up (Figure 10.12)? Two things are needed to make your wishes a reality. One is to establish goals that are compatible with what you have to work with, such as site and timber characteristics. The other is to possess the physical means for managing your forest's silvicultural parameters, i.e., species diversity, stand density, and structure. Timber harvesting provides those means and must be considered from the beginning as an integral part of the planning process.

CHAPTER 11

Reducing fuels and fire risk

Stephen A. Fitzgerald

Introduction

Wildfires are a natural disturbance and have influenced forest and rangeland development across the West. However, over the last century and a half, forests and rangelands have changed dramatically from their presettlement condition. This is particularly true in the drier forests of the West, where decades of fire exclusion have resulted in a buildup of fuel (see Chapter 1). Due to a warming climate, fire seasons are now three to five weeks longer. These trends have created conditions that now spur "megafires" burning 100,000 acres or more, some of which have occurred in central and eastern Oregon in recent years (Figure 11.1).

Photo: Les Zaitz, ©The Oregonian

Figure 11.1. The Canyon Complex Fire near Canyon City, Oregon

Elements of Fire Behavior

Rate of spread—How fast a fire moves in ft/min or chains/hr

Intensity—How hot a fire burns (heat released in BTUs)

Flame length—Surrogate measure for fire intensity

Torching—Flames moving up from the surface into tree crowns

Crowning—Flames spreading through the main tree canopy

Spotting—Spot fires ignited by embers ahead of main fire front

Whirlwinds—Superheated air and turbulent wind conditions forming whirling eddies of fire

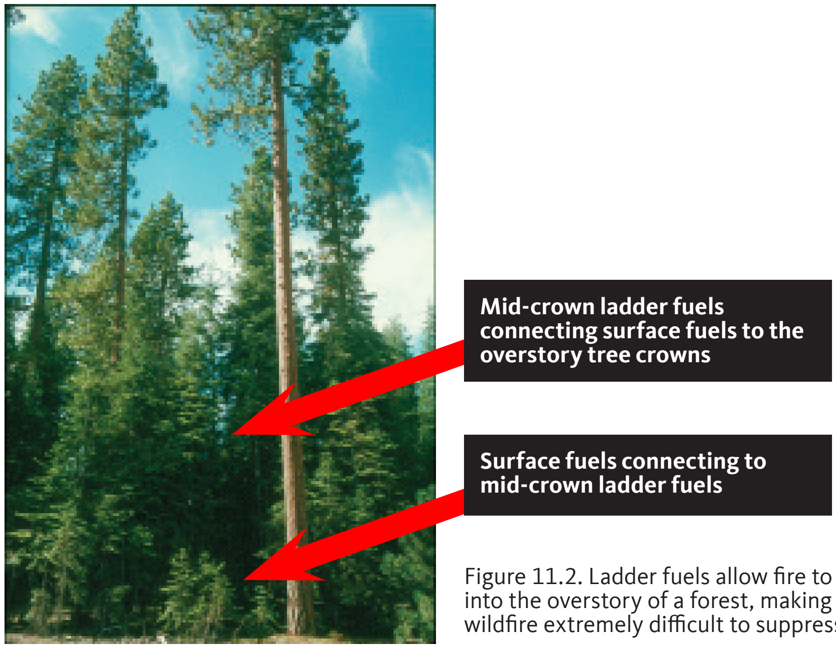

Figure 11.2. Ladder fuels allow fire to climb into the overstory of a forest, making a wildfire extremely difficult to suppress.

For the same reasons, your property may be fire-prone (Figure 11.2) and at risk of severe wildfire and you may be surrounded by other landowners whose property may be at a high risk of wildfire. What can you do?

This chapter discusses what you can do to lower your risk of wildfire and its potential impacts on your property. It provides an overview of fuel and fire behavior and illustrates what you can do to reduce fire intensity to create fire-resistant forests. It should be noted that fire-resistant forests are not "fireproof"—under the right conditions, any forest will burn.

Background on fire science and behavior

What do we mean by fire behavior? Typically, we are interested in how hot the fire burns (intensity) and how fast it moves or spreads (rate of spread). Refer to the sidebar for other elements of fire behavior.

The fire and fire behavior triangles

Three elements are needed to sustain a fire: heat, or an ignition source; fuel; and oxygen (Figure 11.3a, page 211). Take any one of these elements away and the fire doesn't start or it goes out. For example, digging a fire line down to mineral soil, which is noncombustible, removes combustible material on the forest floor (surface fuel) and stops a forest fire's progress if the fire line encircles the fire.

Fire "behavior" is related to its rate of spread (feet per minute) and its intensity (i.e., how hot it burns and how long its flame is). Once a fire ignites in forest or rangeland vegetation, its behavior depends on the three factors that comprise the fire behavior triangle: the amount and arrangement of fuel, the area's topography, and weather conditions (Figure 11.3b, page 211). A change in any one factor during a fire alters its behavior and type (i.e., whether it's a ground, surface, or crown fire). For example, if the weather becomes hot, dry, and windy, the fire will burn with more intensity and move faster across the landscape. If a fire is burning in heavy fuels and then moves into an area with light or discontinuous fuels, fire intensity and spread decrease.

Figure 11.3a. The three elements needed to sustain a fire.

Figure 11.3b. The three factors affecting fire behavior

We have little or no control over most factors in the fire and fire behavior triangles. For example, we can't control the wind, topography, or oxygen or stop every fire ignition. However, one element we can control is fuel. There are several fuel characteristics to be aware of that affect ignition potential, subsequent combustion, and fire behavior (see Table 11.1).

Table 11-1. Fuel characteristics and their influence on fire behavior

Fuel characteristic	How measured or assessed	How it affects fire behavior	Examples
Fuel size	Diameter (inches)	Affects the speed of wetting/drying	<1/4 inch: grass and needles, twigs
			¼ to 1 inch: small branches
			1 to 3 inches: large branches
			3 to 8 inches: large branches, small logs
			> 8 inches: large logs
Chemical content	NA	Increases flammability and BTU	Resin and sap; chemicals in content. Foliage (needles and leaves)
Loading	Tons/acre	Affects quantity of fuel that is potentially available to burn	Light, medium, or heavy loading of fuels
Moisture content	% fuel moisture	The lower moisture content the more readily it ignites and burns.	Fuels with 12% or less (< 3 inches diameter) support active behavior
Vertical arrangement	Visual layering	Creates ladder fuels that support torching and crowning	Tall shrubs, small trees, and medium-sized trees
Horizontal arrangement	Visual patchiness	Influences combustibility, fire, or spread and severity across the areas with medium and high fuel landscape.	Variation of openings with low fuels loading

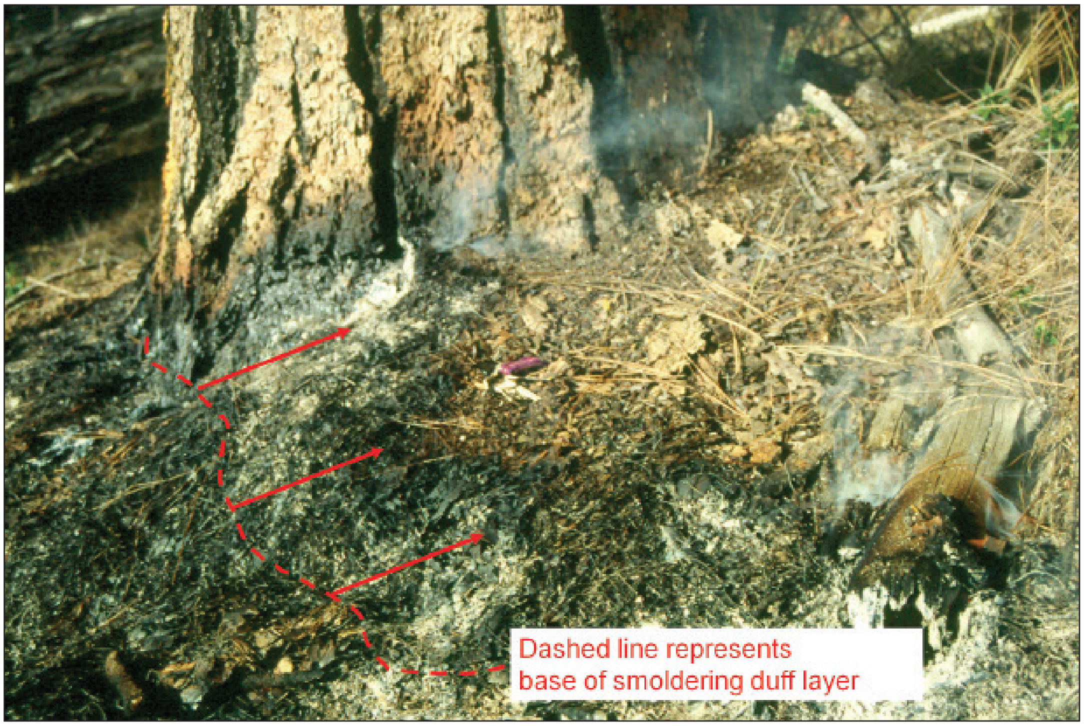

Figure 11.4. A ground fire continues to smolder in the duff at the base of a tree.

We can alter fire behavior by reducing the amount and changing the arrangement of fuel before a wildfire erupts. Recent examinations of large wildfires in the West show fire intensity and severity were usually significantly reduced when fuels had been reduced beforehand.

Photo: Teresa Brennan, US Forest Service

Figure 11.5: A surface fire moves upslope.

Types of fires

A wildfire may be composed of three different types of fire: ground, surface, and crown. The proportion of each type determines the overall severity of the fire as well as the amount of vegetation that is killed or consumed and the degree of soil damage. Fire severity also depends on the duration of the fire, the weather, and topography. Fire severity refers to the impact of the fire on trees and other vegetation (e.g., mortality) as well as on the soil.

Ground fires

Ground fires consume mostly the duff layer and produce few visible flames (Figure 11.4). Ground fires also can burn out stumps and follow and burn decaying roots and decayed logs in the soil. A fire burning in decayed tree roots often goes undetected except when it follows a root near the soil surface. Then, it can emerge, ignite surface fuels, and become a surface fire. Ground fires can often smolder for days and weeks, producing little smoke.

Photos: Scott Isaacson, National Park Service (left) and Wildlandfire.com

Figure 11.6a-b. A passive (torching) fire (left) and an active crown fire (above).

Surface fires

Surface fires produce flaming fronts that consume needles, moss, lichen, herbaceous vegetation, shrubs, small trees, and saplings (Figure 11.5, page 212). Surface fires can ignite logs and other woody debris and decomposing duff, which can then burn (termed glowing combustion) long after surface flames have moved past. Surface fire severity is typically low but can be high if fuel loading is heavy. High-severity surface fires can kill most trees (more than 75 percent) as a result of crown and bole scorch, but their effects can be highly variable, leaving scattered individual and patches of green trees. Surface fires with flame lengths less than 4 feet often can be controlled by ground crews.

Crown fires

Crown fires are either passive or active. Passive crown fires involve the torching of individual trees or groups of trees (Figure 11.6a). Torching is the precursor to an active crown fire, where fire spreads from tree crown to tree crown. Crown fires become active when enough heat is released from combined crown and surface fuels to preheat and combust fuels above the surface, followed by active crown fire spread through the canopy (Figure 11.6b). Crown fires are usually intense and stand-replacing and are strongly influenced by wind, topography, and tree (crown) density.

Four factors influence the transition from a surface fire to crown fire:

- Surface fuel and foliage moisture content
- Surface flame length (affected by fine-surface-fuel loading, wind, and slope)
- Height to the base of tree crowns (i.e., bottom of the canopy)
- Density of tree crowns (degree of overlapping of tree crowns)

Principles of fire-resistant forests

Fire-resistant forests have characteristics that reduce the likelihood of severe crown fires, allowing the forest to survive a surface fire without significant tree mortality in the main canopy. We can lower fire risk and wildfire damage potential by removing or reducing fuels in strategic locations. Again, we can't truly "fireproof" a forest, but we can influence forest fuels so that fire behaves in a more natural way, particularly in ponderosa pine and drier mixed-conifer forests that experienced fairly frequent fire historically.

There are five principles of creating and maintaining fire-resistant forests (Figure 11.7):

- Reduce surface fuels
- Increase the height to the base of tree crowns
- Increase spacing between tree crowns
- Keep larger trees of more fire-resistant species
- Promote fire-resistant forests at the landscape level (beyond the stand level and across your entire property)

By following these principles we can achieve the following:

- Reduce the intensity of a fire, making it easier for firefighters to suppress it.

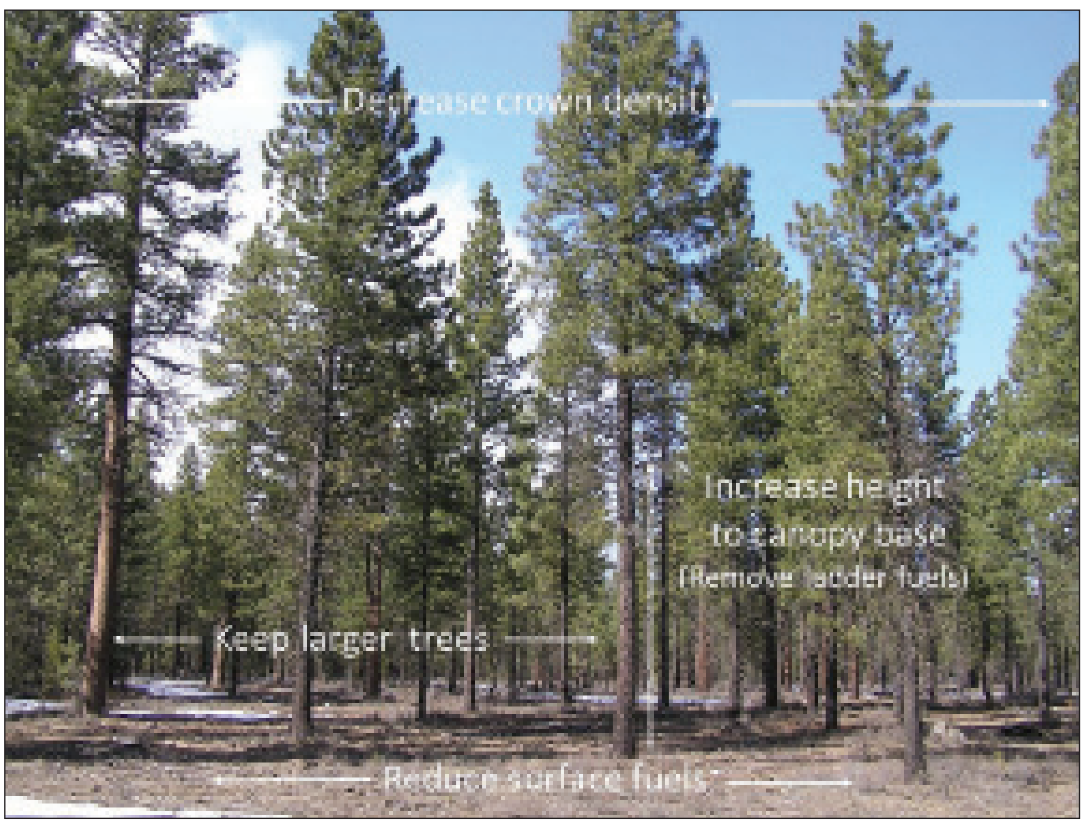

Figure 11.7. The principles of fire-resistant forests

- Increase the odds that greater proportions of the forest will survive a fire. Small trees, shrubs, and other understory vegetation may be injured or killed and a small percentage of larger trees may be killed, but most of the trees will only be scorched and soil damage also will be reduced.

- Reduce the extent of postfire restoration activities that will be needed, such as replanting

Reduce surface fuels

Reducing surface fuels, such as slash and small shrubs, reduces potential flame lengths and fire intensity, making fires easier to control and less likely to reach into tree crowns. Reducing surface fuels means removing significant accumulations of flammable organic material but not eliminating all organic material down to mineral soil.

Increase height to base of tree crowns

When tree crowns ignite (known as torching), the stage is set for a crown fire. Removing surface and ladder fuels and pruning the larger trees raises the base of the forest canopy so that a longer flame is needed to ignite tree crowns. Pruning is particularly effective in young stands, where crowns may still be low to the ground. Prescribed underburning can also increase the height of the lower canopy due to scorching and killing of lower branches.

Increase spacing between tree crowns

When tree crowns are farther apart, it is harder for fire to spread from one crown to another, even when the wind is blowing. Thinning reduces crown density. Reducing the slash generated from thinning will diminish the potential for a high-intensity surface fire.

Keep larger trees of more fire-resistant species

Fire kills trees by heating and thus killing the cambium layer (a layer of cells just inside the tree bark that produces new wood and bark), scorching the foliage, killing the buds, and damaging and killing roots. When thinning to improve fire resistance, leave larger trees with thicker bark that insulates the cambium. Although a fire may scorch the foliage above, the cambium is still protected. Also, large trees tend to have higher crowns, so their foliage and buds are less likely to be damaged by heat from a surface fire. This is particularly true if the stand is thinned from below. (Figure 11.8 a-b, page 216).

Ponderosa pine, western larch, and Douglas-fir tend to develop thick bark that insulates the cambium from heat, and their root systems are deeper and more protected. Ponderosa pine has other features that help it survive fire, including an open crown, high moisture content in the foliage, and thick bud scales. Western larch also is very fire-resistant. Lodgepole pine, the true firs, Engelmann spruce, and hemlock have thin bark and shallow roots and are more easily killed by fire, even a light surface fire. Deciduous trees, such as quaking aspen and black cottonwood that occupy riparian areas, seeps, and springs, are fire resilient because they can resprout after being top-killed by fire.

Promote fire-resistant forests at the landscape level

The larger the area treated, the more effective fuels treatments will be at moderating fire behavior. This includes creating gaps and openings to further reduce the potential for crown fire. Treating in strategic locations can help break up both continuous horizontal and vertical layers of fuels. For example, reducing fuels adjacent to natural features, such as meadows and rock outcroppings, and manmade features, such as roads, helps firefighters connect fire lines to these locations.

Fuel reduction methods

There are a variety of ways to reduce or treat surface, ladder, and crown fuels to create fire-resistant forests. Table 11.2 (page 217) lists fuel-reduction methods, their costs, and the effects of each on surface, ladder, and crown fuels. Since few methods are effective on all types of fuels, they are typically used in combination. For example, a stand may be thinned and pruned, and the resulting surface fuels piled and burned.

Thinning

Common questions about thinning include: Which trees should be selected? How far apart should trees be spaced? And, when should I thin (or not thin) during the year? Below, we address these questions only with respect to creating fire-resistant stands. Making decisions about thinning will involve a variety of other considerations, such as slope, accessibility, and what type of logging equipment to use.

Tree selection

Remove smaller trees and retain larger, more vigorous trees (Figure 11.8a–b). This approach, called "thinning-from-below," removes ladder fuels, raises the base of the overall canopy, and, if enough larger trees are removed, increases the spacing between tree crowns. Large trees are more fire-resistant due to their thicker bark. This approach tends to shift species composition away from shade-tolerant species (e.g., fir) that are often abundant in the understory.

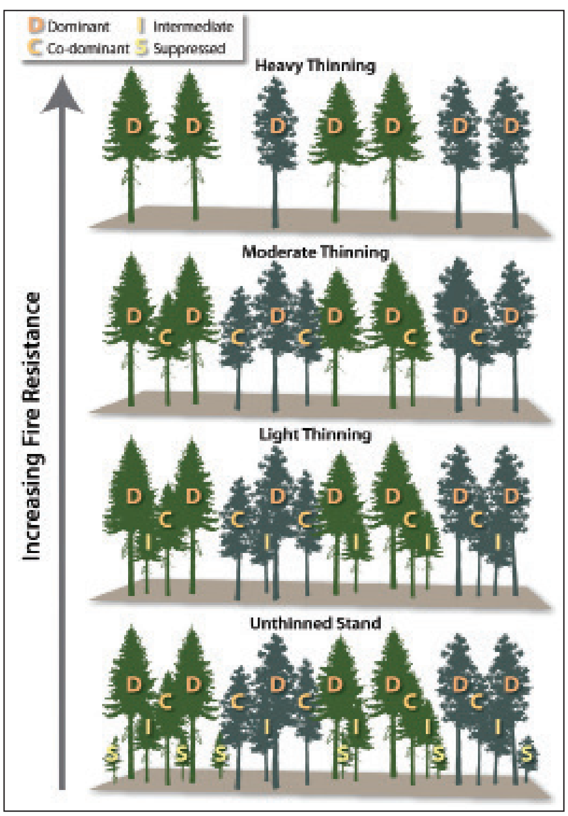

Figure 11.8a-b. Thinning from below (left) and leaving co-dominant and dominant trees improves a forest's fire resistance. A mixed conifer stand (above) was thinned to remove fir species and smaller ponderosa pine. The area in the background remains unthinned.

Table 11.2. Fuels reduction options: The effects of different fuel-reduction methods when used as a stand-alone treatment

Method	Surface fuels	Ladder fuels	Crown fuels	Contract cost ($/acre)	Notes
Thinning	Increase	Reduce	Reduce	Highly variable depending on slope and other terrain factors, stand density, tree size, equipment available, etc. Up to $800 per acre for smaller, noncommercial material but can yield money from larger commercial material.	Not a stand-alone treatment; requires post-operation slash abatement. Pre-commercial thinning to reduce ladder fuels can result in considerable surface fuel on the ground that must be abated. Commercial thinning can utilize most woody material for biomass or saw logs.The value can help offset the cost of treatment and slash abatement.
Pruning	Increase	Reduce	Little to no effect	$50-$250 per acre depending on height and number of trees pruned	Usually done in conjunction with thinning. As a stand-alone treatment (without removal of pruned material), may substantially increase surface fire intensity at base of tree.
Cut-and-scatter	Increase	Reduce	No effect	$25–$45	Use where fuel loads are light. May substantially increase surface fire intensity.
Prescribed underburning	Decrease	Decrease	Little to no effect	$50–$500	Often an initial mechanical treatment is needed to “step down” fuels to a point where safe burning is feasible; liability concerns make it risky for most private owners; smoke management required.
Cut, pile, and burn	Small decrease	Reduce	No effect	$275-$1,500. Major cost is piling.	
Cut, lop, and scatter	Redistribute	Decrease	No effect	$500–$1,500	
Mowing	Redistribute	Little to no effect	No effect	$40–$150	Only fine fuels
Slashbusting/mastication	Increase/redistribute	Decrease	Little to moderate effect	$250–$1,000	

Thinning from below is a common approach in even-aged stands. In cases where you want to maintain or promote a multi-aged forest (a forest containing three or more age classes of trees), a modified approach can be used. Trees can be thinned across the range of diameter or age classes so that stand density and ladder fuels are reduced while maintaining a multi-aged character. Compared to an even-aged stand, such a stand will have a higher risk of crown fire because some younger understory and mid-story trees (ladder fuels) will remain.

Tree spacing

How far apart do crowns need to be to reduce crown fire? In general, if the branches of adjacent trees are overlapping, crown density is high enough to sustain crown fire under the right weather conditions. Conversely, if trees are widely spaced, say with crowns spaced more than one dominant-tree-crown width apart, crown fires are much less likely to occur. Factors that tend to increase the required crown spacing include steep slopes, locations with high winds, and the presence of species like grand fir with dense, compact, and flammable foliage. Tree spacing does not have to be even. Small patches of trees can be left at tighter spacing for wildlife or aesthetic benefits.

Opening up the stand significantly will dry surface fuels due to increased sunlight, surface winds, and temperatures. This may increase surface fire intensity and rate of spread unless total surface fuel loading is reduced. In addition, thinning that allows significant light to reach the forest floor may result in the regrowth of small trees and shrubs, which over time become new ladder fuels. Other issues with very wide tree spacing include increased risk of blowdown, reduced timber yields in the short run, and potential for triggering reforestation requirements. Consider these tradeoffs when making decisions about tree spacing.

Timing

Pay attention to timing when thinning in pine stands. Green slash larger than 3 inches in diameter generated from winter through July can provide breeding material for pine engraver (*Ips*) bark beetles, which may emerge and attack healthy trees. Avoid thinning pine species during this time period or make sure slash is cleaned up quickly afterward. In some areas, there may be additional concerns with Douglas-fir beetles, fir engraver beetles, or spruce beetles breeding in larger-diameter green slash or downed logs.

Pruning

Pruning can be combined with thinning or done as a stand-alone treatment. Pruning removes lower tree limbs, increasing the height of tree crown bases (Figure 11.9). A good height to shoot for from a fire-resistance standpoint is 10 to 12 feet, though pruning even higher is beneficial. The pruning slash should be disposed of through piling and burning, chipping, or, if fuel loads are light, cut and scatter.

Figure 11.9: A young ponderosa pine has been pruned to reduce ladder fuels. Note branches have been piled to be burned later.

To maintain tree health, pruning should leave at least a 50 percent live crown ratio (ratio of the length of the tree crown to the total height of the tree; see Chapter 2) and should not damage the

Figure 11.10a-b. A prescribed fire works its way through a ponderosa pine stand (left). The right-hand photo shows a thinned ponderosa pine stand after a prescribed underburn. Note the light scorch on the lower branches. This underburning greatly improved the forest's fire resistance.

tree bole. Pruning is particularly effective in young stands where tree crowns have not yet lifted (the gradual death and branch shedding of lower tree branches from shading) on their own.

The wide variety of pruning tools includes hand-held saws, loppers, pneumatic shears, power pruners, and ladders. You may also be able to use your chain saw in some situations.

Prescribed burning

Prescribed burning is the regulated use of fire to achieve specific forest and resource management objectives (Figure 11.10a–b). It consists of two general categories: slash burning and prescribed underburning.

Slash burning reduces surface fuels after various silvicultural treatments and is usually done by (1) broadcast burning in larger units, usually clearcuts, or (2) piling and burning within stands, usually after selection cuts. Prescribed underburning is the use of fire within the forest understory. The primary objective of underburning is often fuels reduction, but underburning is also used to achieve other objectives, such as precommercial thinning, nutrient release, wildlife habitat or forage improvement, and control of unwanted vegetation such as western juniper. Prescribed underburning has become more common as our understanding of the ecological role of fire has increased.

Prior to initiating any prescribed underburn, a landowner must develop a professional burn plan. Good planning helps meet predetermined objectives and minimize the chance of an escaped burn. A burn plan includes the following key elements:

- A clear description of the stand or vegetation to be enhanced by underburning and expected outcomes for that vegetation
- Data on fuel amount, distribution, and moisture content as well as the topography and desirable weather conditions on a potential burn day
- Predictions of fire behavior (intensity and spread) based on the above factors
- Ignition patterns and arrangements for holding (maintaining the fire within the area)
- Timing and seasonality of the burn
- Smoke management guidelines

Burn plans should include a map of the unit to be burned, the various types of equipment and other resources needed to implement the project, needed permits, backup contingency plans in the event of an escape, medical and communications plans, plans for public awareness and coordination with other agencies as needed, and postburn plans for mop-up and monitoring.

Often the area to be burned will need some type of fuel pretreatment in order to meet objectives. This could include tree felling and brushing of unwanted vegetation in order to carry the fire or raking or pulling slash away from trees you want to keep (called "leave trees") to increase their likelihood of survival during the burn.

Careful and constant monitoring of weather on the burn day, constant contact with a local weather service, or both is imperative; sudden changes in weather can rapidly change fire behavior, increasing the risk of escape.

Because of its complexities and the associated liability, prescribed underburning is rarely done on private, nonindustrial woodlands because the cost of an escaped burn can be considerable. It includes not only the cost of suppression but also the cost of reimbursing any neighbors whose properties may be damaged. On federal lands, prescribed burning is conducted regularly. Federal agencies are much more willing to accept potential liability as they have the know-how, trained personnel, and equipment to manage a prescribed burn. It is strongly recommended that landowners who would like to conduct a prescribed burn work closely with their local Oregon Department of Forestry professionals and hire a consultant to assist in developing a burn plan and carrying out the burn.

Mechanical fuels reduction (mastication)

Mechanical fuels treatments utilize several different types of equipment to chop, mow, or otherwise break apart (masticate) ladder and surface fuels, such as slash, brush, and small trees, into relatively small chunks or chips, forming a compact layer of woody material that is distributed across the site and later decomposes.

Mechanical fuels reduction equipment includes slashbusters, brush mulchers, mowers, and other devices. The slashbuster is a vertically mounted rotating cutting head on a tracked excavator (Figure 11.11a–b). The brush mulcher consists of a horizontally mounted cutting drum attached to the front of an all-terrain vehicle like a Bobcat or other tracked machine (Figure 11.12, page 221). Mowing of understory brush is effective but is limited to relatively level ground with few rock outcroppings (Figure 11.13a–b, page 221). One attraction of mechanical treatments is their relatively low cost compared to hand treatments or chipping. Drawbacks include potential for wounding leave trees if the operator is not careful or skilled,

Figure 11.11a-b: A slashbuster thinning and fuel reduction operation is underway in young pine stand. Material is left on ground to decompose.

and soil compaction if operating when soils are wet.

The material produced by these processes varies in size but is usually coarser than that produced by most chippers. It still forms a dense fuel bed, however. Compared to more loosely arranged natural fuels, moisture is retained longer and the available oxygen supply is lower, resulting in potentially slower rates of fire spread than would have occurred if the area were left untreated. However, the duration and severity of fire in masticated fuels may be initially higher than in other types of fuels treatments until masticated fuel pieces decompose.

Figure 11.12: A mulcher/masticator

Figure 11.13a-b: A crew (left) mows shrubs in the understory of a ponderosa pine stand. The photo on the right shows the area after the mowing has been completed.

Utilization and slash disposal

During thinning, trees are felled, limbed, and bucked into logs of various lengths. These logs can often be utilized rather than left in the woods. Small logs can be sold as saw logs, posts and poles, and pulp as well as for firewood and other materials for home use. Product sales may help offset the treatment costs, and thinning of larger-diameter trees may even generate a profit. When markets are available, utilization of biomass also may help offset costs.

Once you have utilized all the material that is practically and economically possible, the next step is to treat the remaining slash. There are three primary slash disposal methods: cut, lop, and scatter, pile and burn, and chipping. It's critical to consult your state forestry agency in advance to determine if the proposed slash disposal method will result in acceptable slash reduction levels.

Cut, lop, and scatter

Cut, lop, and scatter is most appropriate for stands with light fuel loads or in areas that are a low priority from a wildfire perspective. Understory trees, branches, brush, and other fuels

Figure 11.14. In a cut, limbed, and lopped operation, understory trees, branches, brush, and other fuels are cut, sectioned into smaller pieces, scattered across the site, and left to decompose.

are simply cut, sectioned into smaller pieces, scattered across the site, and left to decompose (Figure 11.14). This technique does not eliminate fuels—it just redistributes them and gets the material in contact with the ground for more rapid decomposition. Cut, lop, and scatter temporarily increases the total amount of surface fuel and may create a continuous layer of fuels across the ground.

Although ladder fuels may be reduced, overall fire hazard may be increased initially. As the material decays over time, or is burned, the risk of fire declines. A common problem in dry forests is that the slash may take several years to decompose to the point where it no longer poses a significant fire hazard. In higher-elevation areas with a winter snowpack or in higher-precipitation zones, decomposition proceeds more rapidly.

Regardless of the climate, getting the material in contact with the ground will speed decomposition. Ideally, cut, lop, and scatter the material to a depth of 18 inches or less. Use cut, lop, and scatter in low-density stands where existing surface fuels and ladder fuels are light, where decomposition will proceed rapidly, and where a potential short-term increase in fire hazard is acceptable. Also, consider slash levels in adjacent stands. A common practice is to use cut, lop, and scatter in areas with light slash loads and use cut, hand piling, and burning in areas with heavier slash concentrations.

Pile and burn

Pile and burn is a common method for reducing surface fuels generated in thinning and pruning. Piles can be created by hand or with mechanical equipment (Figure 11.15a–b, page 223). Another option is to leave the slash over the winter to let needles fall off (to let nutrients return to the soil) and then pile and burn later.

Guidelines for pile burning:

- Carefully evaluate locations of piles. Place piles at least 25 feet (or more depending on pile size) away from trees, stumps, brush, and logs and 50 feet from streams. Stay well away from snags, structures, power lines, etc.

Figure 11.15a-b: After a stand is thinned to remove ladder fuels (left photo), the piled slash is covered with a piece of plastic to keep a portion of the pile dry to be ignited during wet weather (right photo).

- Construct the piles so they will burn easily. Put small branches, twigs, and brush less than ½-inch diameter at the bottom of the pile to provide kindling, then lay larger limbs and chunks of wood parallel to each other to minimize air pockets. For hand piles, aim for 4-by-4-foot piles; machine piles may be much larger.
- When machine piling, use a brush blade or excavator to avoid getting dirt in the pile. This helps prevent holdover fires that smolder for weeks beneath the soil, suddenly flaring up when winds and temperatures increase.
- Cover piles if they are not to be burned immediately. Cover when the pile is about 80 percent complete, placing the remaining material to hold the cover in place. In Oregon, you must remove the cover prior to burning unless it is made of pure polyethylene plastic (not all plastic is pure polyethylene). Cover just enough of the pile to keep it dry in the center so it will burn easily.
- Burn during daylight hours when conditions are wet or rainy with little or no wind.
- Avoid piling green pine slash more than 3 inches diameter in the late winter through July due to the risk of attracting pine beetles.
- Make sure you have a burn permit from the state forestry office, fire warden, or other local authority that regulates open burning.
- Some areas have a system utilizing "good burn days" based on ventilation index. Make sure you are in compliance.
- Monitor the piles to make sure they are out.

Chipping

Chipping is effective but is also labor intensive, expensive, and requires good access. It is probably best suited to around home sites and defensible-space treatments and along roads where a chipper can be easily maneuvered (Figure 11.16, page 224).

Many contractors, including arborists and tree service companies, have large chippers that can process relatively large-diameter material efficiently. Self-propelled, whole-tree chippers have been developed and may be available for contract work in some areas. Be aware that large piles of chips are a fire hazard from spontaneous combustion. The chips can be scattered across the ground or, better yet, used as mulch for covering skid roads and trails.

Maintaining your investment and summary

Fuels reduction is an ongoing process. The effects of thinning and other fuels treatments may last 15 years or less depending on the productivity of the site and other factors. New trees and brush grow in the understory and develop into ladder fuels. When cut, many brush species can resprout vigorously from root crowns and rhizomes. Species such as manzanita and several species of ceanothus have seeds that remain viable in the soil for many years, even decades, and germinate readily when soils are disturbed. Follow-up treatments will be needed, but they should be less expensive than the initial treatment.

Prioritize your fuel reduction treatments, treating the areas with the highest fuel and fire risk. Because fuel reduction is a lot of work, conduct some fuel reduction on a portion of your property every year so the work is spread out over time and more manageable. How much you do is dependent on your ability, health, and financial resources.

To help defray costs, plan fuel treatments when you are conducting commercial timber harvesting on your property so you can achieve more than one objective (e.g., improve tree health and reduce fuels) at the same time.

Other things you can do to reduce fire risk on your property include these:

- Create strategic fuel and fire breaks using roads, streams, and rock outcroppings as anchor points for firefighters.
- Develop small ponds, create access to streams, or provide water cisterns so that firefighters can obtain water nearby.
- Limit access to your property to prevent unwanted ignitions from human activities.

For a more thorough discussion of what you can do to reduce fire risk, refer to *Reducing Fire Risk on Your Forest Property*, PNW 618, https://catalog.extension.oregonstate.edu/pnw618.

Wildfires do not respect property boundaries. However, there are several steps you can take to reduce your risk of wildfire and to help ensure that if a wildfire does occur on your property, you can reduce its impacts.

Photo: John O'Connor, Oregon Department of Forestry

Figure 11.16. A crew chips up slash after cutting ladder fuels.

APPENDIX 1

Glossary

Advance regeneration—See Regeneration, advance.

Age class—A cohort or group of trees within a stand that are all about the same age and usually similar in size.

Alluvial material—Soil material deposited by running water.

Alluvial soil—A soil developing from recently deposited waterborne sediments.

Artificial regeneration—See Regeneration, artificial.

Aspect—The compass direction toward which a slope faces; e.g., north. Syn. Exposure.

Basal area—The cross-sectional area of the bole of the tree, 4.5 feet above the ground. Basal area (in square feet) = (tree dbh, in inches)^2 x 0.005454.

Basal bark treatment—A treatment for unwanted woody plants and trees in which herbicide is mixed with an oil carrier and sprayed on the lower 15 inches of shrub and tree sprouts. The herbicide is absorbed through the bark.

Biodiversity—Biological diversity; also, the abundance of different animal and plant species on a site.

Board foot – A unit of measure equal to a board that is 1 inch thick, 12 inches long and 12 inches wide, or 144 cubic inches.

Bole—The trunk or main stem of a tree.

Broom—See Witches' broom.

Brushblade—A toothed blade that attaches to the front of a bulldozer. Teeth are 8–10 inches long and allow the operator to pile brush or slash without pushing topsoil into the piles.

Bud scales—Leathery sheaths that cover and protect unopened buds.

Clearcut—An area in which essentially all trees have been removed in one harvest operation. See also Regeneration methods.

Climax—The culminating stage of plant succession for a given site and environment. See also Succession: Climax.

Climax vegetation—The plants that make up the final stage of natural plant succession, in which the plant composition remains relatively stable.

Co-dominant—See Crown classes.

Colonize—In plant succession, to establish first on a site that has been cleared of vegetation due to a disturbance such as fire. See also pioneer.

Commercial thinning—See Thinning, commercial.

Conk—A fungal fruiting body that is hard, woody, or leathery, either annual or perennial, and is formed by decay fungi on trunks, branches, or roots, usually after considerable internal wood decay has developed. The conk produces windborne spores that spread the fungus to other trees.

Crown classes—A system of classifying trees in an even-aged stand; the system characterizes trees' relative position (i.e., size and vigor) in the stand. Crown classes are:

- **Dominant—**The larger trees in an even-aged stand that form the uppermost layer of the canopy. These trees are slightly taller and larger in dbh than trees that form the main canopy layer. Dominant trees have full, symetrical crowns.
- **Co-dominant—**The trees that make up the main canopy layer. They are slightly shorter and smaller in dbh and crown dimensions than dominant trees.
- **Intermediate—**Trees that are shorter than co-dominant trees but still have crowns within the main canopy layer. Intermediate trees have smaller, irregular crowns and smaller dbh than co-dominant trees.
- **Suppressed—**Trees whose crowns are below the main canopy layer. Suppressed trees are smaller in all dimensions than the other tree classes.

Crown ratio—The ratio of live crown length to total tree height. See illustration, Figure 2.15, page 39.

Cull—A tree or log of merchantable size that is not merchantable as timber because of poor form, large limbs, rot, or other defects.

Cut-to-length harvester—A type of mechanical harvesting system in which the harvester fells, limbs and tops a tree then cuts it into desired log lengths.

dbh—Abbreviation: diameter at breast height; that is, diameter of a tree at 4.5 feet above ground level (on a slope, measured on the uphill side).

Decay column—A cylinder (column) of decayed wood within a tree; the column tapers at top and bottom. Usually, decay columns take many years to develop and are associated with external conks.

Defect—Properties of tree bole such as cracks, malformations, or stain that may decrease the value of sawlogs or render the wood unmerchantable for sawlogs.

Diameter-limit cutting—Removing all merchantable trees above or below a specified diameter (dbh), with or without cutting some or all cull trees.

Directed spray—A treatment for unwanted woody plants and trees in which herbicide is sprayed away from the desirable tree seedling onto surrounding competing vegetation in an effort to minimize direct contact (and therefore herbicide injury) to the desirable seedling.

Directional falling; also, directional felling—Felling trees in a predetermined direction to make skidding efficient and/or to avoid damage.

Dominant—See Crown classes.

Down wood; also, down woody debris—Any piece of dead, woody material (e.g., dead tree boles, logs, limbs, or roots) that remain on the ground or in streams in forest stands and serve ecological roles.

Early seral—see Succession and Successional

Early successional—See Succession and successional.

Edge—The more or less defined boundary between two or more elements of the environment; e.g., a field adjacent to a woodland, or the boundary between areas given different silvicultural treatments.

Edge effects—The modified environmental conditions or habitat along margins (edges) of forest stands or patches.

Endemic species—A species found only within a particular, restricted geographic area.

Even-aged stand—A stand composed of trees of a single age class in which tree ages range within 20 years (plus or minus) of rotation. Trees may be in any crown class.

Exotic parasites—Parasites that have been introduced from other regions or countries.

Extirpated—Extinction of a species from a local area.

Fascicle—Structure at the base of conifer needles that binds them together and attaches them to the stem. Also called the needle sheath.

Feller-buncher —Self-propelled machine that fells trees and arranges them in bunches for removal.

Fire exclusion—The process of keeping or reducing the historical frequency and intensity of fire in ecosystems either through direct actions, such as fire suppression, or by removal of fuel from past historical grazing practices.

Forest health—A condition wherein a forest site has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency. A healthy forest is one that reliably will deliver services (water filtering, decomposition, wildlife habitat) or products (edible fungi, timber, wildlife) associated with that particular forest type or landscape.

Free selection; free thinning—See Thinning and Regeneration methods.

Free-to-grow—As defined in the Oregon Forest Practices Act, a condition wherein a seedling or small tree has grown about competing shrubs and herbs and is considered capable of continued growth and domination.

Fuel ladder—Combustible material that provides vertical continuity between vegetation strata and allows fire to climb into the crowns of trees or shrubs with relative ease.

Fuel loading—The amount of fuel (branches, downed logs, etc.) on a site measured in tons per acre.

Fuel reduction—Using mechanical treatments or prescribed burning to reduce surface and ladder fuels with the objective to reduce the opportunity for a severe crown fire.

Fully stocked—See Stocking level.

Gouting—An abnormal swelling of twigs and branches caused by insect infestation such as the balsam woolly adelgid.
Group selection—See Regeneration methods.

Hardpan—A soil layer with physical characteristics that limit root penetration and restrict water movement.
Harvest unit—An area of forest specifically delineated for a timber harvest operation.
High thinning—See Thinning, high.
High-graded; high-grading—Removing most commercially valuable trees in a stand, often leaving a stand composed of trees of poor form and vigor, with poor species composition and severe understocking.
Home range—The area that a species uses in its lifetime to find food, cover, water, and mates.
Hydrologic cycle—The process of evaporation, transpiration, vertical and horizontal transport of vapor, condensation, precipitation, interception, runoff, infiltration, percolation, storage, the flow of water from continents to oceans, and return.

Individual tree selection (ITS)—See Regeneration methods.

J- or L-root—A root that is bent into a J- or L-shape because the seedling was improperly planted in a hole or slit that was too shallow or narrow.
Ladder fuels—see Fuel ladder.
Larvae—The immature forms of many insect species such as caterpillars, grubs, and worms. They develop into adults after going through a resting or pupal stage. Singular: larva.
Late successional—See Succession and Successional.
Latent infections—Dwarf mistletoe infections that have not formed aerial stems because of low light conditions. Aerial stems normally take three to five years to form after initial infection, but plant formation may be delayed even longer in dense stands because of reduced light.
Leave tree—A tree (marked to be) left standing for growth, wildlife, seed production, etc., in an area where it might otherwise be felled. Syn. Residual tree.
Legumes—Any plants in a large family (Leguminosae) bearing nodules on the roots that contain nitrogen-fixing bacteria (e.g., peas, beans, vetch, lupine, clovers).
Lifts—Pruning a tree's lower branches and thereby giving the crown a "lift."
Live crown ratio—See Crown ratio.
Loess—Material consisting mostly of silt-size particles, transported and deposited by wind.
Low thinning—See Thinning, low.

Macronutrients—Chemical elements (not including carbon, hydrogen, or oxygen) that plants and forests need in relatively large amounts. Macronutrients include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S).
Matrix—In a stand, the area between group cuts. In a landscape, the most extensive and connected landscape element that plays the dominant role in landscape functioning.
Mechanical harvesting, mechanized systems—Logging in which most or all of the hand labor is replaced by machines, such as the carrier-mounted shear or feller-buncher.
Microenvironment—The immediate environment of a specific habitat, often that surrounding individual trees or plants.
Micronutrients—Chemical elements that plants and forests need in relatively small amounts. They include iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), boron (Bo), chloride (Cl), and molybdenum (Mo).
Microsite—A small area in which environmental conditions are different from those in the immediate surroundings; e.g., a shaded area behind a stump in the middle of a clearcut.
Midstory—Trees and possibly tall shrubs that form a middle canopy layer.

Natural regeneration—See Regeneration.
Needle sheath—See Fasicle.
Neotropical migrants—Certain species of birds that migrate annually between temperate forests and the

tropics.
Nonserotinous—Conifer cones that do not require fire or heat to open.

Off-site seedlings—Seedlings or trees planted in an area that is in a different seed zone and elevation from that where the seed was collected.
Overstocked—Plantations or stands that exceed the growing-space occupancy relative to an established standard. See also Stocking and Stocking level.
Overstory—Trees forming the uppermost canopy layer. See also Understory.

Patch-clearcuts (also, patch-cuts)—A small area (0.5 to 4 acres) in which most of the trees are harvested. See also Regeneration methods: group selection.
Patch-thin—Thinning within small areas.
Pheromone—Chemicals produced by insects to attract or repel other insects of the same species. Synthesized pheromones are used sometimes in strategies to control insect pests.
Photosynthesis—The ability of plants to capture the sun's energy and manufacture their own food.
Photosynthetic efficiency—The degree to which plants are able to photosynthesize without using large amounts of water.
Pioneer species—Trees (or other plants) that reproduce and thrive on bare sites (e.g., newly exposed soil after disturbances) and persist there (colonize) until supplanted by successional species.
Precommercial thinning—See Thinning.
Prescribed burning; prescribed fire; prescribed underburning—The practice of igniting fire under controlled or specified weather and fuel conditions to safely reduce fuels, prepare a site for reforestation, or to restore fire to ecosystems for ecological purposes.
Radial growth—The number of annual growth rings within the outer inch.
Raptor—Any predatory bird (such as a falcon, hawk, eagle, or owl) that has sharp talons or claws adapted for seizing prey and a hooked beak for tearing flesh.
Reforestation—The natural or artificial restocking of an area with forest-forming trees.
Regeneration (or stocking) survey—A systematic survey to sample regeneration in small plots in order to estimate the number and distribution of seedlings across an area.
Regeneration methods—Approaches to regeneration of a new forest stand. The principal methods are:

Clearcut—A timber harvest operation in which most or all trees are cut down to promote regeneration of a new, young stand.

Free selection—A modification of uneven-aged stand management methods in which the stand is partially cut by group-selection or individual tree selection, depending on the nature of the area being thinned.

Group selection—A method of uneven-aged stand management in which small areas (approx. 0.5 to 4 acres) are cleared of trees to promote regeneration.

Individual tree selection (ITS)—A method of uneven-aged stand management in which individual trees of all size classes are removed more or less uniformly throughout the stand, to promote growth of remaining trees and to provide space for regeneration.

Seed tree—(1) A timber harvest operation in which enough trees are left to provide for natural regeneration. (2) A form of even-aged stand management in which most trees are cut except for a few widely dispersed trees for seed production, which will produce a new age class of seedlings.

Shelterwood—A form of even-aged stand management in which most trees are cut, leaving enough full-crowned overstory trees to provide a less harsh microenvironment for regeneration.
Regeneration, advance—The process by which tree seedlings and saplings become established naturally in the forest understory before any special reforestation measures are undertaken to establish a new stand.
Regeneration, artificial—Creating a stand of young trees by direct seeding or by planting seedlings.
Regeneration, natural—The process by which tree seedlings and saplings become established from natural seeding, sprouting, suckering, or layering, either before or after planned reforestation.
Release—Controlling competing vegetation around seedlings after planting, using herbicides, mulch mats,

or manual scalping to ensure free-to-grow seedlings.

Residual tree—See Leave tree.

Restoration—The process of returning ecosystems or habitats to their original structure, function, and species compositions

Riparian—Related to, living by, or located in conjunction with a wetland or on the bank of a river or stream.

Riparian area—That area adjacent to rivers and streams identified by vegetation, wildlife, and other qualities unique to these locations.

Riparian management area (RMA)—A terrestrial area, defined by the streamside protection laws of Oregon's Forest Practices Act (FPA), of variable width adjacent to and influenced by a perennial or intermittent body of water. The FPA designates what trees, snags, and understory vegetation will be left undisturbed and where certain practices are limited or modified. RMAs are intended to protect riparian areas along shorelines of streams, lakes, reservoirs, springs, marshes, bogs, ponds, and seeps.

Rough—Tree boles that have large limbs. Syn. Limby.

Scarification; scarify—Mechanically removing competing vegetation, debris, and slash; and/or disturbing the soil surface to create mineral soil to enhance natural regeneration or planting.

Seed tree cutting—See Regeneration methods.

Seed zone—Geographic area from which tree seed is collected. Each zone has defined topographic and altitude boundaries.

Seedbed—The soil or forest floor on which seed falls.

Seeps—Water escaping through or emerging from the ground along an extensive line or surface, as contrasted with a spring where water emerges from a local spot.

Self-thinning—The process by which stands thin themselves over time as a result of competition and mortality.

Seral—See Succession.

Serotinous—Cones that require fire (high temperatures) to open.

Shade needles—Conifer needles that have developed in the shade (e.g., on understory trees) and are sensitive to sudden exposure to full sun.

Shelterwood cutting—See Regeneration methods.

Silviculture— The theory and practice of controlling the establishment, composition, constitution, and growth of forests.

Silvicultural system—A planned series of treatments for tending, harvesting, and re-establishing a stand.

Site index—A method of classifying site productive potential based on the height that dominant trees in the stand reach in a specified period (usually 50 or 100 years). Higher site index indicates higher site productivity.

Site preparation—Any mechanical, chemical, or burning treatment to a forest site designed to enhance establishment and growth of planted seedlings or natural regeneration.

Site-adapted species—A species that is naturally (genetically) adapted to thrive in the environment (soil and climate) of the particular location. See also off-site seedlings.

Size class—Within a stand, a distinct group of trees that all are about the same size but not necessarily the same age.

Skidding—Transporting trees or parts of trees by trailing or dragging them.

Skid trail—Skidder path through the woods.

Slash—Severed branches and trees tops created during the course of timber harvesting, thinning, and pruning.

Snag—A standing dead or dying tree. Snags provide important nesting and foraging habitat for many wildlife species.

Species richness—A measure of the number of species present in a community, ecosystem, landscape, region, etc.

Spike-topped (tree)—A tree with a dead top, usually a mark of declining vigor.

Stagnated; stagnation—Very slow tree growth in a forest stand, due to very high density (overstocking). Occurs in dense stands on limited-resource sites. Tree diameter and height growth stall, resulting in a prolonged delay in stand development.

Stand closure—The point at which branches and leaves from adjacent trees begin to touch; the canopy closes, and the live crown begins to climb.

Stand density—The number of trees per acre (tpa) in a stand.

Stand development—A process that includes different stages in the life of a tree stand. In even-aged stands, stages include stand initiation, stand closure, stem exclusion, understory reinitiation, and, theoretically, climax.

Stand stocking—See Stocking.

Stem exclusion—The stage in stand development when some trees begin to die as they lose out in the competition with other trees.

Stocking—A measure of the degree to which the growing space is occupied. Common indices of stocking are based on tpa of a given size, basal area, or tree volume per acre.

Stocking level—A measure of the degree to which the growing space is occupied, relative to a standard usually related to timber production. Stocking levels generally are:

- **Fully stocked—**Stocking at the upper limit of the target stocking range. This is the maximum desired under managed conditions. Allowing stands to grow above this level often incurs a risk of mortality due to competition or beetle attack. Stands at or above this stocking should be thinned.
- **Understocked—**Stocking below the lower limit of the target stocking range for timber production. Stands below this level will sacrifice stand growth but may show accelerated understory development.

Stock-type—A class of seedlings produced by a certain method—such as bareroot, container, transplant, or a combination of these—for a specific period of time. For example, a 2-0 seedling is grown for 2 years in a seedbed. A 1-1 seedling is grown for 1 year in a seedbed and then transplanted at wider spacing and grown another year in a transplant bed. Both trees are 2 years old, but because the 1-1 was transplanted, it is a larger seedling (larger diameter, taller, more root mass).

Succession; successional—The natural replacement of one plant community by another in progressive development toward climax vegetation; the process usually is divided into early or seral, mid and late stages, or species:

Climax—The culminating stage of plant succession for a given environment.

Seral—The beginning stage of species succession for a given site or environment.

Sunscald—Death of cambial tissue beneath the bark on the side of the tree that is exposed to direct sun, often on the southwest side of the tree.

Talus—The accumulation of broken rocks at the base of cliffs or other steep slopes.

Territory—The area of exclusive use that an animal defends against other members of the same species.

Thinning regime—A series of thinnings to achieve certain management objectives, including maintaining stand vigor and avoiding pest-prone species mixtures.

Thinning, commercial—Thinning that produces merchantable material at least equal to the value of the direct costs of harvesting.

Thinning, free—Removing trees to control stand spacing and favor desired trees, using a combination of thinning criteria without regard to crown position.

Thinning, high—A thinning approach that removes trees from the upper crown classes to favor those in the lower crown classes. Syn. Thinning from above.

Thinning, low—A thinning approach that removes trees from the lower crown classes to favor those in the upper crown classes. Syn. Thinning from below.

Thinning, precommercial—Thinning at an early stand age, not for immediate financial return but to reduce stocking so as to concentrate growth on the more desirable trees. The objective is to achieve a density that allows all residual trees to grow to a marketable size.

Tree health—A healthy tree is one that is vigorously growing, relatively free of fungal disease, insect attack, or dwarf mistletoe, and capable of generating natural defensive responses to attack from insects or disease.

Tree injection—A treatment for unwanted woody vegetation in which a hatchet is used to create a wound on the stem of a tree or large shrub and herbicide is injected directly into the wound. Sometimes referred to as a "hack-and-squirt" treatment.

Tree volume per acre—The average cubic-foot or merchantable content of the stand, on a per-acre basis.

Two-aged—A stand consisting of two distinct age classes made up of older overstory tree with younger regeneration below. This is typically achieve by conducting a shelterwood harvest (see Regeneration Methods) but retaining the shelter trees for some period of time.

Understocked—See Stocking level.

Understory—That portion of the trees or other vegetation in a forest stand forming the lowest layer of vegetation, well below the main tree canopy.

Understory reinitiation—The stage in stand development in which the overstory develops gaps (due to tree mortality) large enough to increase light levels in the understory, which in turn is enough for a resurgence of understory vegetation.

Uneven-aged—A stand that has three or more age classes or size classes of trees.

Vertical stand structure—Layers of vegetation in the understory, midstory, and overstory layers of a stand.

Wide thinning—Thinning to leave wide spacing between trees. Generally implies stocking below the lower limit for good timber production; see Stocking level.

Witches' broom—An abnormally profuse, dense mass of host branches caused by dwarf mistletoe or rust fungi.

Yarder; cable yarder— System of power-operated winches used to haul logs from a stump to a landing.

APPENDIX 2

Selected flora and fauna of eastern Oregon

Trees

Common name	Scientific name
Black cottonwood	*Populus trichocarpa*
Douglas-fir	*Pseudotsuga menziesii*
Engelmann spruce	*Picea engelmannii*
Grand fir	*Abies grandis*
Incense-cedar	*Calocedrus decurrens*
Lewis' mock orange	*Philadelphus lewisii*
Lodgepole pine	*Pinus contorta*
Mountain hemlock	*Tsuga mertensiana*
Noble fir	*Abies procera*
Oregon white oak	*Quercus garryana*
Pacific silver fir	*Abies amabilis*
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Red osier dogwood	*Cornus sericea*
Scouler's willow	*Salix scouleriana*
Shasta red fir	*Abies magnifica* var. *shastensis*
Subalpine fir	*Abies lasiocarpa*
Sugar pine	*Pinus lambertiana*
Western hemlock	*Tsuga heterophylla*
Western juniper	*Juniperus occidentalis*
Western larch	*Larix occidentalis*
Western redcedar	*Thuja plicata*
Western white pine	*Pinus monticola*
White fir	*Abies concolor*
Whitebark pine	*Pinus albicaulis*
Willow	*Salix* sp.

Shrubs

Common name	Scientific name
Antelope bitterbrush	*Purshia tridentata*
Baldhip rose	*Rosa gymnocarpa*
Bearberry	*Arctostaphylos uva-ursi*
Big huckleberry	*Vaccinium membranaceum*
Big sagebrush	*Artemisia tridentata*
Bitterbrush	*Purshia tridentata*
Black hawthorn	*Crataegus douglasii*
Ceanothus	*Ceanothus* sp.
Dwarf huckleberry	*Vaccinium caespitosum*
Golden chinquapin	*Castanopsis chrysophylla*

Gooseberry	*Ribes* sp.
Gray rabbitbrush	*Chrysothamnus nauseosus*
Greenleaf manzanita	*Arctostaphylos patula*
Grouse huckleberry	*Vaccinium scoparium*
Lewis' mockorange	*Philadelphus lewisii*
Mallow ninebark	*Physocarpus malvaceus*
Manzanita	*Arctostaphylos* sp.
Mountain-mahogany	*Cercocarpus ledifolius*
Oceanspray	*Holodiscus discolor*
Oregon boxwood	*Pachistima myrsinites*
Pinemat manzanita	*Arctostaphylos nevadensis*
Prince's-pine	*Chimphila umbellata occidentalis*
Rocky Mountain maple	*Acer glabrum*
Red osier dogwood	*Cornus sericea*
Scouler's willow	*Salix scouleriana*
Snowberry	*Symphoricarpos albus*
Snowbrush ceanothus	*Ceanothus velutinus*
Spiraea	*Spiraea* sp.
Wax current	*Ribes cereum cereum*
Twinflower	*Linnaea borealis*
Westernbog blueberry	*Vaccinium occidentale*

Forbs and herbs

Common name	**Scientific name**
Arrowleaf balsamroot	*Balsamorhiza sagittate*
Beargrass	*Xenophyllum tenax*
Birdsfoot trefoil	*Lotus corniculatus*
Brackenfern	*Pteridium aquilinum pubescens*
Broadpetal strawberry	*Fragaria virginia platypetala*
Heartleaf arnica	*Arnica cordifolia*
Lupine	*Lupinus* sp.
Queen's cup	*Clintonia uniflora*
Silvery lupine	*Lupinus argenteus*
Small burnet	*Sanguisorba minor*
Strawberry	*Fragaria virginiana*
Tailcup lupine	*Lupinus caudatus*
Thickleaf peavine	*Lathyrus lanszwertii*
Western hawkweed	*Hieracium albertinum*
Western yarrow	*Archillea millefolium*
White trillium	*Trilium ovatum*
Yellow blossom sweet clover	*Melilotus officinalis*

Grasses and sedges

Common name	**Scientific name**
Blue wildrye	*Elymus glaucus*
Bluebunch wheatgrass	*Agropyron spicatum*
Bottlebrush squirreltail	*Sitanion hystrix*
Cheatgrass	*Bromus tectorum*

Columbia brome	*Bromus vulgaris*
Elk sedge	*Carex geyeri*
Fawn fescue	*Festuca arundinacea*
Hard fescue	*Festuca duriuscula*
Idaho fescue	*Festuca idahoensis*
Intermediate wheatgrass	*Agropyron intermedium*
Kentucky bluegrass	*Poa pratensis*
Long-stolon sedge	*Carex pensylvanica*
Nebraska sedge	*Carex nebraskensis*
Orchardgrass	*Dactylis glomerata*
Pinegrass	*Calamagrostis rubescens*
Pubescent wheatgrass	*Agropyron trichophorum*
Ross sedge	*Carex rossii*
Sedges	*Carex* sp.
Sherman big bluegrass	*Poa ampla*
Slender bog sedge	*Carex lasiocarpa*
Smooth brome	*Bromus inermis*
Timothy	*Phleum pratense*
Western needlegrass	*Stipa occidentalis*

Insects and Diseases

See, Goheen, E. M. and E. A. Willhite. 2006. *Field guide to common diseases and insect pests of Oregon and Washington conifers*. R6-NR-FID-PR-01-06. Portland, OR: USDA Forest Service, Pacific Northwest Region. 327 p.

Mammals and birds

Common name	**Scientific name**
Deer (see also White-tailed deer)	*Odocoileus* sp.
Elk	*Cervus elaphus*
Gopher (see also Pocket gopher)	*Thomonys* sp.
Lynx	*Lynx canadensis*
Mule deer	*Odocoileus hemionus hemionus*
Northern flying squirrel	*Glaucomys sabrinus*
Peregrine falcon	*Falco peregrinus*
Pocket gopher	*Thomonys talpoides; T. Mazama*
Rocky Mountain elk	*Cervus elaphus nelsoni*
Voles	*Microtus* sp.
White-tailed deer	*Odocoileus virginianus ochrouris*
Wolverine	*Gulo gulo*

APPENDIX 3

For more information

Many of the following publications can be ordered or downloaded at the OSU Extension catalog at https://catalog.extension.oregonstate.edu/OSU

OSU Extension publications that support all Manual 12 chapters

Abiotic Injury to Forest Trees in Oregon, EC 1501.

The Care and Planting of Tree Seedlings on Your Woodland, EC 1504.

Biology, Ecology, and Management of Western Juniper (Juniperus occidentalis), TB 152

Successful Reforestation: An Overview, EC 1498

Enhancing Reforestation Success in the Inland Northwest, PNW 520

Selecting and Buying Quality Seedlings, EC 1196

Forest Disease Ecology and Management in Oregon, Manual 9.

Forest Insect Ecology and Management in Oregon, Manual 10.

Harvesting and Marketing Edible Wild Mushrooms, EC 1496.

Introduction to Conifer Release, EC 1388.

Managing Tree Wounds and Stem Decay in Oregon Forests, EC 1519.

Contracts for Woodland Owners, EC 1192.

Land Manager's Guide to Aspen Management in Oregon, EM 9005

Managing Organic Debris for Forest Health, PNW 609

Selecting Native Plant Materials for Restoration Projects, EM 8885

The Hidden Threat in Firewood: Invasive Forest Pests, EM 9137

Managing Insects and Diseases of Oregon Conifers, EM 8980

Pruning Western White Pine: A Vital Tool for Species Restoration, PNW 584

Safe and Effective Use of Chain Saws for Woodland Owners, EC 1124

Management Planning for Woodland Owners: Why and How, EC 1125

Land Manager's Guide to Creating Fire-Resistant Forests, EM 9081

Individual Tree Selection (ITS) in a Northeast Oregon Mixed Conifer Forest, EM 9083

Reducing Fire Risk on Your Forest Property, PNW 618

Tree Growth, Forest Management, and Their Implications for Wood Quality, PNW 576

Small-scale Harvesting for Woodland Owners, EM 9129

Managing Woodland Roads: A Field Guide, PNW 641

Grass Seeding Forest Roads, Skid Trails, and Landings in the Inland Northwest, PNW 628

Timber Harvesting Options for Woodland Owners, EC 1582

Measuring Timber Products Harvested from Your Woodland, EC 1127

Selling Timber and Logs, EC 1587

Woodland Ponds: A Field Guide, EM 9104

Reducing Hazardous Fuels on Woodland Property: Disposing of Woody Material (EC 1574), *Mechanical Fuels Reduction* (EC 1575), *Pruning* (EC 1576) and *Thinning* (EC 1573)

PNW Weed Management Handbook (revised annually), WEED.

Thinning: An Important Timber Management Tool, PNW 184

Trees to Know in Oregon, EC 1450

Shrubs to Know in Pacific Northwest Forests, EC 1640

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Additional resources

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Landowner Fire Liability. Oregon Department of Forestry. http://www.oregon.gov/odf/pubs/docs/landowner_fire_liability_reduced.pdf

Oregon Department of Forestry, general fire page. http://www.oregon.gov/ODF/Pages/fire/fire.aspx

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